Health and Irrigation

Incorporation of disease-control measures in irrigation, a multi-faceted task in design, construction, operation

J.M.V. Oomen
J. de Wolf
W.R. Jobin

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International Institute for Land Reclamation and Improvement/ILRI
P.O. Box 45, 6700 AA Wageningen, The Netherlands 1990.
We dedicate this book to the memory of B.B. Waddy, D.M. D.P.H. A pioneer of research into the health problems associated with the development of water resources and industry in the tropics. He died in 1981. From his writings, we quote:

'Experience of the problems of human health and welfare raised by the creation of lakes has accumulated by now. Most of these problems are very straightforward, and are common to the disciplines of health, agriculture, and sociology. The cost of resettling displaced communities, always much greater than expected, the long-lasting social distress among such communities, and the economic loss due to the flooding of good farm land, are now well known. But they may not be known by governmental authorities, who are happily – and fecklessly – planning to add one more man-made lake to the map of the developing world, in complete and usually misplaced confidence that it will benefit their economy. Mistakes that are repeated with monotonous regularity could be avoided, perhaps without any extra expense, if the authorities for the project concerned were forewarned of them.'

At the beginning of the 1980's, the International Institute for Land Reclamation and Improvement/ILRI approached the Dutch Directorate of International Cooperation/DGIS with a proposal that DGIS assist in financing an ILRI publication entitled *Health and Irrigation*. The origin of this proposal was the contact that had been established between ILRI and Dr J.M.V. Oomen after the publication of Dr Oomen's Ph.D. thesis, *Monitoring Health in African Dams* (prepared under the guidance of Professor Dr H.A. Valkenburg of the Institute of Epidemiology at the Erasmus University in Rotterdam).

It was felt within ILRI that a publication linking elements of Dr Oomen's thesis with features of irrigation could be beneficial to all who are involved in irrigation projects. The book would cover health planning in irrigation projects in areas where water-related diseases (e.g. malaria, schistosomiasis, filariasis, onchocerciasis) were endemic or could become so through the implementation of irrigation projects.

DGIS's response to ILRI's proposal was positive, in principle, but before making a definite decision, it wished to discuss the matter with representatives of the World Health Organization and to hear opinions from Dutch engineering bureaux working in developing countries. The result of these consultations was that, in mid-1983, DGIS made funds available for the preparation of the manuscript of *Health and Irrigation*. In making this decision, DGIS added the provisos that the book give ample attention to practical examples and case studies, and that a Steering Committee be created to advise and guide the authors. The Steering Committee met eight times. Its members were:

- Dr D.C. Faber, Centre for World Food Studies, Wageningen;
- Ir W.C. Hulsbos, Euroconsult, Arnhem;
- Dr J.L.M. Lelijveld, Department of Environmental and Tropical Health, University of Agriculture, Wageningen;
- Drs F. Meyndert, DGIS, later succeeded by Drs M. de la Bey, DGIS;
- Dr A.M. Polderman, Institute for Tropical Medicine, University of Leiden;
- Ir K. Roscher, Department of Civil Engineering, University of Agriculture, Wageningen;
- Ir C. Storsbergen, DHV Consultants, Amersfoort.

The Steering Committee's Secretaries were:

- Ir W.T. Lincklaen Arriens, ILRI, later succeeded by Ir B.T. Ottow, ILRI.

The authors express their appreciation for the constructive criticism they received from the members of the Steering Committee. The work of the two Secretaries deserves special mention. This went far beyond mere secretarial duties to the Committee; it extended to cover an entire literature survey and the processing of its data. Ir W.T. Lincklaen Arriens was also instrumental in realizing the Sri Lanka case study.
Health and Irrigation is being published in two volumes. The first contains Chapters 1 to 10, and Technical Notes 1 to 3. Chapters 1 to 9 and Technical Note 2 are the work of the main authors. Chapter 10 was written by Dr D.H.H. Bol, an economist with Consultants for Development Programmes, Utrecht. Technical Note 1 was written by Dr L. Molineaux, an epidemiologist with the World Health Organization, Geneva. Technical Note 2 was the work of Dr J.A.M. van Druten of the Department of Medical Statistics at the Medical Faculty of the Catholic University, Nijmegen.

Volume 2 was published in advance of Volume I so that it could be presented at the 12th International Congress for Tropical Medicine and Malaria, held in Amsterdam in 1988. In accordance with the DGIS proviso, it contains practical examples and case studies. Much of this was contributed by Dr W.R. Jobin. The case study in Sri Lanka was taken from the field work of the students J.J. Speelman and G. van den Top of the Department of Irrigation and Civil Engineering at the Wageningen University of Agriculture. Another case study was derived from the literature survey conducted by Ir W.B. Snellen of ILRI on ‘Sanitation Works in Java, Indonesia’.

The authors are further indebted to Ir Snellen for his positive criticism of Chapter 10 and for the work he put into completing its final draft.

Data on the geographical distribution of vectors and vector-borne diseases were drawn from publications of the World Health Organization. For schistosomiasis, a separate study was undertaken by Jos L.M. Boeren, a student at the Department of Environmental and Tropical Health, Wageningen University of Agriculture. The support given him by Dr S. Frandsen of the Danish Bilharziasis Laboratory in Charlottlund, and by Dr F.S. McCullough of WHO’s Ecology and Vector-Control Unit in Geneva, is gratefully acknowledged.

We would like to express our thanks to:
- Various departments of the World Health Organization for their comments on the manuscript and for the information they so generously gave us.
  In particular, we would like to thank Dr R.J. Tonn and Dr A. Smith of the Division of Vector Biology and Control and Mrs P.L. Rosenfield of the Special Programme for Research and Training in Tropical Diseases.
  For the very useful contacts with Dr R. Bos, Secretary of the WHO/FAO/UNEP Panel of Experts on Environmental Management for Vector Control, we are very grateful;
- Ir E.L.P. Hessing of the IRC International Water and Sanitation Centre, The Hague, for his support on Chapter 9;
- Dr W. Takken of the Department of Entomology of the Wageningen University of Agriculture for his suggestions on various entomological questions;
- The ILRI Drawing Office for the care and expertise that went into the drawings in the book.

Finally, complying with the request of DGIS, we include the following passage:
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1 Health and irrigation – Some Basic Issues

In the decades that lie ahead of us, land and water development will have a major role to play in increasing the world’s food production – an increase that should primarily take place where food shortages exist or are to be expected, i.e. in the developing countries. It has long been known that by regulating the water supply to a crop, its production can be substantially increased. With the rapid growth of the world’s population and the consequent increasing demand for food, the role of irrigation is a vital one.

Although, on a global scale, only 20 per cent of the harvested area is irrigated, it produces 40 per cent of the total crop production and receives more than 60 per cent of all the fertilizer that is applied (Hotes 1982).

Of the total area under irrigation (roughly 270 million ha in 1986), it is estimated that 65 to 70 per cent lies in the developing world, and that more than half of that area lies in India and the People’s Republic of China.

Irrigation is the principal means by which man modifies his environment to produce more food. New developments in irrigation technology, plus complementary advances in plant breeding and crop protection, and new agronomy ‘packages’, have increased the potential productivity and profitability of irrigated agriculture. This increased productivity comes from higher yields, multiple cropping (often two or even three crops a year), and a reduced risk of crop failure.

We can therefore conclude that irrigation is of great significance for the world’s food production, that it will continue to be significant, and that it is beneficial for food production and farmers alike. Conversely, whenever irrigation is applied in the tropics and subtropics of the world, it can do great harm to the environment and can have ill effects on human health. This is a cause of grave concern which cannot easily be quantified in value terms.

This publication deals with the harm that irrigation can do to human health and the steps that can be taken to prevent that from happening. One harmful effect of irrigation is that it can spread water-related diseases and thus cause the consequent suffering of millions of human beings (Waddy 1975; Worthington 1976; Hunter et al. 1982; Heyneman 1984). Irrigation schemes have often created or enhanced ecological environments that are favourable for the transmission of malaria and other vector-borne diseases: schistosomiasis (bilharzia), dengue and dengue haemorrhagic fever, liver fluke infections, filariasis, and onchocerciasis (river blindness).

Singling out schistosomiasis from the string above and considering the question ‘Bilharzia or Starvation?’ (Obeng 1966), one can see that food must be produced, but that the intermediate snail host of bilharzia must be prevented from establishing itself. From the very beginning, irrigation schemes need to be adequately planned and managed, with environmental safeguards incorporated into them to fight bilharzia. And what holds for bilharzia holds for the other diseases.

Techniques that can create disease-free ecological environments in irrigation schemes are available. In this book, we shall discuss these techniques, their effects, and the necessary measures to bring about change in disease-ridden areas.
1.1 Health through Development

Great differences exist between the prevalent health situation in developed and developing countries. The impact of development on health can be illustrated by the health situation some seventy or eighty years ago in countries which have since become developed. Poor health conditions were commonplace in those countries then, as they still are in less fortunate parts of the world. Table 1.1 provides some striking figures.

| Table 1.1. Range and weighted average of life expectancy at birth, for three groups of countries |
|-------------------------------|-----------------|-----------------|-----------------|
| Life expectancy (years)       | Industrialized countries | Middle-income countries | Low-income countries |
| (at birth)                    | 72-76            | 39-70            | 39-53            |
|                              | (74)             | (61)             | (50)             |


There is historical evidence that the decrease in mortality and the increase in life expectancy in the industrialized countries were associated firstly with the falling incidence of infectious diseases and secondly with the improvement of nutrition. Major factors influencing these changes were:

- Improvements in drinking-water supplies, in excreta disposal, and in nutritional hygiene, which reduced the transmission of many infections;
- The growing awareness of what constitutes good nutrition;
- Demographic changes. Fewer children were born, but they could be given better care and stayed alive.

With this evidence before us, we can draw the conclusion that development offers ample opportunities to improve health: by reducing the transmission of common infections, by improving nutrition, and by controlling the growth of populations.

Internationally, this conclusion motivated the Basic Needs Strategy (ILO 1976), the Primary Health Care Strategy (WHO/UNICEF 1978), and the International Water Decade (World Bank 1980). About the same time, the Panel of Experts on Environmental Management for Vector Control (PEEM) was instituted (WHO/FAO/UNEP 1981).

New irrigation projects, and the population resettlement programs that often accompany them, form ideal targets for applying the principles of health promotion through development. Such projects constitute a large section of the development taking place in the tropical and subtropical zones of Africa, Asia, and Latin America. In many of the countries concerned, the burden of infectious diseases is heavy and the prevailing health situation is poor. Under these conditions, any action to promote health could be highly effective.

Irrigation development brings with it profound ecological changes. In tropical and subtropical climates, these changes have a more severe impact on health than in temperate climates. One reason for this is that vector-borne diseases are already a major public-health problem in the tropics and subtropics, while the ecological changes
brought about by irrigation often lead to the explosive propagation of those vectors. A second reason is that the low standard of living is conducive to the transmission of diseases (see Table 1.2). And a third reason is that the health infrastructure, which tends to be only weakly developed anyway, is unable to cope with the increased burden of diseases.

Table 1.2. Number of infections, deaths, and diseased of major infectious diseases in Africa, Asia, and Latin America (1977-78)* (Source: Walsh and Warren 1979)

<table>
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<tr>
<th>Infection</th>
<th>Infections (1000's per year)</th>
<th>Deaths (1000's per year)</th>
<th>Disease (in 1000's of cases per year)</th>
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<tr>
<td>Water-related vector-borne:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Malaria</td>
<td>800,000</td>
<td>1,200</td>
<td>150,000</td>
</tr>
<tr>
<td>Filariasis</td>
<td>250,000</td>
<td>low</td>
<td>2-3,000</td>
</tr>
<tr>
<td>Dengue</td>
<td>3-4,000</td>
<td>0.1</td>
<td>1-2,000</td>
</tr>
<tr>
<td>Schistosomiasis</td>
<td>200,000</td>
<td>500-1,000</td>
<td>20,000</td>
</tr>
<tr>
<td>Onchocerciasis (skin)</td>
<td>30,000</td>
<td>low</td>
<td>2-5,000</td>
</tr>
<tr>
<td>Onchocerciasis (river blindness)</td>
<td></td>
<td>20-50</td>
<td>200-500</td>
</tr>
<tr>
<td>African Trypanosomiasis</td>
<td>1,000</td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Gastro-enteric:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diarrhoeas</td>
<td>3-5,000,000</td>
<td>5-10,000</td>
<td>3-5,000,000</td>
</tr>
<tr>
<td>Typhoid</td>
<td>1,000</td>
<td>25</td>
<td>500</td>
</tr>
<tr>
<td>Gastro-intestinal worms:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ascariasis</td>
<td>800,000/</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1,000,000</td>
<td>20</td>
<td>1,000</td>
</tr>
<tr>
<td>Hookworm</td>
<td>7-900,000</td>
<td>50-60</td>
<td>1,500</td>
</tr>
<tr>
<td>Respiratory:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acute and chronic respiratory diseases</td>
<td></td>
<td>4-5,000</td>
<td></td>
</tr>
<tr>
<td>Measles</td>
<td>85,000</td>
<td>900</td>
<td>80,000</td>
</tr>
<tr>
<td>Tuberculosis</td>
<td>1,000,000</td>
<td>400</td>
<td>7,000</td>
</tr>
</tbody>
</table>

*) Based on estimates from the World Health Organization and its Special Programme for Research and Training in Tropical Diseases, confirmed or modified by extrapolations from published epidemiological studies performed in well-defined populations. Figures do not always match those officially reported, because under-reporting is common.

1.1.1 Planning Irrigation Projects and Disease Control

The incorporation of environmental safeguards to promote health should be envisaged right at the beginning of the planning process. An excellent example of project planning is provided by the Tennessee Valley Authority (TVA) in its integrated plan for the development of water resources in the Tennessee River Valley. Malaria posed a serious health problem in the region, with wide implications for the economic and social well-being of the population. A direct consequence of any impoundments would be an increased transmission of malaria. For this reason, an integrated strategy of malaria control was incorporated into TVA's program. (More details of this will be given
in Chapter 5 and in Volume 2, Annex 3.1.)

Figure 1.1 illustrates the concept of integrated planning. The adoption of a development project is motivated by the desire to improve human welfare, although economic and technical objectives may dominate the plan. The activities necessary to implement the plan can be designated as primary or secondary, according to their relationship to the objectives. Health considerations are most likely to be included in the project if they can be linked to primary activities (direct health effects) and secondary activities (indirect health effects). Direct health effects, particularly in the tropics, will be those related to vector-borne infections, which can form a threat to the realization of the objectives. Indirect health effects are likely to cover a range of infections of varying significance, with diarrhoeal diseases and nutritional problems the most common.

Figure 1.1 Integrated planning of water-resources development and health

1.1.2 Social and Economic Parameters

The social and economic significance of a disease is broadly indicated by an estimate of the number of days of healthy life lost through the disease or premature death. Such estimates make it possible to rank the infections (Table 1.3). This ranking can then be used, for example, to compare the cost-effectiveness of different options for disease prevention. A major difficulty, however, remains the expression of the health impact in an economically tangible, monetary, measure.
Table 1.3 The health impact of vector-borne infections in Ghana, estimated in terms of days of healthy life lost per 1000 persons

<table>
<thead>
<tr>
<th>Disease</th>
<th>Days of healthy life lost</th>
<th>Lower and upper limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malaria</td>
<td>32,567</td>
<td>27,000</td>
</tr>
<tr>
<td>Schistosomiasis</td>
<td>4,368</td>
<td>750</td>
</tr>
<tr>
<td>Onchocerciasis</td>
<td>1,926</td>
<td>1,540</td>
</tr>
<tr>
<td>Hookworm</td>
<td>1,482</td>
<td>900</td>
</tr>
<tr>
<td>Ascaris</td>
<td>1,222</td>
<td>850</td>
</tr>
<tr>
<td>Trypanosomiasis</td>
<td>195</td>
<td>100</td>
</tr>
<tr>
<td>Guinea worm</td>
<td>108</td>
<td>45</td>
</tr>
</tbody>
</table>

Source: Morrow and Ghana Health Assessment Team (1981)

Cost-benefit and cost-effectiveness analysis are instruments that can be used for the allocation of resources. These analyses will be discussed in Chapter 10.

Applying the cost-benefit method to the health component requires that information be available on the current prevalence\(^1\) and incidence\(^2\) of diseases, and that future trends can be forecast. Epidemiological methods for the collection of this information will be discussed in Chapter 4.

1.2 The Prevention and Control of Diseases

1.2.1 The Natural History of Disease

The natural history of a disease covers both the time that people are at risk of catching the disease, and the course the disease takes in those who are afflicted (see Figure 1.2). Measures to improve health aim at preventing the disease process or its damaging sequelae. On the basis of a disease's natural history, preventive measures can be classified as primary, secondary, and tertiary, according to the stage in which they act on the process. In this epidemiological concept, treatment is also seen as a form of prevention, because it interrupts the process. The degree of success in preventing a disease depends on the completeness of knowledge about its natural history, the opportunities to apply that knowledge, and the actual application of the knowledge.

Primary prevention encompasses any form of health promotion and may be regarded as one of the main factors in producing healthy populations. Health promotion means the creation of healthy and hygienic living conditions in which the basic human needs (food, water, housing, clothing, excreta disposal, and health care) can

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1 Prevalence: Ratio of number of persons with a specified disease at a particular moment in time, to the population in question (e.g. on July 1st 10,000 persons suffer from Schistosomiasis in a population of 100,000; the point prevalence = 0.1).

2 Incidence: The number of newly diagnosed cases of a disease during a defined period (usually 1 year) divided by the population in question (e.g. from January 1st till December 31st 1000 persons are newly diagnosed as having Schistosomiasis in a population of 100,000; incidence = 0.01).
be satisfied. The mere satisfaction of basic needs, however, will not generate an impact on health unless the people use what is provided as it was intended to be used. Health and hygiene education should therefore be a fundamental component in any action to promote health.

Health promotion is not a task for the health sector alone, but for all sectors concerned with social and technical development. The role of the health sector in primary prevention is limited to providing the necessary knowledge and expertise for health promotion, and to providing specific forms of protection through the use of vaccines, prophylactic drugs, disinfectants, insecticides, and other biochemical agents.

Secondary prevention is concerned with the early diagnosis and treatment of people who have the disease, either pre-clinically or clinically. Tertiary prevention aims at limiting the disabling consequences of the disease.

For the control of major infectious diseases, experience has shown that an efficient and reliable control strategy combines both primary and secondary preventive measures.

1.2.2 The Transmission of Infectious Diseases

Infectious diseases are caused by biological agents such as bacteria, viruses, protozoa,
and various types of worms. The diseases are transmitted by the disease agent passing from one person to another, or sometimes, to or from an animal. The carriers of the agent constitute the 'reservoir of infection', and the person (or animal) acquiring the infection the 'susceptible host'. Some of the agents are transmitted by direct bodily contact, but more often they are first expelled into the environment and only reach the susceptible host by some intermediary 'transmission mechanism', which can involve irrigation water, food, etc. In vector-borne infections, the transmission mechanism involves an insect, snail, or an animal (Figure 1.3).

1.2.3 The Integrated Control of Transmission

The burden of infectious diseases in a community can be reduced by the partial or complete disruption of their transmission. There are three ways in which this can be done:
- By interfering with the transmission mechanism;
- By protecting the susceptible host;
- By reducing the reservoir of infection.

Environmental management, or environmental health engineering, can disrupt transmission by eliminating the breeding places of the vectors. This might be supplemented by the use of chemicals, either to kill the disease agents by disinfection, or the vectors with insecticides or molluscides. Biological measures can also be taken. These constitute either genetic manipulation or the introduction of organisms (i.e. predators or toxic plants) which compete ecologically with the disease agents or vectors.

The susceptible host can be made less susceptible through immunization or the pro-

Figure 1.3 Intermediary mechanisms for the transmission of infectious diseases
phylactic use of drugs. (This also applies to susceptible animal hosts.) Further, the susceptible host can be protected by reducing his contact with the vector, by his use of repellants against biting insects, and by screening his house. Also, his village can be sited away from vector-breeding habitats, and domestic water facilities can be provided at places where there are no harmful insects.

The reservoir of infection can be reduced by treating infected and ill people, and by treating or eliminating infected animals.

The integrated control of infectious diseases is a control strategy that combines, if relevant, elements of all three of the above approaches (WHO 1983). As a combination of primary and secondary preventive measures, integrated control is illustrated in Figure 1.4.

1.2.4 Engineering Design Components for Integrated Control

The adverse health impact of irrigation in the tropics and subtropics is well documented (Deom 1982; Hunter et al. 1982), revealing that engineers have an important role to play in the integrated control of diseases. The conventional biological classification of diseases is not helpful to the engineer, because it has no bearing on the environmental changes he might make to combat diseases (Bradley 1974). For the engineer, it is more convenient to have the diseases classified in categories that relate to those aspects of the environment which he can change (Cairncross and Feachem 1983; McJunkin 1982).

![Figure 1.4 Integrated control of vector-borne diseases](image-url)
With the basic needs as its starting point, Table 1.4 presents such a classification. In each category of basic needs, it identifies the transmission mechanisms and indicates those engineering design components that are relevant for disease control (Stephens et al. 1985). These will be further discussed in Chapters 5 to 9.

The most common diseases generated by irrigation are vector-borne diseases. Their prevention is thus the main focus of this book. The epidemiology of these diseases will be dealt with in Chapter 2, the vectors themselves in Chapter 3.

Table 1.4 Transmission mechanisms of diseases, and design components for environmental health engineering that contribute to integrated control

<table>
<thead>
<tr>
<th>Design component</th>
<th>Transmission mechanism</th>
<th>Design feature</th>
<th>Related diseases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occupation</td>
<td>Insect-vector breeding in water/biting near water</td>
<td>Water-based</td>
<td>Malaria, onchocerciasis, trypanosomiasis, other vector infections Schistosomiasis</td>
</tr>
<tr>
<td>Water supply</td>
<td>Water-borne</td>
<td>Quality and/or quantity of water</td>
<td>Diarrhoeas &amp; dysenteries Enteric fevers</td>
</tr>
<tr>
<td></td>
<td>Water-washed</td>
<td>Quantity only</td>
<td>Enteric virus infections Skin infections Eye infections Louse-borne fevers</td>
</tr>
<tr>
<td></td>
<td>Water-based</td>
<td>Protection of water source</td>
<td>Guinea worm infection</td>
</tr>
<tr>
<td>Excreta disposal</td>
<td>Person-person contact</td>
<td>Latrine construction</td>
<td>Diarrhoeas &amp; dysenteries</td>
</tr>
<tr>
<td></td>
<td>Domestic contamination</td>
<td>Excreta treatment</td>
<td>Enteric fevers</td>
</tr>
<tr>
<td></td>
<td>Water contamination</td>
<td>Hygiene environment</td>
<td>Soil transmitted helminths</td>
</tr>
<tr>
<td></td>
<td>Field contamination</td>
<td></td>
<td>Beef and pork tapeworms</td>
</tr>
<tr>
<td></td>
<td>Crop contamination</td>
<td></td>
<td>Water-based helminths (Schistosomiasis)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Filarisis</td>
</tr>
<tr>
<td>Housing</td>
<td>Siting near vector habitat</td>
<td>Siting/screening of houses</td>
<td>Malaria, filariasis, onchocerciasis, trypanosomiasis</td>
</tr>
<tr>
<td></td>
<td>Overcrowding</td>
<td>Space and ventilation</td>
<td>Epidemic meningitis</td>
</tr>
<tr>
<td></td>
<td>Air pollution</td>
<td></td>
<td>Acute &amp; chronic respiratory infections Respiratory malignancies</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Arbo-viral infections (dengue, yellow fever)</td>
</tr>
<tr>
<td></td>
<td>Vector breeding</td>
<td>Water storage</td>
<td>Chagas disease, leishmaniasis</td>
</tr>
<tr>
<td></td>
<td>Refuse</td>
<td>Waste disposal</td>
<td>Soil transmitted helminths</td>
</tr>
<tr>
<td></td>
<td>Construction</td>
<td>Construction materials</td>
<td>Fire hazards</td>
</tr>
<tr>
<td></td>
<td>Fire</td>
<td>Burns</td>
<td></td>
</tr>
<tr>
<td>Nutrition</td>
<td>Lack of calories</td>
<td>Staple crops</td>
<td>Undernutrition</td>
</tr>
<tr>
<td></td>
<td>Lack of proteins</td>
<td>Home-gardens</td>
<td>Protein-caloric malnutrition</td>
</tr>
<tr>
<td></td>
<td>Lack of vitamins</td>
<td></td>
<td>Vitamin deficiencies</td>
</tr>
<tr>
<td></td>
<td>Food storage</td>
<td>Storage facilities</td>
<td>Food-poisoning: diarrhoeas</td>
</tr>
<tr>
<td></td>
<td>Food preparation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy</td>
<td>Use of fire-wood</td>
<td>Kitchen stoves</td>
<td>Food poisoning: diarrhoeas Burns see: Air pollution</td>
</tr>
<tr>
<td></td>
<td>Open fire</td>
<td>Chimneys</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Storage of kerosene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Village infrastructure</td>
<td></td>
<td>Immunizations</td>
<td>Childhood infections, poliomyelitis, yellow fever</td>
</tr>
<tr>
<td>Health care</td>
<td></td>
<td>Mother-Child care</td>
<td>Perinatal/infant mortality</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Education and Communication</td>
<td>Treatment Endemic diseases: malaria, diarrhoea respiratory infections, helminths,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>schistosomiasis etc.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Birth regulation</td>
</tr>
</tbody>
</table>
1.3 Outlook for Irrigation Development

The distribution of irrigated land over the continents is roughly as follows:
- Asia: 68 per cent;
- North America: 13 per cent;
- Europe: 10 per cent;
- Africa: 5 per cent;
- Central and South America: 3 per cent;
- Australia and Oceania: 1 per cent.

For the year 1986, the total irrigated area was estimated at 271 million ha. The annual expansion is of the order of 400,000 ha. This annually expanding irrigated area will certainly present a big challenge to the planners, designers, and operators of irrigation schemes because irrigation will, more and more, be introduced in areas where it is not a well-established form of agriculture, where the individual areas of irrigable land are relatively small, where the general level of crop husbandry is low, where project management is poor, and where rainfall (as the source of irrigation water) is highly seasonal. All these factors are conducive to increasing the areas suitable for the habitats of vectors.

Looking in particular at West and Central Africa, we see that irrigation development in that region seems less promising than elsewhere. Areas suitable for irrigation are relatively small and thus make the costs of irrigation higher than almost anywhere else in the world. (Investment costs are in the order of U.S. $10,000 to 15,000 per ha.) Other disadvantages are the generally low standard of rain-fed agriculture, poor project management, low levels of river discharge in the dry season, and the high rates of evaporation.

1.4 Irrigation Schemes

1.4.1 Their Elements

The three principal elements of an irrigation scheme are its water source, the irrigation and drainage network, and the on-farm management of water.

The scheme water source may be one of the following:
- A large storage reservoir created by the construction of a large dam in a river; it provides water the whole year round;
- Small storage reservoirs created by the construction of small dams; these usually supply water on a seasonal basis only;
- Run-of-river diversions for supplying water on a year-round or seasonal basis;
- River pumping stations;
- Well pumping.

The word ‘reservoir’ to indicate a ‘scheme water source’ is used here in the sense of an element separate from the irrigation and drainage network. However, there are also reservoirs that form an integral part of the irrigation network (e.g. tanks, night-storage reservoirs).

The layout of an irrigation scheme is shown in Figure 1.5. The terminology used is that advocated by the International Commission for Irrigation and Drainage (Bos 1979).
In the irrigation network, the water is conveyed from its source through a main canal, from which it may be diverted into secondary canals. It proceeds further until it reaches a tertiary offtake, which is a structure that diverts water from a main or secondary canal to a tertiary unit. Within the tertiary unit, the farmers are responsible for distributing the water among themselves and for the on-farm management of their water. This includes the application of water to the fields and the drainage of any excess water (from rainfall, leaching, or excess applications of irrigation water). The drainage network forms, as it were, the mirror image of the irrigation network.

The task facing the designer of an irrigation scheme is a highly complex one, combining as it does a myriad of technical, economic, agronomic, social, and environmental factors. Basically, however, the designer’s task is to create a layout that achieves three things: it must use the available water as efficiently as possible; it must enable an equitable distribution of the water among the farmers; and it must not create or intensify health problems.
1.4.2 Categories of Irrigation Schemes

Mather (1983) distinguishes three categories of irrigation schemes:
- Large-scale formal schemes;
- Small-scale formal schemes;
- Small-scale informal schemes (i.e. the village type).
We could add a fourth category: private irrigation, which has undergone a rapid expansion with the development of cheap pumps.

The four categories of schemes, with their differing characteristics, can be expected to have different social and economic consequences, which in turn will create varying levels of the risk of spreading vector-borne diseases.

A large-scale scheme creates major ecological changes over a wide area. Its effects on human populations will often be considerable, with displacement, resettlement, the mobilization of labour forces for the scheme’s construction, the settlement of migrant labour, and the recurring presence of transient, seasonal workers. A large-scale scheme is more likely to multiply the number of pre-project focal points of disease, while the population movement it engenders is more likely to extend the problem beyond the scheme’s boundaries.

A large-scale scheme therefore requires a careful design, with built-in safeguards to prevent a high level of risk, and it particularly needs good management. On the other hand, the large population in a large-scale scheme makes it economically more feasible to provide health services and basic sanitary facilities than in dispersed communities.

In a small-scale formal scheme, fewer people are involved, but disease foci can easily spread diseases beyond the scheme’s boundaries. If the peripheral environment is also suited to vector production, the task of disease control and its cost may prove onerous in relation to the population benefitting. Similarly, the costs of providing community services and health facilities will be relatively high, or, alternatively, may have to be provided at a reduced level. Even so, the combination of good management and farmer participation in schemes of this category offers good prospects for the control and containment of diseases.

What will happen in small informal schemes is less predictable. They are less disruptive of the traditional social and economic status and hardly involve any population movement. By their very nature, they will not introduce major or rapid ecological changes. They will, however, induce changes in the local environment, which may be significant in terms of vector habitat, with a consequent shift in species distribution and numbers. The size of the scheme and the usually minimal infrastructural and institutional support it receives leave it vulnerable to the build-up of adverse health conditions to a point where emergency intervention may be needed.

Private irrigation usually takes the form of multiple small developments, often clustered near population centres with their markets and communities, or possibly even inducing the creation of such centres. This type of irrigation also changes the hydrological environment and the associated ecology. The large numbers of individual enterprises can be a source of risk in endemic disease areas in the absence of proper water management and without a responsive and adequate health service.

The rehabilitation of existing irrigation schemes also deserves mention. Since the 1970’s, rehabilitation has greatly increased in significance, particularly in India, Pakis-
The aims of rehabilitation are to improve and modernize the irrigation infrastructure and its operation and maintenance, but rehabilitation without the incorporation of health safeguards is not worthy of its name.

1.4.3 Dams

The recent history of dams – large and small – has revealed that the construction of each dam was followed by untoward or unforeseen effects (Oomen 1981; Obeng 1977; Worthington 1976; Stanley and Alpers 1975; Ackermann et al. 1973; Rubin and Warren 1968; Lowe-McConnell 1966; ECAFE 1962).

Large Dams

The development of concrete technology since 1900, the use of experimental models for design since 1945, the improvements in hydro-electric engineering, and the invention of giant earthmoving equipment had the combined effect that after 1950 a generation of superdams were constructed.

The World Register of Dams (Brown 1964), after a world-wide survey, lists 10,000 dams of at least 15 m height, even though several countries, one of which was China, could not be included in the survey. Between 1964 and 1971, 2,000 more large dams were added to the list.

Fels and Keller (1973) compiled data on 41 man-made lakes with a surface area in excess of 1,000 km². Seven of these are located in Africa and were constructed after 1950. Of 315 smaller reservoirs, but with a surface area exceeding 10 km², 17 are in Africa. Lake Volta in Ghana, with a surface area of 8,500 km², is at present the largest man-made lake in the world. (The High Dam Lake has a maximum surface area of 6,118 km².)

Small dams

Although precise figures are not available, there are multitudes of small dams in the developing countries. Their effect on agriculture is probably less than that of the large dams, but their impact on disease is probably more severe (Hunter, Rey, and Scott 1982; Obeng 1977). A contributing factor is the ease with which small dams can be constructed at relatively low cost with the now generally available equipment, so that small groups of people (e.g. village communities, farmers' cooperatives, voluntary agencies) can build them. Unfortunately, the undoubted benefit to the community can be offset by adverse effects on health because such developments are usually without any provision for health.

1.4.4 Migration and Resettlement

Population movements as a result of development can increase the transmission of diseases or can introduce new diseases. On the other hand, when resettlement schemes
are being planned, they offer the opportunity to include health promotional measures in the plans (Chambers 1969). The successful implementation of schemes depends to a large extent on the settlers, their sense of well-being, and their willingness to participate. Their active participation in decision-making, both before and after the move, is essential to success.

An important indicator of successful implementation is the duration of the transition period. This is the period from the time of the move until full self-sufficiency, at least in food supplies, is regained. A minimum of two years is considered necessary under optimum conditions.

When resettlement schemes are being planned, the main factors to be considered for the promotion of health and social well-being are those shown in Figure 1.6.

When groups of people move into a new location, there is considerable risk that they will be exposed to diseases for which they have no acquired immunity (Fernando 1984). These may be diseases that are already prevalent in the area (but were absent in the home area) or that will be introduced to the resettlement population by newly-arrived settlers. In any case, resettlement implies that groups with varying degrees of immunity to diseases are being brought together. In this situation, epidemic outbreaks of dysentery or malaria easily flare up. Moreover, resettlement usually means an increase in population density, which in itself facilitates the transmission of diseases.

Resettlement also adds stress to the, often already precarious, health of the settlers. The stress can be physiological, psychological, and socio-cultural, each aggravating the others. Physiological stress is accompanied by a temporary increase of disease incidence and death. Psychological stress has two components: one is grief for the loss of home, lands, and former habitat; the other is the uncertainty as to what the future will bring. The socio-cultural stress mainly concerns a temporary disruption of social relationships and of the efficacy of leadership. Informing the communities beforehand of what they can expect after their move, and soundly organizing the operation itself, will help a great deal in alleviating stress (Scudder 1975).

Figure 1.6 Health determinants of resettlement
Health problems associated with resettlement can arise shortly after the move, or may need more time to develop their full impact. Short-term health problems (common diarrhoeal and respiratory diseases, malnutrition) are mostly related to the forced migration; their impact will be felt in the transition period. Vector-borne diseases may be responsible for epidemics in the beginning, but are more likely to become endemic as time passes.

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