Working Paper No. 7
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An Investigation of Aquaculture Potential in Small-Scale Farmer-Managed Irrigation Systems of Raichur District, Karnataka, India

Aquaculture in Small-Scale Farmer-Managed Irrigation Systems
Funded by DFID Aquaculture Research Programme

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List of Working Papers

Project Summary Report

1. Raichur District: Site for a Study of Aquaculture Development in the Semi-arid Tropics

2. Methods for Participatory Information Gathering and Analysis

3. Socio-economic Analysis of Villages in Relation to Aquaculture Potential in Raichur District, Karnataka, India
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Project background

The arid and semi-arid tropics are areas in urgent need of development. As a home to a large proportion of the world's poor these regions face a future of scarcity of food and insufficient water for consumption and irrigation of crops. It has been predicted that India and Sri Lanka will face a fresh-water crisis in the near future, and as much water is currently wasted due to inadequate management and conservation practices there is a need for more integrated approaches to water management. The majority of India's surface water bodies are used primarily for irrigation. Although large-scale irrigation systems cover more surface area and supply a greater area of farmland, more farmers are dependent on small-scale systems for their daily livelihood. Irrigation systems are often very inefficient water distribution systems, and studies suggest that the efficiency of water use could be improved. The integration of aquaculture (which can be non-consumptive in terms of water use) has the potential to increase food production and improve the efficiency of the use of small-scale irrigation water resource.

These Working Papers are the first stage of the research project 'Small-scale farmer-managed aquaculture in engineered water systems' (DFID project R7064). The project aims to investigate the potential for integration of aquaculture into small-scale farmer-managed irrigation systems in arid and sem i-arid regions of India and Sri Lanka. Intended beneficiaries include the rural poor, which in India belong to the Scheduled Castes (SCs)[1] and Scheduled Tribes (STs)[2]. This part of the project focuses on Karnataka State on the south west of the Indian peninsular.

During the research, the economic and technical feasibility and the social acceptability of the production of fish in such systems of arid and semi-arid regions of Karnataka were investigated. Field research took place from 6 April to 21 May 1998 and included a `Rapid Rural Appraisal' of four villages in. Raichur District, Karnataka, and semi-structured interviews with representatives from the Government Department of Fisheries, marketing organisations, academics and other relevant institutional sectors within the state.

All fieldwork was undertaken in collaboration with the NGO Samuha, an organisation undertaking wide-ranging activities in the arid and semi-arid areas of Karnataka State. Samuha has extensive experience within participatory development and its initiatives range across health, disabilities, women's development, HIV/AIDS, education, animal husbandry, drinking water and sanitation, irrigation and watershed development (Pradeep, 1994). The majority of the work of Samuha is carried out in the districts of Koppal and Raichur with a smaller project in Bangalore. The activities of Samuha are supported by a number of bodies: ActionAid; OXFAM; the Swiss Development Cooperation; the Government of Karnataka and the Government of India as well as individual donors.

The results and analysis are presented in the ten Working Papers listed above. For an overview of the content of each of the Working Papers, see the Summary Report. This series of working papers have been produced principally as a resource for a stakeholder workshop to be held in Coimbatore, 19th - 20'' November 1998. Conclusions and the research agenda are therefore preliminary.

[1] SCs: **lower castes identified by the Indian government as a means of classifying castes for the allocation of benefits.**[2] STs: **all tribals. SCs and STs together constitute the `socially and educationally backward classes of citizens'. The terms form the basis for policies of protection and positive discrimination.**

Glossary

CIFA	Central Institute for Freshwater Aquaculture
DFID	Department for International Development (formerly ODA)
DoF	Department of Fisheries
Kharif	The first growing season (June-October)
NGO	Non-governmental Organisation
ODA	Overseas Development Agency (now DFID)
PRA	Participatory Rural Appraisal
Rabi	The second growing season (November-March)
RRA	Rapid Rural AppraisalRs Indian unit of currency
SC	Scheduled Caste
ST	Scheduled Tribe
1 ha	2.4 acres

Summary

1. In this Working Paper, the different types of small-scale farmer managed irrigation systems of Raichur District, Karnataka State, India, are categorised and their aquaculture potential is assessed. Available water bodies were identified from semi-structured interviews and field visits with the NGO Samuha. Water quality parameters including salinity, phosphate, alkalinity, turbidity, pH, temperature and aluminium were measured. Participatory appraisal was carried out in project villages, and key parameters regarding the use of the water resources and the perceived constraints to aquaculture were identified for subsequent ranking and scoring exercises with farmers.

2. Six types of water bodies used as small-scale farmer managed irrigation were identified: ravine reclamation structures, check dams, nala bunds, irrigation ponds, open wells and farm ponds. No ravine reclamation structures or nala bunds were present in the project villages. Open. wells and irrigation ponds are supplied principally from ground water sources and are perennial, whilst farm ponds and check dams are rainwater harvesting devices and usually seasonal. Water exchange is high and easily manageable in open wells and irrigation ponds and relatively stagnant in farm ponds and check dams (which are primarily ground water recharge structures and soil harvesting structures respectively).

3. Water quality parameters potentially constraining aquaculture are temperature (at the hottest time of the year) and turbidity. A significant difference was found between deeper open wells (mean temperature 30.5°C) and surface water bodies (i.e. farm ponds, irrigation ponds and check dams) (mean temperature 34.5°C). This would principally constrain maximum stocking densities because of the resulting lowering of dissolved oxygen levels as most carp species can tolerate such elevated temperatures. Turbidity is highest in farm ponds and check dams, which consequently displayed much lower levels of natural productivity than open wells. pH was surprisingly high in all water bodies averaging 7.7 in ground water supplies and 8.2 in surface waters. Such levels would not constrain aquaculture and could enhance productivity.

4. Farmers were asked to rank and score the importance of different uses of their water bodies and their perceived constraints to aquaculture. In three out of the four villages irrigation was thought to be significantly more important than all other uses. Other uses cited included water for human consumption, livestock, washing clothes and bathing. Generally there was no agreement between villagers about the importance of the different key constraints to aquaculture. However lack of knowledge about how to carry out aquaculture was thought very important in one village and lack of water for aquaculture very important in another. Because aquaculture is not an activity presently carried out in the area, it is unlikely that villagers are aware of the key requirements, with resulting difficulties in ranking constraints.

5. Open wells and irrigation ponds are thought to have the best potential for aquaculture. Open wells are a traditional means of irrigation and occur in great numbers in the study villages, and some villagers were already growing fish at low densities in open wells. Irrigation ponds were the least numerous water resource, but this type of water body has already been used successfully by the Central Institute for Freshwater Aquaculture to raise major carps. Furthermore irrigation ponds are cheap to construct compared to open wells. Farm ponds are a recent initiative and have been constructed in substantial numbers in project villages at heavily subsidised rates under a Samuha development project. Although they are highly seasonal and subject to extreme water quality fluctuations, they are cheap to construct and constraints may be researchable (e.g. farm ponds could be recharged from perennial water bodies, planted with shelter belts and subsequently converted to open wells. Check dams suffer from many of the same drawbacks as open wells but as they are the only communal water bodies identified (with potential access for landless and waterless villagers) they demand further research.

An Investigation of Aquaculture Potential in Small-scale Farmer managed Irrigation Systems of Raichur District, Karnataka, India

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1 Introduction

In this paper the different types of small-scale, farmer-managed water bodies of Raichur District, Karnataka, India, are identified and their potential for the integration of aquaculture assessed.

2 Methodology

The different types of water body present in the study area were identified from interviews with staff from Samuha (see project background). Visits were made to all different types, and a classification (see Tables 1, 2 and 3) constructed on the basis of physical characteristics, seasonality, water uses, and access and ownership patterns. Four research villages were selected partly on the basis of the number and types of water bodies present, and partly on the basis of socio-economic characteristics. These can be seen in Box 1 and Figure 1. For an outline of the selection of villages, see Working Paper 1.

Box 1: **Research villages in Raichur District**

Village name	**Taluk**
Jumlapur & Ainapur	Kushtagi
Chikkawankalakunta	Yelbarga Pai
Doddi	Lingsugur
Mallapur	Deodurg

In individual villages maps were constructed with villagers identifying the position and ownership of all water bodies. Participatory research was carried out, using individual farm walks and key informant interviews with villagers. The major uses of the water bodies as well as the key constraints to the introduction of aquaculture into small-scale farmer managed irrigation systems were identified in village group meetings, and ranked and scored in order of their importance to individual farmers.

Water quality parameters of individual water bodies were measured, including: salinity, phosphate, alkalinity, turbidity, pH, temperature and aluminium. Measurement of temporal variation in water quality parameters was not possible in the project time frame. The research took place during the end of the summer, at a time where temperatures were at their highest, although the characteristics measured may not be indicative of the worst case situation. Samples were collected in glass bottles and analysed the same day.

3 Classification of small-scale farmer-managed water bodies

From key informant interviews with staff from Samuha staff, six types of small-scale water body were identified in the Samuha project villages. These can be seen in Table 1. Tables 2 and 3 show the results of the classification. Images of these structures are shown in plates 1 to 2.

KARNATAKA

DISTRICT RAICHUR

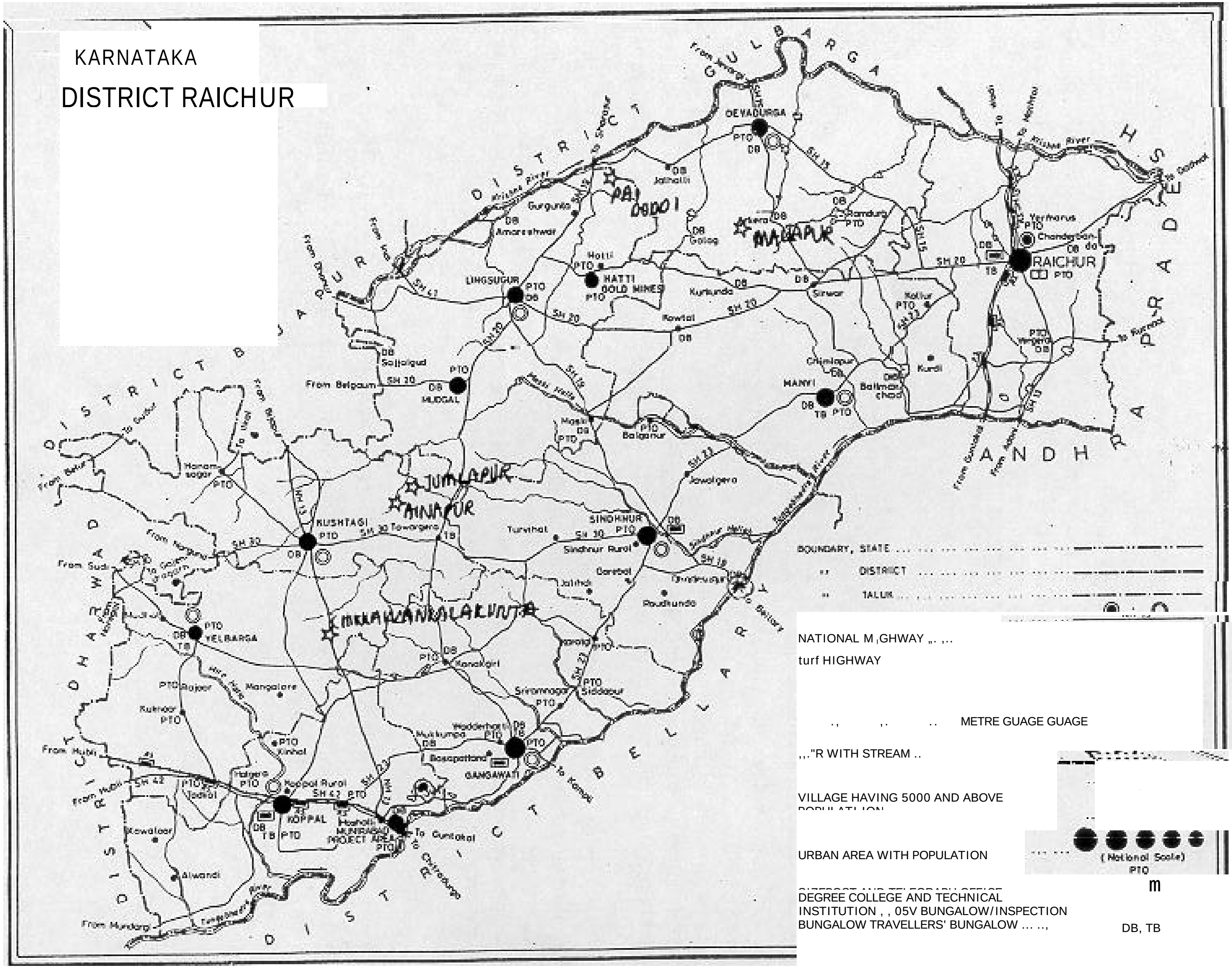

Table 1: Descri tion of water body and age.

Type	Construction	Position in watershed	Primary uses	Other uses
Ravine reclamation structure	Boulder and silt check across ravines 10-20m	Upper	Silt harvesting	Livestock
Check dam	Concrete and stone. Occasionally vented.	Upper to middle	Silt and water harvesting	Livestock, drinking, pumped irrigation
Nala bund	Earth possibly with stone facing.	Middle to lower	Ground water recharge..	Livestock
Farm pond	Terraced excavation (lOx10x3m)	On farm	Ground water recharge. Small - scale irrigation.	Domestic
Open well	Square or circular excavation. Usually l Ox l Om, up to 20m deep. Occasionally stone lined.	On farm	Irrigation	Livestock, domestic
Farm **irrigation pond**	Surface tank impounded by rectangular bund. Earth or concrete. Max. lOx2OxO.7m	On farm	Irrigation	Livestock, drinking, domestic.

Source: semi-structured interviews with farmers and Samuha field staff.

Table 2: Water su l characteristics of water bodies.

Type	Seasonality (post rains)	Principal water source	Max water surface area (ha)	Min draw down (m)
Ravine reclamation Structure	Max. 3 months	Rainfall	0.1-1.5	0
Check dam	3 months to perennial	Rainfall	0.1-1.5	0
Nala bund	3 months to perennial	Rainfall	10	0
Farm pond	3-4 months (most) to perennial	Rainfall	0.1	0
open well	Mostly perennial	Ground water	0.1	0.5-1.5
Farm irrigation and		Ground water (um (pumped)	0.1-0.15	Farmer-managed

Source: semi-structured interviews with farmers and Samuha field staff.

Table 3: Ownership, access and construction costs of water bodies. PIA = Project implementing agency. Samuha charge only 5-10% of this cost to people belonging to Scheduled Castes (SCs) and Scheduled Tribes (STs) respectively (see Working Paper 3 for further explanation of the terms SC and ST). Rs: Indian rupees, Rs 60 -- £l.

Type	Ownership	Access	Maintenance	Cost (Rs)	PIA
Ravine reclamation structure	Farmer, community or government	Community or farmer	WIA /Farmer		Samuha
Check dam	Community or government occasionall farmer)	Community or farmer	WIA /Farmer	50,000	Samuha
Nala bund	Community or government occasionall farmer)	Usually farmer	WIA /Farmer		Samuha
Farm and	Farmer	Farmer	Farmer	3,000*	Samuha
Open well	Farmer	Farmer	Farmer	15,000-30,000	Farmer
Farm irrigation pond	Farmer	Farmer	Farmer	3,000 (10k for bore well)	Farmer

Source: semi-structured interviews with farmers and Samuha staff.

Table 4: Frequency of water bodies in project villa es.

Type	Jumlapur	Chikkawan-kalakunta	Pai Doddi	Mallapur
Ravine reclamation structure	N/A	N/A	N/A	N/A
Check dam	18 (4 with water for six months)	0	5	16
Nala bund	N/A	N/A	N/A	N/A
Farm and	0	11	22	15
Open well	10	30	8	24
Farm irrigation and	1	1	0	0

Source: semi-structured interviews.

Box 2: Other characteristics of small-scale farmer-managed water bodies in the project area.

Except for two dry stone-lined wells in Mallapur, all other unlined wells were subject to varying degrees of collapse during rains. Chikkawankalakunta and Jumlapur were most susceptible having a deeper unconsolidated surface soil layer. In susceptible ponds it typically took between 5-10 man-days to remove the collapsed material.

Except for mati (ox-drawn irrigation system) all wells now had electric pumpsets. Since 1986 the state electricity board has been providing free electricity used for small-scale irrigation purposes (pumps less than 1 t/z hp). Owners previously using diesel pumps have now converted to electricity.

Farmers on lands with shallow gradients use irrigation ponds to increase their irrigation head. They also give emergency irrigation potential during frequent power cuts.
As can be seen, no ravine reclamation structures or nala bunds were present in the project villages, and these were therefore not considered further.

Plate 2: Recently constructed farm pond in Pai Doddi.

Plate 1: Irrigation pond being filled from bore well at Chikkawankalakunta.

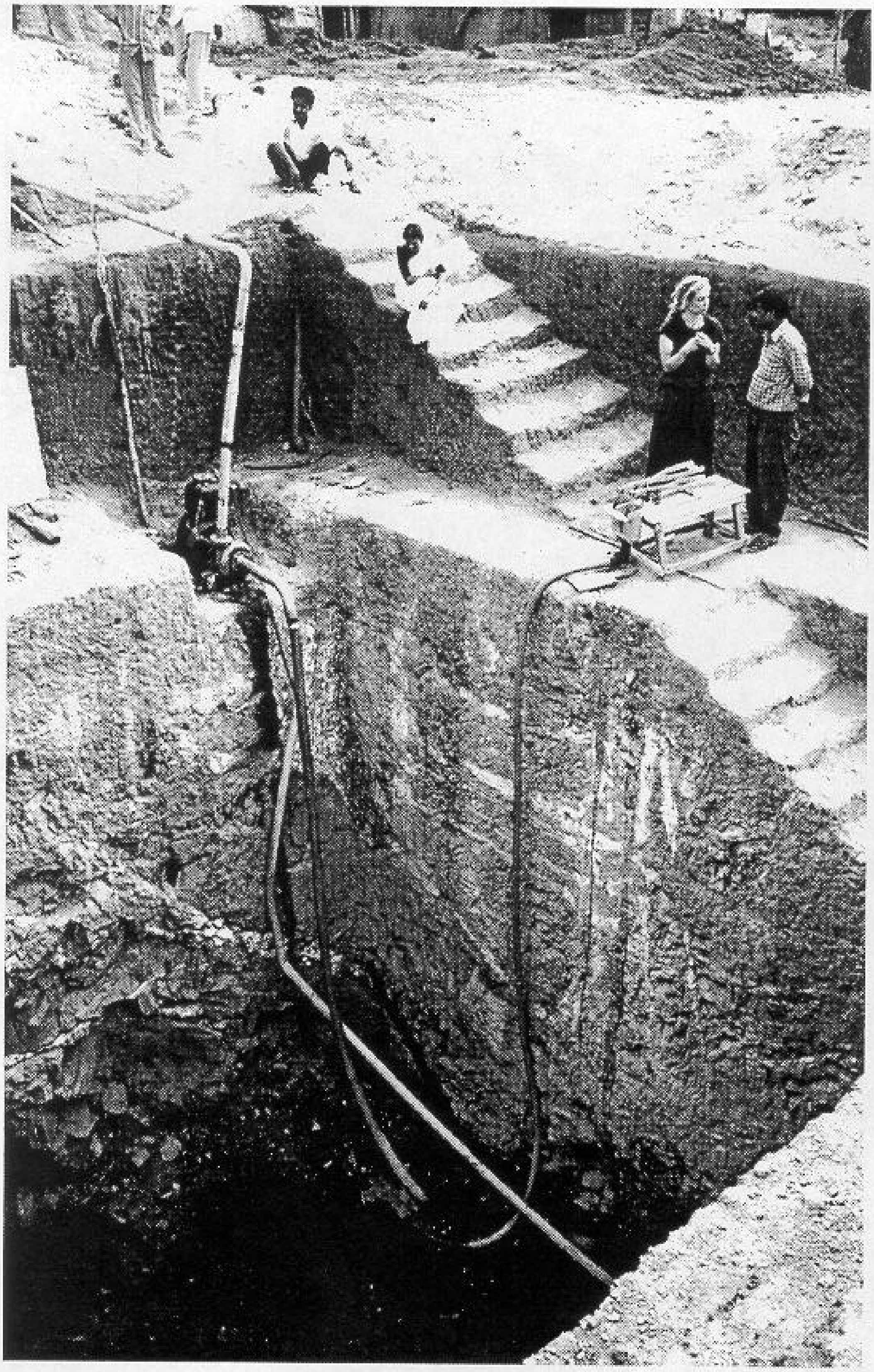

Plate 3: Open well near Mallapur with demonstration paddle irrigation pump and electric pumpset.

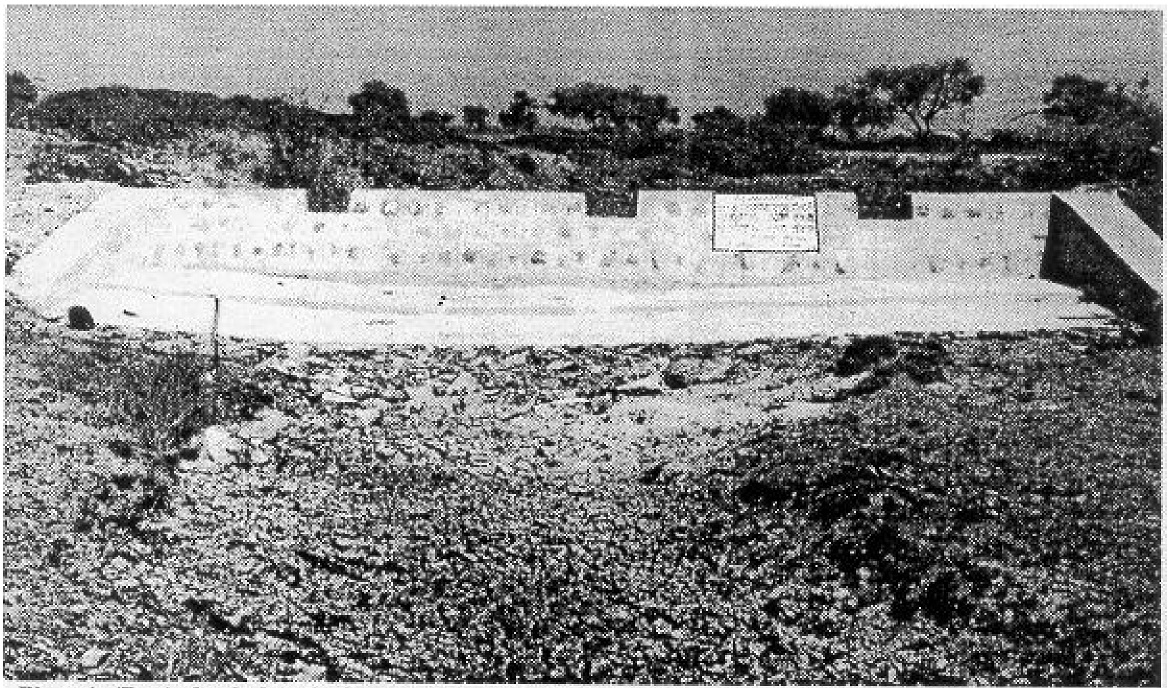

Plate 4: (Dry) check dam in Samuha project village, Raichur District (courtesy of Samuha).

3.1 Results of water quality analysis

Eight open wells, three farm ponds, one check dam and one irrigation pond were assessed. This reflected the relative abundance of perennial water sources in the village (the time of research being the end of the dry season).

Turbidity

The Secchi Disk depth in open wells averaged one metre, the turbidity resulting mainly from organic production, arising largely from natural organic additions. Farm ponds (three assessed) tended to display high levels of phytoplankton hiotnass (with Secchi Disk depths as low as I0-20cm), probably a result of the high light levels present in these water bodies (the water surface in open wells is further down and therefore often very shadowed). Furthermore the residence time of farm ponds may be longer than that of open wells since the latter are used extensively for irrigation.

pH

Ranged from neutrality to highly alkaline (8.64 found in a farm pond in Pai Doddi). Water bodies storing surface waters tended to be more alkaline than those storing groundwater (open wells and one irrigation tank showing means of 8.2 and 7.7 respectively)'. The generally high p11 was unexpected as the villages visited had red alfisols which are reported to be slightly acidic.

Temperature

As calf ix seen from Table 5, the temperature levels ranged from 29.5-32"C (mean 30.5"C) in open wells and from 33-38"C in unsheltered surface: water bodies (mean 35.1"C). Farm ponds with half a meter of water averaged 33"C. The highest temperature was rlleasured in a shallow check dam. As the research was carried out during the hottest time of the year, these results can be taken to represent maximum levels. An independent samples T-test showed the temperature difference between farm ponds and open wells to he highly significant (P= 0.016). Details of statistical analyses can be found in Appendix 2.

An independent samples T-tat showed this difference not to be significant !'=0.59).

Chloride, aluminium and phospate

Chloride levels ranged from 50 - 175mg 1ˉ', following the same trend as pH with lowest levels observed in the open wells. Alfisols have reported high levels of aluminium and iron (Haylor, 1997), but despite this the present study found, aluminium levels to be negligible. Phosphate (1.5-2.8mg h', mean 2.2mg 1ˉ') and alkalinity (234-485mg 1ˉ', mean 385mg 1"') levels were relatively high, consistent with the high productivity mentioned above

Table 5: Descriptive statistics comparing pH and temperature water quality results. Surface bodies refer to farm ponds, check dams and farm irriga on ponds.

Variable	Mean	Std Dev.	Minimum	Maximum	N
H					
O en wells	7.7	.31	7.1	8.1	8
Surface bodies	8.2	**.34**	**7.9**	**8.64**	**5**
Temp. (°C					
Open wells	**30.44**	**.78**	**29.5**	32	8
Surface bodies	**34.6**	**2.16**	33	38	5

Source: water tests taken during period of village research.

Water quality implications for fish health

Of the chemical parameters measured none would be acutely or chronically hazardous to fish health. Red alfisols potentially have high aluminium levels but none was detected. High iron levels are similarly reported (Haylor, 1997), but due to equipment failure this could not be measured. Major carps and common and grass carp can be cultured in brackish water up to 15ppt (silver carp are less tolerant). All (including juveniles) perform best at 3ppt (i.e. iso-osmotic concentration) (CIFA, 1996). Major and common carp are generally tolerant of pH between 5 and 9. The highest levels were found in farm ponds in Pai Doddi (max. pH 8.64). High pH and temperature will increase the concentration of toxic unionized ammonia in stocked ponds, but the pH will probably be reduced by input of fish biomass and increased nitrifying activity, and the levels observed are unlikely to cause any problems. Of most cause for concern were the elevated temperature levels especially in surface waters, although many species of carp can tolerate such elevated temperature levels (and oxygen levels down to lmg 1ˉ'). For aquaculture, stocking densities would have to-be lowered at higher temperatures. However, in many of these water bodies harvesting will be short seasonal and thus harvest should be completed before the hottest time of the year (the time of the present water samples).

Longitudinal water quality profiles (both seasonally and diurnally) will be required for further elucidation of constraints. As high arsenic levels are commonly encountered in ground waters in the region, this should also be checked. In general acceptable water quality was suggested by the presence of several apparently healthy species of fish (including carps and catfish) in open wells of all four villages. However it should be noted that these were stocked at very low densities (these fish were not farmed but were merely hobby activities for farmers).

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The results also showed great variation in the depth of the water table between and within villages. Levels were lowest in Mallapur (open wells averaging 10m), where the low watershed level was due to the recent proliferation of irrigation bore wells.

3.2 Water uses and key constraints to aquaculture

Villagers with and without land and water resources were asked to rank and score uses of water bodies and the constraints they perceived to the introduction of aquaculture. Friedmans two-way analysis of variance was used to assess the degree of consensus in these responses (see Appendix 3.). Tables 6 and 7 show the water uses and constraints to aquaculture as identified in village group meetings in the four villages.

Table 6: Uses of small water bodies as identified by villagers (same uses identified independently in every village). Parameters in random order.

Water use
irrigation
Human consumption
Livestock drinking
Bathing

Table 7: Main constraints to aquaculture. No feed refers to lack of resources to feed the fish, i.e. organic fertiliser, money for chemical fertiliser, or food for the fish. Parameters in random order.

Village	Constraints
Jumlapur & Ainapur	No knowledge No feed No seed No water Risk of loss
Chikkawan kalakunta	No knowledge No feed No markets for fish No seed No water
Pai Doddi	No knowledge

Source: semi-structured interviews and group discussions.

The results of the statistical analysis can be seen in Box 3 and Appendix 3. In the villages of Jumlapur, Chikkawankalakunta and Mallapur (situated in Kushtagi, Yelbarga and Deodurg taluks respectively - see Figure 1 for map of Raichur District) irrigation was significantly more important than most other water uses. This was hardly surprising when the majority of respondents owned open wells, which were built primarily for crop irrigation. The trend in the criteria was for bathing and washing clothes to be the least important uses of the water (this was from a cross-section of male and female participants). For details of the statistical test used, see Working Paper 2.

Results for importance of perceived aquaculture constraints were more equivocal. In Jumlapur lack of knowledge was significantly more important than some other constraints. Here risk of failure also scored highly which can be seen as a corollary of lack of knowledge. In Chikkawankalakunta lack of water was significantly more important than all other constraints and this also scored highly in the other villages (see Box 3). This seemed odd, in view of the fact that most of the respondents had perennial supplies of water. Perhaps this reflected the conceptual novelty of trying to culture fish in such a harsh environment or more probably ; a feeling that the level of production would be low in the quantity of water available. Interestingly where lack of feed was identified as a constraint it scored very low, suggesting that farmers are either ignorant of the feeding requirement or perceive it to be low.

Box 3: **Significant results of Friedmans Tests on the uses of water bodies and the importance of the major constraints to aquaculture in the project villages.** > **denotes significantly more important than (at the a = .05 significance level).**

Main water body uses:

Jumlalpur, Chikkawankalakunta & Mallapur
Irrigation > bathing
Irrigation > clothes washing
Chikkawankalakunta & Mallapur
Irrigation > human drinking
Jumlanur
Irrigation > livestock drinking
Pai Doddi
Test not significant, no significance found for gender and wealth sub-groups.

Importance of major constraints to aquaculture:

Jumlapur

Lack of knowledge > lack of water
Lack of knowledge > risk of loss
Chikkawankalakunta
Lack of water > lack of market
Lack of water > lack of feed
Lack of water > lack of seed Pai
Doddi
Test not significant, no significance found for gender and wealth sub-groups.
Mallapur
Test not significant at village level or for gender sub-groups. Significant result for wealth group 4. Lack of water > lack of knowledge

3.3 Aquaculture potential and constraints in classified water bodies

Table 8 shows the aquaculture potential of the classified water bodies.

Open wells

The widely owned open wells were judged to have excellent potential. They are traditional irrigation systems exploiting groundwater resources and were usually perennial with a minimum draw down. These are deeper than farm or irrigation ponds and their temperature fluctuations are therefore not as extreme. This assessment was supported by the fact that many villagers were keeping small numbers of fish in this kind of water body (and no other). Their main constraint was their tendency to collapse during the rainy season. Open wells are a primary source of drinking water for humans and livestock. Where no nearby alternative source was available this would be a major constraint to aquaculture introduction. The use of the water for washing and bathing would be a smaller constraint and irrigation uses only constraining where no minimal draw down is built in. Because of the use of the water for irrigation, the residence time of open wells is low compared to farm ponds, with resultant lower levels of productivity. If fish are to be stocked at high stocking densities, feeding with high quality feed may be necessary. Because of their largely perennial nature, these water bodies may show potential for use as nurseries for stocking fish in seasonal water bodies.

Irrigation ponds

Irrigation ponds were less productive than open wells (having higher water exchange rates and lower residence time) although they did show good periphyton growth. They could have high potential if extra draw down was excavated below ground surface level. The Peninsular Aquaculture Division has carried out successful trials rearing major carp in such water bodies. Although frequently observed in roadside fields, few (2) were observed in the project villages (Table 4). Conflicting uses of water was less of a constraint for irrigation ponds as water could be drawn directly from the borewell for alternative uses. The potential to manage water exchange is a key strength of both open wells and irrigation ponds.

Farm ponds

Farm ponds have greater limitations. These are very seasonal, silty, have minimal water exchange, and are prone to high extremes of water quality, particularly temperature. Because they are a new technology their numbers are increasing, they are cheap and are less exploitative of groundwater resources. However they were only present where subsidies were available for their construction (i.e. none were present in the village of Jumlapur where no subsidy is available) and some farmers were using farm ponds as the first stage in construction of open wells. The period for which they hold water is also critical. If used for short season harvesting the farmer maybe faced with an emergency harvest of small unmarketable fish during the dry season when demand is lowest (see below). The only choice in such a situation may be to dry the fish for family consumption.

Check dams

Usually community assets, check dams were the only small-scale water resource with potential access for the majority of villagers who do not own their water bodies. They have the largest water areas for part of the year so may be best option for short-season harvesting and on-growing of advanced fingerlings nursed in perennial water bodies. They are subject to many of the constraints faced by farm ponds with the addition of greater potential for escapees during heavy rains. Short season harvesting options for seasonal water bodies are discussed in Working Paper 6.

Type	A **uaculture constraints**	**A uaculture potential**
Ravine reclamation Structure	**Short** Season High silt load Accessibility	Negligible
Check dam	Seasonality Silt levels Escape during overflow. Bunds stabilised with toxic adeo and kali plants. High water temperature No water exchange after rains	Moderate e.g. with use of hapas. Also often the only small scale communal water resource with potential access for landless or farmers without wells, ponds.
Nala bund	As check dam. Large shallow water spread. Ma be too fare to fertilize effectively.	Negligible
Farm pond	High water temperature High organic turbidity Flood potential during rains. Conflict with other uses. No provision for water exchange High pH	Moderate Species tolerant of high water quality fluctations (temperature, DO) may be required. Shade could provided by the planting of shelter belts Cheap construction cost
Open well	Conflict with other uses - especially human/livestock consumption. Risk of collapse of walls in unlined wells after rains. Potential for chemical contamination (e.g. arsenic)	Excellent. Many wells already contained `hobby fish'. Temperatures more stable due to depth. Many wells showed good signs of productivity even with high irrigation exchange rates
Farm irrigation pond	100% draw down often practiced. Temperature may fluctuate dramatically between water replacements. Dependent on regular electricity for water supplies. Few exist in project areas.	Excellent. Suitability largely depends on farmer management. Water showed good periphyton growth but low turbidity due to frequent and complete exchanges. Further excavation would improve draw down and temperature stability.

Source: village research.

Table 8: A uaculture potential in classified water bodies. DO: dissolved oxygen.

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Appendix 1: Results of water quality analyses

Results of water quality analysis carried out in three villages are shown in tables Ala, Alb and Alc. Mean temperature and pH levels were compared between open wells and surface water bodies (check dams, farm ponds and irrigation ponds). Data was pooled for all villages and analysed using an independent samples means test.

Table Ala: Water uali and water body characteristics in Chikkawankalakunta (CWK).

Description	CWK 1	CWK 2	CWK 3	CWK 4
Date	24/4/98	24/4/98	24/4/98	24/4/98
Time	11.30am	12.30am	1.30 m	12.30am
Owner	Yengappa	Hanumappa Gouda	Hanumaparre	Hanumappa
Survey no.	No. 13	1	33	26
Waterbody	Open well	Open well	Surface irrigation tank	Open well
Dimensions (LWD)	l0x10m x 6.5m	l0x10m x 9.5m	15 x 8 x 1.4m	7 x 7 x 6m
Age of water body ears	8	20	1	8
Substrate	Red soil	Red soil	Red soil	Red soil_
Terrain	V. flat	V. flat	V. flat	V. flat
Water depth	1.5-2.5m (unlevel floor)	90cm	40-50cm	1.4m
Seasonalit	Perennial	Perennial	Farmer-managed	Perennial
Min draw down	0.4m	30cm	Almost empty.	25cm
Weather	Clear, very hot	Clear, very hot	Occasionally cloudy, hot.	Clear, very hot
Water quality				
Colour	Green	Clear (ie being filled)	Clear	Green
Turbidit (cm)	195	To floor	To floor	90
Water °C	30.5	29.5	33.5	30.5
Air °C (in well)	33.5	34.5	40	34
-	7.8 -	8.1 - -	7.9	7.85
Alkalinity	254	273.6	248	234
Total hardness				
Chloride (m 1')	75	50	81.25	62.5
Phosphate (rug 1-	1.9	2.9	1.9	2
Aluminium m 1")	0.05	0.15	0.08	0.1
Conductivity (mv)	--52	-	-	-55

Table Alb: Water quality and waterbod characteristics in Pai Doddi (PD).

Description	PD 1	PD 2	PD 3	PD 4	PD 5	PD 6
Date	3/5/98	3/5/98	3/5/98	4/5/98	4/5/98	4/5/98
Time	10.3	1 m	3.30 m	3 m	loam	1.30 m
Location	PD	PD	PD	PD	PD	PD
Owner	Bhimappa	Basavuraj	Amarrapa "	4 acres govt. land	Nandappa	Bhimina
Survey no.	29	17	42		14	87
Waterbod	Open well	Farm and	Farm and	Check dam	Farm and	Open well
Dimensions (LWD)	9 x 9 x 5.5-7m (on sloe)	lox lox 3m (terraced)	7x7x2m (3 terraces)	30 x 23 x 0.5m (max)	9 x 9 x 2m	10 x 10 x 8m
Age of body		1	lyr	Nearing completion	lyr	8 yr.
Substrate	Red to Black near nala	Red soil	Red soil	Red soil	Red soil, very stony	Red soil (2.2m)
Terrain	Sloping to nala	Side of dry nala course	Built in to depression	Small valley with spring	Built in to side of hill	High plateau
Water depth	1.5m	50cm max (3 of 4 steps)	0-20cm	0.5m max	50cm	2m in middle
Seasonality	Perennial	Perennial	Almost perennial	Perennial	Almost perennial	Perennial
Min draw down	0.4m	30cm	Empty	0.5m max	20cm	25cm
Weather	Cloudy	Clear, very hot	Occasionally cloudy, hot.	Clear, very hot	Clear, very hot	Occasionally cloudy, very hot
Water quality						
Colour	Dark Green	Silty / Brown	Green	Peaty	Green	Green
Turbidity (cm)	90	10	>20	30	15	100
Water °C	30	33	38	35.5-40.5	33	32
Air °C (in well)	40	39	42	42	37	39
H	7.58	8.01	7.9	8.42	8.64	7.8
Alkalinity	410.4	485.64	248	475	456	411
Total hardness	743.85	615.6	654	723	733	653
Chloride (mg 1_1)	75	175	75	62.5	100	62.5
Phosphate m 1")	2.8	1.5	2.5	1.8	1.8	1.5
Aluminium (m 1"1)	0	0	0	0	0	0
Conductivity (mv)	41	73.8	118.4	93.2	110	98

Table Alc: Water quality and water body characteristics in Malla ur (MP).

Description	MP 1	MP 2	MP 3
Date	5/6/98	5/6/98	5/6/9_8
Time	5.30 m	2.30 m	4.45 m
Location MPR		MPR	MPR
Owner	Basa a/ Run a a	Shiva a	Basavaraj
Survey no.	46	22	47
Waterbod °	Open well	Open well	Open well
Dimensions (LWD)	6x 7 x 8m	7 x 7 x l lm	6x 6x 1.5m
Age of body	> 100 rs	10 rs	26 rs
Substrate	Red soil	Red soil	Red soil
Terrain	Lowest in micro watershed	Slight sloe to village	Beside nalla
Water depth	1.4m	1.2m	1.5m
Seasonalit Perennial		Seasonal	Perennial
Min. draw down	0.5m	0	Empty
Weather hot. Water quality	Storm approaching	Clear, ver hot	Occasionally cloudy,
Colour	Green	Green	Green
Turbidi (cm)	> l m	65cm	1 m
Water °C	30	30	31
Air °C (in well)	35	36	37
PH	7.85	7.1	7.45
Alkalinity 487		347	342
Total hardness	765	545	546
Chloride m 1"	63	50	62.5
Phosphate (m 1')	1.9	1.9	2
Aluminium (m 1")	0 0	0	
Conductivity (mv)	56	80	29

Appendix 2: Results of water quality statistical analyses

Descriptive statistics and independent samples T-tests of ph and temperature levels for open wells and surface water bodies (including farm ponds, irrigation ponds, check dams) all villages pooled

Variable	Mean	Std Dev	Minimum	Maximum	N	**Label**
ph						
open well	7.69	.31	7.10	8.10	8	
Farm pond	8.17	.34	7.90	8.64	5	
oC						
Open well	30.44	.78	29.50	32.00	8	
Farm pond	34.60	2.16	33.00	38.00	5	

t-tests for Independent Samples of Temperature

Variable	Number of Cases	Mean	SD	SE of Mean
OPENWELL				
Open wells 1	8	30.4375	.776	.274
Farm ponds 2	5	34.6000	2.162	.967

Mean Difference = -4.1625

Levene's Test for Equality of Variances: F= 8.104 P= .016

t-test for Equality of Means

Variances	t-value	df	2-Tail Sig	SE of Diff	95% CI for Diff
Equal	-5.06	11	.000	.823	(-5.974, -2.351)
Unequal	-4.14	4.65	.010	1.005	(-6.805, -1.520)

t-tests for Independent Samples of pH

Variable	**Number** of Cases	Mean	SD	SE of Mean
PROW				
Open wells 1	8	7.6913	.307	.109

Mean Difference = -.4827

Levene's Test for Equality of Variances: F= .305 P= .592

t-test for Equality of Means

Variances	t-value	df	2-Tail Sig	SE of Diff	CI for Diff
Equal	-2.66	11	.022	.182	(-.882, -.083)
Unequal	-2.60	8.00	.032	.186	(-.911, -.054)

Jumlapur

<u>Test for the importance of the different water uses:</u>

Data included 15 scores, of which two are from the same man, for an open well and a check dam as well as 4 ranks, of which 2 are from same man as for scores. 1 rank does not correspond to score. It was decided to use ranks and exclude mistake.

Fr	36.86
df	4
p	<.OS

Test shows a significant difference between the importance of the different water uses. Pair-wise comparisons between the different uses show the following significant results (using a (x = .OS level of significance), where > _ significantly more important than:

Irrigation > livestock consumption

<u>Test for the importance of the different key constraints to aquaculture:</u>

Data included 20 scores and 4 ranks, of which 1 does not correspond. It was decided to use scores and exclude the one, which did not correspond.

Fr	21.82
df	4
p	<.001

Test is significant. Pairwise comparison of the importance of the different constraints was carried out, and below is an

Chikkawankalakunta

<u>Test for importance of different water uses:</u>

Data comprised 12 ranks and 11 scores, of which 3 did not correspond. It was decided to use ranks as above, and to discharge the non-corresponding data, because there is still enough data to carry out analysis. There was one set of tied ranks, so the Friedman test with modification for tied ranks was used.

Fr	21.91
df	4
p	<0.001

Test showed significance so no need to analyse for sub-groups. A Friedman pairwise comparison of the different water uses show the following significant differences (at a = .OS level of significance), where > = significantly more important

<u>Tests for constraints to aquaculture:</u>

In total the data comprised 15 ranks and 15 scores, of which 3 did not correspond. It was decided to use only ranks. This was decided because enough data was available for the test to be carried out on these ranks only.

Fr	18.33
df	4

Lack of water > lack of market
Lack of water > lack of feed Lack
of water > lack of seed

Pal Doddi

<u>Tests for the importance of different water uses:</u>

Data included 11 ranks and 11 scores, of which 5 did not correspond. It was decided to use ranks and to discard non-corresponding data.

Fr 8.4

df 4

p >.OS ,

Test shows no significant priorities, so should try for gender sub-groups. Women first: Fr 6.13

df 4

p >.OS

No significance found. Now men:

Fr 5.6

df 4

p >.OS

<u>Tests for the importance of different constraints to aquaculture:</u>

Data includes 12 ranks and 11 scores, of which 3 do not correspond. It was decided to use ranks only and discard non-corresponding ranks.

Fr 2.33

df 3

p > .OS

Test shows no significance, so analysis was carried out for gender sub-groups. Women: Fr 3.6

df g

p > .OS No significance. Men: Fr 132

df 3

p > .OS

No significance for men either, and the data was therefore analysed for wealth sub-groups. 3 individuals from wealth group 2 and 5 from wealth group 4. Wealth group 2:

Fr 1.00

df 3

Mallapur

<u>Test for the importance of different water uses:</u>

Data included 18 scores and 8 ranks, 5 of which did not correspond. It was decided to use scores because there were more

Fr 24.75

df 4

p <.001

Test show that some water uses are significantly more important than others. Pairwise comparisons were carried out, showing the following significant results (at a (x = .05 level of significance), where > = significantly more important: Irrigation > human drinking
Irrigation > bathing Irrigation > clothes washing Since agreement can be found at village level, the data was not analysed for gender or wealth sub-groups. <u>Test for the importance of the various key constraints to aquaculture:</u>
Data included 15 scores and 7 ranks of which 2 did not correspond. It was decided to exclude non-corresponding scores and use the remaining scores only for reasons as above. The Friedman statistic for tied ranks was used. Fr 0.13
df 2

p > .05

As can be seen the test shows no significant priorities. The data was therefore analysed for gender sub-groups.
Women:
Fr 0.67

df 2

p > .05

Test shows no significance for women. Analysis could not be carried out for men because only two men amongst respondents, and these almost agree.
For wealth groups there were 2 in wealth group 3, 4 in wealth group 4, 3 in wealth group 5 and 3 in wealth group 6.
Group 4:
Fr 6.5

df 2

p < .05

Test shows significant differences between the importance of the different constraints. Pairwise comparisons between the different constraints were made, the significant results of which are shown below (at a significance level of a = .05) where > = significantly more important than.
Lack of water > lack of knowledge
Wealth group 5:
Fr 0.67

df 2

p > .05

Test shows no significance. Wealth group 6:
Fr 1.4
df 2

p > .05