REGIONAL SEMINAR

WATER TECHNOLOGY TOWARDS RURAL DEVELOPMENT

19 – 22 JANUARY 1982

PROCEEDINGS

Organised by

FACULTY OF AGRICULTURAL ENGINEERING
UNIVERSITI PERTANIAN MALAYSIA

SERDANG

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REGIONAL SEMINAR

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WATER TECHNOLOGY TOWARDS RURAL DEVELOPMENT

EDITORS

Mohd. Amin Mohd. Soom
Kwok Chee Yan
Rosnah Mohd. Yusuff

Field Engineering Department
Faculty of Agricultural Engineering
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Preface

The content of this report are the proceedings of the regional seminar on Water Technology Towards Rural Development which was held at the University of Agriculture, Malaysia from the 19th. to the 22nd. of January, 1982. The seminar was one of the activities of the working group for appropriate technology which was set up by the Federation of Engineering Institutions of South-East Asia and the Pacific (FEISEAP). This seminar was held in support of the United Nation's general assembly proclamation of 1980-1990 as the International Drinking Water Supply and Sanitation Decade. The goal of this proclamation is to provide to all people water of safe drinking quality and with adequate quantity and also to furnish the basic sanitary facilities required by the year 1990.

This proceedings consists of speeches of guest speakers, a keynote address, technical papers, discussions and a report on the technical tour to water treatment plant. A total of 27 technical papers were presented. Ten additional papers were circulated during the seminar but only the abstracts are presented in this proceedings. The technical papers, arranged in 9 sessions, represented the experiences of scientists and technologists from United Kingdom, Japan, India, Bangladesh, Thailand, Indonesia, Singapore, Fiji, Papua New Guinea and Malaysia.

The contents of the technical papers are the sole responsibility of the respective authors.

The organising committee of the seminar wishes to express its appreciation to United Nation Educational Scientific and Cultural Organisation (UNESCO) and the University for their financial assistance. Appreciation are also due to all members of the Faculty of Agricultural Engineering and other individuals in the University who have worked very hard in contributing to the success of the seminar.

Field Engineering Department
Universiti Pertanian Malaysia.
1982

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UCAPAN
PENGERUSI JAWATANKUASA PENGELOLA IR. CHOA SWEE LIN DI MAJLIS PERASMIAN PEMBUKAAN SEMINAR SERANTAU "TEKNOLOGI AIR KE ARAH PEMBANGUNAN DESA" Pada 19hb. Januari, 1982

Kami sangat berasa bangga kerana dapat menyambut dan mengalu-alukan kehadiran tuan-tuan dan puan-puan di kampus hijau kami pagi ini untuk bersama-sama menyaksikan perasmian pembukaan seminar serantau "Teknologi Air Ke arah Pembangunan Desa" yang akan berjalan selama empat hari di kampus ini. Lebih-lebih lagi kami sungguh bergembira di atas kehormatan yang diberikan kepada kami dengan kehadiran Yang Berbahagia Encik Harun Din, Ketua Setiausaha, Kementerian Pembangunan Negara dan Luar Bandar, yang sudi datang untuk merasmikan pembukaan seminar ini. Kehadiran beliau ini memberi makna yang sangat besar dari segi sokongan Kementeriannya dan negara ini terhadap perkembangan teknologi air dan pentingnya teknologi itu dalam pembangunan negara.

Seminar ini adalah dikelolakan oleh Fakulti Kejuruteraan Pertanian, Universiti Pertanian Malaysia, dengan penuh kerjasama daripada semua lapisan pegawai Fakulti dan juga daripada pegawai-pegawai lain di-Universiti ini. Kami juga mendapat kerjasama dari Jabatan-Jabatan Kerajaan. Ini bukan sahaja menunjukkan kesedaran atas pentingnya air untuk kehidupan tetapi juga keazaman untuk memajukan dan membangunkan seluruh rakyat khususnya masyarakat luar bandar di-negara ini. Keazaman ini nyata dibuktikan dengan kehadiran Yang Berbahagia Ketua Setiausaha Kementerian Pembangunan Negara dan Luar Bandar sebagai wakil Yang Berhormat Menteri Pembangunan Negara dan Luar Bandar.

Pihak Kementerian Kemajuan Tanah dan Kemajuan Wilayah telah mengambil pendirian yang tegas dengan kerjasama yang diberikan untuk menjayakan seminar ini. Pendirian ini telahpun dibuktikan dengan persetujuan Yang Berbahagia Tan Sri Dato Dr. Arshad bin Ayob, Ketua Setiausaha Kementerian tersebut untuk memberikan Ucapan Dasar atau Keynote Address selepas upacara perasmian ini.

Seminar ini adalah dianjurkan bersama oleh Universiti Pertanian Malaysia, United Nations Educational, Scientific, and Cultural Organisation (UNESCO) dan Federation of Engineering Institutions of South-East Asia and the Pacific (FEISEAP).

Para hadirin sekelian, di sini saya memohon izin tuan-tuan dan puan-puan untuk meneruskan ucapan saya dalam Bahasa Inggeris kerana ada peserta-peserta dari luar negeri.

Distinguished Guests, Ladies & Gentlemen

It gives me great pleasure on behalf on the University and organising committee to welcome you all to the Regional Seminar on Water Technologies Towards Rural Development this morning. Our Minister for National and Rural Development Yang Berhormat Dato' Sanusi bin Junid had kindly consented to officiate at this Seminar but due to a very urgent matter that he has to attend to, he is unable to be present this morning. However, we are very grateful and honoured that Encik Harun Din, the Secretary General for the Ministry for National and Rural Development will officiate at this opening ceremony on behalf of the Hon. Minister. His presence represents the concern that our Malaysian Government has towards the social well being and quality of life in this country, particularly that of the rural areas.

This seminar is organised by the Faculty of Agricultural Engineering, Universiti Pertanian Malaysia, and sponsored by Universiti, UNESCO and the Federation of Engineering Institutions of South-East Asia and the Pacific, (FEISEAP). At the meeting of the FEISEAP Working Group on Rural Technology held in Bangkok in December 1980, it was decided that Malaysia should host this seminar. Universiti Pertanian Malaysia is very pleased to be able to play an important role through this seminar in promoting the development and dissemination of technology suitable for rural development.

Through seminars such as this one, the Universiti and the Faculty in particular hopes to obtain among other things information which will be useful in preparing programmes to train engineers and other technical personnel required in agricultural and national development in this country.

Water, without doubt, is one of the fundamental necessities of life. A suitable supply of drinking water has always been the determining factor in the siting and growth of communities. It has been estimated by the United Nations that some 30,000 people die around the world daily because they had inadequate water or sanitation facilities. Tens of millions of women spend half their day walking in the hot sun to carry home polluted water which would poison them and their families. Cognisant of the need by nations to give appropriate attention to this 'permanent disaster' as the UN calls it, the United Nation General Assembly launched the 'International Drinking Water Supply and Sanitation Decade' in November 1980. Governments of developing countries including Malaysia are becoming increasingly concerned with improving the living and economic conditions of the rural areas. For example, under the 3rd Malaysia plan (1975 - 80) there was a very obvious increase in the allocation of funds for rural water supply development in this country.

In many parts of the world, the basis for successful agriculture continues to be irrigation. In Malaysia, agriculture which forms the backbone of the economy of the country, has been successful because of the abundance of natural rainfall. Our rubber and palm oil production has been very successful in part due to the availability of water. Irrigation schemes providing water to some 300,000 hectares of paddy cultivation has brought Malaysia to about 90% self sufficiency in rice. Future water requirements for agriculture in other countries in this region, apart from other forms of rural water demand, is difficult to predict accurately. But the fact is that agricultural water demand is rising and will continue to increase with other demands.

Besides water for agriculture, the application of water to power generation was a powerful determinant in the evolution of several technologies both in the east and the west. Indirectly water power exerted an important influence on the spread and development of industrialisation. ASEAN countries and others in this region were not spared the difficult times brought about by the energy crisis of the 1970's. Part of the strategy for these countries including Malaysia to reduce their dependency on fossil fuel was to accelerate the hydroelectric power development. Our countries are fairly well endowed with water power, and small-scale or minihydro systems are being considered as a viable source of energy for rural electrification.

Concepts of hydraulic engineering associated with all the three aspects of water useage is centuries old and in each case the fundamental concepts involved have not altered. On the other hand the technology has been changed and improved radically especially in the last 100 years. Although the twin problems of providing adequate water quantities and ensuring their quality do pose significant challenges to engineering, water technology is now well within the compass of engineering, including agricultural engineering. However, they also raise bigger economic, environmental, social and sometimes political issues. These undoubtedly will feature very prominently in present day water technologies. Therefore, water technologies of the 1980's and decades to come will not cover engineering problems only but include those of water resources and their proper management.

In this respect, adequate and suitably trained manpower will be required. Traditionally, many of the people engaged in planning and implementation of rural water projects in developing countries are products of highly structured and specialised training programmes, designed to produce engineers and technicians whose role is to plan, implement and maintain sophisticated urban water treatment and distribution systems in industrialised areas. This background and training experience when transferred into the extremely different environments in rural areas often leads to the imposition of technology which bears very little relevance to the local situation and cannot, in most cases, be sustained by the local people. It is reasonable to assume that some of these problems could be avoided if the training programmes would recognise the importance of understanding the social, economic and cultural forces as they affect the application of engineering principles towards solving of problems in the rural areas.

Recognising that technology for rural development is a complex blend of social, technical, economic and cultural forces, Universiti Pertanian Malaysia has started training programmes in engineering which includes courses in the humanities and social studies. The Faculty of Agricultural Engineering was established in 1975 and has since produced 3 batches of Engineers proficient to serve the Engineering needs of the agricultural sector and related industries. It is now also running a 3-year diploma course is agricultural engineering, which is the first such course in the region. The Agricultural Engineering degree curriculum requires subject matter inputs for other engineering fields such as civil, mechanical and electrical engineering. We therefore have to have the necessary laboratory and manpower facilities in these classical engineering areas to train agricultural engineers effectively. We hope to play a greater role in the training of engineering manpower in this country thereby making fuller use of the physical infrastructure and facilities currently available.

Another major problem that we face today is the increasing per capita demand for water which places a severe strain on water resources. Residents in the Klang Valley are familiar with water rationing which is one direct result. It is difficult to calculate an overall per capita consumption figure. It is estimated that in the United States, the per capita consumption is in the region of 6,000 litres per day. In this country, the figure often quoted for domestic consumption alone is 225 litres per person per day. Not only will the demand for water increase due to per capita consumption increases, it will also increase as the population rises.

Realising these problems and the potential problems that we are likely to be confronted with in the future in respect of water and development, it is indeed timely that this seminar brings together experts from the various countries in South-East Asia and the Pacific who are working in the water technology field. This seminar will afford us the opportunity to

Identify the present status of Water Technology and future developments in the South-East Asian and Pacific Region

Review available Water Technologies applicable for rural development,

Promote the inter-transfer of water technologies between countries in the the region, and

Assess and adopt technology from developed countries suitable for application within the region.

I am very happy to mention that this four-day seminar has brought together officials and researchers from countries within ASEAN as well as outside region including England, Fiji and Papua New-Guinea. I hope that this seminar will benefit all participants. This will only be possible if we will consult with each other and exchange our experiences and ideas. The organising committee has attempted to create an evironment and atmosphere conducive to such exchange and discussions and I hope that at the end of this seminar, many friendships and links would have been established that would pave the foundation for future collaboration and cooperation. The issue of regional cooperation has for a long time been confined to governmental leaders. Although this is very important, it is increasingly being realised and appreciated that for regional cooperation to take stronger roots, people-to-people contacts are necessary. We in Universiti Pertanian Malaysia hope that we have made a contribution towards the attainment of this goal through the holding of this seminar.

This seminar would not have been possible without the hard work of many members and wellwishers, particularly the generous donors who have contributed financially to this seminar. On behalf of Universiti Pertanian Malaysia and the organising committee I wish to take this opportunity to thank all of them. We are especially grateful to UNESCO for financially cosponsoring this seminar and to the Malaysian National Commission of UNESCO for their cooperation. We wish to thank The British Council for bringing participants from the United Kingdom. We would like to extend our thanks to the authors of papers and other resource personnel, chairman of technical sessions and in particular Yang Berbahagia Tan Sri Dato Dr. Arshad bin Ayob for his Keynote Address. Finally I would like to express my personal deep appreciation and gratitude to all the members of the organising committee and others who have pooled their efforts in making this seminar possible.

Tuan-tuan dan puan-puan,

Bagi mengakhiri ucapan saya, sekali lagi saya ucapkan ribuan terima kasih kepada ng Berbahagia Encik Harun Din, dif-dif kehormat dan para hadirin sekelian kerana sudi bersama-sama menyerikan majlis pembukaan seminar ini.

Sekian, terima kasih.

Address by Dr. Upali Kuruppu

Prof. Choa Swee Lin
Prof. Nayan Ariffin, Deputy Vice-Chancellor
Mr. Harun Din, Secretary-General
    Ministry of National and Rural Development
Distinguished Participants
Ladies & Gentlemen.

It is a great honour, pleasure and privilege for me to be present here with you this morning as the representative of Unesco. I bring you greetings and good wishes from the Director-General of Unesco Dr. Amadou Mahtar M'bow and the Director of the Regional Office for Science and Technology for Southeast Asia, Dr. Vivek Prakash.

The subject of rural development is of great importance for this region. It is here that the need for rural development is most pressing and the benefits can be most effective. Countries of this region have high populations which are increasing fast and around three quarters of them live in rural communities.

Till recently most development programs on Science and Technology concentrated on training of personnel and provision of equipment for Industrial advancement and infrastructures for industry. The benefits then accrued to urban and suburban areas while the rural areas were sadly neglected.

One result of this has been the migration of people to cities in search of employment and better living conditions. But this in turn has created serious urban problems. Look at some of our cities. Bangkok with 5 million people, Jakarta with 7 million. We wee the enormous problems of traffic, pollution, water supply, sanitation and drainage these city authorities have to cope with. Imagine what these would be if the populations were doubled? This is a real possibility and in a much shorter period than most people expect, if present trends continue.

One of the most effective ways to handle this problem would be to improve the rural environment and make it more attractive for living. Recognizing this, Unesco places a high priority on integrated rural development, for even small improvements in the quality of life of rural people when multiplied by the large numbers involved would result in a significant global impact.

Sometime back Unesco organized an expert meeting on New Modalities of actions of the organization in the field of technologies for rural development. The meeting concluded that there is a real need for an expanded programme of Unesco action in this field. It was stressed that the different sectors of Unesco dealing with Education, Natural Sciences, Social Sciences, Communication, Culture and Information Services should all contribute to the effort. Attention was focussed on the necessity to reorient education, both formal and non-formal towards the real needs of rural communities, to encourage the scientific and engineering communities to do research on rural problems, to support information exchange on technologies for rural development, to survey and promote the use of traditional technologies and to study the socio-cultural factors influencing the diffusion of technologies in rural areas including the impact of such technologies on rural society. It was emphasised that special attention should be given to involve rural population including women in planning, decision making and implementation to ensure that the application of technology is a true reflection of their needs, interests and potential.

Unesco has many programmes towards the goals mentioned. There is a programme of research, training and demostration aimed at the integrated management of humid tropical zones. It is concerned with the problem of how to transform complex ecosystems with a high biomass, such as humid tropical forests, into agro-foresting areas having sustained production, within social structure which conform to the cultural and ecological characteristics of the countries involved. The problem is one that has particularly acute economic, social and ecological dimensions, since the present rate of clearance of tropical forests is very high and the majority of replacement agro-systems have not so far yielded satisfactory results in the long run. It is estimated that at the present rate of clearance 40% of today's tropical forests may have disappeared by the turn of the century. The Unesco programme comprises three networks of pilot projects. One of the networks is in Southeast Asia.

If we look at the countries of Southeast Asia, we see that the educational infrastructures built up over the past two to three decades are capable of producing the basic stock of scientists and engineers for development. However if we consider the growth of industrial production geared towards development, the results are not up to expectations, indeed disappointing. One reason for this poor performance may be the lack of clear science and technology policies in these countries. Mindful of this, Unesco is organizing the second conference of Ministers responsible for the application of Science and Technology for development and those responsible for economic planning in Asia (CASTASIA II) from 22 - 30 March 1982 in Manila. This conference which will be attended by over 30 countries representaing over half the worlds peoples may well be one of the key conferences of the decade. The conference will review progress since CASTASIA I, held in New Delhi in 1968 and set the guidelines and strategies for mobilising to the utmost the scientific and Technological capability of the region towards accelerated development.

Water is of course an essential requirement for rural development of for that matter life itself. Prof. Choa has admirably covered the importance of water and the scope of the seminar in his address. So I shall not dwell on that. However I wish to draw your attention to certain aspects not directly concerned with water technology, yet have a bearing on the application of water technology to rural development. What are the best means to disseminate technology to Rural Communities? How can we involve the rural folk in the process of applying technology so that it is identified as theirs and not something forced from outside? This is important for acceptance and it gets a commitment for maintenance. Also it is necessary to teach peoples how to manage what is received. In this case water, how to conserve it, put it to best use and avoid waste.

This seminar is an activity of the Working Group for Appropriate Technology. It is one of five such groups set up by FEISEAP. The other groups cover the areas of Energy, Low Cost Housing, Rural and Urban Waster and Instruments. The Appropriate Technology group will hold a Seminar on Dissemination of Technology to Rural Communities in Bangkok from 16 - 20 August 1982. Any recommendations on the subject made by this seminar will be a useful input to that.

Finally we wish to express an appreciation to the Vice-Chancellor and Administration of Universiti Pertanian for permitting this seminar to beheld here. We wish to thank Prof. Choa, the members of the steering committee and all the other staff of the University who have put in so much of their time and effort towards organizing this. Our thanks are due to the National Commission and the Government of Malaysia for their support.

In conclusion, Ladies & Gentlemen I wish you all a stimulating seminar, a fruitful exchange of ideas and experiences and a very pleasant stay in Kuala Lumpur.

Thank you.

Speech Delivered by Yang Berbahagia
Encik Harun Din, Ketua Setiausaha,
Kementerian Pembangunan Negara
dan Luar Bandar

at

REGIONAL SEMINAR ON WATER
TECHNOLOGY TOWARDS RURAL DEVELOPMENT
ON 19TH JANUARY, 1982 AT THE UNIVERSITY OF
AGRICULTURE, SERDANG

First of all, I would like to convey my minister's regrets and disappointments at having to cancel, at a very last moment, his engagement to declare open this important regional seminar. He has also asked me to welcome on his behalf and on behalf of the Government of Malaysia all the delegates attending this seminar expecially those from our friendly neighbouring countries and hope that you have an enjoyable and fruitful stay in this country. He has also expressed the hope that the seminar will be of immense benefits to those of us who are committed to the development of our rural communities. He feels that the experiences and knowledge gained and exchanged, at this seminar will help, on the one hand, to overcome and on the other speed up our development processes.

The Minister, Dato' Sanusi Junid would also like to congratulate the Faculty of Engineering in the University of Agriculture, UNESCO and FEISEP (Federation of Engineering Institution of South East Asia and the Pacific) who have put up such a commendable effort in organizing the seminar. To the University of Agriculture, in particular, the holding of this seminar is indeed timely in the light of the recent "Revival" of the Ministry of National and Rural Development. The Faculty of Engineering must therefore be congratulated in its effort to translate theories into practice, to be in the forefront in bringing about new technology to serve the urgent needs of development.

In Malaysia, although we have achieved much by way of bringing development to the rural areas a lot more could be done and remain to be done. Since we achieved our independence in 1957, we always had a ministry respondible for rural development, although for a brief period, the ministry was dissolved and in the middle of last year, we have reactivated the ministry and give it directive to enhance efforts in rural development. The new ministy was given the task amongst others of exploring ways and means of increasing the income level of the rural community as an added thrust to the overall development of rural communities. The new ministy hopes to activate and revitalise the combined efforts of government and people to achieve its development goals. It will conciousness of development efforts, leading to a more active participation in the only way that rural development could be achieved, that is, through the spirit of "self-help" (berdikari) and "gotong royong". We hope to revive the spirit that we call in this country "gotong royong" which have always been the way of life of our rural community.

At the expense of being guilty of stating the obvious, what must certainly be considered a cliche, water is vital to our survival. We who are living in towns, and developed areas take water very much for granted, like so many other things in our daily life and become conscious only in its absence or when there is a shortage when our lives are directly affected. To us, water is obtainable by the turning of a tap and on rare occasions when there is scarcity, we scream at the top of our voice, but still a large proportion of our own people in the rural areas are daily living with scarcity of clean and safe water and are dependent on wells, streams and canals where supply is subject to frequent dry spells dependent on the whims of nature. The important thing is not so much as having water which is plentiful but having access to good, clean and safe water. Absence of good and clean water are often attributed to the outbreak of such diseases as cholera in the rural areas.

At this juncture, I hope you will allow me time to mention a few facts briefly on the subject of rural water supply in this country. Until quite recently, water has been a state government matter and the development of public water supply has always been based on economic considerations and as a consequence, only areas of heavy concentration of population were given priority and rural areas being less densely populated received minimal attention. In our third Malaysian development plan (1976 - 1980) and as a result of a change of emphasis from one of economic to that of the development of human potentials what was before a state matter became a federal responsibility. In 1974, the Federal Government of Malaysia decided to assist in terms of financial (in the form of soft loans and grants) and manpower assistance. The contribution in 1974 was $ 1,392 million and in 1975 $ 1.663 million and for the 4th Malaysian Plan (1981 - 1985) the figure is $ 283 million. The present situation of the rural areas in Malaysia is that about 62.2% of the rural population are already receiving safe water supply and therefore 38% are still having supplies of water not safe for drinking from sources such as rivers, wells, canals and lakes. The policy of the government is to achieve 100% safe water supply to all rural areas by 1990. It is indeed in line with the UN programme i.e. "The Water Decade Programme" as agreed upon in the "United Nations Water Conference at Argentina in 1977" which I am sure some of your own governments may have participated in.

To me, what is important and should be deliberated at great length at seminars of this nature, is not only the introduction of the new technology but also of greater significance its implementation process. Too often, from experience, projects fail to take off the ground, simply because of the lack of under-standing by the people leading to their lack of enthusiasm and perhaps subsequently to total rejection by them.

In Malaysia, we acknowledge the need for more trained and qualified men, but we are also aware that trained and qualified men are not enough in development. What we need now, especially, a greater sense of dedication and willingness to work hard by govenment and people alike, and without these important ingredients, projects for rural development will surely suffer. We need men with imagination and resourcefulness to implement development projects, using the vast resources of human power available at grass-root level which no doubt is lacking in skill at the moment but certainly not unsusceptable to simple and basic training. One of our main efforts will be to focus on human resources in the rural areas - to orientate them to greater participation in development. It is our hope that this seminar will focus its attention on this important issue, especially, in evolving new and yet simple technology on water supply that could be easily understood and carried out by the rural community themselves. The introduction of any new technology must therefore take note of the participation by the people in the rural areas with minimum and effective training. Active participation by the people in what is being done for them, will bring out greater awareness and commitment to the projects in hand and thus pave the way for success.

In rural development, we have discovered that development of basic infrastructure such as provision of clean and safe water, rural electrification and construction of rural roads by themselves did not necessarily bring about desired development goals. A much more integrated development approach is therefore required. Provision of basic infrastructure will be more effective if traditional rural villages are restructured where isolated homes are brought together [illegible] village where, at the same time the income [illegible] necessarily be dependent solely on agriculture [illegible] supplemented with income from animal [illegible] favourable, on the establishment of [illegible] light [illegible].

While efforts [illegible] experts on water technology involving engineering [illegible] in creating systems which can overcome water supply problems [illegible] technology should always bear in mind our new emphasis to restructure the traditional rural villages by grouping them together, providing them with basic infrastructure, with suitable accommodation and possibly increasing opportunities to raise their level of family income. Such a project is being undertaken at the moment as an experiment, in a place called, Assam Jawa in Kedah, to the north of Malaysia. Perhaps the restructuring of the traditional village into an integrated one will make the task of providing infrastructure, such as water supply much easier and even cheaper than where villages are far apart and unorganised. But the work of providing safe and clean water to 30% of the areas in Malaysia whether in the form of an integrated approach on the lines of Assam Jawa, or as in what is traditionally been carried out, will be pursued with greater vigour and sense of urgency.

Lastly I would like therefore once again to thank the Faculty of Engineering, of the University of Agriculture Malaysia, the UNESCO and the Federation of Engineering Institution of South-east Asia and the Pacific, for inviting the Ministry of National and Rural Development to open this Seminar and I therefore, with great pleasure declare open this Regional Seminar on Water Technolcgy Toward Rural Development.

KEYNOTE ADDRESS AT THE REGIONAL SEMINAR ON WATER TECHNOLOGY TOWARDS RURAL DEVELOPMENT ON 19TH JANUARY, 1982 AT UNIVERSITY PERTANIAN

by

Y.B. Tan Sri Datuk Arshad Ayob
Ketua Setiausaha
Kementerian Kemajuan Tanah dan
Kemajuan Wilayah

The rural sector in this country constitutes about 75% of the total population of the country. However, the standard of living in the rural areas has been lagging behind the urban sector resulting a very distinct trend of rural-urban migration in recent years. With agriculture as the mainstay of our economy, the government has given great emphasis to agricultural and rural development aimed at increasing the standard of living of the rural population. There is no doubt that in rural development, water is a vital factor. Water is our most important natural resources because it is absolutely essential for crops and human beings. The provision of safe water does not merely mean happier and healthier citizens but also must increase economic productivity. Investment in human potential is not only a moral imperative, it is also sound economics. Investment in drainage and irrigation is equally important to ensure the steadier rising in the standard of living of the rural population.

2. In this respect, water resources development could play a very significant role in promoting a more balanced socio-economic growth in the country.

3. Malaysia possesses a tropical climate with abundant rainfall but the total water resources are only moderate due to the high potential evaporation. The average annual rainfall in the country is about 2800 mm (110 inches) and annual surface water resources is estimated at 520 x 10^9 m^3 per year. However, not all the surface water is available for use. At present, approximately 65% of this is estimated to run off the sea and about 25% is instream use for hydro-electric purpose, fisheries, channel maintenance and pollution abatement. Thus only about 10% (52 x 10^9 m^3 per year) is available for development for other purposes such as irrigation, water supply and industrial water supply, etc.

4. Due to the regional imbalance of land and water resources in relation to socio-economic development, problems of water shortage have begun to be experienced in some regions/states. In some regions, limited water resources is constraint to development whilst in others, there is surplus supply to meet all present and future demands. A very pertinent feature of our water resources development programme is, therefore, to support the planned socio-economic development of the country.

5. The New Economic Policy launched at the inauguration of second Malaysia Plan in 1970 had as its fundamental goals the eradication of poverty by raising income levels and increasing opportunities for all Malaysians and the restructuring of society to correct economic imbalance.

6. Poverty is a very common problem in the rural areas. In 1970, 58.7% of the rural household are living below poverty line, constituting

89% of the total number of poor households in this country. Through various intensive development programmes aimed at helping the poor, the percentage incidence of poverty has declined to 37.7% in 1980 although the rural sector still accounts for 85.3% of the total number of poverty households. Despite the substantial progress in reducing incidence of poverty, there is considerable room for improvement in the standard of living of the rural population when compared to the urban areas. Realising this, the Government development programmes will continue to give emphasis to rural development. Under the current Fourth Malaysia Plan, the agriculture and rural development has been allotted a total of $ 8,006.[illegible] million or 20.1% of the FMP total allocation. The various Government programmes that aim to improve the livelihood of the rural population consist of :-

(i) opening up of new land [illegible] settlement of poor farmers who are landless [illegible] owning uneconomic farm holdings;

(ii) in-situ development through integrated agricultural development programmes, crop replanting, intercropping, provision of drainage and irrigation facilities;

(iii) programmes to provide [illegible] social and health amenities [illegible] areas [illegible] potable water supply [illegible] electricity [illegible] roads, sanitation, [illegible]

7. The development of land and water resources is the key element in our rural development programmes. Out of the total land area or about 32 million hectares in the country, about (42%) are considered topographically suitable for agriculture. The productivity of these agricultural lands is, however, dependent on prevalence of favourable soil moisture regime which is dependent on the climate and availability of water [illegible]. Malaysia has a typical [illegible] climate and is also affected by [illegible] influence. This has resulted in considerable month to month and year to year variations in rainfall and hence water resource availability. There are period of droughts which leads to soil moisture stress detrimental to healthy growth of plants whilst at other times, the [illegible] bring with it intense and prolonged precipitation resulting in floods.

8. The control and management of water is, therefore, a crucial factor in our land and agricultural development programmes. Through proper measures, our water resources can be harnessed to promote the socio-economic growth of the country. Water is required for the production of food, drinking and domestic needs, environmental quality preservation which are basic for sustaining human life, and also in energy production such as hydropower generation. The importance or attachment to water is reflected in the traditional mode of human settlement in this country. Land colonisation started from river estuaries and moving inland along the river valleys. The river alluvial plain which is flat and fertile are ideal site for food production whilst the rivers provide the source of water for drinking and domestic needs as well as serving as a means of communication with the exterior or other communities.

9. Concurrent with the Government's policy of poverty eradication and improvement of standard of living of the rural poor, great emphasis

has been given to rural development and in particular, land and water resources development. The contribution of irrigation to increased food production have long been recognised and irrigation development is now used as a tool to increase the income of padi farmers who form one of the major poverty groups in this country.

10. The Agricultural sector makes up 60% of the working population in the country but also has the highest incidence of poverty. The main emphasis of the agricultural and land development programmes is to increase the income of the farmers through raising productivity level, expanding employment opportunities and creating a dynamic economic environment in the rural areas. It has long been recognised that provision of water supply and irrigation system is the most effective means to increase crop productivity.

11. In the last decade, the total investment in drainage and irrigation works amount to 771 million Ringgit comprising of 218 million in SMP and 533 million in TMP. By 1980, a total of 320,000 hectares of padi land were provided with irrigation facilities, 72% of which is capable of double cropping. Our rice production increase from 0.65 million tons in 1965, to 1.15 million tons in 1980, reaching a self-sufficiency level of about 80%. Irrigation and drainage infra-structures combined with the requisite agricultural inputs and supporting services are effective in increasing the income level of the padi farmer and tree-crop smallholders, aside from the fact that these programmes also attract a large number of beneficiaries. Typically, a modest investment to provide basic irrigation facilities for areas previously under rainfed conditions would effectively increase the net return to a farmer by as much as $ 600 to $ 1,500 per hectare per annum. Investment in agricultural drainage would yield benefits of similar order to tree crop smallholders.

12. Under the FMP, the drainage and irrigation programmes will be further intensified with an approved allocation of $ 860 million. The emphasis will be on development and management of water resources to support agricultural development. Detail work programmes cover development. Detail work programmes cover development of water sources, provision of new irrigation and drainage facilities or upgrading of existing facilities and flood mitigation works.

13. In recent years, there is a move towards agricultural intensification as well as crop diversification. This strategy is designed to help the poor farmers with small farm holdings. The available statistics show that 65% of the farm holdings in Peninsular Malaysia are below 2 hectares. Aquaculture has been identified as a very lucrative enterprise and could bring about very substantial increase in income to farmers with relatively modest investment. In this country, there are considerable acreage of land under natural water course, lakes and swamp which could be utilised as sites for aquaculture development. Adequate supply of water of suitable quality is crucial to the success of any aquaculture project and this calls for planned development and proper management of water resources in the country. In the decade of 1971-1980, the Government has given out subsidies to 5,700 fish farmers amounting to $ 9.2 million to finance cost of pond construction and supply of fish and feed. Due to favourable response of the farmers, the aquaculture development programmes will be further promoted under the FMP. Here Majuikan must continue to spearhead aquaculture development in the country.

14. The critical importance of clean water supply needs no elaboration. Demand for potable water supply has grown tremendously since Independence as rapid socio-economic development leads to increase aspiration of people from all sectors for batter quality of life and health standards. In 1959, public water supply system is limited to a few established towns with a combined capacity of less than 0.36 mcmd (80 mgd) but this has now been expanded to a capacity of about 2.04 mcmd (450 mgd). By 1980, 59.4% of the total population were provided with public water supply facilities. The details, however, show that whilst 90% of the urban population in Peninsular Malaysia are provided with potable water supply, the corresponding figure for rural sector is only 47.2%. To alleviate this disparity, an allocation of $ 349.8 million was allocated for rural water supply porject under the FMP and a rural population coverage of 63% in Peninsular Malaysia was targetted. A National Rural Water Supply will be initiated in early 1982 with the objective of formulating a masterplan for rural water supply development up to 1990 for the whole country.

15. Up to 1973, all costs on rural water supply projects in Malaysia except Federal Land Development Authority Schemes were borne fully by the State Governments. As the State Governments financed most of the water supply projects with loans (Federal or Foreign), investments on rural schemes were minimal. Realizing that the States could not afford to provide safe water supplies to rural areas where capital cost per family could be very high, the Federal Government began to assist the States in 1974 by way of a subsidy towards the cost of constructing such rural projects. Federal contribution from 1974 to 1975 amounted to only $ 3.8 million.

16. In the Third Malaysia Plan (1974-1975), the Federal Government budgeted for $ 82 million (later increased to $ 125.7 million in the MId-term Review) as Federal contribution for rural water supplies in Peninsular Malaysia. The primary objective of this programme, which is in line with the Government's New Economic Policy, is to provide treated water supply to more rural people so as to uplift their economic and social well-being. The States have been classified as "Deficit" and "non-deficit" depending on their economic well-being. Deficit States are eligible for 100% Federal financing while non-deficit State are provided Federal assistance amounting to 2/3 of the cost of the rural water supply projects. In the Third Malaysia Plan, the Environmental Health Engineering Unit of the Ministry of Health is also implementing gravity type or sanitary well type community water supply schemes costing $ 9 million in areas where JKR rural piped water systems will not be provided for at least five years. The budget for rural water supply schemes under JKR for the Fourth Malaysia Plan is $ 283 million.

17. A rapid assessment of water supply and sanitation in Peninsular Malaysia was carried out in April 1978 by the WHO and JKR. Earlier in 1970 a nation-wide census was conducted by the Statistics Department on households with access to safe water supplies.

18. As indicated in Table I attached the percentage of total population adequately served in Malaysia (with piped water supplies and sanitary wells) increased from 51% in 1985.

19. Rural coverage was 38% in 1970 (including 22% through house connections) increasing to 49% in 1975 (including 27% through

house connections), and being projected to 83% by 1985 (including 52% through house connections).

20. The remaining population (49% in 1970 and 38% in 1975), mostly living in rural areas manage with water of doubtful quality and seasonal insufficiency form unprotected wells, canals, streams, lakes and rainwater cisterns. This percentage is hopefully expected to decrease further to 12% by 1985 with continued Government emphasis on accelerated water supply development. It must, however, be borne in mind that there are significant regional differences: thus in 1975, 55% of the total population in Malaysia had piped water supply but only 13% in the State of Kelantan and 66% in the State of Johore.

21. Under the Third Malaysia Plan rural water supply programme, about 3,864 km (2,400 miles) of new pipelines were laid in rural areas benefitting about 780,000 people. Extensive rural extensions before completion of source development has caused a marked rise in water demand in some states, thereby using up treatment capacity reserve. For example, in North Kedah, water demand rose by a remarkable 17% in one year from 0.05 cmd (12.5 mgd) in 1979 to 0.06 mcmd (14.6 mgd) in 1980, mainly because of extensive rural extensions. The massive rural supply programme has upset previous planning and provision for source development. The sudden rise in demand growth rate from 6 to 7% per annum a few years ago to 9% per annum due to other factors as well, has thrown the water authorities off balance.

22. Delay in project implementation due to various constraints is another major factor for the present shortcomings. The late approval of Third Malaysia Plan, and the reduction of JKR's bid for fund, has resulted the delay in implementing several major projects. For those projects launched as scheduled, completion is often delayed to varying extent by lack of manpower, shortage of waterworks contractors, shortage of materials, lengthy procedure in appointment of consultants and failure of some consultants to deliver the goods on schedule.

23. Hydropower generation is a competitive source of electricity generation with the high and ever-rising cost of fossil fuels. There are already a number of large hydropower plants in this country, tapping the vast water power potential that exist in some of our larger river systems. To improve the quality of life in the rural areas, the Government introduced the rural electrification programme. In the decade of 1971 to 1980, a total investment of $ 243 million was spent in this sector and by 1980, approximately 52% of the rural households are provided with electricity supply. The NEB has always been on the look out for suitable site for hydro-development. In recent years, NEB has initiated investigation and development of mini-hydro projects as an independent power source to their rural electrification schemes. At present, there are two mini-hydro projects being implemented, one in Ulu Dong and the other in Macap Dam. For many remotely sited communities, mini-hydro may be the only economic solution to their demand for electricity supply, thus demonstrating another contribution of water to the development of the rural areas.

24. As a result of rapid socio economic development in the past two decades, water stress become evident in a number of areas in this country. This is largely due to the seasonal and regional variation in rainfall and streamflow as well as the regional imbalance in the

population density, water shortages are experienced in the State of Perlis, Kedah, Penang and Melaka. I mentioned earlier, only 10% of our surface runoff have actually being utilised. It appears obvious that one solution to our water shortage problem would be to increase the percentage utilisation of our surface runoff through measures such as storage and inter-catchment transfer.

25. Storage reservoir could contribute to higher water yield by storing excess water during the wet months and releasing it for use in the dry months. The storage of flood water during the Monsoon will also help in mitigating floods. The benefits of storage reservoir can be further enhanced by providing for multi-purpose applications such as hydropower generation, water supply, recreation, etc. Storage development, however, is only possible where both the topographical and geological factors are conducive to the construction of dams. Suitable reservoir sites, as one expert put it are 'freaks of nature' and the on-going National Water Resources Study have identified a total of 41 dams to be constructed over the next 20 years. Early measures to conserve and reserve these sites for dam development to meet future needs is, therefore, crucial. Past experience have shown that the main obstacle to reservoir projects is the socio-political objection from residents who have settled in the area of the proposed reservoir site, making it time consuming and costly to resettle these people. But the need of water storage must be given top priority.

26. Inter-catchment transfer of water is a feasible solution to some water stress areas if it is possible to develop and transfer excess water from an adjacent or neighbouring river basins within reasonable cost. The idea is not new and the Muda-Pedu reservoir system of the Muda Irrigation Project in this country is a typical example of water transfer from one catchment to the other. Under the National Water Resourses Study, a number of other inter-catchment and inter-state transfer of water have been identified for implementation to solve the water-stress problems in the more intensively developed areas of the country.

Groundwater

27. Groundwater is a resource that should be explored and fully made use of to supplement surface sources which are now fast diminishing. Endowed with abundant rainfall, Malaysia has never had problems with s urface sources until lately and, therefore, has not given the attention to groundwater which it deserves. Less than 5% of public water supply is from ground sources. All surface water will be completely utilised by 1987 unless new dams are built or the existing strenght be increase in the height of dams like the Klang Gates Dam to capture the vast quantity and run-off to the ocean during rainy seasons. Although expert opinion and JKR's own experience indicate that groundwater is not abundant in the hinterlands of Malaysia because of geological formations, tapping this underground water resource will help in solving some of the rural water supply problems that are being encountered. JKR recognises the importance of groundwater and is currently drilling for groundwater in Kedah and Perlis and has also called for a nation-wide exploration programme to assess groundwater potential under the National Rural Water Supply Study.

28. In recent years, some progress have also been achieved in the development of groundwater for rural water supply as well as irrigation use. Preliminary assessment based on study of geological formations had revealed low when compared to its neighbouring countries. However, the development of groundwater could help to alleviate the water stress problem in some parts of the country. For many inland rural settlement, groundwater may be the most reliable and economic source of water supply to meet domestic, drinking and irrigation needs. Both the DID and JKR have intensified their efforts in exploration and development of groundwater as part of their long-term water resources development programmes. DID has adequate groundwater for tobacco growing at Kandis and for agricultural crop for about 81 hectares (200 acres) and domestic use at Meranti.

29. Recognising the critical importance of water in national development, the Government commissioned a National Water Resources Study in October 1979. The study which is to last for 36 months has the main objective of formulation of a comprehensive and co-ordinated water resources management masterplan for the country. The findings of the study would certainly be of great interest to all Government agencies involved in water-related development activities and is also the first time in this country that an integrated, comprehensive and co-ordinated approach was adopted in the planning for development of water resources on a national basis covering all aspects of water utilisation.

30. Associated with a development of water resources will be the manpower required at various levels, particularly at the Diploma and Professional levels. These personnel must not only be competent in technical specialities, they must also be skilled managers, and have a good understanding of the socio-economic conditions within which they are working.

31. The Faculty of Agricultural Engineering University Pertanian Malaysia can play its role by increasing the production of such personnel and provide specialised training at post-graduate level where necessary.

32. Weather or climate knows no political boundaries. Rain falling in one country may flow or enter into another either as surface runoff, subsurface flow or through streams and rivers. In the absence of co-operative efforts, this water will be wasted as it flows back to the sea. With the rapid economic development taking place in this region, the demand for water will continue to increase. A more effective and efficient system for the utilization of water may be worked out if countries in this region, ASEAN for example, were to pool and share their expertise in water management, this will further strengthen the spirit of co-operation within this region, as well maximising utilization of an increasingly limited resource. Examples of these are the water supply for Singapore and the Golok River Basin Development. If this seminar would discuss the possibility of a joint effort in water resources development and management, it would have achieved its purpose.

33. In developing water supplies for rural communities it may be possible to extract water directly from the rivers. Construction of dams is expensive and reservoirs occupy vast areas of land. Direct pumping from the river which has adequate flow throughout the year has definite advantages.

34. I am glad that University Pertanian Malaysia has organised this seminar on 'Water Technology Towards Rural Development' at this timely movement. I hope that this seminar will provide the opportunity for the experts and participants to exchange views and consider the various pressing issues connected with the water and land resources development of this country. It is also my sincere hope that your deliberations in the next three days will come up with useful suggestions or practical measures to assist in the orderly and planned development and management of our water resources, thus contributing to the socio-economic development objectives of the country and in particular, the rural sector. For the many foreign participants, I wish them a happy stay in this country.

TABLE 1

Water Supply Services Levels (1970 - 1985) Malaysia
(Population Figures in Thousands)

	1970		1975		1980		1985	
	Population	%	Population	%	Population	%	Population	%
URBAN								
a. House Connection	2,024	72.6	2,810	81.2	3,760	86.6	4,798	89.7
b. Standpipes	295	10.6	320	9.2	344	8.0	371	6.9
c. Sanitary Wells	90	3.2	90	2.6	90	2.0	90	1.7
d. Insanitary Wells	303	10.9	190	5.5	105	2.4	61	1.1
e. Others (rivers, etc.)	76	2.7	50	1.5	40	1.0	30	0.6
Sub-Total Urban :	2,780	100.0	3,460	100.0	4,340	100.0	5,350	100.0
RURAL								
a. House Connection	1,653	21.6	2,258	27.1	3,714	39.6	5,461	52.4
b. Standpipes	1,653	12.2	1,081	12.8	1,253	13.3	1,452	13.9
c. Sanitary Wells	306	4.0	801	9.4	1,235	13.3	1,735	16.6
d. Insanitary Wells	3,000	39.2	2,700	31.8	1,968	21.1	582	9.4
e. Others (rivers, etc.)	1,760	23.0	1,600	18.9	1,200	12.7	800	7.7
Sub-Total Rural	7,652	100.0	8.480	100.0	9.370	100.0	10,430	100.0
OVERALL								
Adequate (a + b + c)	5,301	50.8	7,400	62.0	10,396	75.8	13,907	88.1
Inadequate (d + e)	5,139	49.2	4,500	38.0	3,314	24.2	1,873	11.9
Total Urban and Rural :	10,440	100.0	11,940	100.00	13,710	100.0	15,780	100.0
OVERALL								
a. House Connection	3,677	35.2	5,108	42.8	7,474	54.5	10,259	65.0
b. Standpipes	1,228	11.8	1,401	11.7	1,597	11.7	1,823	11.5
c. Sanitary Wells	396	3.8	391	7.5	1,325	9.7	1,825	11.6
d. Insanitary Wells	3,303	31.6	2,890	24.2	2,074	15.1	1,043	0.6
c. Others (rivers, etc.)	1,836	17.6	1,650	13.8	1,240	9.0	830	5.3
Total Urban and Rural :	10,440	100.0	11,940	100.0	13,710	100.0	15,780	100.0

Source : Estimates by WHO, EPU and PWD, 1978 (1).

THE APPLICATIONS OF LANDSAT IMAGERY TO SURFACE WATER RESOURCES IN THAILAND

by

Pongpit Piyapongse
Chief Soil and Water Research Branch, Technical Division,
Department of Agriculture

ABSTRACT

The data obtained from LANDSAT imagery could supply many useful information for surface water resources survey. This study revealed a very clear correlation between the imagery band 7 of LANDSAT and surface water bodies. Upon completion of Thailand's receiving station we could extend services to our neighbouring countries and the data obtained will be very up to date and the quality of out-put is similar to NASA's specifications. In the near future, LANDSAT-D data with higher resolution elements of 30 metres will give us a more detailed imagery. Automatic Data Processing will be a great help in monitoring and inventory of surface water bodies in the future.

I. INTRODUCTION

The role of satellite remote sensing became highly significant at the present time. Since the launching of LANDSAT-1 in 1972, many government agencies in Thailand are making use of the satellite data for their relevant applications. These agencies are Department of Agriculture, Land Development, Forestry Department and many universities with the cooperations and coordinations of The National Research Council of Thailand. One of the useful applications is the delineation of surface water sources for agricultural and energy purposes. Various research projects conducted in several laboratories have confirmed that LANDSAT data can be used efficiently to identify and separate accurately water bodies from soil and vegetation. With these advantages and the completion of Thailand's ground receiving station in November 1981 we could conduct our water resources survey with more confidence.

In 1980 the government launched a project called the Rural Employment Promotion Plan. This Project aimed to stop the mass movement of rural people seeking employment in Bangkok, to increase the incomes of people in rural areas and to relief those people from natural disasters. About 80% of these projects were devoted to water resources such as farm pond projects, reservoir construction, canal digging, and dam construction. In order to give planners and policy makers accurate and fast information, satellite remote sensing became a very useful tool.

II. OBJECTIVES

The objectives of this study were: to test the possibilities of using LANDSAT Imagery to surface water resource survey, to map the study area for water bodies such as ponds and lakes, to assist policy makers in decisions on water resources for the Rural Employment Promotion Programme, and to make an inventory of water resources in Northeast Thailand.

III. MATERIALS AND PROCEDURE

LANDSAT Imagery false color composites of 1:250,000 scale, black and white imagery band 7 (0.8-1.1 micron, near infra-red) have been used as a base map. Visual aids for photo-interpretation such as multiband additive viewer, diazochrome transparencies, and overhead projectors were employed in this study. Topographic transparency maps overlay of 1:250,000 scale have been a great help to find locations on the LANDSAT imagery. Field trips for spot checks were carried out occationally. Gray map print-outs from the Asian Institute of Technology and Chulalongkorn university have been used to check the same areas of study and used as control points.

The study included the following steps of observations:

1) Rapid scanning of the image coverage which revealed the general relationships of landform, lithology and water bodies.
2) Production of topographic base with drainage pattern and location of the water bodies by using topographic map transparency overlay.
3) Analysis of all available sources of information about the study area including field checking for temporal changes. 4) The production of preliminary map. 5) Enhancement of the final map.

IV. RESULTS AND DISCUSSION

The results of the preliminary study indicated that we can use LANDSAT imagery in water resource survey at a very high accuracy. It was proved by using Automatic Data Processing with good programme and good training set at the accuracy of greater than 98% of the water body identification and classification. LANDSAT Imagery is the only fast tool at the present time to be used for water resources inventory.

One of the critical points in delineation of water body is the soil moisture content near the water body. This problem can be solved by using temporal changes of the scene, i.e. both wet and dry season imagery. The fluctuations of high and low water lines of the study areas have been corrected by this method.

Besides the water body study we have found LANDSAT imagery could detect Karst spring in many Karst topography areas of the country. The rise of subterranean streams have been recognized in many areas. These areas are very useful for surface water development.

V. CONCLUSION

LANDSAT imagery false color composites and imagery obtained from band 7 (0.8-1.1 microns) are very helpful in the detection of water bodies and surface water conditions. Several ponds, reservoirs, and depressions have been identified and classified very precisely. Rural development authority may easily use the final products to develop the areas. The fluctuations of high and low water lines of the reservoirs were identified with the aid of LANDSAT imagery in various temporal changes scenes. Many Karst springs in various Karst topography areas have been identified.

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DISCUSSIONS

Q : For the Data received at Thailand's receiving station, what is the frequency of coverage for a particular area of interest?

A : Theoretically, the satellite will cover the same area on an 18 days repetitive cycle. However, the scanner is turned off when the cloud cover is more than eighty percent. In this case an SLAR (side looking airborne radar) will be more appropriate than the MSS (multispectral scanner) since it can penetrate clouds. For our region, imagery is available since Nov. 1981. Orders for any frame may be made through the National Research Council.

Editor's Note: The price list and coverage-area map below were furnished by Mr. Suvit Vibulsresth, Director of Remote Sensing Division, National Research Council, Bangkok 9. Thailand.

PRICE LIST
LANDSAT STANDARD PRODUCTS
REMOTE SENSING DIVISION
NATIONAL RESEARCH COUNCIL OF THAILAND

196 Phahonyothin Road, Bangkhen, Bangkok 10900, THAILAND
TEL. 5790116, 5791370-9 Ext. 401

BLACK AND WHITE PRODUCTS (MSS)

FORMAT	SCALE	PRODUCT UNIT PRICE (US $)
9 inch POSITIVE FILM	1:1,000,000	12
9 inch NEGATIVE FILM	1:1,000,000	12
9 inch PAPER	1:1,000,000	12
20 inch PAPER	1:500,000	20
36 inch PAPER	1:250,000	35

FALSE COLOR COMPOSITE PRODUCTS (MSS)

9 inch POSITIVE FILM	1:1,000,000	35
9 inch PAPER	1:1,000,000	25

COMPUTER COMPATIBLE TAPE (MSS 1 scene 1 Tape) with B & W print 1 set (4 BANDS)

9 TRACKS 1600 b.p.i. BILL*	250

*CCRS or Telespazio Format

SHIPPING CHARGE is additional 10% of the total cost.

NOTE: a. This price list is effective from April 1982, and may be changed.

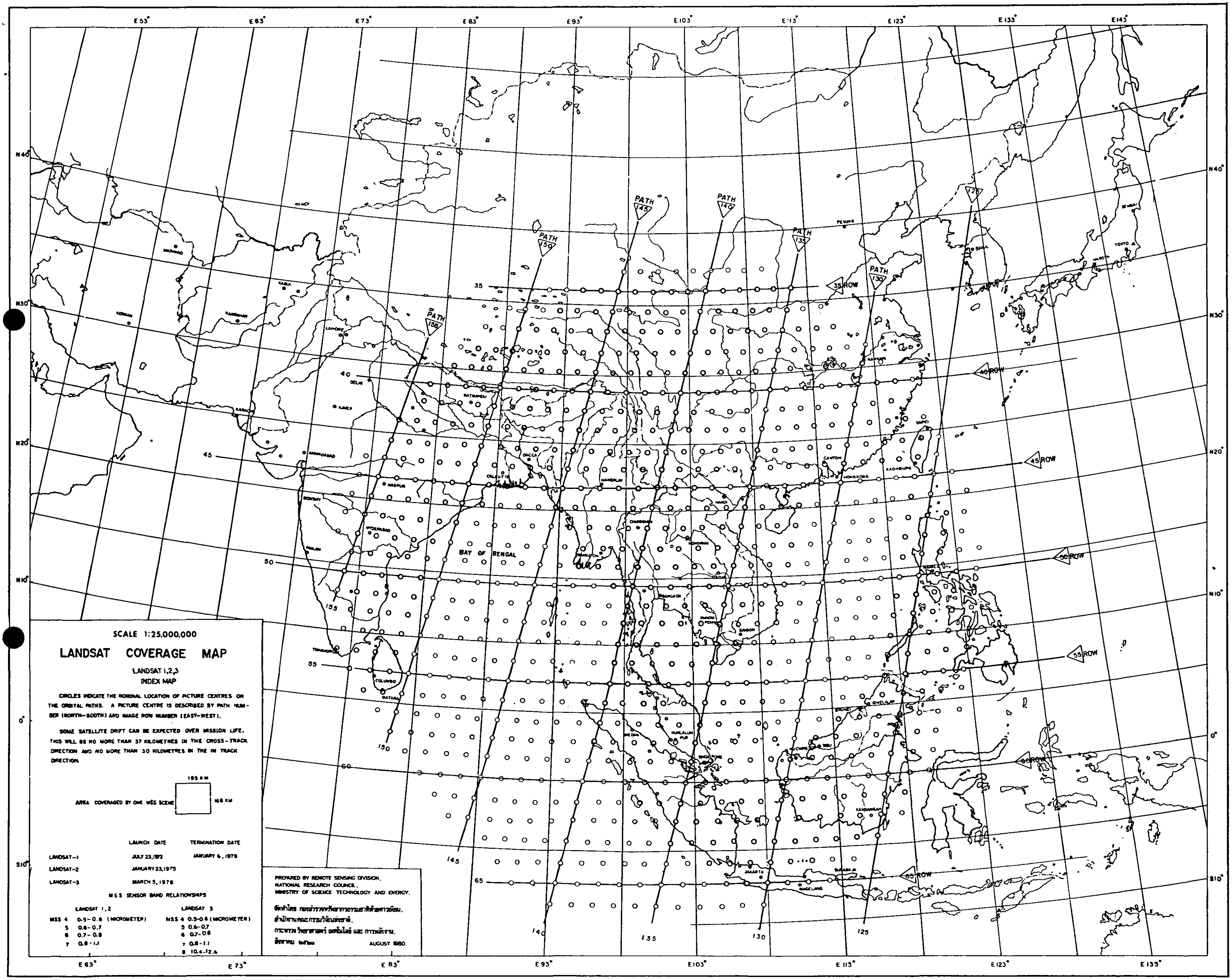
b. In case that delivery placed instructed by users in Thailand, above shipping charge is not required.

c. Shipping method is air-parcel for non - Thailand orders.

d. Payment must be made to "National Research Council".

Please contact the User Services Section of Remote Sensing Division for further assistance.

LANDSAT 1,2,3 INDEX MAP (DESCENDING PATH)



SCALE 1:25,000,000

LANDSAT COVERAGE MAP

LANDSAT 1,2,3
INDEX MAP

CIRCLES INDICATE THE NOMINAL LOCATION OF PICTURE CENTRES ON THE ORBITAL PATHS. A PICTURE CENTRE IS DESCRIBED BY PATH NUMBER (NORTH-SOUTH) AND IMAGE ROW NUMBER (EAST-WEST).

SOME SATELLITE DRIFT CAN BE EXPECTED OVER MISSION LIFE. THIS WILL BE NO MORE THAN 37 KILOMETRES IN THE CROSS-TRACK DIRECTION AND NO MORE THAN 30 KILOMETRES IN THE IN TRACK DIRECTION.

AREA COVERAGED BY ONE MSS SCENE 185 KM × 168 KM

	LAUNCH DATE	TERMINATION DATE
LANDSAT-1	JULY 23,1972	JANUARY 6, 1978
LANDSAT-2	JANUARY 23,1975	
LANDSAT-3	MARCH 5, 1978	

MSS SENSOR BAND RELATIONSHIPS

	LANDSAT 1,2		LANDSAT 3
MSS 4	0.5-0.6 (MICROMETER)	MSS 4	0.5-0.6 (MICROMETER)
5	0.6-0.7	5	0.6-0.7
6	0.7-0.8	6	0.7-0.8
7	0.8-1.1	7	0.8-1.1
		8	10.4-12.6

PREPARED BY REMOTE SENSING DIVISION,
NATIONAL RESEARCH COUNCIL,
MINISTRY OF SCIENCE TECHNOLOGY AND ENERGY.

จัดทำโดย กองสำรวจทรัพยากรธรรมชาติด้วยดาวเทียม.
สำนักงานคณะกรรมการวิจัยแห่งชาติ.
กระทรวง วิทยาศาสตร์ เทคโนโลยี และ การพลังงาน.
สิงหาคม ๒๕๒๓ AUGUST 1980.

Water Supply In Regional Land Development Project
Pahang Tenggara Experience

by

CHEW SWEE HOCK
Penolong Pengarah
Kanan
Jabatan Kerja Raya
Kelantan

PHUA JEE CHIN
Lembaga Kemajuan
Pahang Tenggara
DARA
Kuantan, Pahang

1. Introduction

1.1 Engineers do not always have the pleasure of planning and directing construction activities at his will. Time is always a a major constraint and such time constraints are often caused by many other non-engineering factors. In this paper, the authors shall discuss such problem encountered in the provision of potable water to the settlers in the new towns of Pahang Tenggara Region.

1.2 Pahang Tenggara Development Project, together with several other regional land development schemes in Malaysia, can be classified under rural development, yet it has its own unique features. Conventionally, when one speaks of rural development, one thinks of bringing development to people in the rural areas. In Pahang Tenggara, people are brought from outside into areas developed from virgin jungles. The subtle difference here is that in conventional rural development, people are already there awaiting for development. In Pahang Tenggara, the in-coming settlers expects the existence of the basic infrastructure when they move in. Rather, it is designed that way. Timing becomes very important in the latter case. Miscoordination of activities will give rise to many problems as we shall discuss in the case of water supply.

1.3 Pahang Tenggara Region covers an area of about 10,000 sq. km. at the south-east corner of the State of Pahang. Designed to settle about 500,000 people by the year 1990, it requires the creation of thirty six new towns as have been initially identified in the Master Plan. The urbanisation policy adopted requires all workers to reside in the new towns where physical and social infrastructure are of equivalent standard to those of other developed towns in the country.

The provision of fully treated piped water is one of the basic requirements for all new towns.

2. Design Criteria

One of the design objectives adopted for the new towns is to provide every household with water of the national quality standard. In the course of design, the following criteria for water demand have been adopted:-

2.1 Consumers are classified into the following categories:-

(a) Domestic - all residential housing requirements.

(b) Commercial/Institutional - all commercial, social, institutional (except schools) and government offices.

(c) Schools - primary and secondary

(d) Light Industrial - industries which have no special water demands for processing, cleaning, etc.

(e) Special Industrial - industries where there are special water demands for processing, cleaning, etc.

(f) Heavy Industrial - where quantity of water required is too large to be supplied through the town reticulation system, e.g. palm oil mills, pulp and paper mills.

2.2 Average Flows

The average daily consumptions including allowances for wastage and leakage are taken as follows:-

Domestic = 50 gallons per capita per day (gpad)
(40 gpad for Felda houses where there are no sanitary fittings)

Commercial/Institutional = 2000 gallons per gross acre per day (gpad)

Schools = 10 gallons per pupil per day

Light Industrial = 1500 gpad

Special Industrial = determined on the basis of individual requirements.

Heavy Industrial = not supplied through town reticulation system.

2.3 Peak Hourly Flow Factors

Domestic	:	2.5
Commercial/Institutional/Schools	:	2.5
Light Industrial	:	1.5
Special Industrial (on-site storage for one day's use recommended)	:	1.0

2.4 Fire Fighting Flows

Detached houses area	=	150 gallons per minute
Terrace houses area	=	250 gpm at 10 psi minimum
Others	=	300 gpm at 10 psi minimum

3. Implementation

3.1 For many of the new towns, planting of crops had started even before the towns were conceived. This headstart for the agricultural development created pressure of housing demand which had to be satisfied as soon as possible. As such all activities of town infrastructure construction are critical from the view point of programme analysis. Figure 1 shows the network diagram of the major activities. The time schedule bar chart is shown in Figure 2. The duration of activities are actual average figures. In most cases the gap between events 12 and 14 are much wider.

3.2 As can be seen from Figure 2, the completion of full water treatment system takes longer time than the completion of dwelling houses. The time lag between the completion of houses and the availability of fully treated water is indicated by the gap between events (12) and (14) which on the average is 7 months. In order that the settlers are moved in as soon as possible, some contingency measure has to be taken. This resulted in the three stages of water supply system, namely INTERIM WATER SUPPLY, TEMPORARY WATER SUPPLY and PERMANENT WATER SUPPLY.

3.3 Permanent Water Supply

Designed to satisfy the water demand of the projected population up to 15 years from completion, this system consists of complete treatment stages (flocculation, sedimentation, filtration and chlorination) to produce water to the quality standard set down by the Public Works Department for municipal supply.

3.4 Temporary Water Supply

As a compromise measure while waiting for the completion of the permanent system, chlorinated raw water is supplied to the town. This system makes use of the reservoir and pipe lines of the permanent system. Temporary pumps and intake are used to deliver chlorinated raw water to the reticulation system through the reservoir. The capacity of this system is between 30% to 60% of that of the permanent system, basing on the projected population inflow and the schedule of construction.

3.5 Interim Water Supply

This system caters only for the settlers who come in at the early stages of the town development when even the temporary supply is not ready. As it is meant only as an interim measure, it is designed to deliver water at only 10 to 20% of the permanent supply capacity. Normally the nearest stream provides the source of water. The system consists of a suitably sized diesel pump housed in temporary shed, an elevated pressed steel tank and temporary pipings. Chloride of lime is dosed at the intake well as pumping is going on. The falling main from the elevated tank is normally connected to the temp. reticulation at the initial housing area.

The whole set-up is transferable from one town to another when its purpose at that town has been achieved.

4. Problems in Operation and Maintenance

4.1 If activities can be completed according to the schedule in Figure 2, the problems attached to operating and maintenance of the water supply system should be minimal. For various reasons, however, the lag times of completion of the temporary and permanent systems are much longer in in actual situations.

Because of the urgency of getting labour into the estates in time for the harvesting, settlers are brought in even though only "Interim Supply" is available. This has given rise to many major problems.

4.2 By its nature the Interim Supply cannot cope up with a sudden influx of people. Supply is, by design, limited to only one or two hours a day only. Operation is difficult because the pump house is invariably located at areas with difficult access. Repair of breakdowns will take one or two days, quite often longer. Supervision of operators also poses a problem because of the remoteness of area of operation.

4.3 In the actual situation, even the completion of the Temporary Supply system falls far behind the inflow of settlers, thus creating a situation where demand is greater than the supply. Again supply can only be given at fixed times for three to four hours a day. As a result of this, the following problems are encountered:-

4.3.1 As the reticulation is installed in town which invariably has undulating and hilly topography, and because the whole reticulation is being filled up and emptied everyday, consumers at lower grounds enjoy longer period of supply and at higher pressure. Some high areas may not even get any water at all.

4.3.2 Because the supply is not continuous over 24 hours and is turned on and off at source, consumers tend to leave their taps on all the time. A lot of water goes to waste in this way. (Supply is free of charge in the initial stage until permanent supply is given.) It has been measured that the gross consumption figure can be as high as 120 g.p.c.d. as compared to the design figure of 40 gpcd. Control of wastage is difficult under these circumstances.

4.3.3 The reticulation mains are under cyclic pressure daily. It is difficult to ascertain what ill effects this has on the pipes but it is very likely that joints and tappings may get disturbed over time, resulting in leaks. The pipes, however, are certainly subject to more surge pressures, which can be damagingly high if openning and closing of valves are not controlled properly.

4.3.4 The raw water that is supplied receives only minimal sedimentation at the reservoir before it gets into the reticulation. Most of the suspended solids find their way into the pipes. As there is insufficient water to flush the pipes, sedimentation occurs at sags in the pipeline. There are instances where pipes are completely choked up with silt.

4.3.5 Settlers reserve the pipe water for drinking and cooking purposes and supplement their requirement by washing and bathing in streams and swamps nearby. Occurrence of skin disease has been reported to be higher in areas where stagnant swamp water is used.

4.4 Once the Permanent Supply commences, all the problems mentioned in 4.3 are eliminated. What follow are problems inherent to all municipal supplies.

5. Alternative Strategies

In view of the many problems stated above, what might be the alternatives? Firstly, the settlers themselves have tried to tide over the difficult period by installing shallow wells at their backyard. Not all are successful because of the terrain. For houses at the high ground, the authority concerned has to supply water with tanker during dry periods. But all these are stop-gap measures only and do not solve the overall problem.

Naturally another strategy is to delay the inflow of settlers. This, however, is not workable because of social and political implications.

In the final analysis, if the aim is to provide high standard water supply, the logical steps to be taken to minimize problems will be to speed up the construction of works which are critical activities. It is important that all parties concerned are made fully aware of the implications of delays and are committed towards completing the works within the scheduled time.

6. Conclusion

Unlike other rural development schemes, Pahang Tenggara new town projects do not have the traditional rural setting where population are already on site, sparse and scattered. The projects by-pass this stage, transforming jungle into modern new town in one go. Problems are expected. They are unavoidable. It is hoped that as more experience is gained, problems will be minimised.

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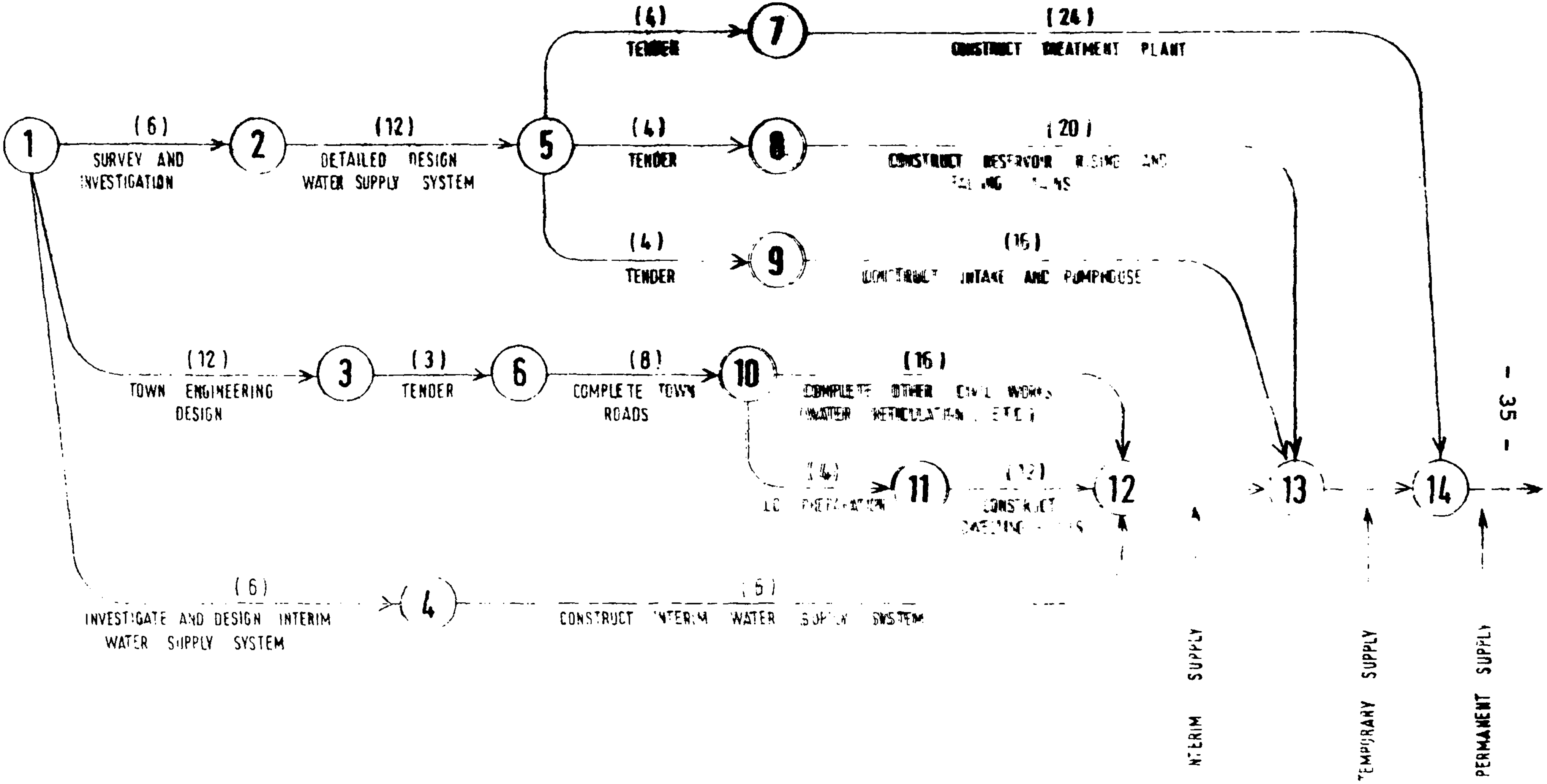

NOTE FIGURES IN PARENTHESIS INDICATE DURATION IN MONTHS

FIGURE 1

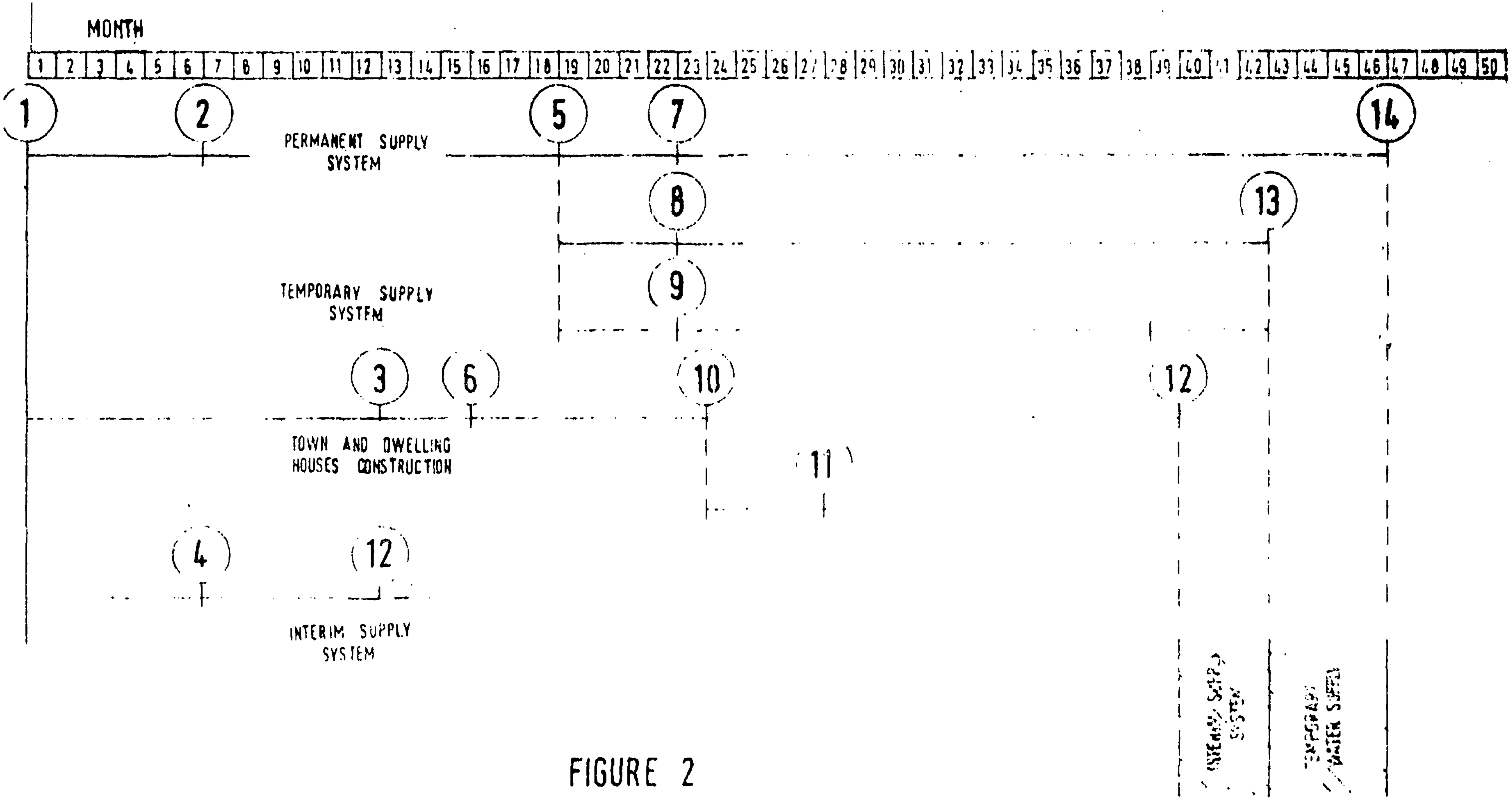
MONTH
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50
1
2
5
7
14
PERMANENT SUPPLY SYSTEM
8
13
9
TEMPORARY SUPPLY SYSTEM
3
6
10
12
TOWN AND DWELLING HOUSES CONSTRUCTION
11
4
12
INTERIM SUPPLY SYSTEM
INTERIM SUPPLY SYSTEM
TEMPORARY WATER SUPPLY

FIGURE 2

The paper was presented by Ir. Tan Boo Dek, Director of Technical Division, Pahang Tenggara Development Authority (DARA).

DISCUSSIONS

Q : You mentioned about wastage of water in the interim system. Is it not possible to install taps which automatically close, like the ones we used to have about 40 years ago? (Tan Sri Daniel - MINCO).

A : We have service connections to every household for future use. Water may come at anytime. Consumers did not bother to close the taps when there was no water. As a result water went to waste when supply came and no one was around.

Q : How closely related is the interim system and the permanent system? Please elaborate on the 10-20% figure.

A : The time lapse between the two systems varies from 7 months to four years. The interim water system is designed for 10-20% of the final projection of the population in that town because only 10-20% of the targeted population is expected to settle initially.

Q : Do you use any prefabricated plant in your interim system? We use this in East Malaysia.

A : No. the system currently being used is a very simple one, comprising of a pump, an elevated tank, a rising main and a falling main-just like a temporary system in JKR. Once the permanent system is installed, only the tank and pump are moved to another location whereas the shed and pipes are left behind.

Q : Has your division looked into the possibility of developing an interim system in such a way that it is actually a small permanent system whereby a series of them can be added on as required at a later stage? (Ir. Choa Swee Lin).

A : Economics of scale is involved here. The main purpose of an interim system is to provide water when the permanent system is not yet ready. The permanent system caters for the final demand. The water retaining structure for the permanent system is a reinforced concrete reservoir of 1.5-2 million gallons capacity as compared to less than 200,000 gallons capacity of the elevated tank used in the interim system. A temporary system is not designed for future expansion.

Q : The average flow quoted in the paper is 40 gpd. How did you arrive at this figure?

A : JKR uses the figure 50 gallons per capita per day based on the recorded consumption on the meter. Since there is no central sewer in our new towns we take away 20% of the figure used by JKR, making the average flow rate 40 gpd.

A SIMULATION STUDY OF RAINFED IRRIGATION IN NORTHEAST THAILAND

Huynh Ngoc Phien
R.J. Hosking[+]
Suvimol Lukkananukul
Division of Computer Applications
Asian Institute of Technology, P.O. Box 2754, Bangkok.

ABSTRACT

A comprehensive mathematical model of the water balance type for the assessment of the potential of rainfed irrigation in Northeast Thailand is developed. It consists of two submodels for generating daily rainfall and estimating daily potential evaporation, respectively. The number of stress days and their frequency of occurrence are computed along with the drainage requirement. Allowing deep percolation as well as overflow, the model is run day-after-day to account for the carry-over effect. Suitable planting dates, drainage and supplementary water requirements are deduced for the principal crops of the region.

INTRODUCTION

The Northeastern part of Thailand, hereafter referred to as the Northeast, covers about one third of the area of the country and has approximately the same share of the population. Climatic and soil conditions there do not favour year round farming. In a previous study (AIT, 1978) it was found that several areas of the Northeast face severe shortages of water for agricultural purposes during many months of the year, but have too much water during periods of heavy rainfall. That study also provided a preliminary assessment of rainfed irrigation for paddy cultivation in the

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[+] Seconded by the Australian Government from the University of Waikato, Hamilton, New Zealand.

region, based upon some assigned values for daily evapotranspiration. In order to have more insight into the potential of rainfed irrigation in the region for different crops, the daily evapotranspiration for each of them should be taken into account along with the occurrence and amount of daily rainfall. Moreover the planting date and growth stage of each crop should also be considered, so that the effect of stress days on the crop development may be assessed as well.

In this paper a comprehensive mathematical model is developed for a water balance analysis whereby the effective rainfall, stress days, and drainage requirement are determined. The model can also be used to estimate the supplementary irrigation water needed.

MODEL DEVELOPMENT

The comprehensive mathematical model comprises two submodels followed by a water balance analysis. The submodels provide the various possible sequences of daily rainfall and evapotranspiration values needed for the water balance analysis.

Generation of Daily Rainfall

Not only the occurrence of wet and dry days but also the amounts of rainfall on wet days are generated. The model should reproduce the following statistics of the historical data at any station:

(1) distribution of monthly rainfall sequences;

(2) mean and standard deviation of maximum amounts of daily rainfall in each month; and

(3) frequencies of wet and dry spells in each month.

These conditions are set as accepted common criteria for daily rainfall simulation (ALLEN and HAAN, 1975).

In this study, a first-order Markov chain model with two states was developed. A dry day has rainfall amount $\leq$ 1 mm, and a wet day rainfall > 1 mm, where the amount is fitted by the lognormal distribution. The generation procedure is as follows.

(a) For each month, the transition probabilities and the parameters μ and σ of the lognormal distribution (after being shifted by $x_o = 1$ mm) are estimated. In this case, only two transition probabilities, denoted by a and b, are needed since the transition matrix can be written as

$$P = \begin{bmatrix} a & 1-a \\ b & 1-b \end{bmatrix} \qquad (1)$$

where a = Prob (dry day/dry day) and b = Prob (dry day/wet day).

(b) A uniform number U on (0, 1) is then generated.

(c) Knowing the state i of one day (i = 0 for a dry day, i = 1 for a wet day), the state j of the following day is determined by comparing U with a for i = 0, or with b for i = 1, respectively. If $U \leq a$ (or b), the following day is dry and hence j = 0. Otherwise j = 1.

(d) If j = 0, the rainfall amount on the following day is set equal to zero. If j = 1, a lognormal variable X with parameters μ and σ is generated, and the rainfall amount is computed from:

$$R = X + x_o \qquad (2)$$

Steps (b) through (d) are repeated after setting i = j, until the desired length of generated sequence is reached.

To start the generation, the state of the first day must be given. It can be determined from the historical data.

Estimation of Daily Potential Evapotranspiration

Actual evapotranspiration data are not available, and thus some estimate has to be made. It is sufficient to estimate the potential evapotranspiration (ETP), since the evapotranspiration (ET) of a crop may be obtained by using the crop coefficient (Ck):

$$ET = Ck * ETP \qquad (3)$$

Due to many missing values in the pan evaporation (EP) data for the Northeast, ETP cannot be estimated from EP for a long period as needed in this study. Therefore, the Jensen-Haise formula was selected following the US BUREAU OF RECLAMATION (1971a, b) in their studies of the Nam Chi and Nam Man projects located in the region. However, for a daily basis this formula has been modified to

$$ETP = Ct * Rs*(T-To)/59.6 \qquad (4)$$

where ETP is in mm/day, Ct is the temperature coefficient in °C, To is the temperature intercept in °C, Rs is the *monthly* total short-wave solar radiation in $Cal/cm^2/day$, and T is the *daily* temperature in °C. The values of Ct and To can be obtained by using the formulae summarised by the MEKONG SECRETARIAT (1975), while Rs may be estimated by using the equation

$$RS = RA * (c+d*SS/S) \qquad (5)$$

where SS and S are respectively the monthly sunshine duration and monthly possible sunshine duration (in hours/day), c and d are two empirical constants (equal to 0.29 and 0.41 according to the MEKONG SECRETARIAT, 1975), and RA is the monthly global short-wave radiation above the atmosphere, which can be obtained from tabulated value (see DOORENBOS and PRUITT, 1977, p. 18) or can be computed *using the empirical equation provided* by the MEKONG SECRETARIAT (1975, p. 89).

In this simulation study, more than one sequence of daily ETP are needed. These are obtained by generating SS and T. The THOMAS-FIERING (1962) model can be used, but to avoid the occurrence of negative values, it is applied to the logarithms of SS and T. Generated values for SS or T will have the same mean, standard deviation, and serial correlation coefficient as the respective historical data.

Water Balance Analysis

In the water balance analysis, for a given month a value for sunshine duration is generated, and for a day in that month values for rainfall and temperature are generated. The sunshine duration and temperature values are used to estimate the daily ETP, and the daily ET using eq. 3. To carry out the water balance computation, the following factors are introduced.

- Water holding capacity (WHC): this may be estimated for each soil type by using the equation

  $$WHC = FC * B * AVE * D \qquad (6)$$

  where FC is the field capacity (in percentage), B is the bulk ratio of the soil, and D is the depth of the root zone. To account for the non-uniformity of the root distribution, a constant factor denoted by AVE is introduced so that the equivalent uniform root zone becomes AVE * D.

- Upper limit of water depth (UP): the maximum depth of water to be ponded on the surface of the soil should be considered. For the Northeast, the value for paddy suggested by the MEKONG SECRETARIAT (1975) is 135 mm; for upland crops, there is no standing water on the ground surface.
- Lower limit of water depth (DMIN): the theoretical limit coincides with the wilting point (WTP). However, for practical application it is defined as:

$$\begin{aligned} DMIN &= WHC \text{ for paddy} \\ &= [WTP + \frac{1}{3}(FC - WTP)] * B * AVE * D \qquad (7) \end{aligned}$$

- Deep percolation (DPER): deep percolation occurs when there is water stored on the ground surface. It may be assumed constant and equal to 3 mm/day for paddy (ADHIKARY, 1979); for upland crops, it may be neglected - i.e. DPER = 0.
- Stress days: a stress day is defined as a day when the water depth is $\leq$ DMIN.

The water balance analysis can be carried out by first computing tentatively the water depth on day k:

$$WD_k = WD_{k-1} + R_k - ET_k - PER_k \qquad (8)$$

where WD_k, R_k, ET_k and PER_k are respectively the water depth, rainfall amount, evapotranspiration and percolation on the day. The value of percolation water is computed as follows:

$$\begin{aligned} PER_k &= 0 \quad \text{if } WD_{k-1} \leq WHC \\ PER_k &= DPER \quad \text{if } WD_{k-1} > WHC \qquad (9) \end{aligned}$$

There are three possibilities:

(1) If $WD_k > UP$, overflow will take place. The overflow (OFL) is computed as:

$$OFL_k = WD_k - UP \qquad (10)$$

The water depth is then set equal to UP:

$$WD_k = UP$$

The effective rainfall (ER) is then computed from:

$$ER_k = WD_k - WD_{k-1} + ET_k + PER_k \quad (11)$$

(2) If DMIN < $WD_k \leq UP$, WD_k in eq. 8 becomes the actual depth for day k, and consequently:

$$ER_k = R_k$$
$$OFL_k = 0$$

(3) If $WD_k \leq$ DMIN, day k is a stress day:

$$ER_k = 0$$
$$OFL_k = 0$$

The drainage requirement may also be evaluated, as the sum of the overflow and deep percolation:

$$DR_k = OFL_k + PER_k \quad (12)$$

The water balance analysis is carried out day-after-day so that the carry-over effect can be accounted for.

MODEL VALIDATION

To validate the developed models, historical data was selected for Khon Kaen, the center of the Northeast. Daily rainfall and temperature data of 24 years (1952-1975) were obtained from ANUKULARMPHAI et al (1979), while the sunshine duration data of 20 years (1953-1972) were taken from the MEKONG SECRETARIAT (1975). For more details see AIT (1981).

Rainfall Generation

The first-order Markov model developed in this study satisfies all the three criteria stipulated before. For example, the computed values of the Kolmogorov-Smirnov statistic shown in Table 1 indicate that historical and generated monthly rainfall sequences can be fitted by the Leakage law in all months; and when there are no zero values, they can be fitted by the Gamma and Lognormal distributions as well (AIT, 1978). Since it thus reproduces the distribution of monthly rainfall sequences, the rainfall model should obviously reproduce all its descriptors such as the mean, standard deviation and skewness coefficient.

Table 1 Values of Kolmogorov-Smirnov statistic (*) in fitting monthly rainfall sequences.

Month	Historical Sequence			Generated Sequences		
	(1)	(2)	(3)	(1)	(2)	(3)
Jan	0.170	-	-	0.190	-	-
Feb	0.071	-	-	0.164	-	-
Mar	0.090	-	-	0.156	-	-
Apr	0.128	0.176	0.144	0.124	0.112	0.116
May	0.075	0.111	0.088	0.136	0.150	0.139
Jun	0.065	0.078	0.808	0.144	0.151	0.144
Jul	0.077	0.099	0.081	0.161	0.144	0.153
Aug	0.166	0.130	0.119	0.142	0.147	0.143
Sep	0.140	0.143	0.133	0.184	0.181	0.185
Oct	0.071	-	-	0.189	-	-
Nov	0.052	-	-	0.171	-	-
Dec	0.049	-	-	0.066	-	-

Notes: (*) critical value at 5% significance level = 0.269
(1) by Leakage law
(2) by Lognormal distribution
(3) by Gamma distribution
(-) not applicable (because of zero values)

In Table 2, the mean and standard deviation of the maximum amounts of daily rainfall in each month are collected, where the simulated values are obtained from 10 generated sequences each having the same length as the historical record. Although the number of generated sequences employed may be small, the simulated values are very close to the respective historical statistics, and this closeness indicates that these descriptors of the maximum amounts of daily rainfall are preserved by the model. The third condition previously set (viz. reproduction of the frequencies of wet and dry spells each month) is also satisfied, but not presented here to save space.

Potential Evapotranspiration

Although the Jensen-Haise formula involves less input data than most alternative formulae, its use may be justified by the fact that the monthly values of ETP computed from this method (with monthly sunshine duration and daily temperature generated by the Thomas-Fiering model) are in the range of those provided by the

Table 2 Mean and standard deviation of maximum amounts of daily rainfall in each month.

Month	Mean		Standard Deviation	
	(1)	(2)	(1)	(2)
Jan	8.817	9.470	15.346	14.674
Feb	16.042	15.715	14.257	15.568
Mar	20.537	20.150	18.792	14.979
Apr	32.883	31.725	19.720	20.330
May	57.912	57.908	26.306	36.910
Jun	52.325	47.337	21.931	37.337
Jul	40.267	37.823	21.612	23.563
Aug	55.496	52.513	23.215	32.145
Sep	60.454	60.387	36.312	39.476
Oct	33.008	32.346	30.004	31.362
Nov	2.812	3.607	5.983	5.924
Dec	1.867	1.899	4.768	5.078

Notes: (1) from historical sequence
(2) from generated sequences

MEKONG SECRETARIAT (1975). For comparison, the mean values are callected in Table 3.

Comment

The use of mathematical models for data generation has several advantages. It can provide as many sequences as required. Each sequence can be considered a realisation of the population involved with parameters estimated from the historical record. Once the parameters have been estimated, the model can be used to generate

Table 3 Mean monthly evapotranspiration

Month	(1)	(2)	Month	(1)	(2)
Jan	147	144	Jul	184	180
Feb	257	257	Aug	171	171
Mar	200	202	Sep	160	159
Apr	220	217	Oct	168	173
May	211	213	Nov	151	151
Jun	188	182	Dec	136	140

Notes: (1) computed for period 1951-1974
(2) obtained from MEKONG SECRETARIAT (1975) for period 1953-1972

data. This can obviously avoid the requirement of an *overlapping period* for the various historical data otherwise needed, a requirement which usually cuts short its length.

MODEL APPLICATIONS

The Markov chain model for daily rainfall generation, and the Jensen-Haise formula for estimating daily ETP, are readily applied in the overall simulation (comprehensive mathematical model) of rainfed irrigation using water balance analysis.

In this study, water depth is treated as a non-negative variable, and thus it is convenient to write:

$$\begin{aligned} UP &= WHC + 135 \text{ mm} && \text{for paddy} \\ &= WHC && \text{for upland crops} \end{aligned} \qquad (13)$$

The depth of ponded water on the ground surface for paddy fields may conveniently be called the surface water depth requirement (SWDR). For upland crops, SWDR is of course equal to zero. The water depth requirement is then:

$$WDR = WHC + SWDR$$

The growing season of paddy may be divided into two stages, and upland crops into four. The crop coefficient Ck in eq. 3 for the respective stages may be obtained from DOORENBOS and PRUITT (1977). Since evapotranspiration is reduced when the water depth is less than WHC, the computed value of ET is adjusted by linear interpolation according to the THORNTHWAITE-MATHER (1955) equation:

$$ET = ET * (WD - WDO)/(WHC-WDO) \qquad (14)$$

where WDO is the water depth corresponding to the wilting point;

$$WDO = WTP * B * AVE * D \qquad (15)$$

For a given crop with a selected planting date, the water balance analysis is carried out day-after-day for the entire growing season, and repeated as many times (i.e. as many years) as needed. The flowchart of the computer program for the water balance analysis is shown in Fig. 1.

In this study the number of replications selected was 50, in order to provide reliable results for the means of the number of stress days, their frequencies, and drainage requirements without

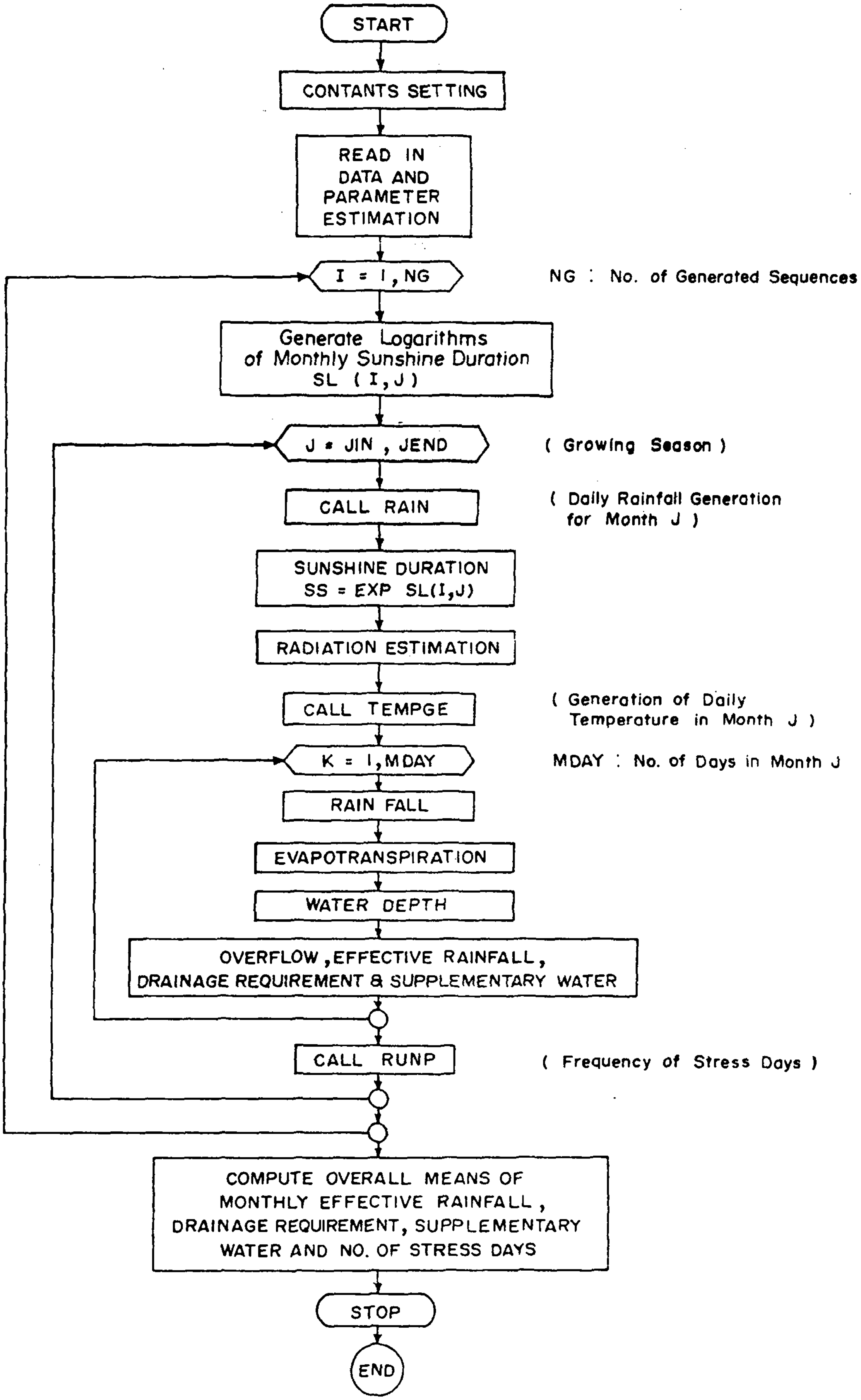

FIG. 1 Flow Chart for Water Balance Analysis

using excessive computer time. Although the comprehensive model was run for other principal crops in the Northeast, only the case of paddy is reported here due to the limited space available - see AIT (1981) for other crops.

The planting date practiced is May 1, and the growing season lasts for about 100 days. Although the period and frequency of occurrence of stress days are available from the computer output, only the mean values of the number of stress days and drainage requirement for the months of the growing season are collected in Table 4 and the mean frequencies of spells of stress days are shown in Fig. 2 (the results for month 4 are not shown, since the growing season extends only 8 days into this month). In the simulation, the water depth on the planting date was set equal to WDR, and hence the number of stress days in this month is low while the drainage requirement is high. Generally, the number of stress days increases from May to July and the drainage requirement decreases accordingly. It is seen from Fig. 2 that the frequencies of stress

Table 4 Stress days and drainage requirements

Planting date	Rank of month	No.of stress days	Drainage requirement (mm)
May 1	1	6.29	80.83
	2	20.96	28.38
	3	25.04	18.00
	Total*	59.58	136.35
Jun 1	1	8.38	21.00
	2	27.58	10.63
	3	15.04	46.75
	Total*	54.88	95.73
Jul 1	1	9.46	67.70
	2	17.75	47.33
	3	14.42	46.65
	Total*	47.05	171.31

(*) for the entire growing season (month 1 - month 4)

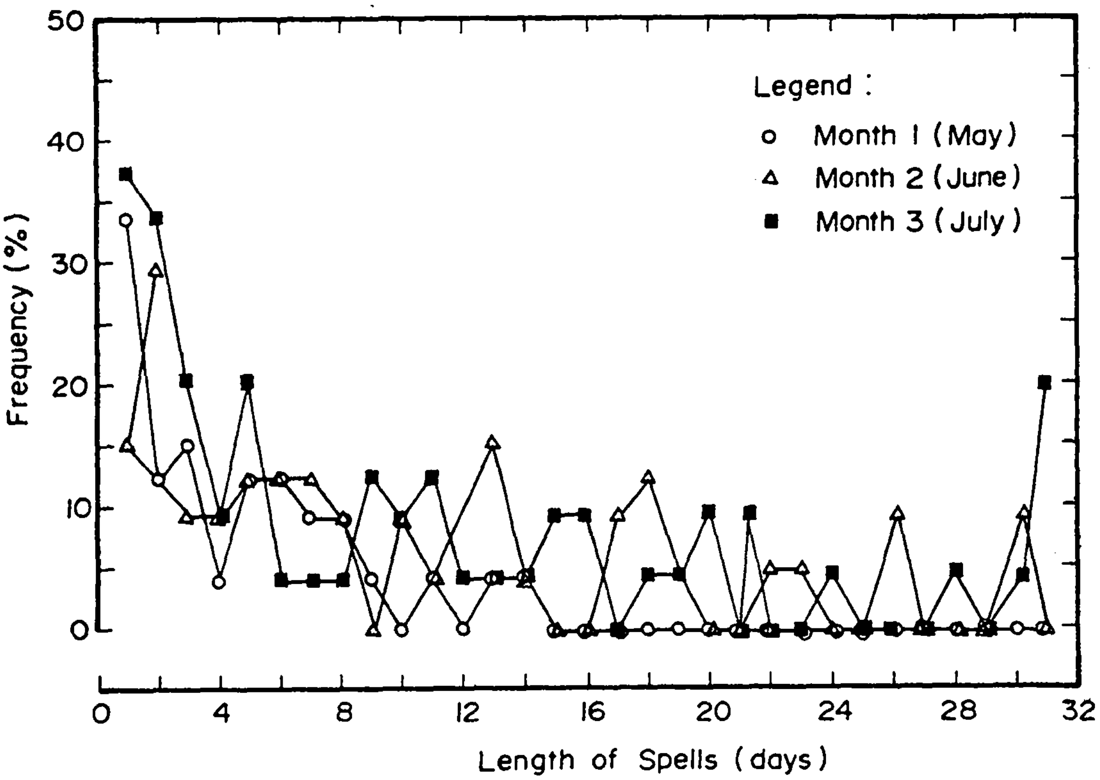

Fig. 2 Frequency of Spells of Stress Days for Paddy Planted May 1

day spells of length > 5 days is quite low (≤ 15% for most of the months) - i.e. on average, spells of stress days lasting for 5 days or more occur less than 15 times in every 100 years. With this low frequency, stress days would not seriously affect rice development and yield.

A more suitable time for any crop may be predicted using the comprehensive model by shifting the planting date. In the case of paddy, if the planting date is shifted to July 1, the number of stress days is lower than for either May 1 or June 1, but the corresponding drainage requirement is very high. Of the three alternatives shown in Table 4, June 1 is preferable because both the number of stress days and the drainage requirement are relatively low.

Assuming that supplementary water is available for supply when a stress day occurs, the amount of water required may also be computed from the water balance analysis. For paddy planted May 1 the supplementary water needed to bring the water depth after the first stress day back to 80, 90, and 100% of the WDR is shown in Table 5. As may be expected, the number of stress days decreases and the drainage requirement increases, compared with when no supplementary water is provided (Table 4); and when supplementary water is added up to the WDR the corresponding number of stress days is least. Note that a 100% irrigation level is most suitable, because although it must of course require the most water on each occasion, the number of occasions is less; thus it turns out that on average it requires the least amount of water while the total drainage requirement is just slightly higher than for 80% or 90% irrigation.

Table 5 Stress days, drainage requirement and supplementary water requirement for paddy planted May 1

Irrigation level	Month	Stress days	Drainage requirement (mm)	Water requirement (mm)
100%	1 2 3	0.71 1.50 1.38	102.95 91.59 97.57	74.71 156.24 143.28
	Total(*)	3.84	323.10	400.25
90%	1 2 3	0.79 1.79 1.50	104.65 91.70 94.68	83.11 187.26 156.52
	Total(*)	4.33	317.13	452.62
80%	1 2 3	0.92 2.04 2.00	102.62 91.85 95.14	96.61 214.24 208.24
	Total(*)	4.34	316.15	540.75

(*) for the entire growing season (month 1 - month 4)

Remarks

In order to select the most appropriate time for the planting date of any crop, several factors (such as the number of crops cultivated in a year, the drainage requirement, suitable time for harvesting, etc.) have to be considered besides the availability of rain water, the effective rainfall, and the occurrence of stress days. The model developed in this study is capable of providing important relevant information - viz. the amount of rain, the evapotranspiration, the occurrence and the period of stress days, the drainage requirement, and the supplementary water needed. It therefore is helpful to decide the most appropriate planting date for a given crop.

SUMMARY AND CONCLUSIONS

A comprehensive mathematical model of the water balance type, consisting of two submodels for generating daily rainfall and estimating daily potential evapotranspiration respectively, has been implemented to assess the potential of rainfed irrigation in Northeast Thailand.

A Markov chain model to generate the daily rainfall data reproduces all the historical statistics set, yet involves few parameters and therefore is easy to use. The estimation of daily potential evapotranspiration by the Jensen-Haise formula involves using daily - instead of monthly - temperature data and monthly sunshine duration, both of which are generated using the Thomas-Fiering model.

The comprehensive mathematical model defines the water content in the soil and on the ground surface (simply called the water depth) for a given crop. The number of stress days and their frequency are computed along with the drainage requirement. Allowing deep percolation as well as overflow, this water balance model was run day-after-day to account for the carry-over effect.

With two submodels validated by the historical data in the Northeast, the comprehensive model readily predicts the number of stress days and estimates drainage and supplementary water requirements for the crops planted in that region. The potential of alternative planting dates can hence be predicted, although certain other factors (e.g. number of crops cultivated each year, or suitable time for harvesting) must be taken into account.

With some modifications reflecting local climatological and soil conditions, the model should also be applicable to other regions.

ACKNOWLEDGEMENTS

The authors extend their sincere thanks to Dr. Apichart Anukularmphai of the Division of Agricultural and Food Engineering, Asian Institute of Technology (AIT) for his valuable suggestions and constructive comments, and to the Royal Government of Thailand for financing the study.

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The paper was presented by Miss Suvimol Lukkananukul, System Analyst at the Division of Computer Applications, AIT.

DISCUSSIONS :

Q : In this form of study are we able to predict any cyclical form of rainfall?

A : Based on historical data and some factors we can predict the cyclical form of rainfall.

Q : In the generation of daily rainfall, you fitted a first order Markov's chain and it was validated by using the monthly rainfall. Was there any work that can support the use of Markov model for the daily rainfall?

Are the transition probabilities a and b in the matrix applicable throughout the year or are these numbers dependent on the month or season only?

A : From Allen and Haan, 1975, the Markov's chain is stationary for a period.

SOLUTION FOR THE UPCONING OF AN INTERFACE TOWARDS A DRAIN

Mohamed Rashidi Bakar
Faculty of Agricultural Engineering
Universiti Pertanian Malaysia
Serdang, Selangor
Malaysia

ABSTRACT

One of the problems encountered in groundwater flow involves an interface between two immiscible fluids. In this paper, the upconing of an interface between flowing fresh ground water and stationary salt water towards a drain will be discussed and solved. The interface flow problem is best solved by mapping the interface onto a hodograph plane so that the unknown curves of the interface in the physical plane are mapped onto known curves in the hodograph plane. This enables the application of conformal transformation or mapping techniques. The relationship of the discharge to the depth of the drain will finally be obtained, along with the equation of the interface. From these relationships, the location of the drain and its limiting discharge, that is the maximum discharge that could be pumped before the salt water starts to intrude into the system, could be computed.

INTRODUCTION

One of the factors that must be considered in a water supply system is the presence of salt or brackish water in the system. Its presence does not only makes one's life miserable but it also affects the piping system. In rural areas, where groundwater had been used quite extensively both for home consumption and also for irrigation of crops, its presence will definitely affects the growth and hence the yield of crops.

Salt water is normally found at a depth greater than the depth of the fresh water. The boundary separating the salt water from the fresh water is known as an interface. For the interface to be abrupt and distinct, it is necessary that the two fluids are immiscible such as oil and water, but in the case of fresh water and salt water, there is always a certain zone of mixing; the interface therefore is not abrupt. However, in this problem, the interface between the salt and fresh water is assumed to be abrupt.

It is of significant importance that drains be positioned or placed at a depth above the depth of the interface otherwise the discharge of the drain will purely be salt water. However, even if the drain is to be positioned above the interface, it does not necessarily means that the water being pumped out is free from salt water. At a certain position of the drain above the interface, if the discharge is low, the interface will not be affected and remains in a horizontal position. If the discharge is increased, the interface will move towards the drain forming a cone-shape figure. This upconing of the interface towards the drain will become unstable if the discharge is further increased resulting in the intrusion of salt water into the drain.

In this paper, the locations and the discharges of the drain will be determined to ensure a steady interface so that no brackish water occurs in the drain pipes.

In deriving the solution of the upconing of the interface towards a drain, several assumptions had to be made. It is assumed that the flow rates in the salt water region are so small that they can be neglected. The salt water and the fresh water are assumed to be divided by an interface rather than a transition zone and that the salt water is at rest. Inhomogenities of the permeability are neglected and only two dimensional flow problems will be considered.

THEORY

The Hodograph

Figure 1 shows the interface between the salt water and fresh water in the physical plane, z. The equation of the interface in this plane is unknown. In order that the equation of the interface be made known, a hodograph technique is used to solve the problem. The hodograph q, is a complex representation of the specific discharge vector (q_x, q_y).

$$q = q_x + iq_y$$

At the interface between the fresh water and the salt water at rest, the pressure of the salt water, P_s, is equal to the pressure of the fresh water, P_f.

The head in the fresh water, ϕ_f, and the head in the salt water, ϕ_s, are related by the following equation:

$$\phi_f = \frac{\phi_s \gamma_s}{\gamma_f} - y \frac{(\gamma_s - \gamma_f)}{\gamma_f}$$

Since the interface is a streamline, the specific discharge vector is tangent to the interface. Applying Darcy's Law and assuming a constant ϕ_s,

$$q_s = \frac{- k\partial\phi_f}{\partial s} = k^* \text{Sin } \delta$$

where s is the coordinate along the interface δ is the inclination, and k is the permeability;

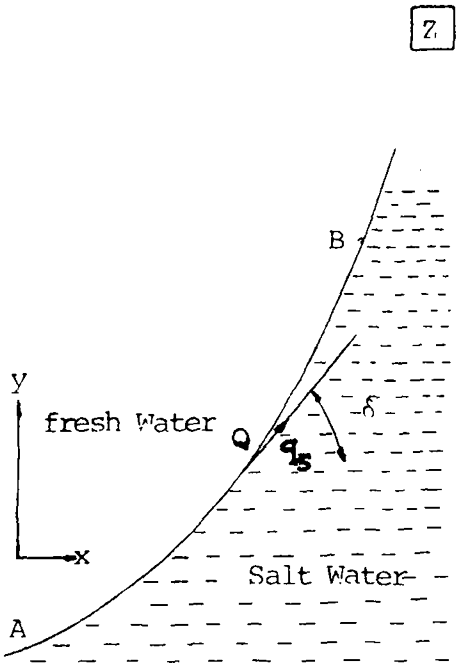

Figure 1. Interface between salt and fresh water

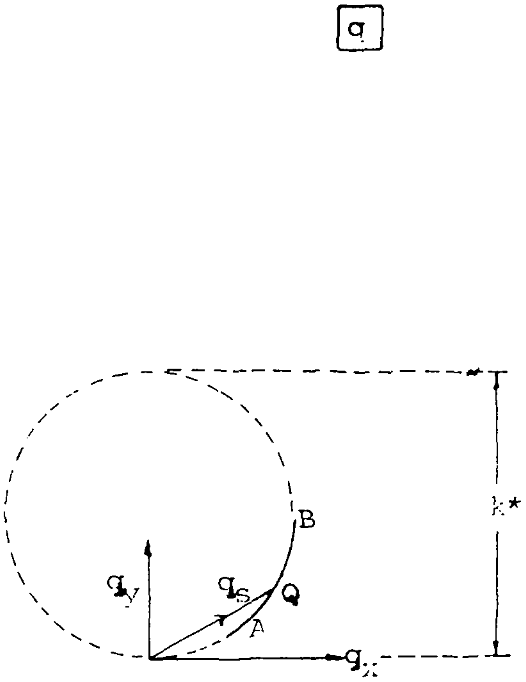

Figure 2. The map of the interface in the hodograph plane

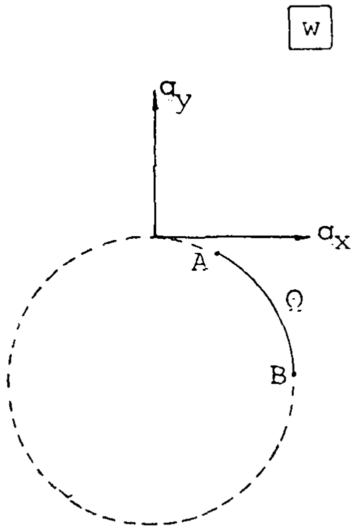

Figure 3. The map of the interface in the w plane

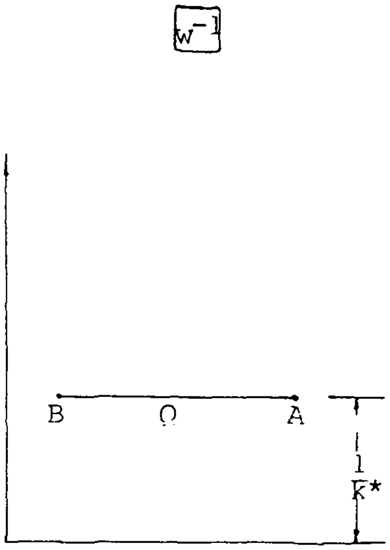

Figure 4. The map of the interface in the w^{-1} plane

$$k^* = \frac{k\ (\gamma_s - \gamma_f)}{\gamma_f}$$

Resolving q_s into it's x-y components and upon simplification results in:

$$q_x = \frac{k^*}{2} \text{Sin } 2\delta$$

$$q_y = \frac{k^*}{2} (1 - \text{Cos } 2\delta)$$

$$\frac{q_y}{q_x} = \tan \delta$$

Solving the equations, simultaneously yields

$$q_x^2 + (q_y - \frac{k^*}{2})^2 = \frac{(k^*)}{(2\ )}^2$$

This equation implies that in the hodograph plane, the interface is represented by a circle of radius k*/2 around the point $q_x = 0$, $q_y = \frac{1}{2}k^*$. The circle passes through the origin and through the point $q_x = 0$, $q_y = k^*$ as shown in figure 2. Figure 2 shows the mapping of the interface onto the hodograph plane.

Thus, the interface which is an unknown equation in the physical plane becomes known in the hodograph plane.

The Specific Discharge Function, w. (Fig. 3)

The specific discharge function, w, is an analytic function of z, the variable in the physical plane. This function is minus the derivative of Ω, the complex potential, with respect to z,

$$w = - \frac{d\Omega}{dz}$$

The specific discharge function is the complex conjugate of the hodograph,

$$w = q_x - iq_y = \bar{q}$$

If the boundaries of the flow regions in the w and Ω planes are known for a given flow problem, the reference plane $\mathrm{Im}\zeta \geqslant 0$ can be mapped onto both regions which gives w and Ω' as functions of the reference parameter ζ ,

$$w = w(\zeta),\ \Omega' = \Omega'(\zeta)$$

The function $w(\zeta)$ can be obtained as follows:

$$w = w(\zeta) = -\frac{d\Omega/d\zeta}{dz/d\zeta} = -\frac{\Omega'(\zeta)}{z'(\zeta)}$$

where the prime stands for the differentiation with respect to ζ Hence,

$$z'(\zeta) = -w^{-1}(\zeta)\Omega'(\zeta)$$

so that $z = z(\zeta)$ can be found upon integration if $w = w(\zeta)$ and $\Omega' = \Omega'(\zeta)$ are known.

Inverted Specific Discharge Function, w^{-1}

The region in the **w** plane is, for the cases considered, bounded by straight line segments through $w = 0$ and circular arcs. The straight line segments corresponds to straight equipotentials and straight streamlines since the directions of the specific discharge vector is constant along such lines. The circular arcs corresponds to interfaces without accretion. The occurence of this circular arcs as parts of the boundary in the w plane overides the use of the Schwarz-Christoffel transformation or one of the transformations for winding polygon to map the upper half $\mathrm{Im}\zeta \geqslant 0$ onto the region in the w plane. Because of this complication, the inverted specific discharge function, w^{-1}, is used.

$$w^{-1} = \frac{1}{w}$$

It will be shown below that the region in the w^{-1} plane will be bounded exclusively by straight line segments, so that the Schwarz- Christoffel transformation or one of the tranformations for winding polygons may be used for the determination of the function $w^{-1} = w^{-1}(\zeta)$

The equation of the streamline interface in the hodograph plane can be reduced to

$$q_x^2 + q_y^2 = k^* q_y$$

using the relationship of $w = \bar{q} = q_x - iq_y$ and on simplication of the equation, w^{-1} function is obtained.

$$w^{-1} = \frac{q_x}{k^* q_y} + \frac{i}{k^*}$$

As Im $w^{-1}(\zeta)$ is a constant, $\frac{1}{k^*}$, the circular segments are mapped onto horizontal lines which lies at a distance of $\frac{1}{k^*}$ above the origin.

UPCONING UNDERNEATH A DRAIN

The upconing of the interface underneath a drain will now be discussed. Figure (5) shows the upconing in the physical plane.

The flow region is located in the complex z plane. The coordinate system in the z(x, y) is chosen as follows. The y-axis points vertically upwards and passes through the drain, R. The x-axis is chosen along the interface in the position when no fresh water is extracted by the drain. N_5, the stagnation point and N_2 are the intersection points of the y-axis with the interface $N_{3B}N_4N_5N_6N_{1B}$, and the line of constant head $N_{1A}N_2N_{3A}$ respectively. The distance between the x-axis and the line of constant head is H. The value of the potential, Φ, along $N_{1A}N_2N_{3A}$ is kH, $\Phi = kH$. N_4, N_6 are the inflection points of the interface.

The boundary of the flow region is composed of straight equipotential and an interface between fresh water and salt water at rest. As had been introduced earlier, problem with this kind

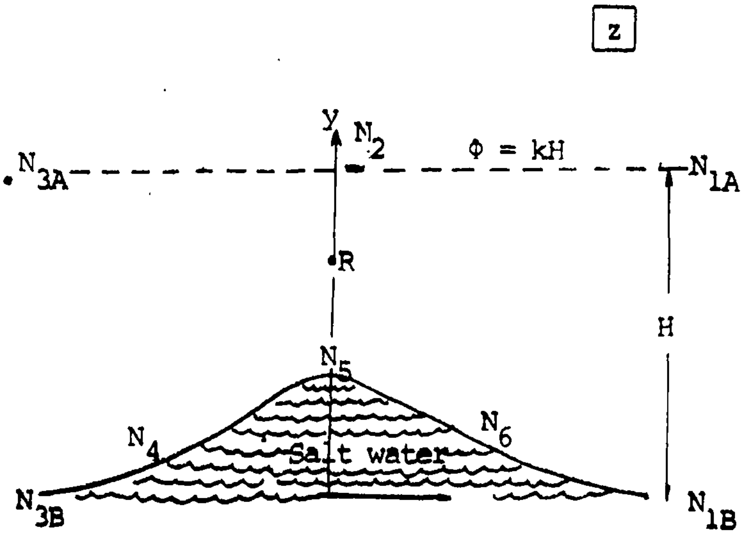

Figure 5. The upconing of the interface underneath a drain

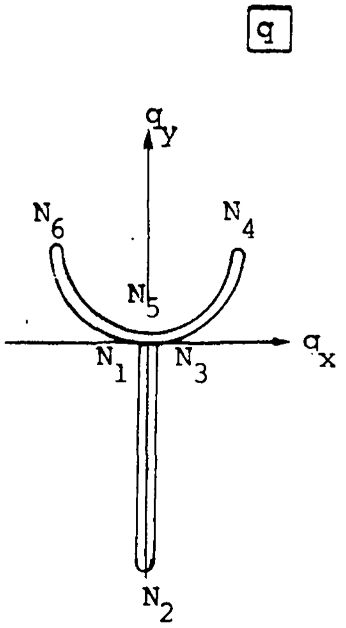

Figure 6. The map of the interface and the potential in the hodograph plane.

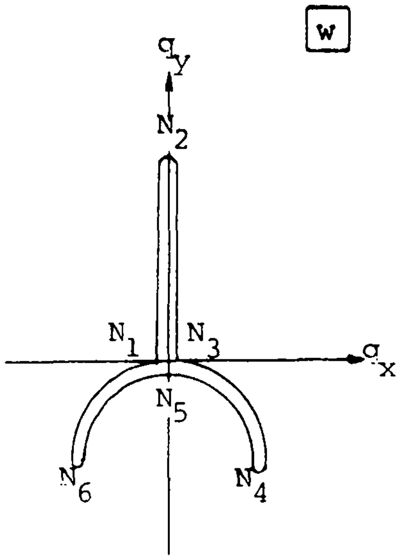

Figure 7. The map of the interface and the potential in the w plane.

of boundary condition can be solved using the hodograph method.

Approach to the Solution

The Hodograph (Fig. 6)

The hodograph, q, is first constructed from the boundary condition in the physical plane. The boundary conditions consisting of the equipotential and the streamlines are mapped onto the hodograph plane. This is done so that the unknown curve of the interface in the physical plane becomes known curve in the hodograph plane.

The region in the hodograph will be found as follows. As was discussed in the previous section, the interface is mapped in the hodograph plane onto a circle, with its center at $\frac{ik^*}{2}$ and of radius $\frac{k^*}{2}$ where $k^* = \frac{k(\gamma_s - \gamma_f)}{\gamma_f}$ At N_1, infinity in the physical plane, z, the specific discharge is zero because the influence of the drain vanishes there. The specific discharge vector is directed vertically downwards at N_2 because $N_{1A}N_2N_{3A}$ is an equipotential. At N_3, again the influence of the drain vanishes because N_3 is at infinity, thus the specific discharge is zero. In the hodograph plane, this equipotential is represented by the straight line $N_1N_2N_3$ with N_2 as the turning point. $N_{3B}N_4$, N_4N_5 are the continous interface with N_4 as the point of inflexion; Thus, these become arcs of circles in the hodograph plane as indicated by the arcs N_3N_4 and N_4N_5 with N_4 as the turning point. Similarly, the interface N_5N_6 and N_6N_{1B} with N_6 as the point of inflection are mapped onto the hodograph as shown in Figure 6. At N_5, the specific discharge is almost zero since it is a stagnation point.

The Specific Discharge Function (Fig. 7)

The region in the w plane is constructed from the hodograph plane, q. This is obtained by reflection of the hodograph plane through the real axis. The boundaries in the w plane are generally the same as that of the boundaries of the hodograph, but with the center of the circles on the opposite sides of the real axis. This is so, due to the fact that the specific discharge function is a complex conjugate of the hodograph, $w = \bar{q}$

The region in the w plane is bounded by straight line segments through $w = 0$ and circular arcs. The straight line segments corresponds to straight equipotentials since the direction of the specific discharge vector is constant along such line. The circular arcs corresponds to the interface. Figure 7 shows the w plane.

Inverted Specific Discharge Function (Fig. 8)

The Schwarz-Christoffel transformation or one of the transformations for winding polygons could not be applied due to the occurence of circular arcs corresponding to the interface in the w plane. Use is therefore made of inverted specific discharge function w^{-1} which will comprise exclusively by straight lines. Thus, enables the use of Schwarz-Christoffel transformation or one of the transformation for winding polygon.

The region in w^{-1} plane is obtained by inversion of w plane, $w^{-1} = \frac{1}{w}$ Straight equipotentials corresponds, in the w plane to straight line through the origin. Transforming w into w^{-1} these lines corresponds to straight lines through the origin of w^{-1} plane. The circular arcs in the w plane which corresponds to the interface are transformed into horizontal straight lines.

The region in the w^{-1} plane is bounded by straight line segments and is represented in Figure 8. $N_1N_2N_3$, the equipotential are mapped onto the vertical $N_1N_2N_3$ in the w^{-1} plane. As was discussed earlier, the arcs of the circles N_3N_4,N_5N_6 and N_6N_1 corresponding to the interface are transformed to horizontal lines N_3N_4, N_4N_5, N_5N_6 and N_6N_1 which lie at a distance of $1/k^*$ above the origin $w^{-1} = o$. The inverted specific discharge function, w^{-1} is

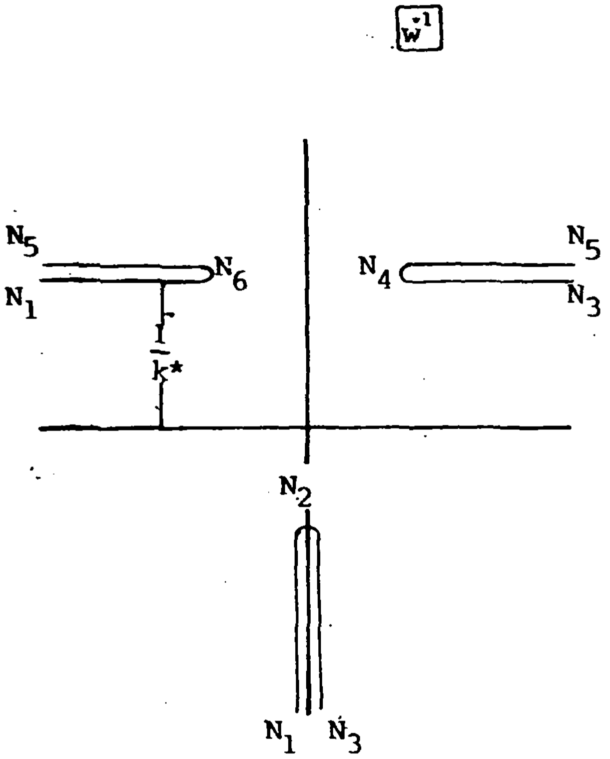

Figure 8. The map of the interface and the equipotential in w^{-1} plane

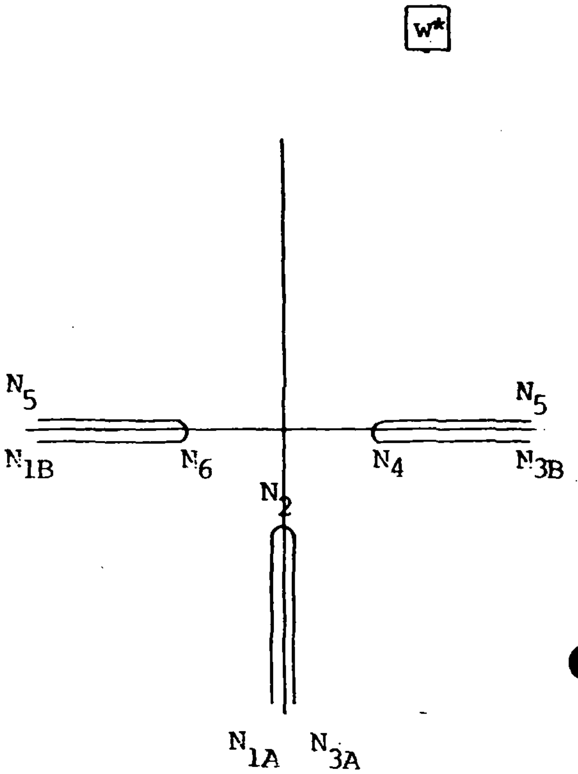

Figure 9. Transformation of w^{-1} to w^* plane

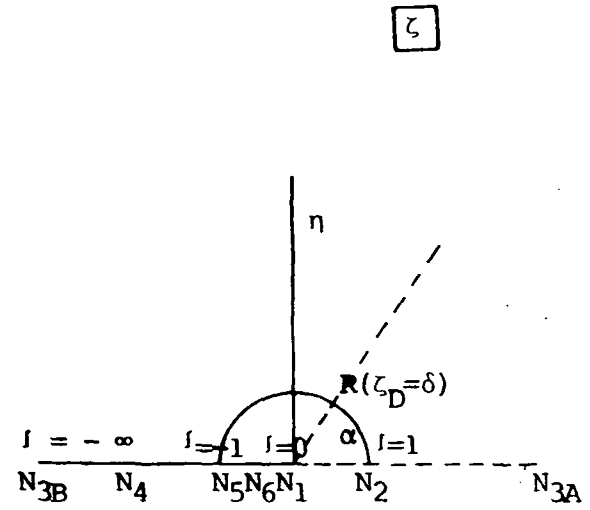

Figure 10. Transformation of w^* onto ζ plane

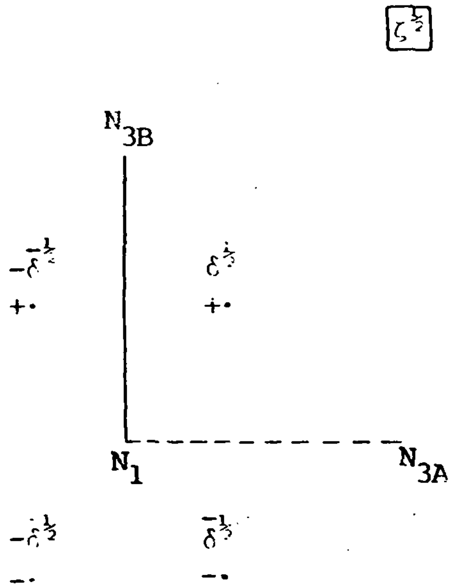

Figure 11. Transformation of onto $\zeta^{\frac{1}{2}}$ plane

zero at points where q is infinite and will be infinite at points where q is zero, as is seen in the equation,

$$w^{-1} = \frac{q_x}{k^* q_y} + \frac{i}{k^*}$$

Figure 8 shows the transformation in the w^{-1} plane

The w* plane (Fig. 9)

In order for the piecewise constant argument transformation be applied, the boundary of the region in the w^{-1} plane must be composed of straight lines through the origin. As seen in Figure 8, the boundaries represented by $N_5N_6N_1$ does not points through the origin. By means of linear transformation,

$$w^* = w^{-1} - \frac{i}{k^*}$$

these two lines are transfered to the origin of w* plane. Figure 9 shows the relationship of the transformation. The function $w^* = w^* (\zeta)$ could be solved by mapping w* onto the region in the $\mathrm{Im}\zeta > o$ by application of piecewise constant argument transformation.

$$w^* = |\alpha| e^{i\tilde{\phi}_n} \prod_{\nu=1}^{n} (\zeta - \tilde{\zeta}_\nu)^{1 - \tilde{k}_\nu}$$

For detail discussion regarding this transformation, the reader is refered to Strack, O.D.L.

The ζ plane is characterized by the following points. N_{1A}, N_{1B} are mapped onto $\tilde{\zeta}_1 = 0$; N_5 onto $\tilde{\zeta}_5 = -1$ and $N_{3A}N_{3B}$ onto $\tilde{\zeta} = \infty$. Since there is symmetry in the z plane with respect to $N_2N_7N_5$, this line will be mapped onto a unit circle in the ζ plane. Use is made of the z plane as well as the w* plane in determining the ζ plane, so that $N_{3B}N_5N_{1B}$ becomes the streamline and $N_{1A}N_2N_{3A}$ becomes the equipotential as is found in the z plane. Figure 10 shows the mapping.

At N_5, $\tilde{\zeta}_5 = -1$, $\tilde{k}_5 = 2$, and at N_1, $\tilde{\zeta}_1 = 0$, $\tilde{k}_1 = \frac{3}{2}$. $\tilde{\phi}_n$is zero because the orientatation is on the origin of the w* plane. With the above values, w* =w* (ζ) can be solved and given as:

$$w^* = \frac{A}{\zeta^{\frac{1}{2}}(\zeta + 1)}$$

where A is a constant

From the relationship of w* and w^{-1} as given by $w^* = w^{-1} - \frac{i}{k^*}$ w^{-1} can be computed.

$$w^{-1}(\zeta) = w^*(\zeta) + \frac{i}{k^*}$$

$$w^{-1}(\zeta) = \frac{A}{\zeta^{\frac{1}{2}}(\zeta + 1)} + \frac{i}{k^*}$$

The Complex Potential (Fig. 11)

The complex potential, as a function of the reference parameter, ζ , will be found by considering the flow in $\text{Im}\zeta \geqslant 0$. The function $\Omega(\zeta)$ will be obtained by applying a method known as the method of images in the $\zeta^{\frac{1}{2}}$ plane. This plane is shown in Figure 11, the upper half plane $\text{Im}\zeta \geqslant 0$ corresponds to the upper right quadrant of the $\zeta^{\frac{1}{2}}$ plane. The boundary conditions in ζ plane prohibits the application of the method of images in the ζ plane. The method is applicable only if the streamline and the equipotential are perpendicular to each other. This situation exists in $\zeta^{\frac{1}{2}}$ plane. The boundary conditions for this flow case in the $\zeta^{\frac{1}{2}}$ plane are that the imaginary axis is a streamline and along the real axis, the potential is $\Phi = kH$.

The flow case with a drain at $\zeta^{\frac{1}{2}} = \delta^{\frac{1}{2}}$ with a discharge Q is represented with two drains and two recharge drains, all with discharge Q . The drains are in the upper half of the $\zeta^{\frac{1}{2}}$ plane and the recharge drains are located in $\text{Im}\zeta^{\frac{1}{2}} \geqslant 0$. Each drain or recharge drains lies at a corner of a rectangle with two sides parellel to the real axis, having its center at the origin. If the drain are located at $\delta^{\frac{1}{2}}$ and - $\delta^{\frac{1}{2}}$ and the recharge drains at

$\bar{\delta}^{\frac{1}{2}}$ and $-\delta^{\frac{1}{2}}$, the complex potential in given by,

$$\Omega(\zeta) = \frac{Q}{2\pi} \ln \frac{(\zeta^{\frac{1}{2}} - \delta^{\frac{1}{2}})(\zeta^{\frac{1}{2}} + \bar{\delta}^{\frac{1}{2}})}{(\zeta^{\frac{1}{2}} + \delta^{\frac{1}{2}})(\zeta^{\frac{1}{2}} - \bar{\delta}^{\frac{1}{2}})} + kH$$

The Function $z = z(\zeta)$

This function is found by integration of the function

$$z' = -\Omega'(\zeta) w^{-1}(\zeta)$$

where Ω' is the first derivative of the $\Omega(\zeta)$ function and w^{-1} (ζ) is the function that been obtained earlier. Solving and applying the boundary conditions the function $z(\zeta)$ is found to be:

$$z(\zeta) = -\frac{H}{\pi} \ln \zeta + \frac{iQ}{2\pi k} \ln \frac{(\zeta^{\frac{1}{2}} + \delta^{\frac{1}{2}})}{(\zeta^{\frac{1}{2}} - \delta^{\frac{1}{2}})} + \frac{Q}{2\pi k} \arg \delta^{\frac{1}{2}} + iH$$

This equation is the same as the one obtained by Strack, O.D.L.

RESULTS AND DISCUSSIONS

The solutions of the upconing of the interface towards the drain can be represented by two equations, namely the complex potential function $\Omega(\zeta)$ and the complex physical function $z(\zeta)$. That is,

$$\Omega(\zeta) = \frac{Q}{2\pi} \ln \frac{(\zeta^{\frac{1}{2}} - \delta^{\frac{1}{2}})(\zeta^{\frac{1}{2}} + \bar{\delta}^{\frac{1}{2}})}{(\zeta^{\frac{1}{2}} + \delta^{\frac{1}{2}})(\zeta^{\frac{1}{2}} - \bar{\delta}^{\frac{1}{2}})} + kH$$

and $$z(\zeta) = -\frac{H}{\pi} \ln \zeta + \frac{iQ}{\pi k^*} \ln \frac{(\zeta^{\frac{1}{2}} + \delta^{\frac{1}{2}})}{(\zeta^{\frac{1}{2}} + \bar{\delta}^{\frac{1}{2}})} + \frac{Q}{\pi k^*} \arg \delta^{\frac{1}{2}} + iH$$

Separation of $z(\zeta)$ into real and imaginary parts x and y

From the solution obtained above, the position of the drain in the complex z (x + iy) plane can now be solved, by separating and equating the real and imaginary parts of the $z(\zeta)$ plane.

The function $z(\zeta)$ can be reduced to

$$z(\zeta) = -\frac{H}{\pi} \ln|\zeta| - \frac{H}{\pi} i\arg\zeta + \frac{iQ}{\pi k^*} \ln\left|\frac{(\zeta^{\frac{1}{2}}+\delta^{\frac{1}{2}})}{(\zeta^{\frac{1}{2}}+\bar{\delta}^{\frac{1}{2}})}\right| - \frac{Q}{\pi k^*} \arg\frac{(\zeta^{\frac{1}{2}}+\delta^{\frac{1}{2}})}{(\zeta^{\frac{1}{2}}+\bar{\delta}^{\frac{1}{2}})}$$

$$+ \frac{Q}{\pi k^*} \arg \delta^{\frac{1}{2}} + iH$$

From the relationship $\zeta = \lambda e^{i\theta}$, $\delta = e^{i\alpha}$, $\bar{\delta} = e^{-i\alpha}$ introduced earlier in the discussion of the interface, the function z can be further reduced to:

$$z = -\frac{H}{\pi} \ln \lambda - \frac{iH\theta}{\pi} + \frac{Q\alpha}{2\pi k^*} + iH + \frac{iQ}{2\pi k^*} \ln (\lambda+1+2\lambda^{\frac{1}{2}}\text{Sin}\,\frac{\alpha}{2}\,\text{Cos}\,\frac{\theta}{2}$$

$$- \frac{Q}{\pi k^*} \tan^{-1} \frac{\text{Sin}\,\alpha + 2\lambda^{\frac{1}{2}}\,\text{Sin}\,\frac{\alpha}{2}\,\text{Cos}\,\frac{\theta}{2}}{\lambda + \text{Cos}\,\alpha + 2\lambda^{\frac{1}{2}}\text{Cos}\,\frac{\theta}{2}\,\text{Cos}\,\frac{\alpha}{2}}$$

Separation of z into its real and imaginary parts yields:

$$x = -\frac{H}{\pi} \ln \lambda + \frac{Q\alpha}{2\pi k^*} - \frac{Q}{\pi k^*} \tan^{-1} \frac{\text{Sin}\alpha + 2\lambda^{\frac{1}{2}}\,\text{Sin}\,\frac{\alpha}{2}\,\text{Cos}\,\frac{\theta}{2}}{\lambda + \text{Cos}\alpha + 2\lambda^{\frac{1}{2}}\,\text{Cos}\,\frac{\theta}{2}\,\text{Cos}\,\frac{\alpha}{2}}$$

and,

$$y = -\frac{H\theta}{\pi} + H + \frac{Q}{2\pi k^*} \ln \frac{(\lambda + 1 + 2\lambda^{\frac{1}{2}} \operatorname{Cos} \frac{1}{2} (\theta - \alpha))}{\lambda + 1 + 2\lambda^{\frac{1}{2}} \operatorname{Cos} \frac{1}{2} (\theta + \alpha)}$$

Solution of ζ if the actual location of the drain is given

The position of the drain in the z plane, $z_D = x_D + iy_D$ can be related to its position in the ζ plane, $\zeta_D = \delta = {}_e{}^{i\alpha}$ by substituting $\lambda = 1$, $\theta = \alpha$ in the above equations resulting in $x_D = 0$ and y_D as given below:

$$\frac{y_D}{H} = -\frac{\alpha}{\pi} + 1 - \frac{Q}{\pi k^* H} \ln \operatorname{Cos} \frac{\alpha}{2}$$

The value of α for a given valve of y_D can be determined from the equation, and the location of the drain δ in ζ plane is obtained by substitution of α in $\delta = e^{i\alpha}$

Position of the Stagnation Point

The position of the stagnation point N_5, of Figure 10 above the x-axis could be obtained by substituting $\theta = \pi$, $\lambda = 1$ in y resulting in

$$\frac{y_s}{H} = \frac{Q}{\pi k^* H} \ln \operatorname{Cot} \tfrac{1}{4}(\pi - \alpha)$$

Relationship Between the Stagnation Point, Depth of Drain and Discharge

Both the equations for y_D and y_s had been developed and they are both in term of α. Elimination of α from the two equations results in

$$\frac{y_D}{H} = \frac{4}{\pi} \tan^{-1} e^{-\frac{\pi k^* ys}{Q}} + \frac{Q}{\pi k^* H} \ln \operatorname{Cosh} \frac{\pi k^* ys}{Q}$$

This equation is represented graphically in Figure 12.

Equation of the Interface

The equation for the interface can be obtained by substituting $\theta = \pi$ since the interface is mapped onto the negative ζ axis, resulting in

$$\frac{x}{h} = -\frac{1}{\pi} \ln \lambda + \frac{Q\,\alpha}{2\pi k^*H} - \frac{Q}{\pi k^*H} \tan^{-1} \frac{\mathrm{Sin}\ \alpha}{\lambda + \mathrm{Cos}\alpha}$$

and

$$\frac{Y}{H} = \frac{Q}{2\pi k^*H} \ln \frac{\lambda + 1 + 2\lambda^{\frac{1}{2}} \mathrm{Sin}\ \frac{\alpha}{2}}{\lambda + 1 - 2\lambda^{\frac{1}{2}} \mathrm{Sin}\ \frac{\alpha}{2}}$$

Figure 13 shows the plot of the interface with $\alpha = 1.3$ and $\frac{Q}{\pi k^*H} = 0.5$. The location of drain y_D and the stagnation point ys are also shown.

Instability of the Interface

This condition occurs if the top if the cone becomes a cusp (Fig. 14) and will eventually results in the intrusion of salt water in the drain. The mapping of ζ onto z is no longer conformal at point N_5 and therefore the derivative with respect to ζ vanishes there.

$$\frac{(dz)}{(d\zeta)}\ \zeta = -1 \qquad = 0$$

Solving the equation, it will be found that the cusp originates if

$$\frac{Q}{2\pi k^*H} = \mathrm{Cot}\ \frac{\alpha}{2}$$

Elimination of α from this equation and that of $\frac{ys}{H}$ leads to

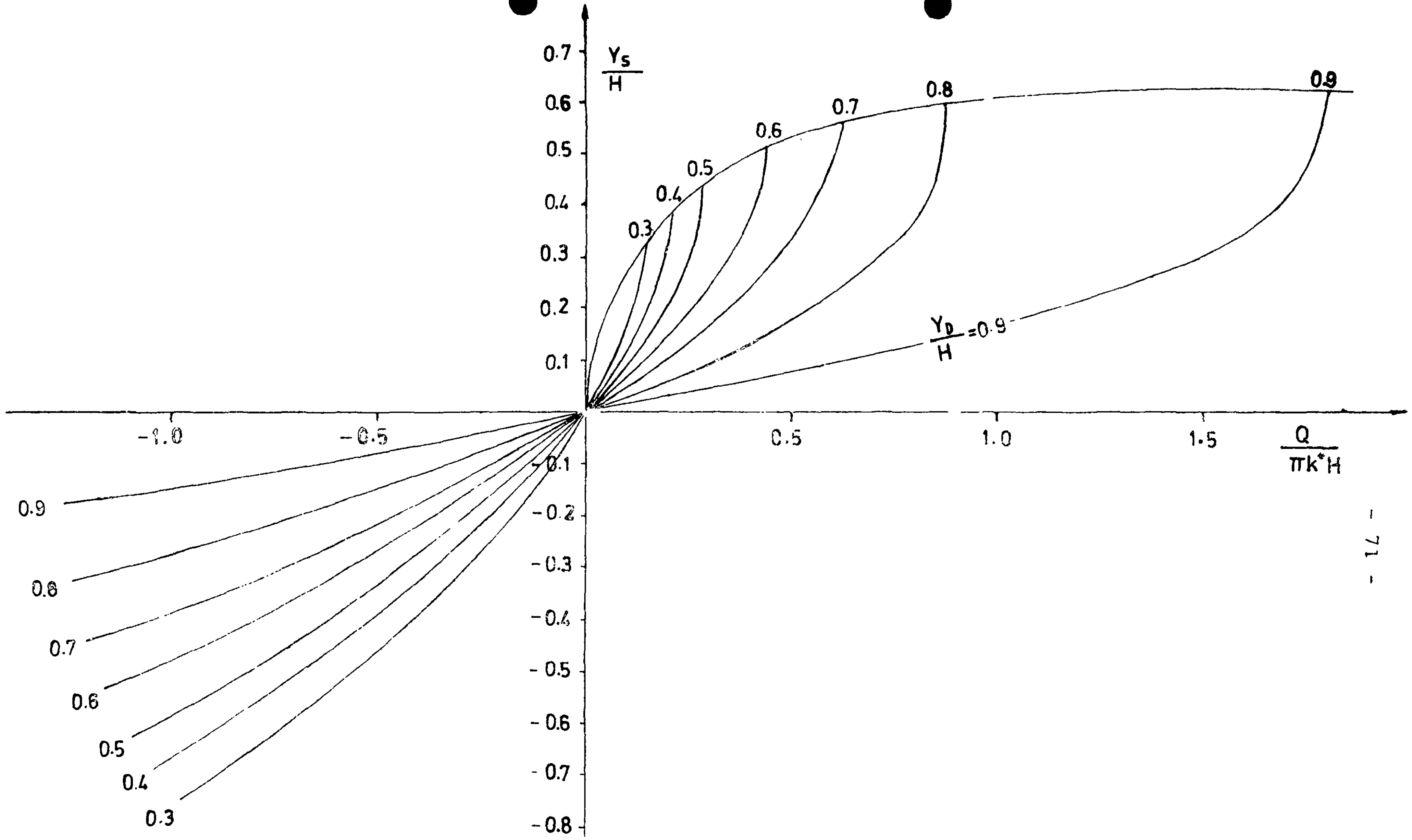

Figure 12. The relation between the unconing $(\frac{Y_S}{H})$ and the position $(\frac{Y_D}{H})$ and discharge $(Q/(\pi k^*H))$ of the drain.

Z

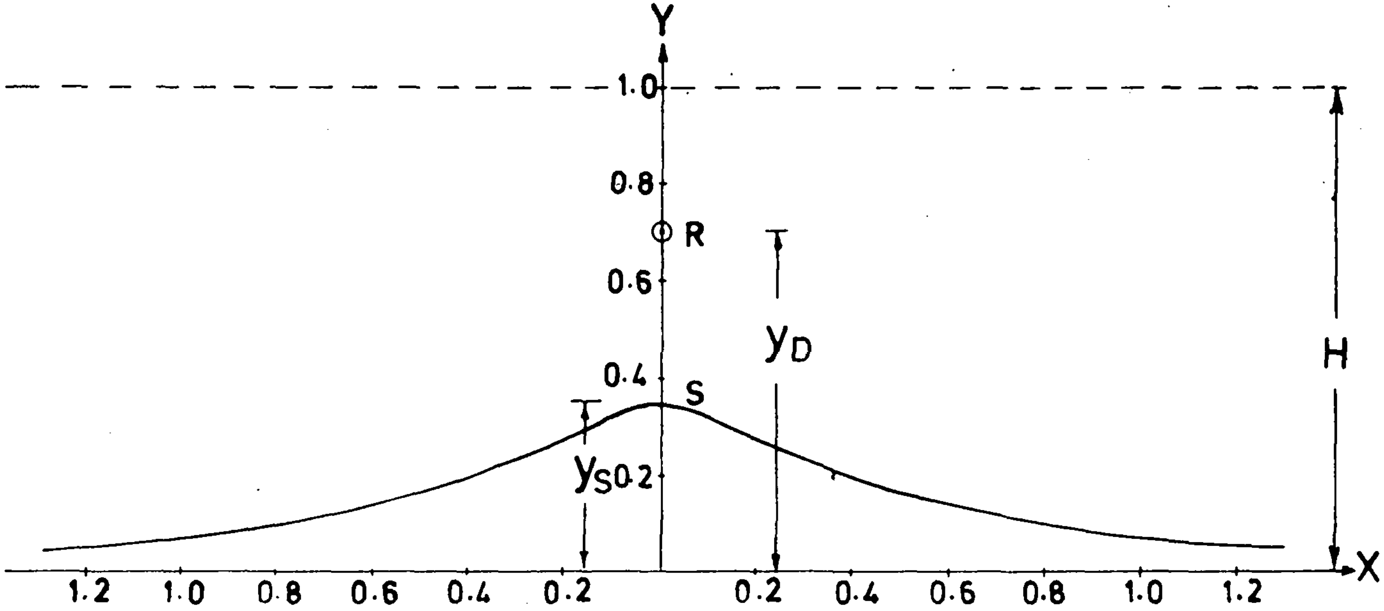

Figure 13. Plot of the Interface with $\alpha = 1.3$, $\frac{\Omega}{\pi k^* H} = 0.5$, showing the location of the drain and the stagnation point.

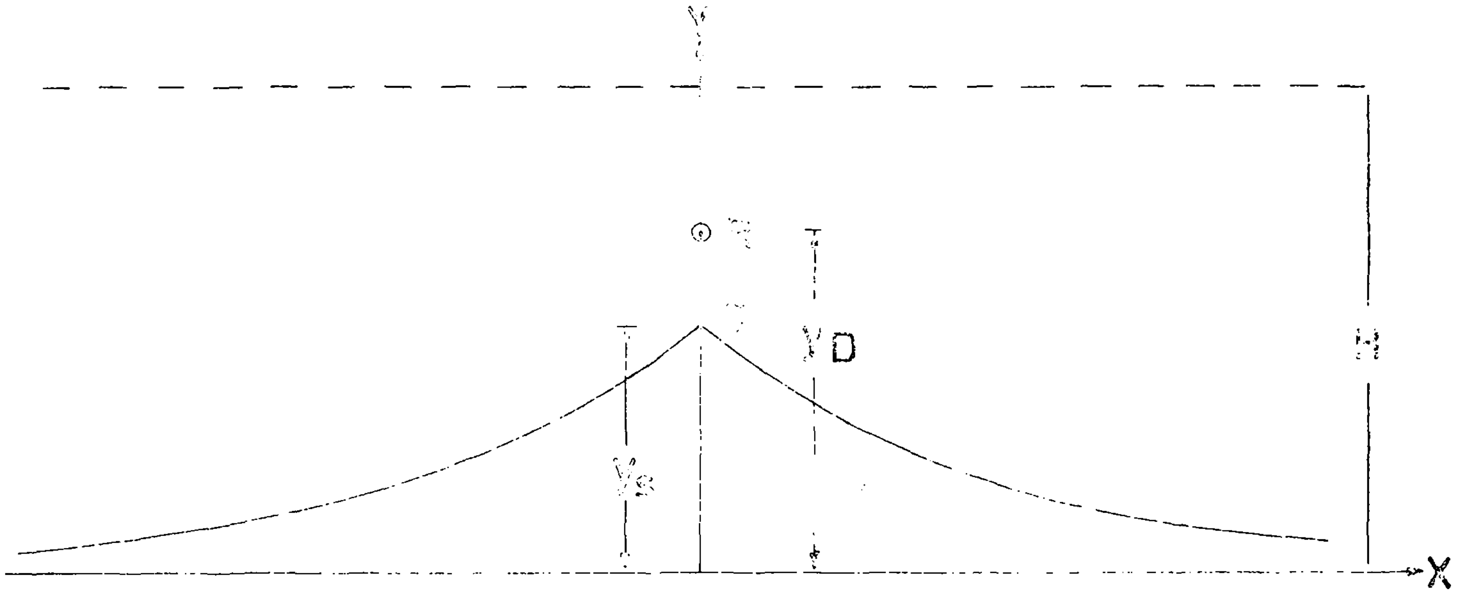

Figure 14. A cusp resulting in the instability of the interface

$$\frac{ys}{H} = \frac{Q}{\pi k^*H} \sinh^{-1} \left(\frac{2}{\pi} \cdot \frac{\pi k^*H}{Q}\right)$$

This equation bounds the graph of Fig. 12 on the upper right.

CONCLUSION

Several equations relating the discharge to the depth of the drain, the stagnation point and also the stability criteria of the interface had been developed. All these relationships are summed up and plotted as shown in Figure 12. The equation and the plot of the interface was derived and plotted as shown in Figure 13.

As can be seen from the graphs of Figure 12, higher values of discharge could be with drawn from the system if drains are located further away from the interface. For a fixed location of a drain, there exists a maximum limit of discharge above which the interface will become unstable and forms a cusp resulting in the intrusion of salt water into the drain pipe. At a constant discharge of lesser magnitude there also exists a critical location of the drain. If the drain is located too close to the interface, salt water will be withdrawn from the system although the discharge is relatively small.

As had been mentioned earlier, the interface separating salt and fresh water had been assumed to be abrupt in deriving the equations and the solution. Since there is always a certain zone of mixing between the two fluids, the result obtained may slightly be affected. However, for immiscible fluids such as water and oil where the interface is distinct and abrupt, the solution obtained would be more applicable.

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DISCUSSIONS :

Q : Is this upconing of interface a prevalent phenomena with regard to water supply for rural areas, especially in Malaysia?

A : In coastal areas, salt water is ever present but we do not know the exact depth. Through continuous pumping of the fresh groundwater, salt water intrusion will take place.

Editor's note :

In coastal areas, the Ghybrn-Herzberg relation approximates the depth to fresh water-salt water interface which is about forty times the height of fresh water above sea-level. Lowering the water table (through continuous pumping) by 1 meter will cause a 40 m rise in the interface. Lowering the water table to mean sea level will bring the interface up to mean sea level which will render the land salty and unfit for agricultural use.

MANAGEMENT OF THIRD WORLD WATER SUPPLIES

John Pickford

Leader, WEDC Group
University of Technology, LOUGHBOROUGH, England

ABSTRACT

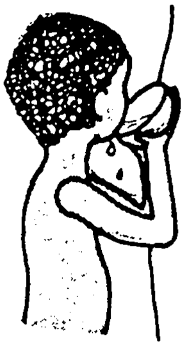
Water for domestic and personal use may be called 'people's water'. The International Drinking Water Supply and Sanitation Decade, 1981-1990, has as an objective the provision of people's water to all the world's population. Water is required for health, convenience and economic progress. Achievement of the Decade's goals depends less on technology than on good and appropriate technical management. In consideration of management and personnel for providing people's water it is found that conservatism of politicians, administrators and engineers sometimes makes them reluctant to depart from policies devised primarily for a small urban elite or from industrial countries. The result is often fallacious policies, with unfortunate consequences. Lip-service is paid to 'intermediate technology' or 'appropriate technology', but most effort has gone to developing hardware with little relevance to the hundreds of millions of underprivileged people whose present water is unsafe, inaccessible or inadequate. A greater need is for policies, programmes and systems which are appropriate for all the conditions of the people for whom the supply is intended. A radical approach is required.

INTRODUCTION

In this technological age it is sometimes assumed that all the world's problems can be solved by technology. This assumption comes especially easily to professional technologists - engineers, scientists, planners, architects, doctors and so on. Similar inflated ideas of their own indispensability are common amongst sociologists, economists, lawyers and accountants. Politicians almost invariably think the world would not go round without them!

However, in the provision of water for people in the Third World we find that expertise of all kinds is not enough. In fact, attempts to apply high professional standards have sometimes proved disastrous. The essential requirement is collaboration of skills and organization of resources in such a way that a certain objective is achieved. That is what we mean by 'management'.

In this paper we are concerned with water supplies for PEOPLE - for women, for children and for men. These water supplies are sometimes referred to as 'communal' or 'community', because most people live in communities - villages and towns and cities. But millions of water supplies are just for one household each. They are sometimes referred to as 'domestic' water supplies, because people use water in their homes. But in the Third World some water-using activities are done outside the home. People often wash their bodies, their clothes and their pots and pans at the source of the water - in a stream or pond or at a spring or public tap. These water supplies are sometimes referred to as 'drinking water', which emphasizes that the *quality* must be good. In fact only a small proportion of water supplies is actually drunk. So we will call these supplies 'people's water' to emphasize that the main reason for the water is the needs of people.



In rural areas it is difficult to distinguish water required for people from water for agriculture. Often animals live in the same house as their owners, and it is just as important to provide water for them as it is for people. However, in this paper we are not concerned with watering crops except in two ways. One is that water provided for irrigation may be taken for people. The other is that wastewater, whether clean or dirty, can be used for watering crops providing it is not contaminated with human excreta. For example, water is often spilled at taps and hand-pumps and this spilled water can be channelled to a neighbouring field.

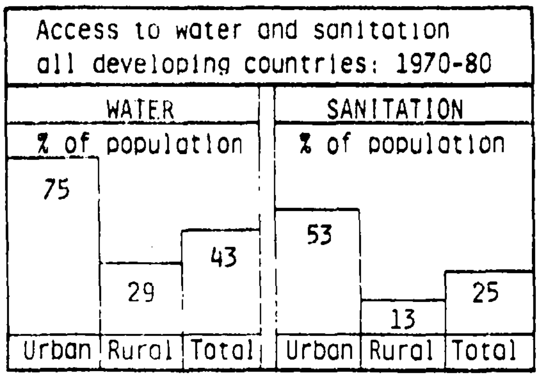
THE WATER DECADE

1981-1990

The United Nations has declared the 1980s as the International Drinking Water Supply and Sanitation Decade. Although the short title is 'The Water Decade' it is only concerned with water for people. Irrigation, hydro-electric schemes and water transport are all very important, but the Decade does not deal with them. Sanitation is associated with water in the Decade because it is equally vital for the health and well-being of people. The most important aspect of sanitation is the removal or disposal of human excreta. People's health and well-being are also influenced by the disposal of wastewater or sullage. This is water which has been used for washing and other domestic purposes. It is sometimes called 'greywater' to distinguish it from foul sewage containing human excreta. A sanitation scheme may also provide drainage of rainwater, and monsoon drains are often used for sullage as well as stormwater. Another connected part of sanitation is removal of solid waste.

The impetus for the Decade arose from Conferences, starting with that on the Human Environment in 1972 and going on through the Habitat Conference in 1976 to the Water Conference at Mar del Plata in 1977. International agencies like WHO, UNICEF, the World Bank and UNDP are closely involved in the Water Decade, but its effectiveness depends on efforts at national and local level.

The objective of the Decade is to provide safe water and **sanitation for all the world's population by 1990.** Estimates by **UN agencies** show that nearly two billion people in developing countries will need new or improved supplies. Three quarters of them live in rural areas.


Access to water and sanitation
all developing countries: 1970-80

This is an enormous task, calling for massive inputs of finance. However, if those without access to safe water are to be provided with it by 1990 one of the greatest requirements is effective and appropriate technical management.

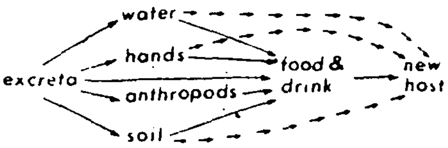
Millions of people in developing countries to be reached by 1990 for Decade's 100% targets

	WATER			SANITATION		
	Urban	Rural	Total	Urban	Rural	Total
Asia & Pacific	203	925	1128	355	1136	1491
Africa	104	310	414	130	342	472
Latin America	108	110	218	212	120	332
Europe*	14	21	35	30	30	60
Middle East	16	22	38	20	25	45
TOTAL	445	1388	1833	747	1653	2400

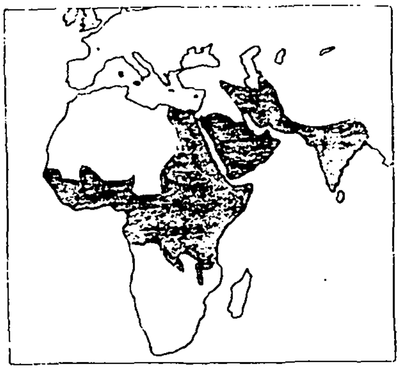
* Included Algeria and Morocco

THE NEED FOR PEOPLE'S WATER

Everyone has some water already. Without it people and animals cannot live. But there is a tremendous difference between a meagre amount of polluted water obtained with difficulty and ample, safe, easily-obtained water supplies. At present 30 000 Third World people die *every day* because of inadequate water and sanitation.

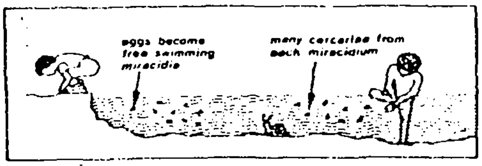


Much of the illness is passed on by 'germs' in the excreta of one ill person to someone else, who then becomes ill. One route is through polluted drinking water. Disease transmission by other means can be prevented if there is water for washing hands, bodies, clothes and cooking utensils. Water for washing need not be safe for drinking. The essential requirement is that there should be enough of it.



▨ Geographical distribution of guinea worm disease

Some water-related illness can be controlled easily. For example, guinea-worm disease, which affects over 200 million people in Asia and Africa, could be eradicated in a few years by such measures as building aprons round wells and public taps, or filtering drinking water through cloth. Other water related diseases are transmitted through water even though it is not drunk. An example is bilharzia. Fresh water snails play a necessary part in passing on the infection. Safe water supplies may enable people to avoid going into infected canals and streams. Bancroftian filariasis, which can lead to swelling of the legs known as elephantiasis, is transmitted by a mosquito whose larvae favour waste water. There is therefore a danger of increased infection where water is supplied without adequate drainage.



Unfortunately most of the people at risk in the Third World do not understand the connection between illness and their water and sanitation. On the other hand they are too well aware of the inconvenience and sheer hard work involved in carrying

water long distances. In most places fetching water is a task for women and children. Many women spend a great part of every day carrying heavy loads of water over long distances. Even when water is nearby a great deal of time is wasted in waiting for intermittent public supplies to be turned on. During the dry season hours are spent digging pits in the beds of dried-up rivers.

The time and effort devoted to obtaining water obviously have economic effects. Often women do much of the agricultural work and could increase the food supply if water was obtained easily. More time could be given to looking after the home and caring for children. Some home crafts now impossible without water could increase family income.

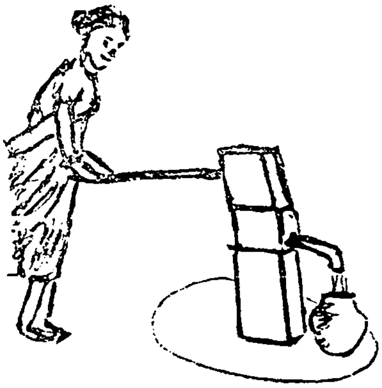
Unfortunately attempts to quantify the benefits of people's water supplies have not been very successful. The cost of illness and lost productivity have been assessed, but are generally unsound. The real measure of the value of improved water is in the lives of the people. When good water is easily available the existence of poor people in developing countries is made less wretched.

THE TECHNOLOGY OF PEOPLE'S WATER

Except in oil-rich nations who can afford to de-salt sea water, water for people comes from one of two sources - rainfall (atmospheric water) and long-term storage underground. Where rain falls fairly regularly throughout the year tanks to store roofwater from individual buildings is a convenient way to obtain good water. However, to be

reliable the size has to be enough to store water needed during the longest dry period. Village ponds or tanks to collect and store rainwater are common, especially in the Indian sub-continent. Their water is almost invariably polluted.

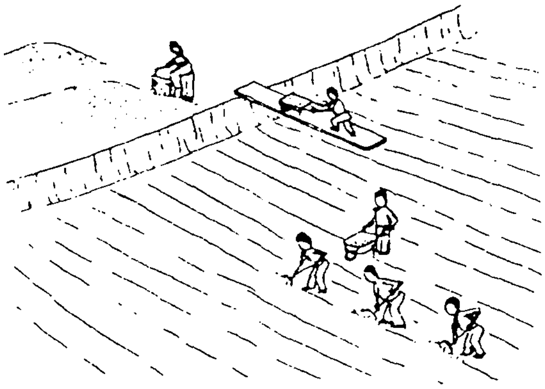
Rainfall run-off across the surface passes to streams, rivers and lakes. Where there is water in all seasons it can be drawn directly, but the water is likely to be polluted by people living upstream. River water can be stored by building dams. Dams also raise the water level and may eliminate the need for pumping. Water can be drawn from a gravelly river-bed by using infiltration galleries and wells; water may be available in the bed when a river has itself dried up.



Rainfall which soaks into the ground near the surface may emerge in springs, which require protection if they are not to be polluted. Shallow groundwater may be lifted from hand-dug wells. With open wells there is again danger of pollution, especially if the well is a 'step-well', where people go down to the water to collect it. Such wells need protection and are best provided with concrete covers, with hand-pumps to lift the water. Deeper groundwater may require boreholes and pumps.

The water management of these sources may be comparatively simple where population is low. As population and demand for water increases, rivers dry up earlier and groundwater levels drop, so there may come a need to control the demand for water, a problem of technical management.

In rural areas water for people should preferably be obtained from sources that are themselves safe - like upland streams, springs and most groundwater. The sources need protection to make sure that no pollution occurs. Where no clean water is available dirty water may have to be treated. Retention in reservoirs removes some suspended solids and microorganisms (PICKFORD 1977). Slow sand filters are generally suitable for rural areas. A great advantage of slow sand filters is that maintenance is by manual labour, removing a thin layer of dirt from the top of the sand (PICKFORD 1980). If the water requires disinfection, bleaching powder is commonly used in rural areas.



There is considerable debate about the *quantity* of water for which a system should be planned. This is one of the most important fundamental decisions to be made in technical management and will be discussed in subsequent sections.

MANAGEMENT AND PERSONNEL FOR PEOPLE'S WATER

It has been suggested (MONTGOMERY) that management must ensure that channels and systems exist for

+ responsive administration
+ promotion of activities and health education
+ efficient delivery of service
+ instruction and operation
+ training in maintenance
+ effective delegation of authority
+ periodic monitoring

Management functions in a framework set by politicians and administrators. Its efficacy depends on the institutional organization, which may or may not be appropriate for the tasks of the Decade. In the Action Plan devised during the Water Conference at Mar del Plata priority area A2 stated that "Action must be taken to remedy ...... inadequacies in institutions and organizations".

One of the difficulties facing planners is to decide what type of institutional structure is most appropriate for ensuring that people's water is available and continues to be available. A number of different patterns have been devised and in some situations all work well. In other situations they prove ineffective. For successful management of rural water the first essential requirement is perhaps that it should be appropriate for the people. As has been written (WILLIS and SPEIGHT) 'Management is a social process and a style of management has to be acceptable to the society in which it operates, and for efficiency will have to change as that society changes'. In other words, *flexibility* is essential. We will see in the next section that lack of flexibility lies at the root of many management failures.

Two aspects of management and organization merit special attention. The first is the financial basis. The second is the extent to which the people themselves should be directly involved in providing and maintaining supplies.

It is sometimes argued, especially by local politicians when dealing with central government, that water should be provided for nothing. It is a gift of Allah to his people. Such a policy is possible when government has ample funds, as in the oil-rich states. However, the majority of Third World nations face tremendous demands for limited resources. It can equally be argued that education, roads, health-care and other social services should all be freely available. Obviously governments of developing countries cannot afford everything. So a completely opposite philosophy is propounded, that the organization should be financially viable. The objectives of this include making consumers aware of the financial consequences of the use of the service (MOULD). Consumer-awareness is one aspect of self-help. It is often argued that people only properly appreciate the value of a service when they contribute to it either financially or by providing labour. Community participation in rural water supply schemes has been very successful in some countries. In Malawi (IDRC) projects for supply of water from high catchments through long pipelines were run by committees chosen by the people. At the village level a committee was responsible for choosing the sites of public taps, building aprons and drains and the maintenance of the taps after completion of the work.

Maintenance by village caretakers has proved effective in many countries. In some areas a great deal of prestige is attached to the appointment of caretakers, who attend courses and are awarded quite elaborate certificates of competence. On the other hand external experts who investigated rural supplies in Lesotho (FEACHEM et al) reported that they were "convinced that voluntary work on a sustained basis is usually too much to ask of a village organization".

The village caretakers are the lowest level of the personnel involved in provision and maintenance of rural water supplies. Artisans and technicians benefit greatly from initial training (or 'human resource development'), especially if it is followed by regular refresher courses.

The academic education of professional engineers rarely prepares them for work in rural areas. Similarly, professional sociologists and economists are ill-prepared for the special problems of underprivileged communities. Too much emphasis is placed on methodology and on assessing the potential for performance. Too little regard is paid to actually doing the job.

In a sense all engineering is management - management of physical and human resources. The requirements of a successful engineer or manager are essentially personal qualities. Of course the engineer must be sound in regard to technology, but more important are motivation, leadership and sound judgement.

FALLACIOUS POLICIES AND THEIR CONSEQUENCES

The policy of training professionals in a narrow specialization ignores the practicalities of rural water supply and also, to some extent, of the majority of Decade-associated works in the Third World. The consequences are that little of what he has learned at University is useful and that he feels frustration because he is not involved in the kind of work which the University regards as worthwhile. Alas, the 'higher' the standard of the college or university, the more likely is it that the orientation of courses will be directed to theoretical, mathematic and analytical efforts. So often academic staff are appointed to the 'best' establishments because of a good 'research record'.

Incidentally, the author's WEDC Group at Loughborough, England, is not concerned with this academic tomfoolery. WEDC believes that above-average ability is required to master the interrelationship between simple technology and the radical approach needed for providing and maintaining water and waste engineering works in developing countries.

Unfortunately, the natural conservatism of many politicians, administrators and engineers makes them reluctant to depart from established practice. Their education, their subsequent on-job training and their whole way of life make them unwilling to introduce change unless it is to their own benefit. Their own environment is generally that of the comparatively prosperous urban elite. Consequently their attitude to rural development tends to be "apply urban standards when possible; if not, do nothing".

Amongst the common fallacies in management which are caused by this attitude are the following. All have been observed by the author in several developing countries.

a. Where there is a public piped supply, all householders who can afford to install house connections should be allowed to, especially if the water is metered and so provides an income. This policy often leads to unacceptably low pressures and intermittent supplies, with resultant health dangers.

b. Whenever possible, a large quantity of water should be delivered regardless of the disposal of waste water. In the absence of proper drainage, this results in pools of stagnant water, with the danger of filariasis.

c. Capital works, preferably funded by cheap loans from international bodies, are the best way to achieve Decade targets. Operation, maintenance, reinstatement of defective components and effective on-going management are given low priority. As a result the Third World is littered with broken-down systems.

d. The main considerations in choice of equipment are low cost and durability. In fact, ease of maintenance by local people should usually be the main consideration for rural water supplies.

e. It is assumed that the public wants 'good quality' water. As a result many people continue to use traditional sources because they prefer a familiar tasting water.

f. Water should be provided by government or public authority with the minimum involvement of the users, except that they may be required to pay part or all of the cost.

The primary objective of rural water supply management must be to improve the quantity, quality and accessibility of water for as many people as possible with the available resources. A fundamental decision is often the volume to be provided. Ex-patriate consultants from north America have designed urban systems able to deliver nearly six hundred litres per person per day (600 l/pd) and quite high levels have been the basis of some rural supply designs on the assumption that all households should be connected to a piped system. Of course taps within a building are desirable. However, it has been found that well-planned public tap systems are satisfactory when delivering only one-tenth of the water needed for house connections. In Malawi (IDRC) 27 l/pd was the basis of design.

Management of water systems needs to take account of general development policies. The kind of decision which is required is whether priority should be given in the allocation of resources to areas or villages where the need is greatest, or to those which can be served most easily. The greatest need - for example, people who now have to carry water long distances - may involve the greatest difficulties in providing a safe and convenient supply.

Good management of rural water supplies should achnowledge the need to dispose of surplus and waste water. In water-short areas there are obvious benefits in directing this to crops, but the dangers of disease transmission have to be watched.

Above all, because good management is so greatly connected with good communication, it is essential that there is real contact with the people who benefit. This is best achieved when the engineering input is provided by those who also appreciate sociological and economic factors rather than bringing in a group of specialists. The community is much more likely to respond to engineers and technicians who are doing something positive than to the finest uninvolved behavioural scientists.

APPROPRIATE TECHNOLOGY

All good engineering should be appropriate (PICKFORD, 1977b). The idea of 'intermediate technology' or 'appropriate technology' has been valuable in focusing attention on 'small is beautiful'. However, much of the effort of those who advocate appropriate technology has been devoted to developing small items of equipment. Many of these are irrelevant (PICKFORD, 1981). They work well when the 'inventor' is around to encourage local effort, but the effort required is too great for the local people alone. Appropriate technology, as far as people's water supply and people's sanitation are concerned, should mean 'appropriate for the people'. This involves a new and radical approach.

A RADICAL APPROACH

Conventional practice and management, whether fallacious or based on sound principles, too often assumes that the professional engineer, health worker, sociologist and economist know best. Success is therefore only a matter of putting their superior knowledge into practice. If it does not suit the people they must be educated in the experts' ways.

A radical approach by definition comes from the roots or goes down to the roots. In the case of people's water supply the roots are obviously the people. A radical requirement of good management is therefore the humility to learn from the people, to be influenced by their decisions and wishes, to be willing to work with them, rather than to use them only as part of the available resources.

This in turn demands an abandonment of the 'mystique' of the professional. Just as much of the medical profession has opposed the use of 'barefoot doctors', so professional managers in water undertakings are reluctant to give responsibility to 'barefoot technicians'. But responsibility must be given to non-professionals. The starting point in the provision and improvement of water supplies should be the people themselves - what they can do - how they can be involved. This is in striking contrast to the occasional enlistment of a sociologist to check 'acceptability' when a scheme has already been finalized.

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DISCUSSIONS :

Q : The proportion of rural people to be served with portable water supply is such a big one. What would be the likelihood of a reasonable success of the water decade? (Ir. Cheong Chup Lim, DID).

A : The water decade is being worked out by National Programmes. There is a national committee in each country. A large number of countries has got a reasonable chance of achieving the target. This applies to countries in SEA and those like Malawi. There is a much less chance of achieving the full decades target in the case of sanitation. Many countries have set their targets lower to provide only 40% of the population to be served with house connections and 60% by handpumps. Only 25-40% will be provided with sanitation in the decade.

Q : What are your views regarding the double standard that only the rural people are encouraged to practise mutual cooperation (gotong-royong) among themselves whereas the urban dwellers are not? (Amriah ; UKM).

A : This is purely financial. Urban people are a prosperous group of people who can afford to pay for the services. Since the rural people are scattered and dispersed, the type of water supply and sanitation need to be kept low-cost and of a simpler kind. It works much better if the people are looking after the maintenance through community participation.

C : Poverty needs more of science. Appropriate technology is often a slogan to dump obsolete equipment of the West to countries in Asia, Africa and Latin America. (Jaswant Singh Bali, Dept. of Agriculture, Malaysia).

A : Hardwares produced in the name of appropriate technology is often not appropriate for the people and situation. Dumping obsolete, old ideas from the West is not appropriate. What is appropriate is what the people need, what is relevant and what is going to work best in that particular situation.

ASPECTS OF AN APPROPRIATE RURAL WATER SUPPLY TECHNOLOGY

P. Reynolds
Lecturer in Civil Engineering
Papua ~~New~~ Guinea University of Technology

INTRODUCTION

A successful water supply scheme is one which provides an adequate amount of water of sufficient quality regularily and reliably. The water supply which achieves these aims whilst using a technology which is not only acceptable to the user, but is also able to be adequately maintained and does not exceed the available purchasing power can be said to have been constructed with an appropriate technology. There will be degrees of appropriateness depending on the emphasis placed on these various aspects (i.e. type of technology, maintenance requirement and cost) and how relevant these emphases are to the actual situation. A low capital cost scheme with a regular maintenance requirement may be appropriate where capital is scarce but where revenue can be generated by the scheme; under different circumstances such a mix of capital and recurrent costs may be quite inappropriate. It is possible that a water supply scheme may be designed for a certain set of conditions and may be appropriate while these conditions exist. A change in the conditions (or an incorrect interpretation of the original conditions) may mean that the original scheme becomes inappropriate. Changes in the conditions are thought to be partly responsible for the failure of a number of rural water supply schemes in the Morobe province of Papua New Guinea. These schemes are described below.

LOCATION

Papua New Guinea as well as occupying approximately half of the worlds second largest island is also spread across many smaller islands mainly to the north-east of the main land mass. The country is in the tropics (between the equator and 12° south). It has a population of approximately 3 million people and it is similar to many developing countries in that it has a high birth rate.

It has a relatively large land area although being geologically young much of the land is not useable in the conventional sense. Rapid urbanisation is taking place near some main centres but more than 80% of the population live in rural areas involved in subsistence agriculture and cash cropping.

One of the eight points which are guiding national development calls in part for an "equalization of services among different parts of the country" and others call for "decentralization" of various activities and for the encouragement of self reliance. The large urban areas already have or are being provided with water supply systems and provision of equivalent systems to the rural areas can be seen as partially satisfying the equalization of services aim and providing part of the infrastructure needed for successful decentralization.

In the rural areas of PNG water is obtained from surface sources (streams and rivers) and groundwater (shallow wells and deeper boreholes). Occassionally where a corrugated iron roof has been used then rainwater is collected but houses are usually constructed of bush materials and roof water cannot be collected. Generally speaking the source of water supplies in the more mountainous regions is surface water whilst in the large flat valleys and along the coastal plains the installed water supplies are usually groundwater systems. Where the hand pump is not working though it is usual to revert to a surface source.

PNG is divided into 20 provinces. The water supply schemes discussed below are all in the Morobe province. According to cards held by the Provincial Public Health Inspector approximately 37 rural water supplies were amongst those installed in the late 1960's and early and mid 1970's. Six of these were gravity reticulation systems (installed in 1974 and 1975) and the others were handpumps mounted on machine drilled boreholes (installed between 1964 and 1972). The water supplies were constructed by an outside agency without any significant local participation. The record show that regular inspection and maintenance visits were made to the various ground water supply schemes following their construction but these ceased in 1969 (6 schemes), 1970 (8), 1971 (10) and 1972 (7). At the time of the final inspection four of these boreholes were dry but the rest were reported to be working satisfactorily.

A recent check of 13 of these schemes has shown that 6 are presently in operation. Of these 6 supplies,1 is a gravity reticulation scheme and the other 5 are groundwater supplies.

In the introduction to this paper it was mentioned that changed conditions can contribute to the failure of a water supply scheme. In this case the change was the cessation of regular inspection and maintenance visits by the outside agency which constructed the schemes coupled with an inability or an unwillingness on the part of the users to become involved in the maintenance and repair of these schemes. In the following paragraphs the present state of one of the gravity reticulation schemes (Gurakor) is contrasted with that of one of the groundwater schemes (Zumin).

GURAKOR

Constructed in 1974. The original design population was 260 but it is now used by less than 50 people. It is a gravity flow system from a source approximately 1 km distance and 39 m above the public taps. At the source a small stream is confined by low concrete walls and into one of these is set a 25 mm dia. galvanised steel pipe. The water flows through a coarse screen (reinforcing mesh) and a fine screen (fly wire) and through a 1 km long pipeline-initially galvanised steel pipe and then 19 mm dia, polythene. The pipe ends at two reinforced concrete tanks (pipes of approximately 1050 mm diameter standing on end) where there is a single tap.

There has been no outside involvement since the scheme was built. Numerous repairs have been made to the exposed section of the pipeline. Repair techniques range from twigs stuck in holes, pieces of car inner tubes wrapped around larger leaks and complete replacement of some short sections of pipe with suitable pieces of bamboo.

While the pipeline has been well maintained the tanks and taps have not. Two years ago there were two taps and a shower head fitted at the tanks but now there is only one tap. The holes in the tank (caused by removing one of the taps and loosening the pipe attached to the other tap) have reduced the effective storage to just a small part of one of the tanks. The damage could be 'wear and tear' or deliberate damage by outsiders. The latter seems unlikely because although the tanks are located only 20 to 30 m away from a fairly busy road the existence of the scheme is not widely known. One person who had lived only about 10 km further up the road since the early 1960's knew of no piped water supplies anywhere in the area.

A justification for providing rural water supplies is often that by improving the standard of living in rural areas the drift of the rural populace to the urban areas may be reduced. The construction of this water supply, while it must have improved conditions for people living nearby, was not of itself sufficient to prevent approximately 200 people from moving away.

ZUMIN

Constructed in October 1966 it consisted of a Tsuda Shiki hand pump mounted on a 35 m deep borehole. The scheme was regularly visited and maintained. The final visit was made in January 1970 when, according to the records, it was reported to be operating satisfactorily.

Subsequent history of the scheme is not known. The villagers say that once the maintenance visits ceased the scheme eventually broke down and there was no one available to repair it. Later the pump was dismantled and removed, it was thought for repair and re-installation, but in fact it has not been returned. Repeated requests for reconstruction of the scheme have not produced any action.

DISCUSSION OF GURAKOR AND ZUMIN WATER SUPPLIES

When constructed these schemes were appropriate. Maintenance and inspection were to be undertaken by the organisation which constructed the schemes. At a later date, for reasons which are unknown, this maintenance and inspection service ceased.

Where the technology involved is fairly obvious and easily understood then there is a chance that the users will be able to maintain the scheme. Where the technology is not understood there is little chance of any useful user maintenance being carried out. None of this matters where regular inspection and maintenance visits are going to be made by an outside agency. In a developing country better use would be made of scarce resources though if the users were responsible for the routine maintenance.

The continuing operation of the Gurakor water supply, where many others have fallen into disrepair, can be attributed mainly to the fact that the people at Gurakor have accepted responsibility for the maintenance of their water supply. Their ability to undertake this maintenance work is based on a number of factors. They are able to do the work (plugging, wrapping or replacing lengths of pipe) and they understand the way that the scheme operates i.e. the technology has been transferred. In addition they must be sufficiently motivated and this will come from a desire to retain the benefits of a safe and plentiful water supply. The failure of many of the groundwater supply schemes would seem to be based on both a lack of understanding of the technology involved and consequently no appreciation of what regular maintenance (lubrication etc.) was required to keep the scheme operating.

Probably the most effective way of becoming familiar with the technology being introduced is participation in construction of the water supply. By having contributed their labour the users will have made an investment in the scheme and the likelihood of vandalism or damage by careless use is reduced. Most important though is the education process which takes place. The users by becoming adept in the skills needed for the construction of the scheme and by coming to understand why regular maintenance is necessary will be able to undertake that maintenance.

All of this is only possible if the water supply scheme is really desired by the users. One way of testing this is by noting the reaction to the suggestion that the users contribute their unpaid labour.

A rural water supply scheme for which this approach was adopted is described below.

WARITZIAN COMMUNITY SCHOOL WATER SUPPLY

The water supply is part of a scheme to upgrade the teachers accommodation at a community school. The scheme was built as a joint effort by parents, teachers and pupils at the school and by staff and students from the Papua New Guinea University of Technology. Maintenance of the scheme is carried out by the teachers at the school.

The scheme consists of an hydraulic ram which utilizes approximately 5 m head of water provided by a small series of waterfalls in a nearby stream. The ram with a 24 m long 50 mm diameter galvanised steel drive pipe utilizes approximately 60 ℓ/min. falling through 5 m to lift 5.5 ℓ/min a height of 40 m through 130 m of 32 mm dia. PVC pipe to a 9000 ℓ galvanised iron tank. From the tank approximately 450 m of 25 mm diameter PVC pipe conveys the water to the houses; the vertical distance between tank and houses is also about 40 m. The peak flow at the houses is 38 ℓ/min. The scheme has been operating for two and a half years.

Community school teachers in PNG are trained in urban areas and then in many cases they are sent to teach in schools in the rural areas. They take with them a desire for some of the benefits of the urban lifestyle. By providing the teachers at this particular community school with the water supply described there are of course the obvious direct advantages of the supply to the teachers. It is hoped that there will be a demonstration aspect as well. This demonstration aspect has been more fully described elsewhere (Reynolds, 1982).

Because the users are teachers they may be quicker to accept the technology being transferred. This approach will be used with some village groups when new water supplies are being installed. It is assumed that they will be just as receptive as the teachers have been.

One important lesson that has been learnt from Waritzian is that the learning period will be longer than the construction time. It is not possible to give detailed maintenance instructions and then to walk away expecting the water supply to operate satisfactorily. Return visits must be made but, of course, the frequency of these visits can be progressively reduced. A hydraulic ram has valve rubbers which need periodic replacement. With this particular scheme it is probably the most complicated regular maintenance operation that needs to be carried out. Assistance was needed with the first valve rubber replacement on site but after that the technique was rapidly learnt. Replacement was needed after about 20 months of operation but the only rubber available at the time was very soft and had to be replaced at 3 weekly intervals over a period of 3 or 4 months until more durable rubber was obtained. The teachers became proficient at valve rubber replacement so that the unavailability of the correct rubber, in fact, benefited the learning process.

CONCLUSION

The continuing operation of the Waritzian Water Supply Scheme is due to the use of an appropriate technology. The appropriateness is not just related to the fact that a hydraulic ram has been used. (Where petrol and diesel are expensive and electricity is not available the ram has obvious advantages though.) The scheme is also appropriate in that the technology has been introduced to the users and the inspection and maintenance of the scheme is being carried out by the users.

For many rural water supplies a successful appropriate technology will include self help construction and user maintenance.

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FIG. 1 Gurakor pipeline showing plug and wrapped repairs.

FIG. 2 A new length of bamboo being installed at a break in the Gurakor pipeline.

FIG. 3 User maintained handpump installed in Sangang village of Morobe province in 1980.

FIG. 4 The hydraulic ram at the Waritzian Community School being repaired by one of the school teachers and a technician from the University of Technology.

DISCUSSIONS:

Q : Do the students know the real problems of the villagers?

Reynolds : Most of the students come from village background and they are aware of the situation in the villages.

Pickford : The attitudes of the educationists will be taken up by the students. If the teachers attitude is such that rural water supply is not important but dy/dx is important then the students will think that only dy/dx is important.

Q : What was the water quality of the three situations you mentioned?

A : For the Gurakor and Waritzian Schemes, the water supplies are taken from streams in a mountainous country. There are no activities taking place upstream. The water was tested and found to be relatively pure. The Zumin groundwater was tested and found to be satisfactory. The water that they are using now is salty water and the quality is not satisfactory.

Q : Is there any other way to encourage the people to continuously maintain the water supply system besides giving certificates? (Ho, Div. of Envt.)

Pickford : In Bangladesh, certificates are issued to the pump caretakers. In other schemes like in Ghana where handpumps are provided by the Canadians, there was a paid system with a mobile team on motobikes. Visits are backed up by teams on landrovers. Anyhow, it is much better if there is someone in the village who can keep the pump going.

Reynolds : In PNG, there was no formal system of giving certificates. Someone in the village who has the aptitude and the skill took over the responsibility. There is a certain amount of status to be a man on the spot who is able to keep the pump going.

USING GROUNDWATER FOR IRRIGATION IN SMALL-SCALE FARMING

Kittipong Vuthijumnonk
Institute of Agricultural Technology
Mae - JO, Chiangmai, Thailand

SUMMARY

In Thailand, farmers who own unirrigable area will usually be cultivated only in rainy season. If they want to increase their annual income they must cultivate for the second time during the dry season. Water is the most important factor for dry season cropping. Farmers have to look for suitable water sources; cheap in investment, adequate water quantity and suitable water quality.

At present, in Chiangmai velley groundwater is being widely developed for irrigation in small-scale farming, and mostly done by the farmers themselves. The development of groundwater, from the farmers' point of view is cheaper in investment and easier in operation than the development of other sources of water.

Nevertheless, it is discovered by a survey in Ban Buag Kang, Chiangmai that some wells are not in operation because it cannot provide sufficient amount of water. The reason is because these wells are drilled within the zone of influent of other wells. The efficiency of using pumps and engines are less than 25 per cent. These indicate that the development of groundwater by farmers has been done without adequate knowledge, information and good planning.

From the economic point of view, the feasibility of using groundwater for irrigation depends solely on the price of agricultural products. It was discovered that tobacco leaves, guaranteed by the Thailand Tobacco Monopoly, Ministry of Finances, give the highest benefit-cost ratio. For other field crops and vegetables, the prices varied from year to year and depend mostly on the middlemen.

To summarize, using groundwater for irrigation in small-scale farming is quite a good investment. It returns reasonable income to the farmers. If the development of groundwater which is done by the farmers are supported by the goverment agencies in someways, such as the knowledge and information about geological structure, feasibility of water sources, methods of planning and selection of water pumps and engines it will return more benefit to the poor farmers.

INTRODUCTION

In Thailand, using groundwater for irrigation is scarcely practiced; It can be seen in someplaces where surface water is limited during the dry season. Chiangmai valley is a good example, in this area if the land is unirrigated farmer can only grow rice in the rainy season. To maximize the production from their land, farmers have to cultivate also in dry season. When second crop cultivation is practiced, water is a limiting factor, because the water consumption is high while surface water discharge is markedly reduced and rain cannot be expected. Farmers have to look for appropriate water sources, good quality, sufficient quantity and reasonable in investment. For small-scale irrigation, groundwater is proved to be a suitable water source.

Farmers have spent a lot of money for developing groundwater. Wells have to be drilled, pumps, diesel or gasoline engines or electrical motors, pipes and other equipment have to be bought for operation. At present the development of groundwater by the farmers is being done without adequate data and proper planning. The investment is higher than it should be, and the efficiency is quite low. Nevertheless, irrigation by using groundwater which is developed and operated by the farmers still returns reasonable income to them.

OBJECTIVES

The objectives of this investigation were:-

1. To know the volume of groundwater which is used for irrigation.
2. To know the relationship between the volume of groundwater, yield from the well and the depth of drawdown.
3. To know the efficiency of pumps and engines used in this area.
4. To know the transmissibility of the aquifer in this area.

METHODS AND MATERIALS

The investigation was done at the farmers' wells in the village. The single well pumping test was used for investigation; the water level in each well was measured before and during ground water was pumped at the rate usually pumped for irrigation. After the pumping stopped, the recovery level of ground water in each well was also measured. The needed data were recorded as followed:-

1. Physical characteristics of each well.
2. Water level in each well.
3. Volume and rate of water discharged.
4. Tape and size of pumps and engines.

These data are shown in table 1.

From this recorded data, some characteristics of well and aquifer can be determined as followed :-

1. Specific Capacity of Wells. This value is indicated by the rate of water discharged from a well per unit depth of drawdown. From pumping test and calculation, the value of specific capacity of each well in this area ranged from 3.00 to 37.10 cubic meters per meter as shown in table 4.

2. The Capability of Wells. The capability of wells is indicated by the transmissibility value. The water level recovery method is used for calculating the transmissibility values. This method is based on the idea that recovery with time after the cessation of pumping will be identical with the changes in water level that would occur if an identical recharge well was superimposed on the pump well. A term "calculated recovery" is used to define the rise in water level in the well at any time relative to the position of water level had pumping been continue to that time. The calculated recovery was plotted on a semi-log-paper as a straight line and the transmissibility value can then be calculated. The value of transmissibility of each well in this area ranged from 19.6 to 222.5 cubic meters per day per meter, as shown in table 4. and figures 1 to 6.

3. Efficiency of Using and Engines: The selection of pump and engine is also a problem, all of the pumps and engines are centrifugal pumps and diesel engines. The engine size ranged between 3 to 5 horsepower. In fact, the size of engine and pump to be selected should depend upon the energy needed for lifting water which is called water horsepower. The water horsepower depends on the head of suction lift plus minor losses in the system and the rate of water discharged. For small-scale farming the discharge is limited by the size of the cultivated area, water consumption and irrigation efficiency. By measuring all needed data the water horsepower is calculated and compared to the size of engine that are used in this area, then the efficiency of using pump and engine can be determined. The efficiency values ranged between 3 and 11 per cent, as shown in table 5.

4. Feasibility of Investment: Farmers have to spend a lot of money on the development of groundwater. Most of the investment are for drilling wells and buying equipment such as pipes and filters, pumps and engines for operation. Operating the system, each farmer has to spend money for energy to lift water for irrigation. The main purpose of pumping groundwater is for irrigation in dry season, so the main benefit from this practice should be the value of agricultural production during that period. In this village the benefit-cost ratio of using groundwater for irrigation during the dry season are shown in tables 6 and 7.

DISCUSSION

Groundwater source in this area has proven to be suitable for irrigation in small-scale farming. Eventhough, the well construction and investment are done by the farmers themselves, it is still a profitable practice. The discharge from shallow well is limited by its depth, this also limit the area of cultivation. By increasing the area of cultivation, more water will be needed. This may be accomplished in two way : i) more shallow wells should be drilled or ii) all existing wells should be changed to artesian wells by deeper drilling.

From engineering point of view the second choice should be more practical because if the number of shallow wells are increased in the area it may be drilled in the influent zone of the other wells. This situation will affect the volume of water yields from the wells. If the artesian wells are drilled, the farmers have to pay more for investment and energy. They have to compare this incremen to the value of production from the enlarged area. However, the farmers are not willing to increase their cultivated area, because they have to borrow money for investment from a bank with a high interest, except when they receive aid from the government. The government can help them enlarge the cultivated area by providing loans with low interest and assist them with technical aspects of construction, operation and maintenance of the system.

Assistance from the government agencies will reduce the farmers' investment and working hours in the field. Farmers may be willing to increase their cultivated area to their maximum capability. This increase will maximize the production from the area which will result in a better economic return to the farmers themselves and also to the country.

CONCLUSION

Using groundwater from tube well for irrigation in small-scale farming in this area has proven to be a profitable practice. Farmers are able to repay loans for deep well investment within 10 years, for shallow well with appropriate crops combination they are able to repay in shorter period.

The farmers' income depends solely on the market price of their agricultural products. In Thailand the market price of agricultural products are mostly dependent on the middleman. The price of some crops varied very much from year to year. This will discourage farmers to enlarge the area of cultivation in the dry season.

Even though the profitable investment has been proven for this kind of practice, the uncertainty due to price variation of crops, accompanied by rapid increases in prices of input especially gasoline, will be a major problem in increasing the area of cultivation by using groundwater for irrigation.

The government should encourage the farmers to enlarge their cultivated areas by these following processes; i) provide sufficient loan for well construction with low interest, ii) assisting them with technical aspects in construction operation and maintenance of the system, iii) the market price of agricultural production should be guaranteed, and iv) the agricultural cooperatives should be established in each village.

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Table 1. Data from Investigation

Well No.	Depth meter	Diameter cm.	Type of Pump	Pump horsepower Ave.	Max.	Water Level meter	Discharge m^3/hr.
1	15	7.5	Centrifugal	4	5	2.91	7.40
2	15	7.5	Centrifugal	3	4.5	4.32	11.70
3	7.5	7.5	Centrifugal	3	4.5	4.83	19.30
4	6.5	6.25	Centrifugal	3	4.5	4.62	11.70
5	21	6.25	Centrifugal	5	6.5	7.36	--*
6	21[1]	7.5	Centrifugal	5	6.5	5.72	19.30
7	21[2].	7.5	Centrifugal	5	6.5	5.61	14.40

Note

* Well was dry after 5 minutes of pumping
1. Pump was placed 1 meter below the groundsurface
2. Pump was placed 1.5 meter below the groundsurface

Table 2. Depth of Water Level in Wells after Start Pumping

Well No.	Depth of Water Level in Wells, meters 0	60 min.	180 min.	360 min.	720 min.	Max. Drawdown meters
1	2.91	4.36	5.29	5.37	5.37	2.46
2	4.32	5.16	5.27	5.88	5.88	1.56
3	4.83	4.91	5.23	5.35	5.35	0.52
4	4.62	5.72	5.77	5.80	5.80	1.18
6	5.92	6.32	6.36	6.55	6.55	0.63
7	5.61	6.03	6.03	6.06	6.06	0.45

Table 3. Depth of Water Level in Wells after Stop Pumping

Well	Depth of Water Level in Wells meters						
No.	30 min.	60 min.	90 min.	120 min.	150 min.	180 min.	210 min.
1	3.85	3.64	3.52	3.20	2.98	2.91	
2	4.95	4.83	4.70	4.52	4.41	4.37	4.32
3	5.28	5.07	5.00	4.92	4.83		
4	5.68	5.56	5.45	5.27	5.09	4.79	4.63
6	6.36	6.13	6.10	6.04	5.97	5.92	
7	5.79	5.73	5.70	5.68	5.65	5.61	

Table 4. Specific Capacity and Transmissibility

Well No.	Max. Drawdown meters	Discharge $m^3/hr.$	Specific Capacity $m^3/hr./m$	Transmissi $m^3/day/m$
1	2.46	7.40	3.00	19.6
2	1.56	11.70	7.50	48.5
3	0.52	19.30	47.10	115.6
4	1.18	11.70	9.90	51.0
6	0.63	19.30	30.60	109.6
7	0.45	14.40	32.00	222.5

Table 5. Pump Efficiency

Well No.	Pump Horsepower H.P.	Discharge $m^3/hr.$	Head m.	W.H.P. H.P.	Efficiency %
1	4	7.40	5.37	0.12	3
2	3	11.70	5.88	0.20	7
3	3	19.30	5.35	0.32	11
4	3	11.70	5.80	0.20	7
6	5	19.30	6.55	0.40	8
7	5	14.40	6.06	0.27	5

Table 6. Benefit and Cost Analysis of Groundwater Use on Different Crop Combination (on 7.875 rai) at 15% discount rate (noland cost)

Crop combination	Investment in well & pump (initial cost)	Maintenance & repair each year	PW of investment	Net return of crop each year	PW of net return of crop	NPW of investment	B/C ratio	IRR
1	470	7.30	512	105.5	617.0	105.0	1.21	18.24
2	470	7.30	512	140.7	823.0	311.0	1.61	27.10
3	470	7.30	512	281.6	1646.0	1134.0	3.22	50.0
4	470	7.30	512	86.1	503.0	-8.4	0.98	14.09
5	470	7.30	512	243.0	1428.0	916.0	2.79	50.0
6	470	7.30	512	382.8	2238.0	1726.0	4.37	50.0

<u>Note</u> Crops combination No. 1 Peanut 7.875 rai Tobacco - rai
2 Peanut 6.875 rai Tobacco 1.00 rai
3 Peanut 2.875 rai Tobacco 5.00 rai
4 Peanut 2.800 rai Tobacco 1.00 rai
5 Peanut - rai Tobacco 5.00 rai
6 Peanut - rai Tobacco 7.875 rai

Table 7. Benefit and Cost Analysis of Groundwater Use on Different Crop Combination (on 7.875 rai) at 15% (with land cost)

Crop combination	Investment in well & pum (initial cost)	Maintenance & repair each year	PW of investment	Net return of crop each year	PW of net return of crop	NPW of investment	B/C ratio	IRR
1	470	7.30	512	68.9	397.0	-115.08	0.76	10.0
2	470	7.30	512	103.1	602.8	90.71	1.18	16.17
3	470	7.30	512	243.9	1426.3	914.24	2.78	50.0
4	470	7.30	512	72.2	422.4	-89.66	0.82	15.0
5	470	7.30	512	224.8	1314.2	820.17	2.57	40.16
6	470	7.30	512	345.2	2018.1	1506.09	3.94	50.0

<u>Note</u> Crops combination No.

1	Peanut	7.875	rai	Tobacco	-	rai
2	peanut	6.875	rai	Tobacco	1.00	rai
3	Peanut	2.875	rai	Tobacco	5.00	rai
4	Peanut	2.800	rai	Tobacco	1.00	rai
5	Peanut	-	rai	Tobacco	5.00	rai
6	Peanut	-	rai	Tobacco	7.875	rai

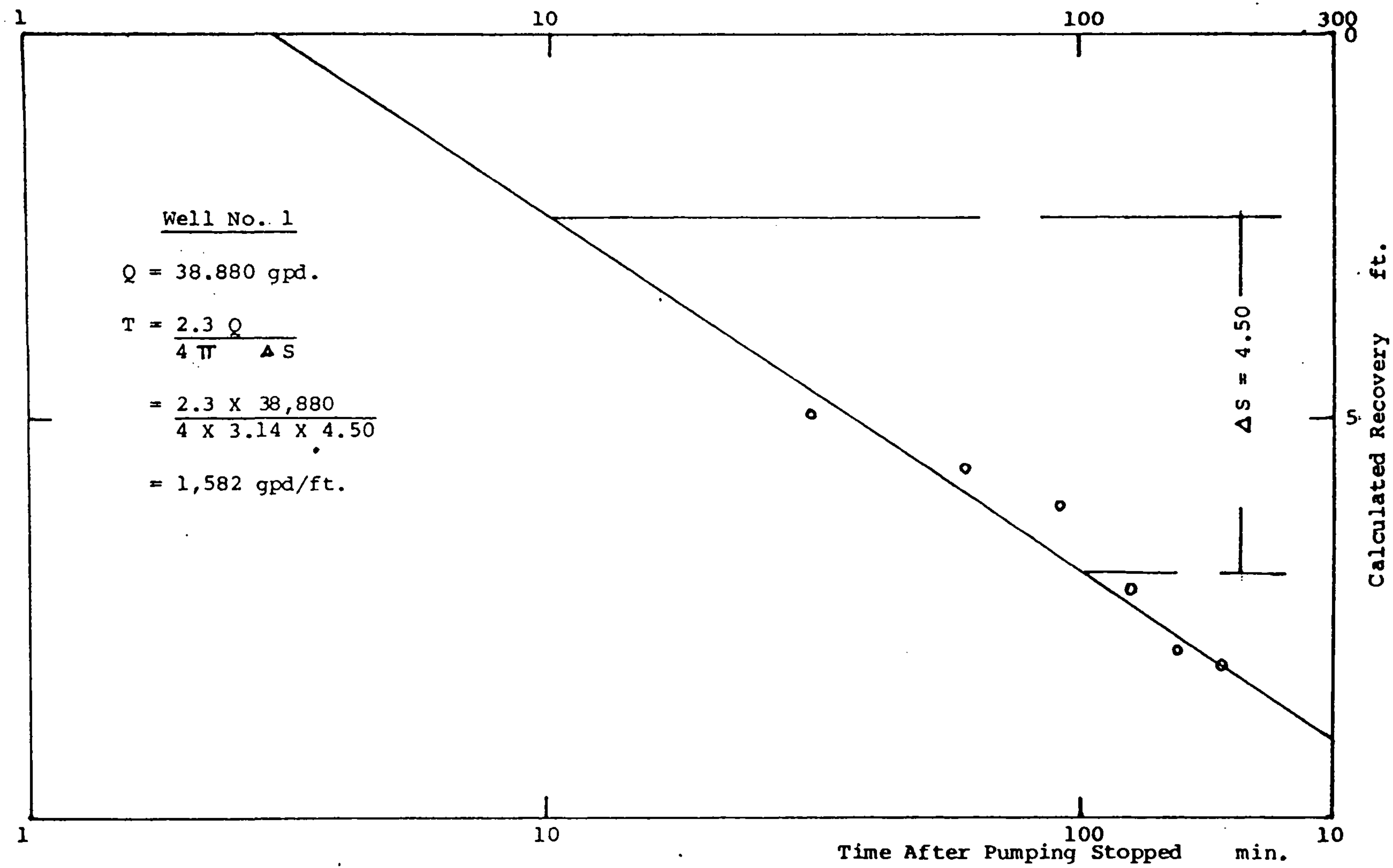


FIG 1 Transmissibility Determination by Recovery-Level Method

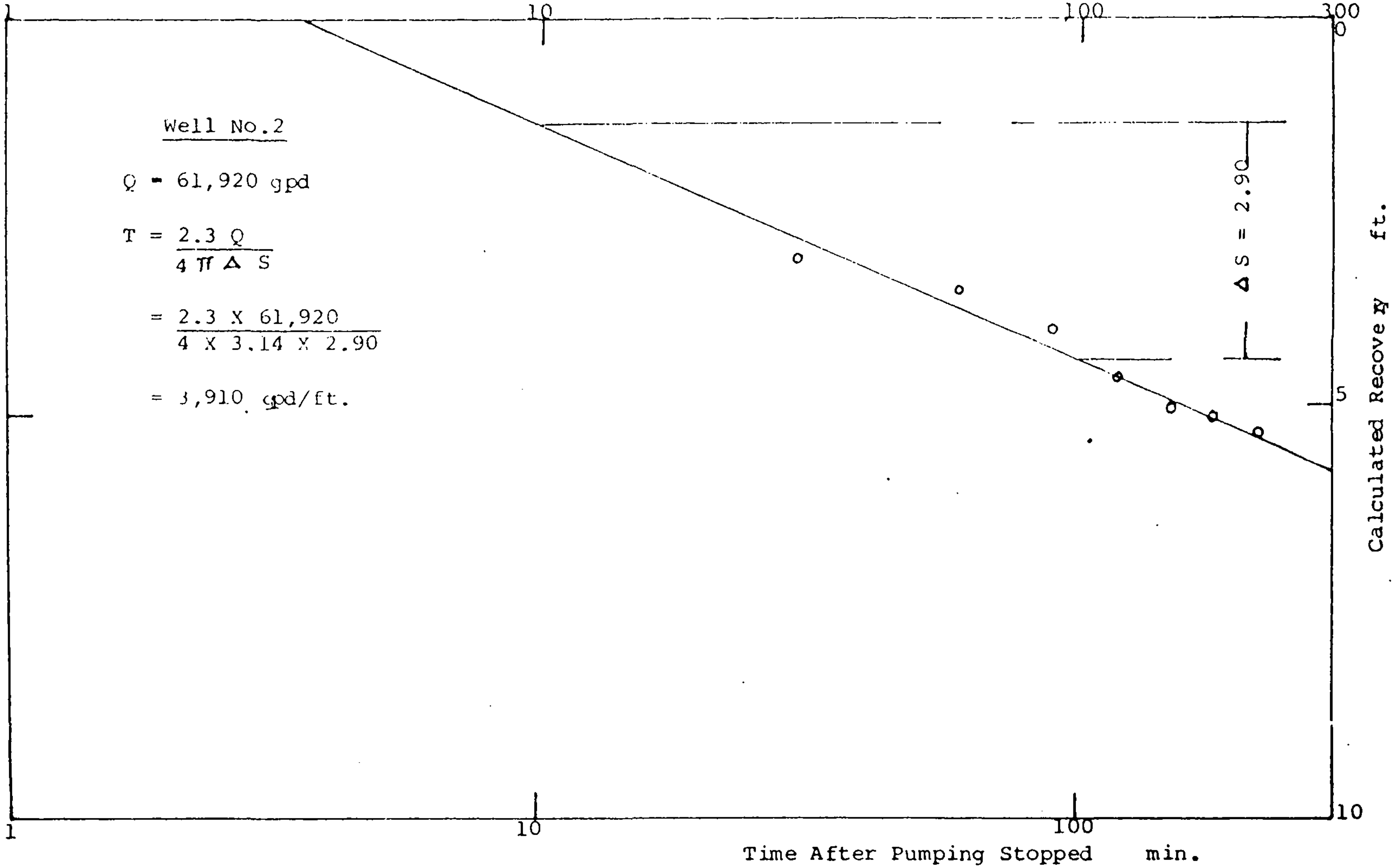


FIG 2 Transmissibility Determination by Recovery-Level Method

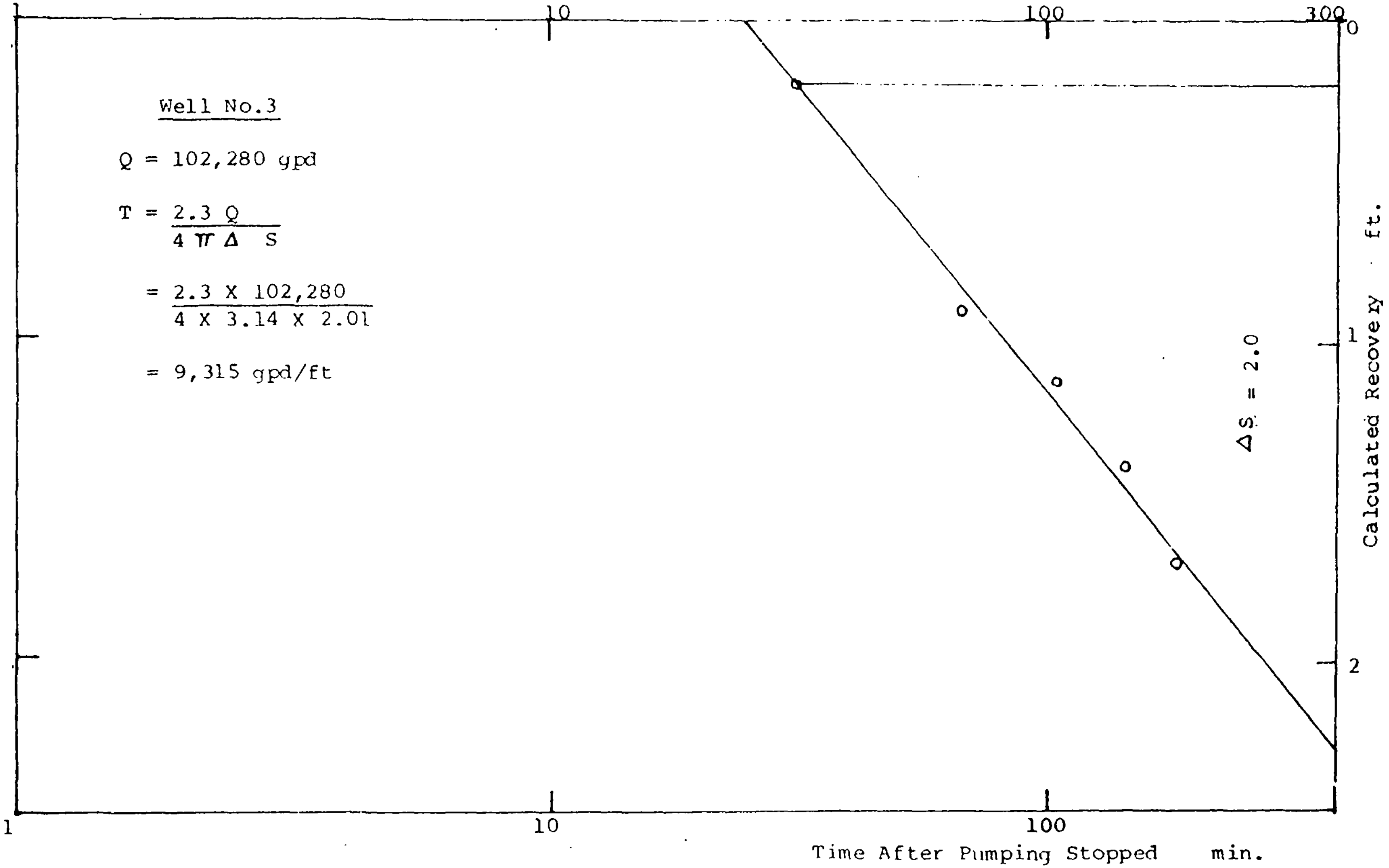


FIG 3 Transmissibility Determination by Recovery-Level Method

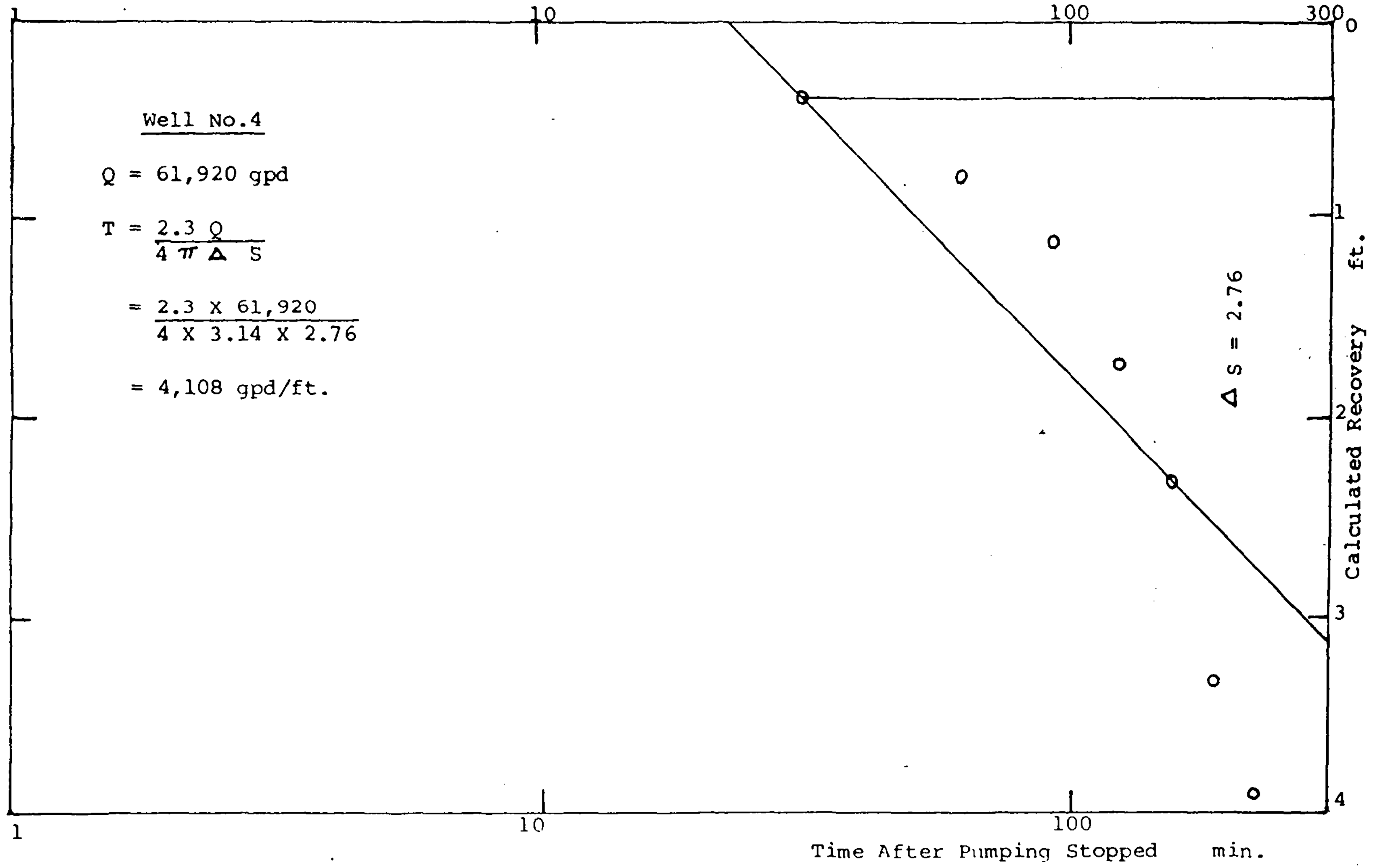
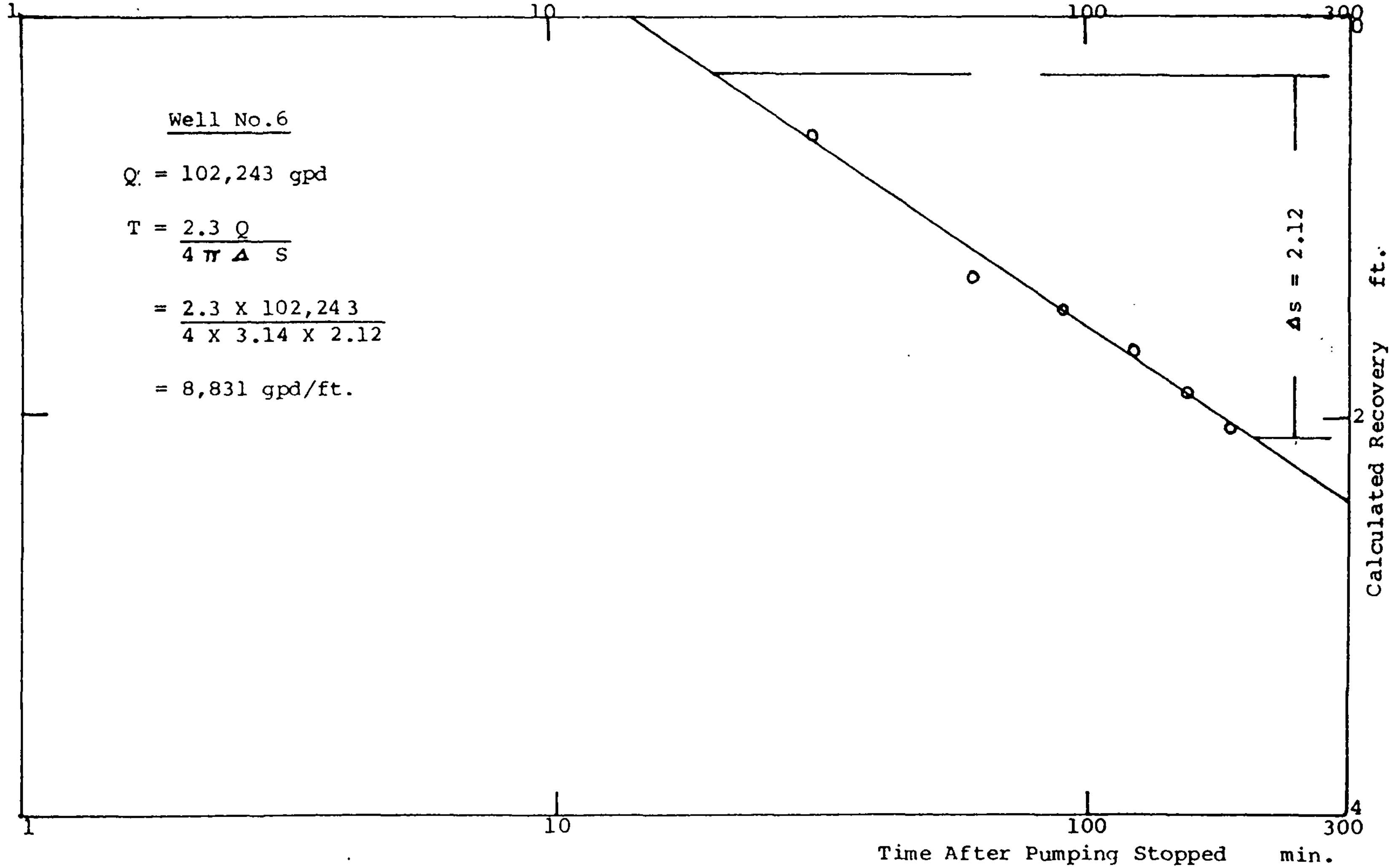


FIG 4 Transmissibility Determination by Recovery-Level Method.



<u>Well No.6</u>

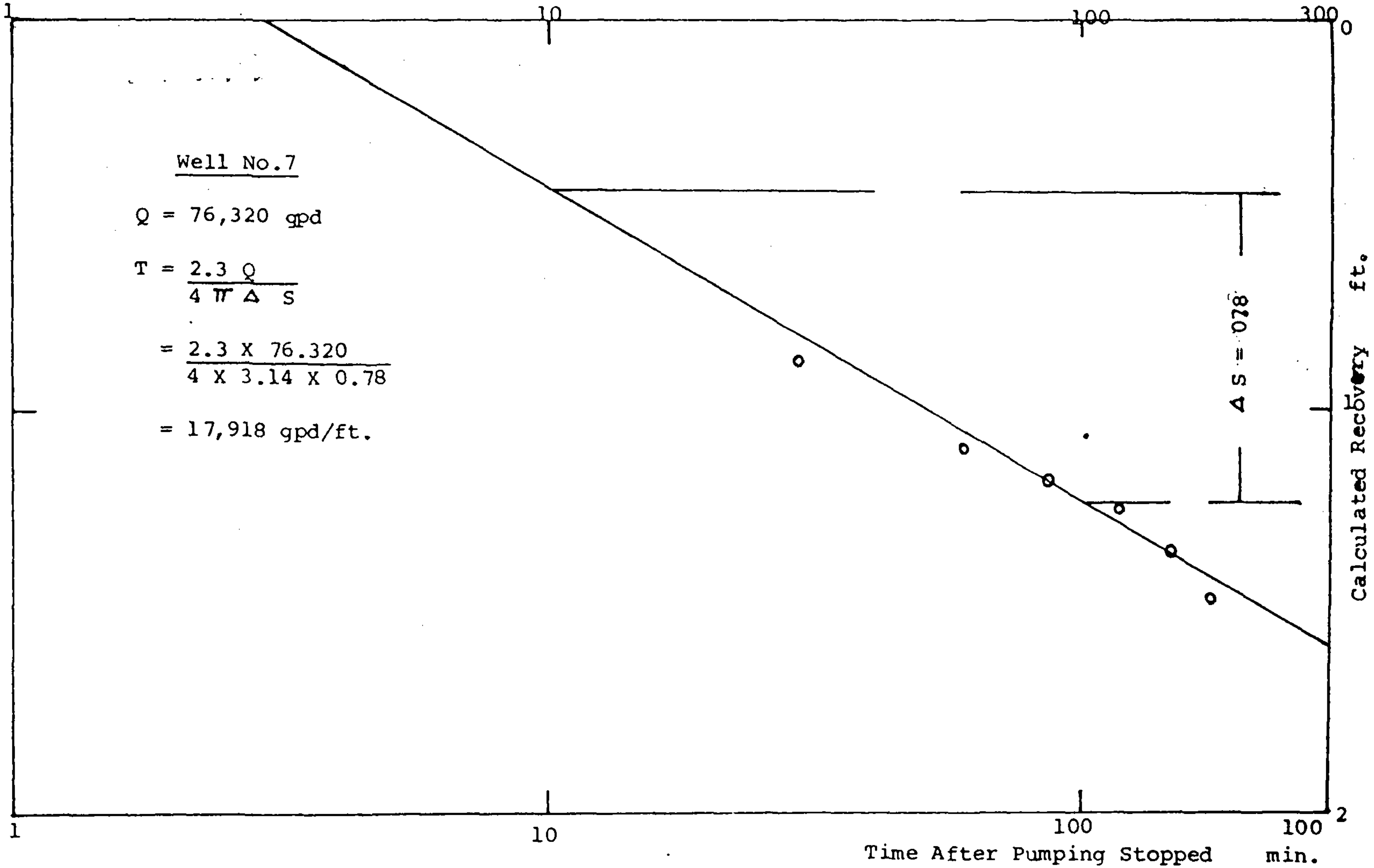
Q = 102,243 gpd

$$T = \frac{2.3\ Q}{4\ \pi\ \Delta\ S}$$

$$= \frac{2.3 \times 102,243}{4 \times 3.14 \times 2.12}$$

= 8,831 gpd/ft.

FIG 5 Transmissibility Determination By Recovery-Level Method.



Well No.7

$Q = 76{,}320$ gpd

$$T = \frac{2.3\ Q}{4\ \pi\ \Delta\ S}$$

$$= \frac{2.3 \times 76.320}{4 \times 3.14 \times 0.78}$$

$= 17{,}918$ gpd/ft.

FIG 6 Transmissibility Determination by Recovery-Level Method

DISCUSSIONS :

Q : You mentioned that finance is one of the aspects that can overcome the problems of the rural people. How do you expect the farmers to pay back the low interest loans?

A : There is an Agricultural and Cooperative Bank in Thailand which supply low interest loans to a group of farmers who submit a working paper on the project stating how they can repay the loan. For those who are unable to do so, the government agency should help them in choosing a profitable crop combinations such that loans can be paid on time.

Q : Since agronomic aspects and water quality are important, why was the status of water quality not included among the four parameters investigated. (Rahim, Forest Research Institute).

A : Water quality was not included because the farmers did not have any problems after using the water for five year. But for new wells, the water should be tested.

Q : What kind of water delivery system did you have?
For the yield increase stated, what was the rate of water use and what was the irrigation cycle? (Mohd. Daud, Felda Sugarcane).

A : There were no recommendations made to the farmers. From my observations the farmers pumped the water from their own wells and they let the water to flow into the irrigation ditches of their small farms. They irrigate when they see the need to do so.

POSSIBLE APPLICATIONS OF IRRIGATION TECHNIQUES IN RURAL AREAS

C.K. Kwok

Faculty of Agricultural Engineering
Universiti Pertanian Malaysia

INTRODUCTION

Irrigation, is very often simply defined as the artificial application of water to soil for the purpose of crop production. This is a very simplistic definition because it does not adequately explain the several reasons for which irrigation is needed. The level of technology which is employed in the application of water varies from the very simple methods which just involves a bucket to the very sophisticated automatic systems which are controlled by microprocessors.

The question then arises as to the appropriate degree of sophistication that would be suitable for the rural areas. While the huge, government operated schemes can employ a fairly high level of technology because of the financial and manpower resources available to it, the small farmers with small acreages, situated away from these schemes often have to resort to very rudimentary systems or are entirely dependent on rainfall. This of course would also mean that their returns will be dependent on the weather. This paper will look briefly into the climatic conditions which make it necesaary to supplement the soil moisture, sources of water which may be used, as well as the methods available to irrigate the crops.

Climatic Conditions

The most important climatic factors which will determine the irrigation requirements are Evapotranspiration and Rainfall. Where the Evapotranspiration exceeds the rainfall, it would indicate that the moisture from the root zone of the plant is being depleted and would have to be replaced. Information on these two factors together with data on the characteristics of the soil and the plants will enable the irrigation engineer to determine the amount of water to apply, how often to apply and the rate of application.

Figure 1 shows the rainfall and potential evapotranspiration for several stations in Peninsula Malaysia. There are at least 5 months during which the potential evaporation exceeds the precipitation. In the East Coast Stations of Kota Bahru and Kuala Trengganu there are nine months when precipitation is less than potential evapotranspiration. While these figures on Potential Evaporation based an Penmans Method should be used and interpreted with caution, they however serve to illustrate the point that periods of deficits occur which require supplemental irrigation. Supplemental irrigation should overcome periods of water stress and result in higher yields.

Sources of Water

Rainfall is the source of almost all water that occur in the tropical regions. Sources of water which may be tapped for purposes of irrigation include surface and subsurface sources.

Subsurface water can be exploited for irrigation purposes. In places where the watertable is high enough open wells may be used to exploit the subsurface water. This type of well is relatively cheap to construct and does not require a high level of technology. It basically consists of a hole dug in the ground and the soil is held in place by a series of culverts lowered into place. An alternative is to use a square section which is made up of wooden planks. Water enters the well from the bottom and through the gaps between the culverts. Yields from such wells are usually inadequate for prolonged periods of irrigation. Some attempts have been made to improve the yields of these wells by increasing the surface areas for the intake of water.

Ong and Aziz (1979) have experimented with no fines concrete for the construction of culverts used in shallow well screens.

Table 1. Testing of No Fines Concrete Samples
(After Ong and Aziz 1979)

Weight of Cube (kg) 6 inch. cube	Porosity %	Permeability m/s	Compressive Strentgth KN/M^2
6.9	16.3	0.022	19,400
5.7	29.6	0.036	4,350
6.0	31.1	0.040	6,030

This test indicated that with no fines concrete the concrete wall was porous and allowed water to flow easity. As the perosity was increased there was a drop in the compressive strength.

During actual test of these culverts in an area which was used for tin mining operations, there was little difference between the no fines culvert and the normal concrete culvert in terms of well discharge. Both wells were pumped at the rate 900 galls/day and the specific capacity after 10 hrs of pumping was 315 gallons/ day/foot of drawdawn. The authors indicate that further work is needed to fully investigate these screens and that gravel packing may be needed in order to realise the advantages of increased porosity of the well screen. Tube Wells is another possible way of exploiting groundwater. This country is only just beginning to make use of this source of water. Capital expenditure for the construction and development of tube wells is very high. The level of technology is relatively sophisticated. It would appear that its use at village level for irrigation would be limited. Surface Water Sources may be obtained by either, collecting the surface runoff and storing it in a pond or reservoir. Alternatively streams may be exploited by either direct pumping or dam construction and diversion canals. The choice of method will depend on the topography, the streamflow rates and the width of the stream.

Some form of pumping device is required to extract and transport the water in a well, pond or stream. Simple centrifugal pumps are now being locally fabricated in many countries in this region. Such pumps are readily available at low cost and this makes it a viable investment for pumping water for irrigation and other purposes in the rural areas. These pumps are invariably powered either by gasoline or small diesel engines. Alternative power sources may be used once these have been proven to be viable.

Method of Water Application

There is a large number of methods available for the application of water to the crops. Figure 2 shows some of the types of irrigation systems that are available.

The source of water, soil type, topography, crop to be grown will determine the selection of the method of irrigation. What ever system is selected, it should meet the criteria of being simple to install and operate, as well as being economically viable.

Surface Irrigation Methods involve the direct application of of water from a canal placed at the higher end of a field. Water is distributed by either the Border, Basin or Furrow.

Sprinkler Methods consists of a pump delivering water through a network of pipes through a rotating nozzle or through perforated pipes.

The lateral and main lines can be shifted to allow the equipment to cover a larger area. This can create a high demand for labour and semi and fully automatic systems have been developed.

Drip Irrigation which is one of the latest methdods, involving the application of water frequently with a volumes approaching the consumptive use of the plants.

Of the three types mentioned, sprinklers and drip methods are the most capital intensive. The cost factor alone will be a serious hindrance to its widespread application in rural areas. However, once designed and installed they can be operated by relatively unskilled labour and is flexible enough for a wide range of soil and topographic conditions.

Surface Irrigation presents itself as a possible system for the small farms. Adequate land preparation is required in order to achieve a satisfactory level of efficiency, and labour availability and costs may be a limiting factor.

Canals could be used to convey water from the source to the field for surface irrigation methods, but this may incur excessive conveyance losses. The use of gated pipes has minimised such losses and provide a controlled discharge into furrows. A simplification of this system can make it suitable for use in small farms. Water is carried to the site under relatively low pressures using PVC pipes. At the field water is released into furrows through orifices spaced at intervals to match the furrow spacing. The size of the pipe and the orifices and the pressure of the water in the pipe should be designed so that it will provide a furrow stream adequate to supplement the moisture deficit in the soil. Using local adaptations it is possible to reduce capital investment when comparing commercial systems.

Sprinkler irrigation may also be considered if we do away with the elaborate designs of commercial systems. Sprinkler heads mounted on PVC risers and connected by PVC pipes may be a viable propositions for farm sizes of 1 - 1½ acres.

Similarly drip irrigation can be used if punched orifices instead of commercial emitter heads are used. The table below gives a brief comparison of several types of irrigation methods.

What ever system is selected, it is important that the farmers are given suitable advise at the initial stages. The amount of water to apply, the frequency of application, the rate of application and the selection of appropriate equipment are important aspects which have to be investigated. It is essential that extension services be able to provide as have access to expertise that can provide advise in this area.

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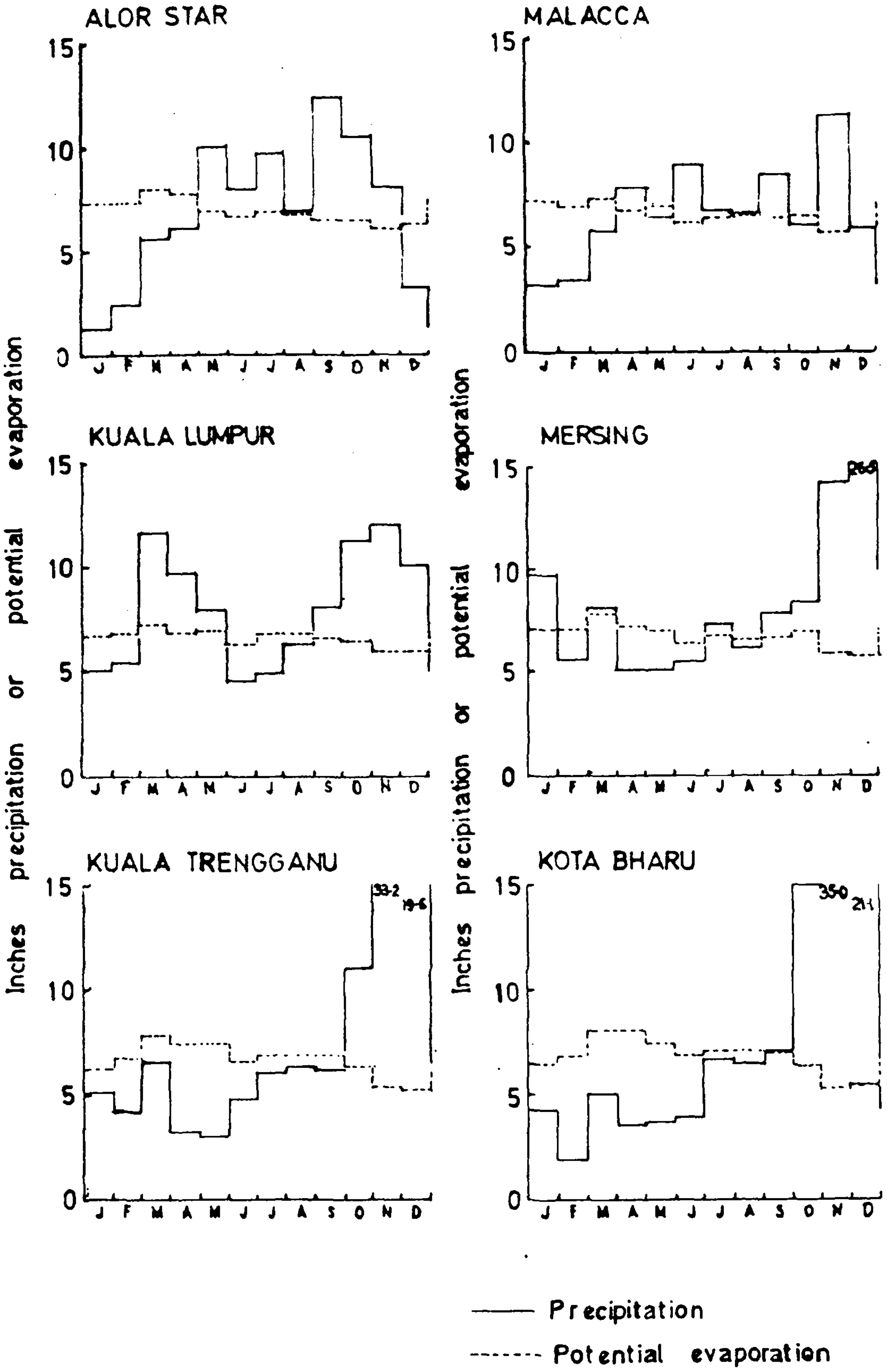

Figure 1 Precipitation and Potential evaporation
(After Wycherley, 1967)

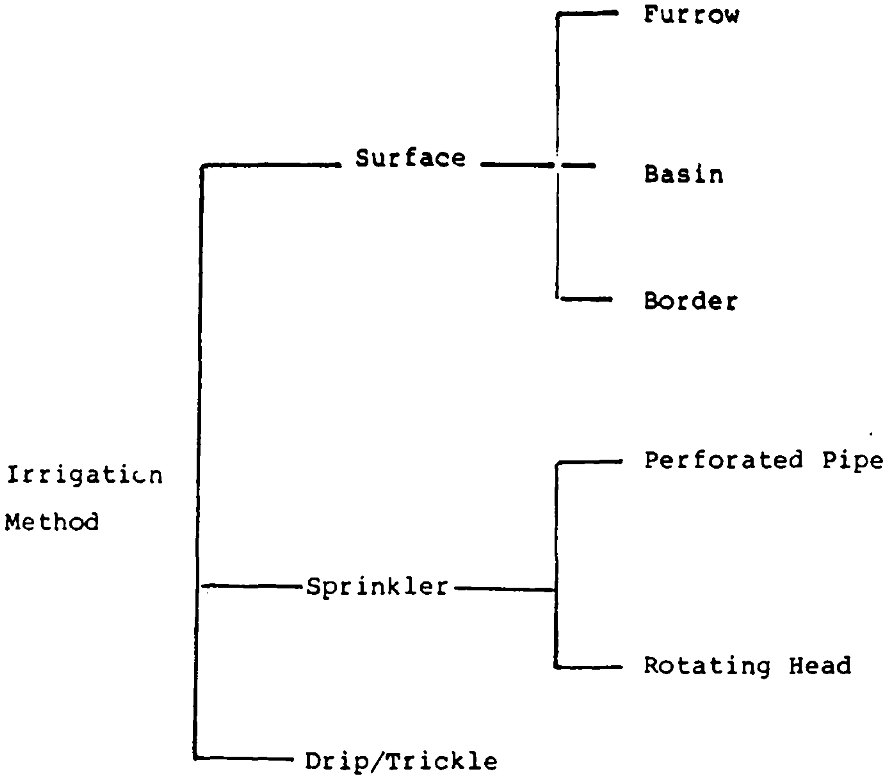

Figure 2. Types of Irrigation Methods

Table 2. Comparison of Irrigation Methods (adapted from Schwarb G.O. et al 1966)

	Adapted to		
Method	Soils	Slope (%)	Remarks
Border	All	Up to 3%	Requires adequate Land Preparation, Application Uniformity and application efficiency fairly high.
Basin	All, except very heavy soils	Less than 2%	Land preparation required. Large flow rate used. Useful for orchards.
Furrow	All, except very permeable soil	Up to 8%	Layout can be complicated on rolling land. Risk of Erosion.
Sprinklers	All	All	High initial investment, high labour required for moving, uniformity affected by wind.

DISCUSSIONS :

Q : For how large an area was the capital cost you stated? What about operation and maintenance cost? Have you compared the use of electrical motor and diesel motor? When using PVC pipes, is it not brittle when continuously exposed to ultravoilet light? (Hamdan Isa, Mini-hydro Dept., LLN).

A : The capital cost I mentioned was for one hectare sprinkler irrigated land. There were no studies carried out to compare the benefits of using the two motors. If one were to be made, of course, O & M costs, kw-hr, etc. will be included. If a system using PVC pipes can last for one-two years, then the farmers might be able to recover the investment.

C : The Penman's method for calculating potential evapotranspiration was formulated in temperate countries. The fluctuations of the parameters in the formula is not sensitive enough for tropical countries where we have forested areas, humid climate and heavy rainfall as compared to the assumption in the use of the formula that there is a uniform cover of short vegetation.

A : Yes, caution must be exercised in its use for our region. The data I used was extracted from Wycherly RRI, 1967. DID has a procedure on its use in Malaysia. (Editor's note : DID hydrological procedure No.17 by F. Scarf, 1977).

C : Bamboo as water conveyance is currently being experimented in Felda Sugarcane. This is very much cheaper than PVC or aluminium. Regarding PVC, it is the excessive working pressure that breaks the joints. (Mohd. Daud, Felda, Sugarcane).

C : PVC should be buried a minimum of 3-6" or deeper, depending on whether heavy machineries will pass over it. Research institutes are requested to release technical information to the farmers through the extension workers. With regard to leaks in PVC joints, the solvent cement must be allowed to set first before the pipes are pressurised. (Aeshah, Dept. of Agriculture).

SOIL MOISTURE BALANCE STUDIES OF LAND SYSTEMS TOWARDS MORE EFFICIENT USE OF GROUNDWATER FOR IRRIGATION

Tejoyuwono Notohadiprawiro
Soeprapto Soekodarmodjo,
Soekardi Wisnubroto,
Rachman Sutanto,

Department of Soil Science
Gadjah Mada University
Yogyakarta, Indonesia.

Introduction

A land system is a gross land pattern, formed by the recurrence of similar sites or site sequences within a finite area, where the sites are defined on partial interdependence and intercorrelation of several attributes. Where a steady state of dynamic equilibrium is approached, there is almost complete interdependence and intercorrelation of attributes and all components of the land are mutually adjusted. This is the case in regions with homogeneous rock, climate, and relief (Ruxton, 1968).

In the present study, a land system is composed of similar rainfall types, physiography, landform, and surface hydrology. As these principal criteria are also major factors of soilscape formation, a land system constitutes a soil association. Each component of a land system commands one or more stages of the hydrological cycle, whether precipitation, evaporation, runoff, surface retention, infiltration, soil storage, percolation, or underground storage. Therefore, a land system forms a practical unit to study the moisture balance, and consequently to design water management.

This study is the first in its kind ever conducted in Indonesia. It attempts towards producing baseline data for a landscape approach of water management. This paper reports the first results of the study, which takes place on a large scale covering the whole area of the Special Territory of Yogyakarta.

DEFINING THE LAND SYSTEMS

Based on a combination of physiography and landform, which also reflects in a general way the surface hydrology, the Special Territory of Yogyakarta of 3,185.77 km^2 is first divided into eight land units. They are (1) The Upper Volcanic Cone of Mount Merapi, (2) The Lower Volcanic Cone of Mount Merapi, including the southward sloping plain of Yogyakarta, (3) The West Progo or Nanggulan Mountains of sedimentary formation in volcanic facies, (4) The Sentolo Hills of platy marls and limestones, (5) The Coastal Plain of alluvial material, (6) The Baturagung Range of sedimentary formation in volcanic facies, (7) The Wonosari Basin of platy marls and limestones, and (8) The Karst Area of Gunung Sewu of more massive limestones. The Volcanic Cone of Mount Merapi consists of holocene andesites and some basalts. The West Progo Mountains are older miocene andesites and dacites. The Sentolo Hills, the Wonosari Basin, and the Gunung Sewu Karst are upper miocene. The Baturagung Range was formed in the same epoch as the West Progo Mountains, but the sediments were partly deposited submarine.

These land units are then subdivided by isohyetals to delineate four rainfall type areas (a) Less than 2,000 mm mean annual rainfall, (b) 2,000 - 2,500 mm, (c) 2,500 - 3,000 mm, and (d) More than 3,000 mm. The final combinations of all the attributes of land make up a total of 21 land systems. Each land system is also described according to its soil association. An almost complete association of all attributes of the land is evident in all except in two of the land units, namely the Lower Volcanic Cone of Mount Merapi and the Baturagung Range. In these two land units the rainfall type varies greatly. All four rainfall types are present here. The least intercorrelation of the components of the land unit with the rainfall type is found in the Lower Volcanic Cone of Mount Merapi. The attributes of the Coastal Plain show also a weak interdependence with rainfall type. There is a gradual decrease in rainfall from west to east along this east-west stretching land unit.

The land units of the Lower Volcanic Cone of Mount Merapi, the Baturagung Range, and the Coastal Plain probable do not yet approach their steady state of dynamic equilibrium. Their soil associations seem to support this presumption. Regosols dominate the Lower Volcanic Cone of Mount Merapi, regosols and litosols are the main associations of the Baturagung Range, while the Coastal Plain is entirely covered by regosols and fluvisols. The other land units are characterized by well established soils, such as vertisols, rendzinas, ferralsols, and luvisols.

An exception is the Upper Volcanic Cone of Mount Merapi. Although its soils are far from being mature (regosols, and many of them are coarse sandy to stony), the climate varies only slightly. The dictating factor here is the high altidude that tends to have more uniform climates. In the order of Upper Volcanic Cone of Mount Merapi - West Progo Mountains - Lower Volcanic Cone of Mount Merapi - Sentolo Hills, Coastal Plain, Baturagung Range - Wonosari Basin, Gunung Sewu Karst, the climate changes from wetter to drier. Table 1 shows the composition of each land system.

METHODS AND MATERIAL

Among the 21 land systems, eleven are sizable relative to the extent of their respective land units. They are 1d, 2c,b,a, 3c, 4b, 5b, 6b, a, 7a and 8a. Land system 1d is not important agriculturally, especially for the development of irrigation, as the texture of the soils is too coars , or the soils are too stony.

Twenty eight observation stations have been installed. One land system may have more than one station for better representation. Eight out of them are equipped with a Class A open pan evaporimeter, a rain gauge (ombrometer), and a lysimeter. The remaining 20 stations have no lysimeters. Form of land use, kind of soil, and the incidence of drought were the land criteria being used to allocate lysimeters to land systems. Soil samples for laboratory analysis were collected from all stations, giving priority of analysis to stations with lysimeters. All stations will be completed with one or more infiltration tubes each. The standard dimensions of the tubes are 10 cm diam. and total length of 30 cm. When installed, the tubes will form a standpipe of 20 cm height above ground level. They are to measure the infiltration rates of the two upper soil layers separately. The first layer will be scraped off to measure the infiltration rate of the second layer. The station distribution is presented in Table 1.

The agrometeorogical data include daily evaporation, daily rainfall, and daily evapotranspiration from the lysimeters which approximates the consumptive use. Potential evapotranspiration may also be approximated more roughly from the magnitude of evaporation using the Penmann factor of 0.75. This latter approximation is used before sufficient lysimeter measurements can be collected.

The field characterization of the soil covers the relief of the site, soil colour, texture, structure, effective depth, and the range of change of the natural water content. The effective depth has been determined on the basis of the vertical distributions of texture, structure, and consistency, the depth to a pan, root distribution, and the evidence of biological activities within the soil profile. The water intake rate will be determined with the infiltration tubes.

The soil laboratory analyses of pore size distribution, bulk density, particle density, porosity, and colour changing point have been finished. The determinations of particle size distribution and aggregate stability are still in progress. The analysis will also includes capillary rise, contact angle, modulus of rupture, dispersion ratio, plasticity index, pF characteristics, and vertical and horizontal hydraulic conductivities.

RESULTS

The preliminary calculation of the atmospheric and soil water balances are given in Table 2. The figures pertaining to the land systems 1c, 2d,c,b,a, 5b,a and 6c,a are still incomplete, so that the soil water balance cannot be calculated yet. The period of July to November falls within the dry season. Except the land systems 5c and 5b which have a negative atmospheric water balance, the rest of the land systems have a positive value. This means that during the dry season most of the land systems, even the driest ones, have a surplus balance. The situation is different, however, regarding the soil water balance. Most of the calculable figures show moisture deficits below the field capacity. Compare columns 4 and 6 of Table 2.

Table 5 approximates the irrigation requirements of the different land systems based on a five day drying cycle in field condition without rain. The land system 5c with the largest soil moisture deficit has also the highest irrigation requirement. The irrigation requirement of the land system 6b which has the second largest soil moisture deficit is also high. The land system 4b has the smallest soil moisture deficit, and also the lowest irrigation requirement. These cases are considered normal. All fine textured soils develop soil moisture deficits during the dry season, unless the mean annual rainfall exceeds 3,000 mm (land system 6d). The land system 3c has a quite high soil moisture surplus, but its irrigation requirement is also high. This might be related to the low water holding capacity of its soils, which have textures of sandy loam to loam and a very low organic matter content. This is a case where the moisture surplus has been wasted.

Comparative to the land system 8a, the land system 7a has a similar atmospheric water balance and both are positive. But their soil water balance are both negative and differ substantially. Evidently, weather alone is not indicative of whether there is sufficient water available in the soil to support plant growth, or should supplemental irrigation be given. It is the intercorrelation of all components of the land that dictates the scheduling of irrigation. By using land systems where the mechanism of factor compensation takes on its full extent, more efficient irrigation can be planned.

In irrigation by gravity flow where the water is abstracted from surface sources, the service area can be clearly marked off from the source area. Where groundwater is the main source for irrigation, the source and the service areas are usually one and the same. In such a case the understanding of the water balance of the site will be crucial. Moreover, groundwater for irrigation is practiced in areas where surface source of water are scarce.

CONCLUDING REMARKS

As the study is only in its first phase, the results should be regarded tentative. It is just covering one dry season. Much more information is still needed which is pertinent to both the dry and the wet seasons, before any conclusive statements can be made. Yet the indications are there, that a landscape approach towards efficient irrigation is promising. A landscape approach to land development is instrumental in regional planning.

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Kami mengucapkan berbanyak terima kasih di atas kerjasama pehak tuan dalam melatih pelajar-pelajar kami.

"BERKHIDMAT UNTUK NEGARA"

Yang benar,

(Mohd. Amin Mohd. Soom)
Penyelaras,
Latihan Praktik Pelajar,
b.p. Dekan,
Fakulti Kejuruteraan pertanian,
Universiti Pertanian Malaysia.

s.k.

Table 1. The formation of the land systems, their sizes and soil associations, and the distribution of the observation stations.

Land Units (physiography, landform, surface hydrology)	Rainfall types (mean annual in mm)	Land Systems	Size (ha)	Soil association	Number of observation stations		
					Complete*	Without lysimeter	Soil sampling
1. Upper Merapi Cone	d	1d	18,632	Grey Regosol	-	-	-
	c	1c	7,012	Grey Brown Fluvisol	-	1	1
2. Lower Merapi Cone, including the Yogyakarta sloping plain	d	2d	7,976	Brown Fluvisol	-	1	1
	c	2c	23,800	Grey Brown Fluvisol	-	1	1
	b	2b	13,032	Ferralsol and Luvisol	-	1	1
	a	2a	14,792	Yellowish Grey to Brown Fluvisol	-	2	2
3. West Progo Mtn.	d	3d	4,008	Brown Ferralsol	-	-	-
	c	3c	17,636	Grey Regosol, Litosol and Luvisol	1	2	3
4. Sentolo Hills	c	4c	3,600	Litosol and Red Luvisol	-	-	-
	b	4b	20,747	Grey Regosol	1	2	3
5. Coastal Plain	c	5c	1,616	Grey Brown Regosol	1	-	1
	b	5b	7,464	Yellowish Grey Regosol	-	1	1
	a	5a	2,364	Grey Brown Regosol	-	1	1
6. Baturagung Range	d	6d	1,496	Litosol	-	1	1
	c	6c	6,040	Grey Brown Regosol	1	-	1
	b	6b	44,112	Brown to Grey Brown Regosol	1	2	3
	a	6a	25,152	Brown Regosol	-	1	1
7. Wonosari Basin	b	7b	5,296	Black Vertisol, Red Luvisol and Rendzina	-	-	-
	a	7a	20,704	Rendzina and Black Vertisol	1	2	3
8. G. Sewu Karst	b	8b	2,000	Litosol and Red Luvisol	-	-	-
	a	8a	71,000	Red Luvisol, Rendzina, Yellowish Grey to Black Vertisol and Litosol	2	2	4

d = >3,000 ; c = 2,500-3,000; b = 2,000-2,500; a = <2,000

* Class A open pan evaporimeter, rain gauge, and lysimeter.

Table 2. The atmospheric and soil water balances of the respective land systems for the period of July-November 1981

Land system	R (mm)	ET (mm)	R - ET (mm)	WHC*) (mm)	R-ET-WHC (mm)	
1c	1658	549	+ 1109	incomp.	incomp.	R = total of five months rainfall ET = total of five months potential evapotranspiration WHC = Water Holding Capacity
2d	484	365	+ 119	"	"	
2c	873	503	+ 370	"	"	
2b	687	552	+ 125	"	"	
2a	1008	756	+ 252	"	"	
3c	1173	430	+ 743	171	+ 572	
4b	657	509	+ 148	154	- 6	
5c	290	569	- 279	268	- 547	
5b	334	549	- 215	incomp.	incomp.	
5a	672	469	+ 203	"	"	
6d	844	694	+ 150	118	+ 32	
6c	1492	600	+ 892	incomp.	incomp.	
6b	572	542	+ 30	241	- 211	
6a	821	626	+ 195	incomp.	incomp.	
7a	763	602	+ 161	185	- 24	
8a	722	549	+ 173	226	- 53	

*) Calculated according to BIRKELAND (1974).

Table 3. Soil physical and chemical properties of the land systems

Land system	Depth (cm)	O.M. %	$CaCO_3$ %	pH (H_2O)	BD[1] g cm^{-3}	PD[2] g cm^{-3}	n[3] %	FC[4] %	WP[5] %	AW[6] (% Vol)
3c	0-20	0.36	1.90	7.19	1.76	2.37	25.7	27.0	10.2	29.6
	20-40	0.38	2.38	7.08	1.63	2.29	28.7	32.4	16.4	26.1
4b	0-25	0.36	1.46	7.56	1.50	1.91	21.5	36.8	29.0	11.7
	25-40	0.37	1.47	7.82	1.14	2.40	52.2	41.9	28.4	15.4
5c	0-20	0.72	2.86	7.42	1.76	2.30	23.4	38.2	25.3	22.7
	20-40	0.36	2.89	7.96	1.41	2.18	35.1	38.0	20.3	24.9
6b	0-20	0.73	1.98	6.40	1.50	2.32	35.3	48.0	21.0	40.5
	20-40	0.74	2.11	6.58	1.50	2.07	27.5	32.6	21.7	16.3
6d	0-20	0.74	1.93	7.22	1.51	2.20	31.1	42.3	29.5	19.3
	20-41	0.37	1.29	7.59	1.54	2.13	27.7	45.6	31.2	22.2
7a	0-23	0.52	2.04	7.77	1.15	2.20	47.7	42.7	22.0	23.8
	23-45	0.37	2.01	7.49	1.31	2.10	37.6	36.9	25.4	15.1
8a	0-18	0.74	2.00	6.97	1.50	2.40	37.5	33.8	14.9	22.3
	18-35	0.76	2.07	6.91	1.30	2.81	28.2	32.1	12.1	15.7
8a	0-15	0.73	1.99	7.23	1.53	1.96	21.9	37.0	25.4	16.8
	15-35	0.78	2.01	7.44	1.52	1.76	13.6	37.0	23.6	20.4

1) Bulk Density
2) Particle Density
3) n(porosity) = $(1 - \frac{BD}{PD})$
4) Field Capacity
5) Wilting Point computed from Color Changing Point
6) % by volume

Table 4. Soil profile characteristics of the land systems

Land system	Depth (cm)	Color	Texture	Structure	Consistency
3c	0-20	Dark grey (5 Y 4/1)	sandy loam	massive	ss - sp
	20-40	Dark Yellowish Brown (10 YR 3/4)	loam	massive	ss - sp
4b	0-25	Dark Yellowish Brown (10 YR 4/4)	clay loam	massive	ss - p
	25-40	Dark Yellowish Brown (10 YR 3/4)	silty clay	massive	ss - p
6b	0-20	Dark Reddish Brown (5 YR 3/4)	clay loam	massive	ss - p
	20-40	Yellowish Red (5 YR 4/6)	clay	massive	ss - p
	40-65	Dark Brown (7,5 YR 3/4)	clay loam	massive	ss - p
	65 +	Brown to Dark Brown (7,5 YR 4/4)	clay loam	massive	ss - p
6d	0-20	Dark Olive Grey (5 Y 3/2)	clay	massive	s - p
	20-41	Black (5 Y 2,5/1)	clay	s.a.b.	ss - p
	65-90	Dark Olive Grey (5 Y 3/2)	clay	s.a.b.	ss - p
5c	0-20	Dark Brown (7,5 YR 3/2)	clay	massive	s - sp
	20-40	Very dark grey (10 YR 3/1)	clay	massive	s - sp
	40-70	Very dark greyish brown (10 YR 3/2)	clay	massive	ss - p
	70 +	Very dark greyish brown (10 YR 3/2)	clay	massive	ss - p
7a	0-23	Black (10 YR 2/1)	clay	massive	ss - p
	23-45	Black (10 YR 2/1)	clay	massive	ss - p
	45-63	Very dark greyish brown (10 YR 3/2)	clay	s.a.b.	ss - p
	63-100	Very dark grey (10 YR 3/1)	clay	s.a.b.	ss - p
8a	0-18	Yellowish red (5 YR 4/6)	silty clay	massive	s - sp
	18-35	Dark red (2,5 YR 3/6)	silty clay	massive	s - sp
	35-55	Dark red (2,5 YR 3/6)	clay	massive	s - sp
	55-90	Dark reddish brown (2,5 YR 3/4)	clay	massive	s - p
8a	0-15	Dark reddish brown (5 YR 3/3)	clay	massive	s - sp
	15-35	Dark reddish brown (5 YR 3/4)	clay	massive	s - sp
	35-65	Dark reddish brown (5 YR 3/4)	clay	massive	ss - p
	65 +	Reddish brown (5 YR 4/4)	clay	massive	ss - p

s.a.b. = subangular blocky; ss = slightly sticky; s = sticky; p = plastic; sp = slightly plastic.

Table 5. The amount of water needed to restore the field capacity of the soils after a five day drying cycle in the field without rain

Land system	3c	4b	5c	6d	6b	7a	8a
Water needed*	28,4	18,5	35,1	30,5	32,5	33,2	19,7

* liters per m^2 to a depth of 30 cm.

The paper was presented by Dr. Notohadiprawiro :

DISCUSSIONS :

Q : Refering to table 5, is there any guidelines or criteria for choosing five days as the irrigation cycle?

A : We asked the farmers about the duration before wilting starts. Their response of five days was used because we are still waiting for the results of our laboratory studies. We hope to give a complete report on this by August in Thailand.

Q : Are there any final agreement on defining the land system? (Piyapongse, Dept. of Agriculture, Thailand).

A : Soil scientists seldom agree on anything, even on soil classifications. Every country has her own system, whether American, Russian, Australian, Canadian or Japanese. In our land system, we are trying to compile certain criteria of land that are relevant for use as a base in the construction of the land individuals. The physiography, landform, surface hydrology and climate should be included. For the time being, we are using only the mean annual rainfall. Superimposing the different rainfall types on the land units, we form the land system.

DRIP IRRIGATION SYSTEM FOR ORCHARD TREES IN MALAYSIA

Amin M. Soom

Dept. of Field Engineering
Faculty of Agricultural Engineering
Universiti Pertanian Malaysia

ABSTRACT

The high annual rainfall of Malaysia is unevenly distributed throughout the year. Supplemental irrigation will be beneficial for good yields and quality of crops. The water saving feature of drip irrigation system warrants adoption of the system on some soils and crops in Malaysia. Marginal land such as bris soils and tin-tailings may be developed for productive agriculture by installing a drip irrigation system to supply moisture, especially during the critical growth stage of the crops. This paper presents drip irrigation system design using drilled holes as emitters. Discharge calibration on 1 mm diameter drilled hole is given. The use of drilled holes instead of commercial emitters reduces system cost, and a less expensive system would make drip irrigation more attractive to potential users.

INTRODUCTION

The average rainfall of Malaysia exceeds 2500 mm annually. With this much water orchard trees are grown without irrigation. However, there are periods of inadequate moisture when supplemental irrigation will be needed to meet the crop water requirement, especially during the critical growth stage, in order to ensure good yields and quality of the crops. The irrigation method to use will depend on the slope of the land, texture and depth of the soil, type of crops, availability, quantity and quality of water, salinity and drainage problems, and the overall irrigation system cost.

Drip or Trickle irrigation technology as the most recent of all commercial irrigation methods is growing rapidly in arid areas of the world. Most of the scientific knowledge and practical experience to date are derived from arid areas. Drip irrigation is widely recognised for its high water use efficiency and low labour requirement. In our climate, the water use efficiency and labour cost are not the most important factors to consider in the selection of a type of irrigation system; nevertheless, the water saving feature, the potential of an improved crop production on existing land and the possibility of cultivating marginal land warrant adoption of the system on some soil types and crops in Malaysia.

Much of Malaysia's arable land is already cultivated. To increase food production to cope with population growth, marginal land such as bris soils and tin-tailings may be developed. Bris soils are found along the coastal stretches of Kelantan, Trengganu, Pahang and Johore, and tin-tailings areas are found in tin producing states of Perak and Selangor. These soils are predominantly sandy with poor moisture retension capacity due to high percolation and high evaporation. They also have intense reflected heat and poor nutrient status. Drip irrigation technology may be adopted here to develop these areas for productive agriculture.

Drip irrigation uses an extensive network of small diameter tubes with water emission points or emitters at necessary spacing to deliver water and soluble fertilizer to the crop root zone. The sizing of tubes for a drip system is based on several factors such as hydraulic principles, emitter flow characteristics, row length, elevation, equipment and energy costs, and water application uniformity desired. The relationship among the above mentioned factors is complex. However, recent research on small tube hydraulics gives us new information that can improve the energy, water and material used efficiency, Watters and Keller (1978), Howell and Hiler (1974), Solomon and Keller (1974) Wu and Gitlin (1974)

This paper presents analytical expressions to relate the physical variables in lateral line hydraulics. Design equations are presented in implicit form that relates lateral length, diameter, operating pressure, emitter flow characteristics, tube friction, discharge uniformity coefficient, emitter discharge exponent, emitter spacing requirement and land slope. The equations are in a formthat can be inserted into many programmable digital calculators and are very convenient for direct application to field use. The equations eliminate the need for design charts and tables. Discharge calibration for drilled hole emitters is given in the second part of this paper.

DRIP IRRIGATION SYSTEM

In a drip irrigation system, water and nutrients are carried in small polyethylene pipes from the supply and applied directly to the soil around the plant roots. Water is applied frequently but at low flow rates, usually between 2 and 10 lph under operating pressure head of a least 10m, to keep the root reservoir near field capacity. Water application efficiency may be as high as 95% which is much higher than other irrigation methods, surface or sprinkler.

The principle parts of a drip irrigation system are the emitters, laterals, submain and main lines. The lateral is a small diameter plastic tube combined with emitters or simply with drilled holes to distribute water to the field. The submain acts as a control system which can adjust water pressure in order to deliver the required amount of flow into each lateral; it is also used to control irrigation time for individual fields. The main line serves as a conveyance system for delivering the total amount of water for the system. Supporting parts such as filters, flushing units, pressure regulator, pressure gauge, valves and fertilizer injector serve different functions in a drip irrigation system.

Lateral Pressure Relations

As the pressure along a lateral line changes due to pipe friction and elevation so does the discharge from the emitters. This causes a non-uniform application of water. Emitter sensitivity to pressure changes can impose serious limitations on lateral line length for a specified uniformity of irrigation, especially on sloping land.

The emitter discharge rate is a function of operating pressure

$$q = kH^{x} \qquad \ldots\ldots (1)$$

The magnitude of x characterizes the discharge-versus-pressure relationship. It is the measure of how sensitive the emitter discharge is to pressure, Fig. 1. The value of x will typically fall between 0.1 and 1.0 depending on the design of the emission device. The magnitude of the coefficient k is a size or capacity parameter for an emitter since its magnitude is equal to the emitter discharge when H equals unity.

The emitter is an important part of a drip irrigation system. Solomon (1976), Karmeli and Keller (1975), and Karmeli (1972) list the desired qualities of a drip emitter. Although the ideal emitter has not yet been invented, Pitchford (1979) is optimistic that an emitter with a high degree of pressure compensation ($x \to o$) is technically possible to achieve. Many emitters are sensitive to pressure variations. In laminar flow x = 1.0. Long-flow-path emitters have x = 0.7 to 0.8. Non-compensating orifice and nozzle emitters are always fully turbulent with x near 0.5. Compensating emitters have x ranging from 0.1 to 0.4.

Emitters may have a designated operating pressure range for predictable discharge, flushing action and safety from rupture. The designated range should be recognized and not be exceeded in the field (Figs. 1 & 2). A wide range of operating pressure (HMAX-HMIN) is a desirable quality in an emitter. The pressure limits should be stated by the manufacturer. Emitter operating pressure limits imply that HN<HMAX and HO>HMIN in the lateral.

Refering to Fig.2, friction loss HF and/or elevation differences HE cause the difference in supply end pressure HN and far end pressure HO. All quantities are defined in Table 1. To get a relation among the variables let us begin with these pressure head terms. As diagrammed in Fig. 2, pressure head components in a lateral are :

TABLE 1. VARIABLES IN LATERAL DESIGN

Variable	Symbol	Units	Description
Roughness coefficient	C	-	Hazen-Williams roughness coefficient for pipe wall
Emitter friction	CE	-	Friction in lateral due to barb or other obstruction to flow
Diameter	D	mm	Inside diameter of lateral tube
Reduction factor	F	-	Reduction coefficient for friction loss in multiple outlet conduit. F = 0.36 for N>30
Pressure	H	m	Operating pressure in the lateral
Elevation	HE	m	Elevation difference in inlet and far end of lateral line
Friction	HF	m	Head loss due to lateral friction
Pressure	HMAX	m	Maximum operating pressure for an emitter
Pressure	HMIN	m	Minimum operating pressure for an emitter
Pressure	HN	m	Pressure head at supply end of lateral
Pressure	HO	m	Pressure head at far end of lateral
Constant	k	-	A numerical constant for an emitter
Length	L	m	Lateral length
No. of emitters	N	-	N = L/S
Emitter flow variation	P	-	Emitter flow variation due to pressure variation for example ± 10% from q equals a P of 10
Emitter discharge	q	lph	Emitter discharge, average design value
Reynolds number	RE	-	Based on total lateral flow at supply end
Emitter spacing	S	m	Emitter spacing on lateral
Discharge exponent	x	-	Emitter discharge exponent, $q = kH^x$

$$HN = HF + HO + HE \quad \ldots\ldots \quad (2)$$

in which HE is the pressure loss or gain due to elevation differences, positive when the lateral runs upslope and negative when the lateral runs downslope. The operating pressure ratio HO/HN is then

$$\frac{HO}{HN} = 1-\left(\frac{HF}{HN} + \frac{HE}{HN}\right) \quad \ldots\ldots \quad (3)$$

The formation of dimensionless ratios reduces the number of parameters by one and eases unit problems.

For irrigation tube economy it is desirable to have wide range of operating pressure range (low HO/HN) so long laterals in a given size can be used on steep slopes (high HE/HN). Fig. 3 shows that the allowable friction loss and elevation can be great when emitters having low x values are used. A preselected value of uniformity P can be maintained.

The irrigation application uniformity is influenced by the emitter discharge characteristics and the pressure differences in the lateral. The design engineer usually establishes a goal in application uniformity and attempts to meet it in the system design.

Howell and Hiler (1974) express emitter discharge variation in a lateral with a parameter P which expresses the difference in supply end emitter flow and far end flow as a percentage. P is the flow variation in a lateral line. For example, ± 10 percent variation equals a P of 10. The selection of a design uniformity P value places limits on the pressure difference HO and HN in the lateral and the discharge variation of the emitter. Using the procedure of Howell and Hiler we can express the inlet pressure, HN

$$HN = \frac{q}{k}\,(1+P/100)^{\frac{1}{x}} \quad \ldots\ldots \quad (4)$$

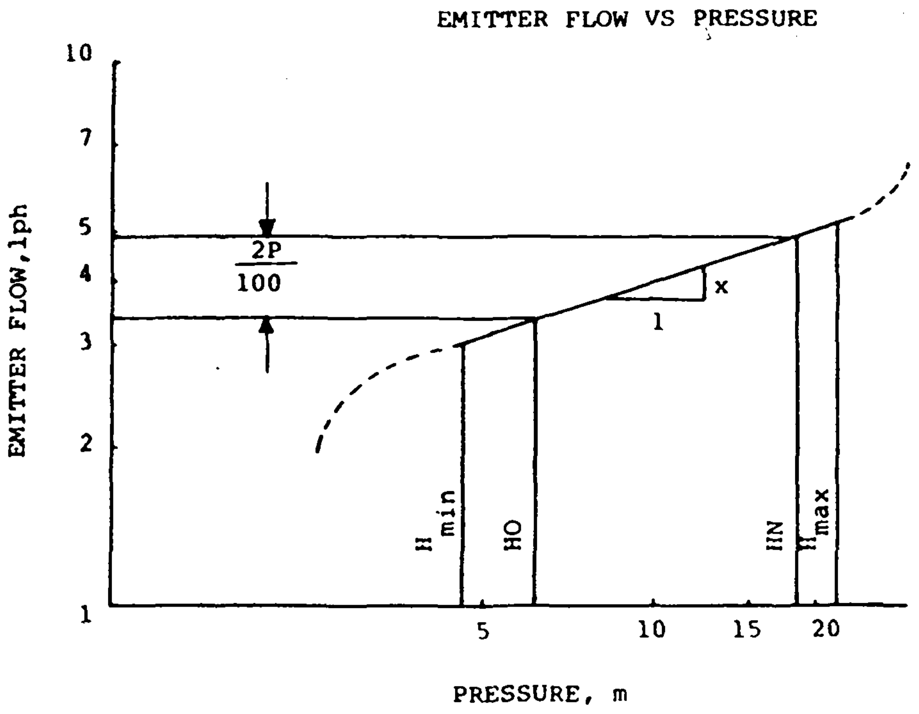

FIG. 1 Discharge versus pressure head for an emitter. The region of validity of $q = kH^x$ is defined by HMAX and HMIN.

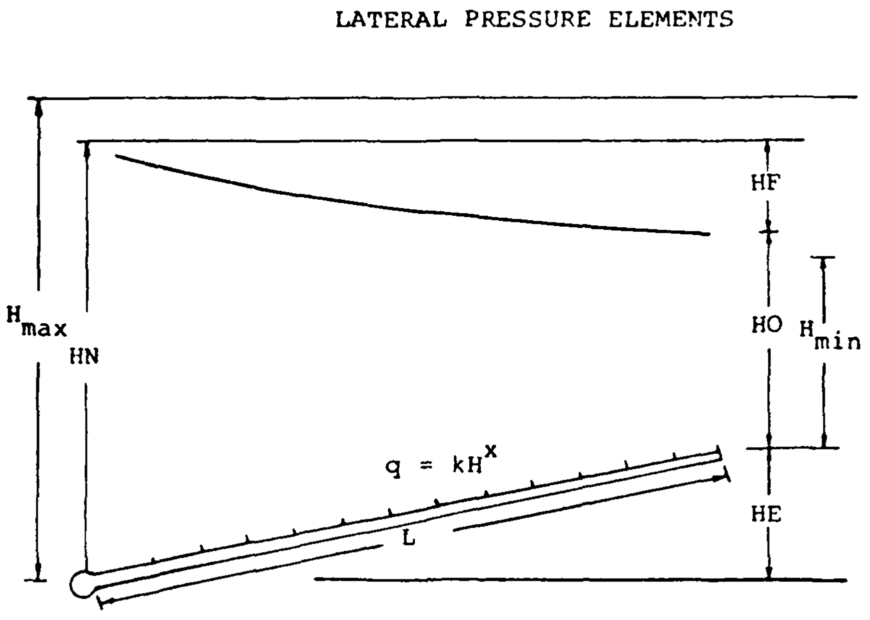

FIG. 2 Pressure head terms in a lateral shown with uphill slope.

and the far end pressure, HO

$$HO = \frac{q}{k} (1-P/100)^{\frac{1}{x}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

The ratio HO/HN

$$\frac{HO}{HN} = \left(\frac{1-P/100}{1+P/100}\right)^{\frac{1}{x}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

relates beginning and end pressure, emission uniformity coefficient P, and the emitter discharge exponent x. A graphic solution to equation [6] is shown in Fig. 3. The selection of a uniformity coefficient P defines the emitter discharge exponent x and pressure ratio HO/HN allowable in the lateral.

If we combine equations [3] and [6] we get a dimensionless ratio of frictional pressure loss HF to the inlet pressure HN

$$\frac{HF}{HN} = 1- \frac{HO}{HN} - \frac{HE}{HN} = 1- \left(\frac{1-P/100}{1+P/100}\right)^{\frac{1}{x}} - \frac{HE}{HN}) \quad \ldots\ldots\ldots\ldots\ldots \quad (7)$$

or

$$HF = HN \left(1 - \left(\frac{1-P/100}{1+P/100}\right)^{\frac{1}{x}} - \frac{HE}{HN}\right) \quad \ldots\ldots\ldots\ldots\ldots \quad (8)$$

in which HE is zero for level land. The lateral pressure head characterized by the beginning pressure HN on the lateral, the lateral line flow variation P, the emitter discharge exponent x, and the elevation head HE, all of which impose a limit on the allowable lateral friction loss HF.

The value of P and x relate to HO/HN in equation [6] and Fig.3. Values of (HF/HN ± HE/HN) are plotted as a function of HO/HN in Fig. 4.

By simultaneous use of Figs. 3 and 4 the irrigation uniformity P and emitter exponent x are related to HF/HN and HE/HN. The algebraic sum of HF/HN ± HE/HN is a single parameter that fixes pressure limits in the lateral. At this point the engineer could

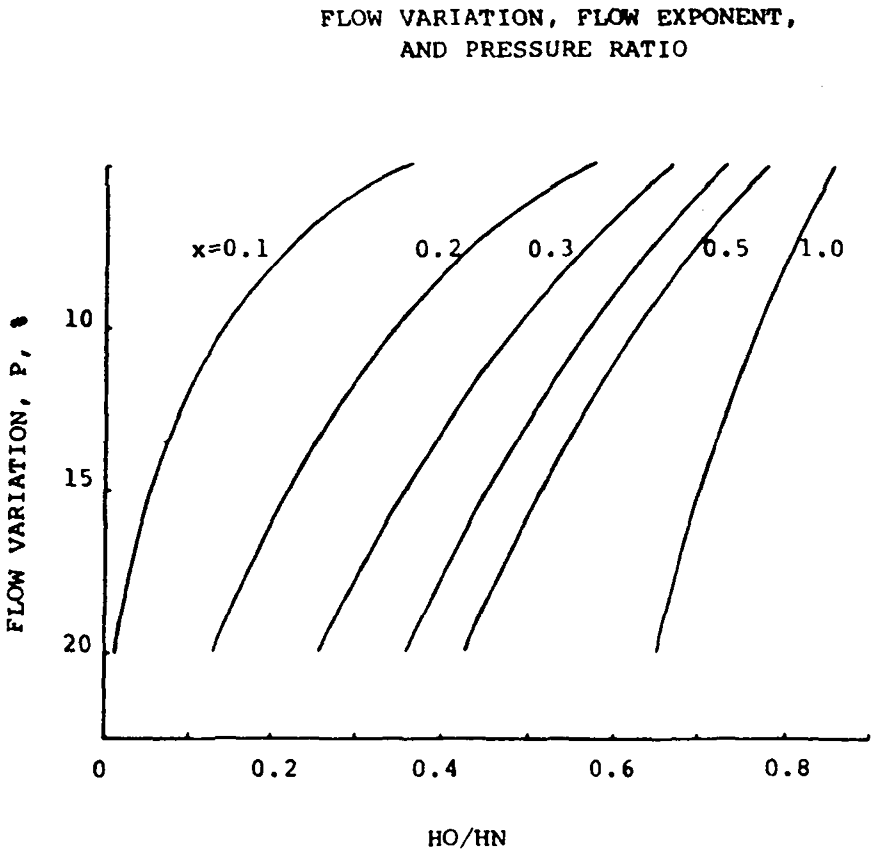

FIG. 3 Graphic solution to equation { 6 }

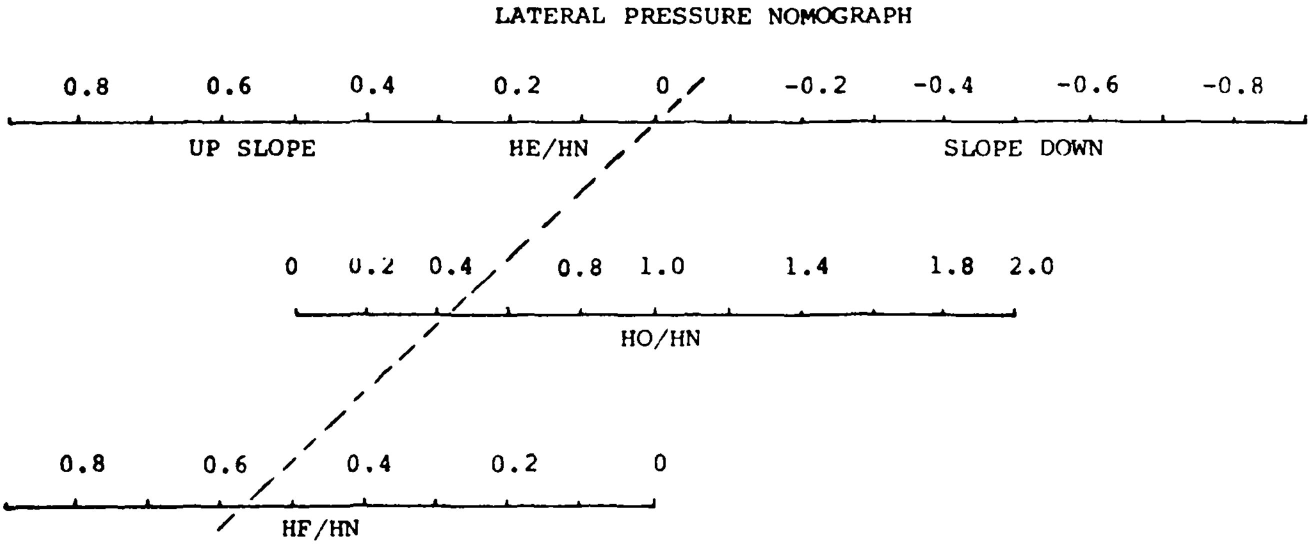

FIG. 4 Nomograph solution to equation(7). Can be used with Fig. 3 to find friction and elevation limits and emitter exponent for desired irrigation uniformity P.

use his preferred method for sizing laterals based on tube friction values and field elevation values. Emitters could be selected based on the required x value.

Lateral Friction Loss

The pressure loss in a lateral can be determined by any one of several friction loss equations and a factor for dividing flow. The Hazen and Williams formula expresses friction loss as

$$HF = 3.169 \times 10^{3} D^{4.871} F \left(\frac{q}{CS}\right)^{1.852} L^{2.852} \text{ .... } (9)$$

The value of the friction coefficient C has strong influence on the friction loss calculation. Many friction loss charts for smooth plastic pipe were developed with a C value of 150 but Watters and Keller (1978) and Howell and Hiler (1974) found that a C value of 130 is more appropriate for the Reynolds number range encountered in drip laterals. Karmeli and Keller (1975) developed a relationship between the C value for open tubing (C = 150) and a reduced value (80<CE<150) that can be used to include the additional friction due to the presence of emitters. Howell and Barinas (1978) measured emitter friction loss in laterals and developed a relation between obstruction area and its friction effect. Solomon and Keller (1974) expressed the friction loss with an exponential decay equation.

Watters and Keller (1978) present data that indicated the Blasius equation for friction loss

$$HF = 0.4716 D^{-4.75} F (q/S)^{1.75} L^{2.75} \text{ .... } (10)$$

is better than the Hazen and Williams equation in the Reynolds number range 3×10^{3} to 10^{5} which occurs in a drip lateral. The ability to adjust the friction factor C for emitter presence in the Hazen and Williams equation is an advantage.

The friction factor is implicit in the coefficient 0.4716 in the Blasius equation.

Limiting Length

An implicit relation among all the variables in a lateral line can be found by combining equation [8] for limiting friction loss and equation [9] (Hazen-Williams)

$$L = 0.0595\ D^{1.708}\ F^{-0.351}\ (CS/q)^{0.649}\ \left(HN\ \left(1-\left(\frac{1-P/100}{1+P/100}\right)^{\frac{1}{x}} - \frac{HE}{HN}\ \right)\right)^{0.351} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (11)$$

By combining equations [8] and [10] (Blasius) one gets

$$L = 1.325\ D^{1.727}\ F^{-0.364}\ (S/q)^{0.636}\ \left(HN\ \left(1-\ \frac{1-P/100}{1+P/100}\right)^{\frac{1}{x}} - \frac{HE}{HN}\right))^{0.364} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (12)$$

These equations while complex in form include all variables involved in the lateral design process. They are length, diameter, operating pressure, emitter flow characteristics, tube friction, discharge uniformity coefficient, emitter discharge exponent, spacing requirement, and elevation. The equations are in a form that can be inserted into many programmable digital calculators.

The two equations are in good agreement at C = 130, Braud and Amin, (1979). The higher the operating pressure the longer the length can be for a constant value of discharge variation P. As operating pressure is increased the friction loss can be larger and still maintain a preselected value of irrigation uniformity P. For a fixed value of other variables the higher the HN, the greater the slope HE that can be taken in the field.

Because pumping costs are proportional to operating pressure, one should remember this fact when choosing a pressure for drip irrigation. Depending on the number of hours per year of operating time, the economic balance of small lateral size with higher friction must be decided, Uys (1977) suggests that the most economic lateral size has 50 to 100 kPa (5 to 10m)friction loss per 100 meters of length.

Application Uniformity, P

Drip irrigation system application uniformity is influenced by the emitter design and pressure differences in the pipe distribution network. A general rule for arid area uniformity is to limit the discharge variation in a lateral line to ten percent of the average discharge. With emitters having discharge exponent of 0.5, this is the result of twenty percent variation in pressure.

In drip irrigation, unlike other irrigation methods, water is applied to a restricted area or volume of soil. In arid areas, the design criteria require that the system be able to supply on a daily basis all water used by the crop. Uniformity of irrigation should be high because the growth and productivity of the crop is directly related to the amount of water it gets. In Malaysia, rainfall is expected to supply most of the moisture needed by the crop. Rainfall is uniformly distributed over the field surface. The rooting system is not restricted to the volume of soil that is wetted by the emitter. Since drought is seldom severe enough to produce no moisture at all, the drip system application uniformity is not so critical as in an arid area. I believe that a 20 percent value for P is not too large for supplemental irrigation in Malaysia.

Drilled Holes as Emitters

Drip irrigation system using commercial emitters wet a small portion of the root zone. A larger coverage is possible only with additional cost for the emitters or an extra lateral line for each row of trees. Emitters may cost as high as 30 percent of the total system cost. To reduce cost, the use of drilled holes as emitters is suggested. A drilled hole gives a jet discharge. The trajectory of the jet discharge can be varied by drilling the holes at different locations around the circumference of the lateral tube. Hence a wider moisture spread is possible. The jet discharge can also be used as an indicator of emitter clogging. The use of drilled holes instead of commercial emitters for water release reduces system cost. A less expensive system would make drip irrigation more attractive to potential users.

Discharge Calibration on Drilled Holes

The performance of drilled holes as emitters was studied at the Agricultural Engineering Faculty, Universiti Pertanian Malaysia. Tests were carried out on two performance criteria: the pressure-discharge relationship and the flow rate sensitivity to water temperature. The experimental drip system consisted of a centrifugal pump driven by a 3 Hp petrol engine, 25mm lD PVC main line, and 300m long lateral line. The lateral was a 13mm black polyethylene tube. Other components include a gate valve, a pressure regulator and a pressure gauge. An in-line filter was placed at the supply end of the lateral. Holes were drilled using lmm diameter drill bit, and spaced 6m apart. Pressure head at the supply end of the lateral was varied from l0m to 2m.

Results

The discharge from a drilled hole emitter is sensitive to pressure. As pressure decreases along the lateral line, so does the discharge. Fig. 5 shows that the first emitter, 6 m away from the supply end, has discharge which ranged from 25 lph at 10 m head to 12 lph at 2 m head. At the 20th emitter, 120 m away from the supply end of the lateral, the flow rates ranged from 13 lph at 10 m head to 6 lph at 2 m head. At the far end of the lateral, 300 m away, the flow rates ranged from 4 lph at 10 m head to about 1 lph at 2 m head. No discharge was observed from the emitters at the far end of the lateral at pressure heads less than 2 m.

Discharge calibration results showed that the flow rates from the first emitter was about twice as much as those from the 20th emitter, 120 m away. The flow rates from the last emitter, 300 m away, were only 17% of those from the first emitter. The pressure discharge relationship as graphed in Fig. 5 showed that the discharge exponent of this emitter is very near 0.5. Equation 1 for drilled hole emitter of 1 mm diameter is then, $q = kH^{0.5}$.

Under the hot sun, water heats up as it travels along the black lateral line. With a water source temperature of 30°C, the water temperature at 120 m away from the source was about 34°C and the water temperature was as high as 42°C at the far end of the 300 m lateral line. The temperature discharge relationship showed that there was an increase in flow rates of about 4.6% per degree rise in temperature. The flow rates at 34°C and 42°C were respectively about 20% and 50% greater than the flow rates at 30°C.

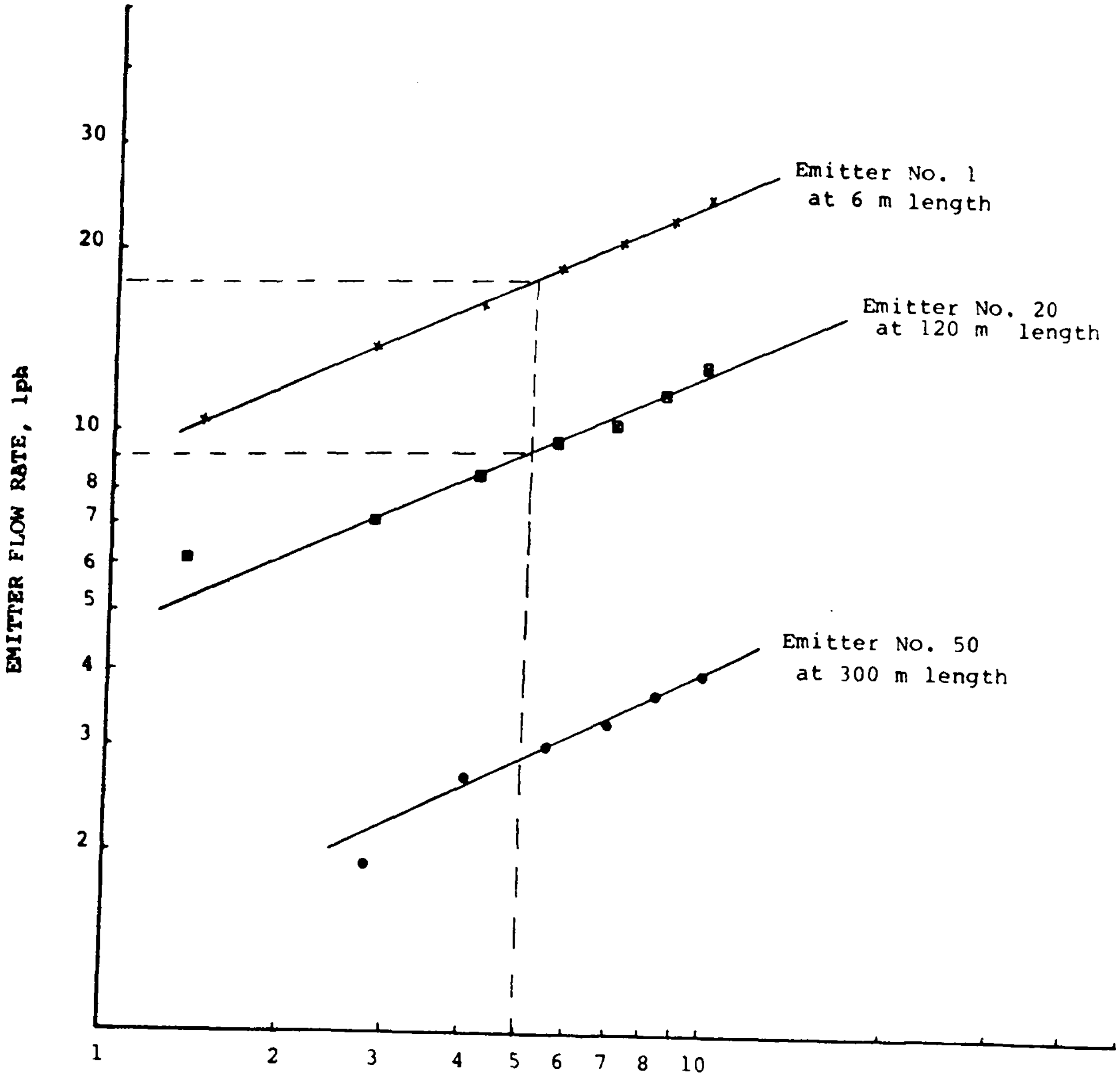

FIG. 5 Discharge versus Pressure head for 1 mm diameter drilled hole. $q = kH^{.45}$

Example

Determine the maximum length of a lateral line on a flat land when drilled holes are used as emitters. Emitter spacing is 6 m and supply end pressure is 50 kPa (5 m head). Application uniformity criteria call for an emitter discharge variation in the lateral not to exceed 20 percent. Three tube sizes are available: 10 mm, 13 mm and 16 mm.

Solution

The limiting length for three tube diameters will be found using equation (12). The actual friction loss HF and the far end head value HO can be calculated using equation (10). Numerical values for the variables are:

D = 10 mm, 13 mm, 16 mm; x = 0.5 (Fig. 5); F = 0.36 (Karmeli and Keller, 1974); S = 6 m; q = 15 lph; HN = 5 m; P = 20%; HE = 0.

D, mm	HN, m	L, m	HF, m	HO, m	HF/HN	HO/HN
10	5	83	2.84	2.16	.57	.43
13	5	130	2.81	2.19	.56	.44
16	5	187	2.85	2.15	.57	.43

SUMMARY

The paper presents new analytical expressions for the variables in a drip irrigation lateral line hydraulics. Design equations are given in implicit form to relate lateral length, diameter, operating pressure, emitter flow characteristics, tube friction, discharge uniformity coefficient, emitter discharge exponent, emitter spacing and land slope. The equations are very convenient for direct application to field problems. A system employing drilled holes as water release is suggested for use in Malaysia. Drilled hole emitters reduces system cost and makes drip irrigation more attractive to potential users.

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DISCUSSIONS :

Q : Your country has experience in practising drip irrigation. What is the initial investment of this system as compared to other systems such as sprinkler.

A : So far we have experimented drip irrigation on small plots only. The high cost of the imported tubing is prohibitive to try the system on a large scale.

Editor's note :

Investment per acre for different types of irrigation system are estimated as follows :-

Flood (water district)	US$	475.00
Flood (well water)	US$	650.00
Furrows	US$	300.00
Sprinkler (permanent set)	US$	1335.00
Sprinkler (hand move)	US$	460.00
Drip	US$	980.00

(Source : Reed, Meyer, Aljibury and Marsh, Cooperative Extension Service, University of California, 1977).

Q : Forestry Dept. has experimented drip irrigation for prop plants. I wonder if you know about the cost impact and the success of that experiment.

A : No. I am not aware of this.

C : We experimented on both drip and sprinkler systems for tobacco on bris soils. We abandoned research on drip because of the poor water distribution. Currently, we are concentrating on solving the problem of high ferrous content of the groundwater. We found out that a sawdust filter medium is capable of reducing the Ferrous content from 5-10 ppm to 0.2 ppm (Mohammud Che Husain, MARDI, Kubang Keranji).

Q : Your paper is only confined to orchard crops, what about plantation crops like oil palms? Moisture is a constraint in some of the inland areas. We do know that the oil palm's use is much higher in the coastal areas. In the inland areas, if we can have a more effective water use, use can be very much higher. What sort of cost one should be thinking for a stand of 55 palms/acre if 13 mm tubing is to be used.

A : What we can do is to get quotations from local importers.

Editor's Note : Emitters account for 25-35% of the cost of the system. Remaining cost is for tubings, fittings and the control head which includes valves, gauges, fertilizer tank, water filters, engine and pumping unit.

A local supplier quoted (1982) the cost for 13 mm PE tubing at M$ 350/1000 ft. Therefore for a stand of 55 palms/acre, the cost of tubing alone would be about M$ 700/=.

Q : What size of drilled orifices do you recommend in the light of prevention of clogging problems?

With 1 mm Ø drilled orifice, we would not require a sophisticated filtering unit. If the water is very dirty, a graded sand filter and a 100 mesh screen will be sufficient. Discharges from a 1 mm Ø drilled orifice ranged from 15 lph at 5 m pressure head to 9 lph at 2 m head.

C : MARDI has experimented drip irrigation on papaya plants. The cost could be as high as $ 12,000/acre depending on whether commercial emitters or punched holes were used for water release. (Aeshah,, Dept. of Agriculture).

C : We received a quotation for drip irrigation equipment on a 10-acre cocoa plantation. The cost was about US $ 1000/acre. (Lim Kim Huan, UPM).

Q : How do you normally punch the hole to get a uniform size? On different types of crops, how do yo place the different emitter openings.

A : We used a battery operated p.c.b. drill which is normally used for drilling printed circuit boards. Drilling will remove some of the material as compared to punched holes where there is no removal of material. For row crops, spacing between emitters might be only one meter apart but for orchards, we might need two emitters per plant to get a wider moisture distribution to cover the root zone of the plant. Using a portable drill we are able to place the emitters at the root reservoir.

C : Felda sugarcane has also tried drip irrigation. The cost per acre was about $ 3000/= depending on the type of emitters used. (Mohd. Daud, Felda, Sugarcane).

C : There is indeed a potential for the use of drip irrigation especially in marginal soil areas where the physiographical conditions appear to lend themselves to this type of application. Perhaps this discussions would be a good impetus for further work to be done by research institutes and the university. (Ir. Cheong Chup Lim, DID).

Water as a Source of Energy for Rural Development

Oral Presentation by Mr. Hamdan bin Uda Mohd. Isa, Project Engineer, Mini Hydro Dept., National Electricity Board, Malaysia.

Summary of Lecture

The increase need for hydropower is a result of the energy crisis of 1973 when the world was made aware of the limited alternatives available for power besides oil. The world reserve of oil in 1980 was about 2 x 10^{12} billion barrels with 75 - 80% being outside the communist countries. The rate of using energy is about 60 x 10^6 barrels per day. At this rate, the oil reserve will not last long.

In Malaysia, mini-hydro projects were embarked on a large scale to provide electricity to the rural areas. This is to increase the standard of living in rural communities and to ensure socio-economic growth. However, the present mode of supplying electricity to rural areas through extension of the main grid and diesel stations are not feasible due to its high cost and related problems.

In the planning of a mini-hydro scheme, the flow and the head must be known. Medium and high heads have a lower capital cost than a low head. A preliminary study has to be carried out to determine the catchment area, the location, the head available, access roads, bridges and potential consumers. Besides topographic maps, aerial photographs can also give additional information on the area. Since a mini-hydro scheme is a small station of 50 - 500 kw, costs for feasibility studies, design and supervision have to be limited. The flow-duration curve and the maximum probable flood level must be determined before designing the scheme.

Mini-hydro is constructed by building a diversion weir on the upstream part of a river. The river is diverted by building an open channel if possible, otherwise a low pressure pipeline is used. At the end of the low pressure pipeline there is a headpond or forebay which will pass the water through a penstock down to the power station and back into the river. The whole system does not consume water but uses the water energy. The environment is conserved in its natural state wherever possible.

DISCUSSIONS :

Q : How would mini-hydro schemes become beneficial in all aspects to the rural communities? (Faizul, NEB).

A : Benefits can be defined in several ways. Currently, the cost of oil is about US $ 34 per barrel, which is high, and mini-hydro provide an alternative means of power generation. The standard of living of the rural community can be improved. It is important to provide a balance between rural and urban communities for a country to be stable. With cheap and reliable electricity, employment may be increased thus reducing the rural-urban transmigration. Cottage industries help to increase the per capita income of the rural people.

Q : What is the minimum head required to operate the mini-hydro? Is there any soil conservation measures taken around the catchment area to reduce the sediment load and therefore reduce the cost of turbine maintenance? (Ong, Dept. of Agriculture).

A : The head may be very high or very low. The lowest head is about 3 m (10 ft) and the highest is about 120 m (400 ft.) Here, it is a question of whether the price we are willing to charge is profitable or otherwise.
The NEB has gone all out to control soil erosion and disturbance to the catchment area. There is always disagreement between the various departments on this issue, and usually there is a trade-off which has to be considered.

A : In the design of the existing mini-hydro schemes how do you tackle the siltation problem? (Faizul, NEB).

A : By building a weir across the river, the width of the river is extended, thus reducing the water velocity to about 2 ft/sec. The sand will settle down behind the weir. The use of a settling basin may also allow the sand and silt to settle.

Q : Can the Drainage and Irrigation Dept. install its own mini-hydro?

A : In Malaysia, approval to generate own electricity must be obtained from the relevant authority.

A VERTICAL AXIS WATER TURBINE FOR ELECTRICITY GENERATION AND WATER-PUMPING

Tengku Mohd. Azzman Shariffadeen, Wan Abu Bakar Wan Abas,
Mohamed Awang Lah

Faculty of Engineering,
University of Malaya.

SYNOPSIS

A new vertical axis water turbine based on the well-known Darrieus system is proposed for extracting power from relatively slow-moving streams. A theoretical analysis of the turbine, based on the Glauert's Actuator Disc Theory, is presented. The variation of the turbine's theoretical performance characteristics, such as power coefficient and drag coefficient, with rotor dimensions are shown. The turbine is also shown to have good self-regulating characteristics. The design of the turbine assembly and a testing system for it are presented. Possible applications of the turbine for electricity generation and water-pumping for irrigation are discussed.

1. INTRODUCTION

Traditional hydroelectric schemes require the construction of dams to extract power from the hydro source, resulting in high cost and the flooding of valuable agricultural land. The turbines available for such purposes work by converting pressure head to kinetic energy, involving high velocities. There exists a need for a run-of-stream turbine that is capable of extracting energy from a relatively slow-moving stream. The turbine can thus be used to supply power in remote areas to which the supply of electricity via the national grid is not feasible on economic grounds.

A new vertical axis turbine, based on the well-known Darrieus system, is proposed. This turbine is a high-performance low-solidity device used for converting kinetic energy from flowing water into shaft power in the same way as any other windmill or turbine that has aerofoil-shaped blades. The use of aerofoils of high lift-drag ratio will give higher conversion efficiencies and rotational speeds than those that can be expected from more conventional machines rotated by differential drag of vanes or cups. The turbine construction itself has the advantage that the immersed length of the blades can be adjusted to suit the depth of water available whilst the diameter can theoretically be as large as required. The configuration of the proposed assembly is shown in Figure 1.

This paper first discusses the performance theory of the turbine and the theory is subsequently utilised to obtain theoretical results for design purposes. Practical aspects for the design of a turbine nominally rated at 1 kW in a river flow of 1.5 m/s are then presented. Finally, application of the turbine for electricity generation and water pumping are briefly discussed.

2. PERFORMANCE THEORY FOR TURBINE

2.1. Development of Theory

Theoretical performance of the turbine is analysed using the Glauert's Actuator Disc Theory (Glauert, 1948) in a manner similar to that followed by Templin (1974). The approach adopted is similar to that of the simplest propeller or windmill disc theories, in which the induced velocity is assumed to be constant throughout the 'disc' and is related directly to the turbine drag. The blades of the present turbine do not lie in a thin disc but rather on the surface of an imaginary body of revolution. Nevertheless, the induced velocity through the upstream and downstream faces of the swept volume is assumed to be the same.

Glauert (1948) showed that the uniform stream tube velocity through the airscrew disc, say V_D, is the arithmetic mean of the ambient fluid velocity V and the final velocity in the wake V', that is

$$V_D = \tfrac{1}{2}(V + V') \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (1)$$

and that the airscrew drag D is shown to be

$$D = 2\rho A V_D (V - V_D) \quad \dots \quad \dots \quad \dots \quad \dots \quad (2)$$

where ρ is the fluid density and A the disc area which, in the present case, is taken as the product of the rotor diameter and its immersed height H.

A disc drag coefficient C_{DD} based on the flow dynamic pressure through the disc, i.e. $\frac{1}{2}\rho V_D{}^2$, and the 'disc' area A is here defined. We write

$$C_{DD} = D/(\tfrac{1}{2}\rho V_D{}^2 A) \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (3)$$

Substituting Equation (2) into Equation (3), we obtain

$$\frac{V}{V_D} = 1 + \tfrac{1}{4}C_{DD} \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (4)$$

For design purposes, we also define a more convenient drag coefficient C_D based on the ambient dynamic pressure $\frac{1}{2}\rho V^2$. We write

$$C_D = D/(\tfrac{1}{2}\rho V^2 A)$$

thus giving the relationship

$$C_D = \frac{C_{DD}}{(1 + \frac{1}{4}C_{DD})^2} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

For a given ambient speed V, turbine geometry and rotational speed ω, both the drag and induced velocity V_i are unknown. If, for a given turbine geometry and rotational speed, we specify initially the disc velocity V_D, where $V_D = V - V_i$, the rotor drag can be calculated from blade element analysis. The corresponding ambient velocity can then be obtained by using Equation (4).

2.2. Blade Element Angle of Attack and Dynamic Pressure

In the course of the theoretical study, we would be calculating the blade element forces. For these calculations, it is necessary to first determine the local aerodynamic angle of attack α and the local relative dynamic pressure q_r.

The blade element angle of attack, which is defined as the angle α between the chord and the direction of motion relative to the fluid, is shown in Figure 2. The direction of the disc velocity is taken to be the same as that of the ambient river velocity. The disc plane shown is perpendicular to the direction of river velocity. The angle θ represents a blade's position, measured in the direction of rotation relative to the disc plane and opposing the direction of river flow. The vector $\underset{\sim}{V}_{rel}$ represents the component of the resultant aerodynamic velocity vector relative to a moving blade element which lies in the blade aerofoil plane, the other component being parallel to the blade spanwise direction and assumed to have have no effect on the blade element aerodynamic forces. The expression for α is obtained by applying the 'sine rule' to the vector polygon.

$$\frac{\omega R}{V_D} = \frac{\sin(\theta - \alpha)}{\sin \alpha}$$

giving, finally,

$$\alpha = \left| \tan^{-1} \left(\frac{\sin \theta}{\omega R/V_D + \cos \theta}\right) \right| \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (6)$$

for $0^\circ < \alpha < 360^\circ$.

The relative dynamic pressure q_r is the ratio of the dynamic pressure of flow relative to the blade element q $(=\frac{1}{2}\rho V^2_{rel})$ to the dynamic pressure through the disc, that is

$$q_r = q \,/\, \tfrac{1}{2}\rho V_D^{\,2} = \left\{\frac{\sin (180^\circ - \theta)}{\sin \alpha}\right\}^2$$

$$= (\omega R/V_D + \cos \theta)^2 + \sin^2 \theta \qquad \ldots \qquad (7)$$

2.3. Aerofoil Characteristics

The two-dimensional aerodynamic data for NACA 0012 aerofoil, i.e. the lift coefficient C_ℓ and the drag coefficient C_d, can be found in Riegels (1961), Abbot and Doenhoff (1949) and Jacobs et al (1939). Riegels gives the coefficients over the range $0^\circ < \alpha < 180^\circ$ at a Reynolds number of 1.8×10^6; Abbot and Doenhoff gives values for $-16^\circ < \alpha < 16^\circ$ at Reynolds numbers of 3×10^6, 6×10^6 and 9×10^6; Jacobs et al gives values for the range $0^\circ < \alpha < 20^\circ$ at a Reynolds number of 0.3×10^6. The instantaneous local blade element lift and drag coefficient of the present construction is grossly, but consistently, assumed to be the same function of the angle of attack as those of a two-dimensional aerofoil in steady flow.

For computation purposes, the lift and drag coefficients are resolved into a normal force coefficient C_N and a chordwise "thrust" coefficient C_T (Figure 3); we write

$$\begin{aligned} C_N &= C_\ell \cos \alpha + C_d \sin \alpha \\ C_T &= C_\ell \sin \alpha - C_d \cos \alpha \end{aligned} \qquad \ldots \quad \ldots \qquad (8)$$

Templin (1974), using the data of Riegels and Jacobs <u>et al</u>, plotted the values of C_N and "adjusted" C_T for the complete range of $0^o < \alpha < 180^o$ and at a Reynolds number of 1.8×10^6. The corresponding values for Reynolds number of 0.3×10^6 was also plotted for the range $0^o < \alpha < 20^o$.

From the relation for the blade element angle of attack given in Equation (6), it can be shown that α lies within the range $0^o < \alpha < 30^o$ for $\omega R/V_D > 2$. The values given by Templin has been used in calculating the turbine theoretical performance since we are expecting to work with a Reynolds number of about 0.3×10^6. However, the variation of the turbine's performance with variation in Reynolds number has also been investigated.

2.4. Disc Drag Coefficient

The rotor drag coefficient C_{DD}, as defined by Equation (3), is determined by integrating the blade element forces over the disc surface, resolved in the direction of the ambient water.

An element of the blade, of chord c and lying within a horizontal slice through the rotor of elemental thickness dy has an area c dy. The normal force dN acting on the element is given by

$$dN = C_N \; q \; c \; dy$$

where C_N is the blade aerofoil normal force coefficient. Similarly, a forward thrust acting on the element is given by

$$dT = C_T \; q \; c \; dy$$

where C_T is the thrust coefficient of the blade aerofoil. When the components of the force are resolved into the direction of the ambient flow, the instantaneous elemental drag is given by

$$dN = q \; c \; (C_N \sin \theta - C_T \cos \theta) \; dy$$

For each blade, this elemental drag varies as the blade makes one full revolution and the average value is obtained by integrating over the range $0 < \theta < 2\pi$ radians. A second integration over the full height of the rotor will then give the total drag. Thus, for N blades of constant chord c, the drag is

$$D = \frac{Nc}{2\pi} \int_y \int_\theta q(C_N \sin\theta - C_T \cos\theta)\, d\theta\, dy$$

Introducing the limits $y = -H/2$ to $y = H/2$ and $\theta = 0$ to $\theta = 2\pi$, and substituting into Equation (3) gives

$$C_{DD} = \tfrac{1}{2} \frac{Nc}{R} \frac{1}{2\pi} \int_{\theta=0}^{2\pi} q_r \, (C_N \sin\theta - C_T \cos\theta)\, d\theta \quad \ldots \quad (9)$$

where, as before, $q_r = q \,/\, \tfrac{1}{2}\rho V_D^{\,2} = (\omega R/V_D + \cos\theta)^2 + \sin^2\theta$. If the disc velocity ratio $\omega R/V_D$ is specified and the blade solidity Nc/R is given, all the quantities in the expression can be computed numerically as a function of the azimuth angle θ. Numerical integration then yields C_{DD}. (A convenient numerical method for the evaluation is given in Templin (1974)). The specified disc velocity ratio can then be converted to the corresponding velocity ratio $\omega R/V$ by using Equation (4), giving

$$\frac{\omega R}{V} = \frac{\omega R}{V_D} (1 + \tfrac{1}{4} C_{DD})^{-1} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (10)$$

The rotor drag coefficient C_D based on the ambient dynamic pressure is then obtained by using Equation (5).

2.5. Power Coefficient

The rotor torque is produced by the thrust component on the blade element. For the element of the blade considered earlier, the torque acting is

$$dQ = C_T \, q \, R \, c \, dy$$

where C_T is the blade aerofoil thrust coefficient and R the radius of the rotor. This torque varies with the blade azimuth angle θ. The total torque from the slice of thickness dy is obtained by averaging dQ over one full revolution and multiplying by the total number of blades N. The rotor torque is obtained by integrating the value obtained over the total rotor height, that is

$$Q = \frac{Nc}{2\pi} \int_y \int_\theta q \; C_T \; R \; d\theta \; dy$$

Substituting for $q_r = q \; / \; \frac{1}{2}\rho V_D 2$ and introducing the limits gives

$$Q = \frac{Nc}{2\pi} \frac{RH}{2} \rho V_D{}^2 \int_{\theta=0}^{2\pi} q_r \; C_T \; d\theta,$$

thus giving the shaft power P as

$$P = Q\omega = \frac{Nc\omega}{2\pi} \rho V_D{}^2 \int_{\theta=0}^{2\pi} q_r \; C_T \; d\theta \quad \ldots \quad \ldots \quad (11)$$

The power produced in the shaft is a certain fraction of the total kinetic energy flow that passes through the rotor disc area. The total undisturbed energy flow is $\frac{1}{2}\rho V^3 A$. However, Glauert (1948) showed that the maximum power that can be extracted is given by

$$P_{max} = \frac{16}{27} \cdot \frac{1}{2}\rho V^3 A \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (12)$$

We thus define the power coefficient C_p of the rotor as the ratio of the shaft power to the maximum power extractable. Hence

$$C_p = P/P_{max} = \frac{27}{32} \left(\frac{Nc}{R}\right) \left(\frac{R\omega}{V_D}\right) \left(\frac{V_D}{V}\right)^3 \frac{1}{2\pi} \int_{\theta=0}^{2\pi} q_r \; C_T \; d\theta \quad (13)$$

For a specified value of disc velocity ratio $\omega R/V_D$ and for a given turbine solidity Nc/R, C_p can be evaluated using numerical integration as before. V_D/V is calculated using Equation (4); thus C_{DD} must be evaluated prior to evaluating C_p.

3. THEORETICAL RESULTS

The performance of the turbine, based on the theory presented, was investigated using the computer. The effects of varying the rotor design variables on the power coefficient and drag coefficient are presented here.

Figure 4 shows, for $\lambda = 0.58$, the effect of varying the blade solidity Nc/R on the power coefficient. The result indicates that the maximum shaft power increases with increase in solidity but does not increase substantially when solidity exceeds a value of about 0.2. The value of the maximum power output decreases at a value of solidity of around 0.4. Low values of solidity produce curves that are more 'flat', i.e., the operating range of the turbine in terms of the velocity ratio $\omega R/V$ is widened. However, working at low values of solidity will result in a reduction in the power extracted.

Varying the solidity also affects the drag coefficient, as shown in Figure 5. The theoretical values approach unity at high solidity and high values of tip-speed ratio. Lowering the solidity causes C_D to reach the value of unity at higher values of speed ratio. From Equation (5), it can be deduced that C_D reaches unity when the 'disc' drag coefficient C_{DD} reaches 4 and, from Equation (4), when V_D approaches one-half of the ambient velocity, i.e. when $C_D = 1$, $V_D = \frac{1}{2}V$. Since the Glauert Theory defines $V_D = \frac{1}{2}(V+V')$, as shown in Equation (1), the wake velocity has theoretically been reduced to zero at this high drag condition. At this point, Glauert's theory breaks down and the corresponding physical flow condition probably changes to an unsteady turbulent wake. The result suggests that a low value of solidity should be aimed for.

The effect of the blade profile, represented by C_{do}, on the power coefficient is shown in Figure 6 for a solidity of 0.375.

The value of the maximum power reduces with increase in the zero-lift blade parasitic drag coefficient; however they all occur at about the same velocity ratio of 3.25. Thus it is of advantage to bring the zero-lift drag coefficient value as low as possible by improving the quality of blade manufacture. However, the theory indicates that, for a zero-lift drag coefficient of as high as 0.02, the maximum C_p reaches a value of well above 70%, which is expected of the very best conventional horizontal-axis airscrews. Nevertheless, for values of C_{do} greater than 0.01, C_p tends to fall sharply with an increase in the velocity ratio. The theory fails for $C_{do} = 0$ since a power coefficient in excess of unity is obtained, which is not possible in practice.

The theoretical effect of adjusting the aerofoil data for Reynolds number was also investigated. The result is presented in Figure 7. At any value of the tip-speed ratio, the power coefficient is seen to be rather sensitive to a change in the number. At high values of velocity ratio, say $\omega R/V>3$, greater efficiency is expected for lower Reynolds numbers.

Figure 8 shows an interesting feature of the turbine, i.e. of self-regulation. This feature is important from the control point of view, with regard to controlling the power output with respect to variations in the velocity ratio $\omega R/V$. Assuming an electrical power output of 1 kW is required at an overall efficiency of 60% including transmission and generation losses, then Figure 8 indicates that at a speed of 30 rpm, this power can be obtained for flow velocities between 1.34 m/s and 1.75 m/s. Bearing in mind the cubic relationship between flow velocity and power available in the water, the power at 1.75 m/s. is actually 2.2 times that at 1.34 m/s. Thus if the rotational speed of the turbine is maintained constant, e.g. by the introduction of variable dummy loads as described in Section 5.1, the self-regulating feature may be capable of maintaining a constant output when the ambient velocity V varies. From the figure, it can be seen that the present design, i.e. Nc/R = 0.3, which is to operate in an ambient velocity of about 1.5 m/s, suits a rotational speed of 30 rpm. thus giving a tip-speed ratio of $\omega R/V = 3.1$. Further results show that increasing the solidity gives better self-regulating effect, but the maximum power is of course, reduced. We will be paying a lot of attention to this feature of the turbine in our design exercises in the future.

The variation in the shaft torque over a half-revolution of the turbine is shown in Figure 9 for turbines with one, two, three and four blades (for multiple blades, they are placed such that the angles between the cross-arms are equal). The results show that the instantaneous torque fluctuates about a certain mean. When the number of blades exceeds 2, the resultant torque fluctuation is reduced. The peak-to-peak fluctuation produced in a set-up with three blades is about 23% of the mean. Considering the fact that the inertia associated with the mechanical components will further reduce the torque fluctuation, this can be taken to be a reasonable value to work with in practice.

4. DESIGN OF TURBINE AND THE TESTING SYSTEM

The design proposed is for the production of a net power output of 1.0 kW at a river velocity of about 1.5 $m.s^{-1}$, assuming at least 25% overall efficiency as achieved by other workers (e.g. ITDG, 1980a). In the course of the design work, parameters such as typical river flow velocities and river dimensions in Malaysia were not available to us. However, for the purpose of the present exercise, the above specifications can be considered to be reasonable. Nevertheless, we are interested in collecting the necessary information on possible sites of application in Malaysia and the power requirement at those sites.

4.1. The Turbine

The turbine blades are straight and machined to conform to the

NACA 0012 profile. This particular profile is chosen because its symmetrical nature makes machining easier, and also because the aerodynamic data for other profiles are not readily available in the literature. The material used is aluminium alloy 6351-T5 (Alcom). Aluminium was chosen for its good endurance, strength, resistance to corrosion, low absorption of water and capability to withstand the expected stresses in comparison to its weight (density of alloy 6351 is 271×10^{-6} $kg.mm^{-3}$). Other alternatives such as steel, plastics and wood are rejected for the present. Steel is not thought to be suitable due to its weight and inferior resistance to corrosion. Wood was rejected because of time constraint, since we were unable to get seasoned and chemically treated wood within the time limit we had at that time. Plastics were rejected due to high cost of production for the limited number of blades we required. However, in future, wood and plastics will be reconsidered since aluminium may not necessarily be the best answer for large-scale production.

The blades have a chord of 0.15 m and a length of 1.2 m. The length represents the maximum possible height of the rotor. Each blade weighs slightly over 2.5 kg. The blades are machined to an accuracy of one thou (2.54×10^{-2} mm). This high accuracy is thought to be essential since the turbine is to be used in verifying the performance theory developed. The choice of size for the blade cross-section is dictated by the maximum size of aluminium sections available in the market. It is to be noted that the temper T5 used is not of the maximum strength, but our request for a better temper of grade T6 could not be fulfilled due to difficulties associated with the extrusion of thick sections.

The turbine assembly itself is as already shown in Figure 1, but in this particular design only 3 blades are used. The blades are connected to the rotor shaft via cross-arms of length 1.5 m which are positioned above the water level. This configuration eliminates the drag that would otherwise be introduced by the motion of the arms in water; it also permits the shaft bearings to be placed above the water level. Design of the cross-arms incorporates facilities for adjusting the effective height and the radius of the rotor. Cross-arm connections to the rotor shaft have facility for varying the number of blades.

An alternative configuration for the turbine assembly, with the cross-arms fixed at the mid-length of the blades, was also considered. This configuration reduces the maximum bending moment, and thus the bending stress, acting on the blades. However, it has the disadvantage of introducing drag due to the cross-arms; hence the cross-arms themselves have to be aerodynamically shaped so that this drag is minimised. Furthermore, the final assembly will require some of the bearings to be placed below the water level. Our calculations show that the present design is sufficiently safe with regard to the expected bending stresses. If the physical dimensions of the blades or the radius of the turbine are to be changed, further calculations have to be carried out in order to determine whether or not the present configuration is still safe.

4.2. Testing System

The initial field run of the turbine envisaged is the measurement of its performance characteristics so as to validate the theory developed. For these tests, the turbine will be mounted onto a pontoon to be driven at various speeds in still water by an outboard motor. The turbine rotor torque and rotational speed, and thus the power, can be measured at various 'ambient' velocities.

The pontoon is a bridge-type platform mounted across two rows of four oil drums each. It has been designed to support the turbine, the measuring apparatus and three researchers. The pontoon measures about 4.5 m. by 4.0 m. It was constructed as an assembly unit, i.e. it can be taken apart, transported to and assembled at the site proper.

5. APPLICATION TO ELECTRICITY GENERATION AND WATER PUMPING

5.1. Electricity Generation

There are two types of AC generator that may be used, i.e. the synchronous and the induction generator. The operation of synchronous generators is widely understood as they are universally used in power stations. Although they cost more, the self-excited, brushless type of synchronous generator is generally available even for a low power rating. On the other hand, an induction generator requires the supply of a lagging excitation current from an external source in order to be self excited. One method that has successfully been used (Brennen and Abbondanti (1977); Woodward (1980)) is by connecting capacitors across its output terminals capable of supplying the highest lagging current demand for the load and the excitation. As the reactive current demand and excitation vary with frequency and the type of load, the net effect of the capacitors is controlled electronically using a thyristor bridge and a D.C. inductor, as shown in Figure 10. The firing angles of the thyristors are varied around 90^o such that the output voltage of the generator is constant irrespective of load or frequency (within a limited range). One significant advantage of an induction generator is that the excitation current and therefore its output voltage collapses when an external short circuit occurs, thus providing a form of automatic overload protection.

A comparison between a few types of locally-available synchronous machines and induction machines of the same rating and speed was made. It was found that a synchronous machine costs about four times and weighs twice as much as an induction machine. These facts, together with its characteristics of easy maintenance and robust construction, favour the use of an induction generator for our work.

Irrespective of the type of generator used, the low speed of the turbine must be stepped up to a speed suitable for the generator. The speed depends on the number of poles and the frequency of the electrical power output. For example, for a 50 Hz output, a 2-pole machine requires 3000 rpm whilst a 4-pole machine requires 1500 rpm. It is also to be noted that a low speed machine normally costs more and is less efficient compared to a high speed machine of the same rating. At the same time, high speed means more expensive mechanical transmission equipment.

For the normal hydro-electric project with head, it is possible though not necessarily cost-effective particularly in the mini and micro range, to construct a flow-control regulator as a means to adjust the turbine output according to the load demand. For the present river current turbine, it is not desirable to control the flow. We have to resort to using an electronic load controller to keep the total load constant. This is to be achieved by the switching in and out of suitable resistive dummy loads when the consumer load changes. By keeping the net load constant, the generator speed and therefore the output frequency is kept within a certain range. A schematic diagram of the proposed arrangement is shown in Figure 11.

Three possible sensing methods for the controller are voltage sensing, current sensing and frequency sensing. The current sensing method was reported to work satisfactorily for both single-phase and three-phase networks while the voltage sensing controller gave favourable results only for single-phase networks (Meier (1981)). When the phases are not properly balanced in a three-phase network, the voltage sensing controller tends to overload the phase that already has the highest load. Although use of the frequency sensing controller has shown satisfactory results for single-phase networks (Woodward and Boys (1980)), experience with three-phase networks is still lacking. All the experience reported are for hydro-electric projects with head. As far as the river current turbine is concerned, the relative merits of various load controller sensing methods depend on the expected speed variation of the turbine.

Induction machines of 1 kW rating, or higher, are normally available for three-phase operation only. This means that a total of three load controllers are necessary, one for each phase. A possible solution to this problem is by converting the three-phase output to a single-phase output using a rectifier bridge and an inverter. Apart from reducing the number of load controllers, this also reduces the amount of wire needed for distribution (assuming that standard wire is used). The disadvantage of this method is that the cost of a commercially-available inverter which gives sine-wave output and high frequency stability is much higher than the cost of two load controllers it has replaced. At present we are looking into the possibility of designing an inverter with an output waveform just adequate for lighting and other less frequency-sensitive loads.

5.2. Water Pumping

The application of the Darrieus turbine to water pumping has been shown to be possible in the literature. For example, ITDG (1980 b) uses a centrifugal pump which rotates at about 1000 rpm and, in a current velocity of 1.2 m/s and for a rotor swept area of 3.75 m^2, obtains a pumping capacity of 200 l/min. over a height of five feet. A driving device of this nature has a clear advantage over more powerful diesel engines by virtue of the possibility of 24-hour utilisation when a suitable storage tank is used.

We are at present looking into suitable systems for the application of the present turbine to water pumping for irrigation of agricultural lands. This will form a further extension of the present project.

6. CONCLUSIONS AND DISCUSSION

A vertical-axis turbine, based on the well-known Darrieus system, is proposed for the extraction of energy from slow-moving streams. A performance theory based on the derivation of Templin (1974) from the Glauert's Actuator Disc Theory, can be used to predict the turbine's performance characteristics of power output and rotor drag. The effects of geometric variables, such as blade solidity and height-diameter ratio for a given disc area, can also be predicted.

The calculations show that the maximum power coefficient, or rotor efficiency, is achieved at a solidity of around 0.3 and tip-speed ratio of 3.5. Lowering the value of solidity widens the useful operating range of the turbine in terms of the speed ratio, but then the maximum power extracted is significantly reduced if the solidity is taken to a value of around 0.1 and below. Blade centrifugal stress will also tend to increase at low solidity due to the high rotational speeds.

The turbine has good self-regulating characteristics which can be used to advantage with regard to generating a constant power output. The present design, which assumes a river velocity of 1.5 m/s, gives reasonable self-regulation if rotational speed is maintained at around 30 rpm.

The theoretical calculations also indicate that the performance of the turbine is sensitive to the zero-lift blade parasitic drag coefficient. For vertical-axis wind turbines, it has been shown that the value achievable with reasonable care in blade design and manufacture results in rotor efficiencies that are comparable to the best horizontal-axis windmills.

The theoretical effect of adjusting the Reynolds number shows that the efficiency is rather sensitive to it throughout the range of operation. Nevertheless, the maximum power attained does not vary significantly and the shift of the peak is minimal, e.g. an increase of the Reynolds number from 0.3×10^6 to 1.8×10^6 (600%) shifts the power peak along the velocity-ratio axis from 3.25 to 2.75 (18%).

Our calculations indicate that a 1 kW power output can be generated by a turbine of practical size. If we consider the use of electricity for lighting alone, the turbine can supply adequate power for a number of houses. At suitable sites, and if extra power is required, a number of turbines can be installed to increase the power capacity. The electricity generated may then be used for refrigeration, TV and cooling fan as well. As lighting and TV are generally switched on in the evening, excess power during the daytime may be used for purposes such as pumping water from wells and for simple processing or light industries. The heat dissipated by the controller dummy loads can be used for drying.

The results of the theoretical performance calculations will be compared to those of field measurements to be carried out in the near future. This will enable us to check the accuracy of the theory, and to make adjustments where necessary. The goal is to produce a comprehensive design guide for the turbine in the form of look-up tables and/or diagrams so that optimum rotor geometric variables, including the blade dimensions, can be readily obtained to suit a given power requirement and working environment.

It has been the prime objective in this project to design a turbine that is appropriate for application in a rural setting. The turbine proposed is low-cost, easy to manufacture and needs little maintenance. Components used are mostly available off the shelf, thus ensuring continued supply and easy replacement. The main item requiring sophisticated fabrication is the turbine blade itself. However, if this turbine is widely accepted, blades of standard sizes can be mass-produced, for example, by extrusion methods. From the environmental point of view, this turbine can be seen to integrate itself easily into the environment with minimal disruption to the natural order.

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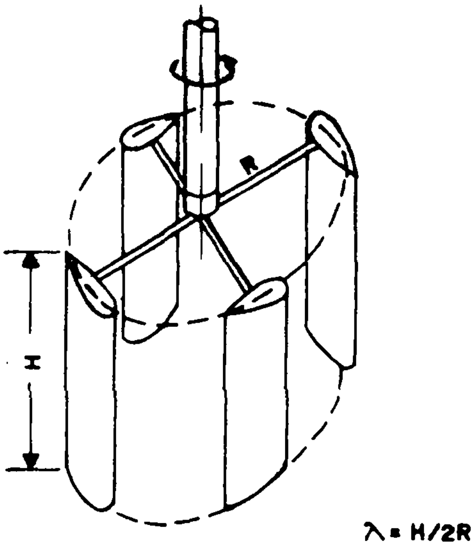


FIG. 1 PERSPECTIVE VIEW OF THE TURBINE

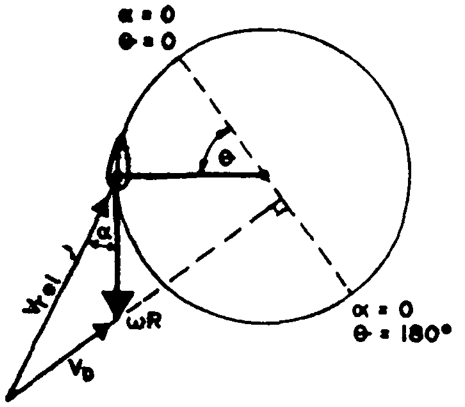


FIG. 2 THE VELOCITY VECTORS

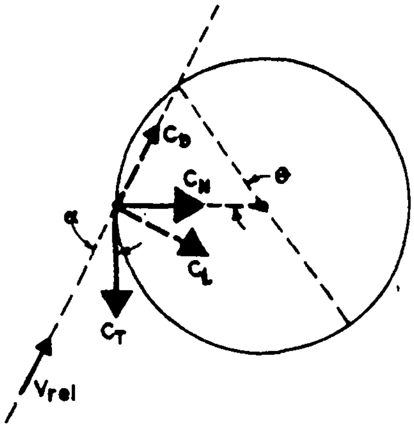


FIG. 3 THE NORMAL AND
THRUST COEFFICIENTS

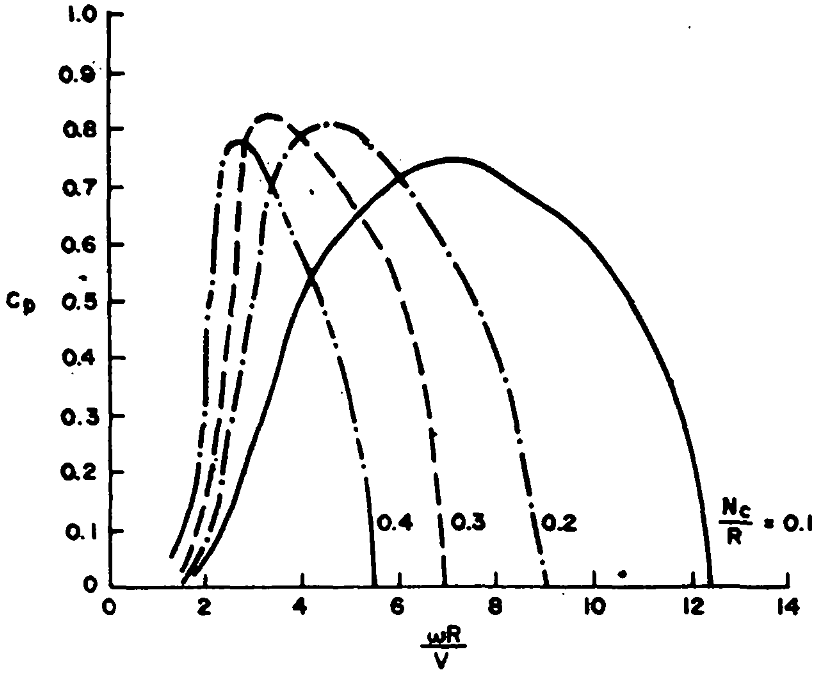


FIG. 4 EFFECTS OF VARYING THE SOLIDITY ON POWER COEFFICIENT

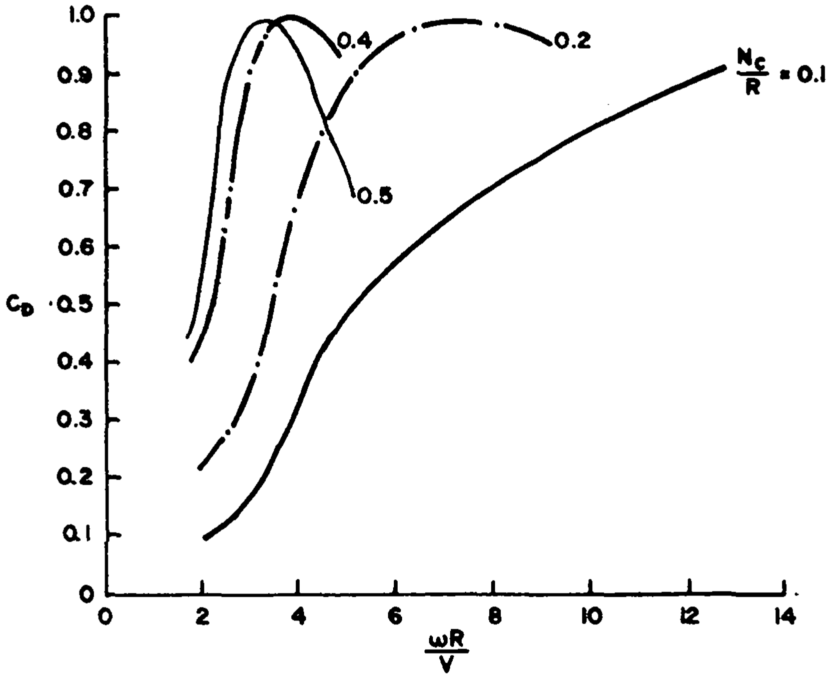


FIG. 5 EFFECTS OF VARYING THE SOLIDITY ON DRAG COEFFICIENT

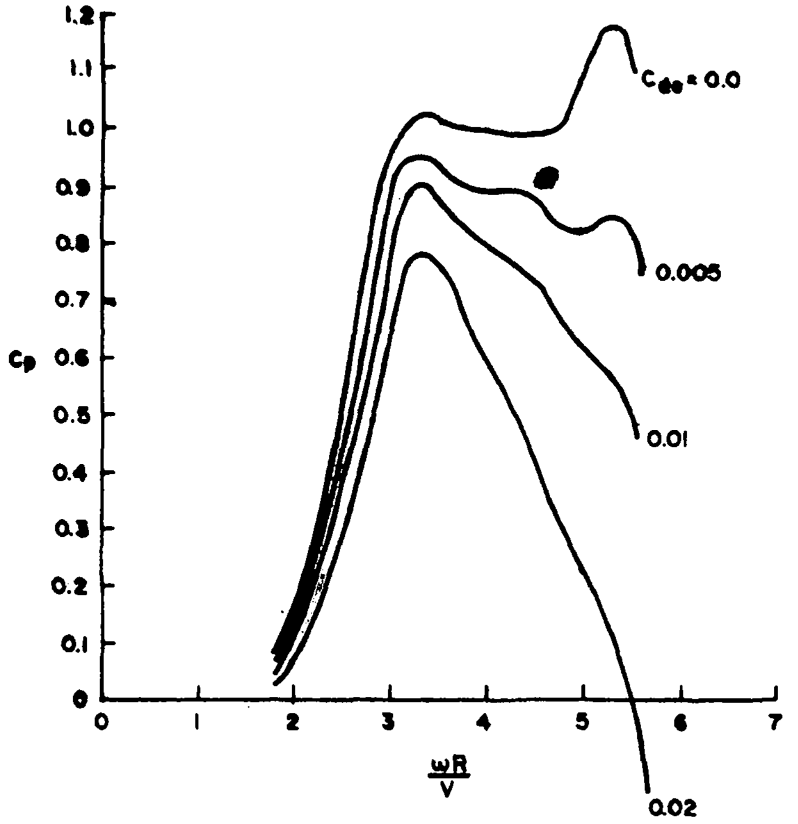


FIG. 6 EFFECTS OF THE BLADE PROFILE

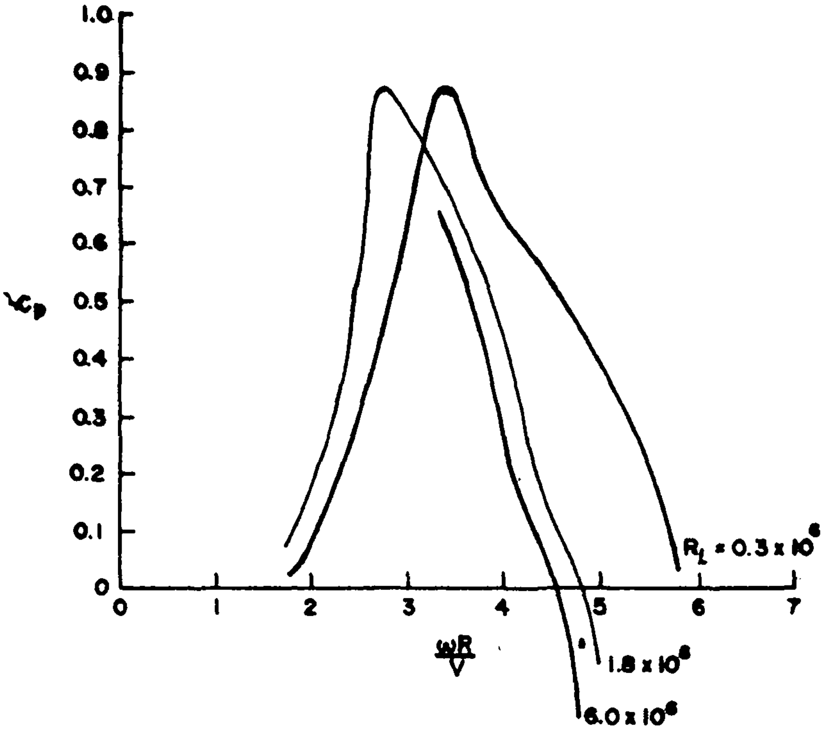


FIG. 7 EFFECTS OF REYNOLDS NUMBER ON POWER COEFFICIENT

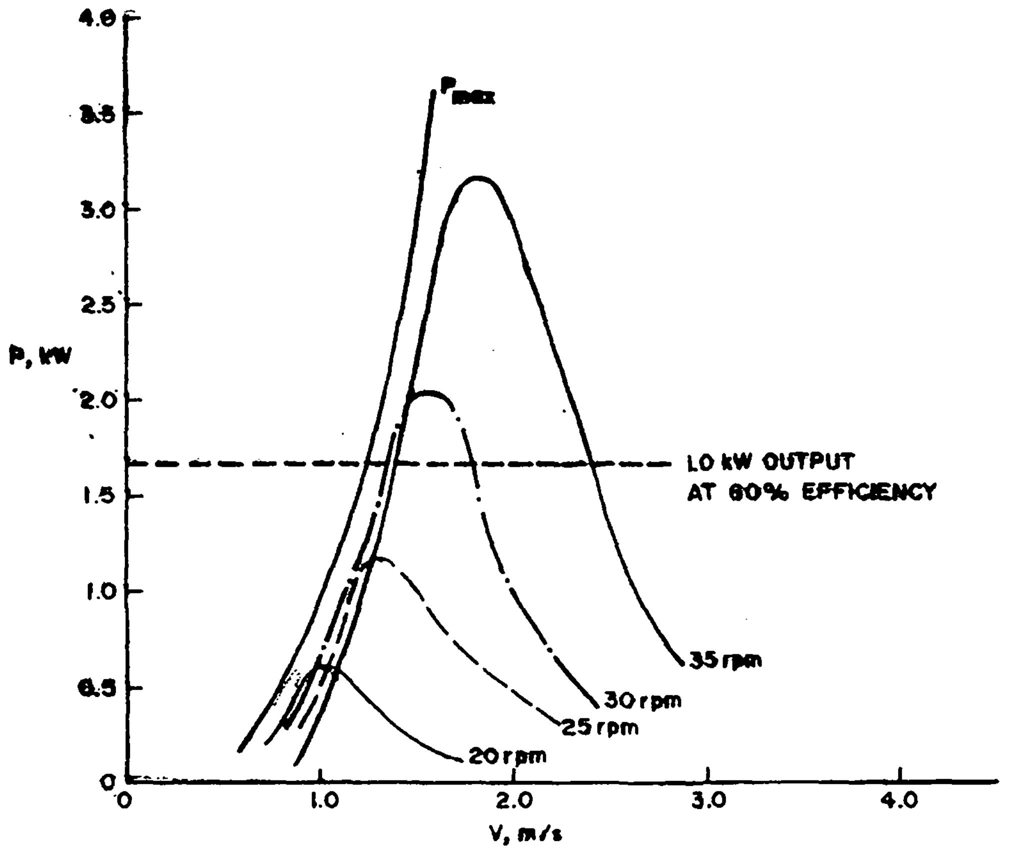


FIG. 8 THE VARIATION OF POWER WITH AMBIENT VELOCITY FOR CONSTANT ROTATIONAL SPEEDS

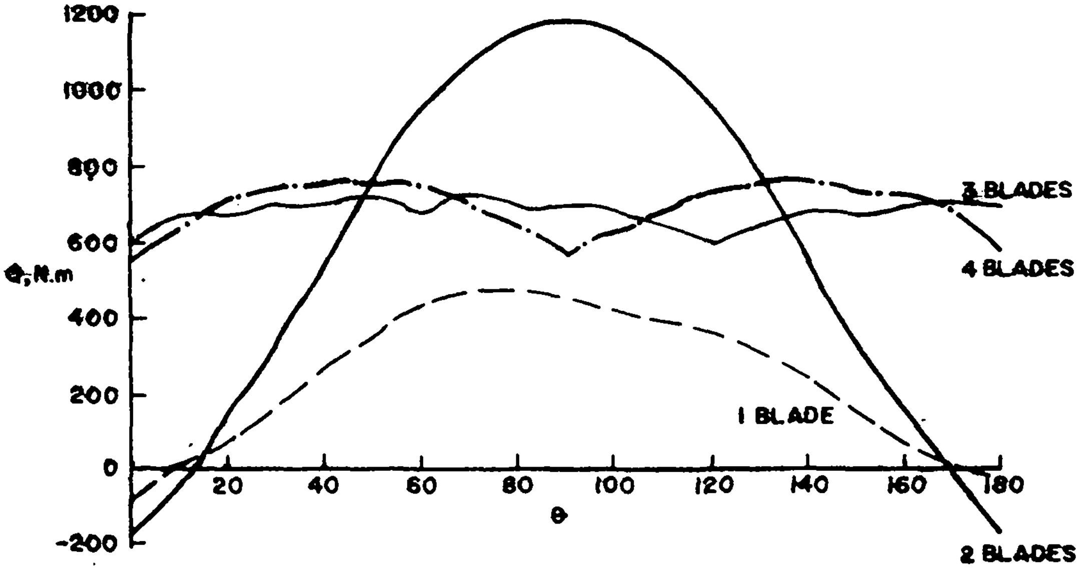


FIG. 9 TYPICAL SHAFT TORQUE VARIATION WITH BLADE POSITION

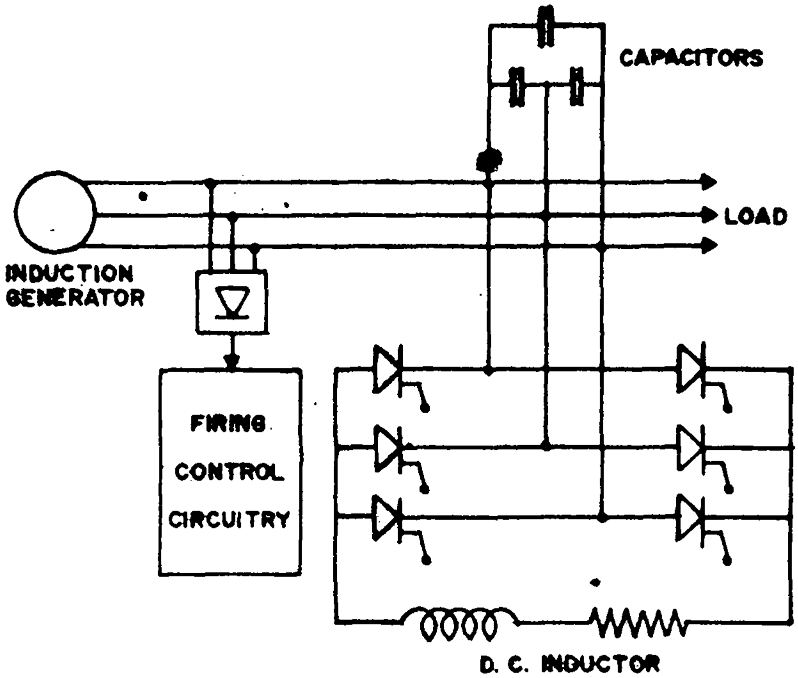


FIG. 10 EXCITATION CONTROLLER FOR INDUCTION GENERATOR (after Woodward and Boys, 1980)

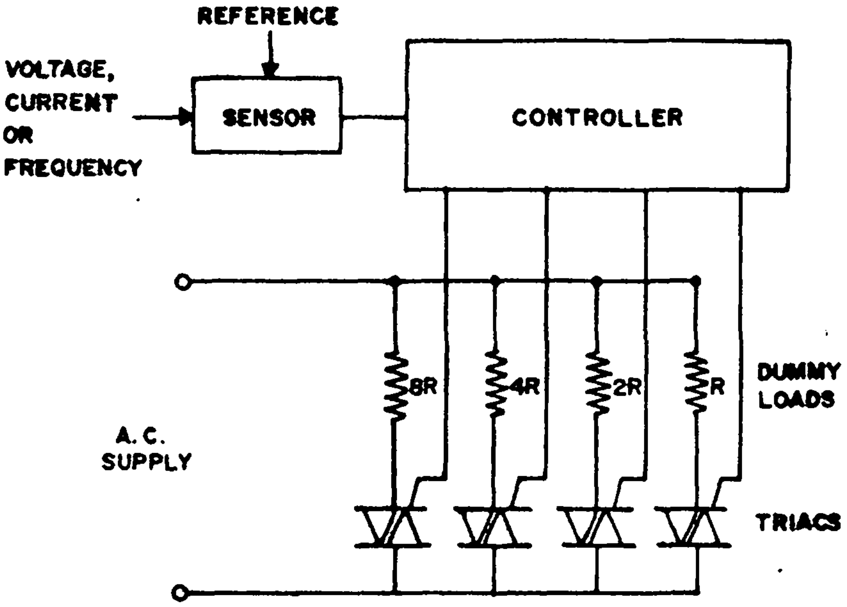


FIG. 11 SINGLE-PHASE ELECTRONIC LOAD CONTROLLER

BAMBOO HYDRAULIC RAM

by

Thamrong Prempridi   Watana Thammongkol

ABSTRACT

With the ever-increasing oil price, the rural people are now facing a higher cost of pumping water for human and crop consumptions during the dry season. Where there is a stream with large channel slope, a water lifting device, hydraulic ram, requiring no extra external energy can be used effectively. Traditional steel ram is still expensive and its weight poses problem of transporting in area with rugged terrain. This paper describes a ram built with bamboo parts and its effectiveness in lifting water for irrigation purpose.

INTRODUCTION

Farmers in the rural area require a large amount of water for their crop requirements. Where the plot of land is situated above the stream or water source, it must be pumped up for use.

In the past pumps that run by gasoline or diesel engines are very popular for use as water lifting devices. With the ever increasing oil price, the cost of pumping water has become one of the main cost of production. To reduce this cost of pumping, a water lifting device that require no external energy, such as a hydraulic ram, has now come back in use by farmers expecially in area of rugged terrain where a stream with large bed slope is available. The conventional rams are usually built by cast iron or steel. Those conventional ram pose a weight problem to farmers both in installation and in maintainance of the set. Hydraulic ram built with PVC parts is one of a good substitution but PVC pipe and accessories are available only in large towns.

The purpose of this study is to see if bamboo, available in all parts of the country, can be used as parts of hydraulic ram so that farmers in the rural areas can construct, install and maintain their hydraulic rams themselves at a reduced cost.

THEORY

Hydraulic ram work on the principle of water hammer occuring when water flowing in a pipe is suddenly stop. Water infront of the valve will be compressed with a rapid rise of pressure. With an appropriate way, this high pressured water can rise to a higher elevation. The compressed column of water will extend along the length of the pipe with a pressure wave velocity of "a_w". The wave reflection are as shown in figure 1.

The pressure wave velocity "a_w" can be found from the following relationship.

$$a_w = \left(\frac{Ew}{\rho (1 + C\frac{D}{T}\frac{Ew}{Ep})} \right)^{\frac{1}{2}} \qquad \text{\_\_\_\_\_\_\_\_(1)}$$

D = pipe diameter

T = pipe thickness

C = a constant depending on the Poisson's ratio of the pipe material

E_p = Modulus of Elasticity of pipe material

E_w = Bulk Modulus of Elasticity of water.

Pressure head rise due to a sudden closure of valve can be found from

$$H_{in} = \frac{A_w}{g}(V_{final} - V_{initial}) \qquad \text{\_\_\_\_\_\_\_\_(2)}$$

$V_{initial}$ = Velocity of water in the pipe before

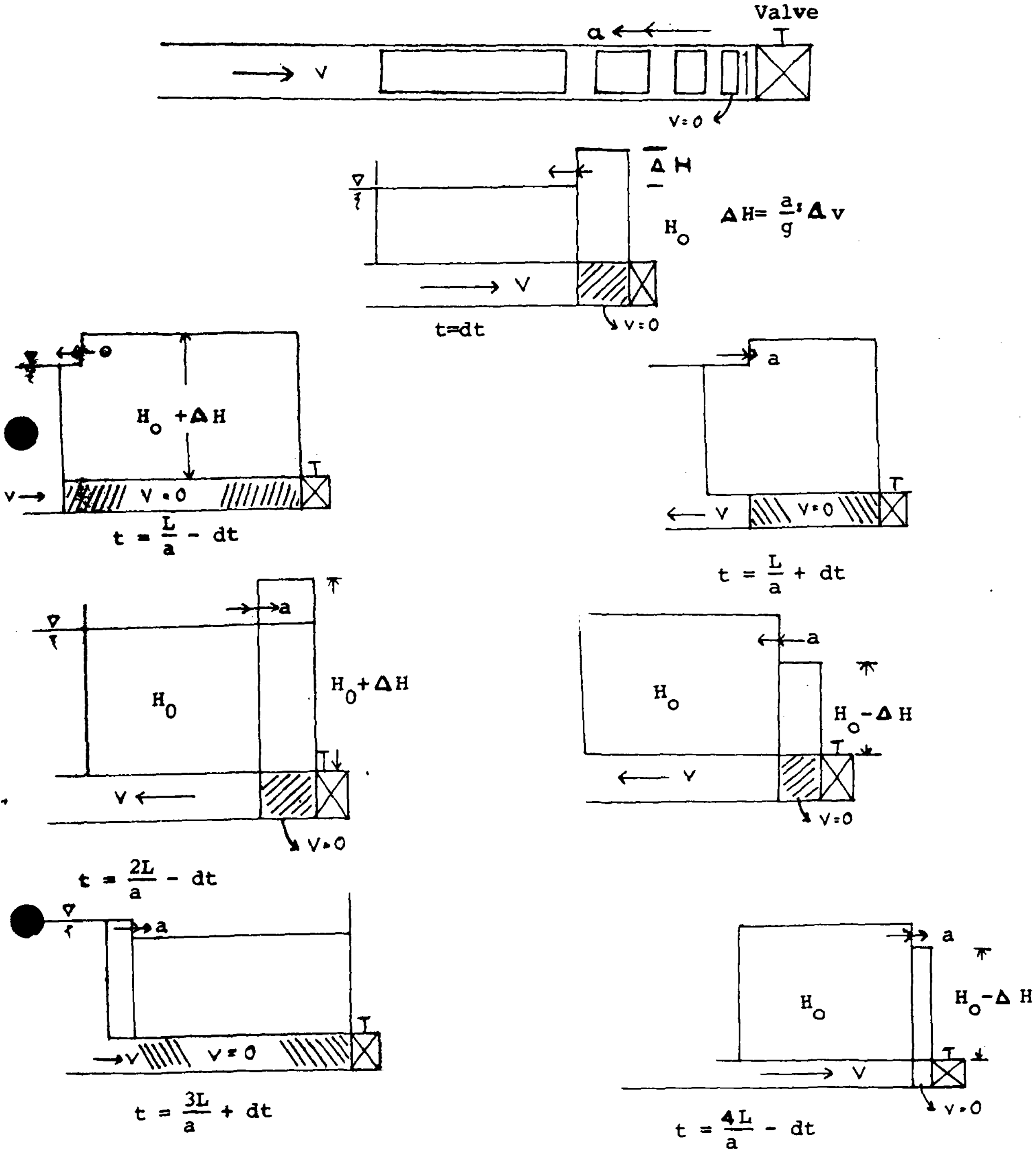


Figure 1 Water hammer wave reflection

closing the valve

V_{final} = Velocity of water in the pipe after closing the valve

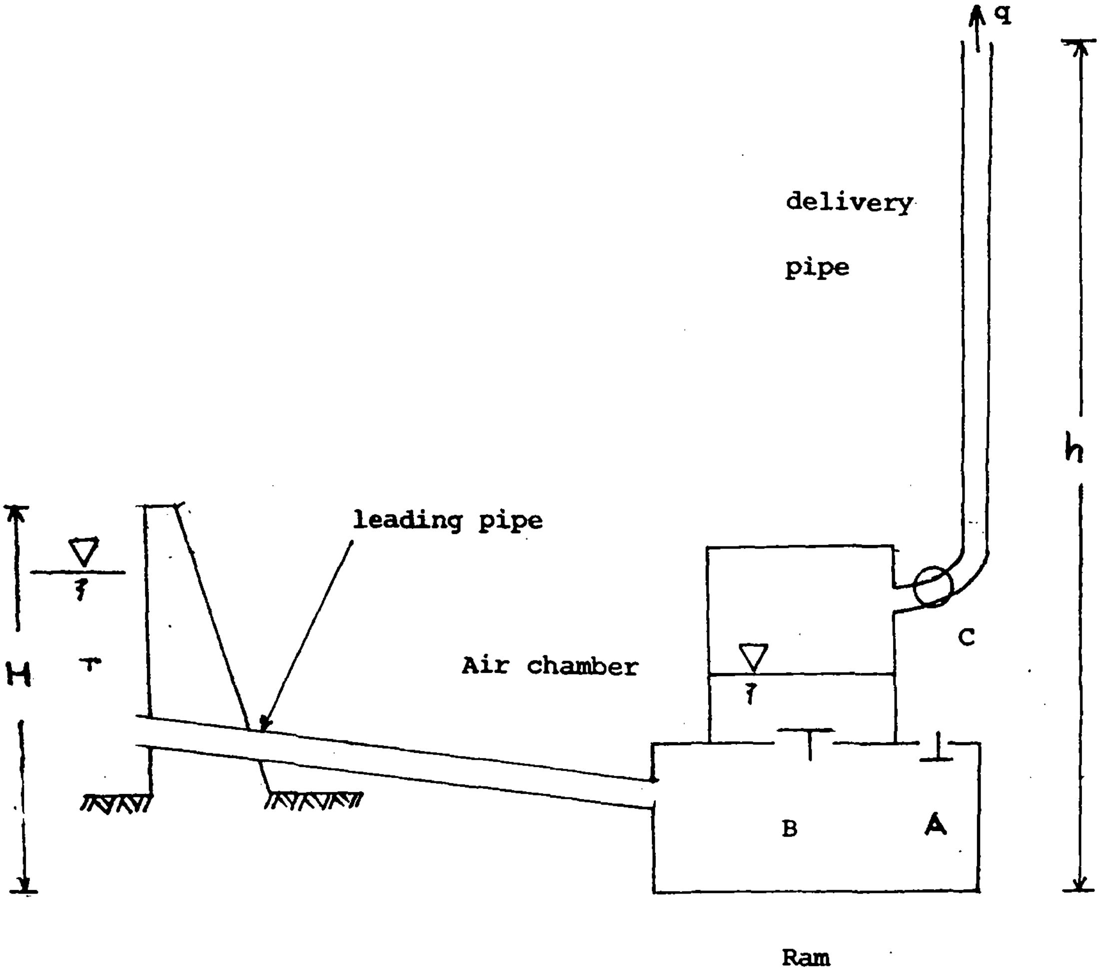
It can be seen that the probable pressure rise depend on many factors but one main factor is the property of the pipe material. Table 1 show some propertics of materials to be used in constructing a hydraulic ram.

Table 1 Properties of pipe materials

	Ep kgf/sq.cm	size cm	Aw m/sec
PVC	0.5×10^5	15 (Exposed)	340
		10 (Underground)	370
Steel	2.1×10^6	10	1000
Bamboo	0.2×10^6	8 (approx)	

OPERATION OF A HYDRAULIC RAM

A hydraulic ram will work when there is a flow of water with a head H in a leading pipe length L. The ram has two valves as shown in figure 2. When the check valve A is suddenly closed, water in the ram will be compressed with a pressure rise Δ H which will enable water to flow into the pressure chamber through valve B. The water in the leading pipe will also be compressed at a rate of water wave velocity, a_w. After an elapsed time of $\frac{L}{A}$ seconds, the water in the whole pipe will be under a pressured head (H + Δ H) which is higher than the pressure in the reservoir, hence some water will start to flow back into the reservoir and the pressure in the pipe go back to H. After an elapsed time of $\frac{2L}{a}$ the water hammer wave will be reflected back to the ram and the condition is a reverse of that at time T = 0. The pressure in the chamber of the ram will suddenly decrease to H - Δ H and the water hammer wave move towards the reservoir once again and reach it in $t = \frac{3L}{a}$ seconds. The pressure of water in the pipe is now lower than in the reservoir causing water in the reservoir to flow in to the pipe and the water hammer waves reflect back to the ram and at the elapsed time of $\frac{4L}{a}$ it will reach the ram. The conditions is again the same as at time



Fiture 2 Hydraulic ram in operation

$t = 0$ and the pressure in the pipe go back to $H + \Delta H$ once more completing the reflection cycle.

Everytime that the pressure in the pipe fall to $H - \Delta H$, the poppet valve A will drop down allowing water in the pipe to flow out through this valve while the check valve B is closed and every time that the pressure in the pipe is at $H + \quad H$ the popped valve will be automatically close and the valve B open to allow water to flow into the pressure chamber. When the pressure in the chamber is high enough to force water through the delivery pipe, the valve C can be opened and water at the rate of "q" will flow out through the delivery pipe.

Efficiency of the ram can be calculated from

$$E = \frac{qh}{(q + Q)H} \qquad \underline{\qquad\qquad} (3)$$

BAMBOO HYDRAULIC RAM

A bamboo ram built with bamboo parts is as shown in figure 3. Concrete were casted around some part of the bamboo pipe so that it can be connected to the leading pipe and the pressure chamber. The chamber is made of galvanized steel pipe.

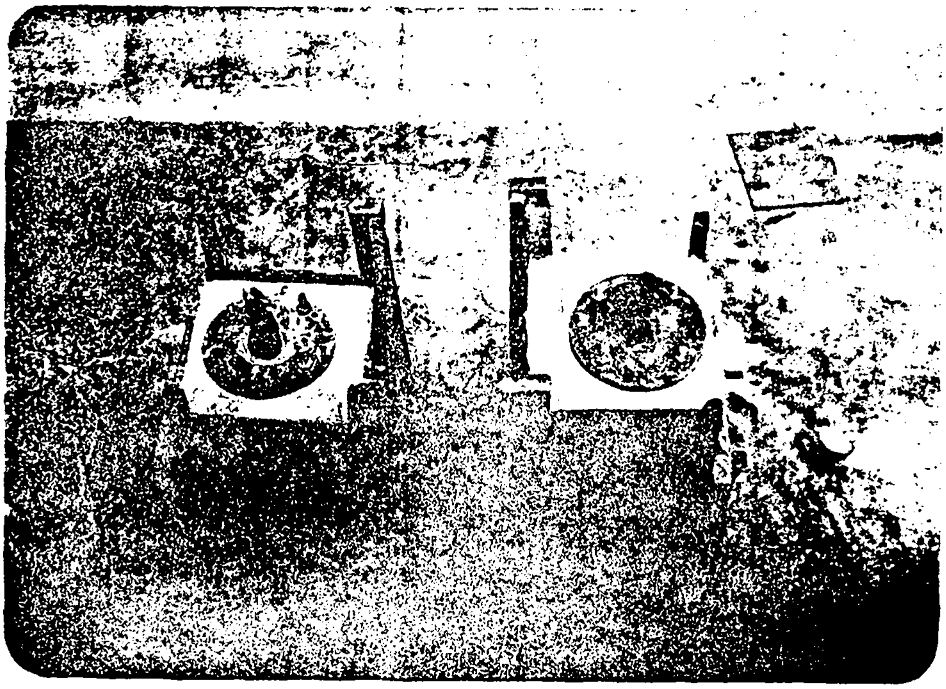
TEST RESULTS

Result of tests, made on the bamboo ram are as shown in Table 2 :

Table 2 Test results made on bamboo hydraulic ram

H m	h m	Q Litre/min	q Litre/min	Efficiency	Remark
1.8	22.3	45.2	15.8	40	
1.7	21.7	46.3	14.2	36	
1.6	20.9	48.9	13.6	34	
1.5	16.2	49.3	12.7	25	

Figure 3 Bamboo hydraulic ram partly casted in concrete



It can be seen that for a small head of 1.8 m, water can be lifted to a height of about 22 m with a delivery rate (q) of 15.8 litre/min enough for watering a small plot of land of about ½ hectar.

However it had been observed that, the leading pipe made of green bamboo will crack along its length when the water hammer pressure was more than 5 atmospheres and the crack will occur at about 1.5 atmosphere when the pipe was left standing in the air for about 1 month. By winding steel wire around the pipe, the maximum pressure that the pipe could stand up increase insignificantly.

Table 3 Comparison of Bamboo and Steel Hydraulic Ram

Description	steel ram		Bamboo ram		Remarks
	weight kg	cost B	weight kg	cost B	
1. Leading pipe (12m long)	90*	2000	12 **	12	* 75 m m ø ** 80 m m ø
2. Ram	38	1200	12***	8	*** bamboo plus cement
3. Pressure chamber	20	800	20	800	

Note:cost does not include labour cost which is available free in the rural area.

CONCLUSION

1. It is possible to construct a hydraulic ram with bamboo parts with advantages of weight saving and reduction in cost.

2. Bamboo hydraulic ram works well but its useful life is still questionable.

3. Bamboo is very strong lengthwise but it is very weak circumferrentially. It strength can be improved if steel wire is wound around the bamboo pipe.

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DEVELOPMENT OF A PLASTIC HANDPUMP FOR RURAL USE IN MALAYSIA

By: Chong Kah Lin, Goh Sing Yau, Tee Tiam Ting

Department of Mechanical Engineering,
University of Malaya, Kuala Lumpur.

ABSTRACT

A handpump design for raising water from wells has been developed for rural use in Malaysia jointly by the Department of Mechanical Engineering, University of Malaya and The Environmental Engineering Unit, Ministry of Health in a project funded by the International Research and Development Centre, Ottawa, Canada. The main features of the pump consist of a mild steel stand, a leverage system of timber linkages and galvanised iron/oil-impregnated timber bearings and a plastic pumping element. The pumping element consists of a PVC plastic cylinder fitted with a sliding PVC piston incorporating 2 polyethylene ring seals and a stationary PVC footvalve. After completing laboratory tests, seventeen of these pumps are currently being field-tested in two rural areas in Malaysia. Initial results on mechanical performance, durability and consumer acceptance after approximately 1½ years of field-testing indicate good promise for more extensive applications of the pump.

1. INTRODUCTION

The population of Malaysia is approximately 13 million and more than half of these live in rural areas where there is no piped water supply. A small proportion of these rural population obtain their water supply from gravity-feed water schemes or hand-dug wells or bored tube-wells fitted with handpumps. Others have to obtain their water supplies from streams or from traditional open wells with rope-and-bucket. A programme to improve the rural water supply was initiated by the Environmental Engineering Unit, Ministry of Health during the last decade. Part of the programme involves digging/boring 2000 new wells every year and fitting them with handpumps.

Most of the handpumps installed in Malaysia are imported from overseas. They include handpumps from India, Japan, Taiwan, United Kingdom and U.S.A. All of these pumps are of the cast metal design. The spare parts normally have to be imported from overseas.

A joint project between the Environmental Engineering Unit, Ministry of Health and the Department of Mechanical Engineering, University of Malaya and funded by the International Development and Research Centre was initiated in 1979 to develop an indigenous design of a handpump which can be produced locally from locally available materials. It must also be relatively cheap and simple to operate and maintain at the village level.

2. PREVIOUS WORK

Numerous handpump development and testing programmes have been reported in various countries [1 → 8]. F.E. McJunkin in reference [1] gave a very useful state-of-art report on the handpump and provided a comprehensive list of bibliography. In recent years, the emphasis in handpump studies has been placed in the development of the handpump for applications in developing countries. Several of these investigations reported on the use of timber [5] and bamboo [2] for the construction of handpumps. Since 1978, the

International Development and Research Centre has encouraged the study of a plastic pump [6] with the view that it may be applied for use in developing countries. Initial studies were conducted at the Waterloo Research Institute, Canada [6] and further tests were carried out at the Consumer Association Laboratories, United Kingdom [7].

3. THE PRESENT WORK

The first phase of the present project lasting approximately one year extended the laboratory investigations of the Waterloo Research Institute and the Consumer Association Laboratories. The second phase of the project lasting approximately two years concerns the development of the plastic handpump designs and field-testing these handpumps in rural areas in Malaysia.

4. THE LABORATORY INVESTIGATION

4.1 Description of the Reciprocating Plastic Piston Pump

The plastic reciprocating piston pump used in the present investigation is as shown in Figure 4.1. It consists essentially of a plastic PVC cylinder with two basically similar PVC valves. The bottom valve referred to here as the footvalve, is in a fixed position at the bottom of the cylinder. The upper valve, referred to here as the piston, is fitted with 2 polyethylene rings and is attached to a piston rod which moves the piston in a reciprocating motion a short distance above the footvalve. The piston and footvalve are provided with through holes for water flow and a valve flap made from natural rubber to cover these holes.

4.2 Definition of Performance Quantities

The mechanical performance of a reciprocating piston pump may be defined by the following quantities:-

(a) Volumetric Efficiency

and (b) Mechanical Efficiency.

The Volumetric Efficiency may be defined as follows:-

$$\eta_{vol} = \frac{\text{Actual volume flow delivered per cycle}}{\text{Volume displaced during suction stroke}}$$

It is a measure of the wastage of maximum possible volumetric output capacity. Valve closure delays and water leakage past piston rings and valves decrease the Volumetric Efficiency.

The Mechanical Efficiency may be defined as follows:-

$$\eta_{mech} = \frac{\text{"What we want"}}{\text{"What we have to do to obtain the above"}}$$

$$= \frac{\text{Work done by lifting water}}{\text{Work Input}}$$

The Mechanical Efficiency may be considered as a measure of wastage of effort as a result of water leakage past the piston rings and valves, friction and other resistance forces.

4.3 The Experimental Rig:

Figure 4.3 shows the experimental arrangement for the testing of the pump over a range of parameters. It consists of a reciprocating piston pump assembly for lifting water up to a maximum height of 9 meters from a central constant level reservoir. The assembly may be converted to 3 meters or 6 meters lifts of water when required. The water at the outlet of the pump is returned to the central reservoir through a return pipe. The pump is driven by a 1 horse-power D.C. motor via a reduction gear and chain-drive assembly. The rotary motion of the flywheel is converted to a reciprocating vertical motion by a pin and slide. Mounting holes at various distances from the centre of the flywheel enable the stroke length to be changed when required. The speed of stroke application may be varied by adjusting the input voltages to the field and armature coils of the D.C. motor.

4.4 Measurements

4.4.1 Measurement of Work Input

Figure 4.4.1 shows a photograph of a strain-displacement relationship during a cycle of operation of the reciprocating piston pump measured using a proof ring attached to the top end of the piston rod. The strain was measured by 4 strain gauges mounted on the proof-ring. The displacement was measured by a potentiometric displacement transducer connected to a vertical sliding pin on the crank of the motor drive. The output signals were frozen on to the screen of a storage oscilloscope and the picture taken with an instant film camera. It is important to ensure that the strain-applied force relationship is linear. This may be checked by a calibration test. If the recorded strain-applied force relationship is linear, the area enclosed by the strain-displacement loop is proportional to the work input per cycle of pump operation. A mechanical planimeter was used to integrate the area enclosed by the strain-displacement loop.

4.4.2 Measurement of Volume Flowrate

To determine the volumetric efficiency of the pump, it is necessary to measure the actual water delivery rate. This can be obtained by weighing the water delivered after a convenient number of strokes. The speed of stroke application was adjusted by reference to a stopwatch but the actual number of strokes completed for the measured delivery was recorded with the aid of a mechanical counter which was set up to be tripped by a bracket on the piston rod.

The height through which the water has been lifted was measured with a measuring tape. This height was used to compute the work output of the pump.

4.5 Results

Figure 4.5.1 shows the variation of volumetric efficiency with speed of stroke application for 3 different stroke lengths. It may be observed that the volumetric efficiency increases with speed of stroke application and stroke length. This is to be expected as the leakage past the piston rings decreases with increasing piston speeds.

Figure 4.5.2 shows the corresponding variation of mechanical efficiency with speed of stroke application and stroke lengths. It may be observed that for the 2 shorter stroke lengths, the mechanical efficiency increases with the speed of stroke application while for the longest stroke length, the mechanical efficiency decreases with speed of stroke application. This is not surprising and may be explained as follows. In the former case, the increase in piston speed increases the water delivery rate (as indicated by the increase in volumetric efficiency) and a small increase in flow resistance forces giving a nett increase in mechanical efficiency. In the latter case where the piston speeds are higher, the increase in flow resistance forces is much larger and outweighs the advantage of the increase in delivery rate giving a nett decrease in mechanical efficiency.

A more detailed discussion of the operating characteristics of the plastic reciprocating piston pump is given in reference [8]. Suffice to say here that the physical parameters of the pump were chosen to give pump performance with high volumetric and mechanical efficiencies.

5. DESIGN OF HANDPUMP

5.1 The Local Requirement

In the design of pumps to draw water from a depth, there is a certain "maximum suction depth" below which it is no longer possible to draw water by suction. Below this depth, water must be raised either by lifting or some other method. This distinction is important as a suction handpump is generally simpler and less expensive than a lift pump. In most lowland areas of Malaysia, the "maximum suction depth" is approximately 8 meters.

The water table in most lowland areas in Malaysia is relatively high and water may commonly be found in depths below ground which is less than the "maximum suction depth". In hilly areas and in some exceptional situations in lowland areas, the water table sometimes falls below the "maximum suction depth". There is therefore a requirement in Malaysia for two variations to the basic design of the handpump i.e. the suction handpump and the lift handpump.

5.2 Common Features of the Suction and Lift Handpumps

Figures 5.2.1 and 5.2.2 show the main features of the present design of the suction and lift handpumps.

The common features of these two handpumps are:-

(a) A mild steel stand.

(b) A leverage system consisting of timber linkages, galvanised iron joints and galvanised iron/oil-impregnated timber bearings.

(c) A PVC plastic pump cylinder.

(d) A PVC plastic piston with 2 polyethylene rings.

(e) A removable PVC plastic footvalve with a rubber seal.

The mild steel stand provides a firm support for the pumping cylinder and leverage system. Timber linkages are used because they are readily available and easy to replace. Oil-impregnated timber bearings have been tested in the laboratory [5] and found to have outstanding performance characteristics. The use of a PVC plastic piston with two polyethylene rings sliding in a PVC plastic pump cylinder reduces substantially the friction without sacrifising high volumetric efficiency [8]. Because polyethylene is softer than PVC, the polyethylene rings will wear faster than the PVC cylinder. These rings may be replaced at a comparatively smaller cost when required. The basic PVC component for the piston and footvalve are identical. This enables a saving in cost through the use of one injection mould for both items.

5.3 The Differences Between the Suction and Lift Handpump Designs

The major features, advantages and disadvantages of the present suction and lift handpump designs are:-

(A) The Suction Handpump

(a) Main features

(i) Both the piston and footvalve are above ground level.

(ii) The riser pipe below the footvalve may be smaller than the pumping cylinder.

(b) Advantages

(i) It is easier to install the suction handpump. The handpump cylinder assembly may be assembled at the workshop.

(ii) The piston and footvalve are readily accessible for servicing and repairs.

(c) Disadvantages

(i) The handpump cannot be used to draw water from depths greater than the "maximum suction depth".

(ii) The handpump requires priming if the footvalve leaks.

(B) The Lift Handpump

(a) Main features

- (i) The footvalve must be less than the "maximum suction depth" distance above the water level and usually below the water level.
- (ii) The piston is approximately 0.3 meters above the footvalve.

(b) Advantages

- (i) The handpump can be used to draw water from depths greater than the "maximum suction depth".
- (ii) The handpump is self-priming.

(c) Disadvantages

- (i) It is generally more difficult to install the handpump.
- (ii) It is more difficult to remove the footvalve for servicing or repairs.

6. FIELD TEST

A total of twelve suction and five lift pumps were fabricated and installed for field-testing in two rural areas in Malaysia. The objective of the field-testing programme is to evaluate both the technical performance under field conditions and the economic feasibility of wide-scale adoption for rural use in Malaysia.

At the time of writing, the field-testing programme is still in progress. After 1½ years of use in the field, no major component has worn sufficiently to warrant replacement. There is some wear in the piston rings but this has not caused any significant deterioration in technical performance (as indicated by measurements of the volumetric efficiency) of the handpump. In one or two wells where fine sand is present in the water, scouring of the PVC cylinder and the polyethylene piston rings was observed.

The details of the field evaluation programme and results will be presented in a later report at the end of the project. However, initial results on mechanical performance, durability and acceptance by villages indicate good promise for wider implementation of the handpumps in rural areas in Malaysia.

CONCLUSIONS

A laboratory investigation on a plastic reciprocating piston pump for raising water was carried out to determine the optimum design for high technical performance as characterised by high volumetric and mechanical efficiencies.

Two variations of the basic design - a suction handpump and a lift handpump were developed and seventeen of these handpumps are currently being field-tested in two rural areas in Malaysia.

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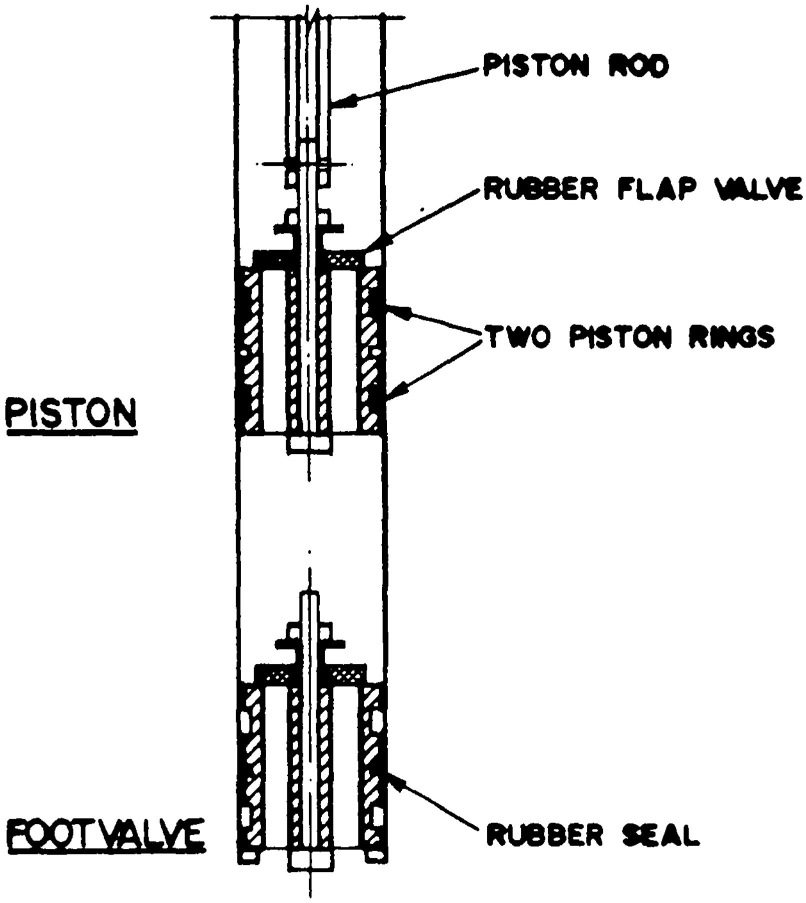


FIG. 4.1 THE RECIPROCATING PISTON PUMP

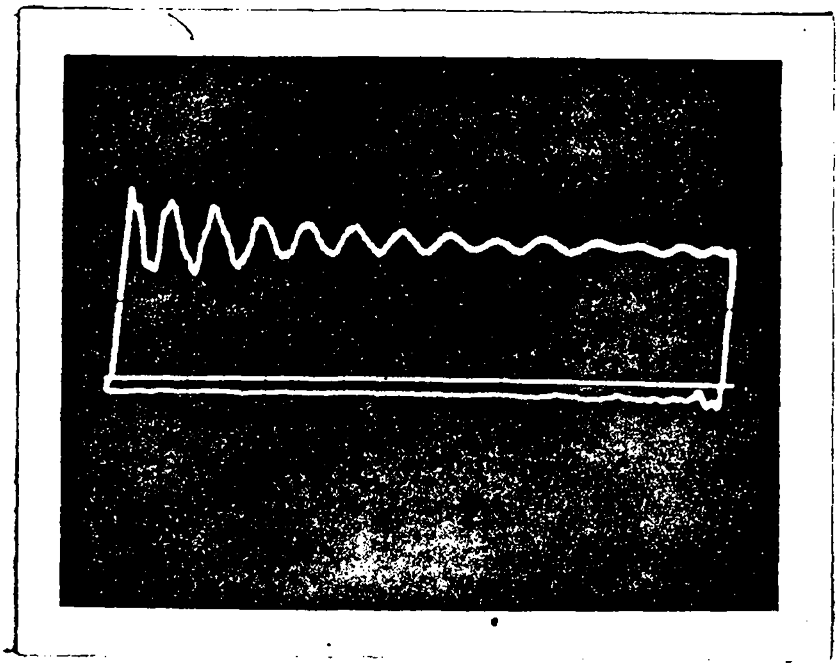


FIG. 4.4.1 STRAIN-DISPLACEMENT DIAGRAM

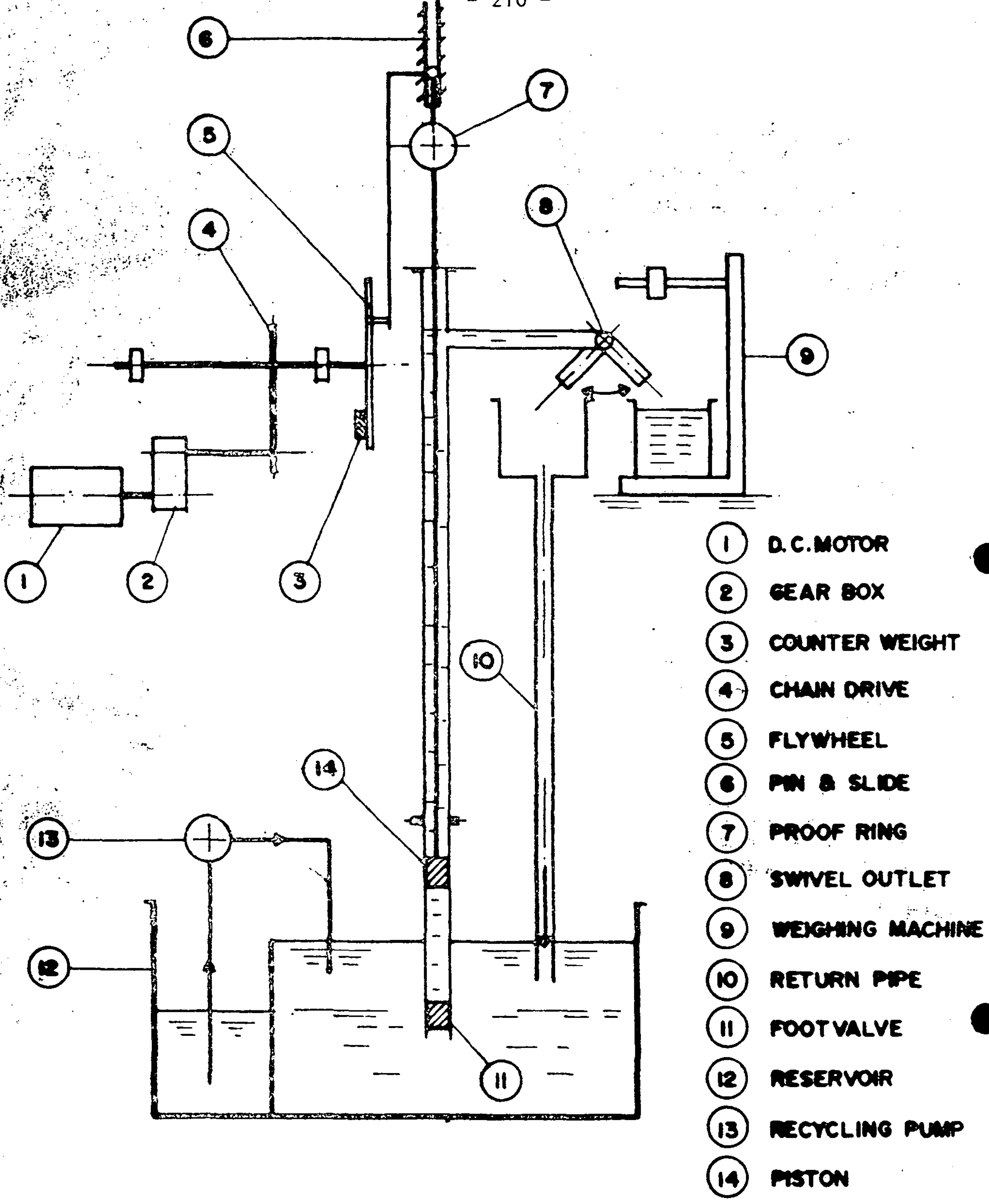
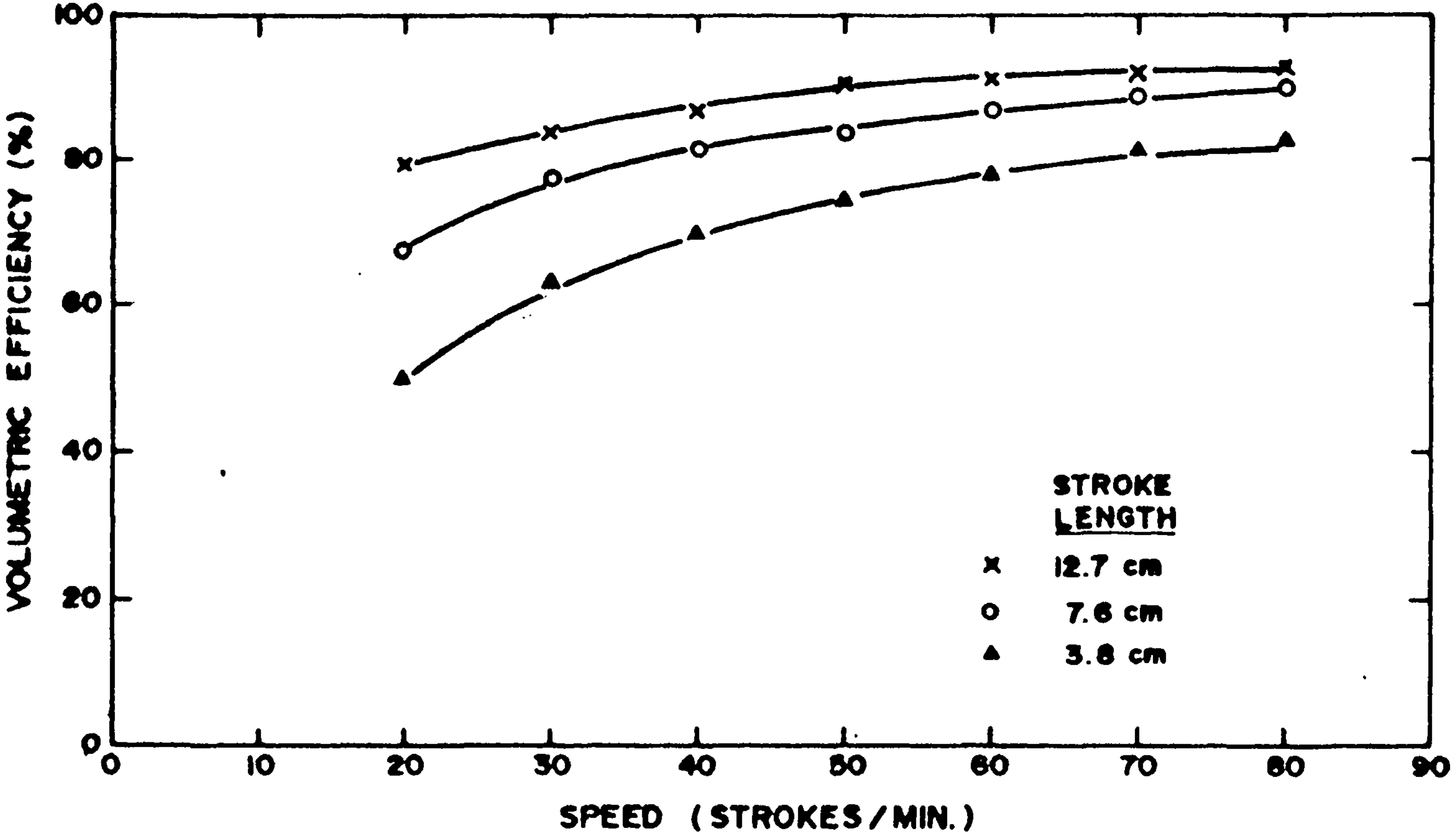
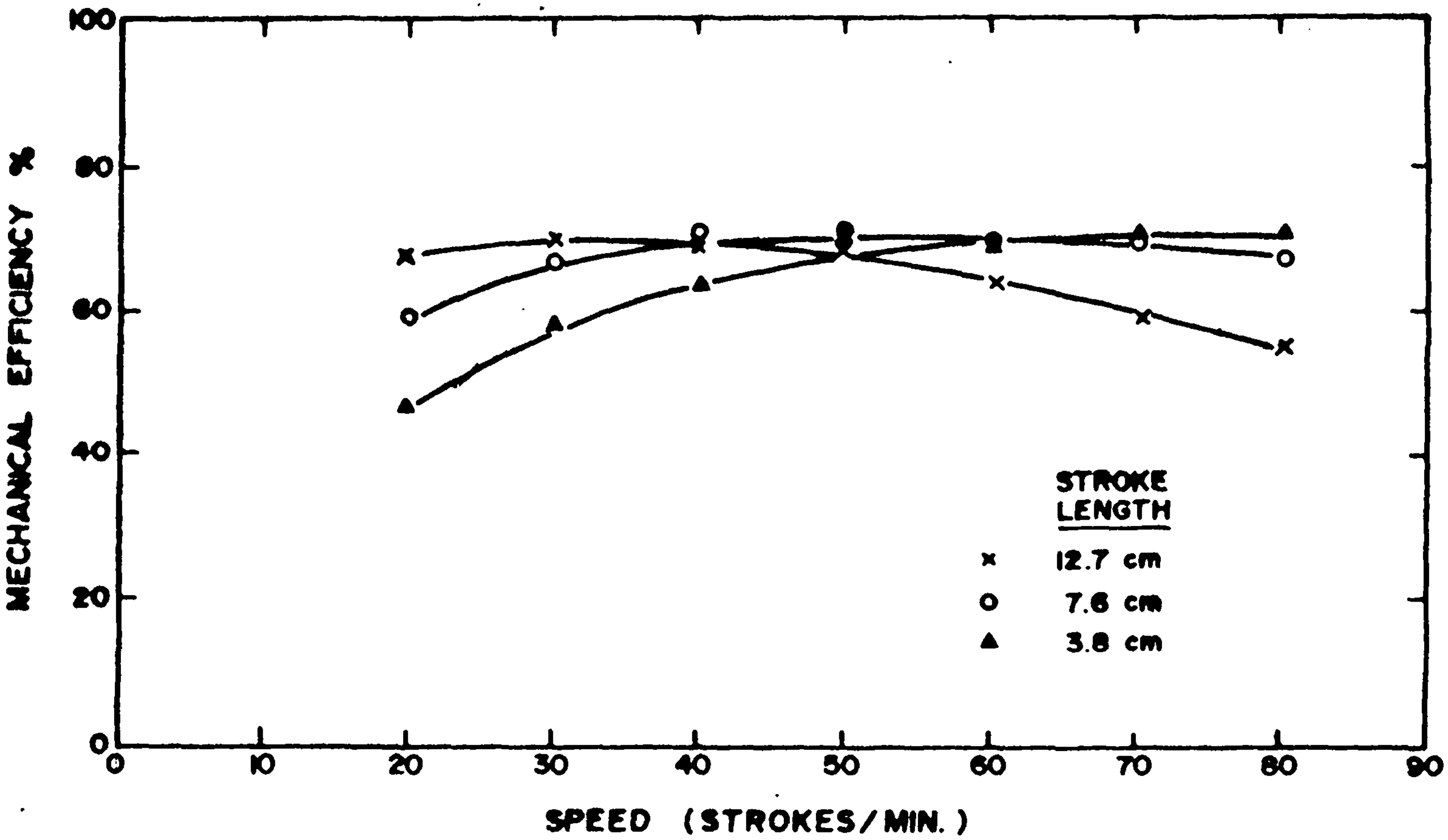


FIG 4.3 SCHEMATIC DIAGRAM OF HAND PUMP TESTING ASSEMBLY



ORIFICE / PISTON AREA RATIO = 16.4%
WATER HEAD = 5.84 meters

FIG. 4.5.1 VARIATION OF VOLUMETRIC EFFICIENCY WITH SPEED OF STROKE APPLICATION FOR 3 STROKE LENGTHS



ORIFICE/PISTON AREA RATIO = 16.4%
WATER HEAD = 5.84 meters

FIG. 4.5.2 VARIATION OF MECHANICAL EFFICIENCY WITH SPEED OF STROKE APPLICATION FOR 3 STROKE LENGTHS

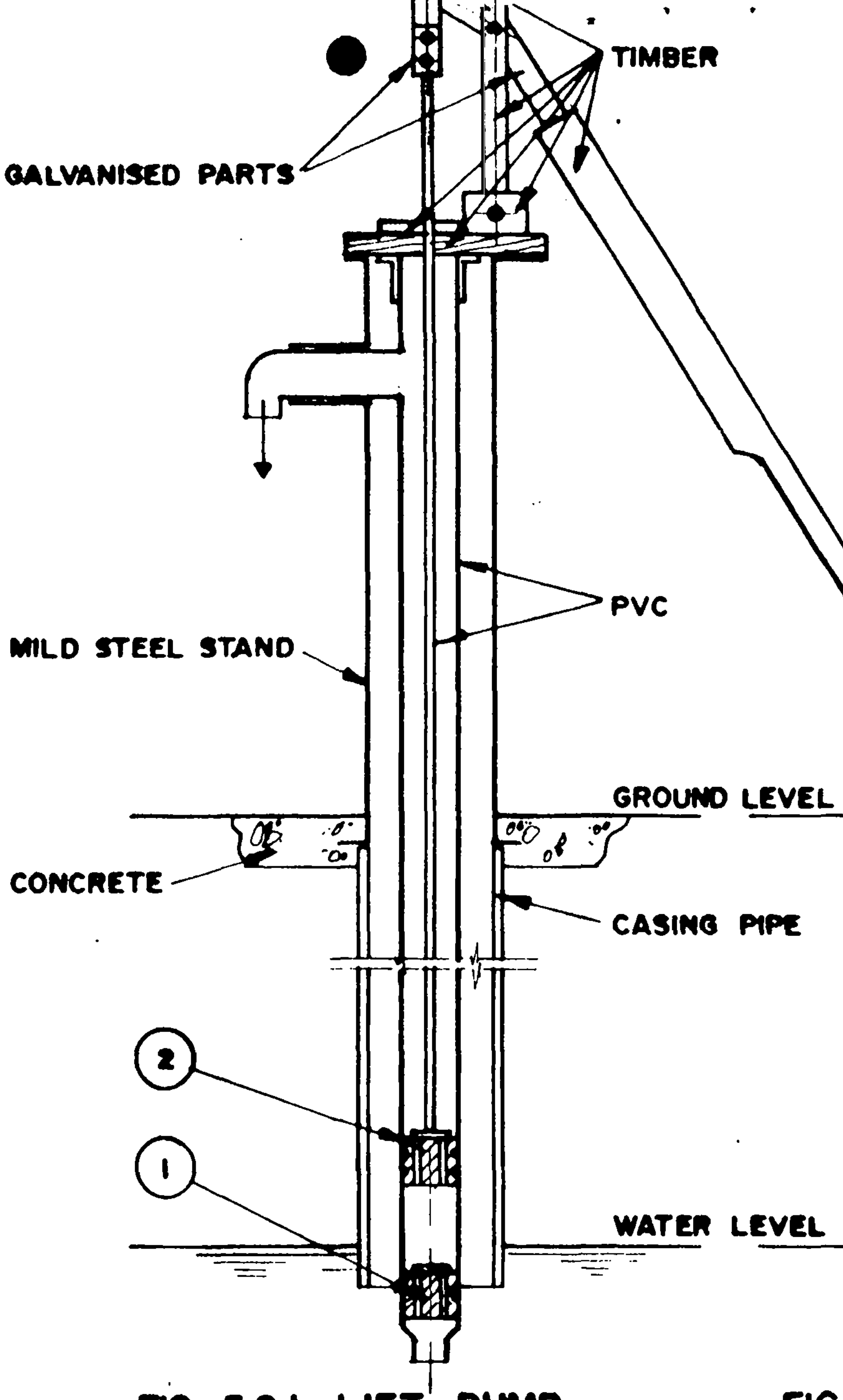


FIG. 5.2.1 LIFT PUMP

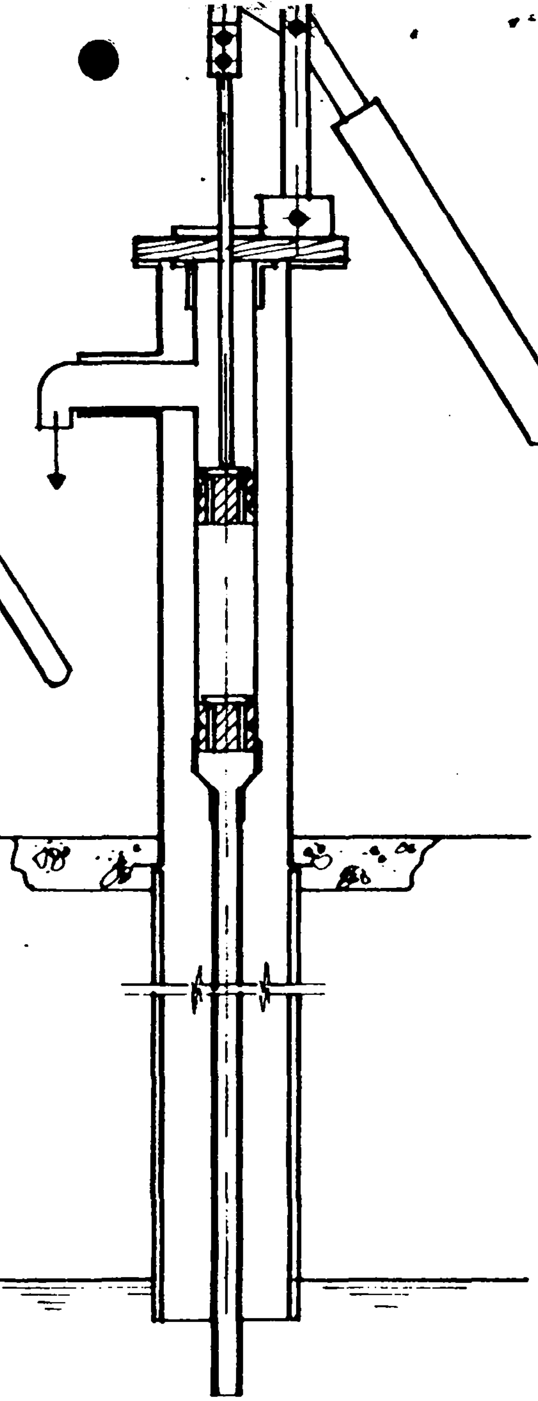


FIG. 5.2.2 SUCTION PUMP

The paper was presented by Dr. Goh.

DISCUSSIONS :

Q : You mentioned that the pump would be very cheap but you did not indicate the cost.

A : Currently, the plastic components cost about $ 200/= We have made 17 of these pumps so far. We are trying to mass produce and we expect the cost to go down to less than $ 150/=. For the next two years we thought of reducing the cost by injection moulding of the pump plunger.

Q : The motorised and automatic Japanese pumps cost about $ 250/= as compared to $ 150/= for the hand pumps. So what are the chances of the rural people in using these hand pumps since automatic pumps are much more convenient to operate with the help of the rural electrification programmes by NEB?

A : There are still remote areas without supply of electricity. But we installed our pumps in areas where there is electricity. The suction pump that is commonly used by the Ministry of Environment, installed in rural areas, is similar to the Dragon pump. I understand there are also private people who buy electrical pump. It is quite a good economy to buy such pumps but there is a problem of lifting water at greater depths. Currently, there is a demand for our pump because there is a problem of sealing with the existing Dragon and Gibson pumps. Our pump is preferred due to its simplicity of maintenance by the villagers and the construction materials are available locally.

C : The Ministry of Health in Thailand has installed quite a number of PVC hand pump to many of the "channel wells" operated by the villagers. The cost of the pump is about M $ 50/= which is too expensive for the farmers. We installed for them free of charge but they have to put up the laboratory that use water.

A : The Ministry of Environment in Malaysia also gives the same insentives to the farmers. Under "gotong-royong, they installed the pump but they never use the laboratory that were constructed.

THE DESIGN AND PERFORMANCE OF A LOW-LIFT WIND-PUMP FOR IRRIGATION PURPOSES IN THE RURAL AREAS

Desa Ahmad
Faculty of Agricultural Engineering,
Universiti Pertanian Malaysia,
Serdang, Selangor.

ABSTRACT

An attempt at harnessing windpower for pumping water in rural areas is described. The work carried out involved the design of a low cost, low-lift wind-pump driven by a horizontal axis windmill, the detailed design of which is given in a separate report. The reduction in cost was suggested by adopting a substantially cheaper methods of construction based on locally available material. Pump was designed using the principle of centrifugal force based on data from Tanzania and IRRI reports. The estimated pumping requirement was 50 m^3/day utilising windpower within a speed range of 3 to 7m/s on 1 to 2 hectares of land grown with dry crops.

INTRODUCTION

Irrigation is a prerequisite for agriculture especially in many arid areas of the world where there is virtually no rainfall to support vegetation. In this country, despite heavy rainfall, the total available water resources is only moderate such that the water deficit and water surplus occur annually with considerable month to month and year to year variation. This is so uneven in the greater part of the country that prolonged dry periods frequently occur during which soil moisture levels are outside the range favouring crop growth. In order to increase agricultural production, it is essential that we have adequate water supply and better irrigation technique for the farmers particularly over large areas in dry land.

In some developing countries, irrigation is done, mainly by manually operated low lift pumps, shallow tube wells and power pumps. Although the use of power pump is increasing in this country, the rate is still very slow due to users low buying capacity, fragmented plots, socio-economic constraint, lack of spare parts, repair and maintenance facilities and most importantly due to lack of awareness of the possibility of harnessing power from other sources of energy. (BARDAIE, M.Z. 1979) has recently pointed out the possibility of using wind powered pumps particularly in the East Coast. Factors related to utilizing windmills for rural applications with special reference to Malaysia have been discussed. In another report (LING, et. al 1980) wind statistics have been examined from which monthly and annual energy that can be harnessed from the wind are evaluated. This preliminary study was conducted in view of the need to expand our irrigated agriculture in order to continuously improve crop production. Hopefully it may stimulate further work on the utilization of wind power for irrigation purposes in Malaysia.

DESCRIPTION

The pump can be represented as shown in Figure 1 (a). It can rotate around the axis AB and is provided with nozzles N at the extremities of the arms and with a valve at the lower end K submerged in water. If the pipe is filled with water and rotated in the direction opposite to the orifice in the nozzle, once operating rotational speed is reached, the water contained in the arms will be forced out through the nozzles by centrifugal force and is replenished through valve D. The shape is almost similar to a horizontal centrifugal pump having rotating arms acting as impellers. The friction inside the rotating arms could be reduced by lowering the fluid velocity in them via having constricting nozzles at their peripheries. These also help preventing air from entering and affecting the priming of the pump. As the velocity of water through the pump is low, discharge can be varied by changing the pump rotational speeds.

The pump used was fabricated from standard galvanised iron pipe of 40 mm diameter for the tubular arms and 32 mm diameter for the vertical section. A bigger diameter would contain bigger volume of water to ensure greater force when moved with greater acceleration. Consequently this would create a region of low pressure which leads to rapid suction of water as a result of atmospheric pressure acting on water surface underneath the pump. To hold the water in the arms as well as the vertical pipe, a footvalve was employed.

EXPERIMENTAL METHOD

Having designed and fabricated the pump, several performance tests at various heads were conducted using an electric motor. A special test rig was constructed using dexion frame. The shaft of the pump was supported by bearings bolted to a plywood cardboard. A polythene plastic sheet was chosen as trough for storing discharged water and supported by iron bars on its inner and outer circumferences. A schematic layout of the rig is given in Figure 1 (a) while Plate 1 illustrates the construction and arrangement of testing rig. Figures 1 (b) and 1 (c) show the future improved version of the pump and its testing rig.

The experiments were conducted at three heads measured by the height of arm above the water level. Pump speed was measured through a variable speed motor connected to the vertical shaft by a V-belt driving a pulley attached to the shaft. Power required to drive the pump was determined at various speeds by measuring the overall power requirement of the motor-transmission-pump assembly. The total losses at various pump operating speeds are presented in Table 1. For the discharge measurement, a technique using volumetric tank was used. This method required time measurement for a given volume of water discharged into a storage tank. A change over device at the outlet of the delivery pipe was employed to permit the flow to be directed to the measuring tank once flow was steady.

RESULTS

Effect of discharge on power requirement.

From Figure 2, the power required increased with discharge. Starting power varied slightly for all heads. At the design head of 1.7 m, the starting power was 190 W almost similar to 1.5 m head.

However at 2.0 m head, the starting power was slightly lower. On the other hand, for a design discharge of 66 litres/min which occurred at 75 RPM, the pump required 300 W at 1.7 m head whereas at 2.0 m head the power required increased only slightly to 310 W.

Effect of speed on power requirement.

Generally as speed was increased, the power required also increased. The highest power was achieved at 1.7 m head compared to 1.5 m and 2.0 m heads. At the same rotational speed, the pump seemed to discharge greater volume but causing greater power requirement at a lower head. Within the range of 65 - 80 RPM the power requirement at 1.7 m head was 1.0 - 1.2 times higher than that at 1.5 m head (Figure 3).

Effect of speed on discharge.

Figure 4 shows that the pump started discharging at three different rotational speeds for the three different heads. At 1.5 m head the pump started discharging at 56 RPM whereas at 1.7 m head, pumping started at 59 RPM. At 2.0 m head a rotational speed of 69 RPM was required for the pump to discharge. A slight deviation was observed at 1.5 m head in that as speed was increased, the discharge tended to remain almost constant beyond 65 RPM.

Relation of efficiency to discharge.

Figure 5 shows that at 1.5 m head maximum overall efficiency occurred at 56 RPM and having a volumetric discharge of 12 litres per minute whilst at 1.7 m head, maximum efficiency was achieved at 59 RPM with a discharge of 16 litres per minute. For 2.0 m lift, the discharge obtained was 19.1 litres per minute at a speed of 69 RPM. Efficiency seemed to fall rapidly at 1.7 m head compared to those at 1.5 and 2.0 m heads when running at the same rotational speed. Similar characteristics were also shown at higher discharge. For the design discharge of 66 litres per minute at 1.7 m head, a maximum hydraulic efficiency of 43% was achieved at 75.3 RPM.

Losses in relation to discharge.

It was observed that beyond 32 litres per minute of discharge (Figure 6), the loss in power was tremendous causing a significant reduction in the pump efficiency (Table 1).

DISCUSSIONS

Pump Performance

The pump characteristics observed seem to have similar pattern to the centrifugal pump characteristics whereby the output and power requirements were shown to decrease as head was increased at the same rotational speed. However, the slight abnormality observed at 1.5 m head was due to clogging of footvalve which permitted less water into the suction tube. Consequently less power was consumed than expected . As regards the discharge values, substantial increase could be improved if trough had its top part covered to avoid splashing. Constant flow of liquid into the delivery tube should be observed to ensure a better discharge flow rate. In the course of the experiment, priming was difficult to maintain as footvalve was constantly clogged with dirt besides valve loose seating which led to the pump occasionally losing its prime. The use of a self priming mechanism has been studied for further development (AHMAD, D.B. 1978).

Pump and Windmill combination.

Figures 7 and 8 show the pump and windmill characteristics both for the savonious as well as the horizontal types. Obviously the use of a savonious rotor combined with the pump is not favourable since the system characteristics would not satisfy the discharge requirement at the designed speed. Being in the unstable region the pump would need a reduction mechanism to match the higher torque and power provided by the rotor in order to operate freely in the system. On the other hand, the rotor characteristics of the horizontal type windmill are better suited to the pump in terms of torque and power requirement at various windspeeds. The crossing points indicate the stability of operation.

For the design discharge of 66 litres per minute the pump required 40 Nm torque whilst the power requirement was 320 W at 75.3 RPM for 1.7 m head. The high starting torque clearly suggests the use of a lighter material for better and economical power consumption. Available data on the use of plastic tubes reveal that to irrigate 50 m^3/day the speed of rotation would be lower with low starting torque. Nevertheless, with a maximum hydraulic efficiency of 43%, the pump will work reasonably well in an area where windspeeds above 3.5 m/s are expected to blow. The suggested combination of windwill and pump is illustrated in Plate 2.

Potential application in Malaysia.

The possibility of employing the pump for irrigation purposes particularly in the East Coast is great since wind statistics are available (Table 2). Monthly and annual energy that can be harnessed from the wind are already evaluated by LING, et al (Figure 9) while factors related to utilizing windmills have already been discussed (BARDAIE, M.Z. 1979). It is anticipated that, this paper will stimulate further research on the utilization of windpower for irrigation purposes in Malaysia besides improvement on pump design for better performance.

CONCLUSIONS

From above it can be concluded that :-

i) The power requirement of the pump increased linearly with speed but non-linearly with discharge.

ii) At the same rotational speed, the pump discharged greater volume at a lower head.

iii) For the same rotational speed, efficiency seemed to fall rapidly at 1.7 m lift compared to 1.5 and 2.0 m heads.

iv) For the same rotational speed, output and power requirements decreased as head was increased.

v) Combination with horizontal axis type windmill was reasonably stable and would operate only beyond 3.5 m/s of windspeed. The use of lighter material should be stressed for economical power consumption while having the capacity to discharge greater volume at lower windspeeds.

vi) Potential use in rural areas in this country is great since data for windspeeds beyond 3.5 m/s are available.

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TABLE 1 : Comparison of power losses and hydraulic efficiency for all heads at various pumps

Head (m)	Pump Speed (RPM)	Total Power (W)	Discharge (%)	Transmission Loss (%)	Drag and Rotation Loss (%)	Hydraulic Efficiency (%)
1.5	56	192	2.9	12.5	84.6	78.0
	59	196	4.5	14.6	80.9	76.6
	62	208	7.8	14.6	77.6	69.3
	69	240	12.8	18.6	68.6	57.3
	75	264	14.5	25.5	60.0	55.3
	82	280	13.9	30.0	56.1	-
1.7	60	212	3.4	14.6	82.0	78.8
	62	220	6.1	14.6	79.3	75.8
	65	240	7.8	16.6	75.6	71.7
	69	264	10.5	18.6	70.9	60.5
	72	288	13.4	22.2	64.4	58.8
	75	300	18.2	25.5	56.3	48.2
	78	340	35.5	28.6	35.9	29.4
2.0	65	208	4.0	16.6	79.4	81.5
	69	228	7.0	18.6	74.4	75.0
	72	248	9.0	22.2	68.8	67.5
	75	268	17.0	25.2	57.8	52.5
	78	296	20.0	28.6	51.4	45.5
	82	328	44.9	30.0	25.1	23.5

TABLE 2 : Annual Percentage Frequency of Wind Speed for Kuala Trengganu, Kota Bahru and Kuantan (1968 - 1977)

Wind Speed (meter/sec.)	Percentage Frequency (%)		
	Kuala Trengganu	Kota Bahru	Kuantan
greater than 8.0	0.2	0.6	0
" 5.5	3.2	4.7	2.5
" 3.4	20.2	22.8	21.5
" 1.6	58.2	41.6	36.9
" 0.3	99.2	69.6	74.6
less than 0.3	0.3	30.4	25.4

(SOURCE: BARDAIE, M.Z. 1979)

1

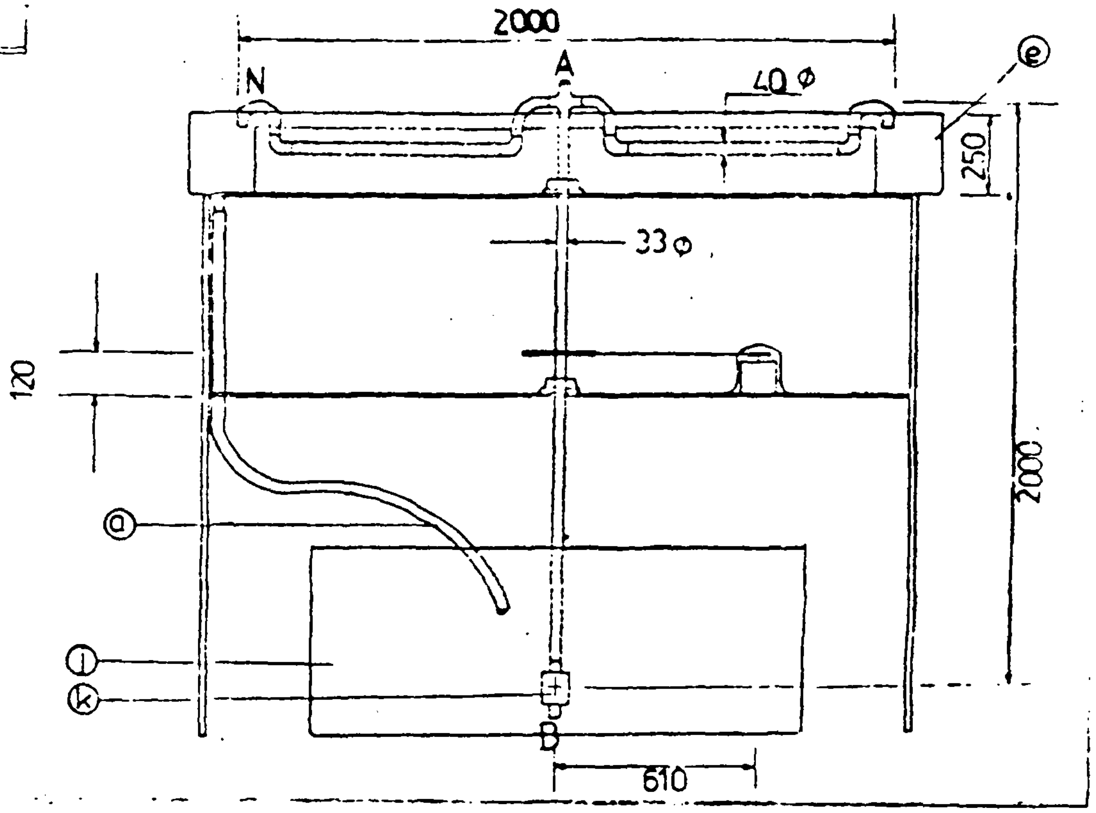


FIG. 1(a) SCHEMATIC LAYOUT OF PUMP AND TESTING RIG.

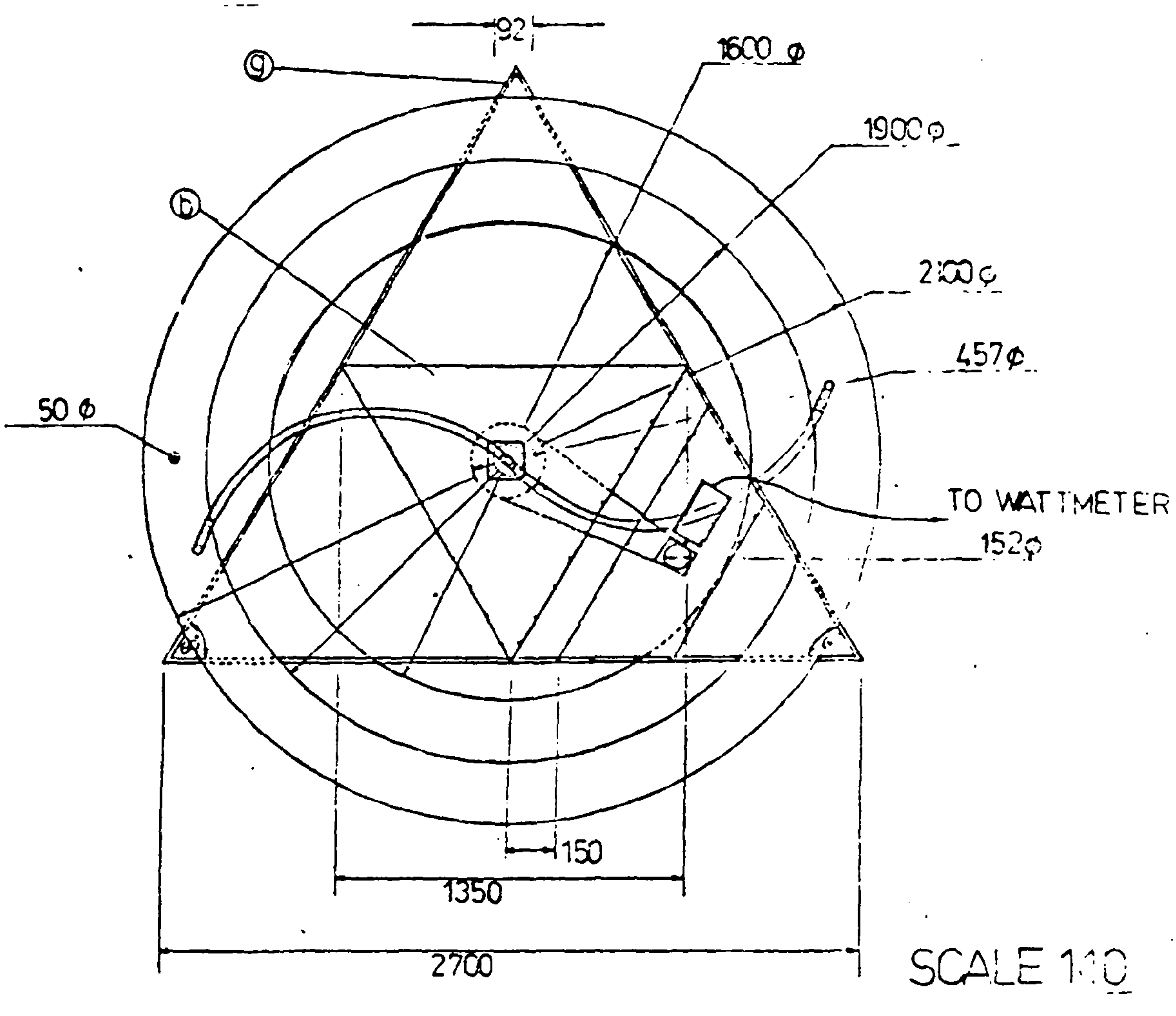


FIG. 1(b) FUTURE VERSION OF PUMP AND RIG (TOP VIEW)

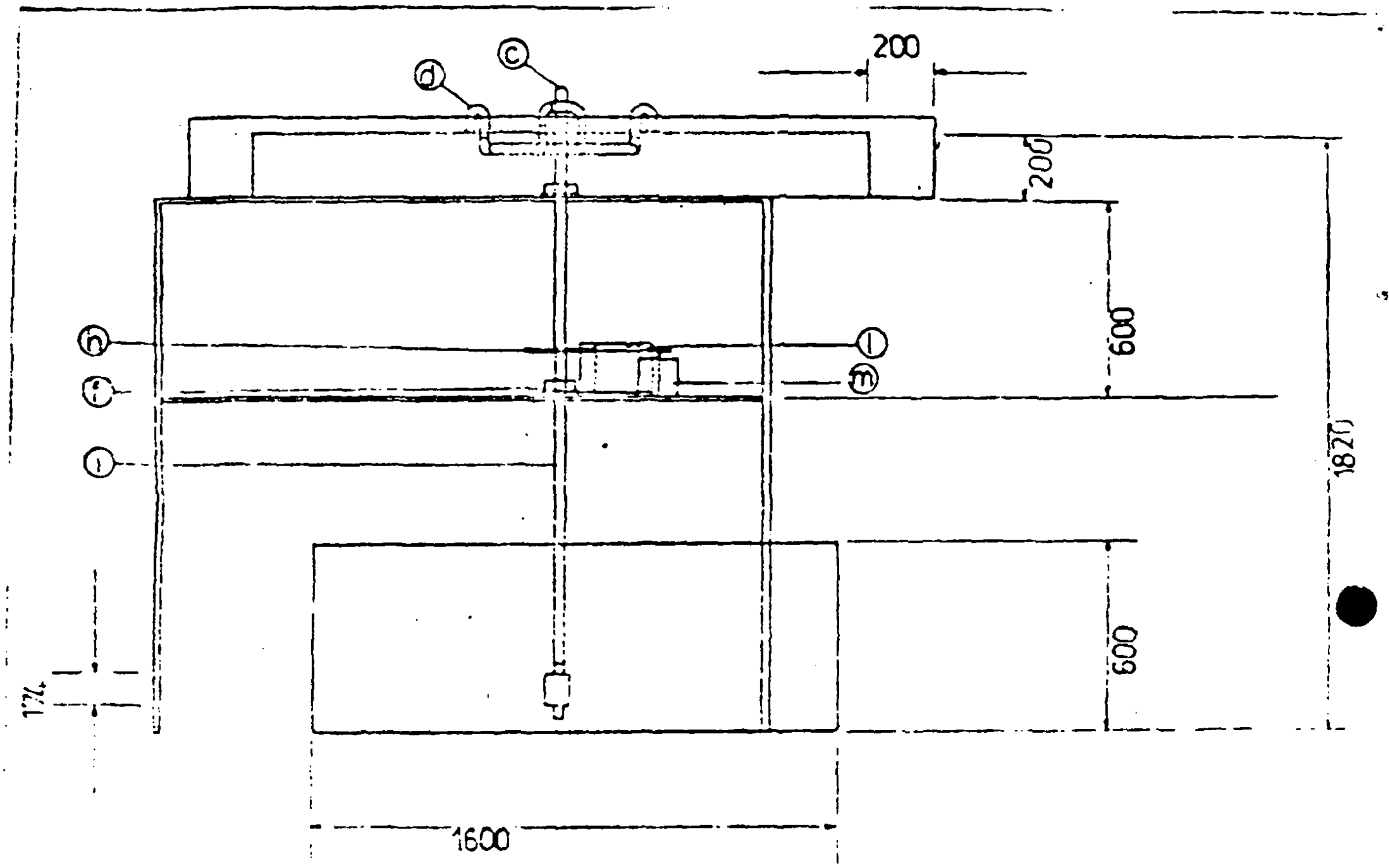


FIG. 1(c) FUTURE VERSION OF PUMP AND RIG (FRONT VIEW)

PARTS 1(a), 1(b), 1(c)

a. DELIVERY TUBE (PLASTIC)
b. SUPPORTING FRAME (PLYWOOD)
c. PLUG
d. TUBULAR ARM
e. CIRCULAR TROUGH
f. BEARING
g. DEXION FRAME
h. PULLEY
i. PUMP SHAFT
j. RESERVOIR
k. FOOT VALVE
l. A.C MOTOR + V. BELT
m GEARBOX.

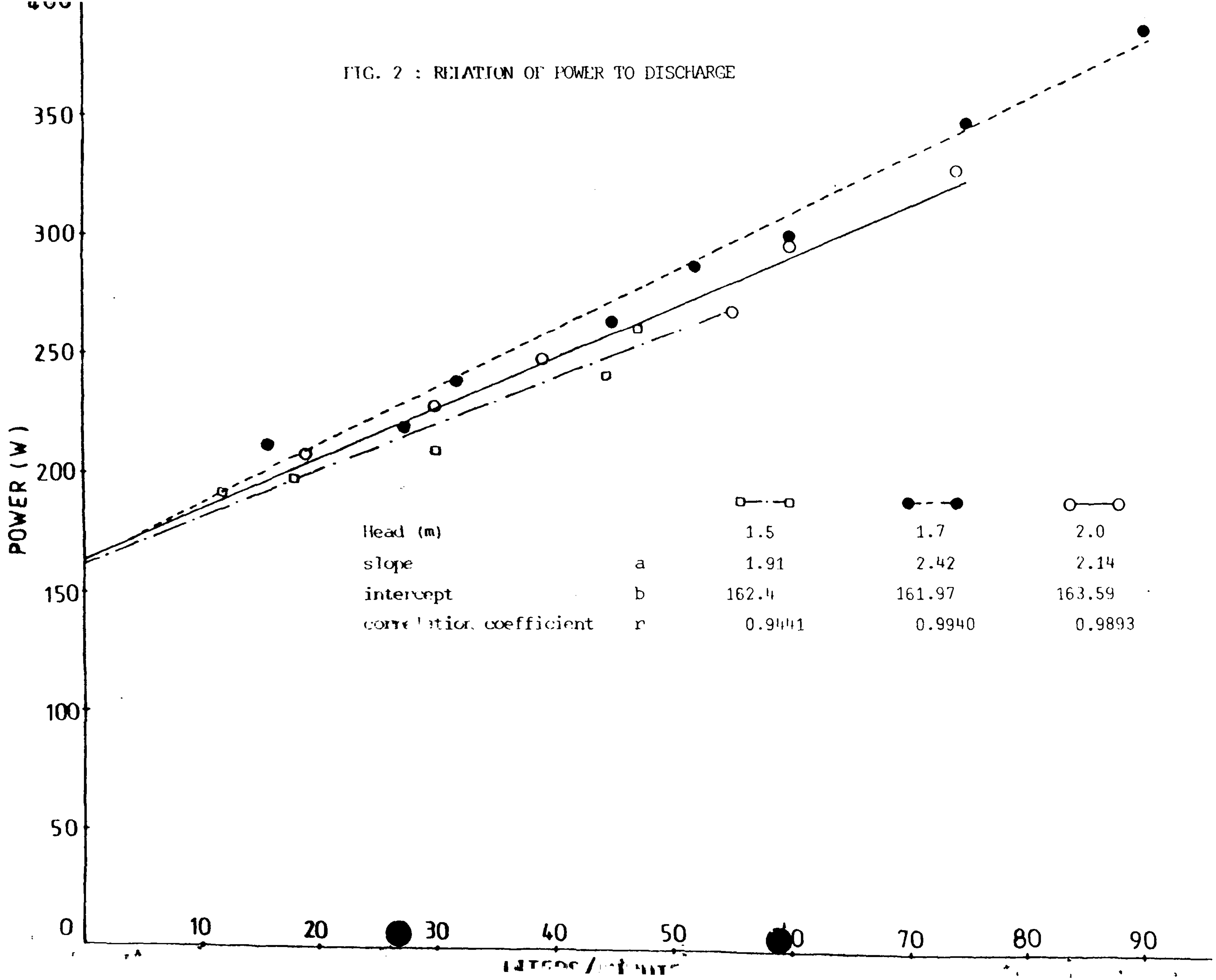


FIG. 2 : RELATION OF POWER TO DISCHARGE

FIG. 3 : RELATION OF POWER TO [illegible]EED

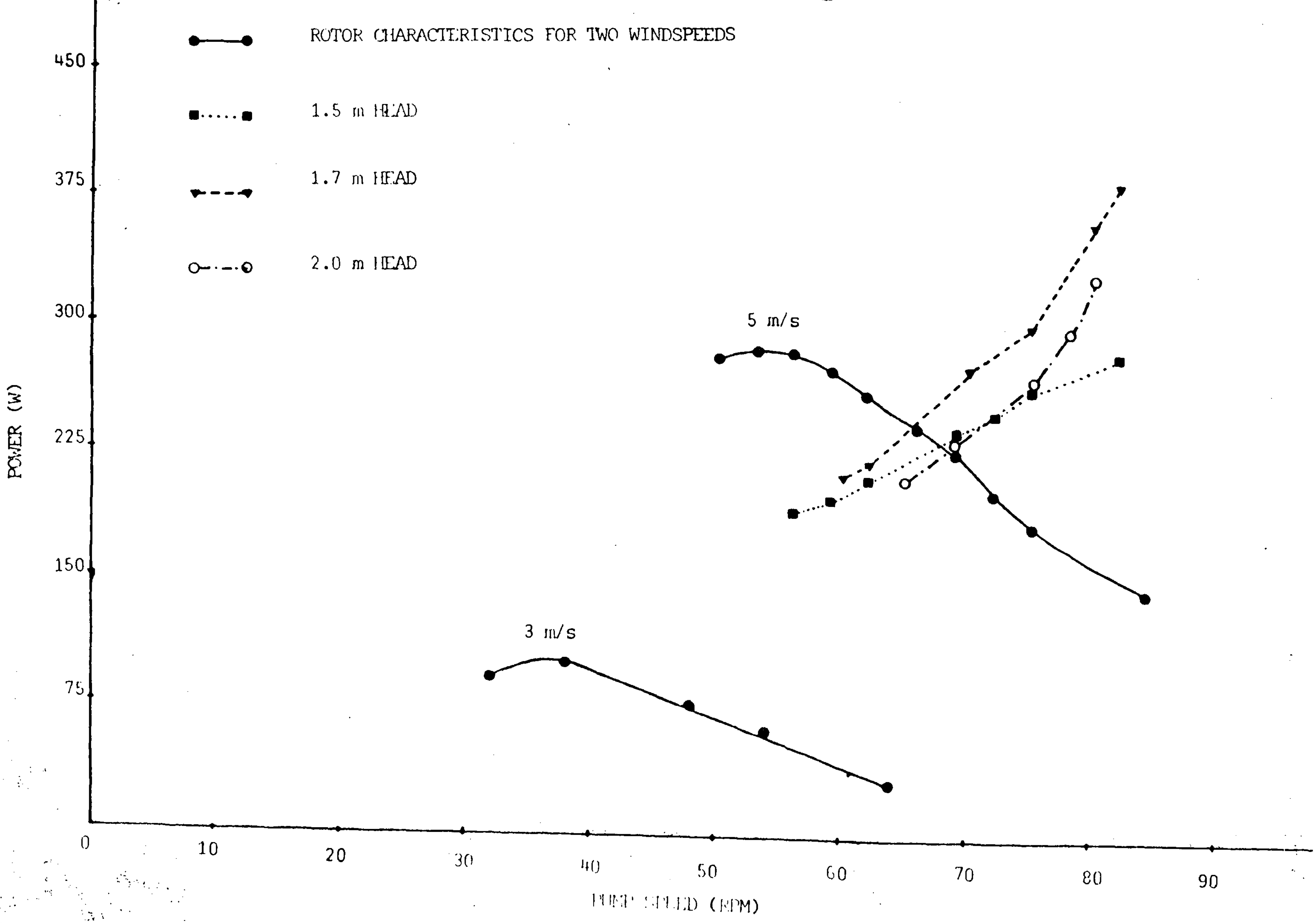


FIG. 4 : RELATION OF DISCHARGE TO SPEED

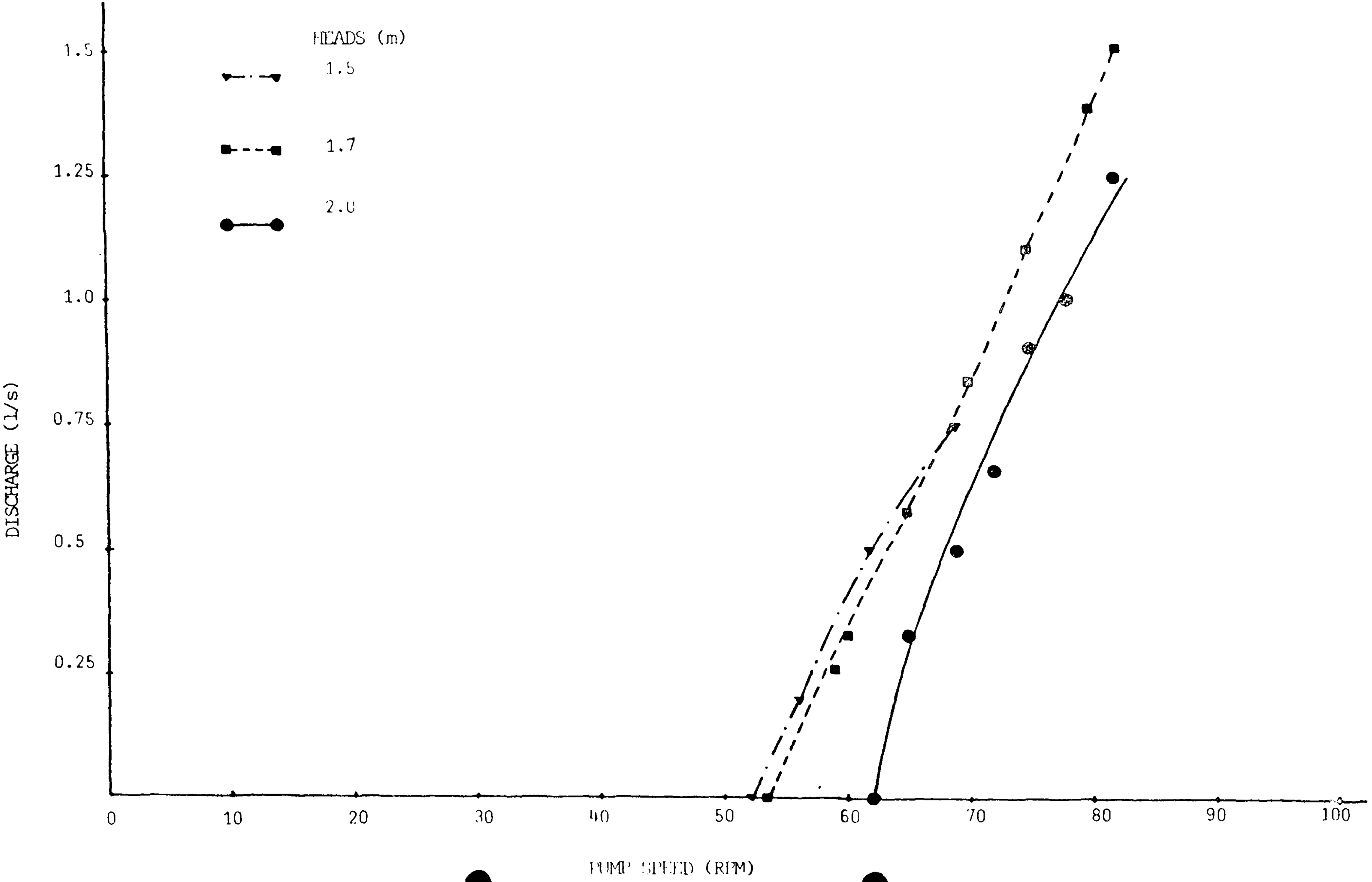


FIG.5 : RELATION OF EFFICIENCY TO DISCHARGE

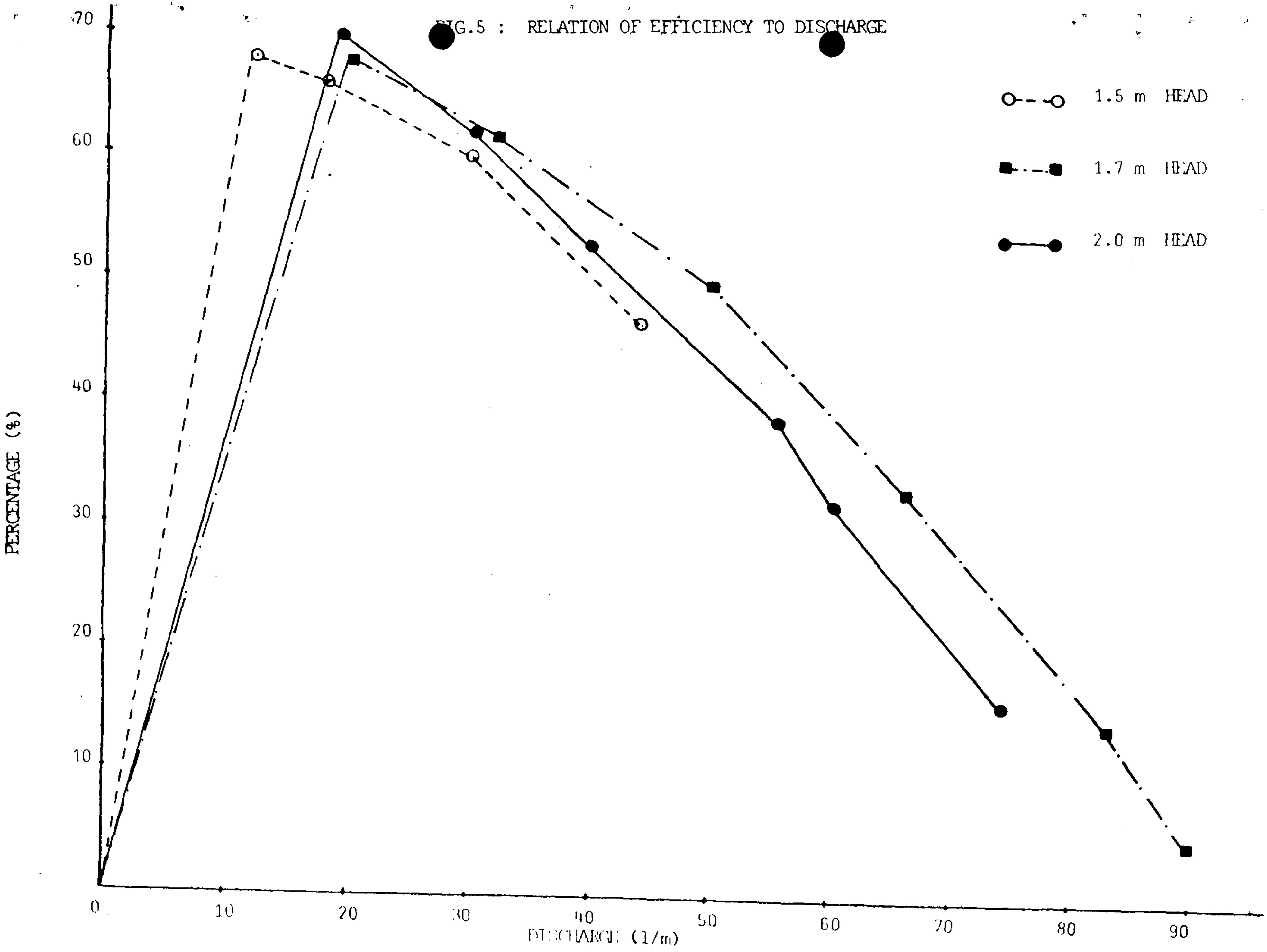


FIG. 6 : HEAD LOSS IN RELATION TO DISCHARGE

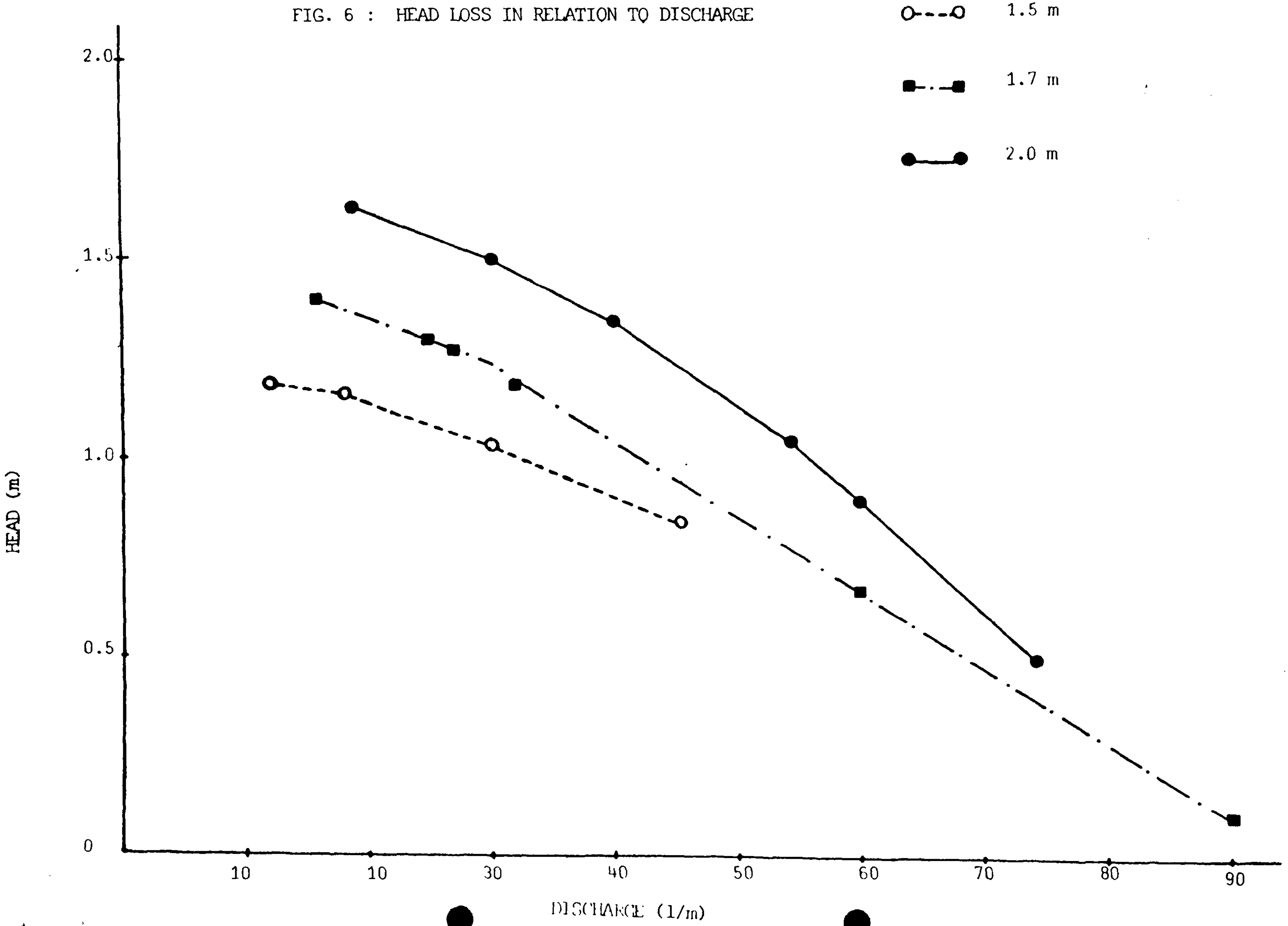


FIG. 7 : WINDMILL/PUMP CHARACTERISTICS ON POWER REQUIREMENT
(SOURCE PARKES, ME, 1974, IRRI REPORTS, 1978)

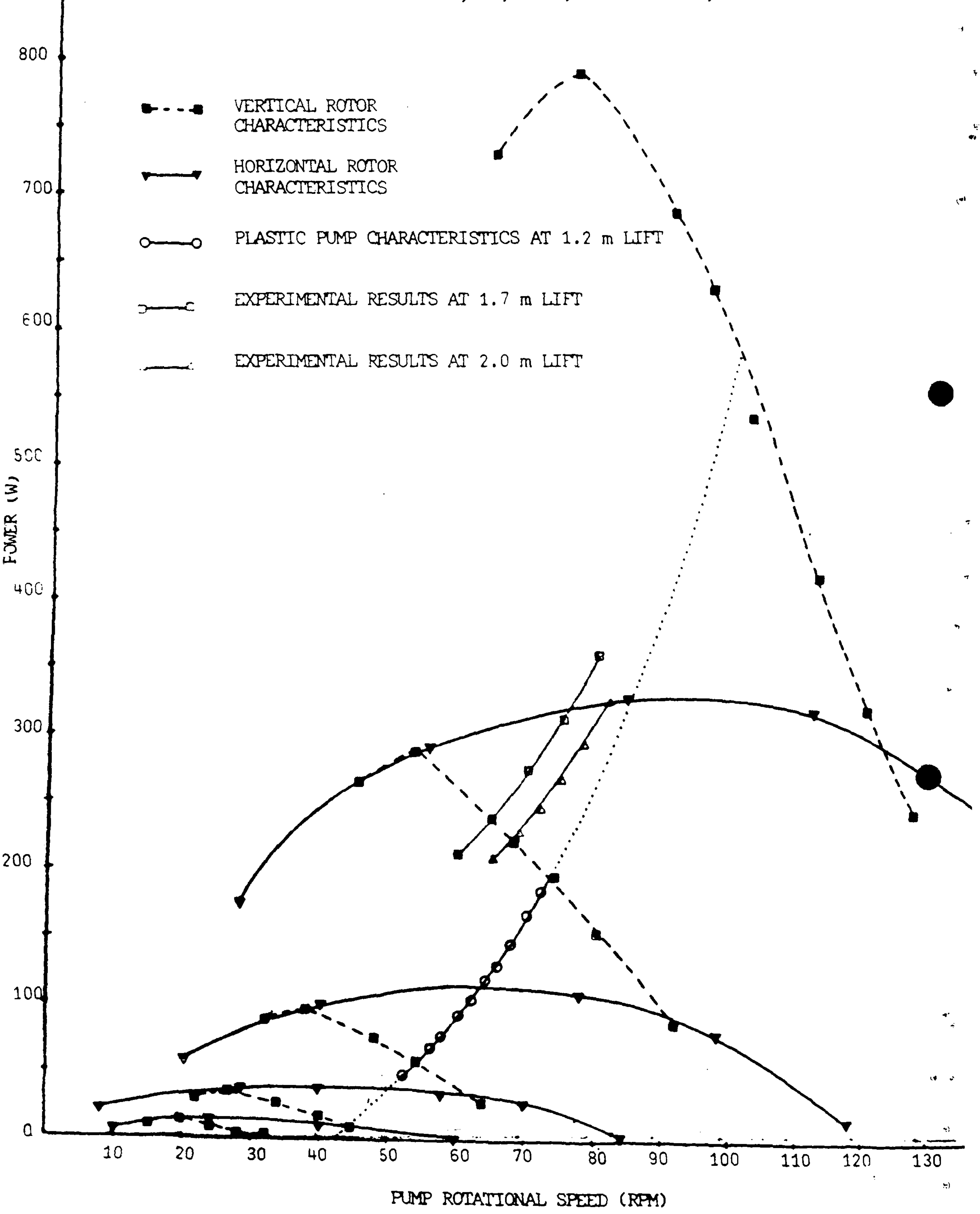


FIG. 8 : WINDMILL/PUMP CHARACTERISTICS ON TORQUE REQUIREMENT (SOURCE PARKES, ME, 1974, IRRI REPORTS, 1978)

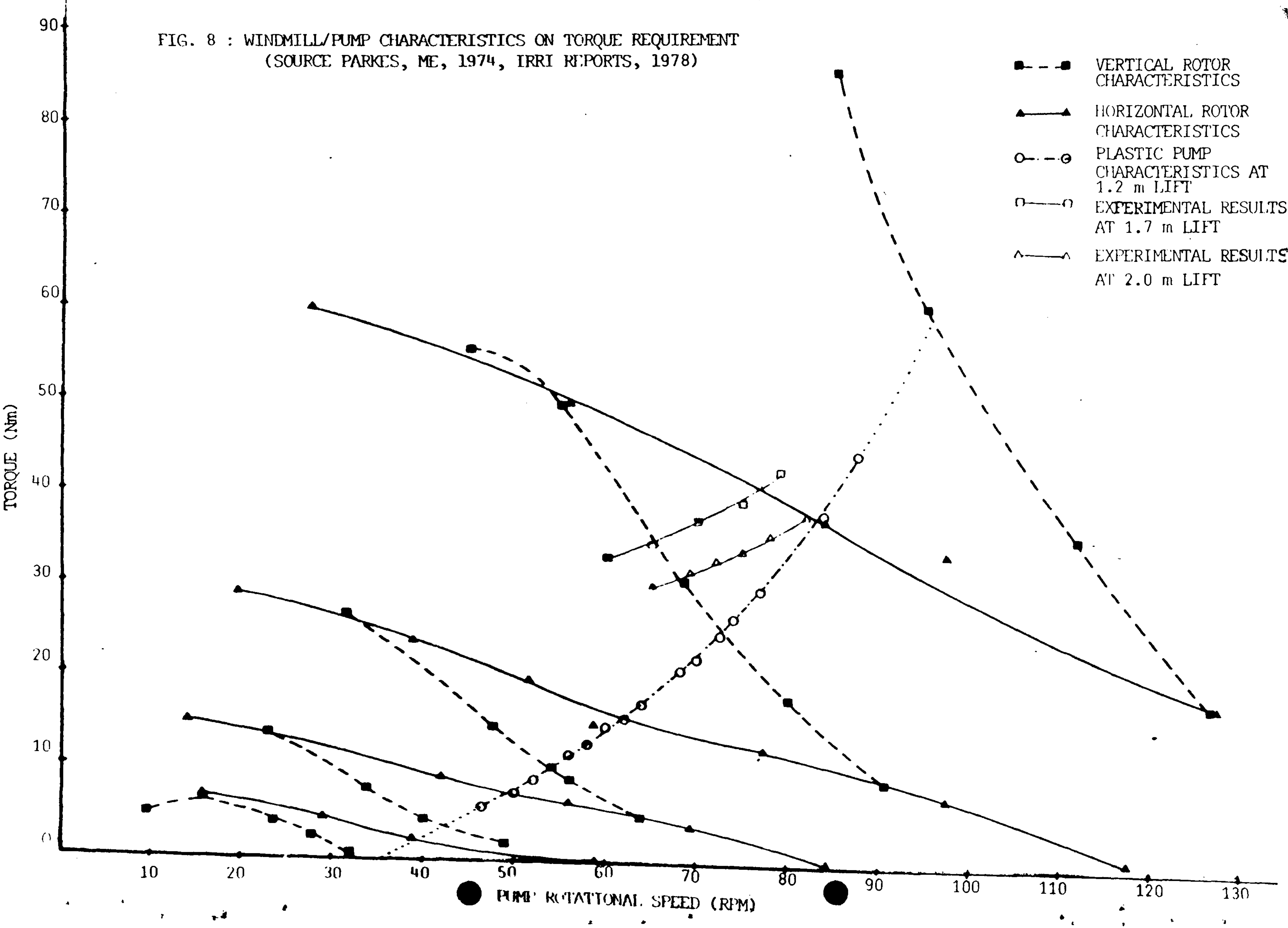


FIG.9 : ANNUAL POWER OUTPUT CURVES (SOURCE LING, F.F, et al 1980)

Rotor diameter = 4 meters

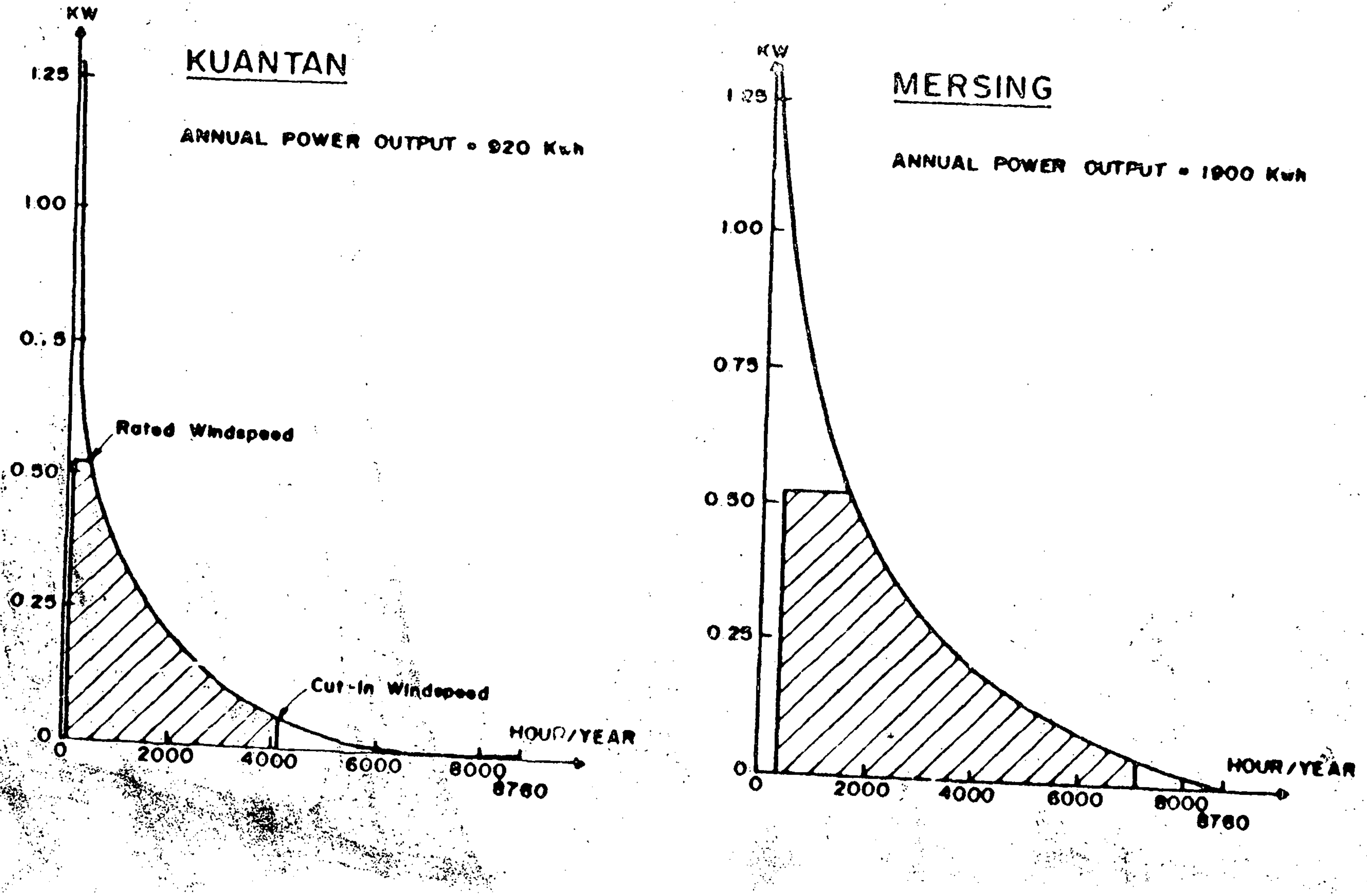
Coefficient of performance = 0.4

Design rated windspeed = 6 m/s

Design rated output = 0.577 Kw

Cut in windspeed = 2.7 m/s

Furling windspeed = 7.6 m/s



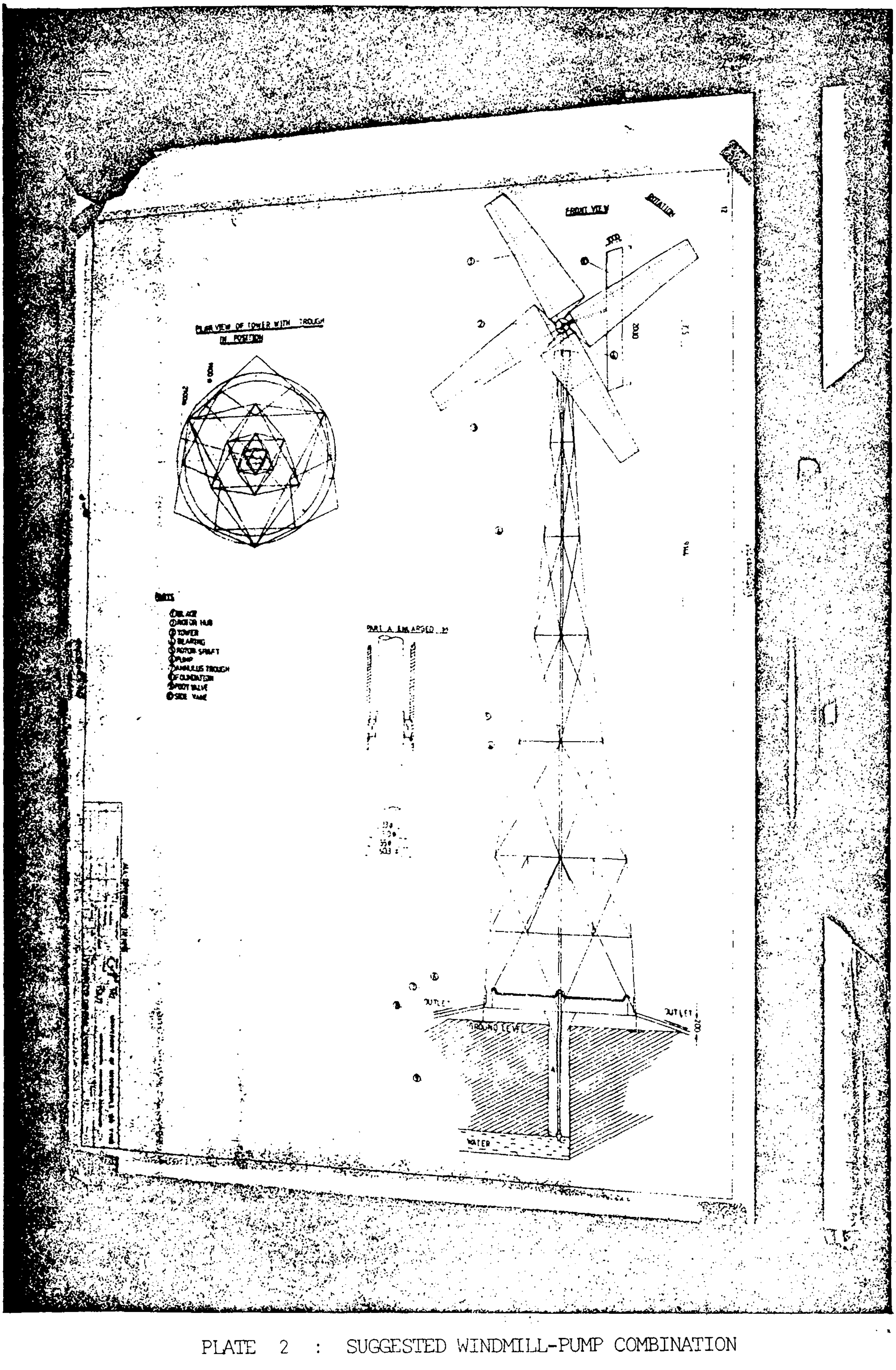


PLATE 2 : SUGGESTED WINDMILL-PUMP COMBINATION

(SOURCE AHMAD, D.B, 1978)

DISCUSSIONS

Q : I have been monitoring the wind data using computer models for the past six years. As you have mentioned, the cut-off speed for the starting torque is about 3 m/s. From the table, 3.4 m/s. occurs roughly 21%. Does it mean that it is 21% of the year? What is the cut-off speed that you will require for the starting torque? (Faizul, NEB).

A : The data is actually based from Tanzania and not from Malaysia. In this country, I see a potential in the east coast states although we have very limited data. My design was based on the wind speed from 3 - 7 m/s. I took 7 m/s as the maximum cut-off speed. From experiments using galvanised iron pipe I observed that the pump could be operated with speeds beyond 3 m/s, and using plastics perhaps we could achieve beyond 1.7 m/s.

C : There are few papers on wind energy in this country, most of the opinion shared together was that for wind power system, we would need some supplementary power source (Faizul, NEB).

Q : From what I could see, your application of wind powered turbine for pumping is not feasible because when the wind is strong it usually brings rain and no pumping is required during rainy season. (Hamdan Isa, NEB).

C : I appreciate the research efforts of the speaker. It seems to me that further developments on the design as he already shown, to produce the starting torque, could lead to a design that is usable for the windspeeds when it is needed.

MAINTAINING WATER QUALITY OF RIVERS - THE CASE FOR AN INTEGRATED APPROACH TO WATER UTILIZATION AND DEVELOPMENT

Ho Yueh Chuen
Division of Environment
Ministry of Science, Technology and Environment, Malaysia

ABSTRACT

Rapid development in Peninsular Malaysia over the last decade has seen a substantial increase in water pollution problems in the country. Additionally, the rapid deterioration of water quality of many of the major rivers particularly in Peninsular Malaysia is a cause for concern. Coupled to this is the apparent decline in the availability of water which is reflected in numerous instances of water shortages throughout the country particularly during drier spells of the year. Control of pollutant sources is a means for ensuring good water quality in rivers. However, pollution control is often not the only means available but what is more often required is the proper development and utilization of water resources. The paper attempts to present the case for the necessity to ensure that future development and utilization of water resources be approached in an integrated manner. It is no longer acceptable to consider water quality and quantity separately.

INTRODUCTION

> Everything originated in the water
> Everything is sustained by water
>
> Goethe

Water is a component of the environment, which is vital for all living organisms. It represents one of the three basic essential requirements for life in the Earth's ecosystem. Not all water is, however, available. Although 70% of the world is covered by water, only a fraction of this is usable by man. The main restriction on the use of water is related to its quality since 97 per cent of the earth's water is saline. In addition, about one third of the remainder is frozen in glaciers or polar ice-caps and the remaining left-over is unevenly distributed. Moreover, the continuous pollution of the existing available 'good' water results in even lesser water being usable.

Peninsular Malaysia lies within the tropics close to the equator, between latitudes 1° 45'N and 6° 45'N and extending from Longitudes 99°35'E to 104° 20'E, covering a land area of approximately 131,900 Km^2. Due to the close proximity of the Peninsular to the equator, it experiences a climate of high relative humidity and uniformly high temperature. In addition, it is endowed with heavy rainfall averaging 2,400 mm per annum. It may be said that Peninsular Malaysia is rich in water resources. However, it cannot be said that all areas do not suffer from want of water, as exemplified by the difficulty in getting water especially during the drier spells of the year in some regions of the country. Very often a reversal of the above situation may occur in that water is available but that its poor quality prevents its use.

WATER RESOURCES AVAILABILITY AND UTILIZATION

Peninsular Malaysia receives an estimated $320 \times 10^9 m^3$ of rainfall annually based on a mean rainfall of 2,400 mm per year. A large part of this is lost through evaportranspiration. Taking into account this loss the total average annual surface water resources in Peninsular Malaysia is estimated at $159 \times 10^9 m^3$ which includes stream flow and the dynamic component of ground water (Pang, 1978). Of this some 65% is estimated to run off to the sea and 25% being used for purposes such as hydro-electric power generation and channel maintenance. Only about 10% ($16 \times 10^9 m^3$) is available for other uses including domestic and industrial water supply and irrigation.

Rivers in Peninsular Malaysia tend to be short and swift. This is because the Peninsular is characterised by a series of mountain ranges aligned north/north-west to south/south-east which effectively divides the country into two. The mountain ranges act as a boundary separating the watersheds of rivers flowing east and those flowing west.

Rivers tend to have steep slopes in the upper and middle stretches, changing abruptly towards its mouth where it becomes more gentle. This characteristic, and the absence of major impoundments account for the rapid loss of water to the sea.

Of the consumptive users of water, irrigated agriculture is the largest consumer representing some 82% in 1976 and is expected to increase to 85% in 2000 (Pang, 1978). Other major users include mining activities and domestic and industrial water supply. Hydropower generation, a non-consumptive user, however, has the heaviest demand on water resources. Based on an initial estimate of future possible hydropower schemes, an area of about 33,60000 km^2 of watershed will need to be utilized (Pang, 1978). This represents a quarter of the land area of the Peninsular where the flow of the rivers in this area will be regulated for a greater part of the year.

An important feature for which little attention has been paid and which needs to be noted is the fact that most rural communities depend heavily on rivers for water supply for their various needs. Traditionally rivers/lakes have been the main source of water for cooking, drinking, bathing and washing of rural communities. Reliance on groundwater is generally limited where surface water is available. Besides, rivers provide the main source of protein to most rural communities, where fish forms one of the staple food.

Water demand over the years is expected to increase substantially. Major increases of water use are expected for irrigated agriculture and for domestic and industrial water supply. Total water demand for the various users, excluding water for hydro-power generation, has been estimated to increase from $25 \times 10^6 m^3$ per day (or $9 \times 10^9 m^3$ annually in 1976 to about $57 \times 10^6 m^3$ per day (or $21 \times 10^9 m^3$ per annum) by 2000 (Pang, 1978).

It is expected that increasing difficulty in securing good quality water will be faced in the coming years especially by the west coast states. Water resources is unevenly distributed and tends to be more favourable in the east coast states than those on the west. Additionally, some states like Melaka, Perlis and Penang have limited water resources within the state and will have to depend on other states to supplement their needs. Rapid industrial development and increasing domestic water demand on the west coast has resulted in greater water stress being experienced in the west than on the east.

Water demand by user sector varies from state to state and river basin to river basin. For instance within the states of Kedah and Perlis the largest user of water is for irrigation - estimated at 90% or more of the total water demand. Whereas water from the Kelang, Langat, Linggi, Melaka and Sekudai Rivers is largely used for domestic and industrial water supply.

WATER RESOURCES MANAGEMENT

Malaysia has a Federal form of Government which means that it has a Central Government and several State Governments. Thus there is a division of powers between the Central and the State Governments in respect of the control and development of resources and related matters. The responsibility for the development and management of water resources has traditionally been fragmented amongst several agencies, each having separate interest on water use. To facilitate the operation of these agencies various legislations were enacted such as the Water Enactments of the various States; Mining Enacments (for states); Land Conservation Act, 1960; Fisheries Act, 1963; the Environmental Quality Act, 1974 and the Local Government Act, 1976.

With respect to matters relating to river water management, the State Authorities hold the powers for administration of land and water, project approval, as well as acts as the authority to issue licence for diversion or use of water. The planning, construction, operation and maintenance of agricultural drainage and irrigation facilities is the responsibility of the Drainage and Irrigation Department. It addition it carries out research and surveys on river hydrology and is concerned with flood mitigation. On the other hand, the Public Works Department or the State Water Authorities have the responsibility to plan, construct, operate and maintain structures or schemes related to water supply for domestic and industrial use, while the Mines Department has the function of controlling the alteration or interference of water-courses for mining purposes. Development of hydro-power is the function of the National Electricity Board. In matters related to control of water pollution, the powers of control can be by various agencies including the State (State Secretary), Local Authorities, Mines Department, Marine Department and the Division of Environment. Thus, the issue of control and management of water is a little complex with involvement by Federal, and State Agencies as well as District or Local Authorities.

QUALITY OF WATER

Water quality of most Peninsular Malaysia rivers especially in the upper catchments remain good but deteriorate in quality lower downstream. In general, rivers on the east coast bear water of better quality when compared to those of the west coast. Where rivers are found within undisturbed forested catchments, the water quality of these rivers is generally good (Table 1).

TABLE 1: Water Quality of The Upper Stream of Some Malaysian Rivers*

River System	Parameter (mg/l)					
	B.O.D.$_5$	D.O.	NH$_3$ - N	PO$_4$ - P	S.S.	D.S
Sg. Juru	1-4	5.6-9.9	0.01-0.17	0.2-1.0	15-225	55-275
mean	2	7.4	0.08	0.4	62	112
Sg. Merbok	1-1	6.2-11.2	0.01-0.18	0.08-0.52	15-75	25-185
mean	1	8.6	0.07	0.21	38	83
Sg. Buloh	1-1	4.0-8.0	0.05-0.32	0.03-0.48	8-340	22-76
mean	1	6.3	0.14	0.12	66	51
Sg. Langat	1-2	5.6-8.2	0.02-0.22	0.06-0.24	20-78	37-65
mean	1	6.9	0.07	0.12	39	48

* Data taken from various water quality studies carried out by the Division of Environment

In general, such rivers show high dissolved oxygen (D.O.) levels generally exceeding 6 mg/l and low Biochemical Oxygen Demand (B.O.D.) concentration, generally less than 2 mg/l. Most rivers have soft waters and are nutrient poor.

Water quality deteriorates mainly as a result of enrichment due to inputs from various sources such as discharges from domestic, animal husbandary and industrial activities. In addition, extensive land development has seen an increase in siltation and leaching of nutrients into rivers, particularly as a result of the increase in

TABLE 2: Water Quality of Some Rivers Affected by Waste Discharges

River System	Parameter (mg/l)					
	$B.O.D._5$	D.O.	NH_3 - N	PO_4 - P	S.S.	D.S.
Sg. Kedah (6206606)	1-10	5.0-5.7	0.01-0.41	0.05-0.38	20-360	30-215
mean	3	5.3	0.13	0.25	103	101
Sg. Merbok (5705605)	1-20	2.6-8.1	0.43-7.05	0.22-5.8	15-255	50-645
mean	5	5.2	3.05	2.15	103	215
Sg. Kelang (3015631)	1-23	0-4.6	0.02-7.50	0.28-7.80	186-9909	76-286
mean	7	1.1	2.91	2.14	1,918	185
Sg. Linggi (2719609)	1-11	4.0-8.4	0.01-0.95	0.06-1.80	11-264	45-153
mean	3	5.9	0.35	0.63	66	71
Sg. Keratong (3029608)	2.84	Not Available	0.08-1.1	0.05-2.00	45-480	45-235
mean	19	-	0.39	0.82	135	97
Sg. Kemaman (4332618)	14-460	0.4-1.8	0.20-11.00	0.05-1.20	20-510	105-820
mean	136	1.0	3.38	0.26	173	349

Data from monitoring studies of the Division of Environment taken over the period 1979 - 1981.

the use of agricultural fetilizers. Toxic substances are generally absent or present in minimal quantities in most Peninsular Malaysian rivers. Table 2 shows the effect of waste discharges on the quality of water of some Peninsular Malaysian rivers. A description as to types of waste affecting the rivers is given below:-

(a) Sg. Kedah at its upper stream (Sg. Padang Terap) is affected by waste discharge from a sugar mill near Kuala Nerang.

(b) Sg. Merbok at its upper stream receives the discharge from three rubber factories near Bedong.

(c) Sg. Kelang receives heavy input of domestic wastes (estimate of 1.3 million population in 1980) and from numerous industrial sources as rubber mills, food processing factories and other smaller industries.

(d) Sg. Linggi which is mainly affected by domestic waste from a population of about 230,000 and wastes from several rubber factories as well as smaller amounts from small scale industries.

(e) Sg. Keratong at Sg. Mengah receives the waste discharge from a palm oil mill.

(f) Sg. Kemaman at Sg. Ransan is similarly affected by the discharge of effluent from a palm oil mill.

The general features of the above described rivers are low D.O. and higher than normal average B.O.D. concentration.

The effect of the discharge of wastes on water quality vares depending on the characteristics of the stream. For instance it is common knowledge that where flow is large (or dilution is high) the effect of small discharges of pollutants on streams is often not significant. In fact small amounts of pollutants, eg. organic waste, may enhance productivity in some rivers. Improve fish catch downstream of palm oil mill discharge has been recorded for some Sabah rivers, eg. Sg. Giram downstream of a palm oil mill. The reverse effect may however be true, that is productivity declines due to pollutants being discharged into streams. Analysis of water pollution complaints(Division of Environment, 1979, 1980) have shown that fish kill due to palm oil waste discharge, for example, has been recorded in Sg. Sepetang, Sg. Bidor, Sg. Bekok, Sg. Bera, Sg. Jekatih, and Sg. Serai in Peninsular Malaysia. Very often records of fish kill coincide with drought conditions resulting in low flow in streams.

Deterioration of water quality associated with low flow of rivers is not confined to effect on fishes. For instance, taste problems in water supply from rivers receiving domestic and industrial wastes have been recorded, for Sg. Buloh, Sg. Linggi and Sg. Sekudai during low flows. Water quality of Sg. Batang Benar (Sg. Linggi) is affected by the discharge of a rubber mill and water users along the river complain that water quality is bad during drought period but not so during the wet period. Water quality towards the estuary of the Melaka river downstream of the tidal barrage has deteriorated due to the increase in pollution load and the lack of flushing of the estuary. The presence of a tidal barrage and the large abstraction of water for domestic and industrial supply upstream has left little water for downstream purposes. In the case of Sungai Tasik Chempedak in Province Wellesley, abstraction of water by two paper mills along the stream resulted in little or not water being left for downstream uses. Wastewater discharged from the two factories constituted the flow of the river downstream. In other instances it has been observed that pollution problems are recent events even though the sources of the pollutants have been there much longer.

It would appear that changes in river hydrology have resulted in pollution problems becoming obvious when this was not so before. It is quite clear, therefore, that water quality is affected by changes in the river system.

WATER POLLUTION CONTROL LEGISLATION

The approach currently adopted in Malaysia to control deterioration of environmental quality in general and river water quality in particular, has been directed at regulating discharges at source. For this purpose three sets of regulations have been formulated for water pollution control under the Environmental Quality Act, 1974. The regulations are:

(a) Environmental Quality (Prescribed Premises) (Crude Palm Oil) Regulations, 1977 - for the control of effluents from palm oil processing mills,

(b) Environmental Quality (Prescribed Premises) (Raw Natural Rubber) Regulations, 1978 - for the control of effluents from rubber processing mills, and

(c) Environmental Quality (Sewage and Industrial Effluents) Regulations, 1979 - for the control of sewage and effluents from all industries other than those for the processing of rubber or palm oil.

The Regulations set effluent quality standards for compliance and they may or may not require the issuance of licence depending on the requirements specified under each particular set of regulation. For instance, both the regulations for the control of discharges from palm oil and rubber processing mills require that such factories be licensed, prior to occupation or use of such premises. For other industries which come under the Sewage and Industrial Effluents Regulation, a licence is required by the industry if it wishes to contravene the provisions under it.

As mentioned previously, the regulations set effluent quality standards for compliance by industries. There are limitations, however, in the use of such standards. For one, it does not provide for control of discharge of total pollutant load into a watercourse. Thus, even if all industries comply with these provisions it would not necessarily mean that water quality of rivers will be maintained in its natural state although the latter aim is the attention. For instance, an average size palm oil mill which complies with the present $B.O.D._3$ concentration limit of 500 mg/l will still discharge a B.O.D. load estimated at 140 kg/day or equivalent to the raw discharge from a population of about 2,800 people. If waste loads from other pollutant sources within the same river basin are considered, the total pollutant load may be substantial enough to affect water quality adversely.

CONCLUSION

The current approach to water resources development and management leaves much to be desired. Whilst there is attempt presently to ensure that development of water resources for a certain use will not interfere with others or that development will be multipurpose there is as yet no integrated approach to ensure the optimal use or benefits to be derived from such development. This situation has been made more difficult by the fact that several agencies both at Federal and State levels have the responsibility to either manage or use water resources. There is no single authority with sufficient powers to oversee or coordinate all aspects of water resources utilization and management.

Numerous difficulties are encountered by such disjointed development and management of water resources. The most common is water resources is developed to the benefit of one but to the detriment of others. This is more serious in areas where water resources are limited and maximal exploitation is carried out. The deterioration of water quality and river ecology is often the victim of such developments. Added to this problem is the rapid deforestation and changes in land use pattern within river catchments.

Studies carried out within the country have shown that river hydrology and water quality changes significantly when their catchments are disturbed. There is sufficient evidence to indicate that rivers within disturbed catchments experience higher runoff, greater fluctuations in flows between wet and dry periods as well as higher instantaneous peak discharges when compared to similar undisturbed catchments. (Shallow, 1956; Huntings Technical Services Ltd., 1971, Daniel & Kulasingam, 1974; Goh, 1981). The studies for example showed that low flows may be reduced by 50% or more whilst peak flows may double in rivers of disturbed catchments. What this essentially means is that the distribution of water is more unevenly spread out with less water being available when it is most needed. In addition, the above studies have shown that sediment yield in rivers within disturbed catchments is higher, sometimes in the order of 30 fold or more, as compared to rivers in undisturbed forested catchments.

Thus we have a situation where catchments of rivers will be more intensively developed. Forests will be removed in favour of agricultural crops such as rubber, oil palm or paddy whilst more land will continue to be alienated for housing, industry, roads and other facilities. At the same time demand on water resources is expected to increase substantially while more waste will be generated from a bigger population and from industry. Some of the waste will eventually end up in our water resources. To maintain water quality and river ecology some consideration has to be given for maintaining as closely as possible the natural hydrological conditions of rivers. A certain flow has to be maintained to ensure that the functions of a river are not adversely effected. One of this function, which is essential for maintaining water quality, is the self-purification capacity of the river.

As discussed previously, the application of effluent discharge standards has its limitation in that it does not control the discharge of total pollutant load into a river. However, setting very stringent standards for discharge may not be practical in that a technology for treatment may not be available nor economically viable. In addition, environmental pollution control has to be balanced with industrial development to ensure that economic stagnation does not occur.

The common approach adopted by many countries would be to require the treatment of waste using the best practicable or available treatment technology. In such a situation the treated waste water would not be of the same quality as the receiving waters. Generally, it would be of poorer quality. However, it is anticipated that natural self-purification processes of the environment would take care of the residual pollutants in the waste. The self-purification capacity of a stream however is limited, beyond which environmental problems arise. The capacity for self-purification of streams depends on several factors such as the biological, chemical and physical characteristics of the receiving waters. Flow of the stream and dilution of the waste are important factors determining this capacity.

In the context of what has been discussed it is necessary that water resources development has to be approached in an integrated manner. The quantitative as well as the qualitative aspects of water resources are inseperable if it is to be ensured that optimal benefits be obtained.

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INDICES FOR WATER QUALITY ASSESSMENT IN RIVERS : A CASE STUDY OF THE LINGGI RIVER IN MALAYSIA

B.N. Lohani
Associate Professor
Environmental Engineering Division
Asian Institute of Technology
P.O. Box 2754, Bangkok

N. Mustapha
Division of Environment
1st Floor, Oriental Plaza
Jalan Parry, Kuala Lumpur
Malaysia

ABSTRACT

Two types of water quality indices, one based on opinion poll and the other on the principles of factor analysis, were developed for the assessment of water in the Linggi River in Malaysia. Both the indices appear to explain the trend in the water quality whereas the water quality index based on the principles of factor analysis seem to have a greater sensitivity. It is felt that water quality indices could be of great uses in providing preliminary idea of water quality situation in river.

INTRODUCTION

Planning for Man's future has necessitated the formation of organisations that monitor the Environment so that past performance can be assessed and future trends estimated. Technical data, however, is often published in a form that is difficult to digest due to its sheer volume, thus the evolution of index numbers or indices. The idea of indices is to relate a group of variables to a common scale, combining them into a single number. The group should ideally contain the most significant parameters of the data set so that the index can describe the overall position and reflect change in a convincing and representative manner. Some information may be lost in the process but in a properly designed index the information loss should be of such a nature so as not to cause distortion or misinterpretation of the results.

Indices have been developed or proposed for resource allocation, location, ranking, standards enforcement, trend analysis, public information and scientific research. Fig. 1 shows water quality indices functioning as a supplementary element of a communications systems without taking over any existing information route, while Fig. 2 shows index construction. (Ball and Church, 1980)

As an entity Water Quality Indices is completely new to environmental management in M'sia. Local studies on river basins, though thorough in establishing the water quality profiles in terms of certain important parameters, lacked any index formulation to illustrate the degree(s) of pollution. In this study the Linggi River in Malaysia is hereby selected for the purpose of developing indices to assess its water quality.

The Linggi River

The Linggi came into focus due to the severity of its pollution problems, evident from complaints and subsequent investigations that revealed the major sources of pollution as being the agro-based industries operating in the basin. Rubber and palm oil mills effluent were found to threaten the freshwater population as well as the padi cultivation, (poor yields of which have been reported in recent years), as most of the waste then was being discharged without prior treatment into the watercourse. Special investigation on this case was added to the regular river monitoring programme that began in 1978. Given the effluent control regulations developed since then and gradually enforced by the Ministry of Environment, Malaysia, it is envisaged that water quality should improve with the years unless the pollution-abatement efforts have been greatly offset by the need for industrial progress. Although the enforcement programmes are still in their infant stage,

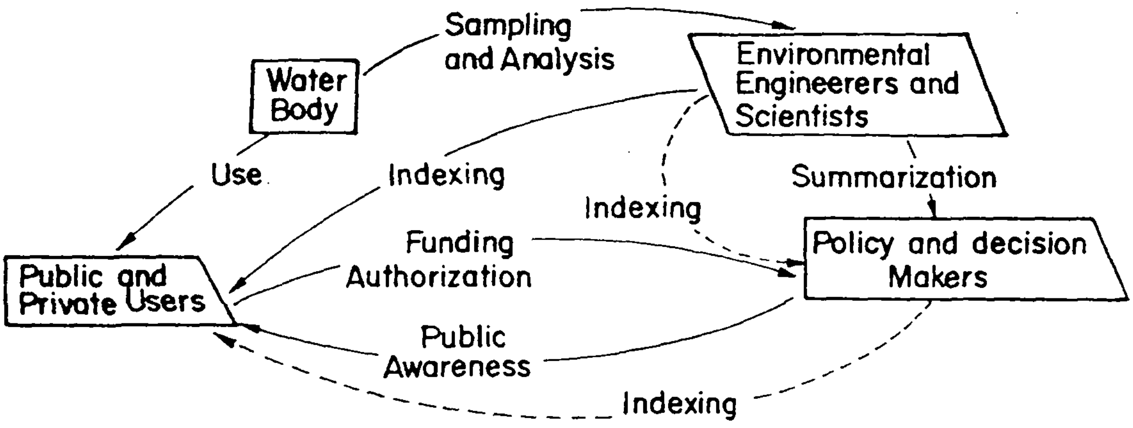

Fig.1 - Water Quality Communication Network

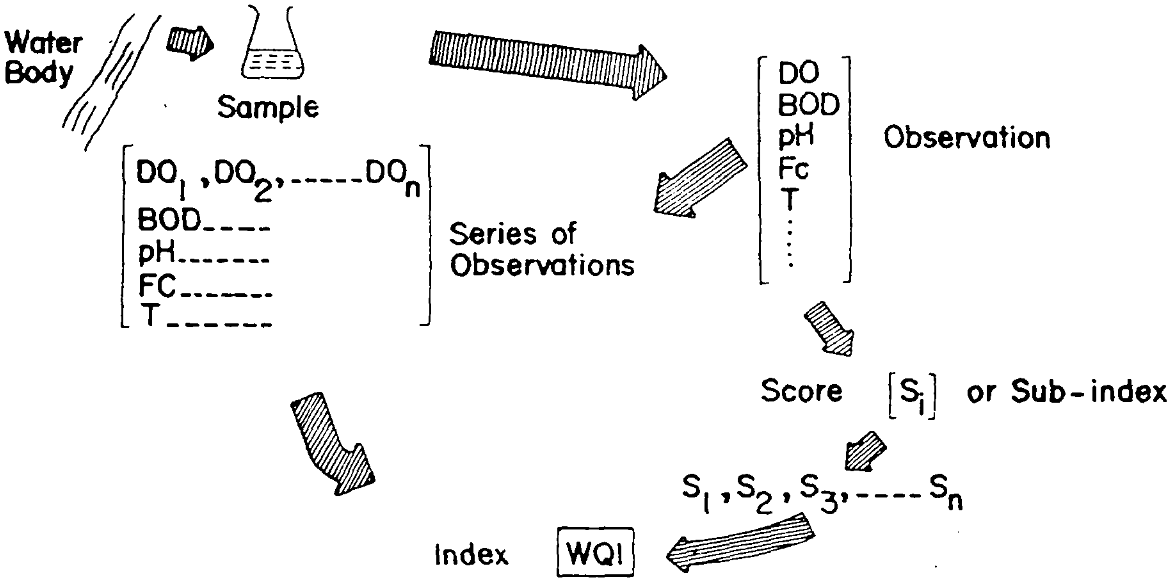

Fig.2 - Water Quality Index Construction

current assessment of Linggi's water quality is still pertinent as an initial step in presenting the state of affairs on record.

In summary, the paper proposes two types of water quality indices which could be used in assessing water quality in the Linggi River in Malaysia and finally presents a river classification scheme for several beneficial water uses in the Linggi River.

METHODOLOGY

Several types of water quality indices have been reported in the literature; two approaches based on opinion poll survey and multivariate factor analysis are presented in this paper.

WQI Based on Opinion Poll

Based on the Delphi technique developed by Rand Corporation, this approach incorporates opinions of experts involved in water resources to obtain a concensus on the type of variable that should be included in developing a Water Quality Index (WQI) and the degree to which each contributes to the index represented by weighting factors. The expert panel are also polled to derive the ratings of the selected variables to show how water quality changes with increasing amounts of each variable.

The steps involved in determinig WQI by the opinion poll method are: (1) Determination of selected variables and corresponding weighting factors, (2) Determination of the final weights, (3) Construction of subindex or rating curves for each selected variable described, (4) Interpolation of subindex from the rating curves developed earlier (5) Calculation of index by the following relation:

$$WQI = \sum_{i=1}^{n} W_i I_i$$

where, W_i and I_i are the weights and subindex value of ith variable. Detail procedure on this approach are available elsewhere (Brown et. al., 1980; Mustapha, 1981).

WQI Based on Factor Analysis

Factor analysis is essentially a technique developed by psychometrists and others for the purpose of determining for each set of variables the proportion of their factor loadings through manipulation of the correlation matrix. It identifies and quantifies underlying patterns of variation in a data set and enables the construction of column vector indices that explain the variation in fewer and simpler number of column vectors than the original input.

Thus the value of factor analysis is dependent on the meaningfulness of the data variability, the number of factors derived being dependent on the variation.

In factor analysis each of n observed variables, i is described linearly in terms of m new uncorrelated common factors, F_1, F_2 ....F_m and unique factors U_j (j = 1, 2, ...n)

$$Y_1 = A_{11}F_1 + A_{12}F_2 + \ldots . A_{im}F_{im} + b_1U_1$$

$$\vdots$$

$$Y_n = A_{n1}F_1 + A_{n2}F_2 + \ldots . A_{nm}F_{nm} + b_nU_n$$

where

Y_j = standardised form of a variable with known data

A_{jm} = factor loading or weight

F_m = function of some unknown variables

U_j = a unique factor

b_j = a unique factor weight

The formula for an index I, constructed from the first factor loadings as follows:

$$I_i = \sum_{i=1}^{n} \frac{A_{ji}}{\lambda_1} Y_j$$

where λ_1 = eigen value for the first factor

A_{ji} = factor loading taken

Y_j = standardised form of variable with known data

and I_i = subindex for that variable

CASE STUDY ON THE LINGGI RIVER IN MALAYSIA

The Linggi River Basin

The Linggi River Basin is shown in Fig. 3 overleaf, while Table 1 gives the relevant statistics. Table 2 describes the types of discharges it receives. Seven sampling stations (Table 3) were chosen

Table 1 - Brief Information on the Linggi River Basin

Total Catchment Area	540 sq. mi. (65% mountainous)
Population	Approximately 300,000
Land Use	Rubber, oil palm & Rice cultivation Industries (Light, and agro-based)
Water Use	Public Water Supply Irrigation Industrial Processing
River Flow	low - 65.3 mgd during February (min 13.7 mgd) flood - 816.5 mgd (maximum daily discharge 271.5 mgd.) average - 267 mgd 198 mgd (50% percentile value)
Distribution of Industries (1977 figures)	Rubber 19 Palm Oil 1 Food 15 Electronics 6 Chemical 4 Feedmills 1 Textile 2 Total 48

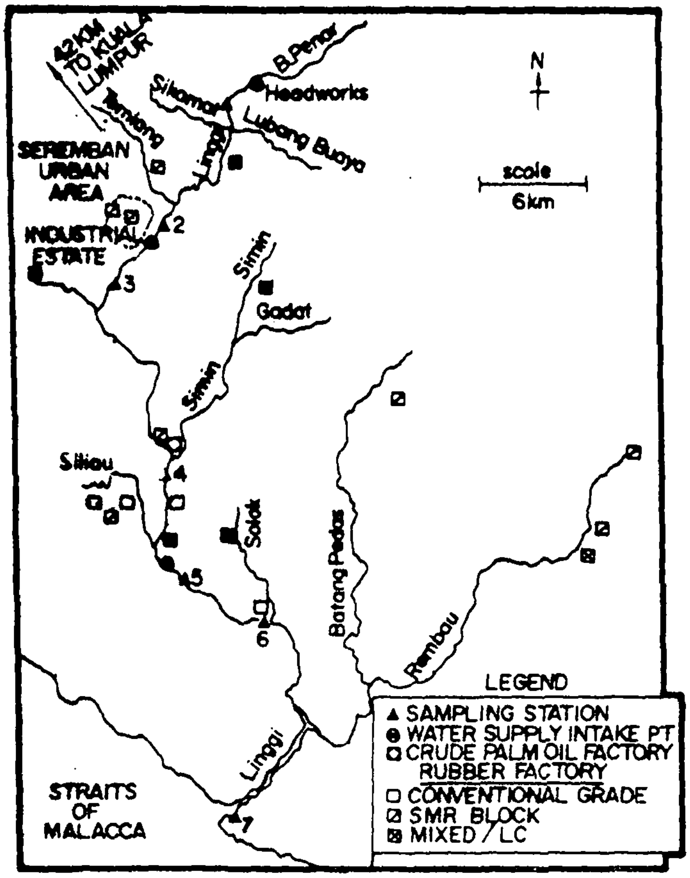

FIG. 3 – THE LINGGI RIVER BASIN

Table 7 - Major Wastes Discharged into the Linggi River

Waste Type	Origin	Characteristics	Main Treatment & Disposal Methods Where Used
Rubber effluent - SMR Block	washings, serum coagulation	acidic, high TS (DS), BOD, COD, AN, TC	Biological, using stabilization ponds or land disposal
- Latex concentrate	washings, serum from centrifugation	acidic, high TS BOD, COD, AN, moderate TC	Biological using stibilization ponds, oxidation ditch, land disposal
- Conventional grade	washings	acidic, high TS (DS), BOD, COD, AN, moderate TC	Biological, using stabilization ponds
Food	washings from storage tanks & equipment, foodstuffs, process waters	high pH, SS, BOD	
Electronics/ electroplating	stripping of oxides, cleaning & plating	acidic, heavy metals	
Chemicals	chemical-contaminated process waters	Variable pH, high COD, SS, DS, org. matter (esp. fertilizers), saponified soaps	
Textile	dyes, other chemical contaminated washings	high pH, BOD, COD, SS	
Palm Oil (crude) effluent	sterilizer condensate, clarification sludge, claybath separators	high BOD, COD, TS, SS, AN, NN (BOD: 20000-5000)	Anaerobic/aerobic pond system, land disposal

Opinion Poll Survey

A total of 105 experts from various organization were polled by mail. Table 4 presents the proportional distribution of participants and the sequence of responses received. Twelve variable arrived in order of importance were DO, BOD, pH, COD, SS, TC, FC, TS, NN, PHE, NH_3-N, oil and grease. The weights and the rating curves of these twelve variable are presented in Table 5 and Fig. 4, respectively.

Factor Analysis Approach

Factor analysis of the water quality data in the Linggi River was conducted using the SPSS Programme Package in IBM 370/145. Three principal components and the representative factor scores are shown in Table 7 and Table 8, respectively.

It is noted that the first factor has high coefficients for BOD, PHDEF, NN and PHE (hereby termed an "organo-chemical"-indicating factor), the second factor for CHLO, COND, and TS, (herby termed "physiochemical" indicator), and the third for COD (thus a "chemical" indicator). Principal components, being linear relationships of the original water quality parameters, can then be used to formulate a general water quality index. The coefficients for each component shown in the Table 7 are computed mathematically so as to maximize its variance subject to the restraint that it be uncorrelated with scores from other components.

Referring back to Table 7 the three principal factors, extracted from a correlation matrix, accounted for 100 per cent of the total variation in the data. The first factor, which explained 44.3 per cent of the total variance was negatively correlated with DOSP and AN. The second factor, strongly correlated with CHLO, COND and TS, was negatively correlated with SS, PHDEF, OG, AN ANN, BOD and PHE.

RESULTS AND DISCUSSION

The results of water quality assessment by the use of both the method - opinion poll and factor analysis - are presented in this for this study and these are shown in Fig. 3.

Table 3 - Stations Along the Linggi River Under Study

No.	Distance from Rivermouth		Division of Environment Code for Station	Description (See also Fig. 3)
	mi	Km		
1	42.0	67.0	2719610	Bridge at Pantai Village
2	34.0	54.4	2719622	Rahang district
3	31.0	49.6	2619607	Mambau Bridge
4	22.0	35.2	2519604	Bridge at Rantau
5	16.0	25.6	2519621	Sua Betong
6	10.0	16.0	2420602	Bridge at Linggi town
7	0.8	1.2	2319601	Rivermouth at Tanjung Agas

Table 4 - Proportional Distribution of Participants in Opinion Poll and the Sequence of Responses

Participant's Agency	Sequence			
	1	2	3	4
Government, semi-government, regulatory	43	22	11	7
Academic Institutions	22	11	7	4
Consultancies (Water engineers, Chemists)	29	14	5	0
Other related Organisations (fre-lance, etc.)	11	7	4	4
Total	105	54	27	15

Questionnaire 1: 51% response

Questionnaire 2: 50% response

only 15 good, the rest improperly filled

∴ 28% actual response.

Table 5 - Significance Ratings and Weights for Variables Included In the General OP WQI

Index Parameters	Mean of All Significance Ratings	Temporary Weights	Final Weights, 12-Var
DO	1.11	1.00	0.13
BOD	1.34	0.83	0.11
pH	1.50	0.74	0.10
COD	1.57	0.71	0.09
SS	1.70	0.65	0.08
TC	1.87	0.59	0.08
FC	1.90	0.58	0.08
TS	1.92	0.58	0.07
NN	2.07	0.54	0.07
PHE	2.10	0.53	0.07
AN	2.18	0.51	0.07
OG	2.32	0.48	0.06

Table 6 - List of Variables Included in the FA WQI

Code	Variable Term	Unit
DOSP	Dissolved Oxygen Saturation Percent	%
BOD	Biochemical Oxygen Demand	mg/l
PHDEF	pH Deflection from Ideal (7.0)	-
COD	Chemical Oxygen Demand	mg/l
SS	Suspended Solids	mg/l
TC	Total Coliform Count	MPN/100 ml
FC	Gaecal Coliform Count	MPN/100 ml
TS	Total Solids	mg/l
NN	Nitrate Nitrogen	mg/l
PHE	Phenols	mg/l
AN	Ammoniacal Nitrogen	mg/l
OG	Oil and Grease	mg/l

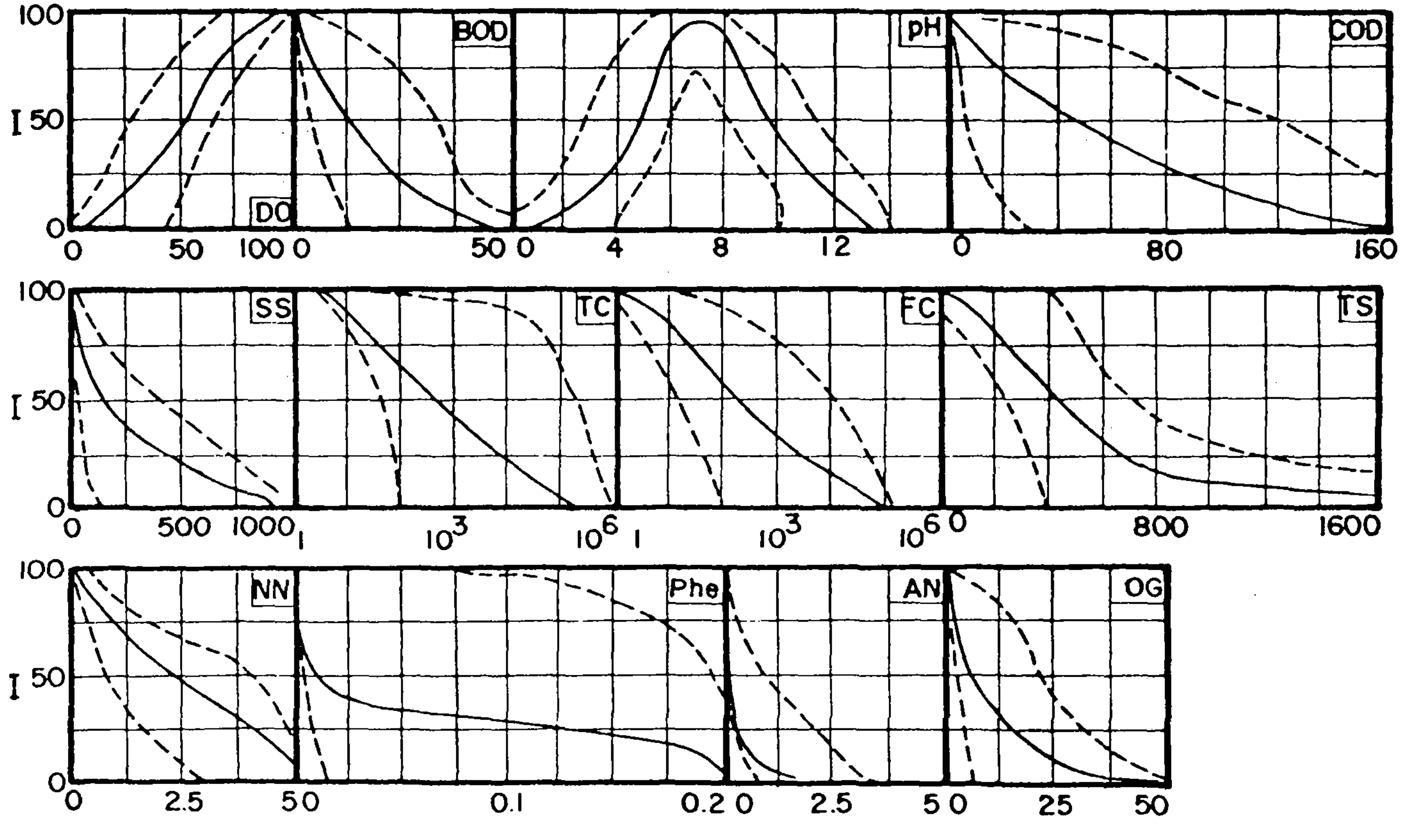

Fig. 4 - Rating Curves for Opinion poll.

Table 7 - Principal Components Analysis

Factor Matrix Using Principal Factor with Iterations				
Variables	Factor 1	Factor 2	Factor 3	Communality
DOSP	-0.80888	0.12111	-0.42066	0.84591
BOD	0.88105	-0.09264	-0.01057	0.78493
PHDEF	0.81986	-0.18168	-0.52365	0.97939
COD	0.53111	0.50933	0.61486	0.91955
SS	0.47800	-0.24322	0.25814	0.35428
TS	0.13916	0.98257	-0.04002	0.98641
NN	0.80504	-0.15102	-0.55552	0.97950
PHE	0.79935	-0.07569	0.11681	0.65833
AN	-0.01616	-0.15379	0.42248	0.20420
OG	0.09498	-0.27479	0.38107	0.22975
CHLO	0.08871	0.98144	-0.10107	0.99839
COND	0.15798	0.98144	-0.10107	0.99839
Eigenvalue	3.96170	3.41927	1.55766	
CUM PCT	44.3	82.6	100.00	
PCT of VAR	44.3	38.3	17.4	

Table 8 - Factor Score Coefficients

Variables	Factor 1	Factor 2	Factor 3
DOSP	-0.09692	-0.12100	-0.20363
BOD	-0.63116	5.42210	-6.32985
PHDEF	5.89040	-6.51147	7.21526
COD	2.94974	-2.75974	3.76841
SS	-19.39354	23.30273	-26.95001
TS	265.44580	-320.95703	371.28345
NN	1.07144	-0.78773	0.51319
PHE	0.23640	-0.29160	0.45059
AN	-0.15752	0.18951	-0.20613
OG	0.00188	-0.02135	0.05646
CHLO	-203.88989	249.45313	-285.78198
COND	-66.62256	78.33594	-92.61475

Section. A typical WQI (based on opinion poll) profile for the water quality data in 1980 is shown in Fig. 5 which displays in general a decline in the water quality with time. Another typical WQI profile (based on factor analysis) at Stations 4 and 6 are shown in Fig. 6 which shows a marked decline in water quality from the upstream to the downstream portion of the river. A general comparison of the results by two different WQI approaches factor analysis (FA) and opinion poll (OP) is made in order to determine the suitability for assessing water quality in the Linggi River. Fig. 7 and Fig. 8 represent the water quality profiles obtained by the two indices. In general both the indices seem to explain the trend, however the FA index appears to show greater sensitivity and hence the more fluctuating nature of the WQI curve.

According to both the OP and FA WQI, the river seems to have improved in two ways, i.e. going upstream and through the years 1978 to 1980. However, in 1980 alone (in all reaches except the most downstream) there has been a slight decrease in quality from February to September. Through the 3-year sampling period, according to Opinion Poll the better reaches range in quality from 60 to 85 (slightly polluted to good or acceptable) middle reaches from 45 to 65, (polluted to slightly polluted) lower reaches from 35 to 70 (badly polluted to slightly polluted). Factor Analysis also showed the same trend (75 to 100, 65 to 80, 35 to 55) as far as general water quality is concerned. The Linggi is least suited for direct consumption, requiring efficient treatment for public water supply, and is more favourable for Fish and Wildlife (especially at reach 67 km and above) and Irrigation. Station 3 and 6 were shown to be the worst polluted parts of the river (reaches 50 to 64 km and 16 to 25 km respectively) and Station 7 although the most downstream proved less polluted than its upstream neighbour station 6. Further details may be read from Mustapha (1981).

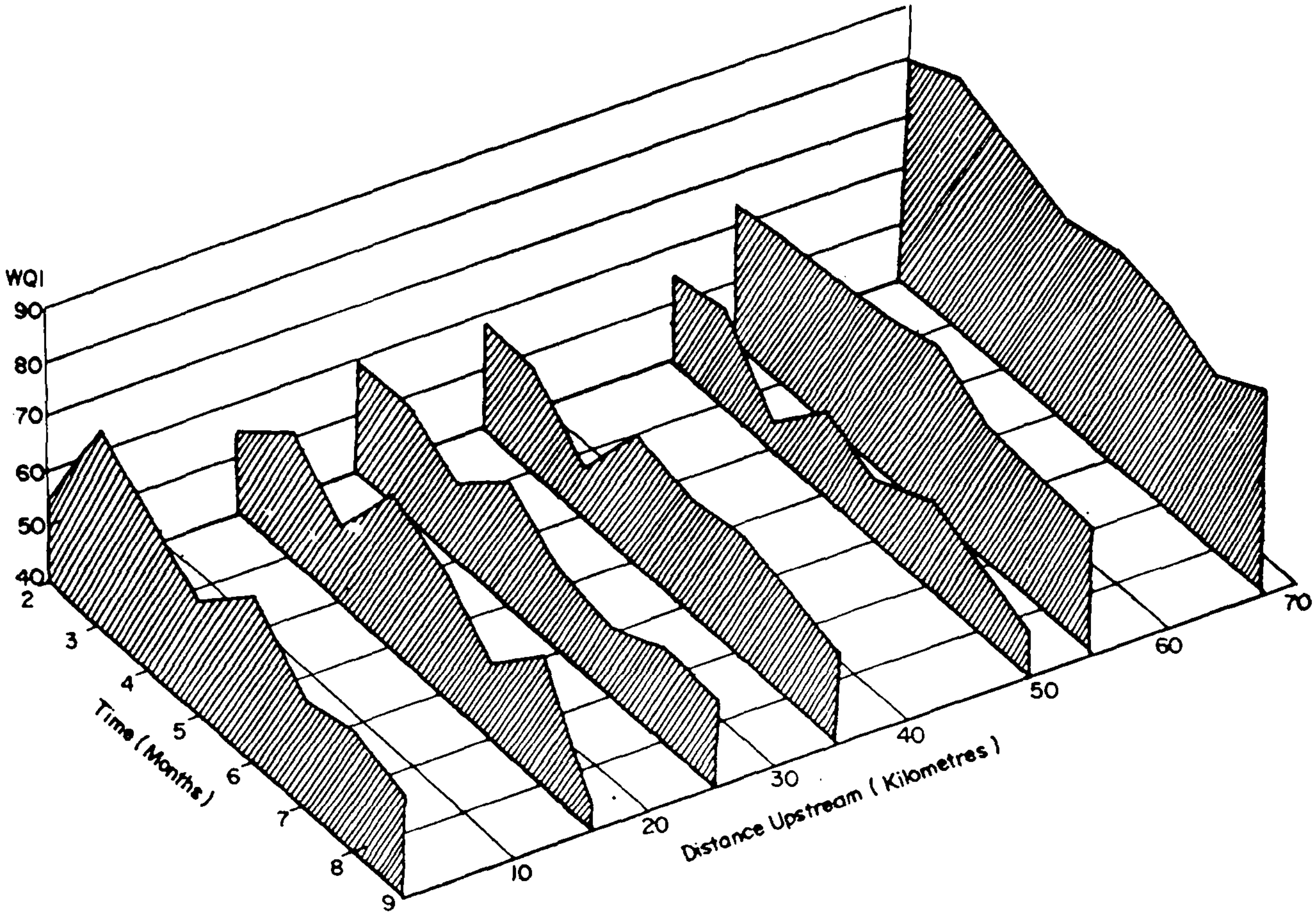

Fig.5 - WQ Water Quality Profile for the Linggi River in 1980.

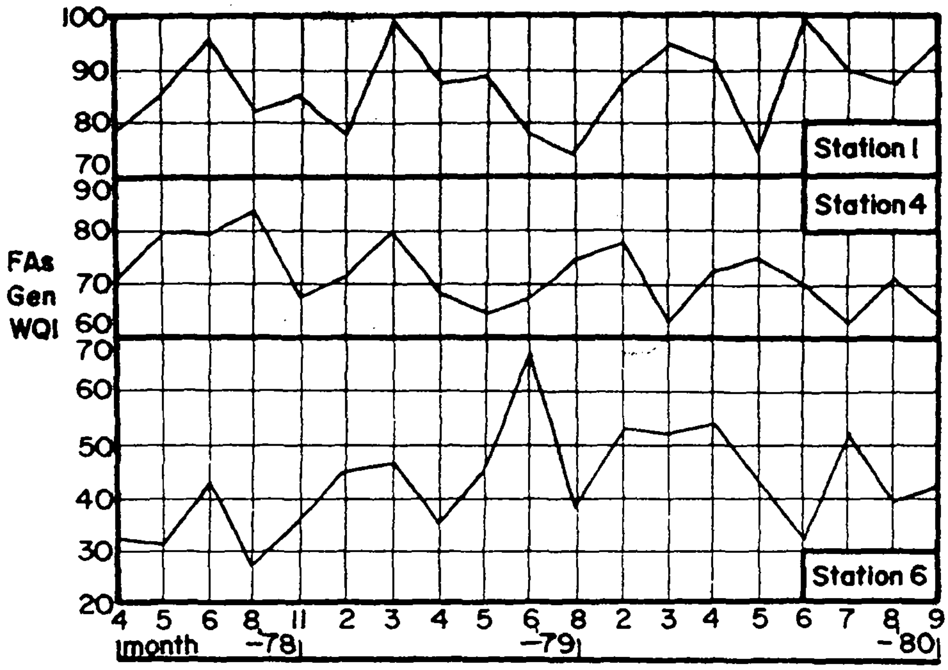

Fig.6 - Gen WQI Trend for 3 typical reaches (1978-1980)

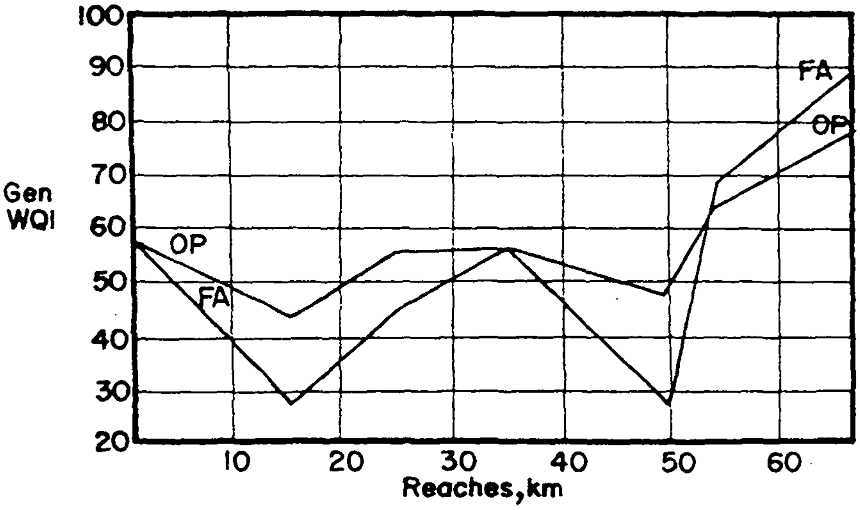

Fig.7 - Gen WQI for all reaches, Sep'80, by FA and OP Index.

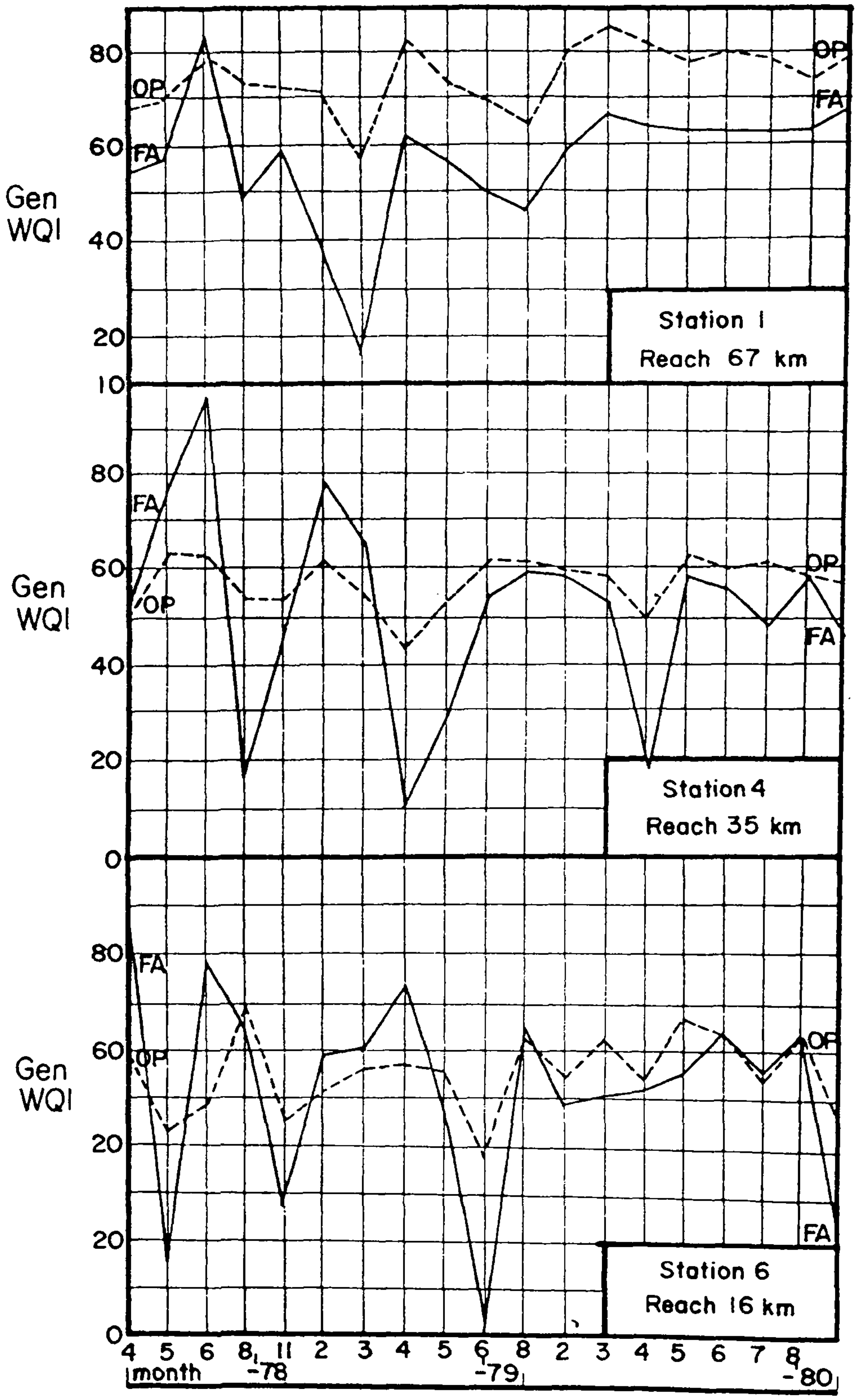

Fig.8 - Gen WQ Trend for 3 typical reaches, 1978 - 1980.

CONCLUSION

Indices (OP & FA WQI) for assessing water quality in the Linggi River in Malaysia were developed. Considering that the ratings and weightings for the OP and FA WQIs were derived by two different and exclusive ways, i.e. one by popular opinion and one purely by the use of computer, it is interesting to see the similarity in their profiles, as testified by the graphical results. The difference between them arises in the vastly fluctuating property of the FA Index at locations of extremely good or extremely poor quality water. Thus the FA Index is found to be more sensitive. Furthermore it has the distinct quality of 'clustering' important variables, therefore indicating the 'type' of pollution affecting each reach.

Now in its similarity to the computer-based FA Index, the OP Index on the other hand may have proved to a certain extent the somewhat underestimated capability of local water resources personnel in perceiving riverwater quality. In addition, continued use of the OP index may be beneficial in the long run, to assess the changes in human perception (regarding water quality) with time. However, it is suspected that, given the computing facilities, the FA Index would be preferable for a system with a large inventory of monitoring data.

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WATER QUALITY MODELING AS A TOOL FOR WATER QUALITY MANAGEMENT

Beng-Tung Ang
Department of Mathematics
University of Malaya
Kuala Lumpur, Malaysia

ABSTRACT

In this paper, we discuss first the general idea of mathematical modeling, and then the particular idea of water quality modeling and its relevance to water quality management. We then present a basic water quality model, explain the basis for its formulation, and describe some practical considerations and steps involved in its construction.

INTRODUCTION

In the formulation of water quality management plans for river basins, water quality models are often constructed and applied. In this paper we explain briefly what is meant by the term, water quality model, and what is its relevance to the overall objective of formulating a water quality management program. We shall not go into much technical details but present the main ideas by attempting to answer the following list of questions.

1. What is a mathematical model?
2. What is a water quality model and what is its role?
3. What can we do with a water quality model?
4. What does a basic water quality model look like?

5. How are the basic model equations derived?
6. What sort of model would be constructed in practice?
7. What are the steps involved in constructing such a model?

The purpose here is to encourage the use of modeling as a tool by removing some myths about modeling and by demonstrating that constructing and using water quality models can in fact be well within the means and abilities of many engineers.

MATHEMATICAL MODEL

A mathematical model of a real-world situation is just a mathematical description of the situation. The word model is used here in the usual sense. We say that some object, M, is a model of another object, S, if the following conditions hold.

(i) There is some collection of components of M, each of which correspond to a component of S.

(ii) For at least some relationships, the relation between the components of M is analogous to that between the corresponding components of S.

For instance, a child's model airplane is a model of an actual airplane. An architect's bluaprint is a model of a finished building.

Note that the model M needs not be an exact duplicate of the object S. In fact, for the concept of model to be useful, M is never identical to S.

If we keep this idea of a model in mind, and then add the adjective mathematical, we should have a reasonable picture of what is a mathematical model - a simplified representation of a real-life situation using mathematical concepts and terminology.

WATER QUALITY MODEL AND ITS ROLE

Figure 1 shows a simplified cause-and-effect chain of relevance to water quality. For instance, land use is a consequence of weather, natural features of river basin, historical events, government policies. Riverflow is a consequence of weather, natural features of river basin and land use. And so the chain continues to'uses of river water'.

Before we can formulate a meaningful management plan, each element of this chain must be studied and properly understood.

In this context, water quality modeling refers to the part where we try to describe mathematically the relationship between the effect (quality) and the causes (river flow, waste discharges).

We can also use the diagram to illustrate a possible way to formulate a water quality control plan and demonstrate a role of water quality model.

First, we fix the desired and effect. In this case, the beneficial uses of the water would first be determined, perhaps by a river classification committee based on biological, socio-economic and political considerations.

Next, the desired river water quality standards would be determined based on knowledge of the quality necessary to support the multiple beneficial uses required of the river water.

Once the quality standards are fixed, we would try to achieve them by controlling the cause (riverflow, waste discharges). A possibility is to leave riverflow to nature and try to achieve our target quality by imposing suitable limitation on waste discharges.

To know what are suitable limits, we need to know (among other things) the quantitative relation between quality and waste discharges which is exactly what the water quality model provides.

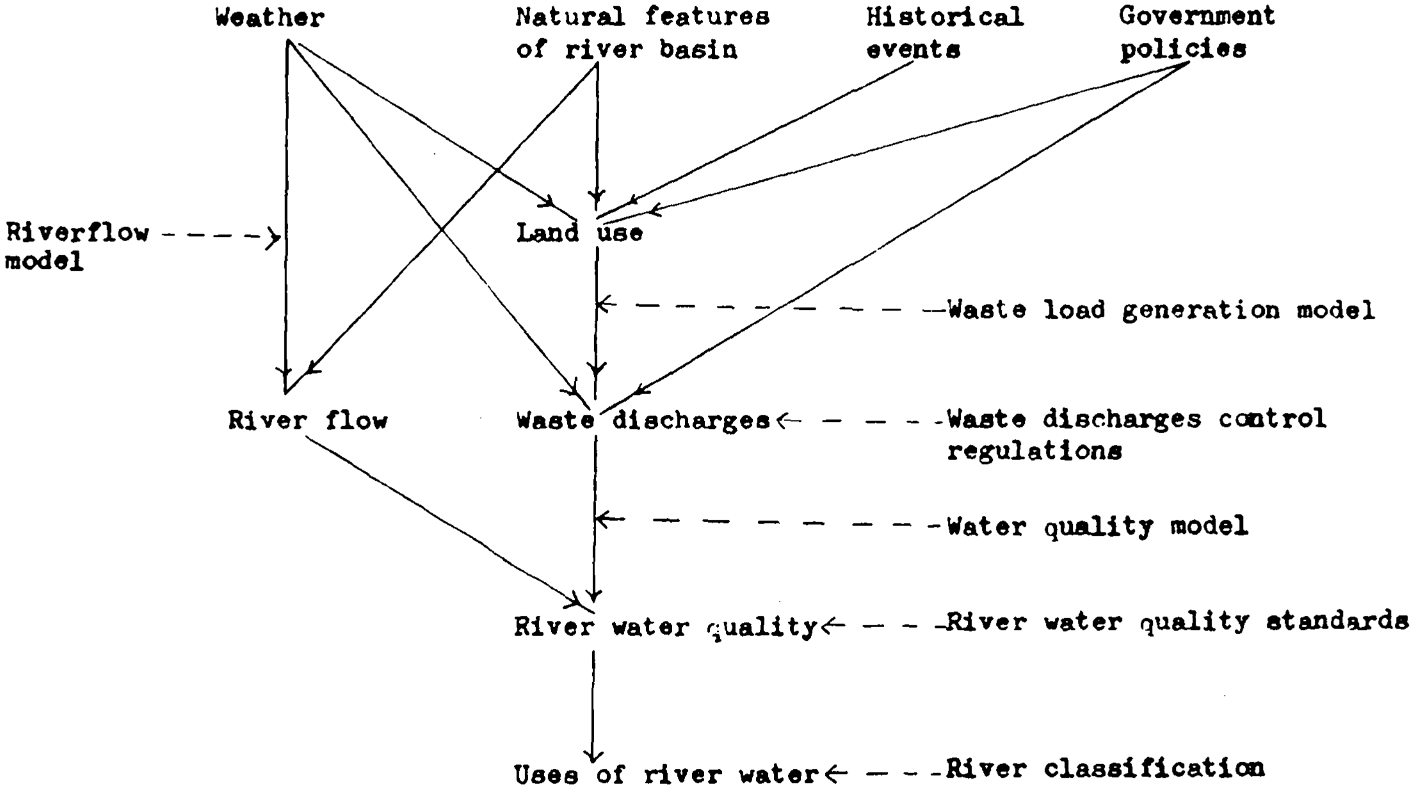

FIG. 1. Schematic diagram showing the chain of causes and effects concerning river water quality

The above refers to the present. If we wish to plan ahead, we must try to predict what is likely to happen in the future. To do that, we would need to go up one more step on the chain and construct a river flow model and a waste load generation model. These are usually models based on which we can make projections about future flow or future level of waste discharges.

USES OF A WATER QUALITY MODEL

A water quality model expresses quality as a function of waste inputs, river flow, river geometry and biological-chemical-physical parameters. We can think of the model as a black box that operates on inputs (waste discharges, riverflow) to produce output (quality). (FIG. 2)

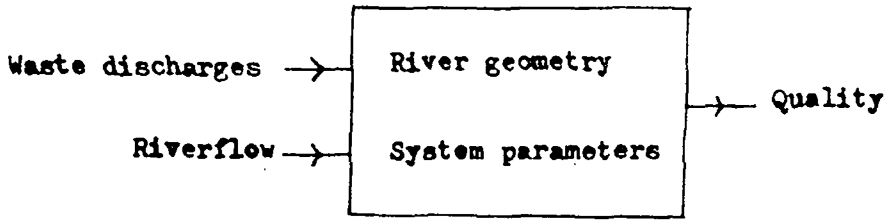

FIG. 2. Model as a black box

To be more concrete, we can even think of the model as a deck of computer program cards which operates on a deck of input cards (data on waste discharges and riverflow) to produce an output printout (water quality). (FIG. 3)

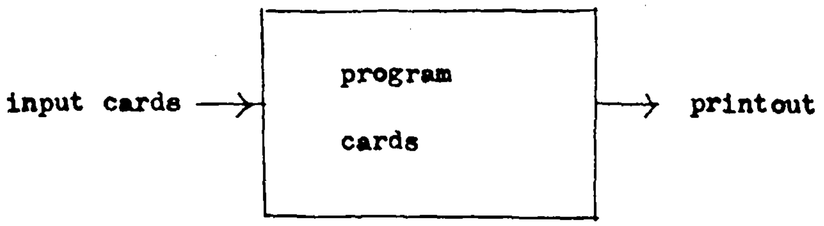

FIG. 3. Model as a computer program

There are various ways to use the model depending on the management problem at hand.

a. To examine response of the river to various waste inputs and riverflow:

This can be done by conducting simulation experiment which is a conceptual experiment where we vary waste discharges or river flow on paper and compute the corresponding water quality.

This may lead to better understanding of the river's behaviour and perhaps suggest suitable control strategies.

b. To evaluate the effectiveness of a proposed quality control procedure

Instead of implementing a certain pollution control scheme, and then waiting to see if it is 'effective', we can simulate the implementation of the scheme by incorporating it in the model, compute the consequence and thereby judge its effectiveness.

c. To estimate waste assimilative capacity of river system

Roughly speaking, this means to determine the maximum allowable waste discharges while maintaining some minimum quality standards.

In other words, we have to solve a mathematical problem of the following type:

Required that quality exceeds some minimum quality
Rearrange model equations to obtain answer of the form, Waste discharge less than maximum allowable waste discharge.

d. To determine the degree of waste treatment required to achieve specified river water quality standards

Suppose the quality control strategy adopted is waste treatment before discharge, we can incorporate this in the model, then solve the model equations to obtain the answer required.

e. To determine the optimum, among a class of possible control strategies, in conjuction with a management model

The water quality model can be incorporated into a management model where cost is considered. Among strategies that meet desired quality standards, we then compute to find the one of minimum cost.

The above refers to the present. When augmented by a riverflow model and a waste load generation model, the water quality model can be used to predict future conditions in the river. This is most essential, as it allows us to plan ahead. For instance, in (e), we need not confine ourselves to finding the optimum strategy for the present, but in fact, expand the problem and determine the optimum strategy over the next five years, or ten years.

A BASIC WATER QUALITY MODEL

The following set of equations represents a basic BOD-DO model.

$$\frac{\partial s_1}{\partial t} = - \frac{Q}{A} \frac{\partial s_1}{\partial x} - \frac{s_1}{A} \frac{\partial Q}{\partial x} - K_1 s_1 \pm \frac{S_1}{A} \frac{\partial Q}{\partial x} \pm S_{d1}$$

$$\frac{\partial s_2}{\partial t} = - \frac{Q}{A} \frac{\partial s_2}{\partial x} - \frac{s_2}{A} \frac{\partial Q}{\partial x} + K_2 (s_{2m} - s_2) - K_1 s_1$$

$$\pm \frac{S_2}{A} \frac{\partial Q}{\partial x} \pm S_{d2}$$

$$s_1(0,t) = \frac{Q_u(t) s_{u1}(t) + Q_w(t) s_{w1}(t)}{Q_u(t) + Q_w(t)}$$

$$s_2(0,t) = \frac{Q_u(t) s_{u2}(t) + Q_w(t) s_{w2}(t)}{Q_u(t) + Q_w(t)}$$

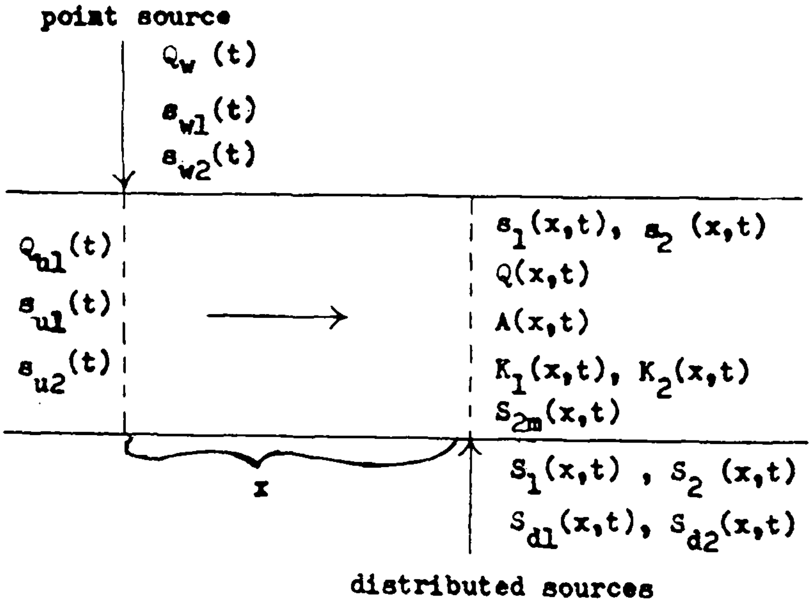

FIG. 4. Variables of the basic BOD-DO model

The symbols appearing in the equations are defined as follows and the situation represented depicted in FIG. 4.

t = time

x = distance downstream from a point source

In what follows, $v(x,t)$ refers to the value of the variable v at distance x and time t.

$s_1(x,t)$ = concentration of BOD (biochemical oxygen demand)

$s_2(x,t)$ = concentration of DC (dissolved oxygen)

$Q(x,t)$ = river flow

$A(x,t)$ = cross-sectional area of river

$K_1(x,t)$ = BOD removal rate by biodegradation

$K_2(x,t)$ = Reaeration rate

$s_{2m}(x,t)$ = saturation DO concentration

$S_1(x,t)$ = concentration of BOD in flow added to river as distributed source

$S_2(x,t)$ = concentration of DO in flow added to river as distributed source

$S_{d1}(x,t)$ = amount of BOD added to river per unit time per unit river volume by a distributed source already present in river.

$S_{d2}(x,t)$ = amount of DO added to river per unit time per unit river volume by a distributed source already present in river.

$Q_w(t)$ = flow of waste discharge at point source

$s_{w1}(t)$ = concentration of BOD in waste discharge at point source

$s_{w2}(t)$ = concentration of DO in waste discharge at point source.

$Q_u(t)$ = flow just above point source

$S_{u1}(t)$ = concentration of BOD just above point source

$S_{u2}(t)$ = concentration of DO just above point source

Notice that only one space variable is involved here meaning that we have taken a '1 - dimension assumption' that quality variables vary only longitudinally, but not laterally nor vertically.

Given Q, A, K_1, K_2, S_1, S_2, S_{d1}, S_{d2}, Q_w, S_{w1}, S_{w2} and initial conditions s_{u1}, s_{u2}, the model equations can, in principle, be solved for s_1 and s_2 at any x and t. However, this requires intensive sampling and monitoring, and the model is seldom used in this form. We emphasize here that this is sort of a prototype model. In practice we would use a suitably modified version of it.

DERIVATION OF BASIC MODEL EQUATIONS

These equations are obtained by considering the mass balance in an elemental slice of the river. (FIG. 5)

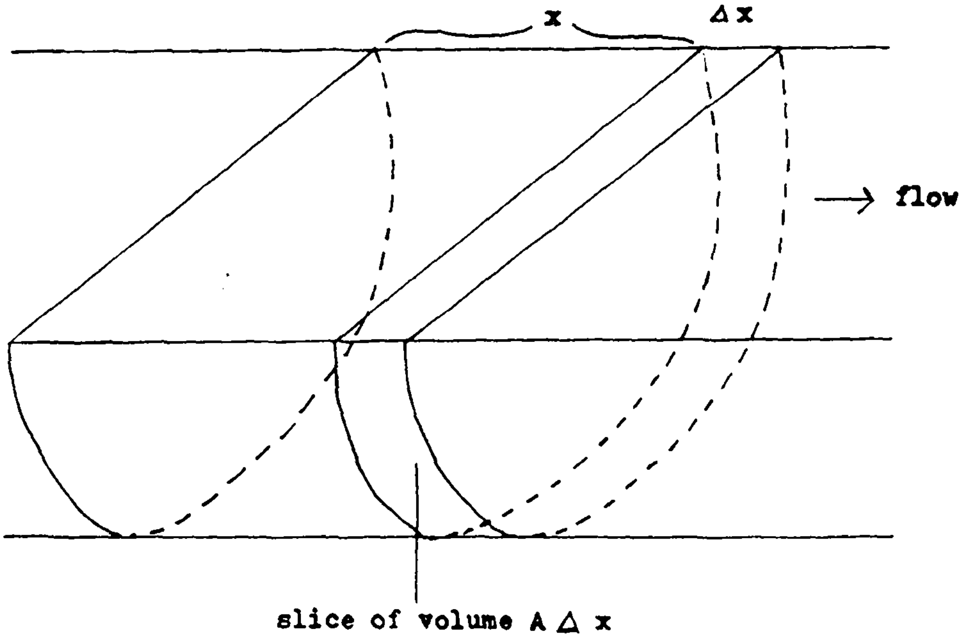

FIG. 5. An elemental slice

Consider the case of BOD. The increase in BOD in time Δt in an elemental slice of volume $A \Delta x$ can be expressed as follows.

$$A \Delta x \Delta s_1 = Q s_1 \Delta t - (Q + \Delta Q) \quad (s_1 + \frac{\partial s_1}{\partial x} \Delta x)\Delta t$$

$$- K_1 s_1 \quad A \Delta x \Delta t \pm S \Delta Q \Delta t \pm A \Delta x \quad S_{d1} \Delta t$$

where the first two terms on the right represent the effect of advection, the third term, that of biochemical reaction and the fourth and fifth terms, the contribution of distributed sources.

Expanding the second term on the right, and dividing by $A \Delta x \Delta t$ gives

$$\frac{\Delta s_1}{\Delta t} = - \frac{Q}{A} \frac{\partial s_1}{\partial x} - \frac{s_1}{A} \frac{\Delta Q}{\Delta x} - \frac{\Delta Q}{A} \frac{\partial s_1}{\partial x} - K_1 s_1$$

$$\pm \frac{S_1}{A} \frac{\Delta Q}{\Delta x} \pm S_{d1}$$

Taking limits as Δx, $\Delta t \rightarrow 0$, we obtain

$$\frac{\partial s_1}{\partial t} = - \frac{Q}{A} \frac{\partial s_1}{\partial x} - \frac{s_1}{A} \frac{\partial Q}{\partial x} - K_1 s_1$$

$$\pm \frac{S_1}{A} \frac{\partial Q}{\partial x} \pm S_{d1}$$

The equation for s_2 is obtained in a similar fashion while the effect of the point source is accounted for by the mixing equations giving s_1 (0,t) and s_2(0,t).

Note that two further assumption are taken in this derivation. First, it is assumed that there is no *dispersion* or *diffusion*. When dispersion is, in fact, significant such as pertaining in estuaries, the model must be modifies accordingly. Also, *first order reaction kinetics* is assumed here for BOD removal and reaeration.

A PRACTICAL MODEL

In practice, a *reach-by-reach modeling* approach is used. The river is first segmented into a number of *constant parameter reaches*. In each reach the parameters, Q, A, K_1, K_2, s_{2m}, S_1, S_2, S_{d1}, S_{d2} are assumed constant. The constant flow assumption implies that the distributed source/sink contribution $S_1 = S_2 = 0$. Also the river is segmented at each point source so that there will be no point source within a reach. (FIG. 6)

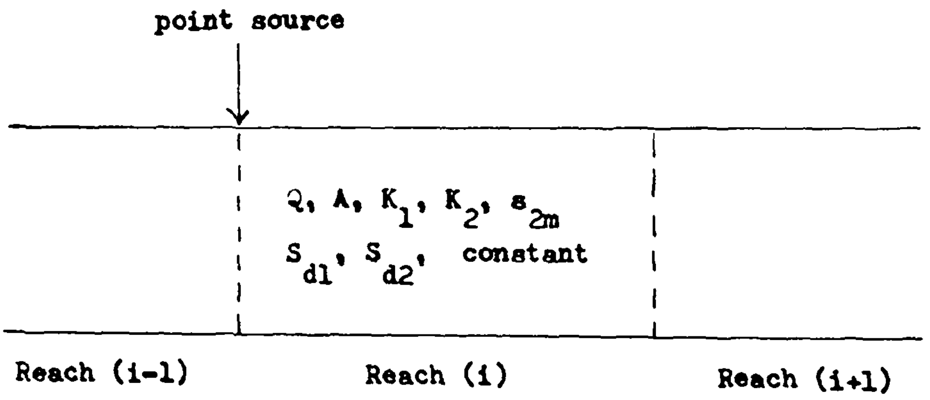

FIG. 6 Reach-by-reach approach

Sampling is further simplified by confining ourselves to temporal steady state models. Thus the point source input Q_w, s_{w1}, s_{w2} and the distributed source/sink contribution S_{d1}, S_{d2} are assumed constant with respect to time. Also,

$\frac{\partial s_1}{\partial t} = \frac{\partial s_2}{\partial t} = 0$ and the model equations can now be written as

$$u \frac{ds_1}{dx} + K_1 s_1 = S_{d1}$$

$$u \frac{ds_2}{dx} - K_2 (s_{2m} - s_2) + K_1 s_1 = S_{d2}$$

$$s_1 (0) = \frac{Q_u s_{u1} + Q_w s_{w1}}{Q_u + Q_w}$$

$$s_2 (0) = \frac{Q_u s_{u2} + Q_w s_{w2}}{Q_u + Q_w}$$

where $u = \frac{Q}{A}$ = stream velocity.

The solution to this system of ordinary differential equation is $s_1 (x) = s_1(0) \exp\left[- \frac{K_1}{u} x\right] + \frac{S_{d1}}{K_1}\left[1 - \exp(- \frac{K_1}{u} x)\right]$

$$s_2(x) = s (0) \exp\left[- \frac{K_2}{u} x\right]$$

$$+ \left[s_{2m} - \frac{S_{d1}}{K_1} + \frac{S_{d2}}{K_2}\right] \left[1 - \exp(- \frac{K_2}{u} x)\right]$$

$$+ \frac{K_1}{K_2 - K_1} \left[\frac{S_{d1}}{K_1} - s_1(0)\right] \left[\exp(- \frac{K_1}{u} x) - \exp(- \frac{K_2}{u} x)\right]$$

A point source at the junction of two reaches is taken care of by mixing equations as before.

Given measurements or estimates of the riverflow Q_u, the BOD and DO concentrations just before the first reach, of the flow Q_w and BOD and DO concentrations (s_{w1} , s_{w2}) for each point source, of the distributed source/sink contributions S_{d1} , S_{d2} and the system parameters K_1, K_2 for each reach, the BOD and DO profile, s_1 and s_2 as functions of x can be evaluated. In other words, the model is completely specified then.

STEPS INVOLVED IN MODEL CONSTRUCTION

We list here the main steps involved in constructing a practical model as outlined above.

a. Identify all point sources/sinks.

b. Identify all distributed sources/sinks.

c. Segment river into constant parameter reaches.

d. Estimate all point source/sink contributions (flow, BOD and DO concentration).

e. Estimate all distributed source/sink contributions (S_{d1}, S_{d2}) for each reach.

f. Determine system parameters K_1, K_2 for each reach.

g. Sample river to obtain observed BOD and DO profile.

h. Compute BOD and DO profile for model and compare with observed profile.

Methods of determining K_1 and K_2 deserve some mention here. Various formulas have been proposed to compute K_2 from relevant hydrological characteristics.

Example.

$$K_2 = \frac{(D_L\ u)^{1/2}}{H^{\frac{3}{2}}}$$

where D_L = diffusivity of oxygen in water

u = velocity

H = depth

For K_1, an estimate may be obtained by collecting a sample of river water and carrying out a laboratory experiment. But such a laboratory estimate may not reflect the actual rate of BOD removal in the river.

It may then be necessary to estimate these parameters from the observed BOD and DO profiles by the method of least squares.

In such a situation, care should be taken to ensure that a sufficiently large number of sampling points are established along the river in order to estimate K_1 (and K_2) fairly accurately and also to validate the model at the same time.

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Drinking Water Quality in a Number of South Pacific Island Countries

G. W. Lee
and
J. E. Brodie*

INTRODUCTION

Most South Pacific island nations lie in regions of high annual rainfall but despite this many of them have growing problems finding adequate sources of drinking water This is particularly so on raised coral islands such as Niue and Tongatapu and coral atolls such as the islands of Kiribati and Tuvalu where there are no significant hills and hence no river drainage. Fresh water supplies on such islands come only from rainwater collection from roof catchments and from boreholes.

It cannot be assumed that such water supplies are regularly tested for chemical and bacteriological quality as most of the islands are separated by large distances from possible testing laboratories and many of the required water parameters must be analysed for within a short time of the water being sampled. Portable water testing equipment has not generally been available. A summary of much of the knowledge of Pacific Island water resources can be found in Dale (1981).

The present study, which will be continuing for some time, aims to monitor drinking water quality in countries of the University of the South Pacific region (Cook Island, Fiji, Kiribati, Nauru, Niue, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu and Vanuatu) using portable chemical and bacteriological water testing equipment.

* Institute of Natural Resources
University of the South Pacific
P. O. Box 1168
SUVA, FIJI

The work has been funded by Australian aid grants to the Institute and South Pacific Commission (SPC) grants for specific projects. Work is being concentrated on water sources where aid agencies such as SPC and regional governments have projects to improve the water supply.

ANALYTICAL METHODS

pH, fluoride, chloride and nitrate were measured by direct measurement after calibration with standards on an Orion Model 407A/F specific ion meter using Orion pH and specific ion electrodes.

Total and fecal coliform counts were performed using a single-step Millipore bacteria testing field kit with a portable MF-Millipore petri dish incubator. Results are expressed as MPN/100ml.

Tuvalu

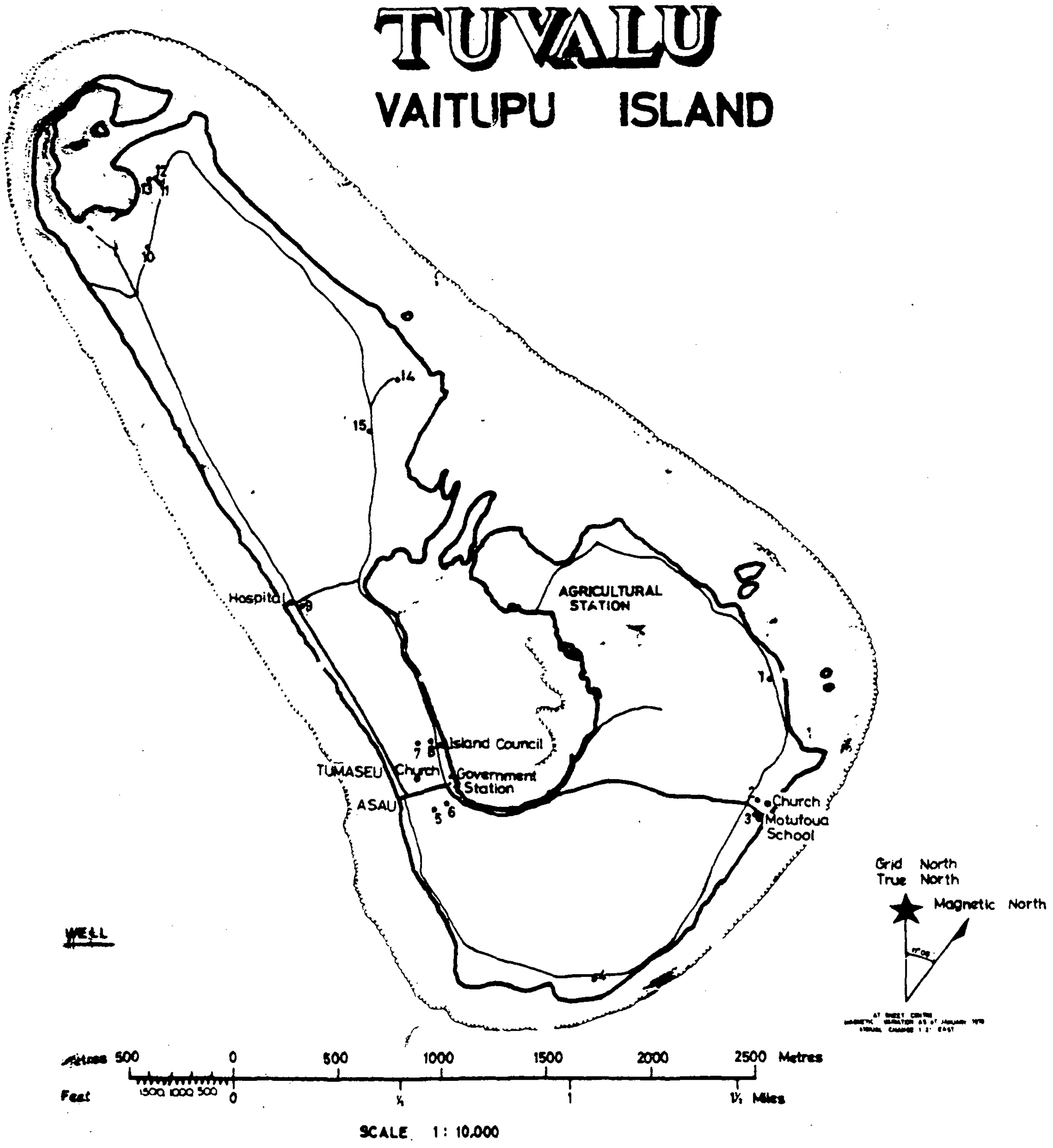
Vaitupu is the largest island of Tuvalu with a total land area of 600Ha and a population of 1200. The island has a secondary school at Motufoua and the Government is developing a agricultural station with emphasis on small animal production as well as investigating the feasibility of establishing a demonstration biogas/ integrated farming project. The people on Vaitupu obtain potable water from rainwater catchment from roofs and in times of low rainfall from four wells on the northern end of the island (Well No.s 10, 11, 12, 13 on Table 1 and Map 1). A number of other wells sited around the island are mostly brackish and are used only for washing and laundry purposes. A preliminary survey by SPC personnel (Dunn, 1978) investigated possible further development of the high quality groundwater and the present study is an outcome of an SPC project to implement this development. A regular and adequate supply of fresh water is also required for the pilot biogas digester project.

Samples were taken from each well over a period of four days. During this time each well (except No. 14) was in constant use by families living nearby. No significant change in the composition o the water was observed, even though the analyses were done when a drought of two weeks duration was broken by rainfall of 35mm. The results of analyses appear in Table 1, Well numbers correspond to the numbers on Map 1. All known wells on the island are marked on the map.

Most of the wells on Vaitupu are contaminated to a greater or lesser extent by seawater and are therefore only suitable as a source of washing water. Wells close to the more inhabited area at the southern end of the island have also high levels of coliform contamination. However, the wells at the northern end of the island, No. 10, 11, 12 and 13 are a source of acceptable quality drinking water and development work on further wells in this area by the SPC will now proceed.

TABLE 1. Well water quality (August, 1980). Vaitupu

Well (see map)	pH	Chloride mg/1	Fluoride mg/1	Nitrate mg/1	Calcium mg/1	Sodium mg/1	Total Coliform mpn	Fecal Coliform
1	7.8	450	0.25	0.96	22.6	295	300	
2	8.3	760	0.34	0.82	25.4	480	>5000	
3	8.0	25	0.25	0.51	14.0	175	>5000	
4	7.45	1140	0.20	3.9	8.3	620	1000	
5	7.6	998	0.25	2.3	5.4	980	1300	
6	7.6	3400	0.32	2.45	47.0	43	>5000	
7		unused,	stagnant					
8	7.4	62	0.25	1.55	4.5	27	>5000	
9	7.6	185	0.23	1.1	3.5	86	300	30
10	7.75	10	0.15	2.8	17.0	4.0	<100	45
11	7.45	17	0.25	0.52	3.1	13.5	400	310
12	7.4	25	0.15	2.1	3.6	13.5	300	100
13	7.55	14	0.17	0.9	2.5	3.2	200	80
14	7.85	1225	0.50	2.6	28.0	345	<100	0
15	7.75	300	0.17	2.[illegible]	15.5	70	<100	50

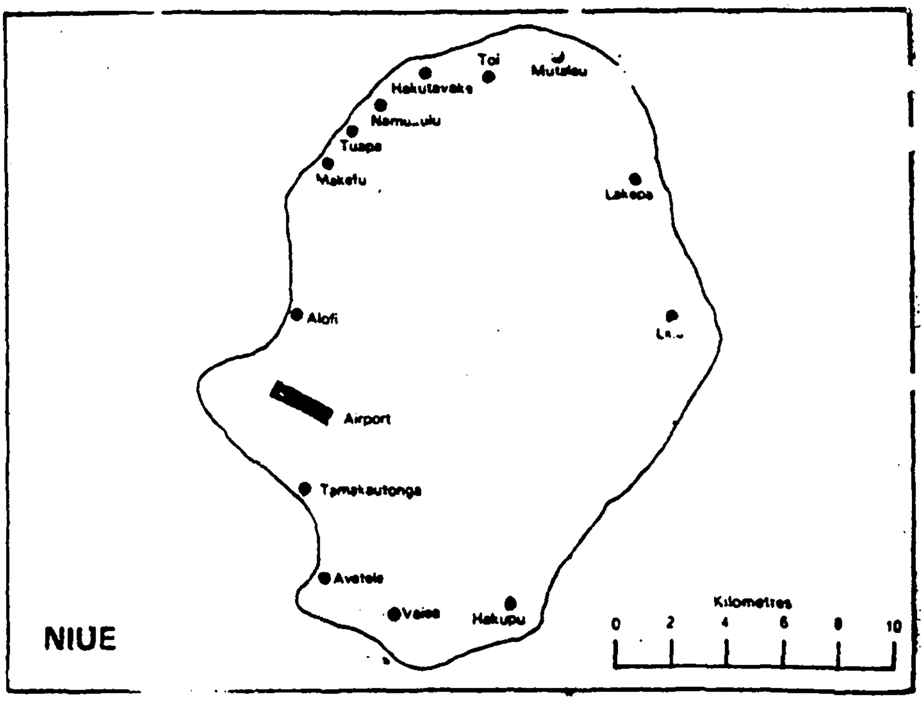

TUVALU
VAITUPU ISLAND
13
12
11
10
14
15
Hospital
9
AGRICULTURAL STATION
1
2
7
8
Island Council
TUMASEU
Church
Government Station
ASAU
5
6
Church
3
Motufoua School
4
Grid North
True North
Magnetic North
WELL
Metres 500
0
500
1000
1500
2000
2500 Metres
Feet
1500 1000 500
0
¼
1
1½ Miles
SCALE 1: 10,000

MAP 1

Niue

Niue is an isolated, uplifted coral island with an area of 260km^2 and a population of approximately 4600 (July, 1979). At present eighteen bores on the island and a number of roof catchments comprise the drinking water supply as the island has no permanent free flowing water. Previous work on the groundwater has shown that it is very hard, with high iron levels and often significant nitrate levels (Downes, 1981). Groundwater quality is now protected by the enforcing by the Health Department of a rigorous set of regulations which relate to siting of dwellings and farms and the burial of bodies in the vicinity of bores.

Seventeen bores and four rainwater tanks were tested in the present study. The results are shown in Table 2 and the bore locations on Map 2. Some bacterial contamination was noted and the high coliform count in the High School rainwater tank ascribed to the presence of a small dead animal in the tank. Further work to measure Fecal Coliform/Fecal Streptococci ratios and hence trace the source of bacterial contamination is now being planned.



MAP 2

Table I. Water quality (March 1981). Niue

Sample No.	Location	pH	Chloride mg/l	Fluoride mg/l	Nitrate mg/l	Total Coliform	Fecal Coliform
1	Airport DW	7.30	11.0	0.05	1.9	0	6
2	Airport SP1	7.40	10.0	0.06	1.0	0	0
3†	Tuila No. 1	7.05	12.0	0.06	2.0	0	0
4†	Tuila No. 2	7.05	12.0	0.08	1.4	300	0
5†	Tuila No. 3	7.15	12.0	0.09	1.65	500	4
6†	Tuila No. 4	7.30	11.0	0.09	1.7	0	0
7	Tamakautonga	7.40	9.0	0.08	1.7	0	0
8	Avetele No. 1	7.55	12.5	0.05	1.8	0	0
9	Vaiea	7.45	11.0	0.06	1.9	0	0
10	Hakupu No. 2	7.50	15.0	0.05	1.6	0	0
11	Liku No. 1	7.50	15.8	0.06	1.9	0	0
12	Lakepa No. 1	7.25	16.5	0.07	1.3	100	0
13	Mutalau No. 1	7.50	19.0	0.07	1.4	0	0
14	Toi No. 1	7.40	23.5	0.08	1.6	0	0
15	Toi No. 2	7.45	45	0.18	1.2	0	0
16	Hakut_vake No. 1	7.45	24	0.18	1.3	100	0
17	Tuapa No. 1	6.95	16	0.17	1.4	0	0
18	Tuapa No. 2	Pump not operational					
19*	Village Restaurant	7.40	16	0.10	1.3	0	0
20*	Burns Philp	7.70	0	0	0	0	0
21*	High School	6.95	0	0	1.5	1800	52
22*	Private	6.90	0	0	0	0	0

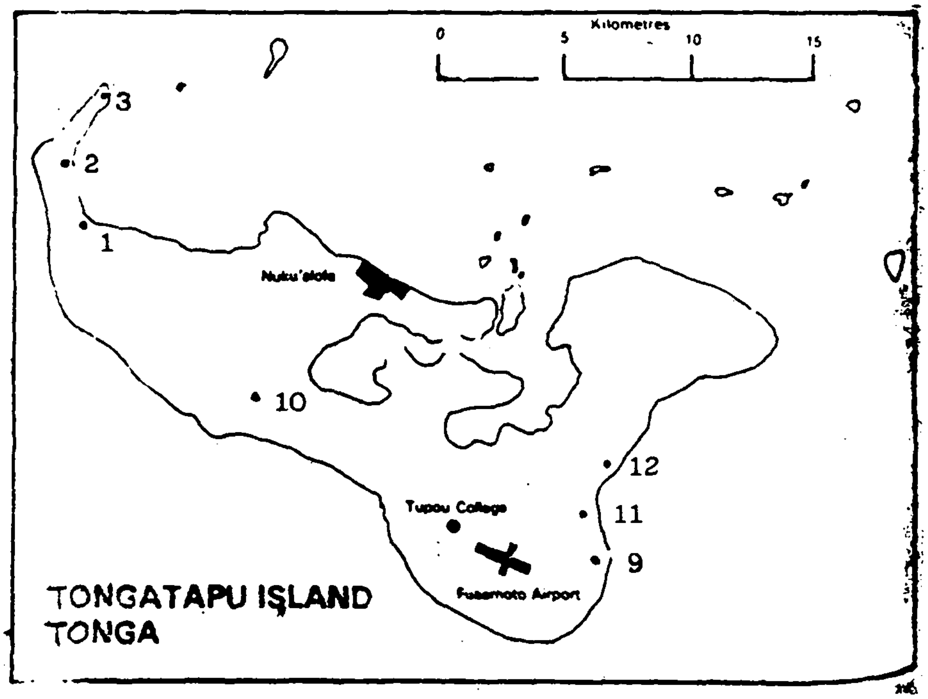
*Rainwater tanks in Alofi

†Tuila is situated immediately inland from Alofi

Tonga

The main island of the Kingdom of Tonga is Tongatapu. This is a flat uplifted coral atoll overlain with a layer of rich soil composed mainly of volcanic ash. It has an area of 260km^2 and a population of approximately 50,000 (1979). Almost all the drinking water supplies for the people of Tongatapu comes from the underground lens of fresh water. The wells range in depth from 10 to 20m and may supply more than one village, (Pfeiffer, 1971; Waterhouse, 1974, 1976). Previous water analysis results (Waterhouse, 1981; Downes, 1981) have shown a good quality water but with high calcium hardness as might be expected in the location.

Twelve heavily used bores were chosen for testing in the present study on the advice of the Medical Officer for Health. The results are shown in Table 3 and the bore locations on Map 3.



MAP 3

Table 3. Water quality (March 1981). Tongatapu

Sample No.	Location	pH	Chloride mg/l	Fluoride mg/l	Nitrate mg/l	Fecal Coliform
1	Fou'i	6.40	260	0.10	0	0
2	'Ahau	6.45	260	0.11	0	0
3	Ha'atafu	6.50	265	0.10	0	0
4*	Maui	6.65	52	0.08	0	0
5*	Coconut Board	6.65	52	0.08	0	0
6*	Joe's Place	6.65	53	0.09	0	0
7	Reservoir	6.40	71	0.09	0	0
8	Airport	6.65	18	0.08	0	0
9	Lavengatonga	6.50	57	0.08	0	36
10	Tokomololo	6.40	38	[illegible]	0	0
11	Fatumu	7.00	110	0.08	0	0
12	Haveluliku	6.90	480	0.08	0	160

* In the capital - Nuku'alofa

As can be seen from the results salt water intrusion is becoming a problem in a number of the bores (Nos. 1, 2, 3 and 12). Two of the bores also show signs of bacterial contamination. Since aquifers in coral formations such as in all the cases in this study are invariably unconfined contamination from surface pollution is always a problem. Further work in the outer islands of Tonga is now being planned.

ACKNOWLEDGMENTS

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WATER TREATMENT TECHNOLOGY FOR RURAL DRINKING WATER SUPPLIES

By

K. M. Yao

c/o WHO, P O Box 2550, Kuala Lumpur, Malaysia

ABSTRACT

The provision of safe drinking water supplies in rural areas is one of the key elements of the United Nations Water Decade Programme. Groundwater of suitable quality is normally selected for this purpose. However, there are cases where surface water is the only available source for rural drinking water supplies. Such a source is often subject to high turbidity especially during and immediately after heavy storms, as well as microbiological contamination of human and animal origin. Existing treatment methods are usually too complicated or too expensive for rural applications.

The paper presents a water treatment system consisting of extended plain sedimentation of 7-10 days and slow sand filtration for rural areas. Such a treatment system does not require sophisticated mechanical equipment, use of chemicals and skilled operators and is able to produce water meeting drinking water quality standards. In places where land is not available for the relatively large extended sedimentation tank or the long detention time in the extended sedimentation tank tends to induce algal growth, tube settlers could serve as an alternative to open plain sedimentation to achieve similar performance.

INTRODUCTION

The provision of safe drinking water supplies in rural areas is one of the key elements of the United Nations Water Decade Programme. Groundwater of suitable quality is normally selected for this purpose. However, there are cases where surface water is the only available source for rural drinking water supplies. Such a source is often subject to high turbidity especially during and immediately after heavy storms, as well as microbiological contamination of human and animal origin. Existing treatment methods are usually too complicated or too expensive for rural applications.

Slow sand filtration represents an ideal, well-established water treatment process suitable for rural areas where costs of land and labour are normally not a problem. A slow sand filter, if properly operated, is able to produce finished water of high sanitary quality, often without the need for further disinfection. However, postchlorination should be provided whenever feasible to protect against post contamination. The filter can be constructed with local materials and operated without skilled personnel. The main drawback of slow sand filtration is that, to be economical, the influent turbidity should be preferably kept below 30 units (Cox, 1969). Many of the mountain creeks used as sources for rural drinking water supplies may provide water of such clarity most of the time during the year. However, turbidity could increase to hundreds of units during the flood season.

This high turbidity is mainly due to natural materials such as clay particles, which could easily clog all the slow sand filters in a treatment plant in a very short time, if there is no adequate prefiltration treatment to reduce the raw water turbidity to a satisfactory level for slow sand filtration. Hence, the key to the successful application of slow sand filtration in many cases is the availability of appropriate prefiltration treatment processes. The purpose of this presentation is to propose simple prefiltration treatment which, together with slow sand filters is able to produce water meeting drinking water quality standards for rural areas. The prefiltration treatment proposed is technically compatible with slow sand filtration in terms of simplicity, use of local materials and without the need for skilled operators.

EXTENDED PLAIN SEDIMENTATION

Plain sedimentation refers the use of properly designed normally rectangular open tanks for the removal of turbidity without chemical coagulation. The pocess is simple and does not require skilled personnel for its operation. Plain sedimentation is however considered to be inadequate for highly turbid raw water containing mainly fine clay particles. This conclusion is presumably based on observations on the performance of many existing plain sedimentation tanks. Recent field experience and laboratory studies, however, indicate that this unsatisfactory performance of plain sedimentation could be due to inadequate design rather than deficiency in the process itself. Most existing plain sedimentation tanks are deep tanks designed for a detention period of around one day with no consideration on the effect of tank depth to settling efficiency. Laboratory test results indicate that the turbidity of raw water from an irrigation canal with an initial value of 250 units could be reduced to 37 units after quiescent settling for 5 days (Yao, 1975). Hence the main problem for the poor performance of existing plain sedimentation tanks is most probably insufficent detention. The term extended plain sedimentation used here refers to plain sedimentation with detention periods far greater than previously used.

It is now well recognized that, for a given detention time, a shallower sedimentation tank would perform better than a deeper one. This is, as a matter of fact, the main basis for the development of tube settlers (Yao, 1973). Many existing plain sedimentation tanks are extremely deep, resulting in poorer settling performance for their designed detention period.

Fig. 1 presents an experimental extended plain sedimentation tank performance curve, showing settling efficiency at different overflow rates expressed in m/day. The curve is based on a series of column settling tests using raw water taken from an irrigation canal (Yao, 1975). Similar curves can be easily constructed by following the same technique described in the reference. However, since natural clay particles are probably not totally different from one place to another, Fig. 1 could serve as a general guide for those without adequate facilities to develop their own curves.

APPLICATION OF EXPERIMENTAL PERFORMANCE CURVE

A first step in applying the experimental performance curve such as the one in Fig. 1 is to determine the required turbidity removal efficiency. As mentioned above, the turbidity of the settled water is preferably no more than 30 units. This leaves the raw water turbidity to be determined by sampling. It is however important to select an appropriate raw water turbidity for practical use. Raw water turbidity may become extremely high for short periods during the flood season. It is not advisable to use those peak values as the design basis. First, the long detention time in extended plain sedimentation tanks may even out such peak values to a certain extent. Second, a slow sand filter may handle influent turbidity slightly in excess of 30 units for very short periods. A reasonable approach would be to use the average of maximum raw water turbidity values measured during the flood season. Generally speaking, a removal efficiency around 85 - 90 percent should be adequate, with extreme cases up to 95 percent.

Once the desirable removal efficiency is known or given, the application of the experimental performance curve is straightforward. Consider a design problem with an average maximum raw water turbidity of 250 units, the sedimentation tank to be 2.5 m deep, the design capacity of a treatment plant design being 20 m^3/day and the desired settled water turbidity of no more than 30 units. The required turbidity removal efficiency is therefore

$$\frac{250 - 30}{250} \doteq 88\%$$

From Fig. 1, for a turbidity removal efficiency of 88 percent, the corresponding design overflow rate should be 0.4 m/day, which means:

$$\text{Detention time} = \frac{2.5}{0.4} = 6.25 \text{ days}$$

$$\text{Volume of tank} = 20 \times 6.25 = 125 \text{ m}^3$$

$$\text{Area of tank} = \frac{125}{2.5} = 50 \text{ m}^2$$

FURTHER DESIGN CONSIDERATIONS

The experimental performance curve is developed based on quiescent settling tests. Considering occasional unusual fluctuations in raw water quality and possible haphazard plant operation in rural areas, it would be a good practice to apply, say, a design safety factor of two to insure reasonable performance under unforeseeable adverse conditions provided that land is available for this added space requirement. With the application of such a safety factor, the design detention time, volume and area of the tank in the numerical example would all be doubled. The large tank capacity resulting from a long design detention time could be useful for storage purposes in cases where the raw water supply is subject to occasional disruptions such as annual irrigation canal cleaning.

Preferably, the extended plain sedimentation facility should have at least two units so that one can be shut down for cleaning during the time of the year when the raw water is relatively clean. Provisions should also be made to bypass the sedimentation facility altogether especially in places where raw water is very clear for a certain period of the year.

Field experience in Pakistan shows that extended plain sedimentation works equally well by the fill-and-draw batch method. In this case, a plain sedimentation tank is filled with raw water as rapidly as possible, left to quiescent settling for the desired period and then drawn off for slow sand filtration. One advantage of this method is the possibility of filling the tank only when the raw water is relatively clean since water intake is not on a continuous basis. There should be at least two settling units in such a plant so that one can be filled up for settling while the settled water in the other unit is being withdrawn for slow sand filtration.

Because of the relatively large volume involved in extended plain sedimentation, attention should be given to low-cost construction methods such as earthen embankment paved with plain concrete or earthen ponds covered wth rubber membrane provided that the latter is locally available.

PLAIN TUBE SETTLING

The long detention required for extended plain sedimentation could be a problem in places where adequate land is not avaialble and in cases where there is a possibility of algal growth.

One solution to the problem is to use tube settlers which require much less space than open sedimentation tanks and are completely free of algal growth sice water flows in closed passages.

Even though some theoretical studies on tube settling are applicable to settling of both coagulated and uncoagulated water (Yao, 1970), most experimental investigations on tube settling and almost all practical installations of tube settlers are for coagulated water. Fig. 2 however presents experimental results of tube settling of uncoagulated natural water taken from an irrigation canal (Yao, 1979). Tube settlers for uncoagulated water is referred to as plain tube settlers here for proper differentiation. In Fig. 2, the triangles are for actual experimental results and the squares are the same experimental results with the application of a design safety factor of two. For instance if the overflow rate of a tube settling setup computed from the physical dimensions of the settler and flow rate is 0.1 m/day, the measured performance is taken as if from a tube settling setup designed for an overflow of 0.2 m/day. The settlers, 11/8 for square settlers and unity for parallel-plate settlers.

For coagulated water, d is normally no more than 10 cm, L is normally no more than 2 m, and the flow through velocity should be preferably less than 0.18 m/min (Yao, 1973). Since the function of plain tube settlers is to remove particles of down to much smaller sizes, both d and v should be kept as small as possible.

To illustrate the design procedure described above, let us consider again the example given above. The required turbidity removal efficiency is 88 percent. From Fig. 2, using the column settling curve, the required overflow rate is 0.09 m/day. Applying a design safety factor of two, the design overflow rate is therefore

$$\text{Design overflow rate} = \frac{0.09}{2} = 0.045 \text{ m/day}$$

Assuming that the tube settler will be of horizontal parallel-plate type having a depth of 2.5 cm and a length of 100 cm, by Equation (1),

$$v = \frac{0.045 \times 100}{2.5} = 1.8 \text{ m/day}$$

$$\text{Detention time} = \frac{1}{1.80} = 0.56 \text{ day}$$

$$\text{Total volume of settlers} = 20 \times 0.56 = 11.2 \text{ m}^3$$

The detention time given above refers to the period the water actually stays inside the tube settler. Considering the space needed for inflow distribution and effluent collection, the overall capacity of the plain tube settling facility would be around the equivalent of a detention period of one day which is about one-sixth of that required for an open extended plain sedimentation tank or one-twelfth of the open tank if a design safety factor is also applied to the latter.

It is important to mention that Fig. 2 is based on test results of a particular natural water. A similar graph should be developed for the natural water the tube settler is to be designed for, if feasible. Fig. 2 may serve at least as a general guide in cases where facilities are not available to develop such a graph for use.

NEEDS FOR FURTHER APPLIED STUDIES

Following applied studies are needed to facilitate the general application of the water treatment system proposed in this paper:

(1) A simple, reliable method to determine the algal growth potential of a given raw water under the prevailing evironmental conditions for decision-making on the suitability of extended plain sedimentation in a given case.

(2) Design and full-scale testing of modular plain tube settlers for use in rural areas.

(3) A convenient method for desludging plain tube settlers.

SUMMARY AND CONCLUSIONS

Slow sand filtration is ideally suited for rural applications. A key element in enabling slow sand filters to be more widely used is the provision of prefiltration treatment processes which will reduce raw surface water turbidity to an acceptable level for slow sand filtration and which are compatible with slow sand filtration in process simplicity and reliability.

Both extended plain sedimentation and plain tube settling are able to fulfill these requirements under favourable physical/environmental conditions. However, further applied studies are necessary to insure the universal applicabilty of these prefiltration treatment processes in rural areas.

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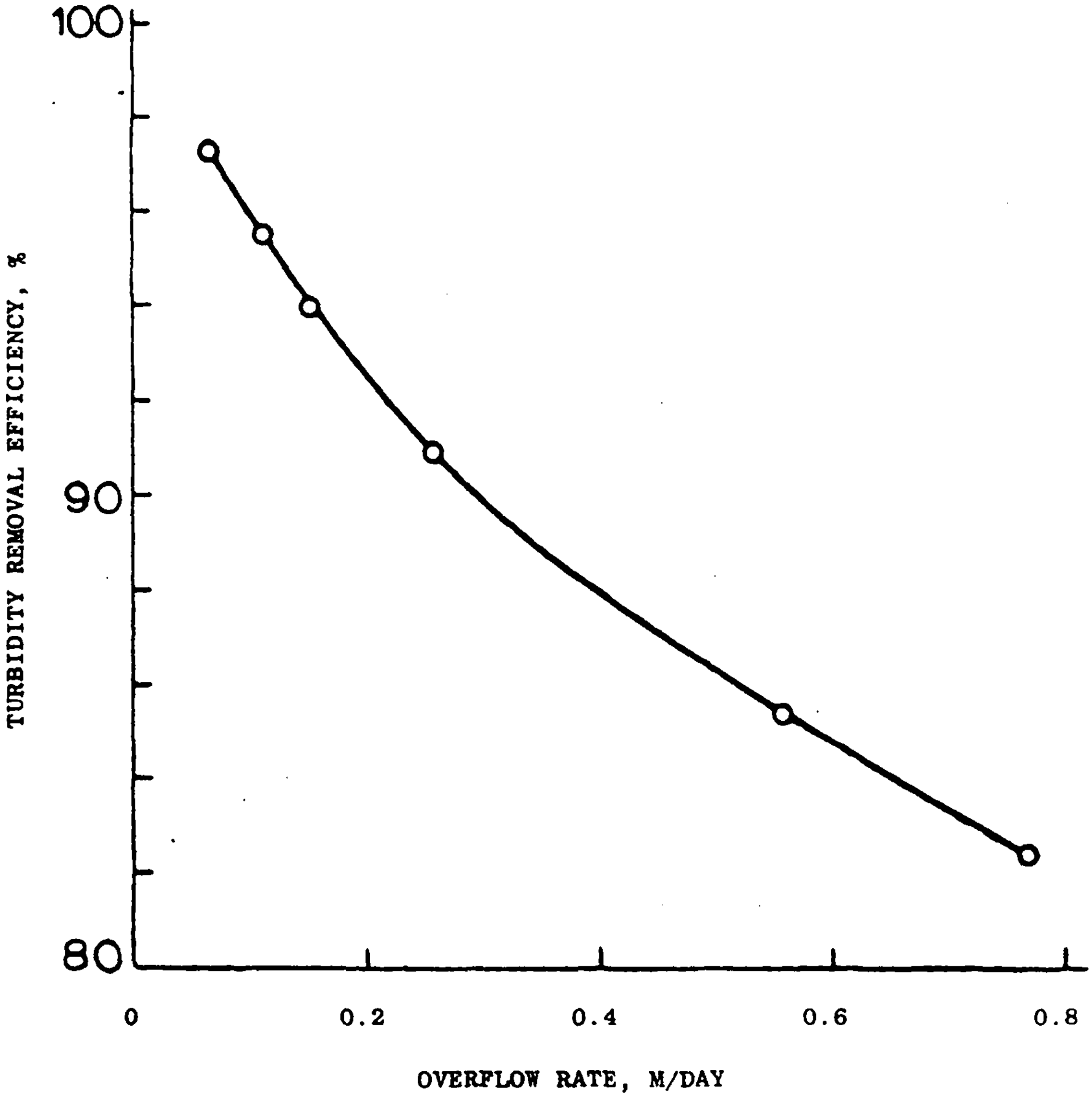


FIG. 1 EXPERIMENTAL PERFORMANCE CURVE FOR EXTENDED PLAIN SEDIMENTATION

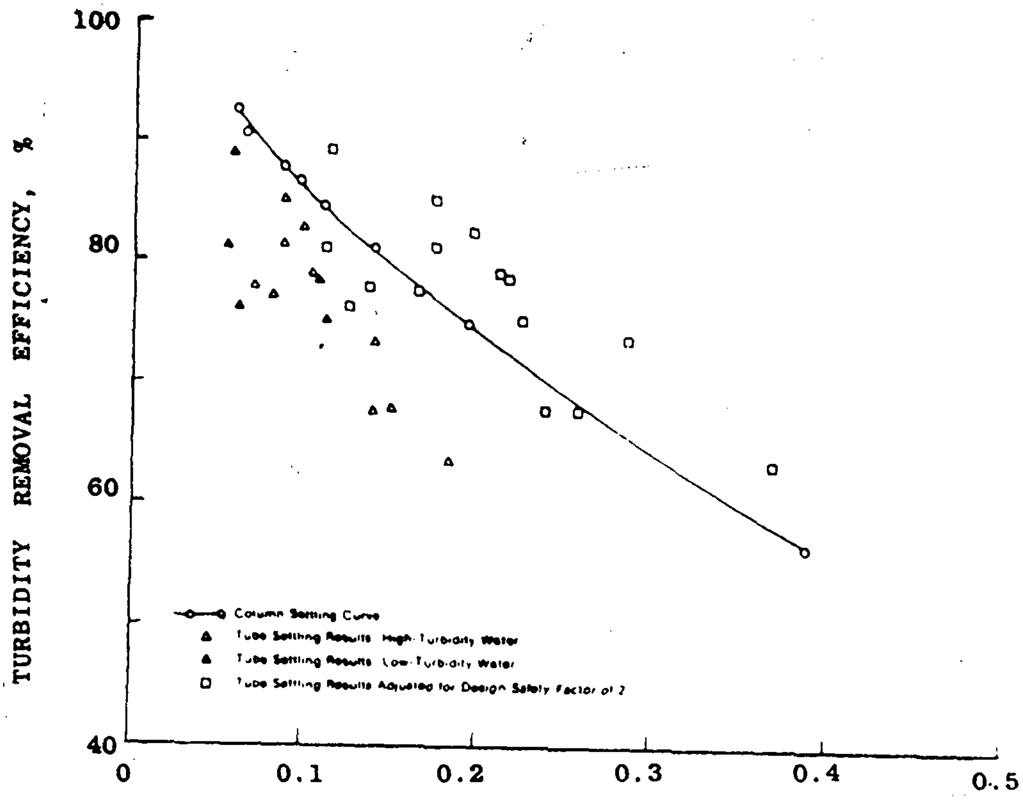


FIG. 2 EXPERIMENTAL RESULTS OF PLAIN TUBE SEDIMENTATION OF NATURAL WATER

WASTE WATER TREATMENT BY SOIL

Tadashi Tanimoto
Japanese Colombo Plan Expert
for National Water Resources Study, Malaysia

Public nuisance, especially water pollution, is becoming more and more serious in the world corresponding to the population growth and economic development. Malaysia enjoyed a remarkably rapid economic growth in the 1970's and it is expected that this high economic growth will continue in the future. There are many palm oil mills and rubber factories in Malaysia. Due to the effluent from these factories, households and manufacturing industries, the water pollution problem has become serious in the public water area especially in rivers. The Environmental Quality Act was enacted in 1974 to prevent water pollution in rivers by restricting the pollution load from palm oil mills and rubber factories, manufacturing industries and sewerage and is enforced by the Division of Environment. Many studies on sewerage development are being carried out and several sewerage systems are under construction in order to prevent water pollution in rivers. However, it takes a very long time to develop a sewerage system and it incurs great expense.

The waste water treatment technology which was newly developed in Japan recently will be introduced here. This is the most economical and energy-saving method as it makes best use of natural characteristics, and treatment within individual household is possible if there is a small garden. This method may be made available Malaysia especially in the rural areas because there are large pieces of land.

1. Historical Method

The activated sludge method is very popularly used for waste water treatment, and many people are believing that this must be the best method. This is a method whereby oxidation is promoted with the help of aerobic bacteria by blowing air and stirring waste water. The merits of this method are that it is suitable for mass treatment and it is convenient for urban area where land for treatment is limited. Moreover, treated water is expected not to vary in its water quality. Though this method can remove about 90% of organic matters, which are expressed in biochemical oxygen demand (BOD) concentration, it cannot remove nitrogen and phosphorus which are the causes of eutrophication in the closed water area. Other defects are that it consumes a lot of energy because only about 5% of blown air would be available for the oxidation and there is a problem of foul odour near the treatment plant.

The methods for waste water treatment which have been used historically are:-

(1) Draining of waste water without treatment
(2) Infiltration to the underground through pit
(3) Oxidation pond
(4) Trickling filter
(5) Biocontact
(6) Activated sludge

The merits and demerits of above-mentioned methods are as follows:-

(1) Draining of waste water without treatment

Pollution in public water area, foul odour and sanitary problem will arise. This method is allowed only when the population and economic activity are very samll though this is the cheapest way.

(2) Infiltration to the underground through pit

Since the clogging by the suspended solid (SS) on the soil surface at the bottom of the pit will occur, only a small volume of waste water will be allowed. This method can purify waste water well as regards its BOD concentration, nitrogen and phosphorus and is very cheap but has the demerits of foul odour and sanitary problem.

(3) Oxidation pond

This is a valid method to remove SS and reduce BOD concentration fairly well but cannot remove nitrogen and phosphorus. It also has defects of foul odour and requirement of a large piece of land compared with the activated sludge method.

(4) Trickling filter

The quality of the purified water by this method will be the best among methods (1) to (4), but this is costly, not suitable for massive treatment and faces foul odour and sanitary problem.

(5) Biocontact

This is a way to purify the waste water by soil utilizing the fact that there is much more bacteria in a solid than in the water. This method can save space but is costly.

(6) Activated sludge

The outline is as mentioned above. This is suitable for the urban area because the waste water will be collected through pipelines to the treatment plant which can be located in sparse population areas.

2. New Waste Water Treatment by soil

The number and kinds of bacteria in the soil are much more than in the water and to utilize oxygen in the soil is more effective than in the water from the energy consumptive point of view.

Oxygen is abundant in the interval about 70 centimeters from the soil surface and the oxidation function is very remarkable with the help of aerobic bacteria. For this reason, it is very easy to remove organic matters, i.e., BOD, and to transform nitrogen ammonia (NH_4-N) into nitrogen nitrate (NO3-N). On the other hand, nitrogen nitrate is transformed into nitrogen gas by anaerobic bacteria in the areas deeper than 70 centimeters from the soil surface where a little nitrogen exists. Soil has a characteristic of absorbing phosphorus almost infinitely.

It is an important fact that the soil is not contaminated even if it is utilized to remove organic matters, nitrogen and phosphorus for a long time. Heavy metals which injure the health of human being are not removed but contaminated the soil. These metals are not removed by any of the methods mentioned in the 'Historical Methods' aforementioned.

The new method is to treat waste water by the above-mentioned purifying capacity of the soil, and utilize both capillary and gravity action through a trench dug under the ground. It has no clogging problem because it does not use the bottom of the trench but use the upper sides of the trench.

The water quality purified by this method is far better than the activated sludge method. It is easy to remove more than 95% of organic metters if the waste water is more or less 200 ppm in BOD concentration. Nitrogen and phosphorus which causes entrophication in the closed water area will be removed . more than 80% and 95% respectively. NH_4-N which is very difficult to treat is nitrified almost completely to NO_3-N and this is denitrified in the anaerobic region. Coliform is also reduced less than 30 per ml. These figures are almost incredible for the people who belive that the activated sludge method is the best. Consumed energy is almost negligible because air is supplied naturally from the soil surface. Some examples are shown in Table 1.

The volume of sludge produced is very small because sludge produced would be eaten or broken down by earthworms and other microorganisms living in the soil.

This method was developed in Japan recently and much data have been collected. Most of them are for the effluent from households, hotels, offices and schools, but some of them are for the effluent from pig raising of which the BOD concentration is more than 2,000 ppm. Validity of this method was verified through more than 500 examples. There is no sanitary problem and odour because it is covered with soil.

The treatment capacity of soil is desired to be about 30 to 50 liters per square meters. If the volume treated per square meters increases, the quality of the water treated becomes bad; on the other hand, better water quality is expected in the reverse case. Though this method requires larger expense of land compared with the activated sludge method, it is very suitable and recommendable to Malaysia especially in the rural area where there is sufficient land. Comparison of the various methods is shown in Table 2.

The structural flowsheet consists of adjustable settling tank and contact aeration bed. The figures are illustrated in Fig. 1 for flowsheet, Fig. 2 for adjustable setting tank, Fig. 3 for longitudinal section of contact aeration and Fig. 4 for cross section of contact aeration bed.

In Fig. 3, waste water coming from the left (here, it is mixed with miscellaneous effluents from the kitchen, laundry room, lavatory, bathroom, etc.) first flow into the sewer intercepting chamber with a filter net in its interior. After eliminating as much of the S.S. (suspended solids) there as possible, the water enters the perforated pipes in the right side laid in the trench.

3. Conclusion

This system seems to be readily available for the rural area. Even in the urban area, if there are suitable land such as parks or unutilized land, the soil under those land can be utilized. Individual houses can also utilized if they have some pieces of garden. The soil surface must not be paved but can be turfed or used for other purposes. The start of the experimentation of the system is recommended as soon as possible on a small scale to check its applicability to Malaysia.

Table – 1

Test Sites	Private Houses						School		Offices				Domitory	
	Mr. U's H. (Nagano Pref.)		Mr. A's H. (Nagano Pref.)		Mr. M's H. (Nagano Pref.)		Kosaka High School (Akita Pref.)		Office S. (Iwate Pref.)		Office K. (Iwate Pref.)		Domitory Y. (Akita Pref.)	
Item Date	20 Feb. '78		4 May '78		4 May '78		25 Jan. '79		28 Nov. '79		22 Dec. '80		17 Oct. '79	
C O D ppm							18.2	0.34		1.40		1.62	34.8	1.34
B O D ppm	285	2.6	693	1.5	3680	2.9	18.6	0.51		0.68		0.68	188	0.98
S S ppm	375	ND	970	34	1700	35	100	2.1		< 1		1.0	34.0	< 1
Coliform$^{\cdot ml}$	25000	0	1300	4	900	0				< 30		< 30		
T - N ppm	7.71	4.12	1.0	0 4			42.7	27						

Remarks; Left column is before treatment
Right column is after treatment

Table 2 A Comparison for Different Treatment Formulae

		Prolonged aeration	Percolation filtering	Biocontact (Rotary disk process)	Soil-type contact aeration
Characteristics of treatement formula		The activity of aerobic bacteria is accelerated by blowing air into waste water and the supernatant separated through sedimentation in the settling tank is disinfected and released	The supernatant sedimentarily separated by initial sedimentation is percolated into a bed filled with gravel and consumed by micro-organisms living on the surface of the gravel. It is then filtered, disinfected and released.	A disk is dipped half into waste water having been separated through initial sedimentation The water is subjected to both aerobic and anerobic treatment by turning the disk and, after being sedimentarily separated through final sedimentation, it is disinfected and released	Diverse microorganisms are supplied into waste water and the contact filter bed by covering the entire treatment tank with soil and thus taking advantage of the activity of soil microorganisms. High treatment can be easily performed and deodorization and the decrease of sludge are possible.
Removal ratio of BOD		90% or more	85% or more	90% or more	95% or more
Amount of sludge produced		40% of BOD removed	40% of BOD removed	40% of BOD removed	30% of BOD removed
Maintenance and operation		Must be attended by personnel.	Same as left	Inspection once a week or so.	Inspection once a month or so.
		Power consumption Large.	Medium	Small	Small
		Sludge return: Requires regulation.	None.	None	None.
		Amount of air: Requires regulation.	None.	None.	Hardly necessary
		Recovery from accident: More than a month.	More than a week.	Same as left.	2~3 days.
Load regulating capacity		Ordinary. (Requires regulating tank.)	Large. (Requires regulating tank.)	Large. (Requires regulating tank.)	Large. (Does not require regulating tank.)
Environments	Foul odor	Occurs. Deodorizing apparatus is necessary.	Same as left. Countermeasures are difficult.	Same as left. Deodorizing apparatus is necessary.	None.
	Occurrence of mosquitos and flies	Occurs. Cover is necessary.	Same as left. Countermeasures are difficult.	Same as left. Cover is necessary	None.
	Scattering of bubbles and waste water	Occurs. Cover is necessary	Same as left Countermeasures are difficult.	Same as left Cover is necessary	None
	Noise	Slight noise. Machine room can be made soundproof.	Same as left. Same as left.	None. Same as left	None. Same as left.
	Scenery	Requires countermeasures.	Same as left.	Same as left	Unnecessary. Scenery is not impaired.
Addition or expansion of facilities		Complicates work. Inevitably uneconomical.	Same as left Same as left.	Same as left. Same as left	Extremely easy. Can be done economically.
Nitrogen treating capacity		Low.	Can be treated to an extent	Can be treated to an extent.	Large. NH_4-N can be treated at less than 1 ppm.
Economy of scale		Large scale → Inexpensive Small scale → Expensive	Same as left	Same as left	Not much difference by scale.
Construction cost (including cost of environment protection precautions) 100t or so per day BOD 20 ppm NH_4-N 1 ppm		280,000 ~ 350,000 yen/t	300,000 ~ 400,000 yen/t	250,000 ~ 300,000 yen/t	230,000 ~ 280,000 yen/t
Winter capacity in cold climate		Lowers. Countermeasures are necessary	Same as left Same as left	Same as left Same as left	Hardly changes. Unnecessary

Fig. 1 Flowsheet

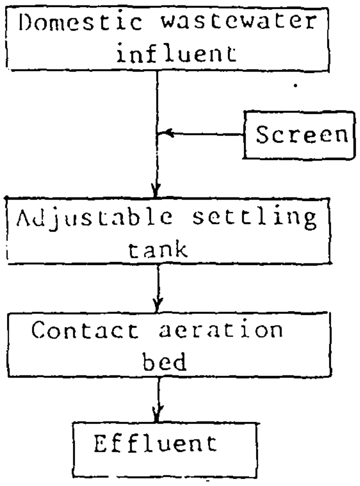


Fig. 2 Adjustable settling tank

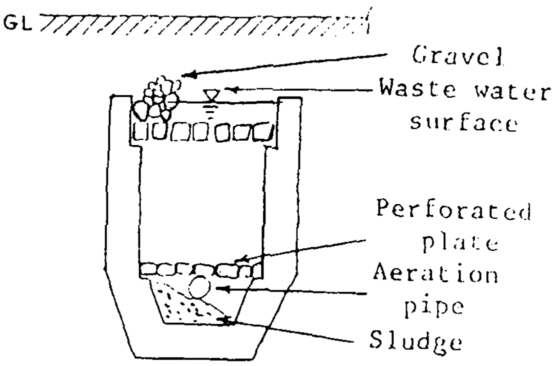


Fig. 3 Longitudinal Section of Contact Aeration Bed

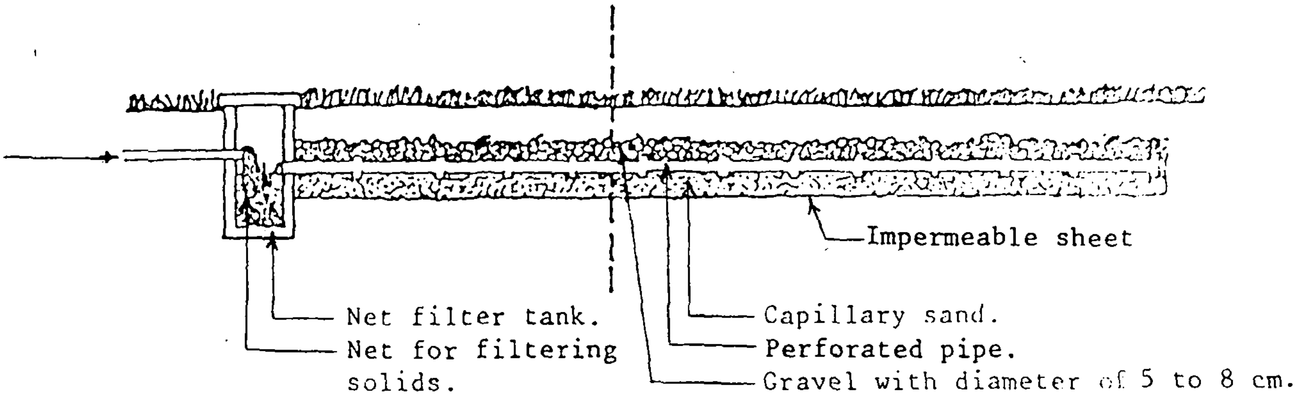
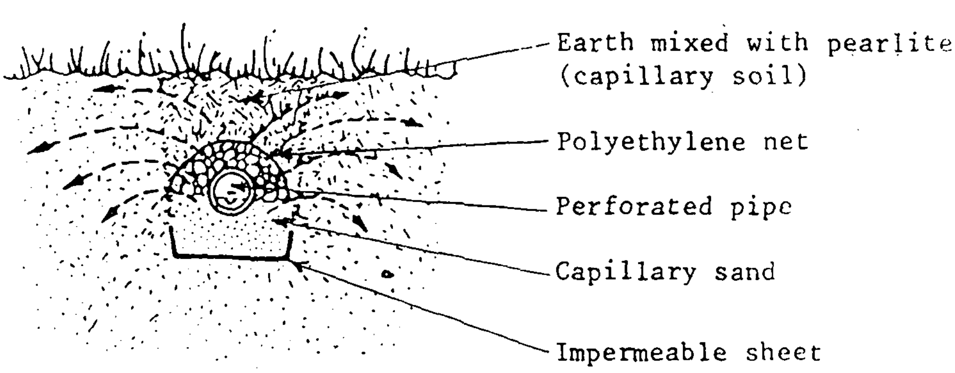


Fig. 4 Cross Section of Contact Aeration Bed



DISCUSSION :

Q : What is the effectiveness of this system when there is a high water table in the ground?

A : The system cannot be used if the water table is about 2 m from the ground surface because the waste water will go into the groundwater without being purified. It takes a long time for waste water to be purified completely. The groundwater must be below 2 m from the soil surface.

DOMESTIC WATER SUPPLY TO RURAL AREAS BY ULTRAFILTRATION

by

Dr. Mohd Salleh Suwandi[1], Dr. Mohd Tusirin Mohd Nor[1] and Dr. Mohd Sanusi Jangi[2]
Research Membrane Group, Dept. of Chemical Technology[1], and
Dept. of Microbiology[2], Universiti Kebangsaan Malaysia

INTRODUCTION

Fresh water is one of the necessities of life and it is commonly obtained from rivers, streams, lakes or rainwater which is collected in small cisterns or large reservoirs. The quality of some waters from these sources is naturally satisfactory for common domestic uses. Others need to be treated so that they are hygienically and esthetically accepted. In a conventional water purification system, sand filteration, softening, chlorination and other chemical treatment processes are employed to remove or reduce objectionable substances such as suspended solids, bacteria and colour. However, this plant can only be operated economically for large scale production of treated water to serve densely populated areas. The supply seldom reach remote areas such as small rural villages or areas where development is in its initial stage. In these areas water is usually used without treatment. The only form of treatment is perhaps boiling when water is used for drinking. However, there are many other domestic works which need water of a reasonable standard and hence pretreatment is required to remove the various objectionable substances mentioned above.

In this paper, the authors propose an alternative method of water treatment. The proposed system can be operated on a small scale basis and hence finds its usefulness in providing treated water in small rural communities. It can be installed either in individual home or on community basis. The treatment system proposed here utilizes membrane filtration technique commonly known as ultrafiltration (UF). In this process, pressure differential provides the driving force to push water molecules to pass through a semi-permeable membrane barrier which retains large molecules and colloidal suspensions. The retention of these species by the membrane enables the process to produce water free of suspended solids, including harmful bacteria. This point will be elaborated and emphasized in the experimental section of this paper. The accumulation of the filtered substances on the membrane surface will increase the hydraulic resistance and consequently will reduce water throughput. This effect, commonly known as 'concentration polarisation' can be minimized by providing shear across the face of the membrane. More detail description of the UF process can be found elsewhere (1).

The only form of energy required in the process is the energy required for cross-flow recirculation and for pressure differential which can be achieved by throttling the flow. Since it is a low-pressure process, the energy requirement is comparatively low. In fact, where electrical pump cannot be installed due to the unavailability of electricity, a common feature of rural areas, manually operated (hand or pedal) pump can be used instead.

It is stressed that the water treatment system proposed in this paper is by no means an ultimate or permanent installation. The conventional treatment plants still represent the cheapest means of obtaining treated water at the moment. However, in areas where development is still at is initial stages and water of consumable quality is required, the UF alternative will definitely find its usefulness.

EXPERIMENTATION

The objective of this experiment is to determine the quality of the permeate of fresh water samples passing through various types of membranes. The permeate quality was measured by the number of micro-organism present, as well as its turbidity and its colour. The water samples were obtained from Bukit Lanjang River, Damansara, Selangor. Its bacterial count was initially determined and found to be $2.5x10^3$ c.f.u./ml. It was believed that the number of bacteria present in the samples was not large enough to be a good representation to show the capability of membranes to retain microorganisms at high concentration. For this reason, simulated water samples containing large amount of microorganism at concentrations up to $5x10^9$ c.f.u./ml were prepared and also tested on the identical set of membranes. The microorganisms chosen to make these simulated water samples were *Escherichia coli* K-12 and *Staphylococeus aureus*. The difference in their morphology, the former being short-rod bacterium and the latter being spherical, provides a good representation of the effect of bacterial shape on membrane retentivity. To complete the experiment, fluxes through the various membranes were also measured at different sampling period to determine the possibility of concentration effect. Information on fluxes are important for determination of energy required for the corresponding membrane process.

Membranes:

Membranes utilized in this investigation were prepared from three different polymers with at least two different Molecular Weight Cut-Off (MWCO) from each of them as is shown in Table 1.

Polysulfone membranes, GR 60P and GR 81P, are "skin" membranes (2). They were purchased from Der Danske Sukkerfabrieker (DDS), Denmark. Polyamide and Polycarprolactam membranes are "sponge" membranes (3) and were cast locally at UKM laboratory. Both sides of sponge membranes can be used for ultrafiltration but with different properties. The (+) side is when the side of the smaller pores facing the retentate and the side with larger pores facing the permeate. If membranes are used reversely, they are called (-) side. Ultrafiltration on the (-) side produces higher flux but less rejection than that of the (+) side. In actual case, the (+) side can be determined easily since it has smoother surface.

Equipment:

Stirred UF cell consists of a perpex cylinder having a capacity of 170 ml capable of housing a membrane sheet with an effective area of 15.3 cm^2. It is fitted with magnetic stirrer having 2.5 cm long stirring bar. The cell can be pressurized using a Nitrogen cylinder and can be pleaced in a constant temperature bath.

DDS Lab Module 20 is a plate and frame UF system consists of maximum 13 plates which can hold membranes of 0.036 m^2 each. The flow channel is 0.5 mm deep in which high shear flows can be developed. Each plate posesses a separate permeate outlet and therefore suitable for investigating the properties of 13 different membranes all at once. The system is pressurized by a piston pump capable of developing pressure up to 70 Bars.

Preparation of Bacterial Suspension:

Cultures of *E. coli* and *S. aureus* were each grown in 50 ml Enrlenmeyer flasks containing 25 ml of Nutrient Broth (Difco) for 18 h at 37°C. Cells from the resultant exponential phase cultures were harvested by centrifugation at 2400 g at room temperature for 10 min., washed and resuspended with 0.85% normal saline to provide a working population of ca. 10^{7-9} cells per ml when inoculated into 5 litres of sterile distilled water. This bacterial suspension was then filtered through the UF membranes.

Procedure:

Prior to ultrafiltration experiment both DDS Module 20 and the stirred cell were sterilized by flushing the system several times with 30% v/v methanol solution. The equipments were rinsed repeatedly using sterilized water to remove traces of methanol.

For DDS system, the sample was put into a feed tank provided from which it was pumped into the UF module. The temperature of the system was set to 30 ± 0.5°C. The inlet pressure was adjusted to an absolute pressure of 3 Bars and an outlet pressure of 2 Bars. The permeate side of the membranes was at atmospheric pressure. With the membranes arranged as listed on Table 1, the effective pressure gradients across the membranes were 2 Bars for GR membranes, 1.5 Bars for M_1 membranes, and 1 Bars for M_2 membranes. The flow rate to the module was maintained at 3.9 1/min. The permeate was collected into a measuring flask to monitor the permention rate (= flux). Sampling of permeates was made at preset volume factors of 1, 1.2, 1.5, 1.9 and 2.8. The factor is defined as a/(a-b) where a = initial volume of water sample in the tank and b = volume of the total permeate.

When batch stirred cell was used, water sample was placed in the cell which was pressurized at an effective pressure gradient of 1 bar and was stirred at 300 R.P.M. The permeate samples were collected at volumes factors mentioned above.

Bacterial Enumeration Method:

The total viable bacterial cells present in the permeate from each membrane system was enumerated using the Miles & Misral technique. Aliquots of 10 µl from each permeate was spot-inoculated in quadruplicates on to the appropriate enumeration medium (MacConkey Agar for *E. coli* and Staphylococci Medium 110 for *S. aureus*; both formulations were from Oxoid). Plates were incubated at 37°C between 24-48 h and counted before confluent growth of colonies appear. The procedure was similarly repeated for river water permeates, except that Plate Count Agar (Difco) was the enumerating medium and an ambient incubating temperature.

Bacterial numbers present in the suspension or in the river water sample before being filtered through the reactor was determined as above using appropriately diluted sub-samples.

Result and Discussion

Table 2 and 4 show the peformance of membranes investigated against *E. coli*. The concentrations of retentate at sampling times were calculated from multiplication of its volume factor and the initial concentration of bacteria in the water sample. This relation is exact if we assume that the permeate contains negligible amount of bacteria. Analysis of the permeates on bacteria count indicates that all membranes investigated are capable of retaining *E. coli* quite well. The increasing order of rejection by these membranes are as follows: $M_2(-)$, $M_1(-)$, $M_1(+)$, $M_2(+)$, GR 60P, and GR 81P. If we define ratio of retentate-permeate (= r.r.p.) as

$$\text{r.r.p.} \quad \frac{\text{concentration of bacteria at retentate}}{\text{concentration of bacteria at permeate}}$$

to indicate the degree of rejection by the corresponding membranes, we can then calculate r.r.p. for every permeate sample. The minimum and maximum value of the r.r.p.'s are listed on Table 8 which indicates the range of r.r.p.'s one may encounter when filtering *E. coli* suspension using these membranes. All values of r.r.p.'s are larger than 10^5. Some data of $M_2(+)$, GR 60P, and GR 81P indicate the r.r.p.'s are ∞, which correspond to total rejection by these membranes. The pore size of these membranes is smaller than the size of *E. coli*, therefore it is believed that the actual rejection of these membranes is in fact complete and the r.r.p.'s of less than ∞ may be attributed by contamination from surroundings. This was confirmed by the positive identification of microorganisms of test on an agar plate left open for a period of a minute in our laboratory.

Table 3 and 5 show the performance of the membranes against *Staphylococcus aureus*. In many occassion the analyses show no microorganism present at permeate, indicating total rejection by all membranes even by the most open membrane investigated, $M_2(-)$. This behavior is expected since *Staphylococcus* is practically spherical of a size 1 μm and has tendency to form a floc of two or more cells, thus increasing the cell size to 2 μm or larger. The conclusion of total rejection was also confirmed by careful experiment on a stirred cell using M_2 membranes and, a more open membranes, CT 35 N. The agar medium chosen for culturing was selective to *Staphylococcus* and results of counting are presented in Table 6.

Experiment with samples from Bukit Lanjang River faced some difficulty. The microorganisms present were of the same type as the ones found in our laboratory. The analysis of permeates (presented in Table 7) were of the same order as the permeates of a run with sterile water. This indicated that the microorganisms present in the permeates of water sample were extraneous contaminants and not of aquatic origin. At present we are still improving our technique of sampling the permeates.

Early fluxes of suspension of *E. coli* and *Staphylococcus aureus* through membranes investigated are presented in the second column of Table 2, 3, 4, and 5. This data is useful for estimation of energy requirement for an ultrafiltration process producing bacteria-free water. For example from Table 3, it is seen that flux of $M_2(+)$ membranes is 53 $l/m^2.hr$. A UF module housing $1m^2$ of these membranes working under pressure gradient of 1 Bar requires an energy of 8150 kJ to produce $1m^3$ permeate. Utilizing a distilier, it can only produce a maximum of 3.7 l water (considering no heat loss to the surrounding). The energy requirements of other membranes can be easily calculated from the above figure of 8150 kJ considering that it is inversely proportional to the flux per unit pressure gradient.

RECOMMENDATIONS

Proposed Treatment Scheme

The new water treatment system basically consists of a pump, an ultrafiltration (UF) module, valves and piping. For the purpose of optimising energy usage the arrangement of these components is important. For rainwater, the most appropriate arrangement is perhaps as shown in Figure 1(a). The rainwater tank is elevated and the UF module is placed at the bottom of the tank. The water head provides the pressure differantial needed by the UF process. If higher pressure is required, it can be provided by throttling the valve. The pipe outlet is submerged under the water surface so that the pump energy will not be unnecessarily used for raising the water. In this scheme, pressure loses will only be due to loses in UF module, valve, pipe and fittings.

For river or pond waters, the arrangement shown in Figure 1(b) is recommended. Again it should be noted that the pipe outlet should be submerged under the water surface. Screen should be installed at the pipe inlet to avoid large particles from entering the UF module.

UF module

There are various types of UF system contigurations or modules, namely tubular, hollow fibre thin channel and capillary modules (4). For the water treatment system described here, it is felt that the capillary module is the most suitable for the following reasons:

1. The module requires low energy. It can produce water flux of 70 l/m^2 h at 1.0 Bar using a 120 watt pump.
2. Very high shear rate can be achieved and hence high flux.
3. The module can be constructed and does not require very strong material of construction.
4. It can be constructed in modular form with one module housing 1.0 m^2 membranes. Plant capacity can be readily increased by increasing the number of modules.
5. It is easy to maintain. It one of the modules in a plant is faulty, it can be easily and readily replaced by a new module.

Recommended types of membranes

Experimental results indicate that DDS membranes, GR 60P and GR 81P, performed excellently. However price consideration and their availability locally limit their usability. M_2 and CT membranes performed well and can be produced locally and cheaply. $M_2(-)$, CT 35 N(+) and CT 35 N(-) membranes posses high flux, better or similar to GR 60P. Considering all these factors $M_2(-)$, CT 35 N(+) and CT 35 N(-) membranes are recommended to be utilized in the above capillary module.

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Consider the case of BOD. The increase in BOD in time Δt in an elemental slice of volume $A \Delta x$ can be expressed as follows.

$$A \Delta x \Delta s_1 = Q s_1 \Delta t - (Q + \Delta Q)\left(s_1 + \frac{\partial s_1}{\partial x} \Delta x\right)\Delta t$$

$$- K_1 s_1 \quad A \Delta x \Delta t \pm S \Delta Q \Delta t \pm A \Delta x \quad S_{d1} \Delta t$$

where the first two terms on the right represent the effect of advection, the third term, that of biochemical reaction and the fourth and fifth terms, the contribution of distributed sources.

Expanding the second term on the right, and dividing by $A \Delta x \Delta t$ gives

$$\frac{\Delta s_1}{\Delta t} = - \frac{Q}{A} \frac{\partial s_1}{\partial x} - \frac{s_1}{A} \frac{\Delta Q}{\Delta x} - \frac{\Delta Q}{A} \frac{\partial s_1}{\partial x} - K_1 s_1$$

$$\pm \frac{S_1}{A} \frac{\Delta Q}{\Delta x} \pm S_{d1}$$

Taking limits as Δx, $\Delta t \rightarrow 0$, we obtain

$$\frac{\partial s_1}{\partial t} = - \frac{Q}{A} \frac{\partial s_1}{\partial x} - \frac{s_1}{A} \frac{\partial Q}{\partial x} - K_1 s_1$$

$$\pm \frac{S_1}{A} \frac{\partial Q}{\partial x} \pm S_{d1}$$

The equation for s_2 is obtained in a similar fashion while the effect of the point source is accounted for by the mixing equations giving s_1 (0,t) and s_2(0,t).

Note that two further assumption are taken in this derivation. First, it is assumed that there is no dispersion or diffusion. When dispersion is, in fact, significant such as pertaining in estuaries, the model must be modifies accordingly. Also, first order reaction kinetics is assumed here for BOD removal and reaeration.

A PRACTICAL MODEL

In practice, a reach-by-reach modeling approach is used. The river is first segmented into a number of constant parameter reaches. In each reach the parameters, Q, A, K_1, K_2, s_{2m}, S_1, S_2, S_{d1}, S_{d2} are assumed constant. The constant flow assumption implies that the distributed source/sink contribution $S_1 = S_2 = 0$. Also the river is segmented at each point source so that there will be no point source within a reach. (FIG. 6)

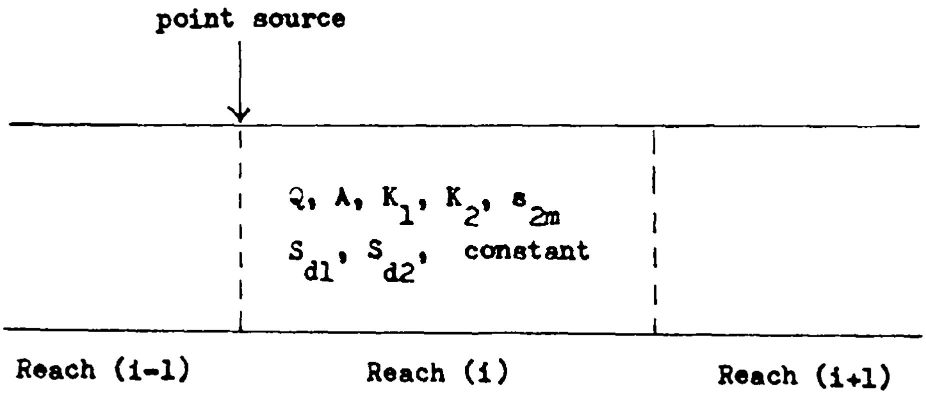

FIG. 6 Reach-by-reach approach

Table 1. Membrane Designation, polymers of contruction, and their Molecular Weight Cut-off

Polymers	Membrane Designation	MWCD (Dalton)
Polysulfone	GR 60 P	25,000
	GR 81 P	10,000
Polyamide	$M_1(+)$	
	$M_1(-)$	
	$M_2(+)$	
	$M_2(-)$	
Polycaprolactam	CT 35 N (+)	50,000
	CT 35 N (-)	

Table 2. Flux and concentration of *Escherichia coli* at Retentates and Permeates of a Simulated Water

UF Unit: DDS-Module 20
Suspension of *E. coli* K-12
Date: 12/7/81

		Concentration of retentate (c.f.u./ml)				
		$4x10^8$	$4.8x10^8$	$6x10^8$	$7.6x10^8$	$12.8x10^8$
Membrane	Early Flux (l/m^2.hr)	Concentration at permeate (c.f.u./40 µl)				
GR 60 P	116	6	5	4	3	0
GR 81 P	45	0	0	1	0	0
M_1(+) old	26	40	27	16	-	7
M_1(-) old	73	31	5	4	4	1
M_2(+)	53	60	13	0	0	0
M_2(-)	200	<200	<100	<100	72	45

Table 3. Flux and concentration of *Staphylococcus aureus* at Retentates and Permeates of a Simulated Water

UF Unit: DDS-Module 20
Suspension of *Staphylococcus aureus*
Date: 10/8/81

		Concentration of retentate (c.f.u./ml)				
		$5x10^8$	$6x10^8$	$7.5x10^8$	$9.5x10^8$	$14x10^8$
Membrane	Early Flux $(l/m^2.hr)$	Concentration of permeate (c.f.u/40 µl)				
GR 60 P	111	0	1	1	0	0
GR 81 P	41	0	0	0	1	0
M_1(+) old	23	0	0	15	10	0
M_1(-) old	74	-	-	-	-	-
M_2(+)	-	1	4	1	0	1
M_2(-)	-	3	19	30	15	10

Table 4. Flux and concentration of *Escherichia coli* at Retentates and Permeates of a Simulated Water

UF Unit: DDS-Module 20
Suspension of *E. coli* K-12
Date: 12/8/81

		Concentration of retentate (c.f.u./ml)				
		$5x10^9$	$6x10^9$	$7.5x10^9$	$9.5x10^9$	$14x10^9$
Membrane	Early Flux (l/m^2.hr)	Concentration at permeate (c.f.u./40 ul)				
GR 60 P	120	2	1	1	0	0
GR 81 P	47	-	0	0	0	0
M_1(+) old	29	14	15	24	14	30
M_1(-) old	83	-	10	20	12	29
M_2(+)	53	2	2	0	3	3
M_2(-)	122	60	50	50	24	59

Table 5. Flux and concentration of *Staphylococcus aureus* at Retentes and Permeates of a Simulated Water

UF Unit: DDS-Module 20
Suspension of *Staphylococcus aureus*
Date: 14/8/81

		Concentration of retentate (c.f.u./ml)				
		$4x10^6$	$4.8x10^6$	$6x10^6$	$7.6x10^6$	$12.8x10^6$
Membrane	Early Flux $(l/m^2.hr)$	Concentration of permeate (c.f.u./40 µl)				
GR 60 P	111	0	0	0	0	0
GR 81 P	46	0	2	0	0	0
M_1(+) old	27	1	0	0	0	0
M_1(-) old	70	0	0	0	0	1
M_2(+)	48	1	1	0	0	1
M_2(-)	112	0	0	0	0	0

Table 6. Flux and concentration of Microorganisms at Retentates and Permeates of Water Sample from Bukit Lanjang River.

UF Unit: DDS-Module 20
Water from Bukit Lanjang River
Date: 5/9/81

		Concentration of Retentate (c.f.u./ml)				
		$2.5x10^3$	$3x10^3$	$3.75x10^3$	$4.75x10^3$	$7x10^3$
Membrane	Early Flux ($l/m^2.hr$)	Concentration of Permeates (c.f.u./40 µl)				
GR 60 P	101	0	0	0	1	1
GR 81 P	38	1	3	2	3	0
$M_1(+)$ old	25	15	7	31	9	19
$M_1(-)$ old	60	5	3	10	5	5
$M_2(+)$	33	0	20	21	5	2
$M_2(-)$	75	7	4	2	5	7

Table 7. Concentration of *Staphylococcus aureus* at Retentates and Permeates of a Simulated Water. Measurement with a Stirred Cell.

UF: Stirred Cell
Suspension of *Staphylococcus aureus*
Date: 18/10/81

	Concentration of Retentate (c.f.u./ml				
	$1x10^6$	$1.2x10^6$	$1.5x10^6$	$1.9x10^6$	$2.3x10^6$
Membrane	Concentration of Permeate (c.f.u./40 µl)				
$M_2(+)$	0	0	0	0	0
$M_2(-)$	0	1	0	0	0
CT 35 N (+)	0	0	0	0	0
CT 35 N (-)	0	0	0	0	0

Table 8. Ratio of Retentate-Permeate Concentration (r.r.p.) of Membranes Investigated to *E. coli* and *S. aureus*.

Membranes	r.r.p.	
	E. coli	*S. aureus*
$M_2(-)$	$10^5 - 1.4\times10^7$	$6\times10^6 - \infty$
$M_1(-)$	$5.2\times10^5 - 3\times10^7$	$4.5\times10^6 - \infty$
$M_1(+)$	$6.4\times10^6 - 2.7\times10^7$	$4.5\times10^5 - \infty$
$M_2(+)$	$2.7\times10^5 - \infty$	∞
GR 60 P	$2.4\times10^6 - \infty$	$10^5 - \infty$
GR 81 P	$2.4\times10^7 - \infty$	∞

DISCUSSIONS :

Q : What is the cost of the membrane per unit capacity? What is the life of this membrane? Can it handle a few hundred gallons per minute?

A : The cost of the membrane is about M$ 500/= per. sq. meter if it is bought from foreign companies. If it is home-made, it could be less than M$ 100/= per. sq. m. including the cost of labour and profit. From the material point of view this is very cheap. One sq. m. of membrane may use less than 10 gm of plastic and the cost of plastic is about M$ 5/= per. kg. Membranes purchased from companies are guaranteed for one year. Since polymide and polycarprolactam are strong polymers like polysulfone, both are expected to work satisfactorily for at least six months.

The membrane is in a one-metre modular form, therefore an increase in capacity will not be a problem since we can hook up more modules up to the required capacity. If we use M_2 (-) which is good enough for retention of micro-organisms, the capacity will be about 112 litre/sq. m/hr.

Q : What would be the required filtration before water enters the module and how long will it take before cleaning is done?

A : The actual operation itself will not have any coarse particles entering the modules since the system has a fairly slow flow rate and low pressure but high shear rate, which means higher flux. There is a scouring effect. The membrane which has capillary size pores will be destroyed if there are coarse materials. Therefore id sand is expected, a simple filtration unit must be installed before the water enters the module.

C : Gravity sand filter can be about 25 times faster than filtration by membranes. A very big area for membrane will be required in an actual treatment plant. Gravity sand filter can filter about 100 gal/sq. ft/hr. as compared to the membrane filter capacity of about 4 gal/sq. ft/hr.

A : It is true. But the water we are getting by using membrane is a pathogen-free water which can be use in hospitals for injection purposes. By using gravity sand filter we still need to treat the micro-organisms, colloidal suspension and colour which go through the filter.

PROPERTIES AND CONTROL
OF THE SALINITY IN VILLAGE TANKS

by

Sacha Sethaputra
Faculty of Engineering
Khon Kaen University
Khon Kaen, Thailand.

INTRODUCTION

Village tanks are widely used to store rainwater for use during the dry season in Northeast Thailand. These tanks are normally located on naturally formed low land areas where small stream runoff or overland flow can be collected.

A few years after construction, the water stored in many of these tanks can not be used due to the high water salinity caused by rock salt (sodium chloride) deposits in the immediate vicinity of the tanks location depending on the tanks locations.

Without a prior geological investigation of each and every site, which in most cases will not be feasible due to its high cost, such contamination can not be completely avoided or prevented in susceptible areas. However, anticipating the behavior of water movement and the salinity distribution within these contaminated tanks would be useful in minimizing or reducing the salinity level.

This paper discusses the formation of saline layer in contaminated tanks and how it affect the overall salinity of the tank water. Undesirable features of the popular overflow type of spillway design is discussed. Alternative designs of spillways for salinity control are suggested.

MECHANICS OF FLOW IN CONTAMINATED TANKS

Flushing of Tanks

Since the storage capacity of these tanks are usually much less than the annual amount of runoff deliverable by the catchment area, spillways are required to pass the excess flow. As a consequence, only a small amount of the annual yield from the catchment area is stored. In terms of the amount of inflow water, any contamination that occur in the tank can be flushed out many times over in a year. For example a typical contaminated tank has storage volume of approximately 100,000 m^3 while the catchment area is 5 km^2 and annual rainfall of 1,200 mm. Calculation shows that this tank can be flushed approximately 60 times annually which is more than enough to keep the tank free of any contamination. However this ideal situation does not always occur due to many reasons such as the spatial and temporal distribution of rainfall and the fact that the water body forms two distinct layers in the tank. The author has the opinion that the latter is the major cause of contamination, remaining to be investigated while the former is within the scope of hydrology.

Causes of Contamination

In a contaminated tank, salt is transported upward from rock salt deposits underneath the tank by both convection and diffusion. Convection is the process when the salt is transported by the movement of the water. The movement of the water is caused by

1. wind blowing over the water surface
2. buoyancy due to heating of the water body by solar radiation
3. current caused by coriolis force

In village tanks, the movement caused by coriolis force can be neglected. Only the wind and solar radiation are the principal causes of mixing.

Diffusion is a molecular mass transfer process caused by concentration gradient. Mass transfer by such action is minor compared to that caused by convection.

Density Stratification

Salinity in a contaminated tank is highest during the dry season when the water volume is minimum. Typical conductivity reading under this condition is approximately 4,000 μmho/cm at 25°C which is equivalent to approximately two parts per thousand of salt concentration. The amount of salt present in the water is sufficient to cause an increase in its density from that of fresh water. During the rainy season the inflowing water, through overland flow and streamflow having density close to that of fresh water, floats on top of the relatively denser water in the tank.

In a typical village tank an overflow spillway is used due to its simplicity in design, construction, and operation. This type of spillway permits the excess water to flow out of the tank over its crest. In this manner, the spillway allows only the top layer of water to flow out while retaining the bottom layer as shown diagramatically in Fig. 1. Accordingly the salinity within the tank increases.

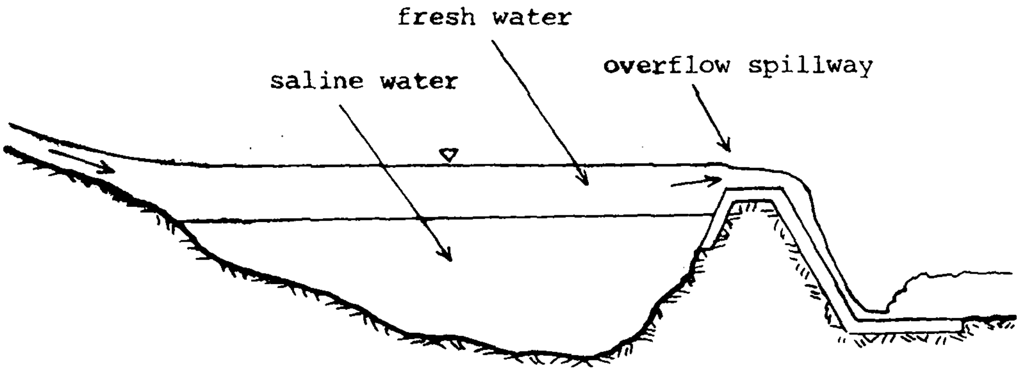

FIG. 1 Saline Layer in a Contaminated Tank

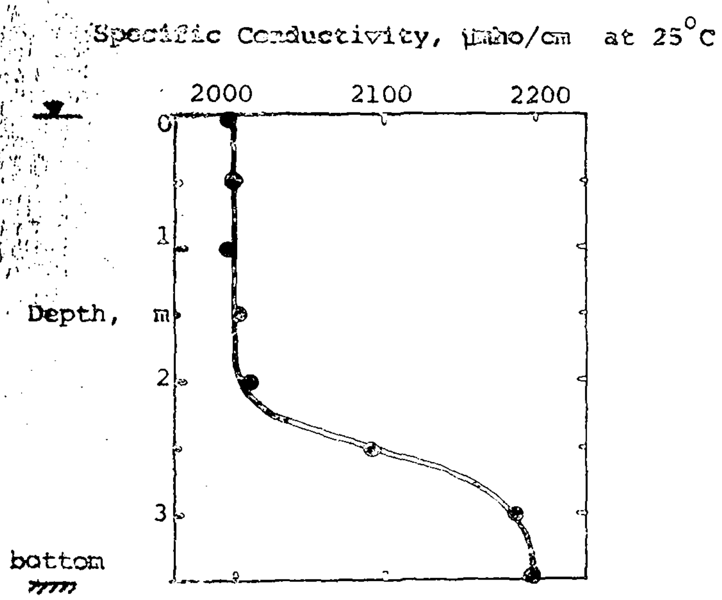

FIG. 2 Variation of Conductivity with Depth

FIELD DATA

At present only limited field data are available. Figure 2 shows the variation of conductivity with depth in a typically contaminated reservoir. The readings were taken in September which is almost at the end of a rainy season. The water level is approximately 12 cm. from the spillway crest level (overflow type). The wind is relatively strong (approximately 15 km/hr) in the direction toward the spillway. The sky is overcast. It is evident from Fig. 2 that relatively fresh water lies on top of contaminated water and according to the reasoning described earlier - is responsible for the increase in the tank salinity. More field data are to be collected to confirm the existence of the density layers.

PREVENTION AND CONTROL OF SALINITY

One obvious way to avoid contamination is to make sure that the sites where the tanks will be located is free of salt deposites. This can be done by conducting geological investigation. However such investigation is usually costly and in most cases are not feasible.

Lining of tank is another possibility for prevention of contamination. Various methods and materials are available. However lining of tanks is unlikely to be a feasible solution for the Northeast of Thailand due to the sheer number of tanks susceptible to contamination and the cost involved.

For those tanks that are already contaminated, it will be desirable at least to be able to control the salinity. As described earlier, one can theoretically flush a typically contaminated tank many times over in a year by the natural rainfall during the rainy season. However, it is unfortunate that most of the fresh water entering the tank is not effectively used to flush out the contaminated water due to the formation of salinity gradient coupled with the spillway design as depicted in Fig. 1. Accordingly in order to control the salinity, it is desirable to have a spillway that will discharge only the bottom (saline) layer. In this manner, part of the contaminated water will leave the tank through the spillway outlet when the inflowing fresh water enters the tanks - thereby reducing the overall salinity of the tank. Some design alternatives for the above purpose are shown in Fig. 3. In Fig. 3 the level of the spillway outlet is important and has to be such that selective withdrawal of the bottom layer occurs. For some simple outlet geometries, criteria for determining the outlet level exist. Some of these are discussed in CRAYA (1949), DAVIDIAN and GLOVER (1956) and HARLEMAN et al. (1953).

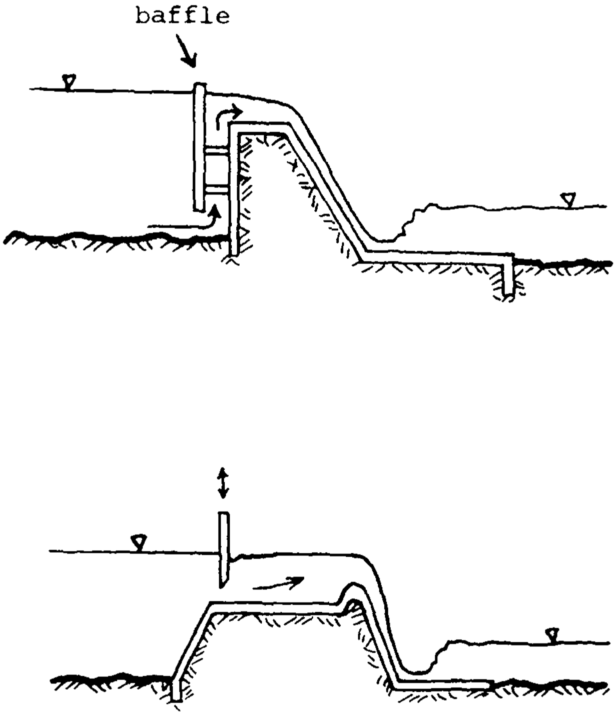

FIG. 3 Some Design Possibilities for Selective Withdrawal

CONCLUSION

It was found that in a typically contaminated tank, the water body separates into two distinct layers during the period when the water flow into the tank during the rainy season. Typical overflow spillway selectively allows only the top layer which is relatively free of contamination to flow out of the tank - while retaining the contaminated bottom layer of water in the tank. This occurs every year until the contamination reaches the state where the water can not be used.

Realizing the formation of layers in the tank, it is possible to design a spillway such that only the bottom or contaminated layer is allowed to flow out of the tank. This effectively flushes out the contaminated water and replace it with the new inflowing water.

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DISCUSSIONS :

Q : When you introduced the baffle in the design for selective withdrawal, did you consider any entry condition to the spillway crest. Is the baffle located at a few spots or throughout the length of the spillway? (Kandiah, DID, Penang).

A : Actually we have not tried this. However I think the baffle should extend throughout the length of the spillway, leaving only the passage underneath for the required water to pass through. To decide on an effective baffle, the depth to the interface should be known. If the baffle is not deep enough fresh water may be withdrawn but if it is too deep, unnecessary costs may be incurred. The most severe constraint is money.

Q : How about the cost of lining the pond? (Dr. Lohani, AIT).

A : A typical pond has about ½ sq. km. in surface area. Therefore the cost of lining with polyethylene sheet is very high.

C : PVC sheet may be used for lining. It cost about M$ 1/= per. sq. m. in Thailand. Thus it will be about five times the cost of the tank to line it with PVC sheets. (Thamrong Prempridi, Chulalongkorn University, Thailand).

PCBs AND PERSISTENT PESTICIDE POLLUTANTS IN MALAYSIAN WATERS AND SOME ECONOMICALLY IMPORTANT MARINE ORGANISMS.

P.M. Sivalingam
School of Biological Sciences, University of
Sciences Malaysia, Minden, Penang, Malaysia.

ABSTRACT

A study on the PCBs and persistent pesticides contamination of Penang waters at eleven predetermined localities have been carried out. In this connection, comparative studies of these biodeposited pollutants in viz. cockles, mussel, rock oysters, etc., were also verified. It was evident that the levels of pollutants in mussels from Penang waters as compared with those from Singapore waters were 2 - 3 times greater indirectly reflecting the magnitude of contamination in our waters.

Similarly, pollutant levels in the Malaysian sea lettuce, *Ulva reticulata* Forsskal, was also investigated owing to its abundance in local waters, role as fish shelter, feed, spawning ground and possible utilization as a prominent human and animal food resource.

The available information from this study envisages the present status of marine environmental contamination in the local context which could be employed as the guideline for rural development of fishing communities.

INTRODUCTION

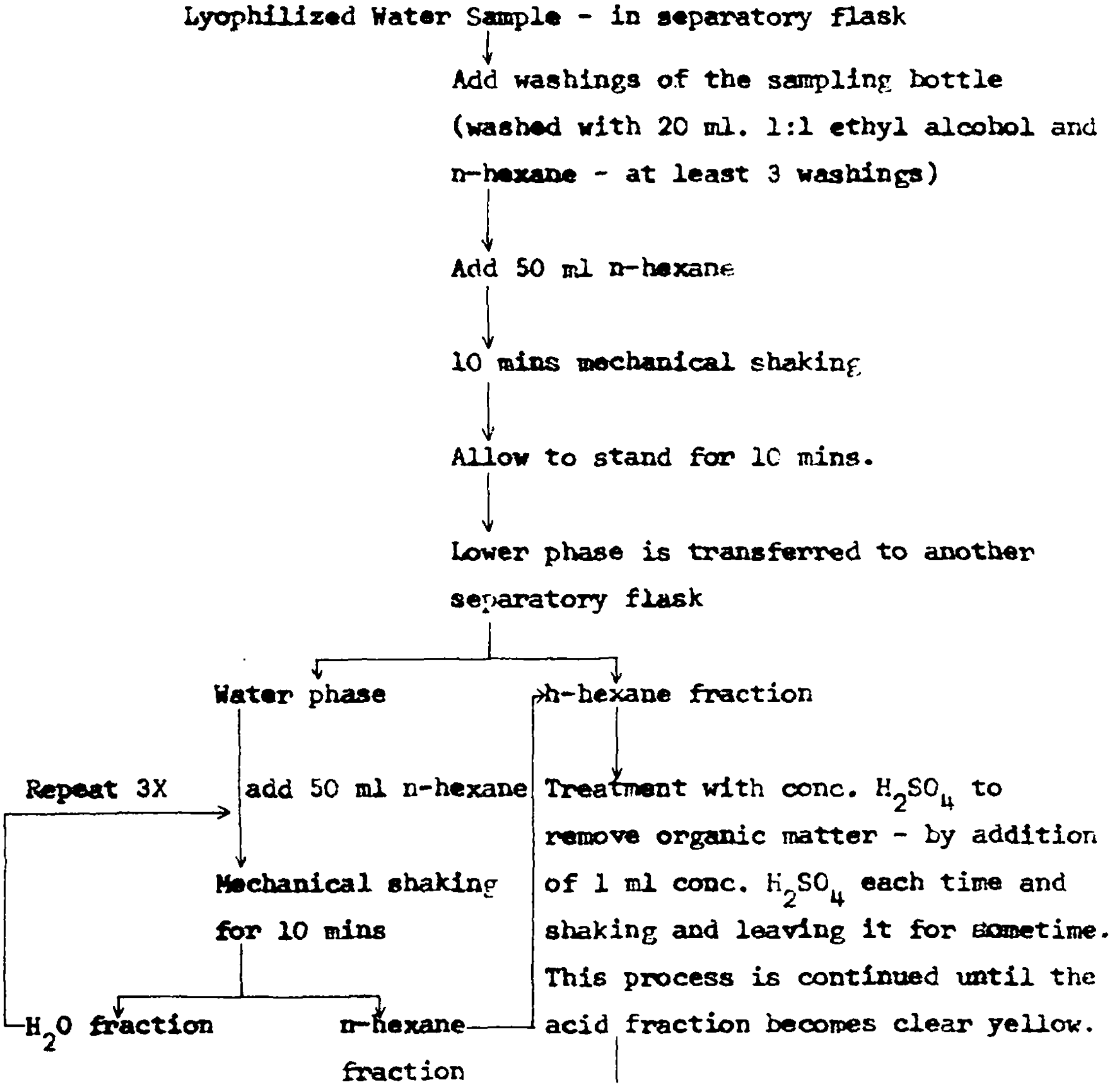
The rapid tempo of industrialization and economical growth has resulted in extreme consequences of environmental contamination in developing Malaysia for numerous fishing communities. A good example of such a problem has been reported by the Consumer's Association of Penang (1976) for the Juru river, Penang. Further, there are other studies of a similar nature with regard to waste treatment of effluents from agro-based industries in correlation with their relative ecological impact on the aquatic environment (CHIN; 1978, RAJAGOPALAN and SIVALINGAM; 1975, SIVALINGAM; 1978a and 1978b, SIVALINGAM and THAVARAJ; 1978).

The levels of heavy metals contents in finfish and shellfish of fisheries landings in the state of Selangor has been reported by LEE and LOW (1976). SIVALINGAM *et al.* (1979) had further done a thorough survey of biodeposited trace elements in coastal molluscs, sediments and sea water samples of the island of Penang. Experimental studies on the modes of biodeposition of trace metals in mussel, *Perna viridis* Linnaeus, (SIVALINGAM and BHASKARAN; 1980, SIVALINGAM; 1981) and the rock oyster, *Saccostrea cucullata* (BORN),(SIVALINGAM; 1979a) has also widened our horizon in this area. Related studies on marine flora (SIVALINGAM; 1978c and 1978d, 1979b), hair of fishing communities (SIVALINGAM and AZURA; 1980) and shrimp paste(SIVALINGAM *et al.*; 1980) have also been carried out lately.

Based on the forementioned elaborately available information on trace elements contamination of this region the author has further extended his studies on PCBs and persistent pesticides contamination of Malaysian waters, economically important shellfish and flora of the marine ecosystem in order to relate its impact on our aquatic environment in relation to rural development of fishing communities. Undoubtedly, it demands indirectly the establishment of a "Mussel-Watch Programme" which would obviously function as the biological sentinel organism of pollutants within the aquatic environment in this region on a long-term assessment basis. The results of these investigations are discussed in this paper.

MATERIALS AND METHODS

Contaminant levels in water samples was performed with those collected in acid washed PVC bottles every month during high tides when maximum mixing occurred ca. 100 yards away from January - December, 1978, at 11 predetermined stations (Figure 1) around the island of Penang, Malaysia. Exactly 1 liter samples from each station was lyophilized to 100 ml prior extraction of the PCBs and persistent pesticides from each water sample individually according to the scheme below before gaschromatographic analysis and identification.



Lyophilized Water Sample - in separatory flask

Add washings of the sampling bottle (washed with 20 ml. 1:1 ethyl alcohol and n-hexane - at least 3 washings)

Add 50 ml n-hexane

10 mins mechanical shaking

Allow to stand for 10 mins.

Lower phase is transferred to another separatory flask

Water phase

n-hexane fraction

Repeat 3X

add 50 ml n-hexane

Mechanical shaking for 10 mins

Treatment with conc. H_2SO_4 to remove organic matter - by addition of 1 ml conc. H_2SO_4 each time and shaking and leaving it for sometime. This process is continued until the acid fraction becomes clear yellow.

H_2O fraction

n-hexane fraction

Removal of acid fraction

↓

Wash 3X with1100 ml of distilled H_2O washed with n-hexane

↓

Removal of water phase

↓

Dehydration through Na_2SO_4 column

↓

Kuderna-Danish concentration to 5 ml

↓

Silica gel column elution with 135 ml n-hexane and collected in a K.D flask.

↓

K.D. concentration to 5 ml

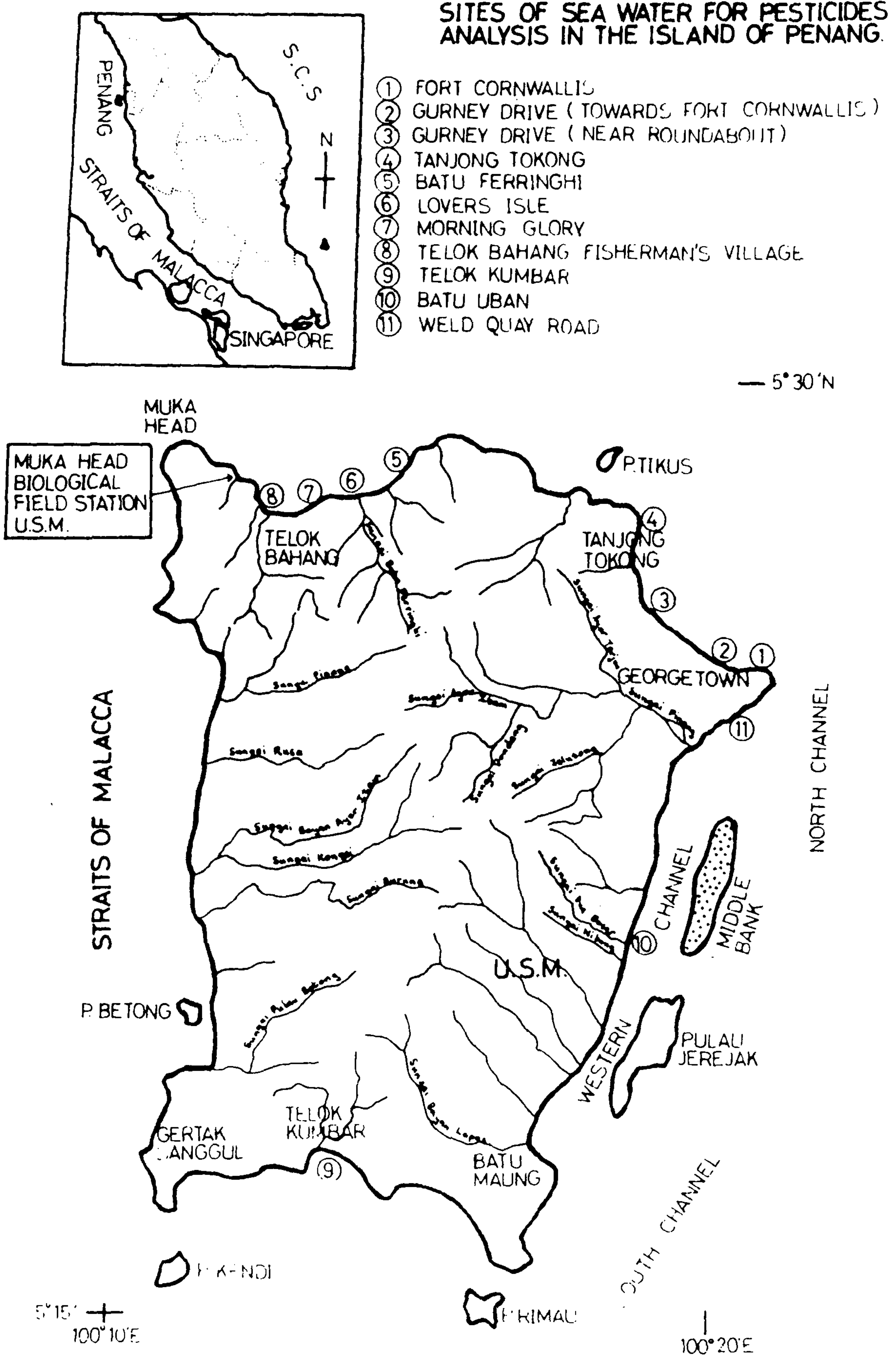
↓

GAS CHROMATOGRAPHY

With regard to shellfish samples, matured cockles, *Anadara granosa* Linnaeus, were obtained from ten different culture farms in the state of Penang, viz., Bukit Dumbar, Pantai Aceh, Kuala Sungei Pinang Site 1 and 2, Kuala Jalan Bahru, Batu Maung Site 1, 2 and 3, Sungai Nibong and Kuala Juru in July, 1978. Other shellfish samples of *Barbatia bicolorata* (Dillwyn), *Atrina vexillum* (BORN), *Pinctada vulgaris* (Schumacher) and *Saccostrea cucullata* (BORN) from the Marine Depot during the same period. Normally, a sample size of 50 individuals were employed for analysis of each shellfish species.

As for mussel, *Perna viridis* Linnaeus, samples they were obtained between May-August, 1979, from 6 stations of Penang waters, viz.. Weld Quay Pier, Marine Depot, Pulau Jerjak, Permatang Damar Laut, Batu Maung and Gertak Sanggul, and 3 stations in Singapore waters, viz., Selatar, Serangoon and Ponggol areas. The harvested samples were 1½ inches long by 1 inch in width. Each sample lot amounted to 25 individuals which were initially culled off contaminants before been sacrificed.

FIG.1. MAP ILLUSTRATING THE SAMPLING SITES OF SEA WATER FOR PESTICIDES ANALYSIS IN THE ISLAND OF PENANG.



For the evaluation of the economically prominent marine flora, *Ulva reticulata* Forsskal, it was obtained during low tides periodically between January 1977 - December 1978 at the Marine Depot, Penang. The fronds were cleaned off epiphytes and other contaminants by washing with filtered sea water and then with distilled water prior processing.

The shellfish sample meat was normally sucked out and blotted with Whatman No. 1 Filter Paper and lyophilized to complete dryness. The fronds of the sea lettuce were also processed in a similar manner. The dried samples were then pulverized using separate mortars and filtered through 20 mesh sieve for homogeneity before extraction of PCBs and persistent pesticide residues in triplicate according to the scheme below prior gaschromatographic analysis and identification.

Pulverized Shellfish/Sea Lettuce sample (5 gms)

↓

Add 5 gm KOH + 50 ml EtOH

2-3 hours extraction and cool
to ca. 50°C

↓

Add 50 ml n-hexane

cool to room temperature

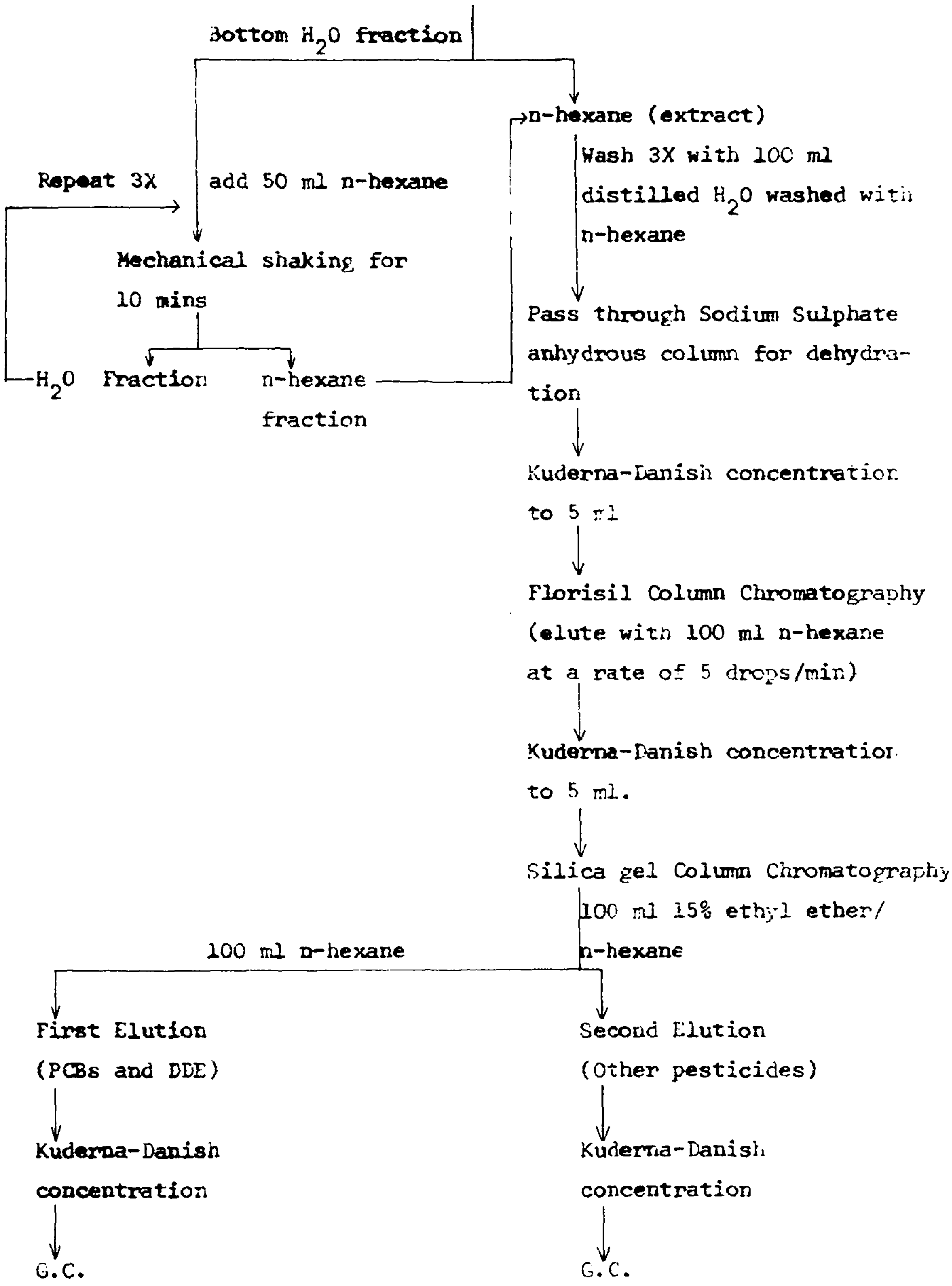
↓

Transfer to a 300 ml separatory flask. Wash container 3 times with
20 ml (1:1) mixture of n-hexane and EtOH
and add into separatory flask

↓

Add 50 ml of distilled H_2O washed with n-hexane

mechanical shaking for 10 mins
and allow to stand for 15 mins
hexane fraction


Bottom H_2O fraction
Repeat 3X
add 50 ml n-hexane
Mechanical shaking for 10 mins
H_2O Fraction
n-hexane fraction
n-hexane (extract)
Wash 3X with 100 ml distilled H_2O washed with n-hexane
Pass through Sodium Sulphate anhydrous column for dehydration
Kuderna-Danish concentration to 5 ml
Florisil Column Chromatography (elute with 100 ml n-hexane at a rate of 5 drops/min)
Kuderna-Danish concentration to 5 ml.
Silica gel Column Chromatography
100 ml n-hexane
100 ml 15% ethyl ether/ n-hexane
First Elution (PCBs and DDE)
Second Elution (Other pesticides)
Kuderna-Danish concentration
Kuderna-Danish concentration
G.C.
G.C.

Gaschromatographic analysis of PCBs and persistent pesticides was carried out using a G.C.-4BM Shimadzu gas chromatograph under the following operating conditions.

Column packing : OV 17/1.5% Chromosorb W
Detector temp. : 210°C
Column temp. : 190°C
N_2 flow : 30 ml/minute
Chart speed : 10 mm/minute
Range : $10^2 \times 8$
ECD : ^{63}Ni

The gas chromatograms were then compareddwith authentic samples of PCBs and pesticides and the amount of the contaminants were calculated using the following formula:

$$\frac{V \times h_{PCB \text{ or } DDE} \times V^1}{m \times v \times h} \times C = \text{result in ppm}$$

where

V = total volume of n-hexane extract (ml)
m = weight of sample (gm)
V^1 = volume of sample injected (ul)
v = volume of standard injected (ul)
h = peak height of PCB or DDE in the standard (mm)
C = concentration of standard (ug/ul)

RESULTS

Table 1 shows the mean contents of the different identified persistent pesticides in water samples from the different stations around the island of Penang. It is obvious that α-, β- and γ-BHC, aldrin, dieldrin and p, p'DDE were the only detectable persistent pesticides in variable levels. On the contrary, the levels of PCBs in all the examined samples were below detectable levels.

TABLE 1: Persistant pesticide levels in tropical waters of Penang Island, Malaysia.

Water sampling localities	Type of identified pesticides (ppm)					
	α-BHC	β-BHC	r-BHC	Adrin	Dieldrin	p,p'DDE
Fort Cornwallis	0.100	0.150	0.455	6.774	0.245	N.D.
Gurney Drive (towards Fort Cornwallis)	0.120	N.D.*	0.521	9.194	0.857	N.D.
Gurney Drive (further away from Fort Cornwallis)	0.138	N.D.	0.976	1.936	0.367	N.D.
Tanjong Tokong	0.053	0.153	1.367	6.290	0.282	N.D.
Batu Ferringhi	0.140	0.325	0.200	6.281	0.490	N.D.
Lovers Isle	0.160	0.300	0.195	10.161	0.490	N.D.
Morning Glory	0.121	0.251	0.631	11.12	0.429	N.D.
Telok Bahang Fishing Village	0.060	0.250	0.260	16.935	0.490	N.D.
Telok Kumbar	0.040	0.455	0.150	10.161	0.473	N.D.
Batu Uban	0.080	1.801	0.391	12.581	0.481	N.D.
Weld Quay Road	0.040	N.D.	0.195	17.900	0.489	35.614

*N.D : not detectable.

α-BHC is least in waters from Telok Kumbar and Weld Quay Road (0.04) while highest in waters from Lovers Isle (0.16 ppm). β-BHC is lowest in Gurney Drive and Weld Quay Road waters (N.D.) and highest in Batu Uban waters (1.801 ppm). α-BHC, on the other hand, is lowest in Telok Kumbar waters (0.15 ppm) and highest in Tanjong Tokong waters (1.367 ppm).

The lowest content of aldrin is found in waters from Gurney Drive (further away from Fort Cornwallis)(1.936 ppm) and highest in waters from Weld Quay Road (13.9 ppm).

Dieldrin is lowest in waters from Fort Cornwallis (0.245 ppm) and highest in waters from Gurney Drive (towards Fort Cornwallis) (0.857 ppm).

As for p,p'DDE it is nondetectable in most stations except for Weld Quay Road station which demonstrated a value of 35.814 ppm.

Table 2 shows the PCBs and persistent pesticide levels in cultured cockles, *Anadara granosa, Barbatia bicolorata, Atrina vexillum, Pinctada vulgaris* and *Saccostrea cucullata*. Evidently, the PCBs (Kanechlor 400) content in cultured cockles along the east coast of Penang Island is higher (198.93-335.31 ppbs) then those in the west coast (160-56.72 ppbs) reflecting a greater extent of environmental contamination due to industrialization. It should be noted that the levels of PCBs in cultured cockles in the Kuala Juru area showed only a value of 193.10 ppb. However, on comparison with other shellfish species of Barbatia bicolorata, *Atrina vexillum, Pinctada vulgaris* and *Saccostrea cucullata* from the Marine Depot they are relatively low.

With regard to persistent pesticides content, only p,p'DDE was detected in the sample from Batu Maung Site 1 (9.24 ppb).

TABLE 2: Levels of PCBs and persistent pesticides in cultured cockles and some common shellfish of the Island of Penang, Malaysia.

Sampling Site	Shellfish sp.	PCBs(KC-400) (ppb)	p,p'DDE (ppb)
Bukit Dumbar	*Anadara granosa*	335.31	N.D*
Pantai Aceh	*Anadara granosa*	249.45	N.D
Kuala Sungei Pinang 1	*Anadara granosa*	174.45	N.D
Kuala Sungei Pinang 2	*Anadara granosa*	160.29	N.D
Kuala Jalan Bharu	*Anadara granosa*	256.72	N.D
Batu Maung 1	*Anadara granosa*	198.93	9.24
Batu Maung 2	*Anadara granosa*	306.38	N.D
Batu Maung 3	*Anadara granosa*	309.94	N.D
Sungei Nibong	*Anadara granosa*	279.5	N.D
Kuala Juru	*Anadara granosa*	193.10	N.D
Marine Depot	*Barbatia bicolorata*	436.55	N.D
	Atrina vexillum	519.79	N.D
	Pinctada vulgaris	467.25	N.D
	Saccostrea cucullata	461.57	N.D

Note: * = not detectable.

The levels of PCBs and persistent pesticide residues in mussels of Penang waters, Malaysia and Singapore waters in comparison with data from other parts of the world is presented in Table 3. Evidently, mussels from Permatang Damar Laut had the least content of p,p'DDE (3.69 ppb) and PCBs (99.9 ppb), which could be attributed to the fact that the vicinity is only a small fishing community without any localised industry. The highest level of PCBs was detected in mussels from Pulau Jerjak probably due to adulteration by paint works of a shipyard located at this island.

TABLE 3: Comparison of PCBs and persistent pesticide residues (DDE/DDT) concentrations in mussels at various parts of the world with that from Malaysia and Singapore.

Locality	Date	Species	p,p'DDE[*]	p,p'DDD[*]	ΣDDT[*]	PCBs[*] (KC-400)	
MALAYSIA (Present Study)	1979						
Weld Quay (old pier)		*Perna viridis*	12.46	ND[**]	12.46	400.9	
Marine Depot		*Perna viridis*	17.38	ND	17.38	442.3	
Permatang Damar Laut		*Perna viridis*	3.69	ND	3.69	99.9	
Batu Maung		*Perna viridis*	17.15	ND	17.15	480.7	
Gertak Sanggul		*Perna viridis*	16.17	ND	16.17	495.9	
Pulau Jerjak		*Perna viridis*	10.12	ND	10.12	599.9	
SINGAPORE (Present Study)	1979						
Ponggol area		*Perna viridis*	7.11	ND	7.11	170.4	
Seletar area		*Perna viridis*	8.12	ND	8.12	256.9	
Serangoon area		*Perna viridis*	7.82	ND	7.62	139.8	
U.S.A. (West Coast)	1976						
Bodega Head		*Mytilus californianus*	17-34.6	7-23	NG[***]	10-50	GOLDBERG *et al.*, (1978)
Tillamook Bay		*M. edulis*	< 3-17	< 2-44	NG	9-25	GOLDBERG *et al.*, (1978)
San Pedro Harbour		*M. edulis*	330-17,000	150-41,200	NG	440-8,700	GOLDBERG *et al.*, (1978)
Puget Sound		*M. edulis*	< 2	NG	< 4	41	GOLDBERG *et al.*, (1978)
San Diego Harbor		*M. edulis*	29-57		NG	560-1,400	GOLDBERG *et al.*, (1978)
U.S.A. (East Coast)	1976						
Narragansett, Rhode Island		mussel	25.6 -37.2	NG	NG	281-625	GOLDBERG *et al.*, (1978)
Portland		mussel	< 7.86	NG	NG	94.6	GOLDBERG *et al.*, (1978)
Boston		mussel	44.4	NG	NG	635	GOLDBERG *et al.*, (1978)
New Haven		mussel	< 7.43	NG	NG	129	GOLDBERG *et al.*, (1978)
Herod Point		mussel	17.6	NG	NG	215	GOLDBERG *et al.*, (1978)
Northwestern Mediterranean	1973-1974	*M. galloprovincialis*	NG	NG	23	258	MARCHAND *et al.*, (1976)
Baltic Sea	1966-1968	*M. edulis*	NG	NG	21	30	JENSEN *et al.*, (1969)
Archipelago of Stockholm	1966-1967	*M. edulis*	NG	NG	40	37	JENSEN *et al.*, (1969)
Holland Coast (Rhine)	1965-1968	*M. edulis*	NG	NG	100-250	600-1,100	KOEMAN & VAN GENDEREN (1972)
Sweden	1972	*M. edulis*	NG	NG	95	13	ICES (1974)
Germany	1972	*M. edulis*	NG	NG	25	90	ICES (1974)
Holland	1972	*M. edulis*	NG	NG	9	237	TEN BERGE & HILLEBRAND (1974)
Canadian Atlantic Coast	1970	*M. edulis*	NG	NG	20	140	ZITKO (1971)
Norway	1972	*M. edulis*	NG	NG	25	30	ICES (1974)

[*] Concentration in ppbs on dry weight basis, [**] ND; not detected, [***] ; not given. KC-400; Kanechlor 400.

Both p,p'DDE and PCBs in mussels of Singapore waters were between 2-4 and 3-6 times lesser, respectively, in content as compared to their Malaysian counterpart. The reason for this could be attributed to the fact that the Malacca Straits resembles a large oceanic lake influenced only by tidal currents with very little movement of the major water mass. In contrast, the Singapore waters have a rapid turnover and high rate of dilution accounted by oceanic currents of the South China Sea and large inputs of water from rivers in the state of Johore and Singapore itself. This is further amplified by the fact that the mussel stations in Penang waters are located at nearby industrial estates of Peninsular Malaysia.

The mean levels of PCBs and persistent pesticide residues in the fronds of the sea lettuce, *Ulva reticulata*, is shown in Table 4. These values are lower by exponential - 3731 times for DDE, 449-1998 times for α-BHC, exponential - 1749 times for β-BHC, 318-2849 times for γ-BHC and 3.2-30 times for aldrin as compared to those found in the water column. A contaminant level of PCBs (16.6 ppb) was detected but is fairly low on comparison to seaweeds of the East Coast of Sicily (AMICO *et al.*, 1979).

TABLE 4: Mean PCBs and persistent pesticide residues content in the economically prominent sea lettuce, *Ulva reticulata* FORSSKAL.

Contaminant	Concentration (ppb g^{-1} dry weight)
PCB (KC 400)	16.6 ± 0.15
DDE	9.6 ± 0.05
α-BHC	0.089 ± 0.012
β-BHC	1.03 ± 0.015
γ-BHC	0.48 ± 0.04
Aldrin	606.8 ± 0.53

DISCUSSIONS

It is evident from this survey that the only detectable persistent pesticides in Penang waters are α-, β- and γ-BHC, aldrin, dieldrin p,p'DDE. Though the contaminant levels fluctuate from sta station to station, the reasons accounting for it is not quite explainable in a crystal clear fashion at the moment, but probably be attributed to oceanographic factors prevailing in the monitoring localities and point sources of the contaminants. Nevertheless, the levels of all observable pesticides fall within the limits of safetiness from the viewpoint of health hazards.

Regarding PCBs, though it is not detectable in a liter of water sample it is considered that larger amounts of water samples (ca. 20 ℓ) be used and extracted via adsorption column chromatography on XAD-2 resin. This would certainly verify the lower levels of PCBs in Penang waters.

Here, it is possible to envisage to a certain degree the levels of PCBs and persistent pesticides contamination in the Malacca Straits because the sampling area falls within the region of tidal flushing activity of the widely considered oceanic lake. However, for precision, extensive research at a number of stations in the Malacca Straits is highly recommended. The investigation should also be extended to the coastal areas of the states of Perlis and Kedah which are the rice bowls of Malaysia where pesticides are extensively used.

Malaysia being the largest producer of aquacultured cockles in the world, the present study on PCBs and persistent pesticides contaminants is extremely relevant in relation with the sharp drop in seed availability. NAKAMURA and KASHIMOTO (1978) have reported the PCBs content in wet tissues of *Crassostrea* from Nagasaki, Hiroshima and Osaka, *Tapes* from Ise and Matsusaka, *Corbicula* from Shimane, *Meretrix* from Korea and *Mytilus californianus* from CA to be 0.014, 0.031, 0.27, 0.006, 0.002, 0.087, 0.015 and 0.004 ppms, respectively. Similarly, SIMS *et al.*, (1977) have indicated that the p,p'DDE levels in bivalves from the Northwest Atlantic to be

0.51 ppm on a wet weight basis. Since its a well established fact that normally the moisture content of shellfish vary between 70-80%, the levels indicated for cockles in our region on a dry weight basis is not in the least astonishing. However, the possibility does exist in that it might effect deleteriously towards larval development influencing ultimately seed production hand-in-hand with complications of other contaminants.

Mariculture of mussels (SIVALINGAM, 1977) is another highly productive source of animal protein in the tropics with minimal investment. Hence, the present investigation is of paramount importance. Comparison of our data with those from other areas, i.e., San Petro Harbor and Boston (GOLDBERG, *et al.*, 1978), of the world indicate that the levels of p,p'DDE in Malaysia as well as Singapore mussels are fairly low. As for PCBs, the levels in mussels from Penang are fairly high if compared to the lower values reported for Bogeda Head, Tillamook Bay (GOLDBERG, *et al.*, 1978), Baltic Sea, Archipelago of Stockholm (JENSENS, *et al.*, 1969) and Sweden (ICES; 1974). However, on comparison with values of mussel from San Pedro Harbor, San Diego Harbor (GOLDBERG, *et al.*, 1978) and Holland Coast (KOEMAN & VAN GENDEREN; 1972) they are still low. A similar tendency is observable for mussels from Singapore.

It should be noted here that the mussel samples from all the stations did not demonstrate contents of persistent pesticide residues other than p,p'DDE although the existence of α-, β- and γ-BHC's, aldrin and dieldrin in water samples has been indicated previously. This could probably be attributed to the possible rapid depuration processes in the organism within the tropics or due to geographical distant locality of the sampled population from the pollutant source. On the contrary, the situation is reverse for PCBs, as it is not detectable in water extracts.

On a regional basis, it had already been reported by MENASVETA and CHEEVAPARANAPIWAT (1979) that the DDT and PCBs content in mussel from river mouths, i.e., Chao Phraya, Ta Chin, Mae Klong and Bang Prakong of Thailand were generally in an order less than that of the North Sea. Thus, on comparison of this status with values obtained for mussels from Malaysian and Singapore waters it is obvious that the present study demonstrates the higher level of pollution in this area.

Taking into account the foregoing one should bare in mind that due to various reasons the availability of spats for establishment of mussel aquaculture farms is encountering some difficulty recently.

The feasibility of using the sea lettuce as a prominent food source has already been reported by SIVALINGAM (1979c). In this regard, the present investigations support this objective from the viewpoint of environmental contamination. However, with the rate of contaminants being dumped into the aquatic environment this might be questionable in the near future.

With this overall perspective of pollutant levels in Malaysian waters and some economically important marine organisms and the present cry over depleting fishery resources, it is imperative to stress on this point towards rural development of fishing communities. In this connection, one should keep, a close watch of the deteriorating aquatic environment and try to establish an integrated fishing community as what is planned for the Besut Fishing Community.

As a proposal, the author suggests that a "Mussel-Watch" programme be established on a regional basis as already been implemented in the USA, Mediterreanean Region, Australia, New Zealand, Korea, Chile, Turkey, Taiwan and Thailand. This will certainly play an important role in our future rural development of fishing communities from the viewpoint of mass mariculture programmes to raise their standard of living from the economical st stance.

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DISCUSSIONS :

Q : You mentioned that you did not detect PCB in the water. Have you done any analysis on larger volume of samples? What sort of levels were there?

A : As stated earlier, we used 20 litre samples for PCB analysis, Normally the analysis for larger amounts require copper tubings and a continuous pumping system to eliminate contaminations. This was impossible to do since we did not have a good research vessel.

Q : In respect of the other pesticides, have you detected BHC in mussels and other shell-fish samples?

A : Due to metabolic degradation etc it did not exist in our chromatogram. It has been eliminated and it was not a problem in shell-fish.

Q : Have you done any analysis on planktons?

A : Yes, it is limited to trace metals and around Penang Island only. It is an important aspect of the food chain. However no work is being done on PCB because of lack of funds.

WATER POLLUTION SURVEY AND THE IMPACT OF FARMING ACTIVITIES ON RESERVOIR INPUTS

Adhityan Appan
Nanyang Technological Institute
Singapore

ABSTRACT

Farming wastes are generally voluminous and potent. To relate runoff quality in such areas to different pollution sources, a water pollution survey can be carried out. The modus operandi of carrying out a typical water pollution survey is explained based on two case studies in Singapore. All sources of pollution on land are physically located, identified, ennumerated and classified. Also, all major watercourses are identified and their flow and quality monitored regularly. The pollution load entering the reservoir is computed by preparing an Input Budget. For this purpose, unit pollution loads of the major contributors like pigs, human beings etc., are determined. For other waste sources that are known to be an integral part of the input, either field measurements are made or values based on literature survey adopted. A comparison of the computed input with the actual input is made to validate the accuracy of assumptions. The Input Budget is also presented both on a subcatchment and total catchment basis for organic (BOD) and nutrient (PO_4) parameters. Conclusions are drawn to assess the impact of farming wastes on the individual subcatchments and the reservoir.

INTRODUCTION

It is known that for every kilogram of animal protein consumed by human beings, over twenty kilograms of wastes are being generated by animals (TAIGENEDES, E.P. 1977). Besides, based on an extensive literature survey, it has been shown that farming wastes due to pig rearing are extremely potent in terms of organic content (BOD) and nutrient potential (PO_4), having equivalent values of 3.17 to 5.18 humans and 1.70 to 2.39 humans respectively (APPAN, A. 1979). Thus, wastes emanating as a result of farming activities pose mammoth problems of both treatment and disposal by virtue of their bulk and potency. These problems are magnified manifold when high-intensity farming is practised within catchments used for the abstraction of water and especially when farming wastes form a major part of the input load into an impounding reservoir. It then becomes imperative that the waste quanta from the farming sector be identified and the degree of contribution established with a view to take necessary remedial action.

AIM OF A WATER POLLUTION SURVEY

Water pollution surveys have been conducted in the past to study and analyse sources like sewage effluents, industrial wastes etc., (DORFMAN, R. and JACOBY, H.D. 1972)(JENKINS, S.R. 1969). But with more recent findings and subsequent legislation on heavy load contributions from non-point sources from the farming sector (FEDERAL WATER POLLUTION CONTROL ACT AMENDMENTS, 1976), the need to appraise the magnitude of farming wastes in whatever form they are disposed is even greater. Hence, the main aim of a water pollution survey is:

a. Physical location, identification and ennumeration of sources on land

b. Monitoring of all waterbodies within the catchment

c. Classification of the sources of pollution and, based on field observations and study, outlining of existing waste disposal pracises and

d. Preparation of an Input Budget of loads on a subcatchment and catchment basis.

MODUS OPERANDI OF A WATER POLLUTION SURVEY

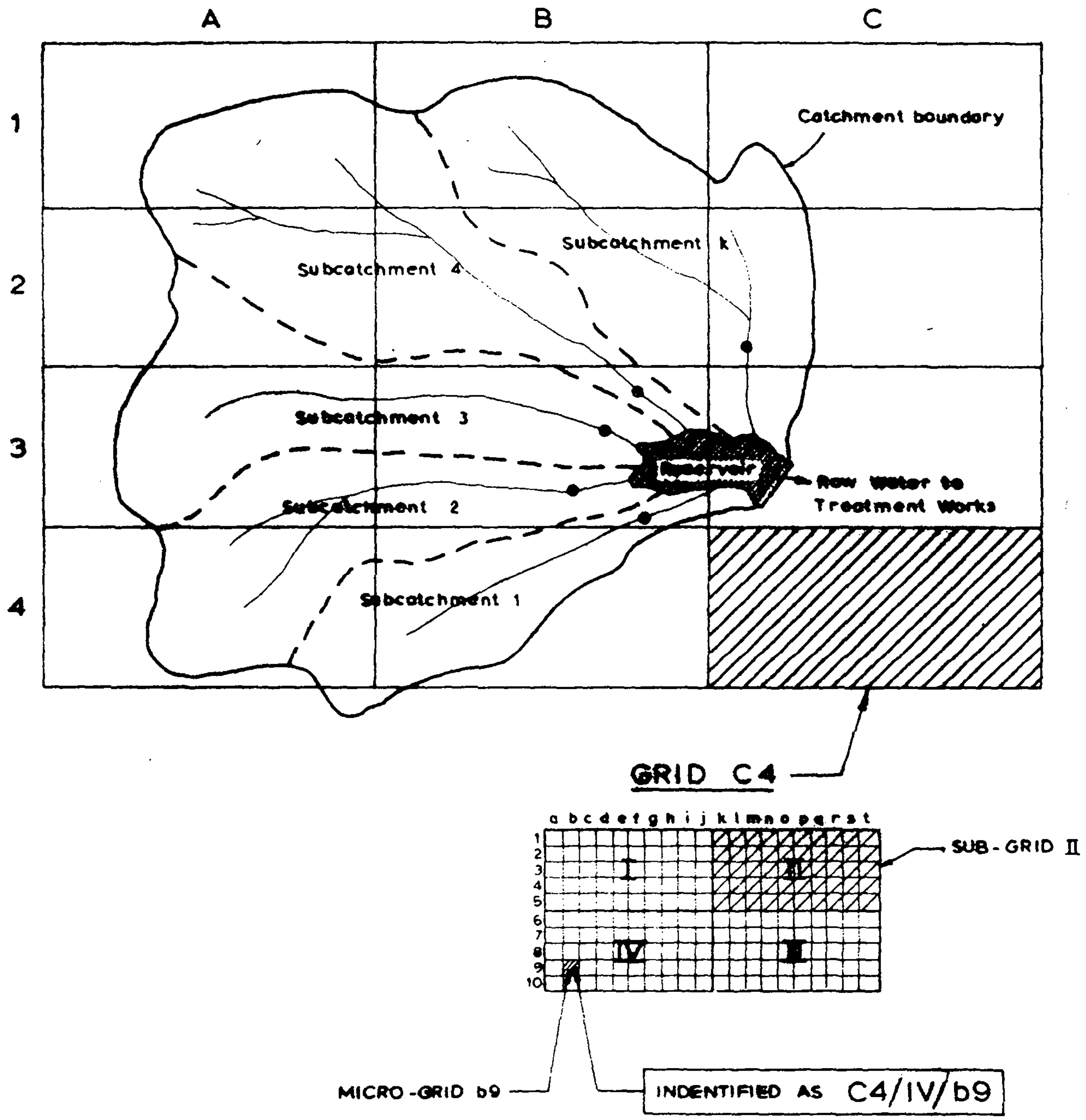
The method of carrying out a water pollution survey, to a great extent, is based on a case study (APPAN, A. 1973). This methodology has been susequently used in another survey (APPAN, A. 1974) and the details outlined mainly refer to these two case studies.

Physical location and identification on land: Before proceeding with any field work, it is necessary to obtain proper location maps encompassing the area so that the watercourses and main morphological characteristics of the catchment are well understood. Having obtained these maps, it is necessary to obtain as much information as possible on the exact location of the pollution sources on land and to make a note of the magnitude or quanta. For this purpose each of the detailed maps (of a larger scale) is divided into grids, subgrids and microgrids as shown in the hypothetical catchment cum reservoir shown in FIG. 1.

Each grid has an area of 500 acres and for ease of field operation a grid is further subdivided into four equal subgrids. Also, a grid consists of 200 microgrids, a microgrid of 2.5 acres being the smallest land area to be dealt with. A suitable system of identification of a microgrid was also arrived at (see FIG. 1).

In the case studies, these field exercises were carried out by semi-skilled staff as field orientation by means of existing landmarks in the available drawings was not time-consuming or difficult. Within each of the microgrids the types, number and location of the pollution-contributing agents were identified and the information logged in standard formats. Also, any relevant practices on existing waste disposal or farming methods were noted.

Monitoring of all waterbodies: In each of the subcatchments, the major watercourse was located and the most ideal point selected



Note: ● Represents sampling points in subcatchments.
1 grid = 4 subgrids = 200 microgrids

FIG. 1. FIELD IDENTIFICATION IN POLLUTION SURVEYS

for collection of water samples and stream gauging. The collected samples, as far as possible, were representative of the subcatchment area and for the stream flow it was ensured that the location of measurement did not fall within the influence of the backwater curve.

For each of these samples, physico-chemical parameters like temperature, colour, pH, Silica , Phosphate, Dissolved Oxygen, BOD, COD, Nitrite, Nitrate and Organic Nitrogen were determined. Besides, bacteriological samples were also collected and tested.

Outfalls from industries discharging into watercourses or sewers were also monitored and analyses for some additional parameters done according to the nature of manufacturing product.

CLASSIFICATION OF SOURCES BASED ON FIELD OBSERVATIONS

Based on an analysis of the information accumulated as a result of the census of the pollution-contributing agents on land, the major sources of pollution in the case studies were identified to be in the following order:

a. Pig wastes
b. Human wastes
c. Industrial wastes.

All these major sources are the result of man's activities and hence existing conditions, practises and habits with respect to the catchments were studied in detail as and when field data was being gathered.

Pig Wastes: The domesticated animals the farmers reared were mainly pigs followed by poultry. There were isolated cases of other animals or birds being reared and there was also some vegetable farming. Besides purely pig farming, a good number of farmers practised "mixed" farming which involved the breeding of pigs along with other farming animals with/without some vegetable farming.

Pigs were bred according to seasonal demands and there was always a wide fluctuation in the number being bred. Pigs were fed in their pens and no special area was provided for the collection of feces and urine. Pig waste was produced copiously and intermittently and to keep the pens clean and the pigs "cool", water was used by the indigenous farmer. In most cases this pig waste was directly discharged into the watercourses but in some of the farms the resultant pig slurry or some of it was channeled to a "slurry" pit. In these slurry pits a thick and hard crust was formed on the top surface which provided anaerobic conditions for the entrapped slurry within the pit. However, the effluents from these slurry pits found their way into the watercourse.

Next to pig farming, the incidence of poultry farming was greatest but, as a potential source of water pollution, poultry wastes bore no threat. Their wastes were removed in solid form because such wastes have a better fertiliser value.

In most of the pig farms there were also hyacinth ponds which were used for growing hyacinth which was used sometimes as fodder. Also there were fish ponds wherein a judicious amount of pig waste, normally from slurry pits, was fed periodically. This waste is excellent nutrient for the plankton which in turn serves as excellent food for the fish being reared.

For harvesting of fish, the fish ponds were dewatered and drained into the nearest watercourses. The discharged pond water did not contribute largely towards the pollutional load as it had been cleansed partly by the cycle of operations undergone by the animal and plant life within (SEOW, P.C. and TAY, G. 1973). However, in summer when the water levels were low, the activating factor for harvesting of fish was the appearance of a few dead fish, perhaps due to fatal oxygen depletion. When these ponds drained there was a turbulent mixing with the benthos resulting in highly polluted discharges (WATTS, J.C.D. 1965).

Human Wastes: In rural areas latrines were found to function as a mode of human waste disposal. In the case of all approved structures there were Septic Tanks or small Sewage Treatment Plants and their effluents were discharged into watercourses.

Industrial Wastes: Industries with solid wastes like saw dust increased the organic load in runoff whereas it was noticed that processing of timber in water imparted colour and odour. With more than half the total wood industries in the country situated in the initial case study area (CHUA, Y.H. 1970), the control in this sector bore more importance. All industries having liquid wastes were required by law to discharge effluents falling well within the (then) mandatory standards for discharging wastes into watercourses or sewers (THE ENVIRONMENTAL PUBLIC HEALTH REGULATIONS, 1971).

Pesticides, herbicides etc,: From information obtained from the relevant authority, it was confirmed that the quantity used which was mainly of a biodegradable type was of a very low order.

PREPARATION OF AN INPUT BUDGET

In the first case study, the area under consideration was already functioning as a water catchment though the impounded water was not yet ready for treatment and use as potable water. The quality of water in the reservoir being of a low order it was considered worthwhile to appraise the magnitude of the load contributions from the various sectors of pollution.

To prepare an Input Budget for the load entering an impounded reservoir, the following steps may be undertaken (APPAN, A. 1977):

a. Initially unit pollution loads from the major sectors of pollution have to be calculated. The methodology involves the selection of sampling subcatchments for which initially an Input Budget has to be prepared. The major sources of pollution in this sampling subcatchment like wastes of animal and human origin should be well-defined. A proper literature survey of these unit pollution loads was carried out and "equivalent human" values obtained as shown:

Table 1. "Equivalent human" values for pig wastes

Parameter	Equivalent humans/pig
BOD	4.13
PO_4	2.22

b. Having obtained the above equivalent values, the rest of the sources like loads due to erosion, rainfall etc, are measured on site or estimated (LOEHR, R.C. 1974, WEIBEL, S.R. 1969). The Input Budget for the sampling catchment can then be represented by the equation:

$$I_{sc} = L_h n_h + L_p n_p E_h + I_e + I_{rf} \quad \ldots\ldots\ldots\ldots \quad \text{Equation 1}$$

where I_{sc} is the measured input in a sampling catchment,

L_h, L_p are unit pollution loads of humans and pigs respectively,

n_h, n_p are numbers of humans and pigs respectively,

E_h is the 'Equivalent human' value from Table 1,

I_e is the load due to erosion etc, and

I_{rf} is the load due to rainfall.

c. From Equation 1, the unit values are obtained and then by simple extrapolation, the input load from each of the subcatchments and the total load into the reservoir are determined. The Input Budget prepared thus is shown in detail in Table 2A (for BOD) and Table 2B (for PO_4).

(NOTE: An alternate and more exhaustive computer solution for determining unit pollution loads (APPAN, A. and CHIN, K.K. 1979) has been published.)

COMPARISON OF COMPUTED AND ACTUAL INPUTS

The Input Budgets as prepared and shown in Tables 2A and 2B represent computed values and have to be checked to confirm the

Table 2A. INPUT BUDGET - BOD

Sub-catchment	Waste loads (in metric tons/annum)					Sub-total
	Pigs	Humans	Indus-tries	Erosion	Rain-fall	
1	376.95	4.22	0.39	37.44	15.20	434.20(6.5%)
2	418.75	10.77	0.82	79.55	32.31	542.20(8.1%)
3	1071.17	45.12	0.60	88.91	36.11	1241.91(18.4%)
4	3565.94	129.59	4.72	116.99	47.51	3864.75(57.4%)
5	228.01	12.08	0.00	23.40	9.50	272.99(4.0%)
6	55.39	50.65	97.58	121.65	49.42	374.69(5.6%)
	5716.21 (84.9%)	252.43 (3.8%)	104.11 (1.5%)	467.94 (7.0%)	190.05 (2.8%)	6730.74(100%) (100%)

Note: Figures in parenthesis represent % of total input.

Table 2B. INPUT BUDGET - PO_4

Sub-catchment	Waste loads (in metric tons/annum)					Sub-total
	Pigs	Humans	Indus-tries	Erosion	Rain-fall	
1	53.11	1.64	0.00	0.27	0.30	55.32(8.8%)
2	43.26	3.08	0.01	0.57	0.65	47.57(7.5%)
3	83.38	10.20	0.92	0.63	0.72	95.85(15.2%)
4	336.68	36.12	0.00	0.83	0.95	374.58(59.4%)
5	21.47	3.09	2.08	0.17	0.19	27.00(4.3%)
6	8.04	20.05	0.00	0.86	0.99	29.94(4.8%)
TOTAL INPUT (into reservoir)	545.94 (86.6%)	74.18 (11.8%)	3.01 (0.5%)	3.33 (0.5%)	3.80 (0.5%)	630.26(100%) (100%)

Note: Figures in parenthesis represent % of total input.

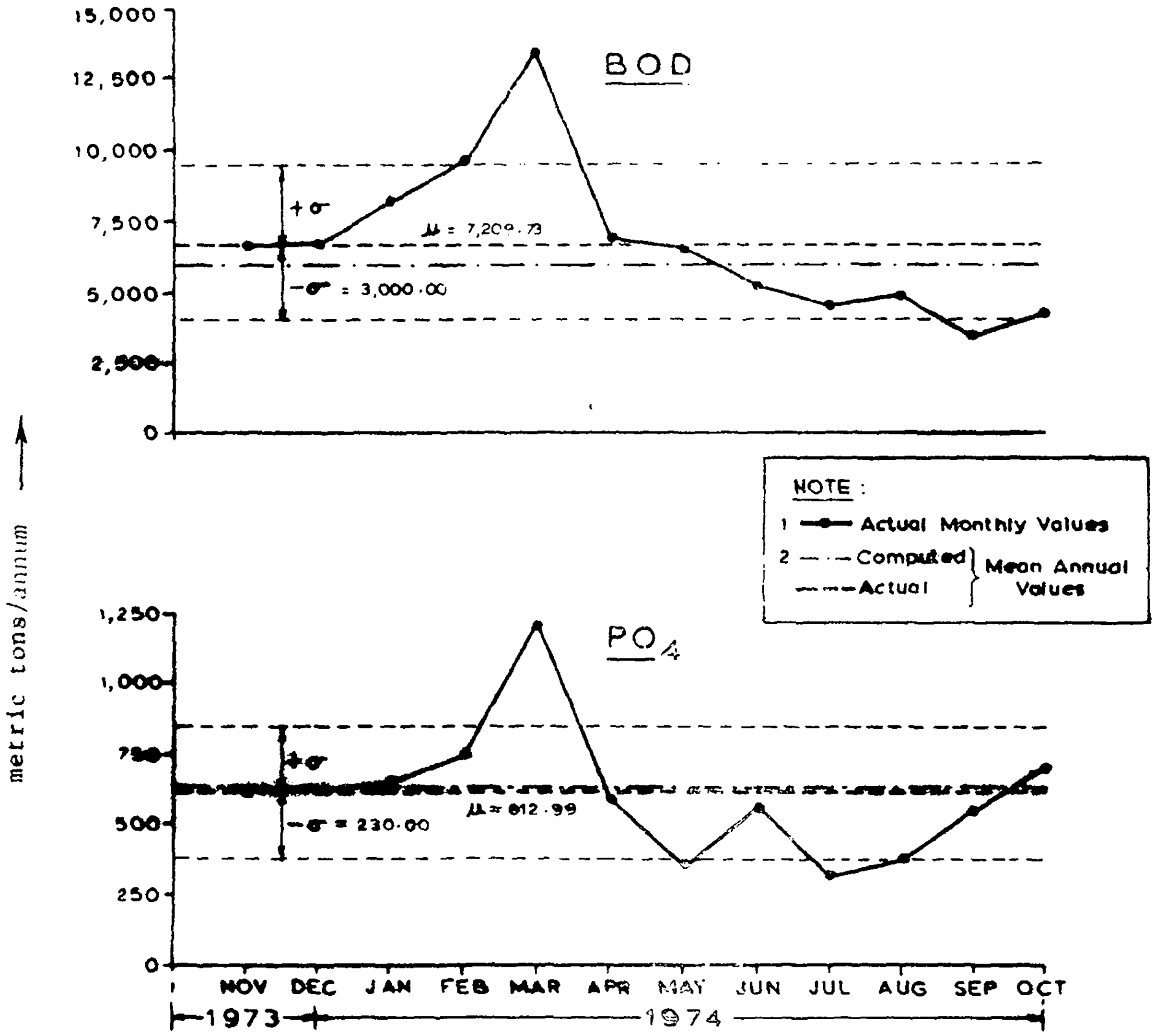
degree of accuracy in the assumptions that have been made. This can be done by comparison of these computed inputs with the actual inputs that can be calculated using all the quality and flow results of the sampling points obtained during the monitoring exercise. Using a suitable time base (of say 1 day, 1 week or 4 weeks), the actual input into the reservoir (L_a) is calculated as the product of the weighted mean concentration of all the streams' quality (C_{wmc}) and the inflow into the reservoir (Q_a). C_{wmc} is representative of the quality and flow of each of the monitored streams in the subcatchments during the period under consideration whereas Q_a is determined by a simple mass balance exercise for the reservoir. (NOTE: For formulation of C_{wmc} and L_a please see APPENDIX I)

The computed and actual inputs (for BOD and PO_4) into the reservoir based on the case study are shown in FIG. 2. A comparison is also made between these two sets of values and shown in Table 3.

Table 3. COMPUTED VS ACTUAL INPUTS

Parameter	COMPUTED Input (metric tons/annum)	ACTUAL Input (metric tons/annum)		% Error
		Mean	Standard Deviation	
BOD	6730.74	7209.73	3000.00	-6.6%
PO_4	630.26	612.99	230.00	+2.8%

From FIG. 2 and Table 3, it can be ascertained that the assumptions made for the computed inputs are quite reasonable and thus the unit pollution approach can be considered to be sufficiently representative.



Note: Sampling period represents the hydrologic year.

FIG. 2. COMPUTED vs ACTUAL INPUTS

DISCUSSIONS & CONCLUSIONS

Pollution Survey: a. Pollution surveys have become a regular and essential feature of water resources development in a country like Singapore where there are competing demands for high-intensity land-use. Such surveys have pinpointed the type of sources, the magnitude of loads generated and the impact of such pollution loads on runoff quality. As a result, anti-pollution measures have been formulated involving massive resettlement of farmers and promulgation of a law banning pig farming in catchment areas. (CATTLE RESTRICTED AREA NOTIFICATION, 1977). On the whole, such water pollution surveys have helped in bringing about an awareness such that in all forms of land development the pollution of watercourses is a constraint that is definitely being taken into consideration.

b. In the initial case study, it was established that in terms of numbers, the pigs reared in farms were the biggest polluters. In almost half the number of farms pig wastes were directly discharged into watercourses.

c. Human waste was the second biggest polluter and generally Septic Tanks were under utilised.

d. A few of the big industries had some form of pre-treatment for their wastes (which was inadequate) and most of the small industries were in the process of having treatment plants installed.

Input Budget: a. The Input Budgets as computed are very informative and can be considered to be a true reflection of the distribution of loads from the different pollution sectors as confirmed by comparison with the actual (steady state) input values.

b. The distribution of input loads in the Budget as shown in Tables 2A and 2B exemplifies the fact that not less than 84.9% of the total input consists of pig wastes. Thus, the Input Budget not only pinpoints the magnitude of load contributed by a specific source but also pinpoints the geographical area in which action has to be taken.

c. The Input Budget also establishes that subcatchment 4 alone contributes the highest fraction of not less than 57.4% of the total input of which 53.0% was essentially from pig wastes.

d. The contribution of BOD and PO_4 from the industrial sector is negligible in all subcatchments except subcatchment 6 where 26.0% of the subcatchment's BOD load is from industries. A closer examination of other parameters could be carried out for this subcatchment to check whether the industrial wastes are toxic, hard to treat or a health hazard. In such cases, the possibility of diverting this subcatchment's runoff can be looked into, the tradeoff being the loss in reliable yield against the additional treatment costs that will be incurred.

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APPENDIX I

Actual Input into a reservoir

The weighted mean concentration of the actual input into a reservoir is given by:

$$C_{wmc} = \left[\frac{\sum_{n=1}^{k} \sum_{m=1}^{\ell} C_{n,m} q_{n,m}}{\sum_{n=1}^{k} \sum_{m=1}^{\ell} q_{n,m}} \right] \text{.................... Equation 2}$$

Where $C_{n,m}$ = the concentration in the n^{th} catchment at time sequence m,

$q_{n,m}$ = flow in the n^{th} catchment at time sequence m,

k = number of subcatchments,

ℓ = number of samples collected.

The Actual Input into the reservoir will then be:-

$$L_a = Q_a \times C_{wmc} \text{ .... Equation 3}$$

where Q_a is the inflow into the reservoir during the period under consideration and is determined by independent mass balance studies.

DISCUSSIONS :

Q : You have mainly dealt with organic pollutants. Have you considered copper contamination? We have a lot of problems with copper which is amended with feed? The discharge of slurries which contained copper had affected the growth of cockles.

A : At that stage of our planning we encountered contaminants of intensities 15 times higher than conventional sources; We were not involved with trace metals, they are limited to industries. In one catchment area which has industries, we diverted the flow into the sea after treatment. Hopefully the trace-metals do not get into the reservoir.

Q : You are well-aware of the IDRC programme in the Primary Production Department in Singapore where pig wastes are under going treatment in high-rate algae ponds for production of animal feed. What is the progress and the feasibility?

A : At the moment the Singapore government resettles the pig-farmers in certain chosen areas to avoid pollution of water courses. It is not known whether the high-rate oxidation ponds is feassible. The high cost of treatment using sophisticated technology may prove to be prohibitive. Currently Singapore is importing pork from Thailand.

Q : Owing to the massive pollution within the catchment area, what is the period before it can be considered safe to serve its purpose?

A : The phasing of the reservoir is done within a lapse of about 18 months before the reservoir could be used. Due to the high chloride content in the water of the estuary, a choice has to be made between pumping out the polluted water or the natural process of dilution by run-off. The latter course was chosen because not only the chloride level is high, it is also highly polluted. The cost of treating this water is about 2½ times those of other waters in Singapore. There was no need of this water then. The planning group preferred to complete the elimination of the pollution first before using the reservoir. It took about 20 to 24 months before the reservoir was finally used.

AN APPROACH TO REDUCING HEALTH HAZARDS IN WATER RESOURCE DEVELOPMENT PROJECTS

R C Carter and M G Kay
National College of Agricultural Engineering,
Silsoe, Bedford MK45 4DT, England

ABSTRACT

Certain kinds of water resource development projects in hot climates have important adverse implications for human health. The major aspects of such projects are discussed in relation to their effects on vector-borne disease. The specific diseases associated with these developments are discussed and tabulated. In the second part of the paper the concept of environmental management for disease control is introduced, and this is discussed in relation to the various phases of project planning and establishment. Finally, recommendations are made concerning action to be taken towards the general acceptance and implementation of such techniques.

INTRODUCTION

The development of water resources, especially in the tropics, has important implications for human health. The impact of such developments on health may be intentional and beneficial as with most domestic water supply and sanitation schemes, or it may be unintentional and adverse, as is the case with many hydroelectric power and irrigation projects. While improvements to sanitation and domestic water supplies have as a major objective the improvement of human health, other types of project whose principle objectives lie in agricultural or industrial development may, and often do, have unfortunate health side effects.

In view of the large amount of literature and case study documentation in this area it cannot be truthfully said nowadays that the adverse consequences to health caused by certain types of water resource development projects are unexpected: unless deliberate measures to avert these consequences are taken at planning, design and operation and maintenance stages, then health problems will occur. This much is clear from past experience, even if it is also clear that the prediction in detail of the effects of environmental change on disease and disease vectors is not simple.

Although human health has to be considered as a whole, especially the total relation of water to health, this paper is concerned with those diseases which require a vector or intermediate host for their transmission. This paper refers to specific important diseases and to specific case studies. A strategy for vector-borne disease control is proposed using environmental management measures and the need to train engineers in such techniques is discussed.

HEALTH IMPLICATIONS

1. Important Facets

It has already been pointed out that it is those projects whose primary objectives do not lie in the direct improvement of public health which often have adverse health consequences. These include irrigation and drainage projects, hydroelectric schemes, and surface water impoundments for other purposes such as flood control, domestic water supply or navigation.

The major physical aspects of water resource development which are of relevance are dams for surface water impoundment, for whatever purpose, and land developed for irrigated agriculture with or without drainage.

The other major facet of water resource development projects which affects their health impact is the degree to which resettlement policy has attempted to reduce man-vector-pathogen contact and provide improved water and sanitation facilities.

1.1 Dams

The impoundment of surface water by ~~the~~ construction of a dam constitutes a very significant and sudden change to the physical environment. The resulting changes in the biological environment can be very important in terms of implications for human health. Because those responsible for planning and design of dams generally have a poor understanding of the ecological and biological implications of the changes they make to the physical environment, untoward and unforeseen results of such development projects can occur. Indeed, Oomen (1981) expresses the opinion that in the recent history of large and small dams, every one has been followed by such unintended consequences.

Stanley and Alpers (1975) document a number of case studies of dam developments in the tropics, all of which have had potentially or actually important effects on human health. These inlude the Kariba, Aswan, Brokopondo, Kainji and Volta dams (in Zambia/Zimbabwe, Egypt, Surinam, Nigeria and Ghana respectively).

In several of these cases, while the natural fast water habitats of the onchocerciasis-transmitting Simulium fly have been submerged and destroyed, the possibilties for the survival and breeding of anopheline and other mosquitoes, and schistosome bearing snails around the newly formed lake have been significantly increased.

In the main the important environmental effects of surface water impoundment are to establish shallow, extensive, still water conditions (often regulated) suitable for the breeding of mosquitoes and snails. If these new habitats are favourable to the local disease vectors or intermediate hosts, or if foreign species can be brought in and established, then there is potential danger to human communities living on or near the lake shore. Each insect and snail species and local strain has its own, sometimes stringent, habital requirements. This fact makes the detailed prediction of ecological change as a result of impoundment a specialist field.

1.2 Irrigated Land

In addition to the surface water reservoirs often associated with irrigation schemes, agricultural land development itself involves environmental changes which affect the disease vector ecology. Surtees (1975) mentions six general ways in which irrigation development modifies the environment and thereby changes the abundance and species composition of insect and other vectors. These are:

simplification of the habitat,
increased area of above ground water,
raised water table,
water flow,
modified microclimate, and
urban development.

The observed result of such changes is to reduce (in the short term at least) the diversity, but to vastly increase the available number of vector breeding sites. Open canals, drainage ditches, borrow pits and other areas of standing or slowly flowing water provide attractive sites for mosquitoes and snails in particular. The problem is exacerbated by poor maintenance of canals and ditches since weed growth slows water flow, encourages sedimentation and thereby produces attractive breeding grounds for disease vectors. Uncontrolled settlement and urbanisation adds even more fuel to the fire with its lack of water supply, storm water drainage, refuse disposal and sanitation.

The extent of the impact of irrigation development on human disease is huge. Schistosomiasis in particular is the disease of irrigation schemes in hot climates. Numerous case studies demonstrate the greatly increased prevalence of the disease only a few years after irrigation developments have taken place. In the case of the Gezira Scheme (Sudan) the impact of schistosomiasis has been such that the scheme as a whole has been branded as a failure (Pollard, 1981). Even if this description may be seen as overstating the case, there can be no doubt that the extent of the health consequences of irrigation developments throughout Africa and elsewhere is enormous.

1.3 Resettlement

The third important aspect of water resources developments, namely resettlement, relates intimately to the previous two. Both dam projects and irrigation schemes involve resettlement of rural communities, and usually an influx of human population. If resettlement is not carefully planned as part of the development project human health problems are sure to occur. Two important aspects of resettlement in the present context are the location of communities and the water supply and sanitation facilities available to them.

One facet of the concept of environmental management as discussed by WHO (1980) is that of "modification or manipulation of human habitation or behaviour.....to reduce man-vector-pathogen contact". Where resettlement planning fails to take account of the dangers of human proximity to vector habitats (many of which are man-made) it is deficient. Uncontrolled resettlement near irrigation canals, lake shores and other water bodies not only puts people in close proximity to insect vector habitats, but also encourages the use of the water for drinking, bathing and washing, with consequent schistosomiasis and guinea worm hazard.

It is clearly desirable for new communities to be sited some distance from open water to reduce contact with the disease vectors. This is only possible though if all the facilities which the lake or canal supplied can be provided within the new settlements. This means, among other facilities, the provision of good water for drinking, bathing and washing, as well as adequate drainage and sanitation. It may also mean the provision of swimming pools for children and others who would otherwise allow transmission of schistosomiasis by their bathing habits.

The essential factor, as Bradley (1977) points out, is that there must be easier access to safe than to unsafe water, for whatever purpose.

The fact is that in the past resettlement policies have not adequately protected the new communities from the disease vectors whose habitats have been produced by some water resource development projects.

2. The Diseases

Feachem (1977) mentions 37 diseases or groups of diseases which are water related and which, therefore, may be affected by water resource developments. A selection of the more important vector borne diseases is summarised in Table 1.

A STRATEGY FOR IMPROVEMENT

3. Introduction

Environmental management involves physical modifications to, or manipulation of, the environment associated with the development of water resources through the construction of dams and irrigation and drainage works to limit human contact with water and to create unfavourable habitats for vectors.

Examples in the more developed areas of the world have shown this to be an encouraging approach. The slow, steady re-organisation of the environment, although mainly for economic and social reasons, was a primary factor in the conquest of such diseases as malaria, plague and yellow fever (WHO 1980). In the tropics too, there are strong indications that environmental management can contribute significantly to the control of vectors and hence to improved community health.

These techniques need to be introduced into projects at each stage of planning, design, construction, operation and

TABLE 1: SOME WATER-RELATED VECTOR-BORNE DISEASES

Disease or Disease group	Pathogenic agent	Vector or Intermediate Host	Vector Habitat	Geographical Occurrence	Estimated No. of people affected worldwide	Actual or potential risk from dam and irrigation developments
Schistosomiasis (Bilharziasis)	Helminth (trematode worm) Schistosoma japonicum mansoni haematobium intercalatum bovis mattheii	Snail Oncomelania spp Biomphalaria spp Bulinus spp Bulinus spp	Still or slow flowing water e.g. lake shores, canals ditches	S.japonicum: Orient S. mansoni: Africa, South America Caribbean S.haematobium: Africa, Middle East	300 million (Jordan 1975)	Very high potential risk of substantially increased prevalence, based on past experience
Malaria	Protozoa Plasmodium falciparum vivax malariae	Mosquito Anopheles spp	Standing water (pools, ponds, borrow pits, etc)	Worldwide in hot climates	150 million clinical cases per year. Estimated fatalities (pre 14 years): 1 million per year (Chasles 1978)	High risk generally of providing new vector habitats, introducing reservoirs of disease among immigrants and introducing new mosquito species.
Filariasis (Bancroftian Filariasis, Onchocerciasis, etc)	Helminth (nematode, filarial worms) Onchocerca spp	Various insects: Simulium spp (Onchoceroiasis) Culex spp Anopheles spp Aedes spp Mansonia spp (Bancroftian filariasis and other filarial diseases)	Simulium spp: fast flowing oxygenated water Mosquitoes: standing water, floating vegetation, polluted water, etc	Worldwide in the tropics Onchoceriasis especially in West Africa	300 million approx. (Chasles 1978)	Simulium habitats are often destroyed by dam development; mosquito habitats are likely to be increased by dam and irrigation projects
Dracontiasis	Helminth (Guinea worm) Dracunculus spp	Arthropod (water flea) Cyclops spp	Small pools of open water, wells, etc	Sub-Saharan & N.E. Africa; Arabian peninsula; Iran; India; Pakistan	ca 20 million cases annually	Risk can be high where domestic water supplies for drinking are inadequate
Trypanosomiasis (Sleeping Sickness)	Protozoa: Trypanosoma spp	Tsetse fly Glossina spp	Riverine bush - shady vegetation near water, High humidity	Tropical Africa		The possibility of creating suitable habitats in vegetation along irrigation canals, etc is significant

maintenance and in the case of existing projects rehabilitation.

4. Planning Studies

For new projects, the early stages of development are of vital importance. The regional and reconnaissance studies establish the principal resources of a region and identify projects for more detailed investigation by feasibility studies. Where water resources are to be incorporated in the regional plan in the form of dams, river training or irrigation and drainage, a broad appreciation of their likely influences on community health is essential. Problems identified at this stage can be tackled within the development plan. If delayed to a later stage they can be extremely difficult and costly to put right. Involving specialist entomologists and epidemiologists into the investigating team would ensure that due attention was given to identifying specific vectors, types and location of their habitats and their behaviour and importance in disease transmission.

5. Design and Construction

In these phases there is a wide range of physical works referred to by several authors (McMullen 1973, Rafatjah 1975, Araoz 1978) which can be incorporated into projects to assist in disease control. However, the relative importance of such measures cannot be considered entirely in abstract, but must be project related because of the wide variation in geographic, ecological and social conditions between countries and even between projects in close proximity. A number of examples would illustrate this point.

Jobin (1978a) discusses physical improvements which relate to snail control on a reservoir in Mauritania. Special control structures are proposed to cause rapid fluctuations in water levels to strand snails; shore lines along the reservoir are to be strengthened and steepened so that the continual pattern of erosion will upset snail habitats, the reservoir is to be fenced because of the close proximity of a large community,and an adequate domestic water supply made available for them.

In Indonesia on the coastal lands where rice irrigation is practised, special dykes are constructed to control salinity levels in tidal areas and so control mosquito breeding. (Darwish 1978). Intermittent irrigation is also encouraged to control mosquito breeding in the rice fields, thus necessitating the construction of an adequate drainage system, which might otherwise not have been needed.

A project in a more arid region is an irrigated sugar cane/citrus estate in South Africa. (Pitchford 1962). The canal system was lined and fenced; drains are deep with almost perpendicular banks and labour is housed away from the irrigation and drainage system and provided with adequate water for domestic use. With no other measures taken there was less than 2% infection of schistosomiasis on the project.

Projects in Puerto Rico highlight the difficulty in deciding what are the most appropriate measures to take. (Jobin 1981). Irrigation schemes in close proximity varied greatly in their schistosomiasis problems. Schemes on sandy soils, with few water-logged areas and better hydraulic control over water distribution, had few problems, whereas schemes on heavier land with swampy conditions had many. Although canals were concrete lined in each scheme, some canals with quite high design velocities harboured snails, whilst others with lower velocities did not. This is an interesting observation when lining is thought by many to be one of the major contributions that engineering can make to snail control in irrigation schemes.

There are many other examples which illustrates the complex interaction of measures which are applicable only to the particular project being considered.

Two important points emerge from the literature. The first is that many of the more important measures which are effective in vector control may already form part of the physical works normally associated with water storage and control. The main reason for their inclusion, however, is unlikely to be for improved vector control, but more strongly linked to economic advantages in terms of better water use or improved crop production. For example, a decision to line a canal with concrete, rightly or wrongly, would undoubtedly be based on the benefits gained from greater water availability from reduced seepage or savings in future maintenance costs. A change from conventional surface irrigation to sprinklers or trickle methods would be based on soils, topography and cropping conditions. Although there are benefits to community health, these are likely to be secondary issues or considered a bonus.

The second point is that many of the items listed by the various authors are concerned with the standard to which the engineering works are carried out, rather than to special features. McJunkin (1975) points out that although there are obvious links between schistosomiasis and irrigation, the link is most strongly associated with defective and inefficient irrigation, poor land preparation and lack of field drainage than with irrigation per se. 'Schistosomiasis engineering in considerable degree is just good irrigation practice'. It is in this context that many developing countries experience problems. They often lack the skills or equipment to carry out work in a proper manner.

A common example of this is that of canal construction where spoil for embankments often leaves extensive borrow pits which fill with water and create excellent habitats for vector breeding. By careful construction, borrow can be sought from land out of command, by broad stripping or from spoil excavated from drainage channels. Similarly, improved construction methods and supervision of canal construction would lead to more compact embankments, less seepage and hence a reduction in the 'wet areas' around canals.

This means providing more highly skilled staff to carry out design and construction tasks and more time and effort spent by construction contractors working to achieve higher standards of workmanship.

6. Operation and Maintenance

This is one of the most neglected areas of project development as most attention, and indeed funding, is generally devoted to the more prestigious activities of constructing new projects. It is this neglect which has led to the need for extensive rehabilitation of many projects and reference is made to this aspect of development in section 7.

The problem of maintenance on a project depends very much on how well the project was constructed in the first place and the care taken in its planning and design. The same can be said for the maintenance of any environmental control measures introduced during earlier stages. As was pointed out above, when measures are delayed to a later stage they can be extremely difficult to rectify.

Operation of a water resources project provides an opportunity to practice various environmental manipulation measures. These could include water level control in reservoirs and draining canals or improved scheduling in irrigation schemes. To carry out these and other tasks implies that the necessary physical works have been provided and sufficient operators and managers with the necessary skills are available.

7. Rehabilitation

This applies mainly to irrigation projects where, throughout the world many have failed in some way to meet planned production targets and a common cause often cited is poor water management practices with resulting low irrigation efficiencies, often much less than 50%.

Physical improvement strategies have ranged from the use of structures to control water distribution more effectively to the re-organisation of field irrigation by improving field layouts and water management practices, land levelling and field drainage. There is considerable emphasis on the latter which is concerned with the application of engineering at field level. This is an area which has been greatly neglected in the past. Rehabilitation is usually carried out for improved agriculture and water use and not primarily for vector control. However, it can be seen that such improvements can create potential for both.

8. Training

One of the major problems of introducing such strategies into water resources development appears to be a general lack of awareness of health problems and how to deal with them among many of those who influence decision making in water development projects such as the construction of dams and irrigation schemes. Those with experience in the developing countries know only too well of the desperate shortage of properly trained people and those who understand the full implications of the work in which they are involved. An immediate requirement would appear to be a greatly increased programme of training so that presently available knowledge can be put to practical use in the field.

In the developing countries, many of which are within the tropics, a detailed awareness of the health problems associated with water is a vital part of a civil engineer's training. This requires a detailed course of study so that young engineers are not only aware of the problems of vectors and the diseases they carry, but are able to do something positive about them when they arise.

9. Conclusions and Recommendations

A number of conclusions emerge from the foregoing:

i) Many water resource projects of all sizes, especially schemes involving irrigation, drainage, and dams have had significant and largely adverse effects on human health through the creation of new vector habitats and the increase of man-vector-pathogen contact.

ii) Deliberate measures can be taken to manipulate the physical environment in such a way that these adverse health effects are minimised.

iii) Unfortunately the present knowledge of environmental management techniques has not been implemented to the extent that it might have been, and this is in large part due to a lack of inter-disciplinary communication and training.

iv) The inclusion of improved environmental management into new and existing projects would generally have a minor effect on project costs since most of the more significant and costly measures such as canal and reservoir lining can be defended on other grounds than only the health advantages to be gained.

In view of these conclusions the following recommendations are made:

i) Authoritative planning, design, and maintenance procedures should be drawn up to relate known and tried environmental management techniques to future water resource developments. The engineers and others who are involved in project development need such guidelines in this as in other non-engineering fields of knowledge.

ii) To further bridge the communications gap between the engineers and medical/biological specialists, in-service education and training courses should be established.

iii) Further work needs to be done to establish the true costs to the community of the adverse health effects of many projects. This is a necessary basis for the allocation of funds to environmental management work.

iv) Finally engineers and planners should work towards the integration, as a matter of course, of health and vector ecological studies into planning, design, construction, and operation and maintenance phases of water resource development projects.

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MODIFIED MATRIX APPROACH FOR ENVIRONMENTAL IMPACT ASSESSMENT OF THE PA MONG WATER RESOURCES PROJECT IN THAILAND

B.N. Lohani
Associate Professor
Environmental Engineering Division
Asian Institute of Technology
P.O. Box 2754, Bangkok

Soo Ah Kan
Division of Environment
1st Floor, Oriental Plaza
Jalan Parry, Kuala Lumpur
Malaysia

ABSTRACT

Several studies on environmental impact assessment of water resources projects in Thailand have been made but the use of quantitative approaches has been almost non-existent. This work represents an attempt to use modified matrix approach to assess the impacts of the Pa Mong water resources project in Thailand. The results of the study show that most of the ecological and physico-chemical parameters are adversely affected by the Pa Mong project whereas many of the parameters of human interest such as public water supply, flood control, irrigation, etc. will improve. Finally a relative quantitative assessment of the beneficial and adverse impacts provides information on the magnitude of the impact for decision making purposes.

INTRODUCTION

The success of large engineering projects which are meant to improve the quality of life of the people is usually assessed by economic analysis; essentially cost-benefit assessment. These projects are often viewed as innocent and beneficial to human welfare, and are generally implemented to solve human needs such as food, water, energy, etc. A good case in point is the building of dams and reservoirs to provide drinking water, hydroelectric power, flood control and irrigation. The building of dams and reservoirs will alter the natural environment, creating impacts that can be temporary or permanent. One of the fundamental impacts of dam building is the change in the physical and chemical characteristics of the water itself which can, in turn, lead to further changes in the ecology, aesthetic quality and the ultimate use of the project area. Other impacts include loss of land inundated by water; resettlement of people affected by the project; loss of wildlife habitats; mineral resources; archaeological treasure; deterioration in downstream water quality, and many other which are associated with or induced by the construction and operation of a dam (Wanner, et al., 1974; Lohani, 1980).

In Thailand, a number of environmental studies have been carried out on water resources projects (AIT, 1972, 1974; EGAT, 1973, 1976, 1978; Mekong Committee, 1979). In these studies, assessment of environmental impacts is usually done in a qualitative and descriptive manner - in a sort of item-by-item review. Quantitative data may be available in many cases, but they are not being made use of to evaluate the impacts.

This work represents an attempt to use one of the established impact assessment methodologies to assess the impacts of the Pa Mong water resources project - a major main-stream project along the Mekong River. The methodology being used is the modified matrix approach developed by Fischer and Davies (1973).

THE MATRIX APPROACH

The matrix approach was first introduced by Leopold, et al. (1971) for impact evaluation. Since then, it has been modified in several forms and used for environmental impact assessment. The approach developed by Leopold, et al. (1971) consists of an open matrix with 100 project actions arranged against a total of 88 environmental parameters. To use the matrix, each project action is checked against the possible impacted parameters. Potential impacts can also be evaluated in terms of magnitude and importance using scaling system such as the one proposed by Leopold, et al. (1971).

Leopold's matrix has been used as the basis for many other matrix approaches for impact assessment. Fischer and Davies (1973) designed a matrix approach that expanded Leopold's concept. Their approach essentially consists of 3 steps for identification and evaluation of impacts: (i) environmental baseline evaluation, where environmental elements are evaluated according to their importance, present conditions and scale of management required; (ii) environmental compatibility matrix, where important environmental elements from (i) are evaluated against project actions for their degree of beneficial and adverse impacts; and (iii) decision matrix, where project alternatives are evaluated against the various environmental components. Several other modifications of the matrix approach have been reported in the literature and no attempt is made to list them here. In this paper, the use of the modified matrix approach, along the line proposed by Fischer and Davies (1973) has been used to study the environmental impact assessment of the Pa Mong project.

THE PA MONG WATER RESOURCES PROJECT

The Mekong River, the longest river in Southeast Asia, forms the boundary between northeast Thailand and northwest Laos. The river flows in a southeasterly direction for some 4,200 km from its source in the high mountain of the Tibetan Plateau before discharging into the South China Sea.

The Pa Mong project is one of the major main-stream water resource projects along the Mekong River. It is planned as a multipurpose project catering for irrigation, power, flood control, navigation, recreation and other associated functions for Thailand and Laos. The project area is located in the northeastern Thailand where the Mekong River forms the boundary between Thailand and Laos (Fig. 1). The dam site is at Kilometer 1603 above the mouth of the Mekong River, about 560 kilometers north-northeast of Bangkok.

The Pa Mong dam is of concrete gravity type with a crest length 1,360 m and a crest elevation of 251.5 m. The spillway capacity is 36,000 m^3/s. When completed, the reservoir will have a storage capacity of about 100 billion m^3 at 250 m water level. The reservoir will inundated about 3,700 km^2 of land. The project possesses an installed capacity of 4,800 megawatts of electric power and a potential to irrigate more than 1.5 million hectares of farmland. The project also greatly improves flood control, navigation and other human activities. However, it also has a number of adverse effects, chief among these are the need to resettle some 200,000 to 500,000 people depending on the reservoir configuration; loss of wildlife; forest and downstream fisheries; increase in soil erosion and degradation of soil fertility and water quality, etc.

APPLICATION OF THE MODIFIED APPROACH

The modified matrix approach developed by Fischer and Davies (1973) is used to evaluate the impacts of the Pa Mong project. Results of a study carried out to develop an environmental evaluation system (EES) for water resources projects in Thailand are being applied to this modified matrix approach (Kan, 1981).

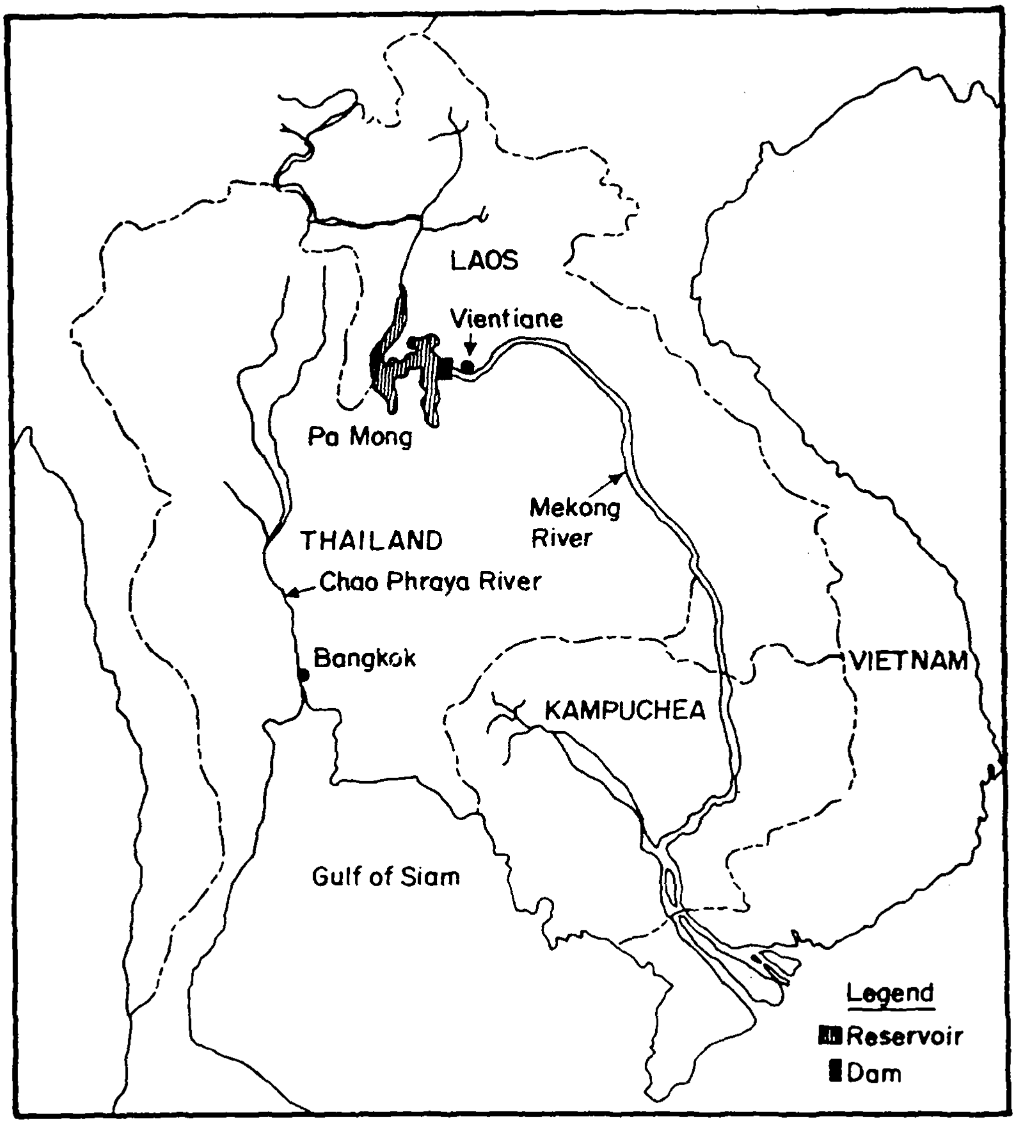

Fig. 1 - Location Sketch of the Pa Mong Project.

The first step of environmental baseline evaluation is shown in Table 1. The scale of importance is derived arbitrarily after studying the relative importance of the various environmental parameters established in the EES, while the scale of present condition is determined from a study of the report on the environmental effects of Pa Mong (Mekong Committee, 1979) as well as using the value functions curves of the various parameters developed in the EES. The scale of management is also arbitrarily determined.

Environmental parameters with an importance rating of 4 and 5 are carried forward to the next step of environmental compatibility matrix. In this step, the cause-effect relationships between project actions and environmental parameters are displayed. Impacts are identified as beneficial (+) or adverse (-), and long term (L) or short term (s). The degree of impact is rated from 1 (low) to

Table I.- Environmental Baseline Evaluation of the Pa Mong Project

Environmental Parameters	Scale of Importance					Scale of present Conditions					Scale of Management				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Ecological :															
Forest					■					■				■	
Wildlife				■						■				■	
Species Diversity			■										■		
Rare&Endangered species		■								■					■
Reservoir Fisheries					■								■		
Downstream Fisheries					■					■			■		
Migratory Fish			■									■			
Benthos		■										■			
Aquatic Weeds			■					■				■			
Eutrophication				■					■		■				
Phisico-Chemical :															
Soil Erosion					■			■							■
Soil Fertility					■		■							■	
Bank Stability			■					■					■		
Sedimentation				■						■		■			
Seismicity		■						■			■				
Flow Variation					■				■		■				
Evaporation				■						■		■			
Temperature Stratification				■						■		■			
BOD			■										■		
Heavy Metals			■					■			■				
Pesticides				■					■					■	
pH			■							■	■				
Salinity Intrusion				■					■		■				
Inorganic Nitrogen			■								■				
Inorganic Phosphorus			■								■				
Water Table					■				■		■				
Reservoir Leakage			■						■					■	
Climatic Changes					■				■		■				
Air Quality					■				■		■				
Human Interests :															
Parasitic Diseases					■				■						■
Public Sanitation				■			■								■
Nutrition			■			■								■	
Crop Production					■		■								■
Aquaculture					■			■						■	
Water Supply					■	■									■
Power Supply					■	■									■
Navigation			■			■							■		
Irrigation					■	■									■
Flood Control					■	■								■	
Resettlement					■					■					■
Highway Relocation		■								■		■			
Archaeological Treasure				■						■			■		
Water Quality				■					■					■	
Transmission Lines			■						■			■			
Recreation				■			■							■	
Landscape				■				■					■		

Table.2 - Environmental Compatibility Matrix for the Pa Mong Project.

	Project Activities	Construction														Operation											Related Activities								
		Land Acquisitions	Access Roads	Stream Crossings	Site Clearing	Transportation	Drilling and Blasting	Demolition	Dam Construction	Erosion Control	Embankment Construction	Outlet Construction	Spillway Construction	Landscaping	Transmission Lines	Reservoir Filling	Spillway Operation	Dredging	Impoundment	Herbicide Treatment	Evaporation Control	Catchment Managemen	Flow Regulation	Outlet Operation	Transportation	Power Generation	Recreation	Agriculture Development	Water Supply	Power Supply	Flood Control	Irrigation	Rural Development	Urban Development	Industrial Development
Ecolog	Forest		-1L		-1L											-5L						+4L												-5L	
	Wildlife		-1L		-1L											-5L						+4L												-5L	
	Reservoir Fisheries																		+5L																
	Downstream Fisheries								-5L								-5L		-5L				-5L	-5L											
	Eutrophication																		-5L																
Physico-Chemical	Soil Erosion		-2L	-1L	-3L	-1S				+3L	+3L						-5L		-5L			+4L	-5L	-5L		-5L									
	Soil Fertility																															-5L			
	Sedimentation																	+4L	-4L			+4L													
	Flow Variation			-1L					-5L										-5L				-5L	-5L		-5L									
	Evaporation																		-5L		+4S														
	Temperature Stratification																		-4L																
Physico - Chemical	Dissolved Oxygen																		-5L				-5L	-5L		-5L									
	Terbidity		-1L	-1S	-2S													-3S	+5L																
	Pesticides																			-4S								-4L							
	Salinity Intrusion																-5L		-5L				-5L	-5L		-5L									
	Water Table																-3L		-5L			+4L	-4L	-4L		-5L									
	Climatic Changes																		-1L			+1L													
	Air Quality					-2S	-4S	-2S				-1S	-1S												-1S										
Human Interest	Parasitic Diseases																		-3L														+4L	+4L	
	Public Sanitation																										-3S						+5L	+5L	
	Crop Production																											+5L				+5L			
	Aquaculture																											+5L							
	Water Supply																							+5L					+5L						
	Power Supply																							+5L		+5L				+5L					
	Navigation			-1L													+5L		+5L				+5L												
	Irrigation																							+5L								+5L			
	Flood Control																+5L						+5L	+5L							+5L				
	Resettlement	-5L	-2L																														+4L	+4L	
	Archaeological Treasure															-4L			-4L																
	Water Quality		-2S	-1S		-1S													-5L		-3S		-5L	-5L			-5L								-5L
	Recreation						-2S							+5L	-4L				+5L			+4L			+4L		+5L								
	Landscape		-2L				-3L							+4L	-4L				+4L			+4L												-4L	-4L

Table 3 - Decision Matrix for the Pa Mong Project

	Project Alternative Environmental Parameters	No Project	With Pa Mong Project
Ecological	Forest	5	-5L
	Wildlife	5	-5L
	Reservoir Fisheries	1	+5L
	Downstream Fisheries	5	-5L
	Eutrophication	4.5	-5L
Physico-Chemical	Soil Erosion	3.5	-5L
	Soil Fertility	2.5	-5L
	Sedimentation	5	-4L
	Flow Variation	4.5	-5L
	Evaporation	5	-5L
	Temperature Stratification	5	-4L
	Dissolved Oxygen	5	-5L
	Turbidity	1	+5L
	Pesticides	4.5	-4L
	Salinity Intrusion	4.5	-5L
	Water Table	4.5	-4L
	Air Quality	4	-4S
Human Interests	Parasitic Diseases	4	+4L
	Public Sanitation	2	+5L
	Crop Production	2	+5L
	Aquaculture	3	+5L
	Water Supply	1.5	+5L
	Power Supply	1.5	+5L
	Navigation	1.5	+5L
	Irrigation	1	+5L
	Flood Control	1	+5L
	Resettlement	5	-5L
	Archaeological Treasure	5	-4L
	Water Quality	4	-5L
	Recreation	2.5	+5L
	Landscape	3.5	+4L

5 (high) (Fischer and Davies, 1973). To obtain the compatibility matrix, the net change in the environmental impact units (EIU) as well as the red flags assigned to the various parameters in the environmental evaluation system framework are used. The resulting matrix is shown in Table 2. It is observed that many of the ecological and physicochemical parameters are adversely affected by the project (with -4 or -5 rating), which most of the socio-economic and health parameters gain from the project.

The last step in the modified matrix approach is the decision matrix. Significant environmental impacts of the Pa Mong project with a value of ± 4 or ± 5 are compared with the present conditions of the project area as obtained in the baseline evaluation step. The decision matrix is shown in Table 3. Most of the ecological and physico-chemical parameters are adversely affected by the Pa Mong project. In many of the human interest parameters, such as public sanitation, flood control, water supply, power supply, etc. The present conditions are bad and these poor conditions will improve substantially with the implementation of the Pa Mong project. However, 3 of the human interest parameters, viz. resettlement, archaeological treasure and water quality register significant impact as a result of the project.

CONCLUSION

This study shows that the modified matrix approach developed by Fischer and Davies (1973) can be a useful tool for impact evaluation of water resources projects in Thailand. The approach is able to display the cause-effect relationships between project activities and environmental impacts for evaluation, which some other approaches such as the environmental evaluation system can not distinctly show.

Major water resources projects will inevitably bring about drastic and often adverse changes in the natural environmental, as can be exemplified by the results of the application of the modified matrix approach to the Pa Mong project. A trade off must be made between environmental protection and resource development. Problem areas which are unavoidable, must be given further investigation to minimize the impacts and to find possible preventive and remedial solution.

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The paper was presented by Dr. Lohani

DISCUSSIONS :

Q : For the no-project option, how do you determine the ratings?

A : It is based on a base-line study.

C : EIA is not necesarily a very decisive method in determining the viability of a project because in the EIA that covers an extensive area where depth and degree are not given ample time by the consultants or the people involved in the projects. In Malaysia two hydro-electric schemes were rejected even though the EIA were excellent. The Pergau scheme was cancelled because land development scheme for plantation crops and settlement was the priority. The Tembeling scheme was rejected because of political factors which involved loan transactions where certain political conditions were not acceptable. Clearly the rejection had nothing to do with EIA. (Faizul, LLN).

Q : Did you consider the political instability in Laos and Thailand when you carried out the EIA? (Faizul, LLN).

A : Yes. This is a political project. The U.N. Commission - the Mekong Committee - has representatives from Loas, Thailand and Vietnam.

DEFINING ROLES OF AGRICULTURAL AND CIVIL ENGINEERS IN WATER TECHNOLOGY TRAINING

By

Abang Abdullah Abang Ali
Fakulti Kejuruteraan Pertanian
Universiti Pertanian Malaysia
Serdang, Selangor
Malaysia

ABSTRACT

Agricultural engineering is a new discipline of the engineering profession, and in Malaysia there still exists at present a reluctance to accept it. In water technology where there is an apparent overlap of responsibilities of agricultural and civil engineers, it is important that their roles should be properly delineated and training programmes for water technologist be tailored for their specific needs.

INTRODUCTION

The intrusion of agricultural engineers into a traditionally civil engineers' domain has been the subject of debate for quite some time. On a wider scale, there is an apparent reluctance of classic engineers to accept the non-classic or newer fields of engineering for fear of diluting or downgrading classical engineering. In Malaysia, the debate is continuing and the present paper shall make an attempt to discuss the different roles of agricultural and civil engineers in water technology, in the light of engineering technology training.

Traditionally, mechanical, electrical and civil engineers have long been involved in the planning, design and implementation of agricultural projects and related industries. Farm mechanization and the design and construction of major drainage and irrigation works for the farmers have become common practice in this country, even before agricultural engineers came into the picture. The classic engineers have been performing their duties in the capacity of agricultural engineers. Through sheer experience, these engineers have learnt to practice agricultural engineering as a profession, presumably without realising it. With whatever knowledge they have gained through professional experience and also perhaps parttime study, they set about such task as setting out field water management schedules for the farmers and advising or planning for farm structures. This is done with little or no background training in agriculture; an important factor for understanding the special requirements in engineering designs for different crops, livestock or farming lands and operations.

This paper is not written to analyse the present performance of traditional engineers acting in the capacity of agricultural engineers, but it shall explore the possibility of defining separate roles for agricultural and civil engineers to enable the development of appropriate training programmes to suit the present need of the country. Each discipline of engineering has a role to play and the goal of educators should be to train manpower to perform specific needs of the society. As professionals, we must adapt ourselves to the changing needs of the country. Basic engineering knowledge and skills is a prequisite to professional practice but not with the exclusion of training in other equally important areas, which is necessary to give engineers the perspective and necessary expertise appropriate to their specialised fields in practice.

ROLE OF AGRICULTURAL AND CIVIL ENGINEERS

Amongst the earliest engineering works of man was the construction of systems to control supply and use of water. This has been made possible by two main reasons. Firstly there is a need to produce food in excess of an individual's immediate needs and hence a more efficient system is necessary. Secondly, community effort to construct and maintain water systems has developed over the years, together with laws to regulate the systems. In the rural areas, there is an increase in agriculture and this will result in an increase in water demand. Likewise, an increase in water supply is necessary for a growing human population. However, in the face of limited water resources, water technologists will have to develop new technologies in order to optimise on the use of available water resources.

The need to design and construct an efficient water supply - distribution - use system demands an understanding of the various factors involved in water resources system. There are the socio-political, legal and economic considerations. The characteristics of the field or area, such as soil conditions and nature of crops are important parameters in the study. In addition, an engineer has to give due consideration to soil and water conservation, and flood control. Thus there is a necessity for any applied water resources analysis, to be designed, constructed or reviewed by those professional engineers who best know and understand the idiosyncrasies of the system.

Urban water supply and drainage, and hydropower generation are undisputable areas of the civil engineering profession. Civil engineers are equiped with the necessary training in hydraulics, hydrology and structures to manage these areas. This covers the use of water for all industrial and municipal purposes.

On the other hand, the use of water for agricultural purposes in the rural areas are better left to the agricultural engineers. Rural irrigation and drainage are in the main for growing crops and breeding livestock. Here the engineer is required not only to build hydraulic structures to satisfy engineering principles but to ensure the suitability of these structures to the agriculture being practised in the particular locality. It is evident that for the design of such structures, many facets of agricultural science and engineering, agricultural economics and rural sociology must be investigated.

The objective of planning any engineering work determines the detail and scope of the data needed. A sound agricultural investigation is equally as important as sound engineering investigation and design, if the return of investment cost is to be realised in increased agricultural production and improved economic and social conditions of the rural population. Land use and crop pattern have to be considered in any agricultural structures design. Low agricultural production is a result of interrelated factors, which are partly due to agro-hydrological deficiencies in the production environment, social and economic factors, marketing and communication and perhaps backwardness of the farmers. Farmers who are not appropriately exposed to agricultural engineering may fail to appreciate the need for any elaborate water distribution and scheduling system impossed on his farming land, and which may go in the way of his traditional routine.

Water is an indispensible element in agricultural production.

It is needed for plant growth, soil preparation, some fertilizing processes, and prevention of excessive salt accumulation in the soil. For each agricultural crop, there is an optimum water requirement. Deficiency or excess of water must be overcome through irrigation or drainage. The crop requirement may vary from time to time during the growing season depending on the stage of plant growth, temperature, humidity, amount of sunlight and other factors. In addition to the water actually consumed by the plant in the process of growth, there are certain unavoidable water losses such as evaporation from soil, percolation and sometimes surface waste, which are dependant upon field conditions. An understanding of the agricultural practice of a particular locality under study is therefore vital to the planning and design of water systems.

Having delineated the different specialised responsibilities of agricultural and civil engineers, it is now necessary to mention that cooperation between the two disciplines is sometimes needed. An integrated land and water development project has to call for the expertise of cooperating professionals. For example, civil engineers will have to depend on agricultural engineers to ascertain agricultural field requirements, and in turn will provide water distribution and supply informations for agricultural engineers to organise water management and schedules for the farms. Increased mechanization of farm operations which is the doing of agricultural engineers can inturn affect or alter the amount and rate of water demand for the farmers and it is necessary that such development in the agricultural practice of the farmers be accomodated in the planning and decision making on water resources.

WATER TECHNOLOGY TRAINING AND CURRICULA DEVELOPMENT

Until the establishment of Faculty of Agricultural Engineering at Universiti Pertanian Malaysia in 1975, engineering education in this country has been focused predominantly towards the classical engineering disciplines. Graduates from the traditional engineering fields of civil, mechanical, electrical and chemical form the bulk of engineers practising in this country. In the absence of agricultural engineers in the past, these professionals have been involved in the planning, design and construction of agricultural projects despite their lack of training in the agricultural field.

The need to produce engineers with an agricultural background to provide technical expertise to the farming sector of the country has prompted the establishment of the Faculty of Agricultural Engineering at Universiti Pertanian Malaysia. Students taking the four-year degree course are trained in the traditional engineering science subjects during the earlier part of the course plus enough exposure to agricultural science subjects. In the final years, the students receive training in the more specialised agricultural engineering subjects in the following broad fields:

- Power and Machinery
- Processing
- Farm Structures
- Soil and Water Engineering

For the purpose of comparison, the four major fields in a civil engineering degree curriculum are:

- Highway Engineering
- Soil Mechanics and Foundations
- Structural Engineering
- Hydraulics

The Bachelor of Engineering (Agricultural) degree curriculum at the Faculty of Agricultural Engineering, Universiti Pertanian Malaysia is shown in Appendix I. As seen in the curriculum in addition to the normal basic and engineering science subjects, students are required to take agronomy, livestock production, principles of plant and animal environment, fundamentals of extension education and introduction to sociology. This is to prepare the students for their work in the farming community. In the field of water technology students are required to take fluid mechanics, fluid dynamics and machines, soil and water conservation engineering, engineering hydrology and irrigation and drainage.

A typical five year Bachelor of Engineering (Civil) degree curriculum is shown in Appendix II for comparison. In the field of water technology students spend two earlier years on mechanics of fluid and the two final years on hydraulics and hydrology. Apart from the humanities subjects such as Malaysian studies and development economics which is necessary for understanding the life of the farming rural community, no attempt is made in a civil engineering curriculum to cover agricultural subjects. This is appropriate in order to allow enough emphasis in the other main areas of the civil engineering profession.

Thus insofar as water technology is concerned, the present agricultural and civil engineering curriculum is befitting the roles of agricultural and civil engineers as has been defined earlier. A civil engineer with no proper training in agriculture should use his knowledge and skill in the appropriate area of urban water supply and drainage while an agricultural engineer, equipped with the necessary agricultural background should set his eyes on rural irrigation and drainage problems. Rural irrigation and drainage projects are closely linked with local farming or cropping pattern and farm mechanization, and it is only proper to leave it in the hands of agricultural engineers.

EMPLOYMENT PATTERN

The work of water technologists or engineers can be summarised into the following main areas:

- Water supply
- Urban drainage

- Rural irrigation and drainage
- Hydropower generation
- Flood alleviation
- Inland navigation

Out of the above six main areas, agricultural engineers should be made responsible for rural irrigation and drainage only. This is commensurate with the small number of agricultural engineers being produced today when compared with the number of graduating and practising civil engineers. In any case for an agro-based country, rural irrigation and drainage can form a major portion of water projects in the country, and the works involved in this area should provide enough employment for agricultural engineers majoring in water technology.

In addition to the above, a large number of agricultural engineers will be required in research. Unlike civil engineering which has been practised for a long time, agricultural engineering is a new profession and researchers are needed to develop this field. Research work in water technology should be viewed in the light of a rapidly modernising agricultural industry in this country.

RESEARCH

Technology and research have combined to give not only tremendous foresight into the consequences of a course of action in water resources development, but also to provide a vast number of alternative courses of action. But extensive data on water requirements in a particular climatic and field condition are needed for an agrohydrological improvement programme. In addition to the normal required information on the amount and distribution of precipitation in an area under study, data on temperatures, humidity of the air and soil, and wind velocities will have a bearing on the water requirements of crops.

It is necessary to collect and record detailed information on water requirements of different crops in selected pilot areas in a particular region. Optimum water requirements for different areas may vary due to various factors such as permeable soil and high surface water losses, and data obtained must relate to local conditions. Agricultural engineers must play a major role in this as they should be in a better position to understand the biological aspects of an agricultural enterprise.

On the other hand, civil engineers must realise that there is the rapidly increasing variety of objectives in utilizing water resources. Civil engineers engaged in large scale water projects must understand and show concern for the effect of their actions on fish and wildlife conservation. Their research should enable them to arbitrate hostile and conflicting demands from powerful pressure groups. Pollution control, repulsion of saline water, flood protection and groundwater replenishment are problems that researchers in this area must attend to.

It is no longer sufficient to respond to local requests with a project that has a favourable benefit-cost ratio. Various factors must be taken into account in the decision process concerning water resources and research is need to build up a library of data which can be used as inputs into any water resources system analysis.

GENERAL RECOMMENDATIONS

The engineering community should acknowledge the need for more specialised fields of engineering to cater for specific needs of the profession. With the present pace of development and industrialization, classical engineering training should be aimed at catering for the traditional areas of the engineering practice. The amount of work in these areas at present is sufficient to keep engineers with classical training background occupied, and they should free themselves from the more specialised areas, which are appropriate for those specially trained in these fields.

Alternatively, if their service is indispensible, then the classic engineers should pursue in-service or postgraduate training in these areas.

In the more specific area of water technology it is suggested that we establish the separate roles for agricultural and civil engineers. Agricultural engineers, appropriate due to their training, should attend to the water resource development of the rural farming community. On the otherhand, civil engineers should manage industrial and municipal water problems in the urban areas. Cooperation at both federal and district levels are often necessary for any integrated water resource development project.

Classical engineering training should serve the areas in which it has been designated to while due consideration should be given to the development of the more specialised and new fields of engineering.

Appendix I

B.E. (Agricultural) Curriculum at Universiti Pertanian Malaysia

1. 4 year degree programme - 8 semesters
2. Final year project is a partial requirement
3. 26 weeks of industrial training

Semester I

Intro. to Agr. Engineering
Eng. Graphics I
Eng. Physics
Workshop Practice
Principles of Biology
Language
Chemistry
Calculus

Semester II

Eng. Graphics II
Computer Programming
Dynamics I
Statics
Language
Prin. of Economics
Differential Equations
Electrical Engineering

Semester III

Theory of Machines
Strength of Materials
Material Science
Fluid Mechanics
Agronomy
App. Maths. for Engineers
Intro. to Sociology

Semester IV

Math. Analysis for Engineers
Theory of Structures
Engineering Statistics
Thermodynamics
Surveying
Fund. of Extension Ed.
Livestock Production

Semester V

- Design of Structures
- Fluid Dynamic & Machines
- Soil Mechanics
- Soil & Water Conservation Eng.
- Work & Heat Transfer
- Electronics & Instrumentation
- Engineering Hydrology
- Non-Technical Electives

Semester VI

- Practical Training (26 weeks)

Semester VII

- Tractor System & Design
- Design of Machines
- Prin. of Plant & Animal Env.
- Engineer & Society
- Seminar
- Project
- Technical Electives

Semester VIII

- Agricultural Machinery
- Irrigation and Drainage
- Farm Structures
- Agri. Process Engineering
- Project
- Technical Electives

Appendix II

A Typical B.E. (Civil) Curriculum

1. 5 year degree programme
2. Final year project is a partial requirement
3. 18 - 20 weeks of industrial training

1st Year

Malaysian Studies or
English Language or
Islamic Education or
Ethics
Maths. I & II
Mechanics I & II
Physics I & II
Chemistry
Engineering Drawing

2nd Year

Malaysian Studies
Islamic Education
Ethics
Math. I & II
Modern Physics
Theory of Machines
Engineering Thermodynamic
Applied Electricity
Surveying
Strength of Materials
Mechanics of Fluid
Civil Engineering Drawing

3rd Year

Malaysian Studies
Basic Principle of Economics
Maths. I & II
Introduction to Computing
Engineering Survey
Mechanics of Material & Struct.
Mechanics of Fluid
Mechanics of Soils
Structural Design

4th Year

Development Economics
Managerial Accounting
Mathematics
Applications of Computer
Mechanics of Structures
Hydraulics & Hydrology
Mechanics of Soils & Engineering Geology
Structure Design
Contract Procedures & Estimating
Highway & Traffic Engineering

5th Year

Mechanics of Structures
Hydraulics & Hydrology
Mechanics of Soils
Structural Design
Management Construction
Water Supply & Sewerage Engineering
Elective Subject

DISCUSSIONS :

C : All engineers should receive common training in fundamental principles for the first three of the five-year course. Only the last two years should differentiate between the various areas of engineering. Specialization should be acquired during employment and the university should strictly deal with the fundamentals of engineering.

For the specific field of water, particularly irrigation and drainage, there is a lot of mixture which is difficult to differentiate into civil and agricultural engineering. The design of high dams is the domain of civil engineers. However, the subject of water supply should not be the duty of civil engineers only.

Agricultural engineers have two important roles to play in this area particularly in Malaysia. Examples are small storage structures or farm ponds of 25 acre-ft and dams below 30 feet of capacities between 5 to 15 acre-ft which account for 80 to 90% of those structures installed. There is still a lot of scope to increase the water supply since only 10% of water is being used. Agricultural engineers can store water in the 50% air space in the soil. Thus could be easily increased to 20%. Two avenues are available to achieve this namely making available thousands of farm ponds, and secondly, groundwater. The latter is a new field of which agricultural engineers appear to be tailor-made. In the field of flood control and overall watershed management, farm-ponds could also be very effective.

Mini-hydro electric power schemes of one kw could be popularised for rural electrification. With certain amount of hydraulics, electrical engineering and strong agricultural knowledge, agricultural engineers will become more handy than the civil engineers in the rural areas. (Jaswant Singh Bali, Dept. of Agric., Malaysia).

C : I agree that any engineer can pick up the special knowledge during employment but it will take a lot of time. Graduates have very little opportunity to study once they are working. This is why there is a need to produce engineers who are more specialized, but not in such a large number that they will find difficulty in employment. (Abang Abdullah, UPM).

Q : There is a seminar programme in the seventh semester. Do the students prepare their own seminar or only participate in the seminar? What about the practical training?

A : The students prepare and present their materials to the class. Normally the topics chosen are related to their final year projects. They have to answer questions raised and participate in the discussion.

A : There are two aspects of practical training, one is a final year project and the other is industrial training. The final year project is carried out in the laboratories or in the field. They have to produce a report on the project as a partial fulfilment to the requirements of the Bachelor of Engineering in Agriculture. In the industrial or practical training, the students are assigned to various engineering establishments off- campus. The students are expected to complete 26 weeks of compulsory training so that they would be able to appreciate the theoretical knowledge they get in the university.

C : Agricultural engineers can be relevant to rural electrification scheme. Most of our farmlands are located in the lowlands where hydroelectric power generation would not depend on catchment areas but on flow/head available. The civil engineering design for low head conditions is very expensive and sometimes impossible. Agricultural Engineers can help NEB to introduce the mini-hydroelectric schemes by providing information on the energy potential of such areas. During one ASEAN conference held in Papua New Guinea sometime ago, it was recommended that ASEAN countries incorporate energy at all levels of National Planning and Educational Policy. I do not see any energy subject in your programme. Can you explain? (Faizul, LNN).

A : We have a four-credit Electrical Engineering course in the second semester, and we could offer courses in rural electrification. But if the National Electricity Board, being the sole agency responsible for electrification, is not willing to employ our graduates, we would rather concentrate on other courses. As of now, even the Drainage and Irrigation Department is still reluctant to employ our graduates who are better trained than the civil engineers in terms of the agriculture that the DID is trying to improve.

Students in the B.E. (Agriculture) programme are well aware of hydraulics structures, flood control and design of small dams. These topics are covered in a course called Soil and Water Conservation Engineering. Groundwater is a topic covered in the Engineering Hydrology course. Both courses are offered in the third year. Pumps and turbines are taught in a course called Fluid Dynamics and Machines offered in the second year. The design, Construction and Management of Waterways is an elective course offered in the final year. (Mohd. Rashidi Bakar).

SUPPLEMENTARY PAPERS

The following paper were circulated during the seminar. The abstracts of these papers are reproduced for the benefit of readers.

Ed.

A RURAL TECHNOLOGY FOR GROUND WATER EXPLORATION IN THE STATE OF BIHAR (INDIA)

K.N. Sharma
Research Engineer
College of Agricultural Engineering and
Technology, Bhubaneswar

ABSTRACT

The state of Bihar has it's much area under Gangetic plain. Stratification of this zone, in general, is alluvial and is available to a sufficient depth. A technique locally called as "Bamboo Drilling' is very famous in this part. This is a rural oriented technique. It does not need any machine. The whole setup consists of some wooden logs, G.I. pipes of 3.2 cm dia and socket enlarer of 3.2 cm x required dia of bore. Popularity of this technique in this region is that the farmer can use his own man power and manage with only two locally trained persons.

SEEPAGE LOSSES IN RICE FIELDS

B. Anjaneyulu
Professor
Ag. E. Dept., IIT
Kharagpur, India.

and

A.K. Chakrabarty
Agrl. Engineer, BAIF
Uruli - Kanchan
Poona, India.

ABSTRACT

When rice is grown in a limited area which is surrounded by fallow fields, seepage losses become predominant. A part of the seepage loss is due to natural flow through the soil and hence is unavoidable. The difference between the actual seepage loss that occured in the loss that should normally occur under a given soil condition would give a measure of the effectiveness of the water management practices adopted by the farmers. Studies were conducted at a field site in India and the actual seepage losses were determined by collecting data on the

total depth of water supplied and the depth of water required for evapotranspiration and percolation. A numerical method was adopted for determining the normal seepage loss that should be expected to occur in different soils. It was concluded that the actual seepage losses in the field were excessive and were due to the poor maintenance of boundary bunds.

WATER SUPPLY FOR RURAL COMMUNITIES: TECHNOLOGY AND ECONOMICS

Dr. M.A. Aziz

Senior Lecturer
Department of Civil Engineering
National University of Singapore

ABSTRACT

This paper delineates various aspects of appropriate technology and economics of water supplies for rural communities. Results of experimental studies of a new approach for surface water purification to satisfactory levels are presented. Various salient features for economising the rural water supply schemes are highlighted. Finally, recommendations are made for a total approach combining the technologies of simple water purification and on-site production of alternate form of energy for overall rural development.

EXPERIENCE GAINED IN THE OPERATION OF THE BIWATER WATER TREATMENT TOWER

A.H. Pe, B.Sc., C.Eng., M.I.C.E., F.I.P.H.E.

Department of Civil Engineering
Portsmouth Polytechnic
Burnaby Road
Portsmouth
Hampshire
PO1 3QL
United Kingdom.

ABSTRACT

This paper relates to the experience gained whilst operating a 1.5 m diameter Biwater Water Treatment Tower in Totton, near Southampton, England. The unit consists of 5 upward flow settlement tanks, I rapid gravity sand filter and a storage tank. All these components are contained in a tubular tower and operate in a similar manner to that of a normal water treatment plant.

The purpose of the trials was to observe the capability of the plant with regard to the hydraulic characteristics and the quality of water produced. The plant was run at a flow rate of 2.5 /s and conventional chemical coagulants were used but no sterilisation was added in these trials.

From the experience gained in operating this plant, it may be said that the plant is capable of being in operation for long periods with the minimum of maintenance and produces high quality water of W.H.O. standard for the water tested.

CALCULATOR PROGRAMME FOR SURFACE RUNOFF MODELS

Prabhat K. Chowdhury

Research Fellow
Department of Agricultural Engineering
Indian Institute of Technology
Kharagpur 721302 WB, India

ABSTRACT

The use of programmable calculators have been presented to popularise the use of mathematical models among the agricultural workers at block level in developing countries for computing surface runoff accurately. Simplified mathematical models for surface runoff are programmed for a pocket size portable calculator without using a printer unit. The programme may be loaded into a Texas Instruments TI 59 Programmable calculator. A detailed user instruction provided along with the programme makes the job of loading the programme, feeding the input data and recording the displayed results easy. As the magnetic card reader facility is available with the calculator, programme loading is not at all a problem. As the cost of the calculator as well as power consumption is reasonable; handy and operation is trouble free, such programmable calculators may be made available at community centres at block level for the use of agricultural workers.

TRACING OF SEDIMENT MOVEMENT IN THE CHAO PHRAYA RIVER

A. YUTHAMANOP
Office of Atomic Energy for Peace
Thanon Vibhavadi Rangsit
Bangkhen, Bangkok-9
Thailand

ABSTRACT

The Royal Irrigation Department has selected a dangerous shoal reach of the Chao Phraya river at Wad Chaiyo region to be an immediate problem. Since this region, the sand-bar is built up on the river-bed and has to dredge from time to time in order to keep the channel for navigation. To improve this situation, a set of 12 bottom panels have been placed into the river, resulting a definite lowering of the bed in the navigable channel and a sand-bar built up behind the panels. The aim of the tracer measurements is to clear up the paths of bed-load movement during lower discharges, when the panel system really can influence the flow and to reveal some facts about their efficiency. The movement of sediment grains along a river-bed can be followed by tracer method only. In this experiment the tracer materials have been selected, using artificial sediment grains, i.e. radioactive chromium-51 incorporated in ground glass and natural sand coated by luminescent pigments. Preparations for the radioactive tracer material and sand coated by luminescent pigment are described and also field experiments are evaluated.

ESTABLISHMENT OF A CROP AND WATER MANAGEMENT DEMONSTRATION AND TRAINING CENTRE, BOROMDHART, THAILAND

Chirtchart Smitobol
Irrigation Agronomy Research Branch
Technical Division, Dept. of Agriculture
Bangkhen, Bangkok, Thailand

ABSTRACT

During the dry season of 1978, field demonstration was carried out in the Boromdhart sub project area, in order to assess improved methods of agricultural production with special reference to irrigation practices.

Level furrow irrigation on a heavy soil with an infiltration rate of about 0.5 cm per hour for mungbean cultivation was found to work well up to a furrow length of 200 metres

Rotation irrigation was practiced under an existed field canal with a flow rate of 60 litres per second. This capacity was originally designed for a 7-day rotation with 24 working hours a day for paddy irrigation. This rate of water delivery is generally designed in the land consolidation projects in the country. With a more complicated furrow irrigation for field crop, however, one round of water delivery to cover the same area took about 15 days at peak water requirement. This happened to be a limit for cultivation of certain field crops that require more water such as maize, soybean, etc. Total water delivered to mungbean field was recorded to be about 27 cm. The field irrigation efficiency was 68 percent.

It was concluded that over all result of the project was quite satisfied.

CANNEL RESPONSE IN AGRICULTURAL WATERSHEDS

Prabhat K. Chodhury
Research Fellow
Department of Agricultural Engineering
Indian Institute of Technology
Kharagpur 721302 WB, India

Vijay P. Singh
Associate Professor
Department of Civil Engineering
Louisiana State University
Baton Rouge 70803 Louisiana, U.S.A.

ABSTRACT

Attempt has been made to predict the flow of irrigation water in an earthen channel with respect to space and time through a simultaneous treatment of lateral inflow, precipitation, infiltration and evaporation. The channel is considered to be a linear one. An exponential form of infiltration equation and a constant rate of evaporation are used in the analysis. The out-flow from the upstream plots, lateral inflow and precipitation constitute the input to the channel, while infiltration through the permeable channel bed and evaporation from the free water surface of the field channel are considered as losses from the channel. Using Saint-Venant equation for open channel flow with required modifications, a general solution is obtained. Some natural flow phenomena prevailing in channels present in agricultural watersheds are shown to be special cases of the general solution.

WATER TECHNOLOGY TOWARDS RURAL SANITATION

Dr. Naresh Chandra Saxena
Faculty of Agricultural Engineering
Universiti Pertanian Malaysia
Serdang, Selangor

S.K. Goenka
Agricultural Engineer
Government of Rajasthan
India

ABSTRACT

Water is world's most misused, misunderstood and yet most precious commodity. It is scarce due to a combination of many reasons. Modern flush laterines use considerable quantity and it is not possible, at present

and in the near future, to consume water at this rate. The laterines can be improved or redesigned for minimum use of water without consuming electricity which is also in short supply or not available in rural areas.

Five cheap rural pans, based on 'do-it-yourself' concept, were proposed, designed and constructed. Each of these were evaluated with respect to the utility, odour-coefficient and nuisance-factor which were defined as a part of this study. It is understood that a private sewage disposal system in the form of septic-tank is costly to the rural areas, and it would be economical to use a suitable sanitary pit without bottom lining.

DEVELOPMENT OF HAOR AREAS

Dr. Abdul Hannan
Prof. + Head
Department of Water Resources Engineering
Bangladesh University of Engineering Technical

ABSTRACT

Haors are natural low-lying areas which remian under deep water during the monsoon. In Bangladesh about 4500 sq. miles of area is occupied by haors in the districts of Sylhet, Mymensingh and Comilla.

The haor area has an elevation varying from R.L. O.O (PWD) to R.L. 15. It extends over the drainage basin of river Meghna and its distributaries in Bangladesh. Many of the Meghna tributaries originate from Meghalaya in India. The tributaries of Meghna carries very little silt and as a result we have the low areas know as haors and beels. The higher land is on the fringes of the rivers and the low land is in the interior.

The entire haor area goes under water during mansoon. After the mansoon the higher lands drain out but lands with elevation 5ft. (PWD) and below known as "Beel" remain permanently under water.

Beel area is very suitable for cultivation of Boro crop. But as the beel area generally suffers from drainage congestion transplanting can not be made early in time. Due to delayed transplanting crop can not be harvested before the onset of the rain which in some years causes early flood and damage the crop. Late harvest also suffers time to time from damage by hail storm.

With power pumps now a days comparatively higher areas of the haor have been brought under boro crop. Even then vase tract of land remains idle during winter due to lack of irrigation facilities. Boro crop and other robi crops can be grown in large scale if irrigation facilities

are provided.

The haor area has an immense potentiality for fish cultivation. The exploitation of the possibility for fish cultivation has not been done in the scale necessary to harness this rich resource from haor area.

For proper development of haor areas studies relating to drainage congestions, availability of irrigation water, fisheries, communication system are essential. Given proper attention to such studies and other inputs haors and beels can provide the nation with huge quantity of carbohydrates and proteins in the form of cereals and fishes. Development of Haor areas will go a long way in achieving the nation's aim of doubling the food production.

Summary of Forum Session

The Forum was conducted on the last day of the seminar. The members consisted of the following members.

(1) Mr. J. Brodie - Institute of Natural Resources
University of the South Pacific
Fiji.

(2) Mr. Peter Reynolds - Department of Civil Engineering
Papua New Guinea University of
Technology.

(3) Dr. Adhityan Appan - Nanyang Technological Institute,
Singapore.

(4) Dr. T. Notohadiprawiro - Departamen Ilmu Tanah
Universitas Gadjah Madah
Indonesia.

(5) Mr. Kwok Chee Yan - Faculty of Agricultural Engineering
Universiti Pertanian Malaysia.

(6) Mr. J. Pickford - Department of Civil Engineering
University of Technology
Loughborough, United Kingdom.

(7) Dr. Thamrong Prempridi - Civil Engineering Department
Chulalongkorn University
Bangkok, Thailand.

(8) Chairman

Ir. Choa Swee Lin - Faculty of Agricultural Engineering
Universiti Pertanian Malaysia.

The forum started with the chairman asking the members of the panel to outline their views on the areas in which scientists in this region should address their attention and to suggest a strategy for the maximisation of effectiveness of new technology.

Mr. J. Brodie began with the comment that participation by the local people was essential. They will also have to be made aware of the health problems which may arise from such schemes. He further indicated that an element of maintainence should be built into schemes at the design stage and equipment used should be easy to maintain in order to ensure the continued functioning of the equipment.

Mr. P. Reynolds said that the seminar covered three broad topics, and the papers on water for personal use were of particular interest to him. He however expressed concern that the work reported by authors at this seminar may take a long time to appear in the technical press and suggested that these authors use the newsletter produced by Dr. Chauray at Chulalongkorn University which reports on the activities of the Appropriate Technology Group of UNESCO/FEISEAP to quickly disseminate their new findings.

Dr. Ahdityan Appan, felt that the papers have been multidisciplinary. He suggested that a status report on the existing practices on water technology for rural areas be produced so that we can identify areas where research is required. He felt that the problems should be considered as a whole and academics conducting research should ensure that the end result should be appropriate and applicable to the rural areas.

Dr. T. Notohadiprawiro felt that water should be considered as a component the system of land. As such, water as a subsystem will be governed by the behaviour of the other subsystems.

Mr. Kwok Chee Yan felt that countries in the region should pool their resources in the exploitation and development of water resources. He further said that education is very important and engineers should not only be technically competent, but must be trained to be aware of the complex socio-economic factors that exist in the rural environment.

Mr. J. Pickford considered that one area requiring further research was the involvement of women in activities pertaining to water technology. He also posed the question as to whether too much effort has been spent trying to develop "appropriate technology devices" which are not likely to work.

Dr. Thamrong Prempridi felt that cost is very important and this was not highligted at this seminar. He also felt that as technocrats we would also have to cater to the needs of administrators and politicians.

The comments of the panel generated discussions from members of the floor. The points raised are listed below.

(i) The concept of watershed management should be given importance. Within this concept, urgent attention should be paid to small water storage structures, groundwater utilisation, and water management in padi areas for multiple cropping.

(ii) A Water Technology Centre should be established in this country to conduct research into all aspects of water.

(iii) Another member of the floor felt that the people should be orientated or motivated to be more receptive of new technologies which are being implemented. He felt that if the people themselves were sufficiently motivated to ask for these facilities, then schemes will have a greater likelihood of success.

(iv) Yet another member of the floor proposed that legislation be implemented to control and regulate the use of ground water.

The following are proposals which were made at the Forum.

(i) There is a need for a policy and legislation to deal with the development of water resources, watershed management and pollution. A water policy which gives due attention to these aspects is needed.

(ii) Technocrats must not only be proficient in their various disciplines but they must also be able to understand the rural situation. On the other hand the rural population should be motivated to accept the new technologies and even perhaps to request for new technology which is appropriate for their need.

(iii) In order to accelerate development there is a case for pooling of resources and exchange of experiences within countries in this region.

(iv) The feelings and needs of the people, who are the end users should be taken into consideration in order to make these technologies more effective.

(v) A Water Technology Centre should be established to conduct research into all aspects of water.

BEKALAN AIR SELANGOR

SUNGAI LANGAT SCHEME - LANGAT DAM

INTRODUCTION

The Langat Dam forms part of the Sungai Langat Scheme which was designed to augment water supply to Kuala Lumpur and the Klang Valley region.

The Contract for construction of dams and ancillary works was awarded to Japan Development and Construction Co. Ltd. in the sum of $31.8 million ringgit in May 1976 and work commenced in July 1976. Impounding of the reservoir started in November 1979 three months ahead of schedule and water started to over spill in February 1981.

The impounding reservoir will enable 85 m.g.d. of water to be abstracted at the existing Mile 10 river intake.

THE WORKS

The Langat Dam is situated at Mile 24 Ulu Langat in a forest reserve in the upper reaches of the Sungai Langat.

It impounds 8,240 million gallons of water at top water level of + 725.00 fet, for regulating the flows in the Sungai Langat according to demands at Mile 10.

The impounding reservoir is formed by a main earthfill dam 200 ft. high by 1,200 ft. long and two subsidiary dams comprising a total of 3.3 million cu. yd. of fill and drainage materials.

A 90 ft. diameter bellmouth spillway will discharge a maximum design flood of 18,000 cusecs through 1,280 ft. of 17 ft. 6 inch diameter horse-shoe tunnel to a stilling basin 300 ft. long x 64 ft. wide x 30 ft. deep at the down-stream toe of the main dam.

For diversion of the Sungai Langat during embanking a 12 ft. 6 inch diameter horse-shoe tunnel 515 ft. long led the diverted water into the spillway tunnel.

A syphon draw-off tower is located adjacent to the diversion tunnel. Reservoir discharges will be released into the river from the draw-off tower through pipework in the diversion tunnel, spillway tunnel and stilling basin. The top of the tower is connected to the crest of the main dam by a 385 ft. access footbridge passing over the bellmouth spillway at mid-way.

SHORT NOTES ON SUNGAI LANGAT TREATMENT PLANT

The Sungai Langat Water Treatment Plant is situated off the 10th mile Ulu Langat Road and is 10 miles (16 kilometres) South East of Kuala Lumpur. The whole scheme was completed in 1980 and is capable of producing a maximum supply of 85 million gallons a day (386,000 cubic metres per day).

Five 16 mgd, four 10 mgd and two 5 mgd pumps are used for pumping raw water from the Langat River to the Treatment Plant. At the Treatment Plant, ALUM and a polyelectrolyte COAGULANT AID are added to the raw water as it passes through the mixing channel. The ALUM dose is 14 to 20 ppm (14 to 20 mg/litre) and the COAGULANT AID dose is 0.01 ppm (0.01 mg/litre). The suspended impurities after the addition of chemicals form floc as it travels through the mixing channel.

The water enters the sedimentation tanks after leaving the mixing channel. In the sedimentation tanks the floc particles settles to the bottom of the tank and the clear supernatant water goes to the filters. These are rapid gravity filters, each capable of filtering 3.5 million gallons per day (14,000 cubic metres per day).

At the filters any carried over floc will be removed and the clear filterate is collected in the clear water channel which leads to the clear water well. In the clear water channel, CHLORINE 3 ppm (3 mg/litre) and HYDRATED LIME 10 ppm (10 mg/litre) are added to the water to sterilise and condition the water respectively. SODIUM SILICOFLUORIDE is also added here to obtain a fluoride ion concentration of 0.7 ppm (0,7 mg/litre) to prevent tooth decay in children. The final pH of treated water is 8.2.

Five 16 mgd, four 10 mgd and two 4 mgd pumps are used to pump the treated water from the clear water well to the Balancing Tank. The water is distributed into the reticulation system from the Balancing Tank to the consumers.

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Regional Seminar "Water Technology Toward Rural Development"

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11. Encik Chan Long Kong - Projects Engineer
United Engineer (Mal.) Bhd.
P.O. Box 115, Kuala Lumpur.

12. Encik Loh Huey Seng - Projects Engineer
United Engineer (Mal.) Bhd.
P.O. Box 115, Kuala Lumpur.

13. Encik Jamal Abd. Nasir bin Ujang - Penolong Pegawai RISDA
Ibu Pejabat Risda, P.S. 1067,
Jalan Ampang, Kuala Lumpur.

14. Encik Hassan bin Mohd. Nor - Penolong Pegawai RISDA
Tingkat Khas, Ibu Pejabat Risda
P.S. 1067, Jalan Ampang, Kuala Lumpur.

15. Ir. Teh King Lian - Asst. Tech. Manager
S.D.C. Negeri Sembilan
No. 3, Jalan Dato Klana, Seremban.

16. Encik G. Macoun - Director
c/o Ranhill Bersekutu
6.01 Wisma Central, Jalan Ampang
Kuala Lumpur.

17. Ir. Anthony Ho - Engineer
Jabatan Kerjaraya
Kuching, Sarawak.

18. Dr. Akira Kamata - Hydrogeologist
Kokusai Kogyo Co. Ltd.
Asahigaoka, Hono 191, Tokyo, Japan.

19. Encik Lim Guan Hock - Civil Engineer
Zaidun-Leeng Sdn. Bhd.
11th. Floor, Ming building
Jalan Bukit Nanas, Kuala Lumpur.

20. Mr. Tony Pe - Lecturer
Dept. Of Civil Engineering
Portsmonth Polytechnic, United Kingdom.

21. Encik Ong Kheng Hoi - Pegawai Pertanian
Tingkatan Kanan
Pusat Kejenteraan Ladang
Jabatan Pertanian, Serdang.

22. Cik Aeshah bte Ismail - Pegawai Pertanian
Pusat Kejenteraan Ladang
Jabatan Pertanian, Serdang.

23. Encik Chow, James
Chemitreat Sdn. Bhd.
14 Lorong Ara Kiri Tiga
Lucky Garden.

24 Encik Tay Kim Ann
Chemitreat (M) Sdn. Bhd.
14 Lorong Ara Kiri tiga
Lucky Garden.

25. Y.M. Ungku Ismail
Chemistreat (M) Sdn. bhd.
14 Lorong Ara Kiri Tiga
Lucky Garden.

26. Cik Siti Hawa Zain
Chemitreat (M) Sdn. Bhd.
14 Lorong Ara Kiri Tiga
Lucky Garden.

27. Encik Yap Siew Fah - D.I.D. Engineer
D.I.D. P.O. Box 1240
Kota Kinabalu, Sabah.

28. Encik Ho Tsun Lin - D.I.D. Engineer
D.I.D. P.O. Box 1240
Kota Kinabalu, Sabah.

29. Encik Ahmad Abdul Rahman - Senior Agric. Officer
Lembaga Kemajuan Pertanian
Kemubu (KADA)
P.O. Box 127
Lundang
Kota Bharu.

30. Encik Zainon Hamid - Timbalan Pengarah
Bahagian Pembangunan Perladangan
RISDA.

31. Encik Tan Say Min - Engineer
Bahagian Pembangunan Perladangan
RISDA.

32. Encik Mohamad Ali Hassan - Lecturer
Department of Geology
Universiti Malaya
Kuala Lumpur 22-11.

33. Encik Roslan Ishak - Civil Engineer
FELDA
Pahang.

34. Encik Hassan bin Mohamed - Civil Engineer
Pejabat FELDA
Felda Wilayan Pahang Tengah
d/a PPP. Tun Razak
Jerantut, Pahang.

35. Encik C.M. Noor Azmi Ibrahim - Pegawai Kanan Risda
Ibu Pejabat Risda
P.S. 1067
Jalan Ampang
Kuala Lumpur.

36. Encik Affandi Tan Abdullah - Pegawai Kanan Risda
Ibu Pejabat Risda
P.S. 1067
Jalan Ampang
Kuala Lumpur.

37. Encik Chan Chee Weng - Penolong Pegawai Risda
Ibu Pejabat Risda
P.S. 1067
Jalan Ampang
Kuala Lumpur.

38. Encik Tserng Goong Farm - Hydrologist
D.I.D.
Badruddin Road
Kuching, Sarawak.

39. Encik Abdul Manaf bin Ishak - Water Works Engineer
J.K.R. Perak
Bangunan Kerajaan Negeri
Perak.

40. Encik B.J. Wood - Research Controller
Sime Darby Plantations

41. Dr. Ho Chai Yee - Senior Agronomist
Sime Darby Plantations

42. Mr. Peter Lim Kim Huan - Agronomist
Sime Darby Plantations

43. Encik Julien K. - Experimental Officer
Sime Darby Plantations

44. Encik Mad Nordin Haji Mahbob - Estates Engineer
Sime Darby Plantations

45. Encik Sulaiman bin Md. Zain - Pegawai Pertanian
Pusat Kejenteraan Ladang
Jabatan Pertanian
Telok Chengai
Kedah.

46. Encik Poh Seng Chai - Pegawai Pertanian
Pusat Kejenteraan Ladang
Jabatan Pertanian
Lundang
Kelantan.

47. Encik Bookeri Ludin - Research Officer
MARDI.

48. Encik Sani Kimi - Research Officer

49. Encik Mahmud Che Hussain - Research Engineer

50. Ir. Liam Tiam Hock - Jurutera Ibu Pejabat
J.P.T.
Karung Berkunci 712
Johor Bharu
Johor.

51. Encik V.T. Singam - Technical Supervisor
J.P.T.
Karung Berkunci 712
Johor Bharu
Johor.

52. En. Mohd. Jamaludin Ayub - Technical Supervisor
Harrison Lister Engineering Ltd.
P.O. Box 166
9 Jalan 222
Petaling Jaya.

53. En. Chee Shui Yong Timothy - Chief Surveyor
S.L.D.B.
P.O. Box 1610
Kota Kinabalu
Sabah.

54. Encik Teo Hock Keng -
Chemitreat (M) Sdn. Bhd.
14 Lorong Ara Kiri Tiga
Lucky Garden.

55. Encik Gan Boon Chee - Project Engineer
C.S.C. Kemico
16 Jalan Dawai
Shah Alam Industrial Estate
Selangor.

56. Mr. Liew Kwet Keong - Project Engineer
C.S.C. Kemico
16 Jalan Dawai
Shah Alam Industrial Estate
Selangor.

57. Encik Tan Poh Seng - Project Engineer
C.S.C. Kemico
16 Jalan Dawai
Shah Alam Industrial Estate
Selangor.

58.	En. Wong Kong Meng, Ivan Tridun Engineers 21 Jalan SS 21/34 Petaling Jaya Selangor.	-	Managing Director
59.	En. Lee Hee Chew Tridun Engineer 21 Jalan SS 21/34 Petaling Jaya Selangor.	-	Sales + Contract Executive
60.	Dr. Koo Swee Hoo Syarikat SAILCOS Sdn. Bhd. 4-5 A, Jalan SS 22/11 Selangor.	-	Director
61.	Puan Amriah Buang Jabatan Geografi U.K.M.	-	Pensyarah
62.	En. Jaswant Singh Bali Department of Agriculture	-	Soil Conservation Consultant
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68.	Mr. Kazal Sinha Ministry of Health c/o Public Health Institute Jalan Bangsar Kuala Lumpur.	-	Public Health Engineer
69.	En. Poo Hai Leong J.P.T Proj. Pemb. Pertanian Johor Barat Johor.	-	Jurutera

70. Dr. B.N. Lohani - Professor
Environmental Engineering
Division
A.I.T. Bangkok.

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Jabatan Parit & Taliair
Projek Barat Laut Selangor
Kuala Selangor.

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Jabatan Parit & Taliair
Projek Krian
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Perak.

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Jabatan Parit & Taliair
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Kuala Lumpur.

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J.K.R.
Kota Bharu
Kelantan.

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J.K.R.
Jelebu
Negeri Sembilan.

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J.P.T
Wisma Sri Pahang
Kuantan.

77. Encik Desa Ahmad - Pensyarah
Fakulti Kejuruteraan Pertanian
U.P.M.

78. Mr. Pongpit Piyapongse - Chief, Soil & Water Research Branch
Department of Agriculture
Bangkok, Thailand.

79. En. Azlan Abdul Aziz - Tutor
Fakulti Kejuruteraan Pertanian
U.P.M.

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Fakulti Kejuruteraan Pertanian
U.P.M.

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Fakulti Kejuruteraan Pertanian
U.P.M.

82. En. Fakhru'l Razi Ahmadun - Pensyarah
Fakulti Kejuruteraan Pertanian
Universiti Pertanian Malaysia.

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Fakulti Kejuruteraan Pertanian
Universiti Pertanian Malaysia.

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Fakulti Kejuruteraan Pertanian
Universiti Pertanian Malaysia.

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Fakulti Kejuruteraan Pertanian
Universiti Pertanian Malaysia.

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Fakulti Kejuruteraan Pertanian
Universiti Pertanian Malaysia.

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Fakulti Kejuruteraan Pertanian
Universiti Pertanian Malaysia.

88. Cik Rosnah Mohd. Yusoff - Lecturer
Fakulti Kejuruteraan Pertanian
Universiti Pertanian Malayisa.

89. En. Abang Abdul Rahim Abang Ali - Tutor
Fakulti Kejuruteraan Pertanian
Universiti Pertanian Malaysia.

90. En. Wan Mohammad W. Hj. Abdullah - Lecturer
Fakulti Kejuruteraan Pertanian
Universiti Pertanian Malaysia.

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Fakulti Kejuruteraan Pertanian
Universiti Pertanian Malaysia.

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Fakulti Kejuruteraan Pertanian
Universiti Pertanian Malaysia.

93. En. Jamarei Othman - Lecturer
Fakulti Kejuruteraan Pertanian
Universiti Pertanian Malaysia.

94. Dr. Sacha Sethaputra - Asst. Professor
Khen Khaen University
Faculty of Engineering
Thailand.

95. Mr. Peter Reynolds - Lecturer
P.N.G. University of Technology
P.O. Box 793
Lae, PNG.

96. Dr. Wan Abu Bakar Wan Abas - Lecturer
Faculty of Engineering
Universiti Malaya.

97. Dr. Adhityan Appan - Assoc. Prof.
School of Civil & Structurel Engineering
Nanyang Technological Institute
Singapore.

98. Dr. P.M. Sivalingam - Lecturer
School of Biological Sciences
Universiti Pertanian Malaysia.

99. Ir. Winsel Ahtos - Engineer
J.K.R.
Kuching
Sarawak.

100. Mr. I.H. Sario - Forest Management Officer.
Forest Department
Sandakan.

101. Encik Hoo Choon Sean - Civil Engineering
Perunding Bakti Sdn. Bhd.
12 Jalan SS/2/67
Petaling Jaya.

102. Mr. Sri Harto - Hydrologist
Bahagian Teknik Sipil
F.T.U.G.M.
Indonesia.

103. Mr. Darmanto - Civil Engineer
Bahagian Teknik Sipil
F.T.U.G.M.
Indonesia.

104. Mr. Anan Yuthamanop - Director of Health Physics Division
Office of At. Energy for Peace
Bangkok
Thailand.

105. Mr. Chong Kah Lin - Lecturer
Mech. Eng. Department
University Malaya.

106. Ir. Mohd. Amin Mohd. Soom - Lecturer
Fakulti Kejuruteraan Pertanian
Universiti Pertanian Malaysia.

107. Cik Fadzillah bte Saiden - Jurutera
J.P.T.
Alor Setar
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108. Ir. Mohd. Rashidi Bakar - Lecturer
Fakulti Kejuruteraan Pertanian
Universiti Pertanian Malaysia.

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Universiti Pertanian Malaysia.

110. Mr. J. Pickford - Lecturer, and Leader of WEDC group
Loughborough University of Technology
U.K.

111. En. Kwok Chee Yan - Assoc. Prof.
Fakulti Kejuruteraan Pertanian
Universiti Pertanian Malaysia.

112. Mr. T. Notohadiprawiro - Lecturer
Fakultas Pertanian
U.G.M
Indonesia.

113. Dr. Thamrong Prempridi - Assoc. Prof.
Dept. of Civil Engineering
Chulalongkorn University
Bangkok, Thailand.

114. Mr. J. Brodie - Lecturer
University of South Pacific
Fiji.

115. Ir. Hishamuddin Jamaludin - Lecturer
Fakulti Kejuruteraan Pertanian
Universiti Pertanian Malaysia.

116. Ir. Hamzah Salleh - Lecturer
Fakulti Kejuruteraan Pertanian
Universiti Pertanian Malaysia.

117. Encik Fuad Abas - Lecturer
Fakulti Kejuruteraan Pertanian
Universiti Pertanian Malaysia.

118. En. Tan Ka Keng - Tutor
Fakulti Kejuruteraan Pertanian
Universiti Pertanian Malaysia.

119. En. Bahanurdin Hitam - Lecturer
Fakulti Kejuruteraan Pertanian
Universiti Pertanian Malaysia.

120. Mr. Lim Yew Cheng - Engineer
Ibu Pejabat
J.K.R.
Semenanjong.

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Ibu Pejabat
J.K.R. Semenanjong.

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J.K.R. Semenanjong.

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Ibu Pejabat
J.K.R. Semenanjong.

124. Mr. Peter Nolasco Danker - Insp. Kesihatan Kanan
Institut Kesihatan Umum
Jalan Bangsar.

125. Cik Mushrifah Idris - Hydrologist
FRI, Hydrology Section
Kepong
Selangor.

126. En. Baharuddin Kasran - Hydrologist
Forest Research Institute
Kepong
Selangor.

127. Encik Abdul Rahim Haji Nik - Hydrologist
Hydrology Section
F.R.I.
Kepong
Selangor.

128. Encik Ahmad Kamal Abdul Hamid - Lecturer
Universiti Teknologi Malaysia
Kuala Lumpur.

129. En. Nasiman Sapari - Lecturer
Jabatan Alam Sekitar
Universiti Pertanian Malaysia.

130. Mr. Lim Beng Sit - Executive
Chemitreat
14 Lorong Ara Kiri Tiga
Lucky Garden.

131. Encik Zainuddin Arshad -
Kementerian Kesihatan
Malaysia.

132. Ir. Pison Hj. Md. Zin - Penolong Pengarah
J.K.R. Bekalan Air
Pahang.

133. Dr. Soekardi Wisnuboroto - Lecturer
Faculty Soil Science
Gadjah Mada University
Indonesia.

133. Dr. Soeprapto Soekadarmodjo - Lecturer
Faculty Soil Science
Gadjah Mada University
Indonesia.

134. Mr. Tadashi Tanimoto - Technical Adviser
National Water Resources Study
Wisma Perdana
Jalan Dungun
Kuala Lumpur.

135. Ir. Bambang Harianto - Lecturer
Faculty of Agriculture
Padjadjaran University
Jalan Bukit Dego Utara
Bandong
Indonesia.

136. Dr. Mohd. Tusiran Mohd. Nor - Lecturer
Jabatan Teknologi Kimia
Fakulti Sains
Universiti Kebangsaan Malaysia
Jalan Pantai Baru
Kuala Lumpur.

137. En. Tan Swee Kee - Jurutera
Jabatan Parit & Taliair
Projek Pembangunan Luar Bandar
Kelantan Utara.

138. En. Teok Boon Pin - Jurutera
Jabatan Parit & Taliair
Rancangan Pengairan Muda
Alor Star
Kedah.

139. Ir. S. Kandiah - Director
Jabatan Parit & Taliair Negeri
Bangunan Tuanku Syed Putra
Pulau Pinang.

140. En. Lim Chow Hock - Jurutera
Jabatan Parit & Taliair Negeri
Peti Surat 201
Alor Setar
Kedah.

141. Y.M. Tuanku Alias Shah Tengku Ibrahim
Jabatan Kerjaraya
Kuala Trengganu
Trengganu. - Jurutera

142. En. Ong Boon Yen - Engineer
Jabatan Kerja Raya
Kuching
Sarawak.

143. Ir. Rasbeer Singh - Engineer
Jabatan Kerjaraya (Water Work)
Temerloh
Pahang.

144. Dr. Ir. Ramdhon Bermanakusumah - Lecturer
Fakultas Pertanian
Universitas Padjadjaran
Bukit Dago Utara
Bandong, Indonesia.

145. Ir. Achmad Baihaki - Dean
Fakultas Pertanian
Universitas Padjadjaran
Bukit Daga Utara, Bandung
Indonesia.

146. Ir. Tossin Apandi - Lecturer
Fakultas Pertanian,
Universitas Padjadjaran
Bukit Dago Utara, Bandung
Indonesia.

147. Ir. Mansor bin Abd. Ghani - Jurutera
J.K.R. Bekalan Air
Kuantan.

148. Ir. Razali bin Abd. Aziz - Jurutera
J.K.R. Bekalan Air
Raub, Pahang.

149. Ir. R. Selvarajah - Penolong Pengarah Kanan
J.K.R. Bekalan Air
Pahang.

150. Ms. Suvimol Lukkananukal - System Analyst
Asian Institute of Technology
Bangkok, Thailand.

151. Dr. Kittipong Vuthijumnonk - Asst. Professor
Institute of Agricultural
Technology
Chiangmai, Thailand.

152. Mr. Watana Thammongkol - Assoc. Prof.
Dept. of Civil Engineering
Chulalongkorn University
Bangkok, Thailand.

153. Dr. Mohd. Saleh Suwandi - Lecturer
Jabatan Teknologi Kimia
Universiti Kebangsaan Malaysia.

154. Dr. Goh Sing Yau - Professor
Mechanical Engineering Dept.
Universiti Malaya.

155. En. Abdul Kamal Abdul Hamid - Lecturer
Universiti Teknologi Malaysia.

156. Dr. A.A. Mainul Hussain - Professor Madya
Fakulti Kejuruteraan Pertanian
Universiti Pertanian Malaysia.

ACKNOWLEDGEMENT

The Editors wish to express their grateful thanks to Puan Khatijah Idris for having undertaken all the typing work during the preparation of this proceedings.

143. Ir. Rasbeer Singh - Engineer
Jabatan Kerjaraya (Water Work)
Temerloh
Pahang.

144. Dr. Ir. Ramdhon Bermanakusumah - Lecturer
Fakultas Pertanian
Universitas Padjadjaran
Bukit Dago Utara
Bandong, Indonesia.

145. Ir. Achmad Baihaki - Dean
Fakultas Pertanian
Universitas Padjadjaran
Bukit Daga Utara, Bandung
Indonesia.

146. Ir. Tossin Apandi - Lecturer
Fakultas Pertanian,
Universitas Padjadjaran
Bukit Dago Utara, Bandung
Indonesia.

147. Ir. Mansor bin Abd. Ghani - Jurutera
J.K.R. Bekalan Air
Kuantan.

148. Ir. Razali bin Abd. Aziz - Jurutera
J.K.R. Bekalan Air
Raub, Pahang.

149. Ir. R. Selvarajah - Penolong Pengarah Kanan
J.K.R. Bekalan Air
Pahang.

150. Ms. Suvimol Lukkananukal - System Analyst
Asian Institute of Technology
Bangkok, Thailand.

151. Dr. Kittipong Vuthijumnonk - Asst. Professor
Institute of Agricultural
Technology
Chiangmai, Thailand.

152. Mr. Watana Thammongkol - Assoc. Prof.
Dept. of Civil Engineering
Chulalongkorn University
Bangkok, Thailand.

153. Dr. Mohd. Saleh Suwandi - Lecturer
Jabatan Teknologi Kimia
Universiti Kebangsaan Malaysia.

154. Dr. Goh Sing Yau - Professor
Mechanical Engineering Dept.
Universiti Malaya.

155. En. Abdul Kamal Abdul Hamid - Lecturer
Universiti Teknologi Malaysia.

156. Dr. A.A. Mainul Hussain - Professor Madya
Fakulti Kejuruteraan Pertanian
Universiti Pertanian Malaysia.

ACKNOWLEDGEMENT

The Editors wish to express their grateful thanks to Puan Khatijah Idris for having undertaken all the typing work during the preparation of this proceedings.