ENVIRONMENTAL ASSESSMENT

SMALL FARMER PILOT IRRIGATION PROJECT

SWAZILAND

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LIST OF ACRONYMS USED

ASAE	American Society of Agricultural Engineers
BEO	USAID Bureau Environmental Officer for Africa
EA	Environmental Assessment
EPA	U.S. Environmental Protection Agency
ESCOM	South African Electrical Supply Commission
ETMA	USAID Environmental Training and Management Project in Africa
HA	Health Assistant (Ministry of Health)
MOAC	Ministry of Agriculture and Cooperatives
MOH	Ministry of Health
MOW	Ministry of Works, Power and Communications
OR	Oral Rehydration
PID	USAID Project Identification Document
RDA	Rural Development Areas (MOAC Program)
REO	USAID Regional Environmental Officer (Nairobi)
RHM	Rural Health Motivator (MOH)
RWBDCP	USAID Rural Water-Born Disease Control Project
SEB	Swaziland Electricity Board
SNL	Swazi Nation Land
USAID/S	U.S. Agency for International Development/Swaziland
VIP	Ventilated Improved Pit Latrine
WASH	USAID Water and Sanitation for Health Project
WDP	Water Dispersible Powder
WHO	World Health Organization

I. PROJECT OBJECTIVES AND BACKGROUND

OBJECTIVES

In conjunction with the USAID/Swaziland Country Development Strategy Statement for FY 1982, the Project Identification Document (PID) for the Pilot Small Farmer Irrigation Project (645-0217) on Swazi Nation Land (SNL) identifies the following objectives:

- to increase employment opportunities;
- to increase agricultural productivity; and
- to increase incomes.

ALTERNATIVES CONSIDERED

The following alternatives were considered and rejected in the preliminary analysis for the project:

No Development

Irrigation development on SNL, which offers the greatest potential for increasing productivity and incomes for small farmers, would continue at a slow pace. Adverse environmental impacts would indeed be reduced under this alternative in comparison with the proposed alternative. The potential beneficial impacts, however, in terms of improved health and well-being, would also be reduced.

Dryland Farming

This option would limit action in increases in cultivated acreage and soil amendments, even though rainfall throughout Swaziland is inadequate to make efficient use of such changes.

Beneficial impacts would most likely be less than under the proposed action. Adverse impacts could be equally significant, however, as even dryland farming will involve serious risks of soil erosion and reduced water quality, as well as the health impacts of labor movement and use of agricultural chemicals.

Estate Agriculture

This option, with a relatively successful history in Swaziland, would imply the development of much larger areas, including higher management and infrastructure costs, beyond the levels envisaged for this project. Adverse environmental impacts could also be much more significant, relating primarily to alterations of riverine hydrology (e.g., dam construction), water quality and habitats for molluscan hosts of schistosomiasis.

On the other hand, it is recognized that adverse impacts will likely always result from any scale of increased irrigated agriculture or dryland farming. It is also possible, however, to take appropriate actions, especially with small irrigation systems, so as to minimize those impacts and provide net benefits in conjunction with the purpose of the project.

II. SUMMARY

MAJOR CONCLUSIONS

The analysis concludes that the potential adverse impacts identified in the "Scoping Statement" can be minimized by the incorporation of appropriate engineering design features, project management, monitoring, evaluation and training components. Particular features required to minimize impacts should include:

- soil and water conservation measures, such as erosion and control and proper water management;
- provision of improved domestic water supplies and sanitation; and
- regulation of pesticide use.

Numerous impacts could be eliminated by progressing from surface (furrow) irrigation to more efficient systems (such as sprinkler and trickle), but at higher capital investment.

MAJOR ISSUES

Since actual project sites and particular crops remain to be chosen, it was necessary to make certain assumptions regarding these variables in impact assessment. Monitoring and evaluation components of the pilot project are therefore considered especially important.

The final evaluation will require thorough re-examination of the anticipated and actual impacts of the pilot project, which is expected to provide a model for future expansion.

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Scale effects in a greatly expanded irrigation program could establish new priorities for environmental protection, otherwise inconsequential at a pilot stage of operation.

III. PURPOSE AND METHODOLOGY

This assessment is intended to provide environmental guidelines for project design, implementation, monitoring, evaluation and training.

This analysis is based upon a review of existing literature; interviews with host country officials, USAID-project staff, other donor agency staff and representatives of the private sector (listed in Appendix G1); and site visits to existing and proposed irrigation schemes in Swaziland (Appendix G2).

The discussion assumes a "worst case" scenario, providing for a conservative approach to project design. An attempt has been made, however, to propose pragmatic criteria that can be applied and monitored under field conditions without compromising project objectives.

IV. PROPOSED ACTION AND IMPACTS

As stated in the PID, the project will develop pilot irrigation schemes to test the following: individual vs. group schemes; various types of technology (e.g., furrow, sprinkler, gravity fed, pumped); groundwater irrigation; various cropping patterns; farmer organization and management; credit and financing arrangements; and water use and maintenance programs.

The project proposes to train some 1,200 farmers and 120 government personnel in irrigated agriculture and extend 250 loans. A total of about 1,200 hectares in plots of various sizes will be developed on Swazi Nation Land.

It is assumed, therefore, that the project may involve the following activities in various combinations at different sites and on different scales: dredging, dam construction, pond excavation, stream/river diversions, canalization, pipeline laying, pump installation/operation, land clearing/forming, fencing, field diversion structures/gates, drainage, access road construction.

Major physical environmental impacts, without the implementation of environmental protection recommendations are expected to be the following:

- increase in soil erosion resulting from improper flow velocity or soil texture in unlined canals and land surface modifications;
- increase in soil salinity as a result of improper irrigation water management, especially in surface

irrigated farms; and

- change in surface water quality especially with sediments from agricultural land getting into streams and reservoirs.

The major health impacts, without the implementation of recommended measures, are expected to be:

- increase in transmission of schistosomiasis to an unknown but potentially major degree, especially among children (but affecting all ages), on a localized basis in the middle and lowveld;

- increase in transmission of other enteric parasites, resulting from changes in demography and water use and sanitation patterns, in all veld types; and

- increase in acute and chronic toxic effects of dermal, inhalation and oral exposure to pesticides and herbicides, primarily among applicators.

All these effects can be controlled, but probably not completely eliminated, if corrective measures are implemented in conjunction with effective monitoring and evaluation procedures.

V. AFFECTED ENVIRONMENT AND CONSEQUENCES

DESIGN-ENGINEERING ASPECTS

Canal Use and Protection

Two methods of irrigation were identified in the Rural Development Areas (RDA), cooperative or farmers association and individual small schemes: surface (furrow) and sprinkler. Most of the schemes are furrow irrigated, a typical system including a diesel or electric pumping plant, a reservoir, unlined canals and land leveling. Canals and irrigated areas are normally protected from animals by fences.

The RDA schemes ranging from 10 to 25 hectares are designed and constructed by the Ministry of Agriculture and Cooperatives and the area is divided into small lots of 0.4 hectares to 1 hectare when the scheme is completed. There is no rent or water charge in any of the schemes. In theory the farmers are responsible for the maintenance of the canals, but this is rarely carried out and when the water delivery and distribution system fails, the scheme is abandoned.

The cooperative and farmers association schemes range from 20 to 100 hectares and the individual plots tend to be larger than in RDA schemes. The cooperatives and associations are responsible for purchasing the pump, pipelines and any other permanent equipment. The Ministry of Agriculture and Cooperatives assists farmers by providing cleaning and land leveling equipment, installation of pumping plants and construction of canals. The farmers are responsible for the management of the irrigation scheme, but adequate maintenance is not carried out. A better situation is at Magwanyane and Mankantshane schemes, but schemes at Kalanga must be probably rehabilitated.

The individual schemes vary from the small furrow irrigated garden to the 12-hectare sprinkler schemes. The Ministry of Agriculture and Cooperatives, offers assistance and design and installation. The small furrow schemes are normally gravity fed from streams and the construction is carried out by the farmer. Better operation and maintenance of these schemes was noticed.

Non-adequate maintenance of unlined canals in small farmer irrigation schemes has created sediment deposits, the vegetation is interferring with normal canal operation and large quantities of water are lost by seepage.

Unlined canals should be cleaned at least once a year to remove sediment deposits and excess vegetation and reshape the canal. Canals should also be inspected each year for erosion and bank scouring. Animal maintenance should be done before sowing or planting the first crops. This period varies from Highveld to Lowveld and with the crop. A crop calendar is shown in Appendix E3.

In order to assure better canal protection, fencing should be extended to all irrigation schemes. Animal traffic and separate livestock water supply should be provided. (Cover protection may be more expensive and protective vegetation or trees and bushes may interfere with canal and field operation in the small irrigated farms.) Farmers at Emgomfelweni scheme in Mahlangatsha RDA supplied the fencing materials and provided labor for installation.

Also, increased use of pipeline would reduce maintenance and protection problems and avoid costly rehabilitation of irrigation schemes. The Irrigation Section of MOAC has already successfully installed low pressure pipe systems in areas where irrigation supply contains low amounts of sediment.

Animal Facilities

Livestock is an important sector in the traditional subsistence agriculture of Swaziland, but the high livestock rate is deteriorating the soil and water resources. When associated with small irrigation schemes, livestock is in some cases producing damage to the irrigation facilities and leveled agricultural land. Even though many of the irrigation water supply and distribution systems in the Swazi Nation Land are protected; it is recommended to provide fencing for the livestock. This would help also in collecting manure which is necessary to be applied to the irrigated land to improve organic water content and soil physical qualities.

Wood and steel posts are available for fencing. Barbed or woven wire should be used alone or in combination. Barbed wire above woven wire keeps large animals from leaning over or breaking down fencing, while below woven wire keeps the small animals from digging under the fence.

Selected progressive farmers may want to install electric fencing which has low cost and is effective. Electric fencing helps also in managing pasture and rotation grazing. Electric fences powered by batteries or solar cells are being used successfully in the small farming in the Caribbean.

Adequacy of Field Drainage

Swaziland soils are normally well drained soils, except for the western and eastern Lowveld. Drainage requirements were considered in the planning and site selection in most of the small irrigation schemes in the Swazi Nation Land. However, because of lack of a detailed soil survey and non-adequate land forming, some of the irrigation schemes present drainage problems. Sources of excess of water are precipitation, irrigation facilities, overland flow and underground seepage from adjacent areas and over-irrigation.

Maintenance of natural and open drains, where such systems exist, is not adequate in the small farming irrigated schemes. Lack of proper maintenance has created sediment in the drains, erosion of drain canal and side slopes and high sediment load in the drainage water. Also noticed was an excessive growth of weeds and grasses and growth of undersirable woody vegetation. Lack of maintenance of land leveling has reduced the drainage in the small irrigation schemes.

Even drainage is not a major problem in the small irrigated farms, a detailed soil survey is necessary before any system rehabilitation or site selection of new irrigation schemes.

There is very little existing information on flooding in irrigated areas. There are no records of damages and little information on flood plains and elevations. Field observations indicate that the flood plain damage potential is limited to a few roads and bridges, diversion and canal systems and areas of agricultural land.

Flood control measures or reducing flood-flows by watershed treatment, and flood control reservoirs should be considered before developing any new irrigation schemes. Implementation of these measures that retard the flow or reduce the runoff could be an important step toward conservation of natural resources.

Flood and Canal Bank Erosion Control

As already mentioned in the previous subsection, there is very little existing information on flood conditions and there are no records of eventual damages. The Water and Related Land Resources Framework Plan prepared by the U.S. Army Corps of Engineers is proposing seventeen damsites selected for the maximum river control.

River Basin	Proposed Dams
Lomati	1
Komati	2
Komati Tributaries	5
Mbuluzi	1
Upper Great Usutu	1
Ngwempisi	1
Mkondo	1
Lower Great Usutu	1
Lower Great Usutu Tributaries	3
Ngwavuma	1

A national program for flood control including construction of flood control reservoirs and various watershed treatments would reduce flooding hazards.

During high flows, soil which washes from fields and burned and overgrazed areas can make streams highly turbid. However, the naturally low turbidity during low flows indicates that turbidity would not pose constraints to water use.

Bank canals in the small irrigation schemes in Swazi Nation Land are normally protected by vegetation and were not noticed to have any severe bank erosion problems. However, weeds along canal banks are permitted to seed and may become a major source of weed infestation of crops. If erosion is occurring, additional grade control or energy-dissipating structures may be needed. Ditches adjacent to structures can often be stabilized by placing course pit-run gravel in the ditch.

Water Quality and Quantity

The surface and groundwater of Swaziland is generally of a good quality. The pH averages 7.2 with less than ranges from 6.1 to 8.9. Turbidity levels are low during the most seasons, but seasonal rains cause considerable turbidity in rivers. Alkalinity averages 30 mg/L and ranges from 2 mg/L to 172 mg/L. Hardness averages 40 mg/L and 1,300 mg/L, respectively.

Only at Lubuli station in the eastern Lowveld has high total dissolved solids been noticed; hardness and alkalinity range to 1,020 mg/L and 1,300 mg/L, respectively.

Water quality analyses in the Mbuluzi, Little and Great Usutu Rivers and Big Bend Canal are presented in Appendix E5. Guidelines for interpretation of water quality for irrigation are presented in Appendix E6.

It is noted that a low pH could cause problems with any corrosive metals used in irrigation water delivery and distribution systems. This would require the use of non-corrosive metals.

Turbidity could pose a seasonal constraint by accelerating sedimentation of in-stream irrigation storage reservoirs. Better watershed management by proper land use and extension of conservation practices or contouring, strip cropping and terracing would reduce turbidity and sedimentation problems.

A more comprehensive water monitoring and testing program at the national level would help irrigation in the small schemes and better protect the quality of water resources.

Swaziland is well endowed with surface rivers which provide the main source of water for agricultural use. The rivers originate in the highlands of Drakensberg and flow across the country draining into the Indian Ocean. Most of the rivers have a seasonal flow, but the larger rivers are perennial. An estimated 37,000 hectares from which 900 hectares in Swazi Nation Land are presently irrigated from surface water.

From the existing information on groundwater, there are no aquifers capable of sustaining large irrigation areas, and it is estimated that irrigation would expand mostly from surface sources. There is potential for small irrigation schemes under 50 hectares throughout the country.

It is to be noted that all irrigation schemes on Swazi Nation Land are required to have a permit from the Water Apportionment Board to use water from a stream or river. In addition, the project must be approved by the Central Rural Development Board.

Soil Quality

Information on the soils of Swaziland is based on soil survey of the country by G. Murdoch in 1968. The soils are complex and, except for alluvial soils, have developed in place from underlying parent rock and thus reflect the weathering and chemical characteristics of the rock base.

In the Highveld, upper Middleveld, and Lubombo regions, the main soil types are deep, acid and freely drained red and yellow ferrisolic and ferrallitic soils. These soils, except for the Lubombo region, have little natural fertility because of excessive leaching. With adequate fertilization and lime application, these soils can produce high yields. Drainage, infiltration and moisture-holding properties make them good for dryland or irrigated cropping, except in the areas with steep slopes or where the soils are too thin.

Soils of the lower Middleveld region are characteristically gray or red light-textured soils derived from granite or gueiss. Depth is between 40-70 cm. Shallowness and light texture of the soils restrict available moisture-holding capacity for dryland cropping. Their fertility is generally low and erodibility high.

The western Lowveld region is underlain by sandstones and shales which give rise to heavy-textured clay-pan soils. Poor drainage and high salinity restrict their use for irrigation, while poor moisture-holding properties in the light soils tends to reduce the dryland cropping yields.

The eastern Lowveld region is underlain by basalt which gives rise to an association of red, brown and black clays. About 45% of the area is shallow - 20-40 cm. Soils' fertility is good except for a shortage of phosphorous. The poor drainage of the black clays and their high solicity and salinity in low-lying areas limit their use for irrigation.

The G. Murdoch soil survey has limitations in using the survey for detailed planning. As mentioned previously, a more detailed soil survey and more extensive basic laboratory data to support soil survey interpretation are needed for site selection and project monitoring of pilot small farmer irrigation schemes.

Soil salinity is not presently a problem in the small irrigation schemes in Swazi Nation Land, but non-adequate irrigation water management may produce salt accumulations. If salinity of soils occurs, leaching is the only way by which the salts added to the soil by the irrigation water can be removed satisfactorily. Sufficient water must be applied to dissolve the excess salts and carry them away by drainage. Other concepts that may be of help in controlling salinity are the use of amendments, deep tillage and preplant irrigation.

Present Storage Facilities

In many small irrigation schemes in Swazi Nation Land, small storage reservoirs are essential elements in a complete farm water delivery system. The on-stream reservoirs are fed by continuous or intermittent flow of surface runoff and streams, while the off-stream reservoirs are constructed adjacent to a continuously flowing stream and a pipe or canal diverts water from stream into the reservoir.

The long-term, temporary and overnight storage reservoirs are used in connection with pump and gravity systems and with surface and sprinkler irrigation methods and combined with other facilities like pipelines and canal delivery systems. The reservoirs are normally unlined and losses by evaporation and seepage are appreciable. Few of them are sealed with plastic membranes. No filamentous or free floating vesculor weeds were noticed in reservoirs or canals.

In order to minimize any negative environmental consequences from reservoirs development, the Ministry of Agriculture and Cooperatives should intensify its efforts to reduce seepage losses. Extension workers should be involved in organizing annual storage reservoirs and canal systems maintenance as recommended in the section, "Canal Use and Protection."

Fisheries are not normally associated with the storage reservoirs in the small irrigation schemes. However, the Ministry of Agriculture and Cooperatives, Fisheries Section, is promoting and establishing fish ponds primarily in Rural Development Areas.

Energy is an important factor for irrigation and the installation of micro-hydroelectric power generators could be a viable solution for the small irrigation schemes. There are no such generators presently in the small irrigation schemes in Swazi Nation Land, but the pilot project should consider the micro-hydroelectric power generator.

PUBLIC HEALTH ASPECTS

The health impacts of irrigation systems are most closely associated with:

- patterns of water use and contact, both for agricultural and domestic purposes;

- practices of environmental sanitation and excretal disposal; and

- exposure to agricultural chemicals (discussed under Section VII below).

The importance of the first two items relates to the role played in routes of pathogen transmission by water, food, excreta, animals and direct personal contact, all of which may be altered either directly or indirectly by irrigation. Irrigation involves changes in the way of life for subsistence farmers, not the least of which include new habits and tasks relating to domestic water use and sanitation. Since water is a vehicle for many enteric parasites as well as a habitat for certain disease vectors/hosts, increased agricultural use and distribution of water can act to spread these pathogens and increase health risks. For this reason, safe, improved means of domestic water supply and sanitation to ensure public health are believed to be necessary complements to irrigation, so that the intended economic benefits of irrigation can be fully realized.

In Swaziland, moreover, three factors allow certain communicable disease risks of small-scale irrigation to be generally classified in terms of veld type. These factors are:

- climatological and topographical features affecting the persistence of disease organisms, vectors and hosts;

- hydrological and hydrogeological features affecting the adequacy of domestic water supplies; and

- hydrological, topographical and residual soil characteristics affecting the engineering requirements of irrigation systems.

An assessment has been made of the health-related features of existing irrigation schemes from field observations and relevant supplemental literature. The existing status and health impacts are analyzed according to veld type, where appropriate. Measures that may reduce or eliminate the risks are presented in Section VIII.

Domestic Water Supplies

Drinking Water - In the most comprehensive statistical survey to date of water use and sanitation practices in Swaziland (Green, 1982), the Ministry of Health (MOH) and the USAID-assisted Rural Water-Borne Disease Control Project (RWBDCP) have identified the following types of drinking water access by homesteads on Swazi Nation Land:

Rural Drinking Water Access*

Source	Adjusted Frequency (%)
River or Stream	35.9
Unprotected Stream	28.6
Standpipe or Tap	17.2
Spring, Protected from Animals	7.1
Borehole or Well	4.2
Enclosed, Protected Spring	2.7
Stagnant Pool or Dam	2.5
Collected Rainwater	1.8

*From Green, 1982, 0. 13. These figures do not permit a projection regarding the ultimate source of a reticulated supply (17.2%), nor of the actual quality (safety) or a particular source.

The study further indicates an average daily per capita consumption of about 6.6 liters, typically involving (using weighted averages of data presented therein) two one-hour round trips each day to fetch water. Little home treatment (such as boiling) is effected, and storage and final use practices do not assure that an originally safe water is consumed as such.

By far, the major supply of rural drinking water in Swaziland, therefore, is from untreated surface water (flowing or impounded), followed by springs and then borehold (groundwater) supplies. Although comprehensive data are scarce, a government water sampling program indicates acceptable chemical quality of surface waters for potable supplies (U.S. Army Corps of Engineers, 1981). At least one baseline study (Bell et al., 1978) supports this conclusion, although numerous surface waters were found to be fecally contaminated. Furthermore, it was noted that such raw waters will exhibit varying seasonal quality, as well as upstream to downstream. Much contamination was suspected to be of animal origin (i.e., cattle). The springs sampled in this study exhibited bacteriological quality within a more acceptable range than surface sources.

The few data available for groundwaters indicate varying chemical quality affecting primarily taste. These relatively hard waters may even have beneficial health impacts, due to observed inverse correlations between water hardness and cardiovascular disease (U.S. NAS, 1977), although no "water factor" causality has yet been proven. On the other hand, certain groundwaters have exhibited nitrate concentrations up to several times the level associated with methemoglobinemia in infants. The source(s) of nitrate contamination in groundwater (in the southern Lowveld) remain to be identified, however. Even fewer data exist on the bacteriological quality of groundwater, although such sources are to be preferred over surface water for potable supplies. Certainly not enough effort has been expended to date in Swaziland on the feasibility of the expanded use of groundwater for domestic purposes, especially in the Low- and Middleveld, and such an examination merits immediate attention. Canadian support in this endeavor is uncertain. Appendix H1 summarizes certain groundwater data and projections by one private sector firm.

Some water quality data are summarized in Appendix H2.

Given the distribution of currently available supplies among the three veld types, therefore, quantity and quality problems generally increase from the Highveld (primarily spring sources) to the Lowveld (primarily major rivers and impounded water bodies). Although the Rural Water Supply Branch (Ministry of Works), the Rural Development Areas Program (Ministry of Agriculture) and MOH all have small programs for developing rural water supplies, it cannot be assumed that adequate drinking water points will exist in potential small farmer irrigation schemes. Indeed, field observations of existing sites supported the findings of the noted studies. In some cases, irrigation systems have brought untreated water closer to homesteads, thereby increasing convenience, and most likely consumption, by an unknown degree. Some beneficial impact on the prevalence of socalled "water-washed" infections, such as scabies and trachoma, may therefore result. But systems that impound water also encourage use of the lowest quality source when alternative supplies are not easily accessible, particularly a problem in the Lowveld.

What is lacking is a more coordinated approach among the above-mentioned organizations, so that design criteria for rural water supply systems established by the Rural Water Supply Branch (Appendix H3) can be implemented and monitored. Even greater coordination will be required with local authorities for operation and maintenance of simple "micro-systems."

Bathing - RWBDCP (Green, 1982) gives statistical evidence of rural bathing by both children and adults primarily in rivers and ponds, especially during times of the day when the risk of schistosomiasis transmission is highest. A major reason may be that improved alternative facilities rarely exist. None were observed in connection with existing small-scale schemes that were visited. On the other hand, only a site-specific investigation can determine whether river and pond bathing constitutes a serious health hazard. In the Highveld above about 850 meters, secondary molluscan hosts of schistosomiasis are extremely rare, even in impounded waters. (One site at about 1,000 meters supported a proliferation of Limnaea sp., the most common molluscan resident of Swaziland, but no host snails were found.) In the lower Middleveld and especially in the Lowveld, however, impounded waters will be expected to support particularly Biomphalaria pfeifferei, resulting in increased prevalence of

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S. mansoni. Previous detailed study in Lowveld irrigated estages (Logan, 1979) supports this conclusion.

The larger rivers of both the Middle- and Lowveld, especially where flowing over soft, unstable bedrock (below 5 in Mohs' scale) to create uniform channels of alluvia, provide relatively host-free swimming holes. Conversely, watercourses in the Middleveld forming detached pools over hard bedrock such as granite, present considerable risks to bathers (Appleton, 1979).

Washing of Clothes and Cooking Utensils - Although these activities involve less water contact than bathing, they may present even greater risks to the vast majority of rural homesteads without improved washing areas, especially in the Middleveld. Small streams and brooks that are inadequate for bathing may nonetheless be used for laundering. These sources provide excellent habitats for Bulinus (Physopsis) sp., the intermediate host for S. haematobium. Ideal habitats could be established downstream of diversions for small-scale irrigation if the source is a limited-discharge tributary of a larger river.

Other Non-Domestic Water Contact

Contact with waters harboring the two molluscan hosts of schistosomiasis in the Middle- and Lowveld can occur in irrigation canals, poorly drained fields and dam seepages as a result of farming tasks and personal transport. Since drainage does not appear to be a major problem in the small-scale schemes envisioned in the project, and crossing watercourses involves short-term contact, the main risk is to agricultural workers in constant contact with slow-flowing (less than 0.5 m/sec) canals. An abundance of B. (Physopsis) sp. was identified in standing water of secondary cement-lined canals in one Lowveld cooperative scheme. Non-viable snails were found resting on wet sediment in the canals, dessicated by direct sunlight, and none could be recovered below the sediment surface.

Environmental Sanitation and Excreta Disposal

Excreta Disposal - An effective and hygienically safe means of excreta disposal in rural Swaziland is the Ventilated Improved Pit (VIP) latrine (see Appendix H4). The existence and use of such facilities in both irrigated and non-irrigated areas is rare, however. MOH and RWBDCP have identified a statistically significant variation in the percentage of homesteads having latrines (of any type, safe or unsafe, used or unused) according to region (Highveld - 39.2%; Middleveld - 31.1%; Lowveld - 12.3%) and level of education. Available latrines are used by few children under the age of four, whose stools are most often "thrown in the bush." The MOH extension service (primarily through Rural Health Motivators and Health Assistants) nevertheless is shown to have an impact by the RWBDCP. Other study (Bell, et. al., 1978) supports the official recognition of the acceptability of latrines in rural areas, although it is believed that much more extension work is needed. Insofar as even small scale irrigation projects can cause changes in patterns of demography and labor movement (towards increasing concentration of people and animals) in an environment that can effect greater hydraulic transport of fecal pollutants, the absence of properly used, improved latrines (as observed in numerous existing schemes) presents one of the most serious health risks of the proposed project. Latrines alone may significantly reduce the transmission of latent soil-transmitted helminths such as Ascaris, Trichuris, Ancylostoma and Strongyloides. It was observed that even small individual schemes without latrines can involve the boarding of permanent wage labor at the homestead site, exacerbating focal population densities. Demographic changes resulting from this project, and their impact on health, will therefore have to be considered.

Other Environmental Sanitation Issues - MOH and RWBDCP note additional issues relating to personal cleanliness, food handling and infant feeding, which unless approached concurrently with water supply and excreta disposal aspects of irrigation projects, may prevent the achievement of significant health benefits. Non-latent viruses, bacteria and protozoa with relatively low infectious doses depend on "short-cycle" person-to-person routes for their survival. Specific pathogens within this class of organisms are believed to be the main causes of infant diarrheas, the primary cause of mortality in Swaziland and a major priority of MOH. Curative approaches, such as the Ministry's oral rehydration (OR) program now being given increased attention, may be the only means for achieving short-term impact. Coupled with long-term preventive measures, such as sanitation, such a primary health care strategy makes good sense.

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Animals - Cattle reside on SNL at greater densities than people. Small-farmer irrigation can be expected to increase cattle densities on beneficiary farms as individuals invest their increased cash incomes. This phenomenon has already been observed on some of the individual schemes visited. Although stock are rather scrupulously kept out of irrigation plots (but less frequently main canals) by fencing, they have free access to rivers, streams and occasionally reservoirs used by bathers and water gatherers. Moreover, cow dung deposited in fields and canals is washed into water courses during summer rains. The problem is exacerbated when corrals are located near water bodies or cattle have free access to public standpipes. Fecal-oral transmission from cattle to humans of such parasites as *Taenia saginata* and various *Salmonella* spp. can be aided by close contact in water-mediated environments.

Storage of produce can be expected to increase as farmers grow more crops on irrigated lands under this project. To that extent, the health implications of increased rodent populations must be borne in mind. Insecure crop storage techniques were observed during field visits, and attention will have to be given to monitoring the presence of nuisance animals, such as rats, and to developing control procedures if necessary.

Other Health Hazards

Other potential risks of this irrigation project primarily include drowning of toddlers, construction accidents and alcoholism.

Drowning in irrigation canals has been identified as a significant cause of mortality in the 2-4 age group in Nile Delta villages, which are served by a wide network of unprotected river diversions (Kielmann, 1981). While not expected to be a major problem in this project, the risk should be appreciated and proper protection (fencing) provided.

Construction accidents are a risk of any project involving physical infrastructure. Unskilled labor should be closely supervised, especially when machinery is being used.

Alcoholism is a major problem in Swaziland. While the etiology is complex, physical displacement of individuals and families has long been known to have psychological impacts that can increase the risk of alcoholism. Although labor displacement will be minor in the pilot project, the long-term effects from a greatly expanded national program over the next generation merit consideration.

VI. WATER-BORNE DISEASE

Two documents produced by the RWBDCP were available for review by the Environmental Assessment (EA) team: "A Knowledge, Attitudes and Practices Survey of Water and Sanitation in Swaziland" and "Preliminary Report of the Swaziland Schistosomiasis Survey."

Additional relevant documents and data were provided as available (e.g., Logan, 1979; Bell et. al., 1978). Discussions and field visits were conducted with project personnel and counterparts to assess the survey results to date.

IMPORTANCE OF LOCAL WATER-BORNE DISEASE

The single most important water- and sanitation-related disease problem (and a primary priority of the Ministry of Health) remains infant diarrheas, most probably of viral and bacterial origin. This problem tends to be most acute in the Lowveld, where water and sanitation deficiencies are most acute. Under-two mortality is greater than 150 per 1,000 live births, much of which can be attributed to diarrheal disease. The construction of VIP latrines and health education by MOH with the assistance of RWBDCP are elements of a preventive control strategy, which is to be linked with clinic- and outpatient-based curative services, such as OR.

Cholera has received much recent attention due to the 1981-82 epidemic that started in the mid-Lowveld, spread to the Manzini area and then to the northern and southern portions of the Lowveld. About 767 cases with 31 deaths were documented, the first case being identified on October 6, 1981, and the last about mid-May 1982. The epidemic coincided with drought conditions in the Lowveld. This year, with the critical October-December period passed, only 8 cases and no deaths have been reported, although epidenic foci are now centered across the border in Natal and Transkei.

Malaria is the other disease of recent epidemic importance in Swaziland. (P. falciparum only; imported cases of P. malariae reported occasionally.) Since 1946, however, transmission has dropped steeply with control efforts and acquired immunity. The last epidemic cycle occurred during 1977-78 in a previously unstricken focus near Big Bend (mid-Lowveld). Currently, the disease is of minor importance, with the number of identified cases reported in 1982 (155 - 0.23% active and 0.43% passive prevlaence rates) being the lowest since 1974, although the number of cases reported in November and December 1982 were the highest in three years, centered in the Manzini area. Chemoprophylaxis for P. falciparum (chloroquine) is administered to an unknown proportion of adults (tablets) and children (syrup) of the Lowveld high-risk group, which numbers approximately 275,000. Chloroquine is also used for chemotherapy. No chloroquine resistance has been reported. Primaquine is administered for the treatment of P. malariae.

Schistosomiasis remains an endemic problem of lesser import than infant diarrheas, even in irrigated areas. The MOH-RWBDCP survey has focused on primary schools (the high-risk group) in the High-, Middle- and Lowveld (as well as the Lubombo region).

During 1982, prevalence rates of S. haematobium and S. mansoni were monitored and positive cases were treated (S. haematobium with Bilarcil [metrifonate] and S. mansoni with Ambilhar [niridazole]). New areas will be surveyed during 1983. Prevalence rates of S. haematobium (20.2% overall) were found to be highest in the Middleveld (31.2%) and lowest in the Highveld (4.5%). Certain localities, however, exhibited extremely high rates (over 90%), indicating at least the potential for increased importance of the disease, especially with irrigation. Prevalence rates of S. mansoni (9.4% overall) reached a peak in the Lowveld (17.2%) with a low point in the Highveld (0.8%), although Lowveld-Middleveld differences were not statistically significant. A detailed study of schisto-somiasis prevalence on irrigated estates in the Lowveld (logan, 1979) found rates of S. mansoni infection between 40% and 60% spread across all age groups. The exacerbating effect of labor migration is also noted.

Other most prevalent enteric parasites monitored in the school survey include Ascaris, Trichuris, Ancylostoma, Hymenoplepis nana and Giardia. A clear distribution pattern did not emerge according to veld-type. Relatively low rates of Ascaris prevalence in the Lowveld may be attributed to reduced egg persistence due to drought. In summary, the prevalence of these parasites was average to low in comparison with other developing countries, possibly reflecting the relatively low population density in Swaziland.

Appendix H5 presents overall morbidity and mortality data compiled by MOH. For the third quarter of 1982, diarrheas/other enteric diseases and respiratory tract infections (in roughly equal proportions) accounted for almost half the total visits as reported by clinics and hospital outpatient departments. Inpatient-based mortality data for 1979 show the importance of tuberculosis and other respiratory diseases for the total population, in addition to enteritis and other diarrheal diseases. Appendix H5 suggests that about one-third of all inpatient deaths were caused by diseases preventable by improved sanitation.

IMPACT OF PRESENT IRRIGATION SCHEMES ON INCIDENCE OF WATER-BORNE DISEASE

To date, RWBCDP has not been set up to monitor this variable in detail. Some data have been collected for the prevalence of S. mansoni in general relation to Lowveld irrigation, summarized in Appendix H6. Biomphalaria pfeifferei has been recovered almost exclusively in retention ponds, canals and drainage ditches associated with irrigation schemes. Schemes in the Middleveld would be susceptible as well. Bulinus (Physopsis) sp. also was recovered by the EA team in Lowveld irrigation canals with flat gradients. More detailed monitoring of the effect of operational variables of irrigation systems (e.g., water level fluctuation, water application frequency) would assist in identifying the most cost-effective environmental control strategies for schistosomiasis. Current staffing levels at MOH, however, would not permit regular and detailed monitoring without a major shift in emphasis, which may not be justified when comparied with other MOH priorities. Under present conditions, therefore, the small farmer irrigation project could expect only occasional monitoring support from the MOH.

The MOH Malaria Control Unit reports that very few vector mosquitos (<u>Anopheles gambiae [Giles]</u>) Have been recovered from existing irrigation schemes, both furrow and sprinkler systems, including the large Lowveld sugar estates. The local vector is primarily an exophilic breeder, preferring small collections of water in the bush. Irrigation schemes, therefore, are believed to have minor impact on the transmission of malaria in Swaziland. Some cases are reported on Lowveld estates; these are believed to be imported and controllable.

DESIGN OF PRESENT SCHEMES RELATIVE TO VECTOR/HOST HABITATS

Numerous schemes were visited which utilize concrete trapezoidal canal sections on gradients sufficient to maintain velocities in excess of 0.5 m/sec., thereby preventing small accumulation. Likewise, no host snails could be recovered from a small reservoir using a siphon for allegedly rapid draining (periodicity unknown). This reservoir, situated in the Lowveld, appeared to be an otherwise ideal habitat (unlined, much bank vegetation). These design features, however, did not result from a conscious attempt to control malaria and schistosomiasis. The RWBDCP expects to place more emphasis on such aspects of its terms of reference in the future. Shortages to date in both expatriate and the counterpart staff, however, strictly limit the absorptive capacity of a project charged with a variety of major tasks.

EFFECT OF LOCAL CLIMATE ON DISTRIBUTION OF VECTOR/HOST POPULATION

The schistosomiasis survey has identified little or no active transmission in the Highveld, due to a near absence of host snails at higher altitudes (probably a temperature effect). These findings support those of earlier work (Appleton, 1975), indicating relative safety above 850 meters. Middleveld areas not currently harboring significant numbers of B. pfeifferei, however, should not be assumed to remain so if impoundment or low-gradient drainage were provided in new irrigation systems. On the other hand, preference of B. (Physopsis) sp. for small spring-fed streams in the Middleveld implies both the difficulty in controlling S. haematobium through appropriate design of irrigation systems and the only indirect relationship between the two.

Anopheles gambiae (Giles), the local vector of malaria, is also ill-adapted to Highveld altitudes. In fact, very few are found even in the Middleveld, although this is most likely due to effective control measures. Furthermore, the winter climate, even in the Lowveld, promotes hibernation and reduced viability of eggs.

AQUATIC AND DITCH-BANK WEEDS

Sessile grasses along unlined irrigation canals with low gradients can slow water velocities sufficiently and provide enough shade on hot days to create ideal snail habitats. This condition is most important in the Lowveld. No control is currently exercised. Removal of vegetation from long stretches of unlined feeder canals is not critical where gradients are sufficient to maintain immobilizing velocities throughout the wetted perimeter, but the practice is nevertheless advisable at least where water-contact activities are carried out. Moreover, the absence of bank vegetation by itself will not assure an absence of snails; water velocity is a more critical variable.

PESTICIDE AND MOLLUSCICIDE PROGRAMS IN USE IN IRRIGATED AREAS

The health hazards of agricultural chemicals in Swaziland are discussed in Section VII below.

Chemical control of snails is not a high MOH priority, although Bayluscide (niclosamide) is applied focally to large reservoirs at the beginning of the transmission season in the Lowveld after site survey and analysis. Details can be found in Appendix H7.

For the control of A. gambiae, DDT (75% WDP) is employed for residual effect on adults and Abate (temephos) is used as a larvacide. Pre-transmission spraying is done focally in response to space-spray collections or the previous year's record of ten or more site-specific positive cases. Larviciding is also done focally where larvae are identified. No DDT resistance is reported, despite its (judicial) use for approximately twenty years. Monitoring for vector resistance should be done again, however, and on a more frequent basis. The agricultural use of DDT (cornstalk borer, American Bollworm) should be noted, and MOH proposes to have it limited to malaria control operations only. Further details regarding mosquito control by insecticides are presented in Appendix H8.

VII. GENERAL IMPACTS ON INCREASED ENERGY PESTICIDES, FERTILIZER AND WATER USE

ENERGY

The Swaziland Electricity Board (SEB) national power system covers the entire country and energy can be supplied anywhere in Swaziland. The SEB Edwaleni Hydroelectricity generates not 21.5 megawatts (MW). Two 4.5 MW diesel generators are also located at the complex for peakload. Additional power requirements, about 57% of total consumption, are purchased from the South African Electrical Supply Commission (ESCOM). Other than SEB, major energy producers in Swaziland are the Havelock Mine, Usutu Pulp Company, Ubombo Ranches and Mhlume Sugar Company.

Domestic, commerical and industrial consumption has increased annually over the past ten years. Irrigation consumption has increased also due to expanded facilities and increased pumping requirements at the sugar companies and estates.

In order to meet the increased demand, the SEB is constructing the Luphohlo-Ezulwini Hydroelectric Scheme with an installed capacity of 28 MW. Swaziland may also build a coal-fired thermal plant in the Lowveld region or additional hydropower facilities.

The pilot small farmer irrigation scheme other than gravity fed would be powered mostly be electrical motors. Energy requirements will vary with static lift, friction losses, motor and pump efficiency, irrigation method and annual crop consumptive use. In relation to the irrigation method, energy requirements will increase in the following order: surface, trickle, and sprinkler.

In order to minimize the impact on energy resources, energy conservation techniques and scheduling to reduce peak energy demand should be considered. Pumping energy requirements can be calculated as: $PE = \frac{0.0271\ ADH}{E \cdot Ep}$ (Batty et. al., 1975).

Where: PE = pumping energy kWh
A = irrigated area, ha
D = net depth of irrigation, mm
M = total dynamic pumping head, m
E = irrigation application efficiency, decimal form
Ep = pumping efficiency, decimal form.

The equation shows that PE can be lowered by (a) reducing net depth of irrigation, (b) reducing total pumping head, (c) increasing irrigation efficiency, and (d) increasing pump efficiency.

The main health impacts of increased energy use relate to mining, transport and source generation for coal-fired electric plants and water impoundments for hydroelectricity. Accidents are the main impact of direct combustion of fossil fuel. Such effects are extremely long-term, indirect and marginal for this project in particular, but should be recognized if major irrigation development were to ensue.

PESTICIDES

Considering the undesirable and damaging effects on the environment of many pesticides, especially the persistent organochlorines, agricultural projects as the pilot small farmer irrigation schemes should be planned to minimize the need of these chemicals as production inputs.

Integrated pest management is a management technique that minimizes the amounts of toxic or environmentally harmful pesticides employed. Its general objective is to use a mixture of biological, cultivation and chemical means to keep pest populations at levels that are not economically significant. Integrated pest control is also a promising answer to the environmental hazards of toxic chemicals and the predictible insect population instability resulting from their excessive use.

Malkerns Research Station should start as early as possible preinvestment studies on integrated pest management in pilot small farmer irrigation schemes and results should be incorporated in a project paper.

The primary health risk is acute, and chronic oral, dermal, and inhalation exposure faced by applicators and other agricultural laborers is serious. The effect could be serious in this project, given the minimal training and protection afforded the often young and unskilled laborers charged with the tasks. It should also be noted that the provision of protective clothes would have little impact in a poorly controlled and unaccustomed environment.

Ingestion of residues by consumers of treated food crops is a lesser but realistic risk.

Potential carcinogenicity is of little consequence under current conditions in Swaziland, given a permissably high discounting of long-term risk in view of low life expectancy (42 years) and relatively severe short-term risks. The same point could not be made for teratogenicity, however; the role of contaminants in nominal products (such as TCDD in 2, 4, 5-T) should not be overlooked either in this regard or in that of acute toxicity. Long-term risks to downstream populations as a result of the possible contamination of water supplies and food-chain concentration is viewed herein as minor, although were this pilot project to lead towards greatly expanded irrigation in the future, such impacts should be evaluated at an appropriate time.

Appendix H9 gives a rough approximation of the usage of the major pesticides and herbicides for various crops in Swaziland. Appendix H10 lists the full range of such chemicals that are available from one of the two in-country suppliers. Effective registration laws do not exist, although attempts are made to apply the South African guidelines to formulation and application. Extension workers are not believed to be in a position, however, to carry out or otherwise effectively communicate the guidelines to farmers.

FERTILIZER

Irrigation increases considerably farm production, but at the same time the use of fertilizer will also increase. Additional favorable circumstances will make possible the increase in fertilizer consumption. These circumstances include the availability of locally produced and imported fertilizer and available agricultural credit for small farmers.

Any fertilizer application should be based on soil analyses and consideration of the heterogenity of subtropical soils. If fertilizer is applied by irrigation water in surface, sprinkler or trickle schemes, all components of the system must be corrosion resistant and the system should be thoroughly flushed with water at the end of irrigation. The use of organic fertilizer, which also acts as a soil conditioner improving soil physical qualities, should be encouraged.

Controlled use of fertilizer would minimize any negative impact on physical environment.

The important health risk arises from the potential contamination of drinking water supplies by nitrate from nitrogen fertilizers. Reduced nitrogen (nitrite) in the body can cause anoxia and death in infants by lowering the oxygen-carrying capacity of the blood. Methemoglobinemia has been noted at nitrate levels of about 45 mg/L in water.

To obtain a very rough estimate of the magnitude of the problem, assume the following:

- small farmer cultivating one hectare in the Lowveld applies a total of 300 kg N per year on two crops;

- uptake by vegetation, denitrification and microbial incorporation removes 90% of the applied N; and

- of the 500 mm annual rainfall, 10% is available for groundwater recharge; in addition, of 500 mm irrigation water applied in furrows over half the area, 5% is available for groundwater recharge.

On a gross annual basis, therefore, and not accounting for considerable variation in hydraulic loading, 30 kg of N may be leached to the groundwater by 750 m^3 of surface drainage over the one hectare. The average nitrogen concentration in the leachate would therefore be about 40 mg/L (or about 180 mg/L as nitrate). If the leachate itself were directly available to water supplies, concern could arise. Its impact on groundwater, however, is a function of mixing and dilution, which is difficult to estimate without detailed knowledge of the aquifer characteristics.

WATER USE

The physical environment impacts arising from water use in agriculture are changes in water quantity and quality and soil erosion and salinization. Existing water quantity and quality should not be a problem for pilot small farmer irrigation schemes, but large irrigation developments should be carefully planned. Soil erosion and salinity are potential impacts but could be minimized by following the recommended measures.

Water use for agriculture is interconnected with other uses. An adequate cooperation should be as follows: primary - drinking water, water for agriculture, industries, fisheries; secondary - protection from floods, use for power production.

The health impacts result partly from alteration of habitats of vectors and hosts of diseases such as malaria and schistosomiasis. In certain areas, filariasis and onchocerciasis may be important, but not in Swaziland. Water and excreta-transmitted pathogens resulting from changes in domestic water use patterns and population movements likewise may create adverse impacts. These issues have been discussed above in Section V and will not be mentioned further.

VIII. RECOMMENDATIONS

ENVIRONMENTAL CRITERIA FOR SITE SELECTION OF PILOT SMALL FARMER IRRIGATION SCHEMES

Physical Environment

The pilot small farmer irrigation schemes could be located in the Highveld, Middleveld, Lowveld or Lubombo regions. The following environmental criteria should be considered in the site selection process (for crops other than rice).

Soil Type and Depth - A detailed soil survey should be made for each potential site. Soils with following characteristics for the maximum depth of rooting zone could be considered for irrigation:

- no extremes of texture (no coarse sand or heavy clay), optimally sand loam to clay loam;
- high or medium available water-holding capacity;
- good to moderate permeability through all soil horizons and through underlying material; and
- gentle gradient.

The use of U.S. Soil Conservation Service standards is recommended.

Quantity and Quality of Available Water -

- Irrigation diversions should consider the hydrologic changes in order to ensure that minimum flow required is provided.

- Irrigation water should be analyzed for salination, toxicity and pH (guidelines in Appendix E6).

- A permit to use water from a stream or river should be obtained from the Water Apportionment Board.

Soil Erosion Potential - Climate, soil, vegetation and topography factors should be analyzed in order to estimate the erosion potential. The rate of erosion should not be greater than 3 tons/hectare/year. U.S. Soil Conservation Service recommendations should be used.

Flooding Potential - Even though there are no records of damages from flooding in Swaziland, watershed characteristics should be considered in order to avoid any flood hazards.

Drainage Requirements - Soils of Swaziland are normally well drained except the heavy textured clay-pan soils in the western Lowveld and black clays in the eastern Lowveld.

The detailed soil survey for each potential site should include determination of in-site hydraulic conductivity.

Energy Source - Where gravity fed systems are not possible to be installed, electric pumping plants should be preferred over diesel because of higher efficiency and easier maintenance. Micro-hydroelectric power should be considered along with Swaziland Electricity Board power.

It is recommended that the personnel involved in the development of pilot small farmer irrigation schemes will attend the seminar on micro-hydroelectric power generation which will be held in April 1983 in Swaziland.

Note: Mapobeni area in the Lower Usutu River basis is recommended by the Soil Scientist and Irrigation Section, MOAC as a potential priority site for pilot small farmer irrigation schemes.

Public Health

Health criteria for site selection of pilot irrigation schemes are listed as algorithms in Appendix H11. These are the minimum items to be considered when evaluating potential sites. USAID/S should request MOH and RWBDCP to review the criteria and make additions where appropriate, coordinating these with standard government criteria. USAID/S should also request MOH and RWBDCP to develop a methodology for the evaluation of potential sites according to these criteria, possibly using a field survey checklist. USAID/S, through RWBDCP, should identify the government body responsible for site selection, and the methodology should be carried out according to their procedures. Potential sites should be ranked in a summary report. Final site recommendations, based on an evaluation of non-health criteria as well, should be submitted to the Regional Environmental Officer for review and approval.

ENVIRONMENTAL DESIGN FEATURES FOR REHABILITATING AND DESIGNING SMALL FARMER IRRIGATION SCHEMES

Physical Environment

An evaluation of small irrigation schemes considered for rehabilitation is required. The purpose of evaluation is to determine the degree of any environmental deterioration and the system performance perimeters and provide information that will assist the design team. Field evaluation procedure and interpretation are described in Farm Irrigation System Evaluation: A Guide for Management (Merriam and Keller, 1978).

Static lift, pressure supplied, friction losses in the pipelines and pump and motor efficiency as related to the energy use in the small schemes considered for rehabilitation should also be evaluated.

Rehabilitation of small irrigation schemes should include reclamation of eventually deteriorated environment.

- Any change in water availability and quality should be discussed with the Water Apportionment Board. If a permit for the water supply required by the pilot project cannot be obtained, the scheme should not be considered for rehabilitation at this time.

- If water velocity in canals has produced soil erosion, the canals should be redesigned considering limiting velocities (Appendix E4). Lining canals is an effective way to prevent canal erosion. ASAE Standard S-289 should be used.

- If soil salanity occurs, reclamation by leaching can remove up to 80% of the soluble salts. Amendments may have to be applied for successful reclamation.

- Seepage from water delivery and distribution canals could be reduced by canal lining with concrete, asphalt, rubber or plastic products. Lining also reduces maintenance, controls week growth, ensures more dependable water delivery and protects neighboring land from water logging and salt accumulation.

The use of environmental criteria for site selection of pilot small farmer irrigation schemes would minimize the negative environmental consequences. In addition, the following items should be considered:

- Crop water requirements - The small pilot farmer irrigation schemes should be designed considering local data for consumptive use. The use of general formula or assumptions should be avoided. In relation to the pilot project, Malkerns Research Station should give priority to applied research on irrigation water requirements for important crops, irrigation scheduling and fertitility practices for irrgated crops.

- Land forming - Undesirable soil movement can occur as a result of land forming. Any land forming operation should consider ASAE Engineering Practice EP 302.2.

- Farm roads - Access ways for farm inputs and outputs and for system operation and maintenance should be considered at the design stage.

- Irrigation method - The pilot small farmer irrigation schemes should consider surface (furrow), sprinkler and trickle irrigation methods. ASAE engineering practices and standards as EP 267.5, EP 405 and EP 408 should be used on design. Sprinkler and trickle methods would produce less negative environmental impacts and have a higher water and energy use efficiency. Excellent results were obtained using trickle irrigation for vegetable crops (two chamber tubing) and fruit trees (emitters) in tropical soils in the Caribbean.

The design of the pilot small farmer irrigation schemes should be based on an integrated approach to the irrigated agriculture. Domestic water supply, rural roads, new crop system, including tropical hybrids highly disease and heat resistant, and marketing systems should be developed in the same time. The integrated approach will better protect the environment and assure the success of the project.

Public Health

Site selection criteria are intended to minimize adverse health impacts and reduce costs of the small farmer irrigation project. Even if all "Primary Site" criteria are met however, certain actions should be taken during implementation to ensure maximum public health benefits. These minimum design criteria are listed in Appendix H12. If a project site does not meet all the "Primary Site" selection criteria (i.e., "Secondary" or

"Tertiary Site"), then additional design criteria should be included. These additional criteria are also listed in Appendix H12, and are applicable to both new and rehabilitated sites. For drinking water supplies, the criteria listed in Appendix H3 should be followed. USAID/S should request MOH and RWBDCP to recommend these additional health measures as appropriate in consideration of each particular site. Documented recommendations should be evaluated and approved by the REO.

Before any pesticides, herbicides or other chemical growth retardants are used in the project, USAID/S should notify the REO of the particular chemical(s) proposed and request him/her to check its registration status with the U.S. EPA. The REO should then make recommendations concerning the approved use and procedures for monitoring that use to the Mission. In addition, the list of chemicals in Appendix H10 should be assessed by the REO in terms of the EPA registration status for the specified crops, which can be furnished by the Bureau Environmental Officer. Furthermore, and where appropriate, the following principles should apply:

- DDT should be reserved for malaria vector control only.
- Chemicals in Toxicity Classes I and II should be avoided.
- Broad-spectrum chemicals should be avoided.

Monitoring

Monitoring of the pilot small farmer irrigation project should include an annual assessment of any significant changes in environment. Monitoring can be done by trained extension workers or technical personnel. A monitoring checklist is presented in Appendix E10.

Soil analyses and water quality laboratories should be available. Also the pilot schemes should be provided with water flow measurement devices (trapezoidal flumes, water meters, etc.) for periodical survey on water use.

Attention should be given to the pest monitoring using integrated pest management techniques. Pest monitoring will include twice-a-week field survey on sample plots and could be done by the Pest Management Specialist/Entomologist from the Malkerns Research Station.

Project monitoring for public health should be of two types:

- to provide a record of whether and how project covenants, criteria and action plans are carried out; and

- to provide technical data on the impact of disease control measures implemented in pilot shcemes for evaluation and redesign under expanded projects.

The first kind of monitoring may be carried out by the drawing up of a checklist that can be used in the field by a trained extension agent. A sample checklist is shown in Appendix H13. USAID/S should request MOH and RWBCDP to develop such a checklist, which would be reviewed and approved by the REO.

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The second kind of monitoring can be carried out by conducting baseline and periodic surveys of vector/host-related and other parasitic diseases on one or two existing schemes, as well as on one or two new schemes. The baseline survey should be conducted prior to site improvements. The first follow-up should occur one year after the completion of physical works as certified by the above-mentioned checklist and each year thereafter until the completion of the project. At a minimum, the survey should include schistosomiasis, Ascaris and Entamoeba sp. monitoring. The MOH survey unit in Manzini is most appropriately placed to carry out this monitoring. More detailed monitoring would be desirable if set as a MOH priority. It should be designed in consultation with the RWBDCP Public Health Engineer.

Evaluation

After one year, site selection criteria should be reviewed internally from the standpoint of their appropriateness and the methodology with which they are applied. USAID/S should request assistance from the centrally-funded WASH project for this evaluation.

USAID/S should request the REO to prepare terms of reference for an external mid-project evaluation, focusing as a minimum on the following items:

- an implementation assessement of the effectiveness with which design criteria are applied and followed, particularly for sites that do not meet all site selection criteria. The assessment should be based on reviews of the monitoring reports and site visits.

- a technical assessment of the degree to which water-related diseases are controlled by specific engineering design and operation feastures of the project. The assessment should be based on site visits and the parasitic disease survey results in project files.

- an assessment of any additional training requirements which may be apparant from the analyses listed immediately above.

The final external evaluation should address all the elements of the mid-project evaluation, including specific considerations for scaling up of certain pilot project activities. In particular, the environmental issues under Section VII of this report that may be of little impact for a small pilot project should be re-assessed at this stage.

A sample of project impact matrix for physical environment is presented in Appendix E11.

ENVIRONMENTAL TRAINING REQUIREMENTS FOR EXTENSION WORKERS

Physical Environment

Extension workers assigned to the pilot small farmer irrigation schemes should be trained in environmental protection in order to minimize the negative environmental aspects of the project. Training of professional and technical personnel related to the pilot project is also recommended.

For the extension workers, the training should be less theoretical and emphasize more practical and operational aspects. The training program should include conservation of soil and water resources, on-farm irrigation water management and evaluation of irrigation systems and practices.

Conservation of Soil and Water Resources -

- Soil losses and erosion control practices.
- Terracing.
- Farm earth embankments and ponds protection and maintenance.
- Land forming.
- Farm drainage systems.
- Control of seepage and evaporation surpression.
- Surface (furrow), sprinkler and trickle irrigation methods.
- Water measurements.

On-Farm Irrigation Water Management -

- Basic water management concepts.
- Irrigation scheduling techniques and instruments.
- Salinity control.

Evaluation of Irrigation Systems and Practices

- Performance parameters.

- Field evaluation and interpretation: surface (furrow), sprinkler and trickle methods.

The pilot small farmer irrigation project will undoubtedly introduce new soil and water use and associated agricultural features which will be unfamiliar to the farmers. Consequently, the training of extension workers should start as soon as the project paper is approved. A request to Environmental Training and Management in Africa (ETMA) for assistance in training on conservation of soil and water resources and to the U.S. Department of Agriculture for on-farm irrigation water management and evaluation of irrigation systems and practices should be made in advance.

Public Health

USAID/S should request the regionally-funded Enviromental Training and Management Project in Africa to evaluate training needs for agriculture, health and rural water extension agents with the relevant ministries and investigate whether ETMA services apply.

Training to ensure beneficial health impacts under the project should address appropriate topics, individuals, methods, and timing. as described in Appendix H14.

For training of extension agents and farmers in safe methods of pesticide formulation and application, USAID/S should approach the centrally-funded project designed to provide short-term assistance in that topic.

Furthermore, it is worthwhile to stress basic educational elements, as well as those of extension training, for a beneficial-health-impact strategy; that is, a sensitive approach to the behavioral changes necessary to extract the maximum benefit out of new technologies is also a key element to any public health engineering program. USAID/S should request close support therein from the MOH and RWBDCP, which are working with such issues. This emphasis on disease prevention should be coupled with clinic-based curative programs, such as OR.

PROJECT-RELATED TECHNICAL ASSISTANCE

The EA team identified the need for further short-term technical assistance at the project design and/or implementation stages:

- Agricultural Engineer, soil and water oriented for field evaluation of surface and sprinkler irrigation schemes proposed for rehabilitation;

- Pest Management Specialist with occupational health experience to short-list recommended chemicals and propose specific methods for risk reduction. REDSO should be approached for assistance.

- Hydrogeologist - due to the uncertain but optimistic potential for small-scale groundwater development for domestic supplies in rural areas of Swaziland, a hydrogeologist should assist in identifying project sites by means of topographical, geological and geophysical survey. Alternatively, consulting services with access to high-speed drilling equipment (a necessity in Swaziland) are available in-country. Representative costs are included in Appendix H15.

OTHER RECOMMENDATIONS

Institutional

Although the Ministry of Agriculture and Cooperatives is the lead agency for this project, all health-related measures should involve close participation by the Ministry of Health. Likewise, domestic water supply improvements should involve the Ministry of Works. The Director of Medical Services (DOM) and Deputy Permanent Secretary (MOW) have been briefed on the pilot project and have offered their support. A working relationship with the two assisting ministries should be cultivated, as they can provide appropriate technical support to MOAC. Both should be consulted during the project design phase. RWBDCP is well positioned to help coordinate this interaction and assist with the setting up of specific procedures.

A technical committee including specialists from the three Ministries, College of Agriculture, Malkerns Research Station and USAID/S should be appointed for the first phase of the project (five years). The committee will coordinate site selection, design, implementation, monitoring and evaluation of pilot small farmer irrigation schemes.

Management

At the field level operation, the District Commissioner's office should set up a working group of the agricultural, health and rural water supply extension staff. Certain training workshops could be held together so as to develop a team approach to site selection, project design, implementation, and monitoring. Significant potential exists for greater private sector involvement in training, and the project design team should discuss this with USAID/S.

Financial

The investment cost per irrigated hectare varies considerably with the type of water delivery and distribution system and with the irrigation method. A decision of what irrigation system to install should be made only after a detailed economic analysis of operation and maintenance costs.

Preliminary estimates suggest that basic health infrastructure (water supply, sanitation, directly attributable irrigation system improvements) could be provided to project sites at a rough cost of E100 per capita. Associated technical assistance costs are difficult to assess at this stage. Some cost figures that may be of use to the project design team are presented in Appendix H15.

Although disbursement and cost recovery aspects need to be worked out, it is believed that increased local responsibility, achieved in part through financial contributions by the beneficiaries, will be critical for project success.

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XI. APPENDICES

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Temperature at Selected Stations (Degrees C)

Station	1975 Absolute Max.	1975 Mean Max.	1975 Mean Min.	1975 Absolute Min.	Longterm Data Absolute Max.	Longterm Data Mean Max.	Longterm Data Mean Min.	Longterm Data Absolute Min.
Highveld								
Havelock	32.4	22.0	11.2	-1.2	35.6	22.4	11.1	-1.2
Mbabane	32.5	21.9	10.5	-3.8	37.2	22.6	10.8	-8.4
Hlatsikulu	30.6	31.2	11.4	0.5	37.2	21.0	11.5	-2.8
Middleveld								
Matsapa	35.0	24.7	13.9	2.0	42.5	26.2	13.8	0.0
Nhlangano	33.4	22.9	11.7	-1.5	38.4	23.7	11.8	-5.4
Lowveld								
Big Bend	38.0	27.9	14.5	-1.9	42.4	28.9	14.9	-3.5
Lavumisa	41.5	29.0	13.6	1.1	44.5	29.6	15.2	-0.5
Lubombo								
Siteki	35.7	24.1	13.8	4.5	41.4	25.0	14.1	2.4

Source: Annual Statistical Bulletin, 1976 (7).

Rainfall at Selected Stations

Station	Longterm Mean Years	Longterm Mean mm	1975 mm	Maximum Year	Maximum mm	Minimum Year	Minimum mm
Highveld							
Havelock	39	1,697	1,808	1955	2,706	1970	1,034
Mbabane	68	1,396	1,887	1939	2,080	1912	899
Hlatsikulu	68	1,138	1,228	1939	1,703	1935	671
Middleveld							
Matsapa	72	900	838	1909	1,602	1945	468
Kubata	57	791	1,192	1918	1,380	1930	318
Nhlangano	40	862	929	1960	1,273	1935	550
Lowveld							
Homestead	60	682	943	1919	1,173	1935	325
Big Bend	46	563	984	1973	907	1945	308
Lavumisa	41	566	300	1942	853	1935	201
Lubombo							
Siteki	72	954	994	1913	1,515	1935	366

Source: Annual Statistical Bulletin, 1976 (7).

PLANTED AREA AND YIELD OF CROPS

IN SWAZILAND, 1974/75

CROP	TOTAL		INDIVIDUAL TENURE LAND		SWAZI NATION LAND	
	AREA (ha)	YIELD (m. tons)	AREA (ha)	YIELD (m. tons)	AREA (ha)	YIELD (m. tons)
Maize	65,947	93,911	4,948	5,950	60,999	87,961
Sugar Cane	19,060	1,781,012	18,929	1,767,042	131	13,970
Cotton	17,583	16,723	6,247	6,820	11,336	9,903
Groundnuts	5,808	2,503	--	--	5,808	2,503
All Dry Beans	3,572	2,598	210	189	3,362	2,409
Sorghums	3,449	2,320	2	4	3,447	2,316
All Potatoes	1,787	10,737	294	2,218	1,493	8,519
Rice	1,613	4,418	1,613	4,418	--	--
Pineapples	1,205	17,394	1,205	17,394	--	--
Grapefruit	1,193	24,832	1,193	24,832	--	--
Oranges	1,063	29,063	1,063	29,063	--	--
Wheat	446	442	446	442	--	--
Pecan Nuts	383	7	383	7	--	--
Tobacco	334	306	74	52	260	254
Avocados	221	117	221	117	--	--
Bananas	150	945	150	945	--	--
Mangoes	114	729	114	729	--	--
Naartjies	82	58	82	58	--	--
Granadella	56	33	56	33	--	--
Tomatoes	40	225	40	225	--	--
Misc. Vegetables	21	534	21	534	--	--
Lemons	11	30	11	30	--	--
TOTAL AREA PLANTED:	124,138		37,302		86,836	

Source: Central Statistical Office, 1976 (7).

CROP CALENDAR

CROP	SOWING PERIOD	HARVESTING PERIOD
Beans (rain grown)	After the first spring rains (Highveld)	2-3 months after sowing
	January - February	May - June
(irrigated)	Throughout the winter, best in March	September - October
Cotton	Usually early in October	March - June
Groundnut	October - November	February - April
Maize	September - November	March - May
Potatoes: Highveld	September - December	December - February
Middleveld and Lowveld	February - March	May - June
Rice	December - January	July - August
Sorghum	September - October	April - June
Sweet Potatoes	March September - November	May - June January - March
Wheat	May	October
Sugarcane	March - May	July - August (15-18 months after planting)
Tobacco	October	January - March
Pineapple	March and September	Mid-January to April (15-18 months after planting)
Citrus Crops	April - June	May - August

Source: Central Statistical Office, 1975 (7).

FORTIER AND SCOBEY'S LIMITING VELOCITIES WITH

CORRESPONDING TRACTIVE FORCE VALUES

(STRAIGHT CHANNELS AFTER AGING)

		FOR CLEAR WATER		WATER TRANSPORTING COLLOIDAL SILTS	
MATERIAL	n	Velocity (fps)[a]	Tractive Force (psf)	Velocity (fps)	Tractive Force (psf)
Fine sand colloidal	0.020	1.50	0.027	2.50	0.075
Sandly loam, noncolloidal	0.020	1.75	0.037	2.50	0.075
Silt loam noncolloidal	0.020	2.00	0.048	3.00	0.11
Alluvial silts, noncolloidal	0.020	2.00	0.048	3.50	0.15
Ordinary firm loam	0.020	2.50	0.075	3.50	0.15
Volcanic ash	0.020	2.50	0.075	3.50	0.15
Stiff clay very colloidal	0.025	3.75	0.26	5.00	0.46
Alluvial silts colloidal	0.025	3.75	0.26	5.00	0.46
Shales and hardpans	0.025	6.00	0.67	6.00	0.67
Fine gravel	0.020	2.50	0.075	5.00	0.32
Graded loam to cobbles when noncolloidal	0.030	3.75	0.38	5.00	0.66
Graded silts to cobbles when colloidal	0.030	4.00	0.43	5.50	0.80
Coarse gravel noncolloidal	0.025	4.00	0.30	6.00	0.67
Cobbles and shingles	0.035	5.00	0.91	5.50	1.10

Notes:

a. SI conversions: 1 psf = 4.88 kg/m^2 = 47.88 N/m^2; 1 fps = 0.305 m/s.

Source: From Lane (1955).

WATER QUALITY ANALYSES

WATER QUALITY CRITERION	MBULUZI RIVER (a)	LITTLE USUTU RIVER (b)	GREAT USUTU RIVER (c)	BIG BEND CANAL (d)
pH	6.6	7.1	7.0	7.0
Dissolved Solids mg/L	25	25	135	40
Total Hardness C CO_3 mg/L	9	8	32	20
Calcium mg/L	2	2	7	4
Magnesium mg/L	2	1	4	2
Sodium mg/L	3	4	13	9
Chloride mg/L	3	3	10	4

Note: (a) and (b) are at stations in the Highveld,
(c) and (d) in the Lowveld. (from Murdoch, 1970).

GUIDELINES FOR INTERPRETATION OF WATER QUALITY FOR IRRIGATION[a]

WATER QUALITY CRITERION	DEGREE OF PROBLEM		
	NONE	INCREASING	SEVERE
Salinity EC (dS/m)	<0.75	0.75-3	>3
Specific Ion Toxicity			
Sodium (adj SAR)	<3	3-9	>9
Chloride (mol/m^3)	<4	4-10	>10
Boron (mg/L)	<0.75	0.75-2.0	>2.0
Miscellaneous Effects			
Nitrogen (mg/L)	<5	5-30	>30
Bicarbonate (mol/m^3)	<1.5	1.5-8.5	>8.5
pH	Normal range 6.5 to 8.4		

[a] From Ayers and Westcot, 1976.

CROP SALT TOLERANCE LEVELS FOR CROPS[a]

CROP	YIELD POTENTIAL 100% ECe	100% ECw	90% ECe	90% ECw	75% ECe	75% ECw	50% ECe	50% ECw	Max.ECe
Field crops:									
Barley[b]	8.0	5.3	10.0	6.7	13.0	8.7	18.0	12.0	28
Corn	1.7	1.1	2.5	1.7	3.8	2.5	5.9	3.9	10
Cotton	7.7	5.1	9.6	6.4	13.0	8.4	17.0	12.0	27
Sorghum	4.0	2.7	5.1	3.4	7.2	4.8	11.0	7.2	18
Soybeans	5.0	3.3	5.5	3.7	6.2	4.2	7.5	5.0	10
Wheat[b]	6.0	4.0	7.4	4.9	9.5	6.4	13.0	8.7	20
Vegetable crops:									
Beans	1.0	0.7	1.5	1.0	2.3	1.5	3.6	2.4	7
Cantaloupe	2.2	1.5	3.6	2.4	5.7	3.8	9.1	6.1	16
Carrot	1.0	0.7	1.7	1.1	2.8	1.9	4.6	3.1	8
Lettuce	1.3	0.9	2.1	1.4	3.2	2.1	5.2	3.4	9
Potato, sweet potato	1.6	1.1	2.5	1.7	3.8	2.5	5.9	3.9	10
Forage crops:									
Alfalfa	2.0	1.3	3.4	2.2	5.4	3.6	8.8	5.9	16
Bermuda grass	6.9	4.0	8.5	5.7	10.8	7.2	14.7	9.8	23
Orchard grass	1.5	1.0	3.1	2.1	5.5	3.7	9.6	6.4	18
Sudan grass	2.8	1.9	5.1	3.4	8.6	5.7	14.4	9.6	26
Wheat grass	7.5	5.0	9.0	6.0	11.0	7.4	15.0	9.8	22
Fruit crops:									
Apple, pear	1.7	1.0	2.3	1.6	3.3	2.2	4.8	3.2	8
Date palm	4.0	2.7	6.8	4.5	10.9	7.3	17.9	12.0	32
Fig, olive, pomegranate	2.7	1.8	3.8	2.6	5.5	3.7	8.4	5.6	14
Orange, grapefruit, lemon	1.7	1.1	2.3	1.6	3.3	2.2	4.8	3.2	8
Plum, peach	1.6	1.0	2.1	1.4	2.9	1.9	4.2	2.8	7

Notes:

a. All values are in mmhos/cm at 25°C.

b. During germination and seedling stage ECe should not exceed 4 or 5 mmhos/cm. Data may not apply to new semidwarf varieties of wheat.

Source: Ayers and Westcot (1976).

IRRIGATION SYSTEMS IN RELATION TO SITE AND SITUATION FACTORS

SITE AND SITUATION FACTORS	REDESIGN SURFACE SYSTEMS	SPRINKLER SYSTEM	TRICKLE SYSTEM
Infiltration Rate	moderate to low	all	all
Topography	moderate slopes	level to rolling	all
Crops	all	all	high value
Water Supply	large streams	small streams	small streams, continuous and clean
Water Quality	all, but very high salts	salty water may harm plants	all, can use high salt water
System Efficiency	average 60-70%	average 70-80%	average 80-90%
Energy Requirements	low	moderate	low to moderate
Management Skills	moderate	moderate	moderate to high

Numerical Index to ASAE Standards, Engineering Practices, Data

Explanation of ASAE designation:

The letter *S* preceding numerical designation indicates ASAE Standard; *EP* indicates Engineering Practice; *D* indicates Data. A decimal and numeral following the file number indicate the number of times a document has been revised. Thus ASAE S201.4 indicates *Standard* number 201, four times revised. The letter *T* indicates tentative status. Always refer to ASAE Standards by complete designation to avoid confusion with standards of other organizations. For example: Order ASAE S201.4.

*New standards since last publication.
†Revised or reclassified standards since last publication.

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*New standards since last publication.
†Revised or reclassified standards since last publication.

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*New standards since last publication.
†Revised or reclassified standards since last publication.

DOCUMENTS WITHDRAWN FROM PUBLICATION AS ASAE STANDARDS WITHIN THE LAST FIVE YEARS:

Published last in 1981:

S262T	Sprinkler Irrigation Technical Data Sheet
EP382	Establishment of Highway-Landowner Drainage Facilities

Published last in 1980:

EP256.2	Refrigeration Equipment Capacity for Bulk Milk Cooling Systems
EP264.2	Minimum Requirements for the Design, Installation, and Performance of Sprinkler Irrigation Equipment
S334.1T	Dimensioning Standards and Terminology for Permanently-Installed Auger Conveyors

Published last in 1979:

D240	Grain Storage Loads, Pressures and Capacities
S314	Implement Power Take-Off and Drive Line Pedestal Shafts

Published last in 1977:

EP345.2	Design of Farm Waste Storage Tanks (Superseded by D384 and EP393)

Published last in 1976:

S305.3	Operator Protection for Wheel Type Agricultural Tractor (Superseded by S383)
S306.3	Protective Frame for Agricultural Tractors—Test Procedures and Performance Requirements (Superseded by S383)
S336.1	Protective Enclosures for Agricultural Tractors—Test Procedures and Performance Requirements (Superseded by S383)
R357	Drawbar for Forestry Tractors

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PILOT SMALL FARMER IRRIGATION SCHEMES PROJECT

MONITORING CHECKLIST

(Physical Environment)

ITEMS TO BE SURVEYED	DESCRIPTION	SIGNIFICANT CHANGES
Water Quality:		
total salts		
sediment levels		
Water Quantity:		
project inflows		
outflows		
Ground Water:		
quality		
levels		
Soils:		
salinity		
alkalinity		
fertility		
Irrigation Scheme Maintenance		
canals		
equipment		
Drains Maintenance:		
canals		

PROJECT IMPACT MATRIX: PHYSICAL ENVIRONMENT

PROJECT COMPONENTS	ENVIRONMENTAL COMPONENTS: AGRICULTURAL LANDS	SOIL EROSION	SLOPE STABILITY	ENERGY/MINERAL RESOURCES	SURFACE WATER QUANTITY	SURFACE WATER QUALITY	GROUND WATER QUANTITY	GROUND WATER QUALITY
PLANNING AND DESIGN								
PROJECT LOCATION								
LAND FORMING								
SURFACE WATER								
GROUND WATER								
DELIVERY SYSTEM								
DISTRIBUTION SYSTEM								
PUMPING AND CONTROLS								
SURFACE DRAINAGE								
WATER RECOVERY/DISCHARGE								
CONSTRUCTION								
LAND PREPARATION/FORMING								
DELIVERY/DRAINAGE SYSTEM								
ACCESS ROADS								
CONSTRUCTION/METHODS								
OPERATION								
CANALS, DRAINS AND EQUIPMENT MAINTENANCE								
SOURCE PROTECTION								
WATER MANAGEMENT								
EXTENSION SERVICES								

Scale

ND = Non-determinable
HA = High Adverse
MA = Medium Adverse
LA = Low Adverse
0 = None or Insignificant
LB = Low Beneficial
MB = Medium Beneficial
HB = High Beneficial

APPENDIX E11

ENVIRONMENTAL IMPACT OF THE RURAL DEVELOPMENT AREA PROGRAM (RDAP)[a]

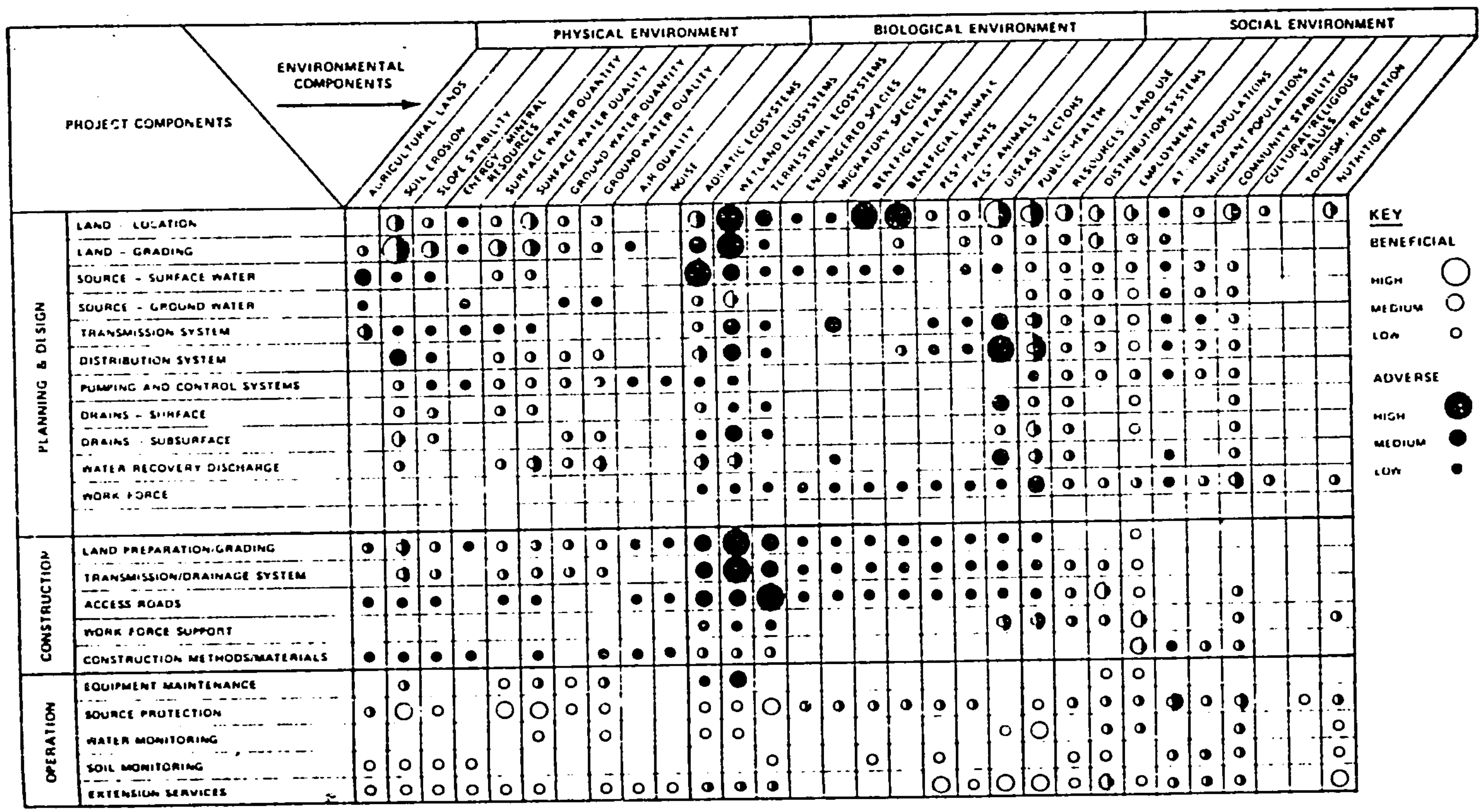
ENVIRONMENTAL RESOURCE OR VALUE	NET EFFECT[b]							QUANTITY (IF KNOWN) OR COMMENTS
	1	2	3	4	5	6	7	
Topography							x	130,000 ha terraced, contoured
Geology				x				
Soils--arable							x	130,000 ha protected
--grazing							x	280,000 ha eventually improved
Surface water			x					Small increase in ppm N
Goundwater				x				
Wildlife and endangered vegetation					x			Protection of valleys in Lubombo that serve as habitat for rare species of flora and fauna
Woodland reforestation and protection						x		70,000 ha eventually
Air				x				
Noise				x				
Climate				x				
Public health and safety--short term			x					25-50% increase in bilharzia
--long term					x			More and better acces to clinics
Historic and cultural resources				x				
Natural resources (soil, range, forest)							x	482,311 ha enhanced
Aesthetic factor						x		More pleasing landscap
Human resources						x		200,000 people served by extension

Notes:

a. From Roder (1977).

b. Net effects are classified as: (1) large loss; (2) significant loss; (3) small loss; (4) no significant change; (5) small gain (6) significant gain; and (7) large gain.

SMALL-SCALE IRRIGATION
AND ON-FARM WATER MANAGEMENT POTENTIAL IMPACTS[a/]



a/ Source: Environmental Design Considerations for Rural Development Projects (1980).

APPENDIX E13

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SWAZILAND

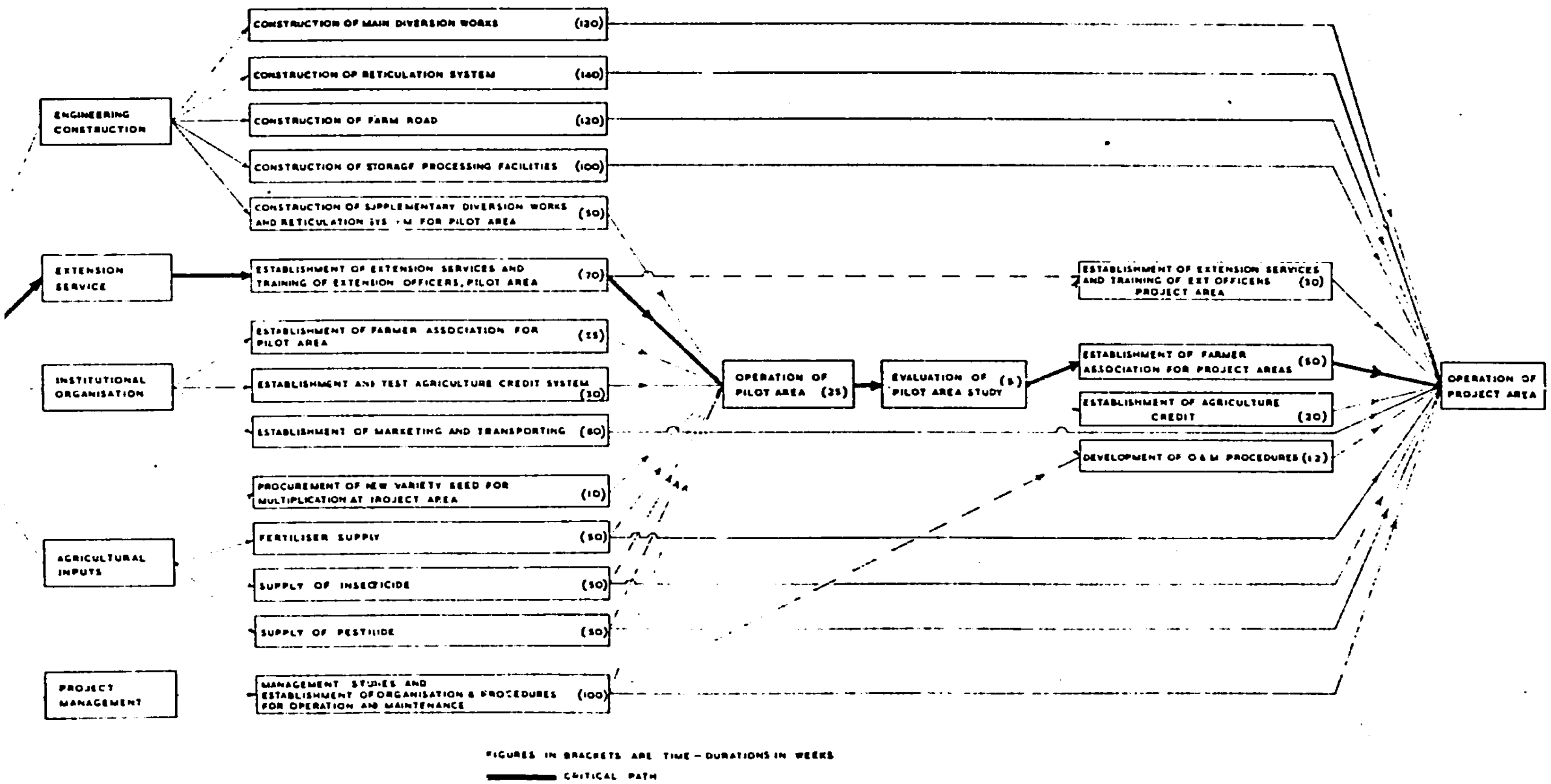
RECONNAISSANCE STUDY: USUTU AND NGWAVUMA RIVER BASINS a/

Net Irrigation Requirements and Expected Yields

		Irrigation Requirement (mm)													Expected Yield (T/ha)
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Annual	
Rainfall (at Lowveld Research Station)															
Mean		49	77	86	94	75	61	38	21	12	10	10	30	563	
20% probability		36	57	63	69	55	45	28	15	9	7	7	22	413	
Net Irrigation Requirement (at the plant)															
Summer:	Cotton	75	77	143	180	133								608	3.0
	Maize	88	157	156	44							38	70	553	7.0
	Groundnuts	122	102	156	72									452	2.8
	Soya Beans	122	122	166	72									482	2.5
	Sorghum	121	115	167	38									441	6.0
	Rice		232	171	163	129								695	5.0
Winter:	Maize						111	51	91	72	9			334	7.0
	Soya Beans					113	120	106	16					355	2.5
	Beans						127	88	94					309	1.5
	Wheat							37	69	65	94	35		300	4.0
	Potatoes								100	57	92	6		255	20.0
	Onions								128	68	85	50		331	30.0
	Tomatoes								112	48	92	130		382	25.0
	Cabbages							115	63	42				220	20.0
	Green Beans							120	73	40				234	12.0
	Green Maize								102	38	94	83		317	30,000 cobs
Perennial:	Sugar Cane	114	132	161	172	148	142	84	62	48	54	77	91	1,285	100.0
	Pineapple													n.a	26.25

a/ Source: Tate & Lyle Technical Services Ltd. (1982).

APPENDIX E14



INTEGRATED PLANNING IN WATER DEVELOPMENT PROJECTS (FAO, Irrigation and Drainage Paper No. 10 (1971)

APPENDIX E15

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APPENDIX G1

LIST OF PRIMARY CONTACTS

I. Government Organizations

Ministry of Agriculture and Cooperatives

Mr. Gilbert Dlamini	Deputy Permanent Secretary
Mr. Victor Pungwayo	Director of Agriculture
Mr. Robert Thwalla	Senior Agricultural Officer
Mr. Patrick Lukele	Director, Rural Development Areas Program
Mr. J. L. Mbingo	Commissioner of Cooperative Development
Mr. A. Sukati	Chief, Land Development Section
Mr. N. Portch	Chief, Irrigation Section
Mr. Petros Dlamini	Irrigation Section

Ministry of Health

Dr. Michael Dlamini	Director of Medical Services
Mr. Leslie Mtetwa	Senior Health Inspector
Mr. Peter Mathews	Chief, Malaria Control Unit
Mr. Wilson Nkambule	Health Assistant (Siphocosini)

Ministry of Works, Power and Communications

Mr. Chris M. Mkhonza	Deputy Permanent Secretary
Mr. Tom Brook	Senior Water Officer, Public Works Department

Ministry of Commerce, Industry, Mines and Tourism

Mr. A. M. Vilakati	Chief Hydrogeologist and Director, Geological Survey and Mines Department
Mr. Fred Stocks	Drilling Superintendant

Ministry of Economic Planning and Finance

Mr. Neal Campbell

Tibiyo Taka Ngwane (Tibiyo Fund)

Mr. Sipho Dlamini

II. Parastatal Sector

Rural Water Supply Board

Mr. Geoffrey A. Evans	Chief Engineer (CDA)

Mr. Charles Parker — Design Engineer (CDA)

Swazi Dairy Board

Dr. Khoza — Director

III. Private Sector

Gibb Hawkins & Partners (Swaziland)

Mr. James A. Richards	Resident Representative
Mr. Peter Drummond	Civil Engineer
Mr. Rob Sawyer	hydrogeologist

Farm Chemicals Ltd.

Mr. Richard M. Fowler — Director, Swazi Mills

IV. USAID

Resident Staff

Mr. Robert Huesmann	USAID Mission Director
Mr. Charles Lahiguera	Deputy Chief of Mission (Embassy)
Mr. Paul Daly	Agricultural Officer
Mr. Chuck DeBose	Health Officer
Mr. William Hammink	Assistant Agricultural Officer

REDSO/Nairobi

Dr. John J. Gaudet — Science, Technology and Environment Advisor

USAID-Assisted Projects

Dr. A.W. Hoadley	Public Health Engineer, Rural Water-Born Disease Control Project (RWBDCP)
Dr. Jean-Paul Chaine	Epidemiologist, RWBDCP
Mr. William Lawrence	Sanitarian, RWBDCP
Dr. Edward Green	Social Scientist, RWBDCP
Mr. Doyle W. Grenoble	Horticulturalist, Cropping Systems Research and Extension Training Project
Mr. Frank Ferenchek	Civil Engineer, Rural Development Areas Program Infrastructure Support Project (RDAPISP)
Mr. Evan Neilson	Soils Scientist, RDAPISP
Ms. Kathy Connolly	Public Health Statistician, Ministry of Health
Dr. Richard Downs	Anthropologist, Pilot Small Farmer Irrigation Project, Socio-Economic Assessment Team (TDY)

V. Other Donor Agencies

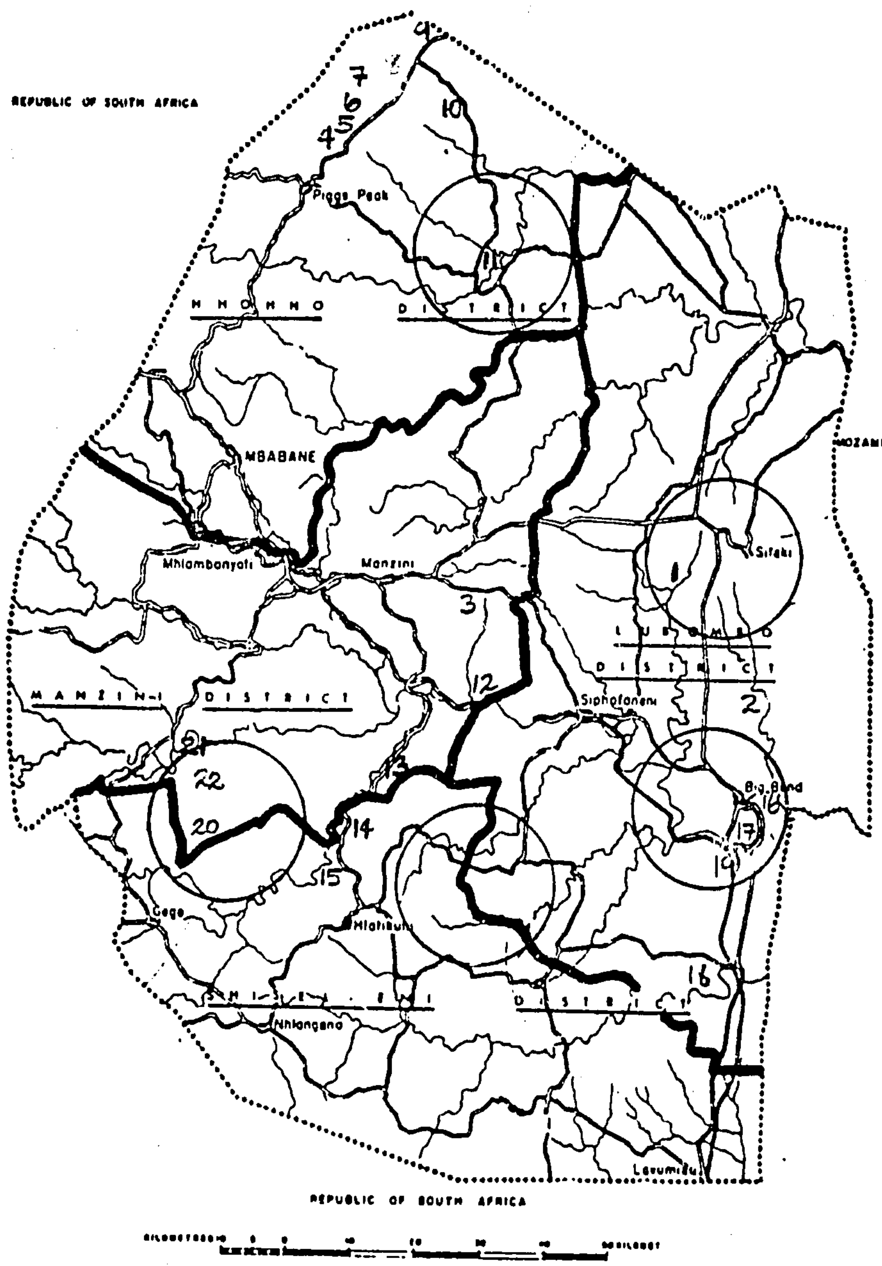
World Health Organization

Dr. Raymond Chuntung	Epidemiologist

World Bank

Mr. Geoffrey Read	UNDP Inter-regional Project INT/81/047: Demonstration Projects in Low Cost Water Supply and Sanitation, World Bank, Washington, D.C.

Swaziland Districts



Field Visits

(Numbers locate sites listed in Appendix G2b following)

APPENDIX G2b

RECORD OF SITE VISITS AND OBSERVATIONS

VELD TYPE (1)	SITE NO. (2)	NAME (3)	DATE VISITED (4)	TYPE ORG. (5)	APPROX. NO. OF HOUSEHOLDS[b] (6)	APPROX. IRRIGATED AREAS (ha)[b] (7)	IRRIGATION – SOURCE (8)	IRRIGATION TYPE (9)
Highveld	20	Mgomfelweni	1-19-83	RDA	18	8	Spring	Furrow
	21	Mancubeni	1-19-83	RDA	34	14	Ngwempisi River	Furrow
Middleveld	4	Phophonyane	1-12-83	Farmer Assn.	11	25	Small river	Furrow
	5	Mavulandlela	1-12-83	RDA	18	12	Spring	Furrow
	13	Chifod Manana	1-11-83	Individual	1	3-4	Mkhondo River	Sprinkler
Lowveld	1	Kalanga	1-13-83	Cooperative	25	25	Shallow groundwater	Sprinkler (converting to furrow)
	2	Magwanyane	1-13-83	Cooperative	36	45	Impounded surface water	Furrow
	9	Border Gate	1-12-83	RDA	80	40	Impounded surface water	Furrow
	11	Balekane Dairy Farm	1-12-83	Swazi Diary Board	30 single workers	100	Komati River	Sprinkler
	12	Gwebu	1-11-83	Individual	1	6	Usutu River	Sprinkler (temporarily inoperative)

SITE NO.	ENERGY AND STORAGE (10)	FARM DELIVERY (11)	DOMESTIC WATER SUPPLY (12)	SANITATION (13)
20	Gravity from reservoir	Pipe	Separate spring w/ reticulation	Pit latrines
21	Electric pump to fenced canal to holding pond	Pipe	Reticulation (from river?)	Some latrines
4	Electric pump to holding pond (under construction)	Pipe	River (plan pump and reticulation)	Some latrines
5	Gravity from reservoir	Lined canals	Homesteads not observed; assume springs and reservoir	None observed near site; homesteads distant
13	Tractor-mounted diesel pump; no storage	Pipe	River	No latrines
1	Diesel pump; 250 Ac-ft reservoir	Pipe	Borehole for RDA staff Piped irrigation water for farmers	None observed on site; homesteads distant (<1 km)
2	Diesel pumps; 8 Ac-ft pond	Cement-lined canals	Impounded surface water (direct or indirect via pond); treatment system inoperative	Some pit latrines
9	Gravity from reservoir	Pipe	Reservoir	None observed near site; some homesteads distant (<1 km)
11	2-stage elec. pump; rubber-lined holding pond	Pipe	Under construction (elec. pump from river with filtration & chlorination	Communal pit latrines
12	Diesel pump; no storage	Pipe	River	No latrines

VELD TYPE (1)	SITE NO. (2)	NAME (3)	DATE VISITED (4)	TYPE ORG. (5)	APPROX. NO. OF HOUSEHOLDS[b] (6)	APPROX. IRRIGATED AREAS (ha)[b] (7)	IRRIGATION SOURCE (8)	IRRIGATION TYPE (9)
Lowveld	16	Kole'	1-10-83	Individual	1	28	Usutu River	Sprinkler
	17	Crookes Plantations (Pty) Ltd.	1-10-83	Private Estate	210-350 (seasonal variation)	i) 500	Usutu River	i) 90% furro 10% sprinkler
						ii) 630		ii) 75% furro 25% sprinkler
	18	Zakhe	1-10-83	Farmer Assn.	11	40	Ngwavuma River	Furrow (adaptable t sprinkler)

Notes:

a. Other sites visited but not included in table

3 – Ngulweni water supply
6 – Women in Development Village Technology Unit
7,8 – Chinese-assisted irrigated schemes
10 – Miawane Herefords RDA water supply excavation
14 – Reservoir for potential Mkhondvo Valley irrigation
15 – Whales Ranch
19 – Lowveld Farmer Training Center
22 – Kamnyani water supply (RDA)

b. Data supplied by Crop Production Section, MOA, Manzini

c. The information contained in this table does not represent experimental results from a random sample survey. Rather, it is a summary of brief field observations by the EA team.

SITE NO.	ENERGY AND STORAGE (10)	FARM DELIVERY (11)	DOMESTIC WATER SUPPLY (12)	SANITATION (13)
16	Diesel pump; No storage	Pipe	River (via irrigation piping)	No latrines
17	Electric pumps; Holding ponds	Canals: unlined- (main) lined (secondary) Pipe (sprinkler)	River (via canals)--filtered and chlorinated w/reticulation to homesteads)	Exterior Pour-flush latrines; in-house showers
18	Diesel pump Pond with siphon	Pipe	River (direct or via irrigation pipe)	None observed near site; homesteads distant (<1 km)

7.0 RELATIONSHIP OF GEOLOGY TO GROUNDWATER

The principal locations where groundwater is found are:

1. In areas where there are considerable depths of weathered granitics.

2. In the sandstones of the Stromberg and Ecca formations, where faulted or at intrusive contacts.

3. In the Lowveld basalts, at intrusive contacts with dolerite dykes and in stream bed alluvium.

4. In the jointed rhyolites of the Lebombo range.

To 1978, the Department of Agriculture reports some information relating to 212 boreholes. All wells were cased into bedrock. Very few had slotted casing, and none were with screens. No groundwater was being extracted from alluvium.

Yield reported from these holes and their relationship to geological formations are as follows:

1. Weathered granites: over 4500 lph (litres per hour) for 40% of holes.

2. Stromberg and Ecca Sandstones: yield unreported, however the comments indicated "good" yields.

3. Basalts: 35% of holes yielding over 4500 lph.

4. Lebombo rhyolites: yields unreported, however, aquifers were located at depths of about 125 m.

Source: E.H. Hanson & Associates (for the Canadian International Development Agency), 1982.

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Of 92 holes recorded in the Karroo, 21 were dry and 56 yielded less than 150 lph. Only three holes have been bored into the Molteno and Cave sandstones.

In the review of all yield data, consideration was given to the fact that the estimated yields were determined from air lift (which may only indicate about 50-60% of actual well capability) or low yield pump capability. The latter may be a result of pump supply in Swaziland during the various programs or pump restriction due to well diameters.

These considerations, we believe, have resulted in the estimated well yields being lower than the actual aquifer capability.

It is also expected that state-of-the-art well construction using well screens and gravel pack where necessary along with proper well development procedure will produce more efficient well systems as compared to such systems previously installed.

A preliminary groundwater yield capability map at scale 1:250,000 is attached as Plan No. 3 and is entitled Generalized Groundwater Probability.

This map was prepared based on our interpretation of the available geologic and groundwater data and our experience in similar type of aquifer conditions.

The groundwater probability map indicates in relative terms the potential for obtaining a successful groundwater supply.

The areas marked "good" have weathered and fractured old granites at the bedrock/overburden interface. This feature will provide the strongest aquifer potential. The potential of single well systems yielding in excess of 25,000 litres per hour is better than 50/50. Multiple well systems should have minimum interference at relatively tight well spacing. Well yields utilizing multiple wells will be dependent on local recharge conditions. The areas marked "fair" have fractured sandstones, sandstones, and weathered or fractured basalt as the principal aquifer. The potential of single well systems yielding between 2,500 - 25,000 litres per hour is 50/50.

Multiple well systems will cause some interference and spacing requirements of some 0.25 - 0.50 kilometres would not be unusual.

The area marked "poor to fair" represents fractured Lebombo rhyolitic tuffs as the principal aquifer. Yields would be in the ranges of fair described above however the well depth would be in excess of 125 metres. This unit applies only to the Lebombo Escarpment.

The area marked "poor" has serpentinites, gabbros, gneisses and doleritic soils as the rock material. The majority of wells in this area will be "dry".

The groundwater probability map has attempted to consider the major fracture and shear zones (see Plan No. 5) however groundwater piping through these features is extremely difficult to predict unless field tests have been completed.

In general one can assume that these zones can produce in excess of 25,000 litres per hour when in contact with any reasonable recharge feature.

8.0 CLIMATOLOGY AND RECHARGE

Although the long term annual rainfall of the Lowveld area is only from approximately 600 - 800 mm it is to be remembered that the basin receives infiltration from the western Middleveld and Highveld and the Lebombo Mountains to the east. It has been estimated that approximately 20% of the rainfall, 75-80% of which occurs from October - March, goes to groundwater recharge. It would appear that a preliminary computer simulation model should be constructed for the entire Kingdom to permit for a better assessment of the relationship of climatology/recharge/geology as it will apply to delivery capabilities of groundwater systems. This can be carried out once some drilling information has been obtained and general aquifer characteristics for the relative units as presented on Plan No. 3 are determined.

Some data, however, does indicate that the recharge potential is good. The present wells at the Royal Swazi Spa Hotel at Ezulwini exhibit minor drawdown when pumped. This eight multiple well system has been utilized to pump in excess of 1,000,000 litres per day from a well field spaced within one kilometre with no indications of any detrimental effect to the static water level.

Shallow overburden wells have been reported to be effected by local seasonal recharge variations, however, we have found no evidence to suggest this for wells located at the overburden/bedrock contact or within the bedrock aquifer itself.

As a preliminary conclusion, review of the rainfall data and basin characteristics of Swaziland, one can generalize that there is adequate recharge for major groundwater development to take place.

10.0 GROUNDWATER EXPLORATION PROGRAM

Discussions with government personnel in Swaziland identified a need for a groundwater exploration program to establish the groundwater potential for the country of Swaziland. Groundwater is required for domestic rural water supply and for agriculture.

A groundwater exploration program relative to Swaziland requires two fundamental features for successful completion:

a. an authority having the responsibility to carry out the management, data collection, and data assessment for such a program, and

b. the proper equipment to carry out the physical placing of test wells and carry out necessary testing to obtain data.

Realistically, neither at present exists with the government of Swaziland.

The Geological Survey and Mines Department has assumed the role of groundwater management. However, the hydrogeologist cannot respond to the assumed responsibilities because the department's terms of reference as to groundwater management are not clear within the government. There exists a need to establish a centralized authority for groundwater management having specific terms of reference and recognized by the government. The authority should have jurisdiction to allow for data collection and control of all groundwater supplies in Swaziland as well as having the ability to carry out testing and well installation programs.

It is the opinion of government personnel in Swaziland that this authority can be established and should be responsible for the proposed groundwater exploration program.

The personnel and staff of the Geological Survey and Mines Department are the most likely candidates for such an author..y. The geologist and hydrogeologist Mr. Vilankati is Canadian trained. His staff is continuously involved in subsurface exploration and can be trained in current state-of-the-art groundwater exploration techniques. The department presently has a reputable drilling supervisor, Mr. Fred Stokes, who has experience with hammer percussion-rotary drilling machines. Discussions with the department personnel have indicated that the man-power requirement of 10 - 12 men for the groundwater development program and the management of potential authority responsibility can be met.

The equipment available to the government of Swaziland does not lend itself to groundwater exploration. Their existing diamond drill casing equipment and cable tool drill rig cannot carry out any credible groundwater exploration program. The government will require hammer percussion-rotary drilling machines for the program as well as all support equipment.

Hiring drilling equipment from South Africa to carry out a major groundwater exploration program would be very expensive. The current charges per foot for work in Swaziland are approximately 20.0 R for drilling and 20.0 R for casing relative to a 6 inch diameter well. The South African drillers do not appear to be practicing state-of-the-art technology since well screens, gravel parking, proper development, and proper test-pumping techniques are not utilized.

Therefore, the authority which will carry out the management of the groundwater exploration program will requir. the full complement of drilling and testing equipment as well as support equipment.

As mentioned previously in this section, it appears that the manpower requirements to carry out a successful program are available in Swaziland. There will be a requirement for outside assistance in the establishing of a central authority to address the Swaziland requirements and to assist the development of the groundwater program. This will also include assistance in the organization of system and the development of schemes of service. It is recommended that the services for the overall program be provided through one company thereby providing a co-ordinated input and consistent project assistance throughout the entire project.

The groundwater exploration program should consider two Phases. Phase 1 should concentrate in the area of greatest need - the Lowveld. This program will require approximately one to two years to complete, however, some practical preliminary data should be available within six months to one year which can be utilized for agricultural purposes. Phase 2 will follow in the Highveld, Middleveld, and Lebombo regions and will require two to three years for completion. In total the groundwater exploration program for Swaziland should require five years.

10.1 EQUIPMENT REQUIREMENTS

The equipment requirements are based on a list developed in Swaziland with representatives of the Geological Survey and Mines Department. For purposes of this report we have considered only the equipment required to initiate Phase 1 of the groundwater exploration program. Phase 2 projections will appear in Section 10.3.

We recommend the purchase of the following equipment: *

a. Two Futros Model FU-1600 Drills (or equal) mounted on International Chassis capable of drilling to a maximum of 300 metres for a 400 mm borehole. The drill equipment should be complete with drill rods and 4 sets of hammers, hole openers and drill bits, to provide 100 mm, 200 mm, 300 mm, and 400 mm diameter boreholes. The Futros Model FU-1600 is manufactured in Canada and contains approximately 80% Canadian content.

The drill rigs should be complete with an initial supply of spare parts, on-site start-up servicing and a one year warranty on components.

Any future spare parts may be obtained from Futros Equipment Canada Inc., however, the drill can be "tailored" such that the majority of spare parts can be obtained locally in Swaziland. For example - the truck chassis can be specified as International, which is compatible with local parts suppliers.

The estimated cost for two drill machines complete is $1,000,000.00.

b. Two truck mounted water tanks having a minimum capacity of 5,000 litres. These tanks should be square providing dual usage for transport of miscellaneous equipment.

The estimated cost for two truck mounted water tanks is $100,000.00.

c. One portable 750 - 900 C.F.M. compressor at 350 R.P.M. for well development purposes.

The estimated cost for the compressor is $120,000.00.

d. One single axle maintenance truck complete with arc and gas welding equipment.

The estimated cost for the maintenance truck is $25,000.00.

e. Three British Leyland "Land Rovers" to be used for personnel transport.

The estimated cost for the land rovers is $75,000.00.

f. Two portable generators (100 kw) to be used for test-pumping of wells.

The estimated cost for the generators is $60,000.00.

g. A Case 580D backhoe with front end loader (or equal) for purposes of digging mud pits.

The estimated cost for the backhoe is $60,000.00.

h. Two HACH portable lab units model DR-EL/4 (or equal) for carrying out field groundwater chemical analysis.

The estimated cost for the portable lab equipment is $3,000.00.

i. One HIAB (or equal) model 550 hydraulic loader for mounting on the service vehicle and to load pipe.

The estimated cost for the loader is $15,000.00.

j. Two ATCO (or equal) 10' x 40' trailers for housing technical staff at the drill sites.

The estimated cost for the trailers is $50,000.00.

k. The following miscellaneous equipment for the groundwater program:

ITEM	ESTIMATED COST
6 tons bentonite	$ 1,000.00
2 marquis type tents	$ 1,000.00
4 electric tapes	$ 1,000.00
10 Stevens model F recorders	$ 8,000.00
1 Johnson SR-5000 E-logger	$45,000.00
Radio communication (10 units)	$ 9,000.00
Sample bags	$ 200.00
Sample bottles	$ 500.00
Miscellaneous Rigid tools	$ 5,000.00

l. Two of each 220 V Grisan Submersible Pumps (from Matsapa, Swaziland) for use during test pumping of the following models: 30-300 (1.5 H.P.), 30-600 (3.5 H.P.), 30-1000 (5.0 H.P.).

The estimated cost for the pumps is $6,000.00.

m. Steel well casing material for Phase I of the program. We estimate the initial order require 1,500 metres total of sizes ranging from 100 mm diameter to 400 mm diameter.

The estimated cost for well casing is $750,000.00.

n. Stainless steel well screens in 1.5 metre lengths, both telescoping and pipe size. The initial order should include the majority in the order of 100 mm diameter with some 200 mm, 300 mm, and 400 mm diameter size, complete with lead packers.

The estimated cost for the well screens is $50,000.00.

The total cost for the initial order of equipment is estimated at $2,382,700.00. All materials excluding the pumps are of Canadian origin and majority (+80%) Canadian content. The shipping time from Canada to Swaziland is estimated from 4 to 6 months.

COMPONENT PARTS (SWAZILAND) (PTY.) LTD.

BRISAN SUBMERSIBLE PUMPS OPERATING IN SWAZILAND AS AT 30TH JUNE, 1981: BOREHOLES ONLY.

LOCATION	AREA	BOREHOLE DEPTH FEET.	APPROXIMATE PUMPING CAPACITY (I.G.P.H.)
Murray & Roberts	Elwandle	240	1000
Saint Joseph Mission	Kabhudla	150	900
Salesian High School	Manzini	200	300
Nsoko Trading Store	Nsoko	50	500
Saint Theresa School	Manzini	250	300
J. H. Anderson	Manzini	175	400
Dept of Agriculture	Motshane	150	1000
Tinkhukhu Poultry Farm	Malkerns	75	1500
A. Hubard	Malkerns	110	1200
T. Kunene	Manzini	200	600
Royal Swazi Spa Hotel	Ezulwini	150	300
Royal Swazi Spa Hotel	Ezulwini	110	1000
Royal Swazi Spa Hotel	Ezulwini	150	250
Royal Swazi Spa Hotel	Ezulwini	150	250
Royal Swazi Spa Hotel	Ezulwini	150	560
Royal Swazi Spa Hotel	Ezulwini	175	5500
Royal Swazi Spa Hotel	Ezulwini	220	3000
Royal Swazi Spa Hotel	Ezulwini	175	2200
Libby's	Malkerns	150	1000
Tibiyo Taka Ngwane (Head Office)	Lozitha	75	600
Swaziland Wholesalers	Malkerns	60	300
D. Goldblatt	Ezulwini	110	300
H. Masuku	Elwandle	175	200
Waterberry Park	Ezulwini	105	800
Keir & Cawder (Swaziland)	Manzini	150	800
Tinkhukhu Poultry Farm	Malkerns	150	600
J. Davidson	Malkerns	120	1800
The Haven Rest Camp	Elwandle	80	200
B. Van Heerden	Elwandle	150	1000
Tibiyo Taka Ngwane	Malkerns	80	1500
Dr. A. Neumalo	Ezulwini	150	150
Holiday Inn, Staff House	Ezulwini	80	800
Sitobela Health Clinic	Madulani	220	600

COMPONENT PARTS (SWAZILAND) (PTY.) LTD.

BRISAN SUBMERSIBLE PUMPS OPERATING IN

SWAZILAND AS AT 30TH JUNE, 1981.BOREHOLES

ONLY.

LOCATION	AREA	BOREHOLE DEPTH FEET.	APPROXIMATE PUMPING CAPACITY (I. G.P.H.)
Uncle Charlie Hotel	Manzini	150	800
J. Gwebu	Sigcaweni	120	600
A. Catterick	Malkerns	60	500
A. Thompson	Manzini	150	120
Malkerns Dairy Farm	Malkerns	120	500
J. King	Lobamba	100	1200
Keir & Cawder	Manzini	100	200
S. Z. S. Dlamini	Malkerns	105	800
R. B. Sibandze	Ezulwini	150	850
J. Martin	Mbabane	175	300
Keir & Cawder	Manzini	150	350
Malkerns Dairy Farm	Malkerns	150	750
K. Nagin	Matsapa	80	500
K. Nagin	Matsapa	95	570
T. Barah	Manzini	120	500
Libby's	Malkerns	120	1000
Tibiyo Taka Ngwane	Ezulwini	70	300
Jacaranda Farm (Tibiyo)	Malkerns	120	350
Libby's	Malkerns	110	800
Mrs Douglas	Malkerns	150	600
Libby's	Malkerns	85	3000
Libby's	Malkerns	110	3000
Dept of Agric (Mpisi Farm)	Kabhudla	85	3500
MatsHane Garage	Motshane	120	250
D. Mantia	Malkerns	95	120
D. Foss	Malkerns	75	800
Keir & Cawder	Mahlanya	60	750
J. Mundell	Manzini	120	600
Ehlanzeni Farm	Kabhudla	150	520
Malkerns Dairy Farm	Malkerns	150	660
The Bible Institute	Ezulwini	170	600
Sobhuzi Waya School	Nkamboni	150	3300
Embassy House	Mbabane	60	800

COMPONENT PARTS (SWAZILAND) (PTY.) LTD.

BRISAN SUBMERSIBLE PUMPS OPERATING IN SWAZILAND AS AT 30TH JUNE, 1981: BOREHOLES ONLY.

LOCATION	AREA	BOREHOLE DEPTH FEET.	APPROXIMATE PUMPING CAPACITY (I. G.P.H.)
Swaziland Brewers Ltd	Matsapa	65	1300
Manzini Bible School	Elwandle	75	500
H. Steffen	Nsoko	550	200
V. J. Bunn	Elwandle	100	800
Swaziland Railways	Nsoko	120	600
Logoba Nursery School	Logoba	80	750
Holiday Inn	Nhlangano	65	450
R. G. Dlamini	Ezulwini	120	300
Mr. S. Vilakazi	Malkerns	145	800
Swaziland Chemical Industries	Ezulwini	165	550
A. Hamilton	Kabhudla	135	500
Z. Mokelay	Malgwane Hill	60	800
Mpaka Refugee Centre	Malindza	80	3000
Lusito Child Centre	Malkerns	85	200
D. R. James	Malkerns	110	300
F. Oswin	Nhlangano	100	250
A. Khumalo	Zombodze	85	350
National Bahia Centre	Ezulwini	120	250
Diamond Valley Motel	Ezulwini	85	500
Peter Thorne	Malkerns	110	800
Ikhwezi Investment	Ezulwini	150	1200
Harmond Electrical Contractors	Manzini	50	250
D. Motsa	Manzini	80	250
Peter Duffy	Manzini	120	600
A. Fenny	Kabhudla	95	800
Dr. Samuel Hynd	Elwandle	85	220
H. Sussman	Manzini	110	800
Captain Vic Fouche	Manzini	130	800
Roberts Construction	Ezulwini	170	250
R. Zwane	Manzini	120	300
Diamond Valley Motel	Ezulwini	95	300
Baron Construction	Manzini	170	150

BRISAN SUBMERSIBLE PUMPS OPERATING IN SWAZILAND AS AT 30TH JUNE, 1981, BOREHOLES ONLY.

LOCATION	AREA	BOREHOLE DEPTH FEET.	APPROXIMATE PUMPING CAPACITY (I. G.P.H.)
Timbali Caravan Park	Ezulwini	110	800
Ezulwini Greyground	Ezulwini	100	600
B. Packard	Malkerns	55	800
W. Wright	Malkerns	120	250
E. Remberg	Manzini	240	120
Rural Water Nhlangano	Nhlangano	220	1500
Timbali Caravan Park	Ezulwini	130	800
Rural Water	Nhlangano	100	200
E. S. Khumalo	Shiselweni	100	250
Lomahasha Border Post	Lomahasha	120	800
Tinkhukhu Poultry Farm	Malkerns	220	600
D. Motsa	Lobamba	85	800
Mahamba Border Post	Shiselweni	150	250
Malkerns Country Club	Malkerns	115	1200
Ndzevane Refugee Centre	Big Bend Nsoko	110	3500
Rural Water Siteki	Lubombo	220	3000
E. Naumann	Malkerns	60	800
Hermond Electrical Contractors	Big Bend	135	200
L. E. Pierce	Manzini	125	300
Keir & Cawder	Manzini	150	600
Dr. D. Lapping	Nhlangano	120	500
A. Hamilton	Lesthovu	140	200
A. Camp	Ezulwini	110	700
Salesian Community Centre	Malkerns	115	1200
Rev Hlata	Kwaluseni	65	300
Sunset Village	Ezulwini	85	1300
E. Vickery	Malkerns	95	700
Emkhuzweni Health Centre	Lukhondze	150	100
Emkhuzweni Health Centre	Lukhondze	65	500
Emkhuzweni Health Centre	Lukhondze	85	200

APPENDIX B

TEST DRILLING, TEST WELL INSTALLATION AND AQUIFER TESTING

a. The purpose of initial drilling is to obtain basic subsurface data. The use of this data will eventually lead to the utilization of the groundwater resource with a water well or the total abandonment of a geologically unfavourable area.

b. An exploratory test hole should be drilled from ground surface to competent bedrock, where applicable. The test hole should be capable of accepting a 50 mm diameter threaded and coupled casing for eventual use as an observation well.

The test hole should be carefully logged by the supervising hydrogeologist noting changes in overburden or fractured bedrock, water loss or any other unusual conditions. Samples should be obtained from every 2 metre drilled interval or at any change in strata. If the equipment is available, an electric log should be taken of the completed borehole.

If groundwater is encountered, a 50 mm diameter well point screen should be installed into the aquifer. The observation well is to be developed using compressed air. A water sample should be obtained at time of developing. The completed observation well is to be monitored daily for static water level data. The tops of the wells should be surveyed relative to a common datum. A minimum of two observation wells in each study area will be required.

c. Following a review of all data upon completion of the initial test drilling, a test production well program will be detailed.

d. The test production well drilling will be of a size that if necessary a minimum 100 mm diameter threaded and coupled casing may be installed. It is anticipated that a minimum 100 mm diameter stainless steel screens will be installed into the aquifer formations. The drill hole will be carefully logged by the supervising hydrogeologist. The approximate depth to aquifer and thickness of aquifer should be determined from previous test drilling and testing, however, depth of hole and location of well screens will be a field decision carried out by the supervising hydrogeologist.

The well will then be developed with air until the water pumps clear at a maximum pumping rate.

If a 50 mm diameter observation well has not been previously installed within an acceptable distance from the pumping well, then one will be installed and developed a distance twice the thickness of the aquifer from the test production well.

Test pumping will be carried out on the test production well with measurements taken at all observation wells within the study area.

e. At all times during the progress of the work, and upon completion of observation wells and test production wells, temporary capping will be placed on the wells so as to prevent tampering with the well or the entrance of foreign matter into it. This temporary capping should be to the satisfaction of the supervising hydrogeologist.

f. All wells shall be drilled with care exercised to achieve plumbness and straightness.

g. The Contractor shall keep an accurate record as assembled of the order, number, size, and length of the individual pieces of pipe installed in all wells.

h. At least 12 hours will elapse between the completion of well developing and test pumping.

i. The test pumping installation shall be such as to allow for the installation and for the lowering of an electric tape for measurement of water levels in the pumping well.

j. A valve must be provided on the test pumping installation to enable the discharge to be varied. The rate of pumping must remain constant throughout the entire test, despite increased pumping lifts.

k. Test pumping will consider the following:

(1) the static water levels in the pumping well and the observation wells will be measured at one hour and at 5 minutes prior to the start of testing.

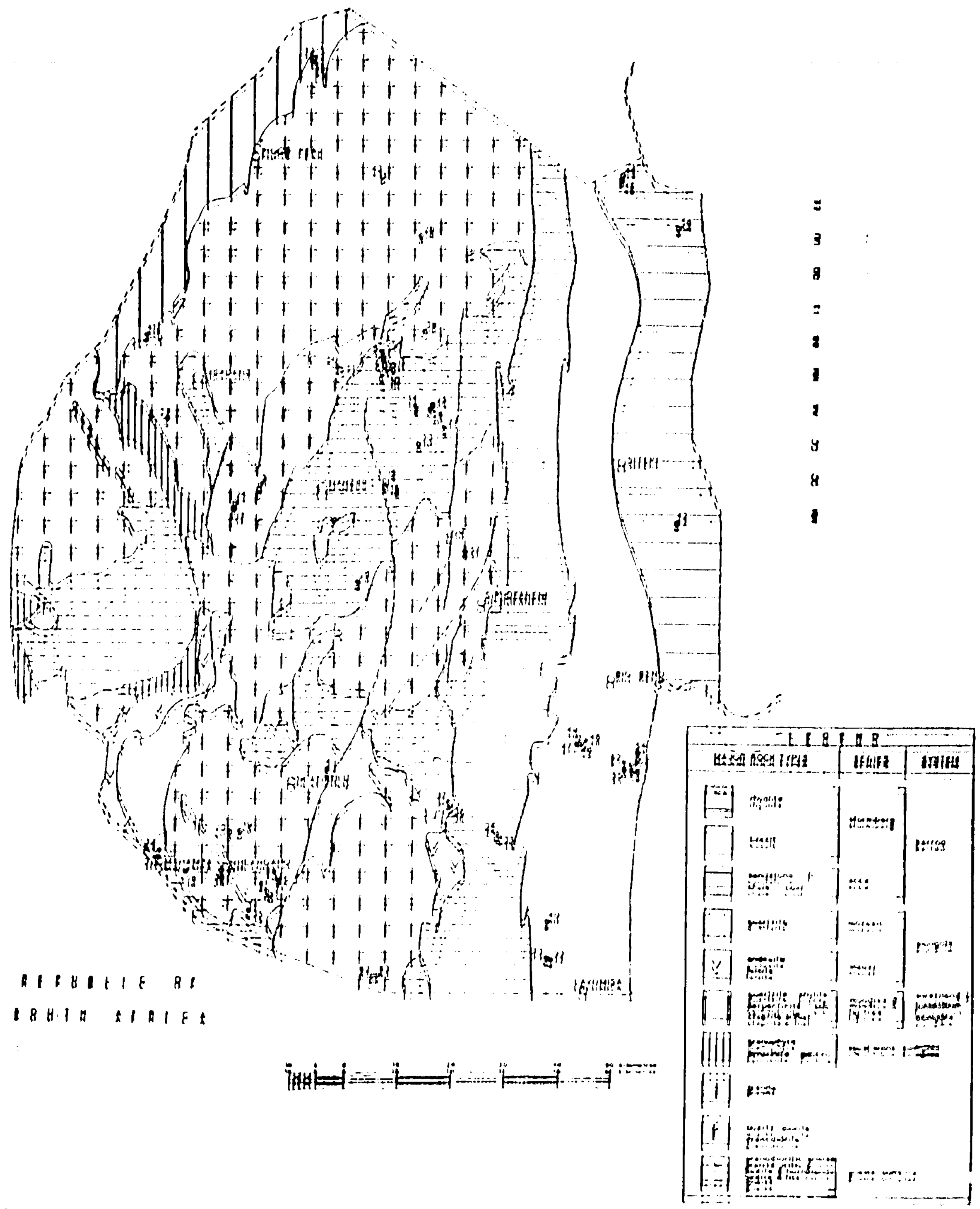
(2) all measurements are from zero time - the time when the pumping equipment is activated and readings on all wells are taken simultaneously at 30 seconds, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 15, 20, 25, 30, 40, 50, 60, 75, 90, 105, and 120 minutes, and thereafter every 30 minutes until 12 hours of pumping has elapsed. Thereafter readings are taken every hour for a minimum period of 24 hours from start of pumping. The decision to terminate testing will be that of the supervising hydrogeologist.

After the test, the recovery levels will be taken at the time intervals stated above, measured simultaneously on all wells from the moment pumping ceases until stable conditions are reached.

l. Samples of water will be carefully taken from the well during test pumping at the start of the test and every 12 hours until pumping has been terminated. The water samples should be tested for pH, total dissolved solids (by evaporation), Nitrate (N), total Iron (Fe), total hardness ($CaCO_3$), Chloride (Cl), Calcium (Ca), Magnesium (Mg), Sodium Potassium (as Na), and Sulphate (SO_4).

One sample obtained towards completion of testing should be submitted for bacteriological analysis.

GEOLOGICAL MAP OF SWAZILAND SHOWING BOREHOLE LOCATIONS (GIBB HAWKINS BOREHOLES ONLY)†



†Source: Gibb Hawkins Ltd., Swaziland.

SELECTED WATER QUALITY DATA

APPENDIX H3

Memorandum

FORM NO: F 73

From: Water Quality Analyst

To: Dr. A.?. Hoadley:

Date Jan 17/93.

Our Ref: WQ5, Nitrate/Chloride levels.

Your Ref:

As per conversation nitrate and chloride levels for RWSB systems have been categorized as follows: Table 1: Mountain streams., Table 2: Borehole systems., Table 3: Rivers/dams., Table 4: Multiple intakes..

The proposed maximum permissible level for Nitrate-N for RWSB systems is 30mg/l. No limit has been set for chloride as a level for community rejection of a water supply based on a salty taste is yet to be determined.

Table 1: Mountain stream.

RWSB SYSTEM	RU No.	NO_3-N	Cl
Ezulwini	003A	0.4-3.3	5-60
Ezulwini	003B	1.0-3.6	60
Bambeleze	061	0.5-1.[illegible]	6-60
Ekuthuleni	151	0.[illegible]-[illegible].0	21-80
Nsabaneni	139	0.6-4.0	13-30
Ntondozi	188	0.4-3.6	13-35

Table 3: Borehole systems.

RWSB SYSTEMS	RU No.	NO_3-N	Cl
Mzimnene	170	3.0-3.[illegible]	15-46
Nora	083	[illegible]	11-[illegible]
Nkambeni	007	[illegible]	[illegible]
Kalanga	1[illegible]8	1.[illegible]-11.[illegible]	[illegible]

Table 3: Borehole systems contd.

RWSB SYSTEMS	RU No:	NO_3-N	Cl
Lekhyiza	193	0.6-1.3	130-150
Mafutseni	134A	1.3-3.0	46-75
Mafutseni	134B	2.0	60-35
Malindza	150	0.3-1.0	130-160
Nkenjane/Hlamkane	052	1.0	36
Lwandle	184	1.6-3.0	6-55
Ekuphumuleni	164	1.1	11
Nsangweni	093	3.2	[illegible]

Table 4: [illegible]

RWSB SYSTEMS	RU No:	NO_3-N	Cl
Mpolonjeni	160	0.3-1.0	1.5-0
Nkanjeni	011	1.0-3.3	13-136
Ebenezer	101A	1.3	65
Ebenezer	101B	0.1	61
Esiesineni	122	0.3	3-39
Lwandle	166	0.8-0.9	15-30
Mpolonjeni	060	0.3-	60-96

Table 4: Multiple intakes.

RWSB SYSTEMS	RU No:	INTAKES	NO_3-N	Cl
Jacks	[illegible]	B,B4,[illegible]	[illegible]	3-136
Matsha	[illegible]	B5,B4	1.4-[illegible]	7-15
Bethel	033	[illegible]	[illegible]	[illegible]
Gege	016	B5,B5	[illegible]	[illegible]

APPENDIX H3

DESIGN CRITERIA

RURAL WATER SUPPLY SYSTEM

S W A Z I L A N D

1. **POPULATION ESTIMATE**

   10 people/homestead.

   Source: census records [illegible] and 8-10 people/homestead determined by C.U.A.

   Number of homesteads determined by air photos, orthophoto maps, [illegible] field maps and verified in field.

2. **POPULATION FORECASTS**

   3% increase per year

   Source: census records

   Also consider resettlement plans.

3. **DESIGN LIFE**

   Up to 1990 (or minimum 10 years).

   Source: U.N. drinking water decade.

4. **RATE OF CONSUMPTION**

   a) Standpipe.

   (i) homesteads:

   25 l/c/day [illegible]

   Source: 1. WHO; Water Supply for Rural Areas and small Communities: (15 l/c/day)

   2. I.V.S.; Lesotho Village Water Supplies (30 l/c/day

   (ii) day schools:

   No. students x 35 l/c/day

   b) Flush toilets — or taps and laboratories only

   (i) day schools — 30 l/student/day

   65 l/student/day [illegible]

   Source: WHO: IBRD

   (ii) Boarding school (W. shower)

   170 l/student/day.

   c) Private house connection

   (i) Inside tap only

   57 l/c/day

   Source: WHO: IBRD

(ii) Showers & Toilets

250 l/c/day

Source: WHO : IBED

d) Gardens (Vegetable)

1500 l/day

@ 760 l/hr

Source: WHO : IBED

e) Wash houses & Showers

125 l/person/day

(v) It is requested to estimate the actual number of people utilizing the facilities.

Source: WHO: Camp use less kitchens, flush toilets and home use.

f) Clinics

(i) taps only & day patients

25 x 1/2 x No. of patients/day

(ii) Full facilities & overnights

170 l/bed/day.

Source: WHO "Camp use"

g) Offices with toilets

30 l/occupants/day

5. PEAK DEMAND

a) Max. hourly consumption

4 x mean daily

Source WHO IBED

b) Minimum flow for number of standpipes on line

No of standpipes	Design flow (l/sec)
1	0.25
2	0.50
3-4	0.75
5-6-7	1.00
8	See (a) Above

6. FEEDER PIPE DESIGN

a) Gravity feed

1.5 x mean daily flow

b) Pumping main

$1.5 \times$ mean daily flow $\times \frac{3}{24} = m^3/8$ hr.

7. MAXIMUM PUMPING TIME

8 hrs/day

to feed 1.5 x mean daily demand.

8. STORAGE RESERVOIR CAPACITY

a) Gravity feed or pumping:

~~[illegible]~~ x mean daily demand

b) Windmill:

4 x mean daily demand

9. MAXIMUM PUMPING RATE FOR BOREHOLE

0.7 x Measure pumping rate

10. MAXIMUM DISTANCE TO STAND PIPES

200 M

Source : Rural Water Supply Board

11. MAXIMUM NO. OF PEOPLE SERVED PER STAND PIPE TAP

100 persons

Source : ODM recommendation

12. PIPE PRESSURE

a) Minimum at Standpipe

10 metres

Source : WHO IBED

b) Maximum static pressure

i) Less than 6 bar

O.K.

ii) 6 - 10 bar

consider reducer

iii) Over 10 bar

install reducer

13. MAXIMUM FLOW VELOCITY

63 mm Ø - 2 m/sec

75 mm Ø - 3 m/sec

14. MINIMUM PIPE SIZE

No. Standpipes	Size (mm)
1	20
2-3-4	25
5	32

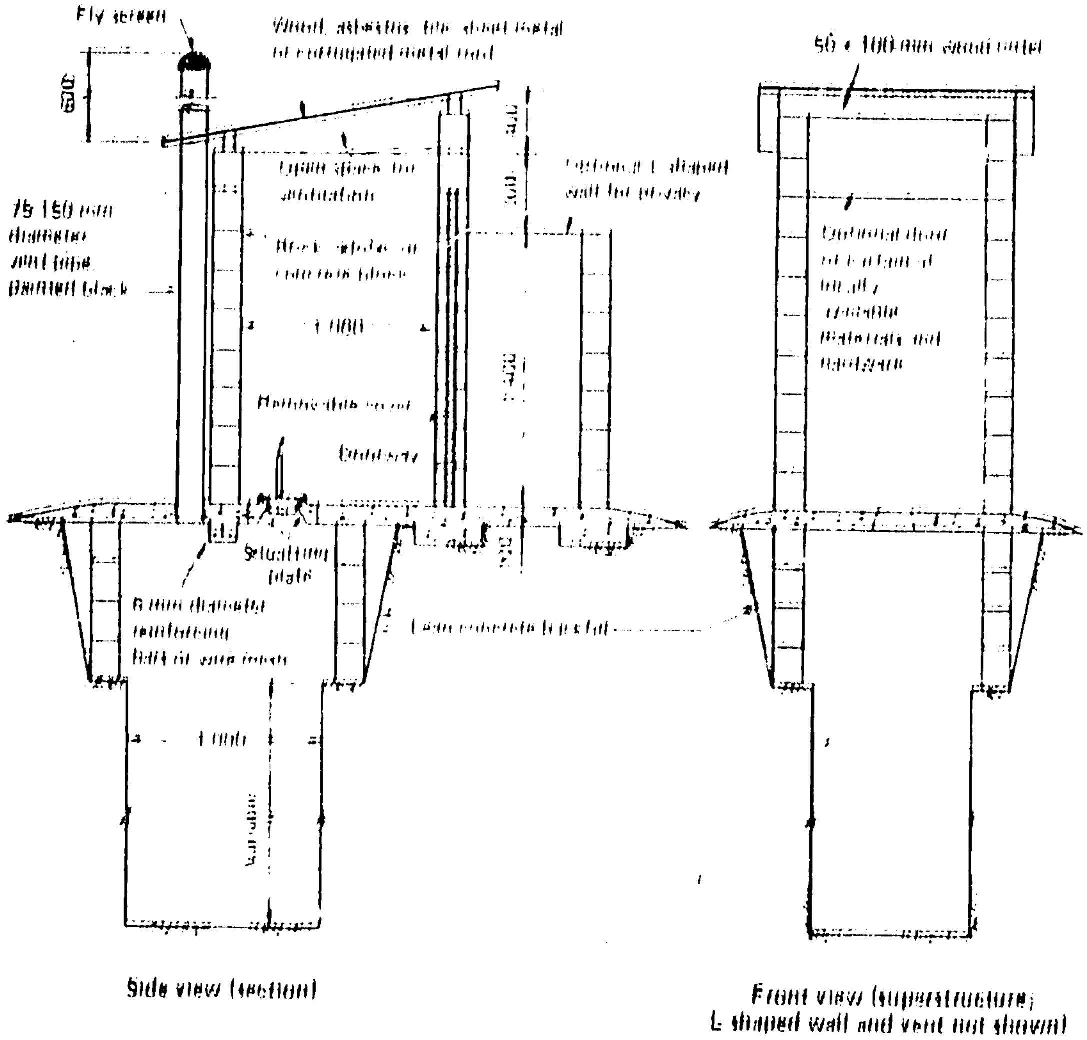
15. MAXIMUM COST PER PERSON

E50/person

Source : Rural Water Supply

Rural Water Supply Engineer

Figure 5 - 2 Ventilated Improved Pit Latrine (measurements in millimeters) (millimeters)



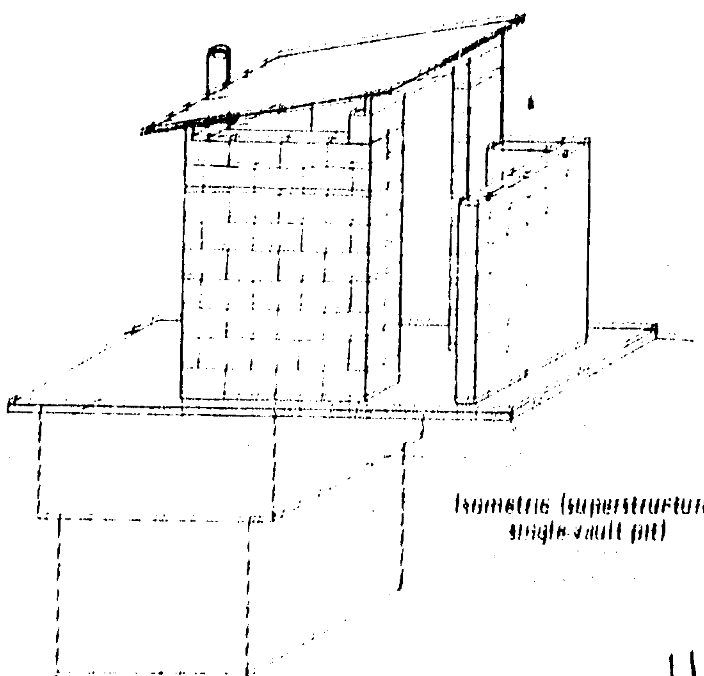
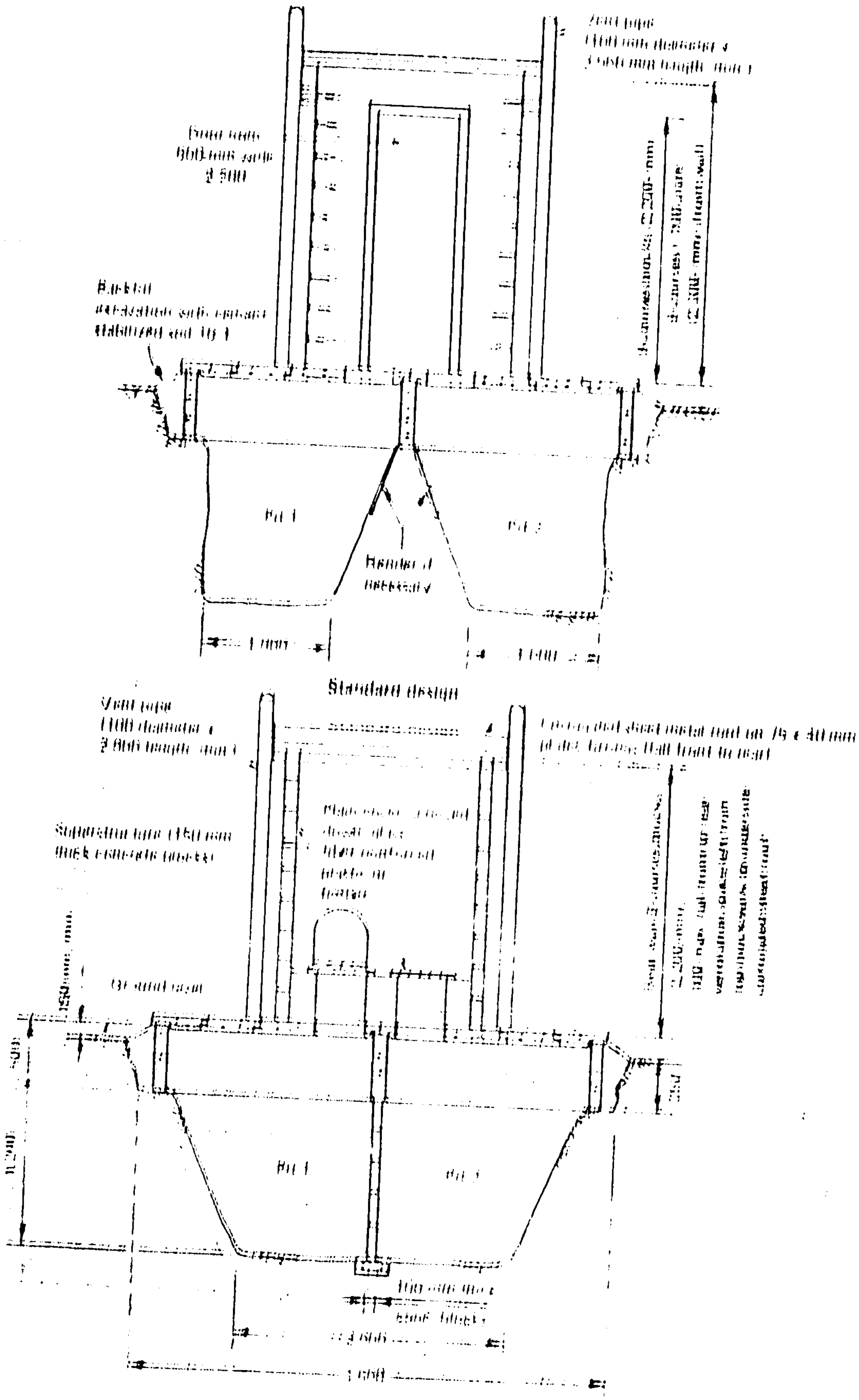


Figure 5-3 Ventilated Improved Double-pit Latrine (millimeters)

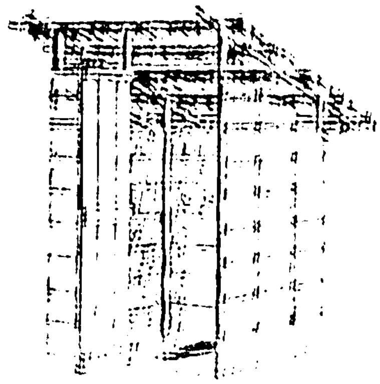


Standard design

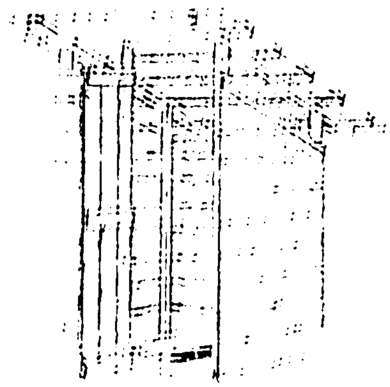
Optional design

Source: Adapted from R. Carroll (1984)

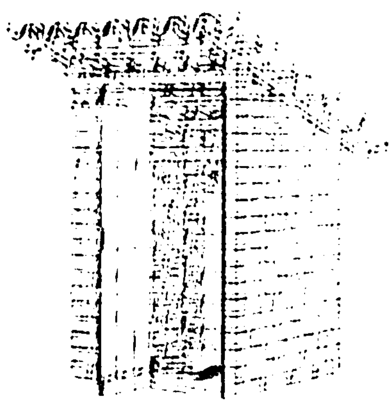
Figure 8-1: Alternative Materials for Latrine Superstructures
Part A:



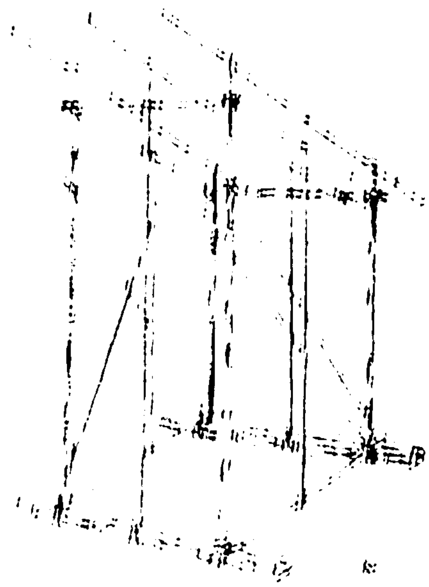
A. Mud and wattle walls and palm thatch roof



B. Timber walls and corrugated iron or asbestos cement roof



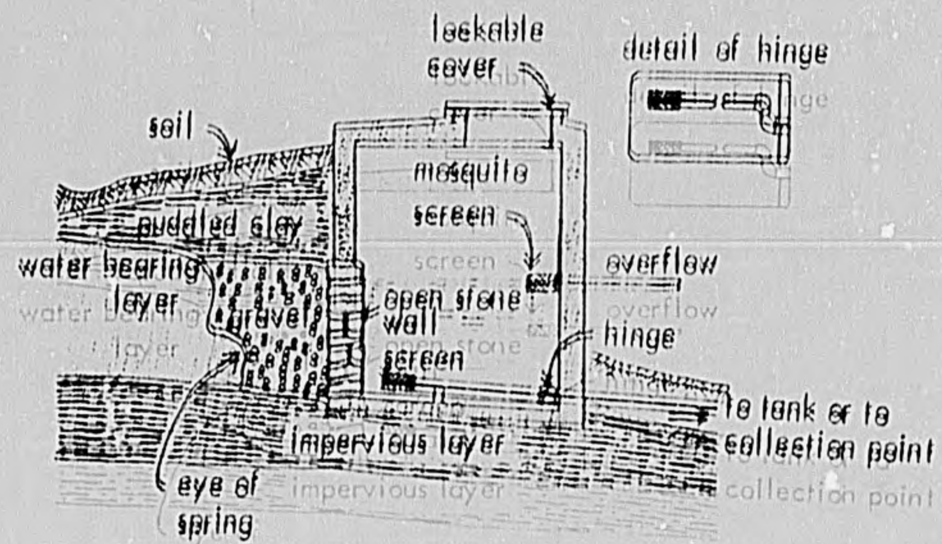
C. Brick walls and tile roof (an alternative is concrete block walls and corrugated iron or asbestos cement roof)



D. Rough cut tree limbs and logs

SPRING PROTECTION

SPRING PROTECTION



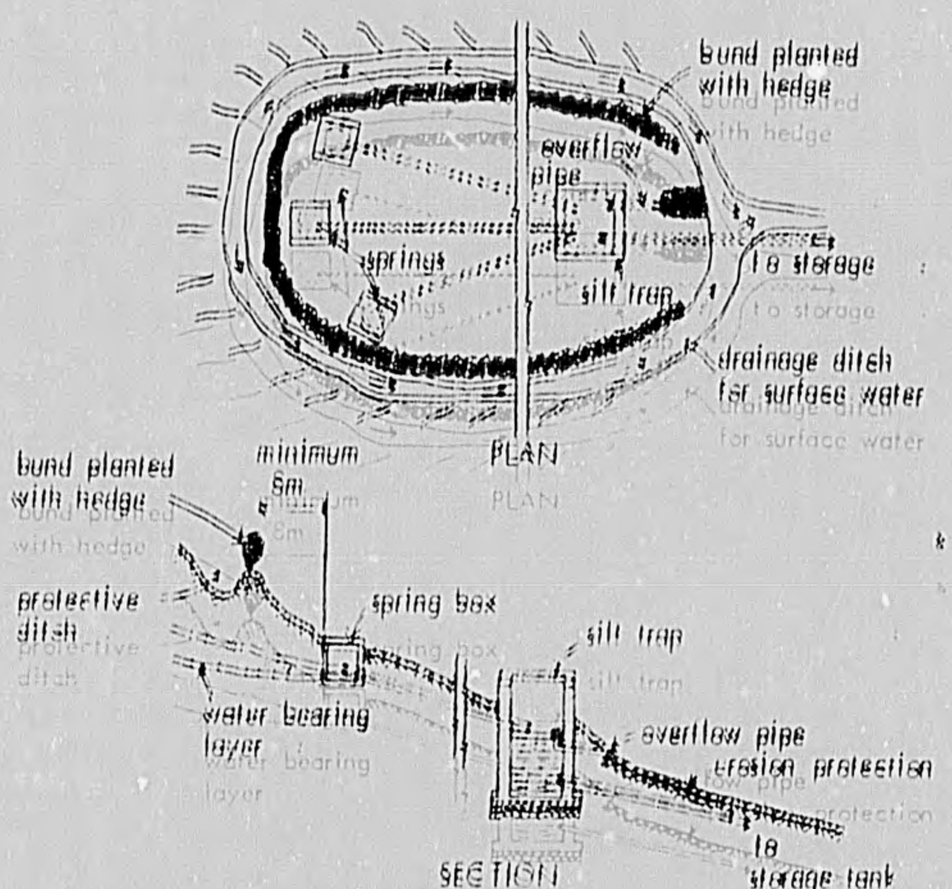
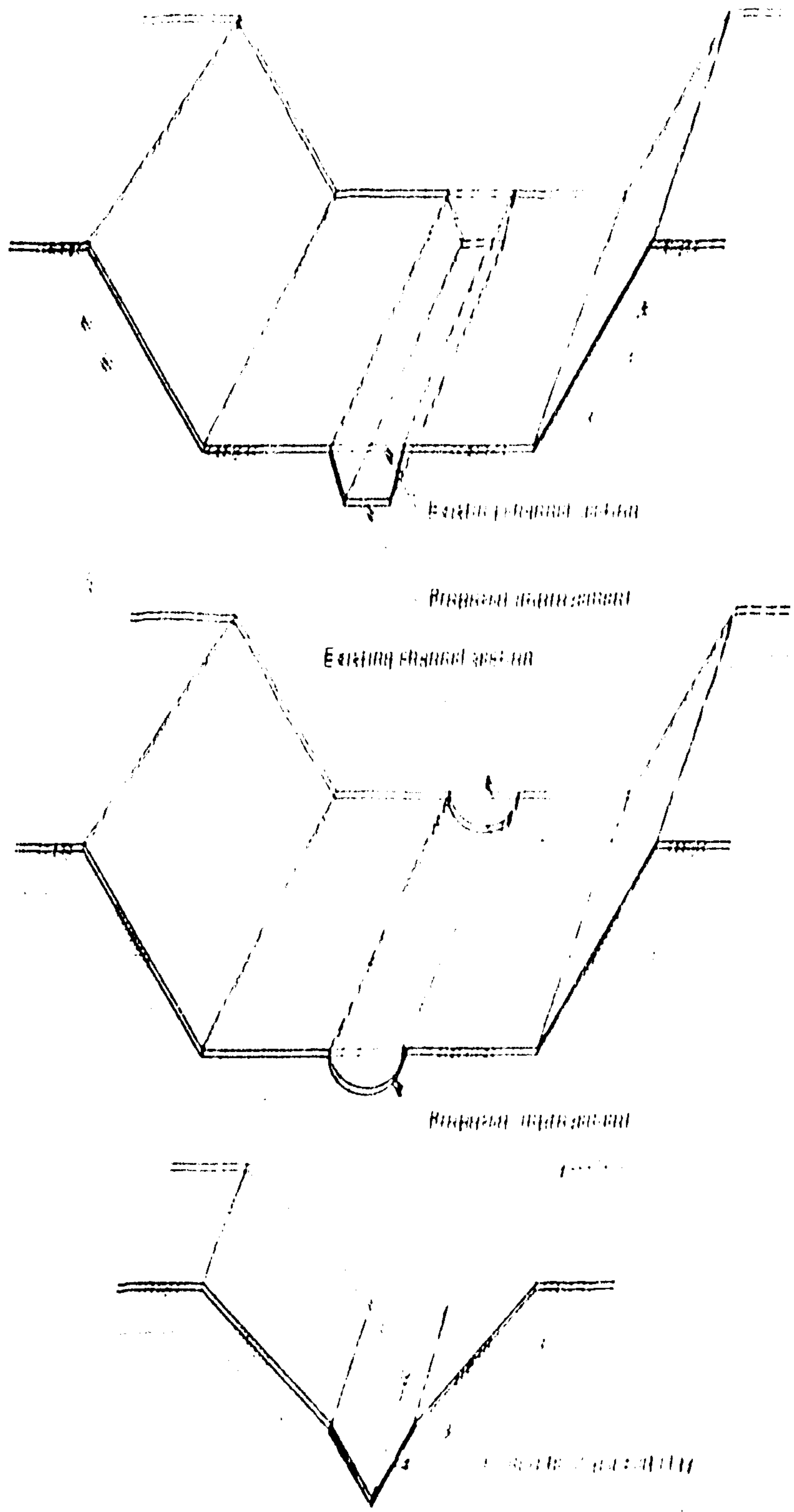


Figure 10-1: Improved Stormwater Channels for Drainage of Sullage



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Best Available Document

SOURCE: Statistics Unit, Ministry of Health

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	TOTAL
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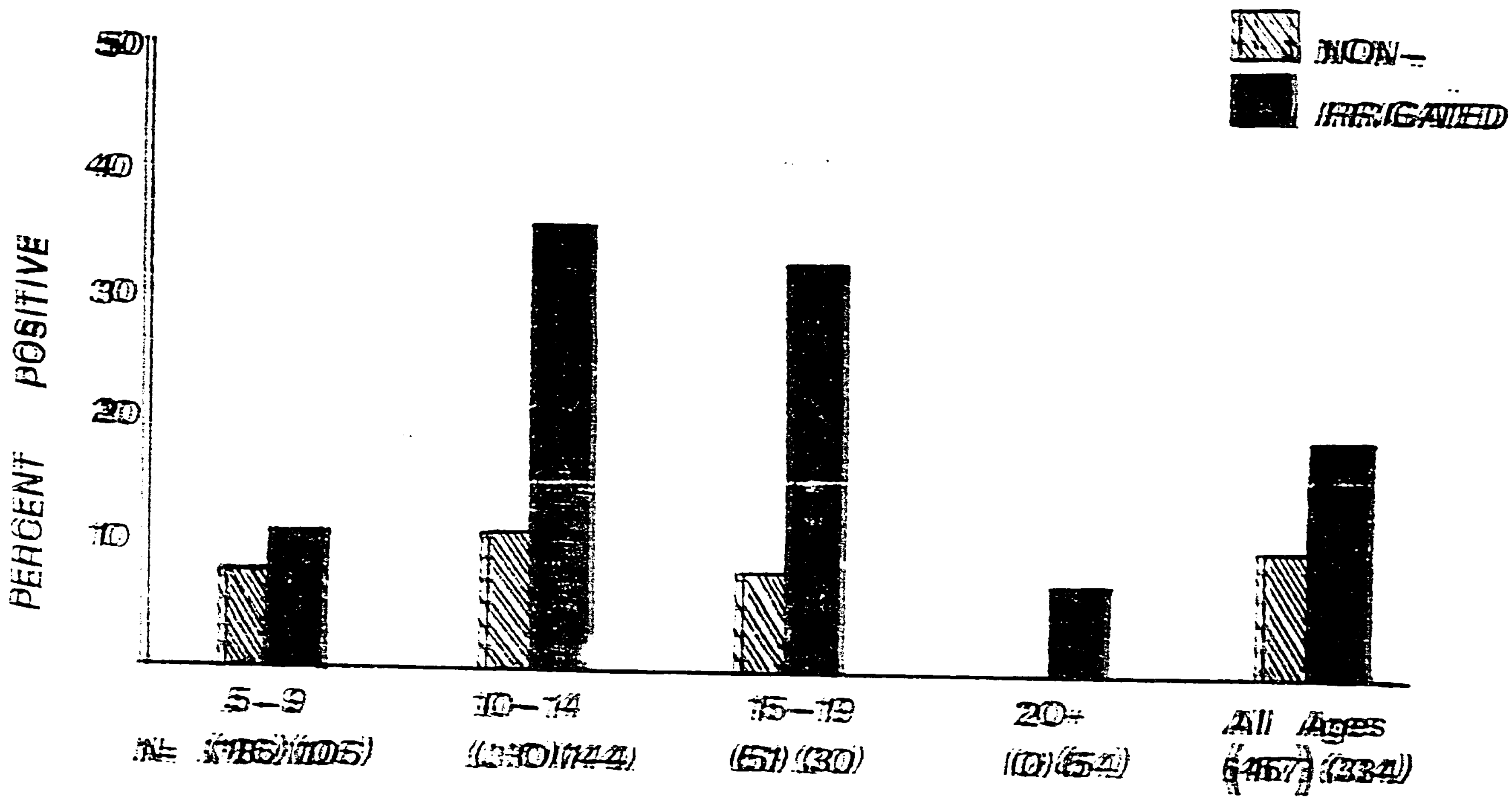
[illegible] delivery modes

AGE DISTRIBUTION OF <u>S. MANSONI</u> IN THE LOWVELD OF SWAZILAND (1982)



Source: MOH Schistosomiasis Unit, Manzini

APPENDIX H6

APPENDIX

CHEMICAL CONTROL OF SNAILS IN SWAZILAND

__Agent:__ Bayluscide (niclosamide)

__Formulation:__ 70% wettable powder

__Solution:__ 10 grams per 10 liters water, hand-weighed, hand-mixed

__Application:__ 20-liter CP3 knapsack sprayer

__Frequency:__ once per year, commencement of transmission season (one-half recommended frequency)

__Toxicity:__ Technical: Acute oral LD_{50} (rat) > 5000 mg/kg

CHEMICAL CONTROL OF MOSQUITOS IN SWAZILAND

A: Adults

Agent: DDT

Formulation: 75% water dispersible powder

Solution: 889 grams per 10 liters water
hand-weighed; hand-mixed

Application: 13-liter Hudson Expert compression sprayer; flat-fan nozzle spray to give 2 g/m² on treated surfaces (walls; ceilings)

Frequency: once per six months; commencing November, if indicated by:

a) night collections

b) space spray; or

c) 10 positive cases from previous year

Toxicity: Technical: Acute Oral LD_{50} (rat) = 113 mg/kg

Acute oral toxicity (man) = 350 mg/kg

B: Larvae

Agent: Abate (temephos)

Formulation: 4 lb/gal; emulsifiable concentrate

Solution: 1 ppm; hand-mixed

Application: 13-liter Hudson Expert compression sprayer; when indicated by identification of larvae

Frequency: once every 10-14 days

Toxicity: Technical: Acute oral LD_{50} (rat) = 2030 mg/kg

ESTIMATED USES OF MAJOR CHEMICALS ON CROPS IN SWAZILAND

CROP & PURPOSE	RECOMMENDED	USED (no: applications x no: Ha/yr)
Maize: 50,000-70,000 ha (82/83)		
Weedicides	Bladex Plus	400
	Eptam/Super	100
	Gardomil	100
	Dual	100
	Lasso	30
	Atrazine	100
Insecticides	Cutworm Thiodan Bait	1000
	Kombat Bait	500
	Dipterex	300
Stalkborer	Dipterex Granules	3000
	DDT 25 EC	3000
	Dipterex 95	500
	Azodrin	300
Cotton: 15,000 ha (82/3); 25,000 ha (80/1)		
Weedicides	Treflan	3000
	Dual	50
	Cotoguard	50
	Fortrol	300
Insecticides	American Bollworm DDT	5000
	Curacron	300
	Red & Spiny Bollworm	2000
	Sevin	
	Sevimol	5000
Red Spider	Dimethoate	15000
	Tedion	1500
Other pests--jassid, stainer, grasshopper, Plusia looper, American, Red, Spiny bollworm, etc:	Ripcord	10000
	Decis	1000
Diseases	Verticillium Wilt	Rotation
	Fusarium Wilt	Rotation
	Rhizoctonia	Captab/PCNB seed treatment

CROP & PURPOSE	RECOMMENDED	USE (no. applications x no. Ha/yr)
Groundnuts: 2,000 ha?		
Fungicides	Daconil	
	Benlate	
Sorghum: 2,000 ha?		
Aphids	Dimethoate	
Stalkborer	Dipterex 2½ G	
Sunflower: 50 ha?		
Potatoes: 500 ha		
Insecticides	Dimethoate	
Aphids	Pirimor	200
Tubermoth	Azodrin	100
Fungicides		
Light Blight	Ridomil MZ	100
Early Blight	Rovral	50
Early & Late Blight	Dithane M45	1000
	Copper Oxychloride	50
	Antracol	50
Tomatoes: 250 ha		
Insecticides		
Aphids	Dimethoate	
	Pirimor	
Red Spider	Dimethoate	
Russet Mite	Kelthane	
American bollworm	Orthene	
Fungicides		
Light Blight	Ridomil MZ	
Early & Late Blight	Dithane	
	Daconil	
	Antracol	
	Copper Oxycloride	
Cabbages: 400 ha		
Insecticides		
Diamondback moth	Orthene	
	Dipterex	
	Malathion	
Aphids	Dimethoate	
Cucurbits:		
Insecticides		
Pumpkin Fly	Lebaycid	
Fungicides		
Powdery Mildew	Bayleton	
Downy Mildew	Dithane M45	
Powdery & Downy Mildew	Daconil	

1V

CHEMICALS AVAILABLE FOR AGRICULTURAL USE IN SWAZILAND

Farm Chemicals Limited
SWAKI Group Co.
Tikhuba Street
P.O. Box 158
Manzini (Phone: 52201)

TRADE NAME	COMMON NAME
Acarol 500 EC	Bromopropylate
Acrex 43% EC	Dinobuton
Acricid 40% MO	Binapacryl
Actril DS	2,4-D + IOXYNIL
Afalon 50% WP	Linuron
Akar 50% EC	Chlorobenzilate
Ametrex 500	see Gesapax
Antracol 70% WP	Propineb
Arkotine 25% MO	D.D.T.
Atrazine 500 FW	see also Gesaprim
Agral 90	
Atrazine 80% WP	Atrazine
Avigard 50% EC	Mercaptothion
Azodrin 40 WSC	Monocrotophos
Azodrin 25 ULV	Monocrotophos
Basagran	Bendioxide
Basamid	Dazomet
Basfapon	Proprop
Bayfolan	3:2:1(22) Foliar
Baygon 20% EC	Propoxur
Baygon Aerosol Surface Spray	Propoxur (Green)
Bayleton 5% WP	Triadimefon
Bayleton EC	
Bayleton 25% WP	
Benlate	Benomyl
Benzilan 50% EC	see Akar 50% EC
Berelex Tabs.	Gibberelic Acid
Bexadust	see Lindane
B.H.C.	see Double Benhe
Birsol	see Arkotine
Bladex Plus 5 SC	Cyanazine/ Atrazine
Bladex 5 SC	see Fortrol
Blue Cross	see Malathion 1½% I
Brushkiller	see 2,4,5-T
Bravo 500 SC	Chlorothalonil
Calcium Arsenate	Calcium Arsenate
Carbaryl 5% Dust	Carbaryl
Celphos	see Detia
Cidial	see Tanone
Citowett	Wetter/Sticker
Combi Fluid 6 (U 46)	2,4-D + M
Copper Oxychloride 50% WP	Copper Oxychlor
Cotogard	Fluometuron + Prometryne

TRADE NAME	COMMON NAME
Cotoran 80 WP	Fluometuron
Cotnion 35 EC	Azinphos Ethyl
Cotnion 35 ULV	Azinphos Ethyl
Curacron	Profenofos
Cupravit 50% WP	Copper Oxy-chloride
Curaterr 10% G	Carbofuran
Daconate	MSMA
Daconil 2787	Chlorothalonil
Daconil 720 SC	
Dacthal W-75	Chlorthal
Dalapon	see Basfapon
Dazzel	see Kyazinon
D.D.T. 75% WP	D.D.T.
D.D.T. 30% ULV	D.D.T.
D.D.T. 40% ULV	D.D.T.
Dedevap	Dichlorvos
Def	Defoliant
Detia	Aluminum Phos-phate
Diazinon	see Kayazinon
Dieldrex 15% EC	Dieldrin
Dieldrin 50% WP	Dieldrin
Digermin 48% EC	Trifluralin
Dimethoate 40 EC	Dimethoate
Dimethoate 40 ULV	Dimethoate
Dimethoate 20 WP	see Rogue
Dipterex 2½% G	Trichlorfon
Dipterex 95 SP	Trichlorfon
Disyston 5% G	Disulfoton
Dithane M 45 WP	Mancozeb
Diuron 5 SC	Diuron
Diuron 80% WP	Diuron
Double Benhex	Gamma - B.H.C.
Dopax 500 FW	Metolachlor Ametryne
Dowfume	see Methal Bromide
Dual 720 EC	Metolachlor
E.D.B. 93.2	Ethylene Di-B
E.D.B. 4.5	Ethylene Di-B
Endosulfan 50% WP	Endosulfan
Endosulfan 35% ULV	Endosulfan
Endosulfan 30% ULV	Endosulfan
Eptam Super	EPTC
Ethrel	Ethephon
Faneron 50 WP	Bromofenoxin
Ferrous Sulphate	Ferrous Sulphate
Folidol 25% WP	Parathion
Folidol 50% EC	Parathion
Folimat 80% EC	Omethoate
Fortrol 5 SC	Cyanazine
Formex	
Gardomil 500 FW	Terbuthylazine Metalachlor

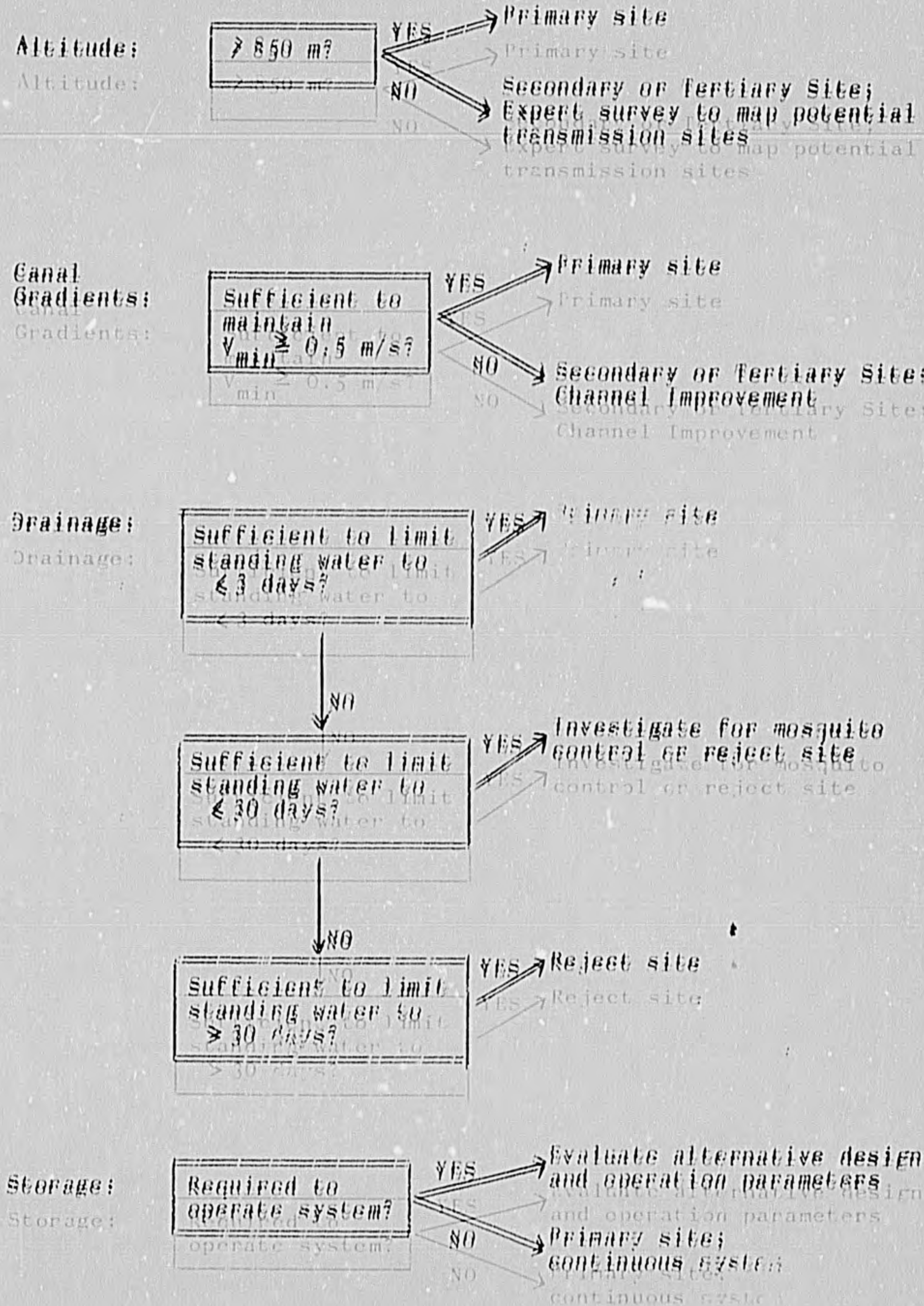
TRADE NAME	COMMON NAME
Gardona 50% WP	Tetrachlorvinphos
Gesapax 500 FW	Ametryne
Gesagram 500 Flowable	Atrazine & Metolachlor
Gesagram 12½ G	Atrazine & Metolachlor
Gesaprim 10 G	Atrazine
Gesaprim 500 FW	see Atranex 50
Gesaprim 80 WP	see Atranex 80
Gramoxone	Paraquat
Gramuron	Paraquat + Di
Gusathion A 35% EC	see Cotnion 35
Hostathion 40% EC	Triazophos
Hyvar X	Bromacil
Kaptan 75% SD	
Kaptan 75% WP	see Merpan
Karbadust 5%	see Carbaryl Dust
Karmex	see Diuron
Kelthane AP	Dicofol
Kelthane MF	Dicofol
K.O.P. 40:40	see 40/40
Kupmite	see Akar 50 EC
Kyazinon 27.5 EC	Diazinon
Lannate WP	Methomyl
Lannate 20 L	Methomyl
Lasso 384 EC	Alachlor

TRADE NAME	COMMON NAME
Lebaycid 50% EC	Fenthion
Lindane 0.6% Dust	Gamma B.H.C.
Magnesium Sulphate	MgSO 4
Magnit	MgSO 3
Malathion B	Mercaptothion
Malathion 50% EC	Mercaptothion
Malathion 1½% PG Dust	Mercaptothion
Malathion 25% WP	Mercaptothion
Malathion ULV	Mercaptothion
Manganese Sulphate	MnSO4
M.C.P.A. 400 g/litre	M.C.P.A.
Merpan 75% WP	Captan
Metasystox (R) 25% EC	Oxydemeton Methyl
Methyl Bromide	Methyl Bromide
Micronol	Anti-Evaporant Oil
Minifume	E.D.B. Applicato
Monocrotophos	see Azodrin
Morestan 25% WP	Chinomethionate
Nemacur 40% EC	Phenamiphos
Nuvacron 40% EC	see Azodrin 40 %

TRADE NAME	COMMON NAME
Orchex N 695	Narrow Range
Orthene	Acephate
Parathion	see Folidol
P.C.N.B. 75% WP	Quintozene
Perfekthion	see Dimethoate
Phosdrin 2 EC	Mevinphos
Phostoxin	see Detia
Phyomone	Naphthaleneacetic
Pirimor 50% WP	Pirimicarb
Pix	Cotton Growth Regulant
Planavin 4 SC	Nitralin
Pymist 40 EC	Pyrethrin/Piperonyl
Red Triangle	see Lindane 0.6% D
Ridomil MZ	Metaxanin + Mancozeb
Ridomel 5 G	
Rinoxin L.C.	Warfarin
Ripcord 20	Cypermethrin
Rogor	see Dimethoate
Roque 20 WP	Dimethoate
Roundup	Glyphosate
Rovral 50 WP	
Roxion	see Dimethoate
Sencor 70% WP	Metribuzin
Semeron 25 WP	Desmetryn
Sevimol 30	Carbaryl/Molasses
Sevin 85 S	Carbaryl
Sevin 5% Dust	see Carbaryl 5% Dust
Sodium Molybdate	
Solubor	Boron
Spredwett	Wetter/Sticker
Staley's Sauce	Fruit Fly Attractant
Stam LV 10	Propanil
Snytok 10 G	Sodium Fluosil
Surcopur	Propanil
Sumifly	Fly Spray
Tamaron 600	Methamidophos
Tanone 50 L	Phenthoate
Tedion 8.0% EC	Tetradifon
Temik	Aldicarb
Thiodan 25 ULV	Endosulfan
Thiodan 35% MO	see also Thionex 35 E
Thionex 35% EC	Endosulfan
Thiodan Cut Worm Bait	Endosulfan
Tordon 225	Picloram + 2,4,5-T
Torque 50% WP	Fenbutatin
Torque 55 SC	Fenbutatin
Treflan 48 EC	Trifluralin
Triflurex	see also Digermin 48% EC
U 46	see Combi Fluid (

TRADE NAME	COMMON NAME
Ultracide 40% EC	Methidathion
Ustilan 70% WP	sulfodiazol
Ustilan 10 G	sulfodiazol
Zinc Oxide	ZnO
Zinc Sulphate	Zn SO4
2,4-D Amine 7:2	2,4-D
2,4,5-T 720 g/ Litre	
2,4,5-T 480 g/ Litre	
2,4,5-T 480 g/ Litre	
40/40	D.D.T. Carbax

HEALTH-BASED SITE SELECTION CRITERIA



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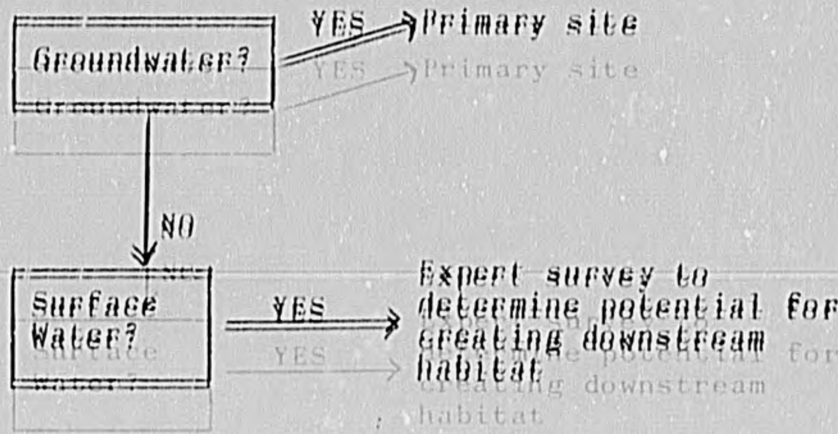

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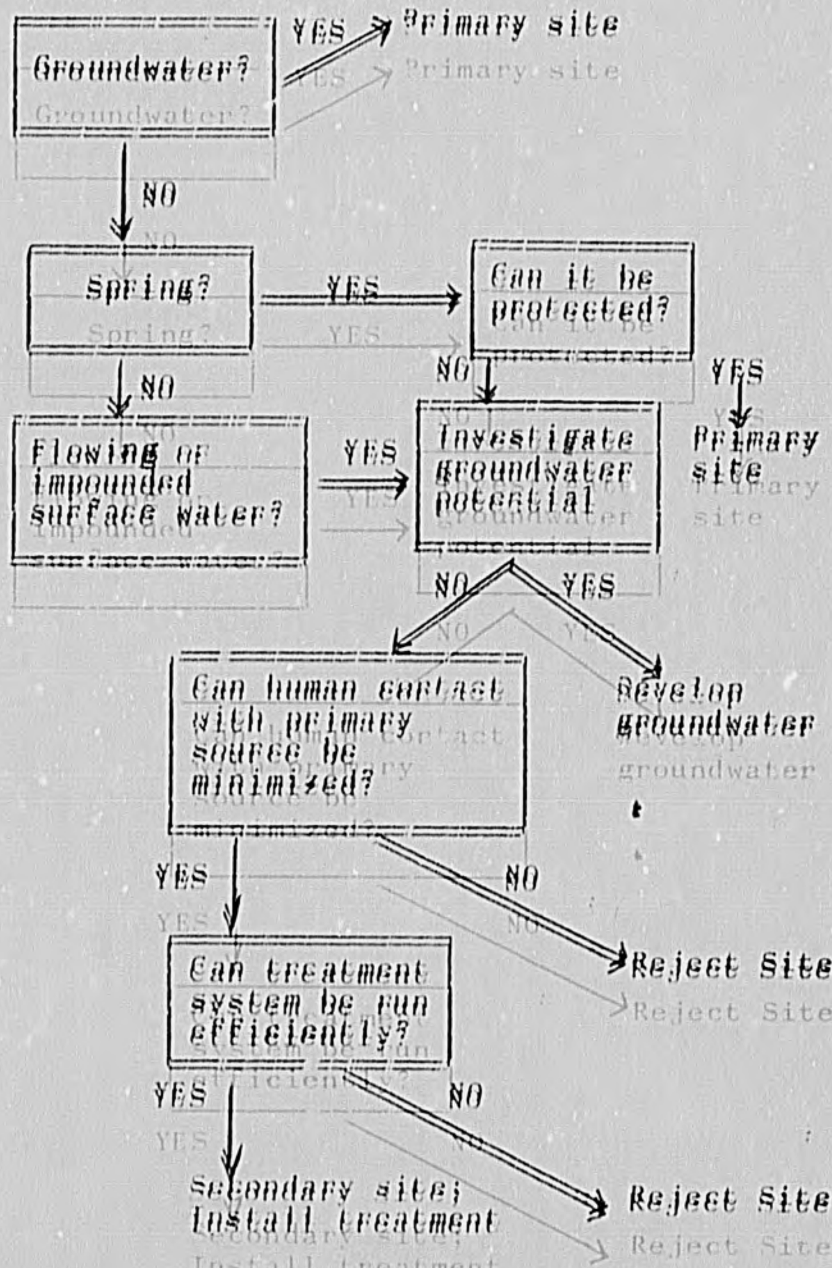
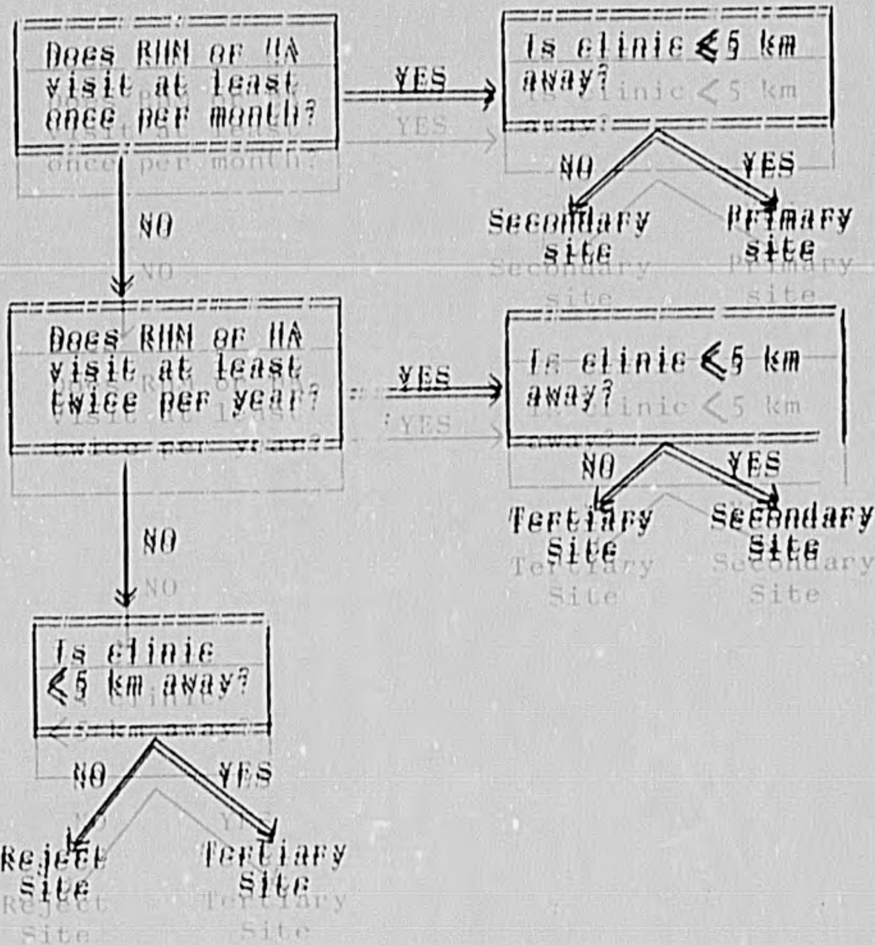
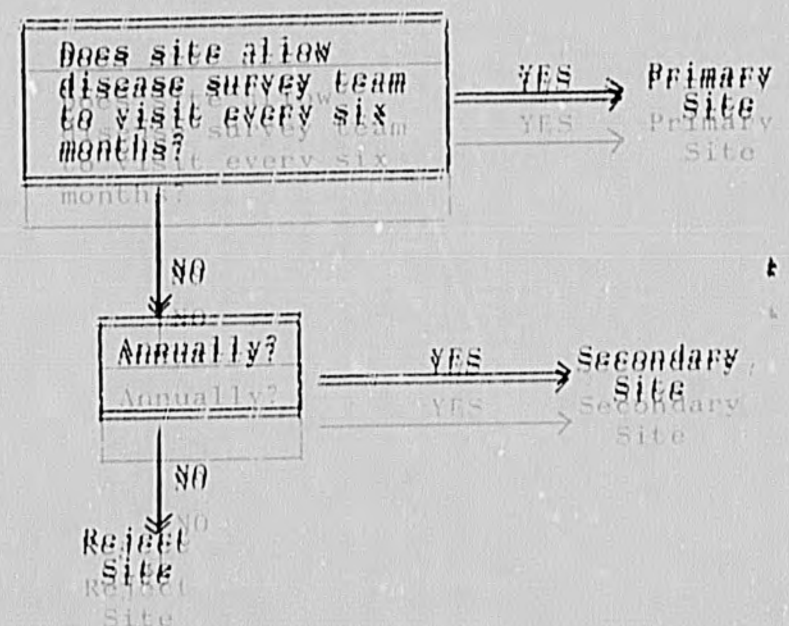


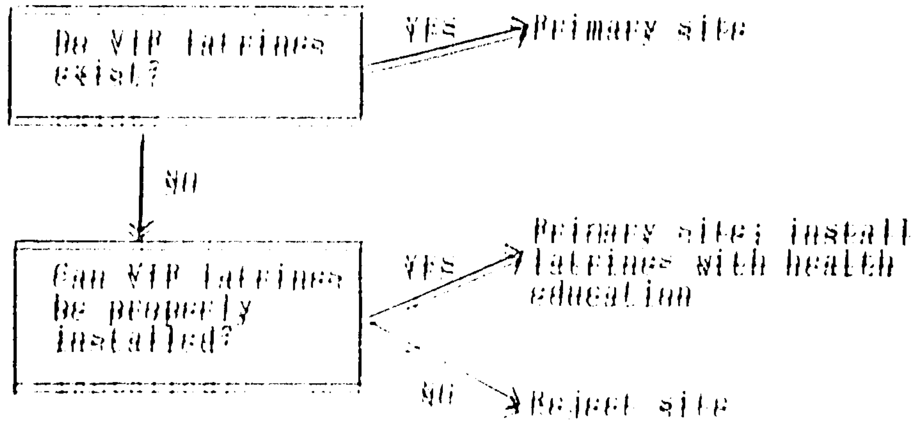
Access to health extension services:



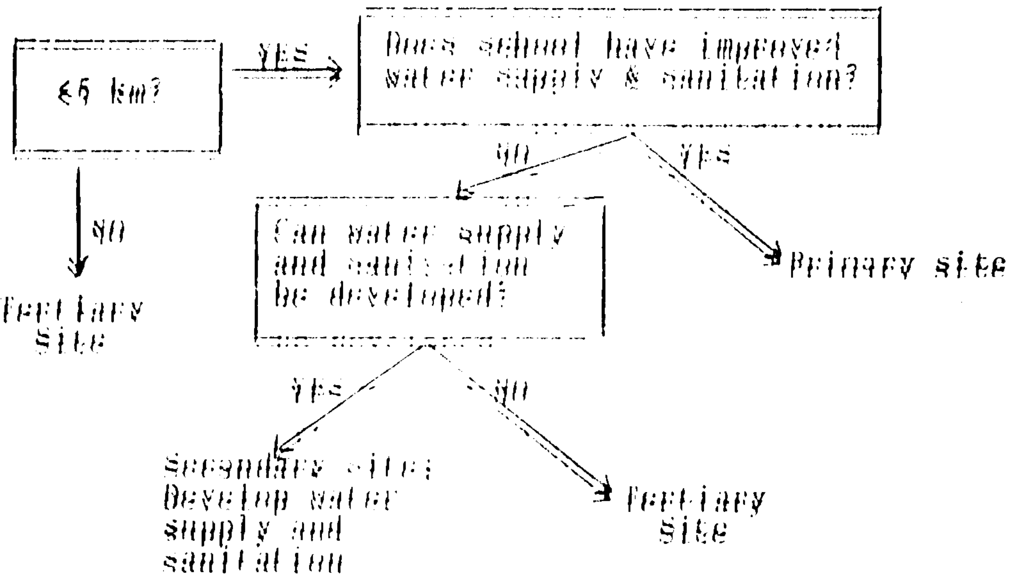
Access to technical monitoring:



Sanitation:



Access to schools?



HEALTH-BASED DESIGN CRITERIA

A: Minimum Considerations (If meeting all "Primary site" conditions)

1: <u>General</u>

==Development of adequate domestic water supply according to Ministry of Works criteria and setting up of local capability to operate and maintain

==Development of adequate sanitation technology (VIP latrines) together with sanitation education and oral rehydration program; according to Ministry of Health criteria:

2: <u>Specific</u> (Middle and lowveld only)

==Main irrigation channels should have limited access (fe[illegible] appropriate); major water-contact points [illegible] be Parshall-flumed and lined with trapezoidal [illegible]tions

==We[illegible] vegetation should be kept clear 100 m u[illegible] 50 m downstream of contact points on ma[illegible]

==Separate bathing facilities should be provided for children; can be river or canal diversion with unsubmerged pipe inlet (screened with mosquito mesh) to 6 m diameter lined reservoir

MAINTENANCE: Drain and clean once per month

==Bathing facilities should be provided at schools where possible

==All secondary canals should be lined with concrete trapezoidal sections

==All water control in canals should be by manual gate valves, rather than weirs; open sumps should be eliminated

==All canals and delivery structures should be maintained by removing sediment once per month

==Separate watering troughs should be provided for animals

==Public water taps should have large drainage aprons (3m diameter), laundering blocks, and should be fenced from animals

B: Additional Considerations (for relevant "Secondary" and "Tertiary Site" parameters:)

==Where $V_{min} \leq 0.5$ m/sec for trapezoidal sections, straighten canal, increase hydraulic radius (semi-circular sections) or install piping

==Storage reservoirs to be fenced (in conjunction with alternative domestic water supply under (A) above)

==Reservoir shorelines should be straight and on the maximum structurally stable slope

==Vegetation should be removed from shorelines on a monthly basis

==Drawdown and filling cycles should be designed to operate on a 5-10 day period

==Syphons for water level control should be limited to small reservoirs

==Seepage problems from dams should be eliminated by draining and lining with appropriate materials

==Reservoir outlet structures should be placed as far as possible from shorelines, in the consideration of hydraulic characteristics of the facility

SAMPLE IMPLEMENTATION MONITORING CHECKLIST

Site:

Date:

Reviewer:

Site Selection Criteria

	Site Classification			Comments
	Primary	Secondary	Tertiary	
Altitude				
Canal Gradients				
Drainage				
Storage				
Irrigation Water Supply				
Domestic Water Supply				
Sanitation				
Access to Schools				
Access to Health Extension Services				

	Site Classification			Comments
	Primary	Secondary	Tertiary	
Access to Health Extension Services				
Access to Schools				
Access to Technical Monitoring				

Special Surveys Required to Evaluate Site Potential

	No	Yes (attach report)
Vector transmission sites		
Mosquito Control		
Snail Control		
Groundwater survey		

System Design and Implementation (Appropriate drawings should be attached)

	Type Work	Date Commenced	Date Completed	Approv
Main canals				
Bathing facilities				
Watering troughs				
Public taps				
Secondary canals				
Reservoirs				
Fencing				
Shorelines				
Drawdown				

	Type Work	Date Commenced	Date Completed	Approval
Reservoirs (continued)				
Lining				
Outlets				
Inlets				
Domestic Water Supply				
Sanitation				

Operation & Maintenance

	Date Visited	Comments
Bathing Facilities	________	
	________	
	________	
Treatment System	________	
	________	
	________	
Public Taps	________	
	________	
	________	
Main Canals	________	
	________	
	________	
Secondary Canals	________	
	________	
	________	
Reservoirs	________	
	________	
	________	

Ministry Certifications

Ministry of Health

Ministry of Works

Ministry of Agriculture

HEALTH-RELATED TRAINING REQUIREMENTS

A. Topics

--elementary map reading, including topography

--sketching and orthogonal drawing

--siting levels

--pipe laying

--reading scales

--stream flow measurements using weirs

--masonry skills, such as mixing cement and concrete (for latrines & spring boxes)

--elementary carpentry

--elementary plumbing (e.g., changing washers and valve seats)

--correct siting of pit latrines

--simple analysis of soil structure and moisture-holding capacity

--visual survey procedures and identification of host snails and vector mosquitos

--simple water quality testing

--community relations and motivation

B. Individuals

==extension staff of MOH and MOW

==school teachers and headmasters

==high school students

==college students

C. Methods and Timing

==Weekend workshops for students (local)

==One/two week workshops for existing staff (District level)

==Long-term weekly seminars for school teachers (Central level)

==All programs should issue certificates of completion and other merit incentives

==Private sector sponsorship where appropriate

SELECTED COST DATA

COST ESTIMATES ([illegible])

RURAL WATER SUPPLY PROJECTS

ITEM	UNIT COST (E)
Chlorinator	300
Filtration systems 1 l/s	3000
2 l/s	4500
15 m³ concrete reservoir	2700
30 m³ " "	4200
50 m³ " "	5300
70 m³	5500
90 m³	7500
200 m³ Steel tank	21000
9 m³ G.I. Tank plus 2 Mag Bars	450
4 m³ Tank stand	900
6 m³ Tank Stand	1200
8 m³ Tank Stand	1500
Boreholes	2000
Pipe + Trench and Place	
P.V.C.	
110 mm Cl12	13.80
110 mm Cl9	12.40
110 mm Cl6	9.20
110 mm Cl4	8.00
90 mm Cl12	11.25
90 mm Cl9	9.20
90 mm Cl6	7.50
90 mm Cl4	7.10
75 mm Cl12	7.80
75 mm Cl9	6.70
75 mm Cl6	6.00
75 mm Cl4	5.60
63 mm Cl12	6.65
63 mm Cl9	6.45
63 mm Cl6	5.10
63 mm Cl4	4.75
50 mm Cl12	4.80
50 mm Cl9	5.50
50 mm Cl6	4.35
50 mm Cl4	4.20
40 mm Cl[illegible]	4.50
40 mm Cl[illegible]	4.00
[illegible] mm [illegible]	[illegible]

ITEM	UNIT COST (£)
Polyethylene	
32 mm s112	4,20
32 mm c10	3,90
32 mm c16	3,30
25 mm s112	3,50
25 mm s10	3,80
G.I.P.	
3"	13,50
2 1/2"	11,75
2"	9,75
1 1/2"	8,25
1 1/4"	6,10
1"	5,65
3/4"	4,85
PRV	675
Stand pipes and drains	195
Pumphouse	900
Pump and engine	3800
Contingencies 10%	
Overhead 8%	
Additional Transport if over 50 km from station. 5%	

[illegible]

GIBB HAWKINS AND PARTNERS (SWAZILAND)
CONSULTING ENGINEERS

INCORPORATING
SIR ALEXANDER GIBB & PARTNERS
HAWKINS HAWKINS AND OSBORN

REPRESENTATIVE PARTNERS

R O HAWKINS — Pr Eng BSc FICE FSAICE
[illegible] SCOTT — Pr Eng [illegible]
[illegible] — Pr Eng BSc [illegible] FICE
[illegible] — Pr Eng BSc FSAICE
[illegible] EASTWOOD — Pr Eng [illegible] FSAICE [illegible]

ASSOCIATES

[illegible] — Pr Eng BSc MICE [illegible]
[illegible] — Pr Eng BSc MICE

RESIDENT REPRESENTATIVE

[illegible] RICHARDS — BSc Eng MICE

P.O. BOX 1038
MBABANE
SWAZILAND

EMPIRE BUILDING
ALLISTER MILLER STREET
MBABANE
TELEPHONES: [illegible]
TELEX: [illegible]

PLEASE REFER TO

S2/E/301A

21 January 1983

U.S. Aid Department, United States Agency for International Development,
U.S. Embassy,
Private Bag,
MBABANE.

Attention : Mr. Daly

Dear Sir,

COST ESTIMATE FOR GEOPHYSICAL SURVEYING, DRILLING AND TESTING OF BOREHOLES

Further to enquiries regarding the above made by your Mr. F.P. Carrol, we enclose the following cost estimate :

Geophysical Survey

The amount of time taken to complete the geophysical survey for a particular borehole is variable depending on the geology and associated groundwater potential of the area being considered.

Generally borehole surveys involve one or two days work in the field. Based on a survey of one day duration the following costs would apply;

Engineering Geologist 8 hours @ E25=00	E 200=00
Hire of Electro-Resistivity equipment @ E50=00/day	E 50=00
Travelling = approximately 200 km @ 30c/km	E 60=00
Preparation of report	E 120=00
TOTAL FOR SURVEY	E 430=00

[illegible]

Drilling

The costs are based on the drilling of a borehole 45 m deep. In certain cases it may be necessary to drill a series of boreholes dependant upon the results of the geophysical survey and the drilling of the initial holes.

Drilling of borehole 45 m depth @ E28=00/m	E 1 260=00
Supply and install 35 m (approx.) of casing @ E17=50/m	E 437=50
Travelling 100 km @ E3=00/km of Drilling Team	E 300=00
Supervision of Drilling by Engineering Geologist 8 hrs @ E25=00/hr	E 200=00
Travelling = approximately 200 km @ 30c/km	E 60=00
TOTAL FOR DRILLING	E 2 257=50

Testing

Testing of the yield per borehole :

Install and remove pump	E 200=00
Eight hour pumping test and two hour recovery test = 10 hours @ E18=00/hr	E 180=00
Travelling for testing team 100 km @ E1=00/km	E 100=00
	E 480=00

Summary

Geophysical Survey	E 430=00
Drilling of Borehole	E 2 257=50
Testing of Borehole	E 480=00
TOTAL	E 3 167=50

The above cost estimate is subject to variation being dependant on the extent of the geophysical survey and amount of drilling found to be necessary and which in turn is related to the geological condition of the area under consideration.

However, the estimate provides a good basis for determining the costs involved in a borehole survey. Our Engineering Geologist is very experienced in this type of work having carried out many assignments of this nature for numerous clients throughout Swaziland and the firm could provide all the necessary services required for carrying out a detailed survey.

Should you require any further information, please do not hesitate to contact us.

Yours faithfully,

GIBB HAWKINS AND PARTNERS (SWAZILAND)