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Addressing Groundwater Depletion Through Community-based Management Actions in the Weathered Granitic Basement Aquifer of Drought-prone Andhra Pradesh – India

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Dedicated to the memory of the late Shridar Swarnalapha, an exceptionally dedicated young hydrogeologist, who died on 1 December 2008 in a tragic road accident whilst working on the APFAMGS Project and collaborating with a World Bank – GW.MATE Assessment Mission to Andhra Pradesh.

Some 85% of the land-area of Andhra Pradesh is underlain by the Weathered Granitic Basement 'hard-rock' aquifer system, which forms extensive but shallow (low-storage and easily depleted) groundwater bodies. Everywhere outside the main irrigation-canal command areas (associated with the Godavari and Krishna rivers) the groundwater resources of this aquifer system have become (or are approaching) a condition of 'over-exploitation', with numerous negative consequences for farmers and State Government (SG) alike. Andhra Pradesh has pioneered the promotion of community-based groundwater management (CBGWM) through such projects as APWELL (SG led and Dutch supported), APFAMGS (UN-FAO supported without direct SG intervention), and two follow-up World Bank-financed initiatives (APCBTMP and APDAI). This Case Profile presents in summary form (a) the main groundwater typologies which are required to frame soundly-based management approaches (b) an assessment of experience in the four major CBGWM projects named above and ways to increase their synergy and (c) some 'institutional adjustments' which could help to address the key challenges of 'post-project' sustainability, up-scaling and replication. The major contribution of all those involved with these projects is fully acknowledged – including participants in the 'Groundwater Initiatives – Towards a Synthesis of Strategies' Workshop held in Hyderabad during January 2009.

GROUNDWATER RESOURCE SITUATION & ISSUES

General Hydrogeological Setting

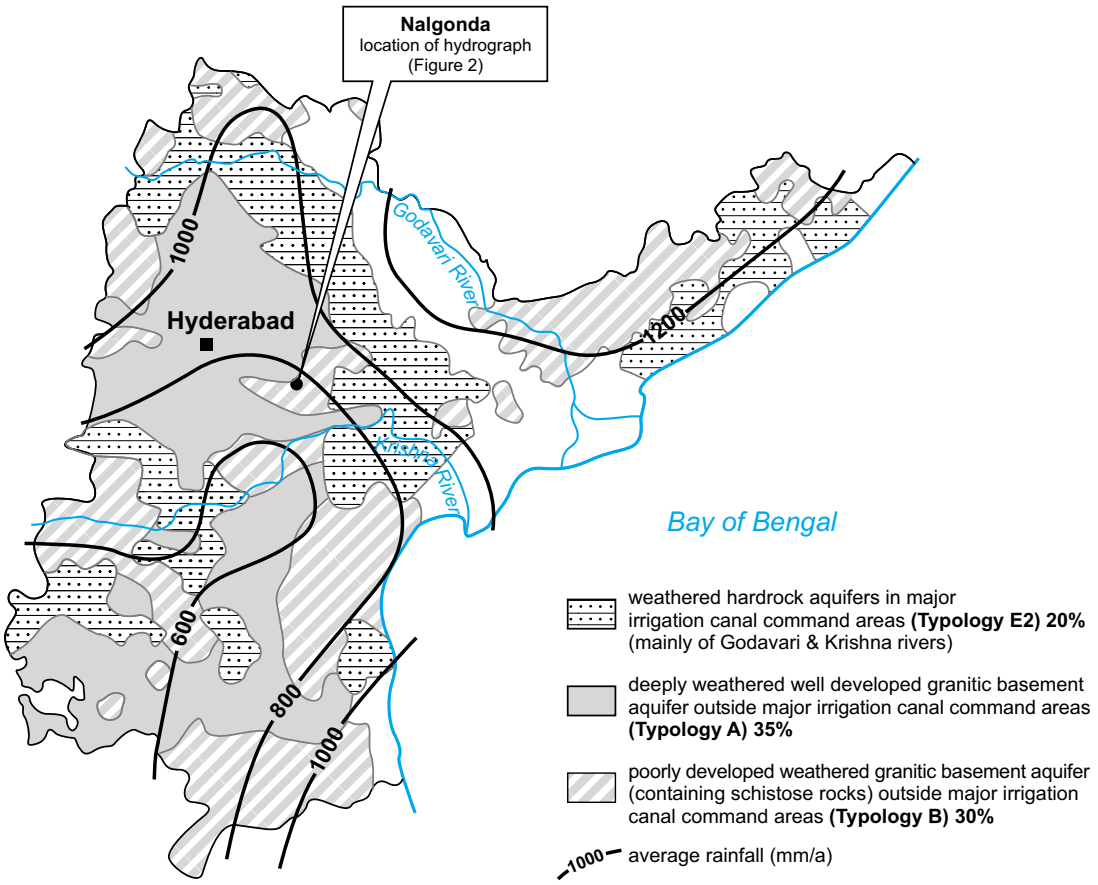
- Around 85% of the land-area of Andhra Pradesh is underlain by granite and granitic gneiss basement rocks (Figure 1). Although these rocks have negligible primary porosity and very limited fracturing at depth, they have been decomposed and fractured by repeated cycles of deep tropical weathering which have created

[1] Groundwater Department, Government of Andhra Pradesh

an aquifer system with extensive, low-storage, 'groundwater bodies' that are annually recharged to varying degrees by the monsoonal rains – and whose groundwater resources are the focus of this Case Profile.

- The landscape has many residual hills (with outcrop granitic basement) and an extensive pediment with a large number of small (2nd order) sub-basins drained by ephemeral streams (whose orientation is often controlled by fault lineaments).

Figure 1: Simplified hydrogeological sketch map of Andhra Pradesh State



- Following dialogue with GW-MATE, AP State-Groundwater Department (AP-GWD) re-mapped the entire state by hydrogeological typologies related to 'groundwater resource management considerations' and this Case Profile focuses on 'Typologies A & B', which together comprise about 65% of the total land-area:
  - Typology A is associated with a more favorable geomorphology where weathering and fracturing form more continuous groundwater bodies with their greatest thickness (typically 15-25 m) along lineaments below topographic lows, but with thinning towards topographic highs – these groundwater bodies have useful (although not large) storage and recharge which permits significant dry season irrigation but are prone to depletion through excessive irrigation abstraction (especially in a sequence of poor monsoon years)

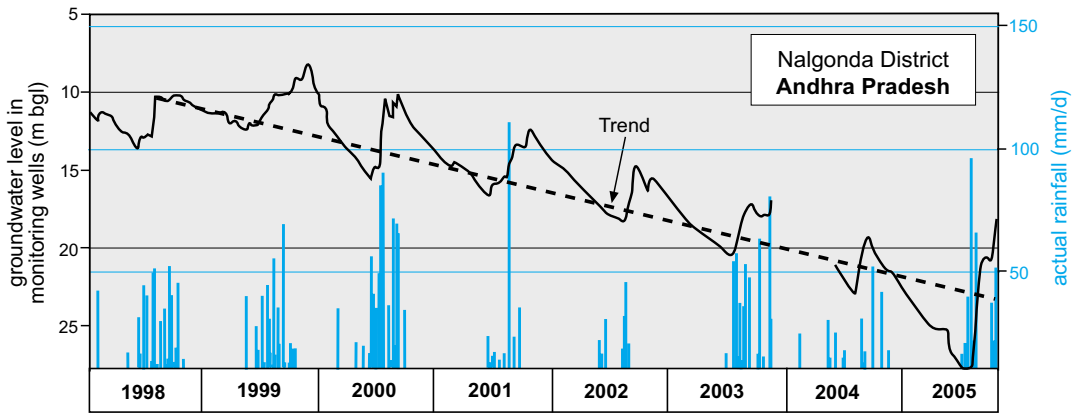
- Typology B corresponds to areas where groundwater bodies are more patchy, shallow and thin, which often appear to be related to more schistose bedrock leading to higher clay content on weathering – their groundwater storage is much reduced and can be rapidly depleted by irrigation bore well abstraction.

- A minor proportion of the Weathered Granitic Basement (just over 20% of the total land-area) falls within the command area of major irrigation canals deriving from the Godavari and Krishna Rivers (Typology E2 in Figure 1). In these areas demand for groundwater for agricultural irrigation is much less (because its cost to the farmer is relatively high and most irrigation needs are served by canal water) – thus the overall level of groundwater development is put at only 22% and, although the hydrogeological characteristics of these area are similar, they are not discussed further in this Case Profile.

- Current average rainfall in most of the area under consideration (Figure 1) totals 600-1000 mm/a, but is highly concentrated in a single monsoon season (June-August) during which 'natural recharge rates' are believed to average 70-100 mm/a. In contrast groundwater extraction rates had grown by the late 1990s to reach an equivalent of 120-180 mm/a (curiously almost regardless of water well densities – given that the entire area is heavily populated and cultivated).

- Thus Aquifer Typology A, in particular, widely exhibits a condition of very intensive abstraction and in consequence the groundwater table has declined steadily in many areas from the late 1980s, with only partial (but temporary) recovery in years of exceptional rainfall (Figure 2) – although there are some indications of recovery in the exceptional monsoons of 2005-07. In total there was widely a net fall in 'pre-monsoon water-level' of 10-15 m during 1995-2005, with almost all dug wells then drying-up early during the rabi season and bore well yield reduction/failure becoming commonplace as the water-table passes the critical depth of 15-25 m (depending on location and area). The Aquifer Typology B, which has significantly lower available storage, is somewhat different in as much (where intensive exploitation has been attempted) it will be seriously depleted annually except in years of exceptional monsoon rainfall, but in turn replenishment would occur more rapidly.

Figure 2: Selected groundwater level hydrograph for the Weathered Granitic Basement aquifer



Weathered Granitic Basement – Characteristics as an Aquifer

- Typology A of the Weathered Granitic Basement Aquifer has been researched in detail at a few locations situated 20-50 km south of Hyderabad[2] – and this work reveals the following:
  - the aquifer generally comprises two interconnected layers – a phreatic layer in the weathered zone down to maximum depths of around 15m (although thinning onto topographic highs and close to 'residual hills' (where it can be overlain by up to 2 m of colluvial cover) and a deeper fractured zone usually to about 30 m depth (which may in the valley floors exhibit slightly high groundwater heads)
  - the weathered and fractured aquifers are believed respectively to have transmissivity T = 20-40 m^2/d and 50-80 m^2/d (although the latter is much more variable even over short lateral distances), with the specific yield of the phreatic layer Sy = 3%
  - about 90% of 'natural groundwater flow' is usually concentrated in a 5m or so thick horizon at the base of weathered zone and top of fractured zone, and thus the depth to 'effective base' of aquifer is usually in range 15-25 m.

  It is stressed that the aquifer characteristics of Typology B are significantly poorer than these, but they have not been researched in such detail.

- Isotope studies reveal that in some areas the lower fractured part of the aquifer system contains groundwater with significant C14 age (>1000 years) indicating a deeper component of groundwater circulation associated with certain fracturing and jointing, but (not surprisingly) for the most part the groundwater is modern. More surprisingly associated hydrochemical studies only locally show signs of quality deterioration due to human or animal effluents and agrochemical use.

- For the purposes of groundwater resource management it is necessary to identify where 'manageable groundwater bodies' occur within the Weathered Basement Aquifer System as a whole – and for this purpose it is pertinent to concentrate on continuous and perennial groundwater bodies capable of supporting significant dry-season abstraction of agricultural irrigation (as illustrated schematically in Figure 3). However, the Weathered Granitic Basement Aquifer can provide rural drinking-water supplies over considerably larger areas, since the required yield can be obtained from more localized groundwater-bearing fractures and the related demand does not bring into question resource sustainability.

Current Groundwater Resource Utilization

- Groundwater resources are exploited by dug wells penetrating to just below depth of weathered zone and bore wells from 30-50 m deep (whose yields are variable but with 55-80% achieving 2-3 l/s).

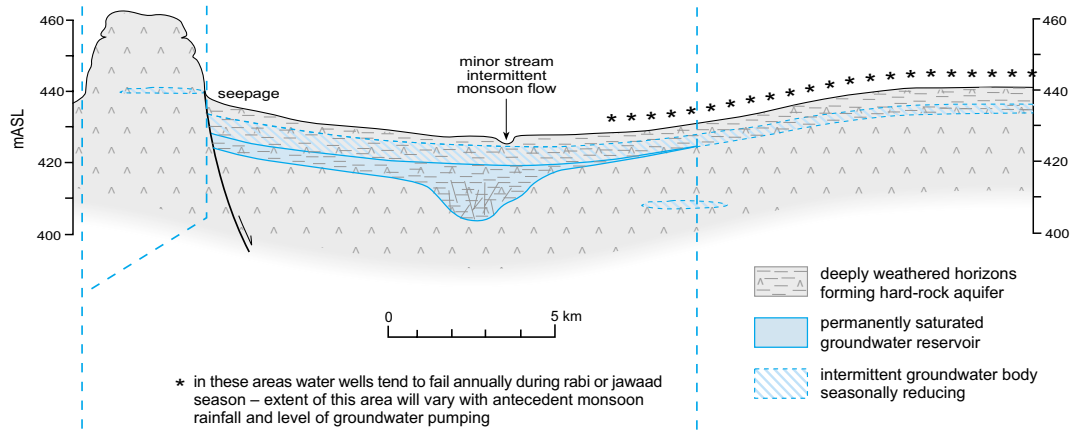
- During the past 40 years the number of dug wells has remained at about 0.9 million, but with an increasingly large portion falling dry or becoming 'seasonal'. But during the past 25 years or so there has been a rapid growth in the number of bore wells to the current estimated total of at least 1.74 million (with depths steadily increasing during this period from about 30 m to over 60 m) and a 2-fold plus increase in the area under groundwater irrigation to about 3 million ha.

- But this massive expansion of groundwater use has had serious impacts. In 2008 application of the

[2] Pradeep Raj 1996 Journal Geological society of india 48; Sukhija et al 2006 Hydrology Journal 14; Dewandel et al, 2007 Hydrogeology Journal 15.

CGWB Groundwater Resource Estimation Methodology (which is not ideal for this type of hydro-geological terrain) suggested that, of the 1227 blocks of 100-300 km^2 into which the state is divided, 300 were at a critical or overexploited level of resource exploitation and a further 208 semi-critical (the former categories were confirmed by the fact that they exhibit a falling groundwater level trends both pre- and post-monsoon). It is worth noting also that, according to AP-GWD (Andhra Pradesh Groundwater Department) many of the remaining 719 blocks although classified as 'safe' groundwater exploitation for agricultural irrigation is not feasible. When one considers only 'non-irrigation canal command areas' exploitation looks even more intense with on average 78% usage of the total potentially-available groundwater replenishment – and in many districts (eg. West Godavari, Mahabubnagar) the figure rises to above 100% (compared to sustainable levels of below 70% if minimal downstream environmental needs are respected).

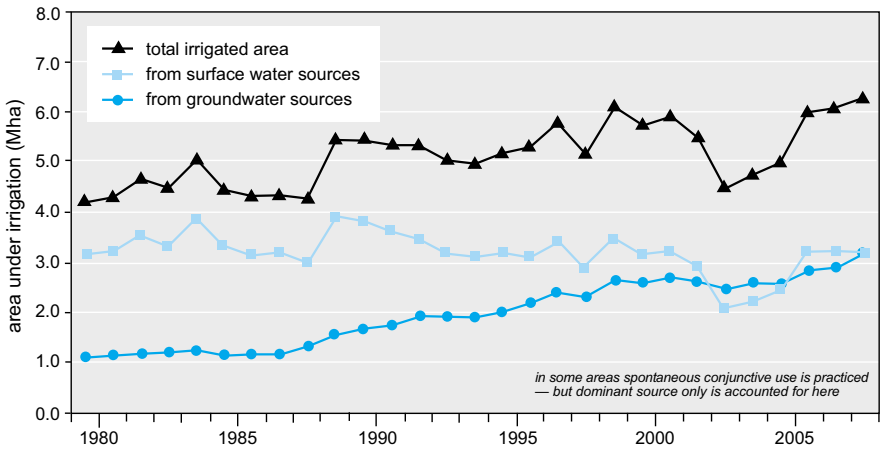
Figure 3: Typical hydrogeological cross-section of weathered granitic basement aquifer system illustrating occurrence of groundwater bodies and related development prospects and management needs

GROUNDWATER BODY	*'run-off zone'*	***PERENNIAL ('storage zone')***	***SEASONAL ('recharge zone')*** *may be linked to the finer grained metamorphic crystalline rocks*
			
Groundwater Resource Potential	continuous groundwater body of limited extension and storage - but capable of useful well yields for both kharif and rabi irrigation (or perennial crop production) over significant land areas		patchy limited storage and yield, draining rapidly after monsoon recharge – used for village water supply and sometimes for rabi irrigation but suffers severe yield reductions during Feb-May
Village Water Supply Improvement Options	groundwater available but good sources required for larger villages – sometimes necessary for VWSC to requisition irrigation wells for village supply or to reduce interference on village wells		establish performance of existing water wells and potential for recharge enhancement – VWSCs must protect improved sources from irrigation well construction
Approach to Groundwater Resource Management	form AMOR for 'groundwater body' by VWSC's and other stakeholders to regulate dry-season irrigation use, facilitate water savings and resolve conflicts		no systematic approach necessary or feasible but VWSC's could participate in AMOR because of 'downstream' relation
Socio-Economic Development Level	more densely populated – irrigation of rabi and/or perennial jawaad crops practiced on significant proportion of land area but competition for available storage can lead to conflicts between irrigators and drinking water supply		occasional larger village – some kharif irrigation but only limited rabi cropping, thus population have to migrate seasonally to work in irrigated agriculture or urban industrial areas

VWSC - *village water supply committee*
AMOR - *aquifer management organization*

- The rapid and steady increase in groundwater irrigation in the last 30 years may be contrasted with the development of surface irrigation (Figure 4). Over the same period the area under surface irrigation did not increase overall in spite of substantial investment in irrigation infrastructure and institutional change. This contrasts with very little public investment in groundwater management.

Figure 4: Evolution of total areas irrigated under groundwater and surface water during 1978-2008 in AP State



Resource Management – Critical Issues & Preferred Approaches

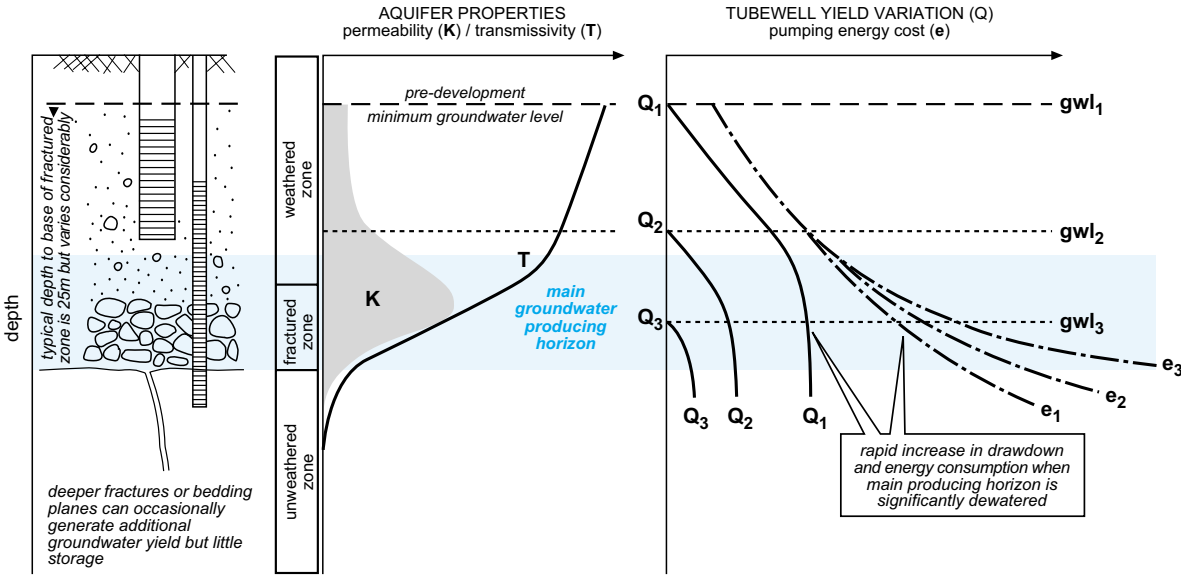
- The available storage of groundwater bodies is strictly limited by their weathering characteristics and water-bearing properties, and this storage reduces markedly as the water-table falls through the most productive horizon situated typically between 10-20 m below land surface (Figure 5 - shaded blue). If groundwater resource abstraction significantly exceeds average recharge rates this horizon is rapidly dewatered (to gwl_3 and below) leading to dramatic increases in pumping head losses and energy costs (e_3) with little increase in water-supply (Q_3).

- But the existence of flat-rate electricity tariffs has allowed very inefficient groundwater pumping practices to arise and to persist, with farmers:
  - continuing to operate tube well pumps at groundwater levels which are far too low and at which well entry and pump friction losses are very high
  - leaving pumps switched-on to obtain a supply when the power-system activates (since it is not operating on a regular time-base).

  Such practices would be completely uneconomic if farmers felt the full-cost of the electrical energy consumed.

- The consequences are clearly reflected in the limited data on the rural electrical energy consumption for groundwater pumping:
  - in the early 1980s there was very little rural electrification but through a combination of diesel-engined pumps and animal-powered pumps some 1.12 Mha of Andhra Pradesh were under some level of groundwater irrigation

Figure 5: Typical hydrogeological profile of an Indian weathered 'hard-rock' aquifer system with indicative pumping yields and energy costs



- by the early 1990s and with widespread rural electrification the area irrigated with groundwater had only expanded modestly – and to achieve a further 60% increase in the irrigated area between 1990-91 and 2004-05 the electricity consumption increased by approaching 120% to total a very large 12,240 GWhr.

In effect a significant part of the electrical energy currently being consumed appears (incidentally) to be used overheating pumps rather than generating an irrigation water-supply – representing a serious waste of scarce energy resources.

- Investment in water well drilling in all hard-rock terrains is always a gamble (in terms of obtaining a sustained yield sufficient for mechanized irrigation pumping) – but the risks increase markedly (perhaps even exponentially) when through excessive development the water-table falls below the 'weathered zone' and into fractured bedrock. This hydrogeological condition has very serious impacts on attempts to mitigate rural poverty (Table 1). The existence of flat-rate energy tariffs favors the better-off farmer against the poorest farmer (in Andhra Pradesh for example 13% of irrigated land is in holdings of more than 10 ha whilst 72% is less than 2 ha), since with deeper bore wells it allows him to continue pumping (albeit very inefficiently) from greater depths – and puts him in a position of 'owning' both more land and all of the water at the times of maximum crop value (late in the cool dry (rabi) season and into the hot dry 'summer' (jawaad) season).

- Two factors dictate that, in the type of groundwater situation found in the Weathered Granitic Basement Aquifer of Andhra Pradesh, the resource management approach has to be founded primarily upon promoting CBGWM:
  - the very large number of individually small groundwater users involved, which would make the task of state-government resource regulation simply impracticable
  - the characteristics of the aquifer system itself and the fact that falling groundwater table will not be

Table 1: Negative consequences of groundwater resource over-exploitation for rural poverty alleviation

CONSEQUENCES OF OVEREXPLOITATION	IMPLICATIONS FOR POVERTY ALLEVIATION
Higher Bore Well Construction Costs	larger drilling depths and costs for (poorer) 'late-comers', who anyway usually have smaller-sized and poorer-situated land holdings (with less chance of siting successful bore wells)
Competitive Water Well Deepening	richer farmers are more able to finance water well deepening and poorer farmers less able to obtain and repay bank loans
Decreasing Water Well Yields	less water available via informal 'water markets', crop losses and/or reduced irrigated area, reductions in farmer income, default on loan payments especially by poorer farmers with spiralling debt, sale of land to richer farmers at low price, discredit socially and even suicide
Failed Water Well Investments	widespread default on loan repayments, increased risk exposure for 'rural development banks' and more expensive loan prejudicing poorer farmers
Village Water-Source Failure	reduced yield and/or failure of drinking water wells in rabi or jawaad season, quality deterioration (F content or salinity), increased water collection distances, return to use of 'unsafe sources'

accompanied by irreversible aquifer side-effects and/or environmental degradation (although increasing and troublesome fluoride concentrations may arise) and the draw down effects of intensive abstraction are rather localized and essentially confined to the immediate micro-watershed and in many cases village panchayat area (excluding however the issue of stream base flow diminution with its broader 'downstream effects').

- But, of course, the fact that the preferred management approach is community-based does not (and must not) exclude SG agencies from the need for action, such as:
  - transparent information provision on groundwater resource status
  - supporting the elaboration of cropping plans designed to reduce groundwater and energy use whilst increasing crop productivity per unit water and energy consumption
  - ensuring sustainability and replicability of community-based initiatives through appropriate incentives and building them into watershed management programs
  - facilitating investment in complementary measures – such as making micro-irrigation facilities available at attractive rates
  - wherever possible realignment of policies in other sectors that are acting as 'drivers' of groundwater use.

- In this context the SG agencies will need to resist the idea that simply improving 'irrigation water efficiency', through introduction of high-technology precision irrigation techniques, will solve the problem. It must be recognized that with current irrigation practices a substantial proportion of so-called 'water losses' are in fact by seepage of irrigation water returns to groundwater and their elimination would thus not represent a 'real water resource saving'. What is required is more balanced crop planning and water budgeting aimed at reducing 'non-beneficial transpiration and evaporation' of groundwater per ha and at increasing groundwater productivity per m^3 consumed, as well as improvements in irrigation water-efficiency. This may also require reducing the overall irrigated area and making changes in crop

selection. The big gain of micro-irrigation is in the higher yields and better quality produce they can provide.

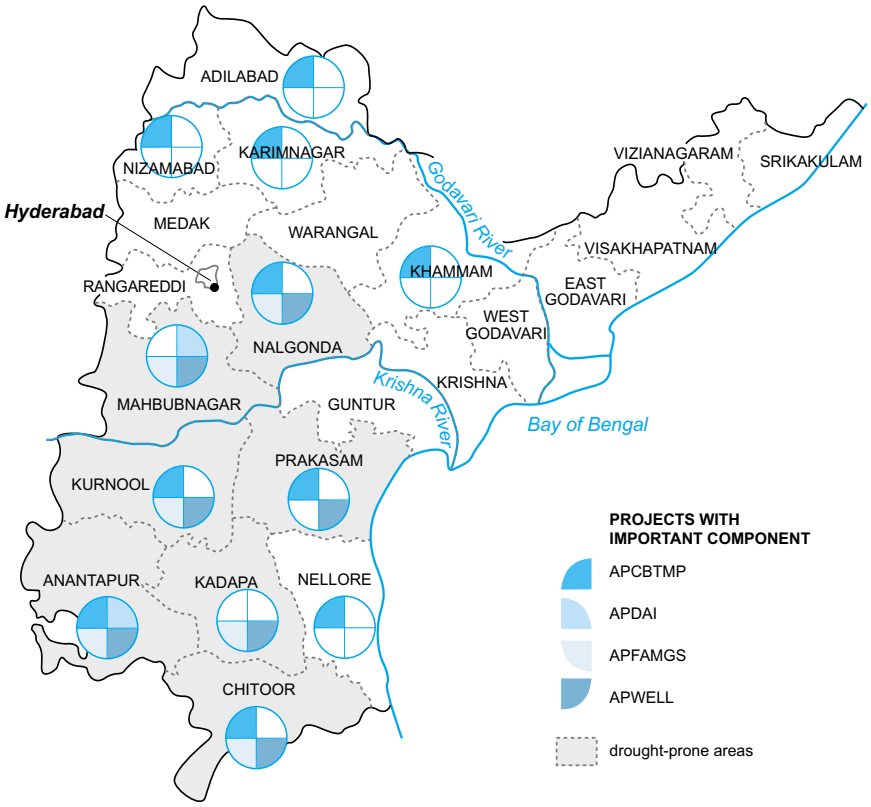
EXPERIENCES WITH COMMUNITY – BASED GROUNDWATER MANAGEMENT

- The main conclusion of the previous section – that in the Weathered Granitic Basement Aquifer of Andhra Pradesh the resource-management approach is best founded primarily upon promoting CBGWM – is consistent with the pronouncement of the Concerned Expert Group of the Government of India-Planning Commission (2007).

- In 1974 the AP Irrigation Development Corporation (APSDIC) was set up to promote groundwater-based irrigation facilities among small and marginal farmers in areas un-served by major and medium irrigation-canal command systems. They promoted, operated and maintained about 20,000 community bore well irrigation schemes, which in 1994 were handed over to farmers.

- Based on the success of the community bore well schemes, APSIDC proposed the APWELL Project which (supported by Dutch funding) was launched in 7 drought-prone districts during 1995-2003 – and subsequently APFAMGS was established in 2006 (with UN-FAO funding but no SG support). More recently SG has requested support from the World Bank to include a groundwater component in the APDAI and APCBTMP projects. The district-wise location of these 4 projects is shown in Figure 6.

Figure 6: Location of the principal experience with CBGWM in Andhra Pradesh



- Thus there are now almost two decades of experience of CBGWM in Andhra Pradesh, with numerous achievements and certain difficulties having been encountered. Nevertheless, the challenge of post-project Sustainability, Up-scalability and Replicability (SUR), and the role that the SG should play, are not yet clearly resolved. These challenges and future prospects are discussed in the last two sections of this Case Profile.

The Foundation Provided by APWELL

- The pioneering APWELL Project covered around 14,000 ha of irrigated agriculture in 370 villages, involving 14,500 marginal farmers, in 7 of the 8 drought-prone districts of Andhra Pradesh (Figure 6). From 1995 it facilitated watershed conservation, recharge enhancement, installing community water wells and distribution systems, improved irrigation practices and rural electricity provision, as well as promoting sustainable agriculture practices and more profitable but less water-consuming crop selection. But the really key innovation was the concept and practice of Participatory Hydrological Monitoring (PHM) – with the training of some 3,450 Water User Groups, 600 Female Self-Help Groups and 250 Groundwater (Bore well) Users Associations.

- Although the primary objectives of APWELL were promoting rural groundwater development, a project assessment undertaken in 2002 showed that due to the introduction of micro-irrigation practices:
  - groundwater use had become more efficient
  - crops had diversified towards less water-consuming types, with crop yields and agricultural incomes increasing
  - felling of trees and deforestation had decreased
  - employment for landless had increased, with poverty being reduced
  - migration from the land had stopped even reversed
  - land values had tripled and the social status of farmers increased.

- Following these experiences, some social regulations were put in place in an attempt to balance groundwater use – in some places these rules were managed locally without outside support but a more recent field assessment made the need for after-project follow-up clear (Table 2).

An Independent Assessment of APFAMGS

- The APFAMGS Project (scheduled 2006-09) is taking the APWELL experience a step further. It has adopted a sub-basin approach for selection of habitations (unlike APWELL which selected villages with an 'exploitable surplus' of groundwater) and, although it covers the same 7 drought-prone districts, includes only about half of the APWELL villages. Implementation is via a nodal executing agency supported by a number of well-motivated local NGOs (Non-Governmental Organizations) working closely with socially-sensitive hydrogeologists – in order to convey realistic messages, and propose technically-sound and economically-feasible management measures.

- The objective is to equip farmers with the necessary knowledge, data and skills to manage the groundwater resources available to them in a sustainable manner, mainly through controlling demand. It has endeavoured to 'demystify science' and translate hydrogeological and groundwater management concepts so as to make them accessible to poorly-literate groundwater users. In addition, the project

Table 2: Degree of sustainability of main measures introduced with APWELL

COMPONENTS INTRODUCED 1995-2003	PRACTICE IN 2006	KEY LESSONS
WATER AND ELECTRICITY USE		
Water Wells & Distribution Systems Constructed (3,450 WUGs trained)	– most wells are functioning – water sharing taking place among 90% WUGs – pipelines for water distribution functioning	– proper bore well site selection/construction lead to sustainable water use – supply-side measures should be complemented with demand management
Irrigation Practices	– very few farmers practice – only some use drip and sprinkler irrigation	– farmers cannot afford, thus financial support required – stronger follow-up required
Electricity Provision	– farmers drilled more wells where power supplied 4 hr/day – major problem - erratic power availability – panels boards functioning albeit some parts missing	– better coordination between water and power sectors required
SUSTAINABLE AGRICULTURAL MEASURES		
Paddy Cultivation Discouraged	– everyone cultivated some paddy	– focus on SRI paddy
Integrated Nutrient & Pest Management	– limited	– stronger follow-up required
Electricity Provision	– doing reasonably well	– good scope

also facilitates access to information about irrigation water-saving techniques, improved agricultural practices and ways to regulate on-farm demand for water – but it does not offer any incentives in the form of cash or subsidy.

- In addition to PHM (through 230 rain gauges and 2,100 observation wells operated by the community), the project has trained 7,000 farmers on crop water budgeting (CWB). The main vehicle for education and capacity building is the Farmer Water School, which comprises of a meeting of 25-30 farmers every 15 days with participatory on-farm learning.

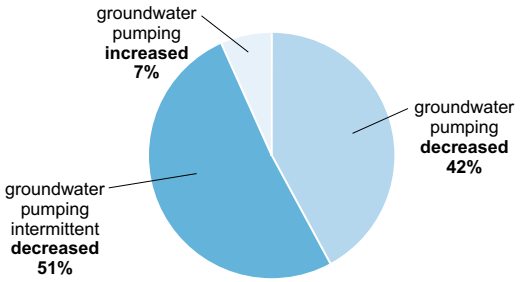
- At the end of the main monsoon (September) the proposed groundwater abstraction is derived by aggregating information collected from each farmer on intended rabi (dry season) planting. Comparison of proposed groundwater use with available groundwater reserves provides the groundwater body balance and influence farmers to refine their cropping pattern.

- The project operates through community-based organizations – village-level Groundwater Management Committees (GMC) comprising representatives of all groundwater using families in the community. The GMCs for a given groundwater body, sub-aquifer unit or sub-basin are federated into an aquifer-level organization (Hydrological Unit Network or HUN). The project has established 555 GMCs falling under 63 HUNs, and it is through these organizations that communities are collecting and analyzing data and implementing decisions for sustainable groundwater management. The HUNs now have official legal status and run the Farmer Water Schools themselves.

- Unlike most other attempts at CBGWM, APFAMGS does not seek an agreement from communities to reduce their groundwater use – farmers are free to make crop planting decisions and extract groundwater as they desire, and there is no collective agreement by communities on self-regulation of groundwater use. The project therefore relies solely on the impact of groundwater education to influence individual decisions of thousands of farmers regarding the crop selection and irrigated area in the post-monsoon season.

- In addition to the APFAMGS Project database (which exhaustively covers the Project area) and ad-hoc remote sensing information, the World Bank commissioned a farmer survey from the University of Hyderabad. Analysis of this collation of sources undertook by the World Bank has reached the following results:
  - in a majority of the project areas, the interventions have succeeded in beginning to build a link between water availability and water use for agriculture – in the years when water availability is low at the beginning of the rabi season (either due to low rainfall and consequently low recharge, or due to high groundwater abstractions in the kharif season decreasing availability for the rabi season), groundwater use has been reduced counter to the normal behavior whereby water availability in the aquifers is not a factor influencing groundwater use, and aquifer depletion often worsens in drier years – and this path-breaking achievement can be understood in terms of the impact of ground-water availability information on farmer decision making
  - the reductions in water use in these areas are achieved by a combination of crop diversification and water-saving irrigation methods – in effect six of the eight hydrological units sampled reported a reduction in the area under high-water-use crops, and the cumulative reduction of 43% during 2 years in rabi paddy area contrasts with the total area under rabi paddy in Andhra Pradesh which increased 5%
  - the remote sensing analysis for one selected HU showed that area under high water use crops (>1000 mm) decreased by almost 11% from 2004-05 to 2007-08, whereas area under the low water use crops (<375 mm) increased by roughly the same amount
  - in terms of cumulative water abstractions, 42% of the HUs have consistently reduced the rabi draft over the three years of project operation, while 51% have reduced the draft intermittently, and only 7% have witnessed an increase in groundwater draft during this period (Figure 7), and Figure 8 shows the behavior of HUs where groundwater draft has decreased
  - this impact is unprecedented, in terms of reductions actually being realized in groundwater draft, and in terms of the geographic extent of this impact, covering dozens of aquifers and hundreds of communities – while these results are preliminary and pose a number of questions on how exactly

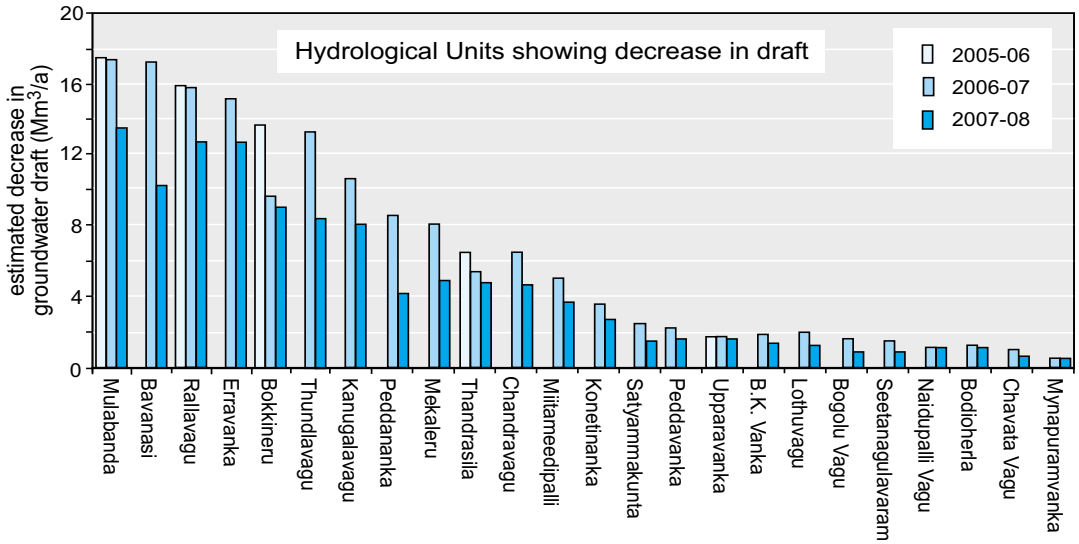
Figure 7: Groundwater pumping changes in APFAMGS Hydrological Units



this impact has been achieved, they do indicate that APFAMGS may be the first example globally of large-scale success in groundwater management by communities

- moreover, project area farmers have not sacrificed profitability to reduce water use; on the contrary they have consistently improved their profitability with the NVOs (Net Value of Outputs, Table 3) per ha nearly doubling during the project period compared to inferior and much more erratic results in similar non-project areas.

Figure 8: Achievements of APFAMGS-GMCs in reducing groundwater overdraft



- The following combination of factors appear to explain the success of this approach:
  - opportune information on groundwater availability as a key input to the farmer's 'risk management paradigm' – with relatively small monsoons usually being followed by reduced sowing in the rabi season

Table 3: Comparison of net agricultural output value from selected APFAMGS-HUN 'project' and 'non-project' areas

NAME OF HUN	NET OUTPUT VALUE (US$/ha) 2008 prices		
	2008	Base Year	% Change
PROJECT AREAS (field crops only)			
Chandrasagar	1040	555	+87
Mallapavagu	611	360	+69
Peetheravagu	468	440	+6
NON PROJECT AREAS (field crops only)			
Chandrasagar	269	396	-32
Mallapavagu	216	161	+34
Peetheravagu	154	319	-52

- the low-storage fast-response hard-rock aquifers with annual replenishment provide a natural cap to overdraft, but estimates of available groundwater and projected demand provided in time to inform rabi planting
- repeating crop water planning over a number of years provide a sound framework for farmer decision making
- reductions in groundwater overdraft are not coming from 'altruistic collective action', but from multiple individual risk-management decisions of farmers – hence no authoritative leadership is required for enforcement
- the impact of micro-irrigation and moisture conservation in most cases stretches far beyond water resource saving because they make it possible to increase crop yields thus combining agricultural growth with reduced groundwater consumption.

- The challenge of post-project sustainability has been addressed by the fact that APFAMGS basically relies on behavioral change enabling more rational individual decision-making. Up-scalability and replicability is expected to be facilitated by a process enabling farmers to become trainers and by virtue of demonstrations to bring other communities on board. However such communities may be subject to unexpected circumstances, and thus the SG should keep a vigilant eye and provide unintrusive support to ensure robust SUR.

Groundwater Management as a Component of APDAI

- The AP Rain-Shadow Areas Development Department was established to intensify, coordinate and increase effectiveness of disperse government assistance for sustainable development in the drought-prone districts shown in Figure 6. In order to take into account both short-term and long-term effects, strategic responses to drought need to be planned and implemented at the level of a group of villages with district and state government agencies facilitating the process.

- The APDAI Project is being implemented during 2006-09, and undertaking a range of pilot projects in Mahbubnagar and Anantapur Districts through a coordinating NGO collaborating with District Collectors, under the oversight of the Principal Secretary of Department of Rural Development. The main groundwater management–related interventions are:
  - **connecting several individual bore wells**[3] through a pipeline network for sprinkler irrigation allowing a larger area to be cultivated with less water, and improving social equity by encouraging non-well owners to make use of the shared system
  - **soil moisture conservation** through enhancing soil water retention capacity and drought resilience by promoting increased biomass at farm level with tree planting on bunds, cultivating some green manure field crops and improved composting.
  - **promotion of SRI (System of Rice Intensification)** – by transplanting rice after 8 days in carefully-prepared plots irrigation is provided intermittently every 2-3 days instead of paddy inundation, which greatly reduces consumptive water use and weed growth but requires extra agricultural labor.

- By December 2008 the five shared-groundwater pilots were at various stages of development with one (Chellapur) already operational. In part of this village 5 bore wells (developed 3-4 years ago after dug wells failed) were joined to a single pipeline to irrigate about 25 ha – the irrigation system by a designated

[3]The concept of sharing bore wells has also been piloted by the Center for World Solidarity (CWS) with similar results to APDAI.

person with operation and maintenance costs equally shared through a common fund. The community itself has agreed on the following regulations and guidelines:

- no new bore wells to be constructed in next 10 years
- one bore well must be rested every day (for 20% of reduction in water/electricity use)
- during drought the land under irrigation should be reduced proportionally
- all shareholders must use water-saving cultivation methods
- crop plans must be made for the season, with priority to food and fodder crops
- area under paddy to be reduced, with no paddy cultivation during rabi season.

Contrary to what might be expected, bringing bore wells under common management was not so difficult to implement in Chellapur – and this is facilitating the process in the other pilot areas. One benefit of shared systems is that they make supplementary (protective) irrigation of kharif crops easy – because with the combined pipeline and sprinkler system a large area can be covered. The other immediate result of introducing the shared system has been an increase in groundnut cultivation in the rabi season, since this crop responds very well under sprinkler irrigation which reduces the incidence of fungal infections.

- Overall APDAI seems promising, but a field assessment similar to the one undertaken for APFMAGS would shed more light on actual groundwater resource savings and achieved increases in economic output. As regards SUR it is noteworthy that while the formal adoption of local rules provides a solid basis for participation, State legislation will have to be cautiously amended to align with local operational realities.

APCBTMP - Shaping Groundwater Component of a Supply-Side Initiative

- The WB-funded Andhra Pradesh Community-Based Tank Management Project (2007-12) spreads across 21 districts (including the drought-prone districts indicated in Figure 6) and aims to rehabilitate about 3,000 irrigation tanks and restore 250,000 ha of irrigated land in order to optimize agricultural production. The ´groundwater dimension' is addressed in each one of the project components :
  - **strengthening community-based organizations** – Water User Associations (WUAs) in tank areas have traditionally consisted only of surface water users, but thanks to a recent SG instruction they will now also include groundwater users
  - **participatory hydrological monitoring** – PHM and CWB, whose effectiveness has been demonstrated in APWELL and APFAMGS, are included to inform surface and groundwater management decision-making
  - **agricultural livelihoods support** – acknowledging that sustainability is not only about wise water management, this component aims at improving water productivity as well as returns to crop and fish farming through a combination of improved water management, agri-business information services, animal husbandry extension, improved fish-farming practices and foreshore plantation – and the recent APDAI experience in coordinating fragmented government support programs could be particularly useful in the future.

- The water well inventory is undertaken through participatory field surveys wells, the depth of the weathered basement aquifer is estimated and the influence of tanks on the groundwater flow regime assessed. Hydrogeologically the irrigation tanks selected occur in both Typologies A and B (Figure 1)

with fairly flexible criteria but with the general aim of having 4 irrigation tanks per assessment unit. As of September 2008, 127 out of a project target of 1,200 tanks had been identified all of them falling into Typology A. The project is still at an early stage as regards the groundwater component and careful attention to detail will be required. The scale of implementation is even larger than APFAMGS and there is a risk of the CBGWM approach suffering because of a combination of project pressures and cumbersome internal procedures.

- Once irrigation tanks are selected, groundwater users in their command area and zone of influence are organized informally into 4-6 Groundwater User Groups (GUGs) per village to assist in the monitoring of groundwater levels and measuring discharges. A nominated executive body consisting of 2 persons (one being a woman) from each GUG will mobilize training and other related activities, conduct meetings at village level, and assist in proper monitoring of data and maintenance of records.

- The initial results from project implementation indicate that:
  - individual users have actively participated in delineating the influence zones of irrigation tanks but moving from informal to formal user organization has not been easy and the SG has indicated that groundwater users should be co-opted into existing WUAs – but a stronger link between the project's tank rehabilitation and groundwater management components must be ensured for a balanced approach to emerge; moreover problems arising where the selected tank cannot easily be related to a single groundwater management need to be addressed
  - the ability and willingness of communities to design their own coping mechanisms for groundwater sharing in water-stressed areas needs to be complemented with an adequate support of 'resource persons' for training (as has been developed in APWELL, APFAMGS and APDAI).

- Over large areas of Typology B groundwater exploitation for irrigation has led to widespread drying-up of water wells in the shallow weathered aquifer and farmers are drilling very speculatively in efforts to intersect deeper fractures in the basement rocks, which if and where 'successful' will only make the communal situation worse. Sustainable community use of the weathered basement aquifer will require a moratorium on the drilling and use of deep bore wells to enable the aquifer to re-fill and thus allowing the introduction of a CBGWM approach – this hypothesis could be pilot-tested by selecting a groundwater body where irrigation abstraction is either naturally decreasing because of urbanization and/or where farmers could be compensated for not pumping deep bore wells.

ORGANIZATIONAL DIMENSIONS OF MANAGEMENT – FACING THE 'SUR' CHALLENGE

- In its major attempt to promote CBGWM Andhra Pradesh, like many developing states, faces the significant challenge of post-project Sustainability, Up-scalability and Replicability (SUR) which relates in part to institutional and organizational issues above the local village level. The previous section discussed in detail at the 'local scale' and in this section the larger river basin and SG are considered.

River Basin Level

- Andhra Pradesh SG is considering the establishment of 5 River Basin Authorities (RBAs) to take over all 'water resources management functions' in the longer run. This could incidentally create special problems for groundwater resources because it could result in:
  - 'local scale' groundwater issues not getting the special attention they need and deserve
  - breaking-up the 'critical mass' of experienced SG groundwater professionals.

  It will be essential that explicit attention to governance/management of groundwater resources is given during RBA development, given the major importance of groundwater to livelihoods, food production and drinking water-supply.

- This will require an 'innovative organizational structure' to ensure that best use is made of SG's limited but experienced personnel base in groundwater resources management – in the interest of both basin and local level management and state-level monitoring, planning and policy aspects. A key requirement during institutional strengthening will be to keep the AP-GWD together, while gradually strengthening the RBA teams. The hydrogeological characteristics of Andhra Pradesh, however, are such that the most appropriate scale for groundwater management actions is at micro-catchment, groundwater body and village level – following the approaches of APFAMGS and APDAI - and not at river basin level (which is better suited to larger-scale planning and consideration of conjunctive use).

State Level

- The AP-GWD, which reports to the Irrigation Department is the nodal agency for all groundwater related activities of the state and its main functions are the following :
  - monitoring groundwater levels and quality especially in rural areas
  - periodic assessment of groundwater resources
  - prioritizing areas for rainwater harvesting, recharge enhancement and groundwater conservation (through introduction of micro-irrigation, change in cropping pattern, etc)
  - creating public awareness on various issues related to groundwater use
  - assisting in the implementation of regulatory provisions .

- In addition, recently they have been asked to take the lead on the APCBTMP Groundwater Component and are in the process of evolving into a groundwater management agency. Nevertheless, this evolution has not been as fast and robust as required because still most of their effort is channeled into monitoring – and they have continued to suffer from a lack of appropriate personnel and other resources, and have not been able to bring in some specialists in the agronomic and social-science disciplines.

- In order to face the groundwater management challenge it will be necessary for the AP-GWD to :
  - have a higher status in the state government hierarchy
  - be connected to budget decisions on all projects related to groundwater management
  - forge stronger linkages with the Rural Development Department
  - strengthen their overall capacity also at both state and district level.

The Legal Framework

- The relevant legislation to CBGWM initiatives is the **Andhra Pradesh Farmers' Managed Irrigation Systems (APFMIS)** Act 11 of 1997, which provides for farmers' participation in the management of irrigation systems through Water Users Association (WUA), and considers that all landholders within the delineated command area constitute the members of the WUA. In addition this has been complemented by:
  - various instructions issued by the SG in 2003 ordering that District Collectors co-opt as WUA members persons having customary rights and who are dependent on water sources for their livelihoods
  - on September 2008 the SG further instructed District Collectors to co-opt 'groundwater users outside the irrigation-canal areas but within demarcated tank influence zones for Participatory Groundwater Management (PGM) activities'

  The WUA movement in Andhra Pradesh is, however, not without its drawbacks – particularly in the surface irrigated areas the active role of WUAs in water management is poor. Thus using the Society Act to give legal status to groundwater management organizations (as has been done with APFAMGS-HUNs) appears more promising.

- The key legislation dealing with groundwater is the **Water, Land & Trees Act (WALTA) 10 of 2002 (amended 2004),** which aims at promoting water conservation, tree cover and regulating the exploitation and use of ground and surface water for sustainability. It envisages formation of authorities at the State, District, Division and Mandal levels – with the Mandal authority nominating the WUA Presidents.

- The above acts do not provide much scope for PGM, and as a result a number of ad-hoc approaches have been devised in each of the CBGWM schemes discussed above – from informal organizations to relying on village level associations to promote proposals to SG for the formation of Groundwater User Groups & Groundwater Management Committees.

- The main provisions of WALTA on groundwater management are:
  - water well owners must register their wells by paying a small registration fee
  - landowners wanting to construct new water wells must have a license for their electricity connection and a permit from the designated authority (who assess the acceptability of the proposed site in relation to neighboring wells and the state of resource development)
  - drilling rig operators have to obtain a feasibility certificate from the AP-GWD and cannot charge a landowner for a water well drilling failure.

  A shortcoming of this Act is that it does not address existing wells and the situation of overexploitation nor is there any scope for locally-agreed regulations to be endorsed. However, a much bigger problem is that the Act has been cumbersome to implement and that there is confusion on who is responsible for what enforcement – and a systematic assessment of past implementation difficulties together with a review of the powers is required.

SUMMATION OF EXPERIENCES AND PROSPECTS

- Andhra Pradesh arguably has more experience in promoting CBGWM than any other Indian state and than almost any other part of the world – even if much of the experience is still at pilot project stage. However, the potential for SUR (as assessed in the four contrasting initiatives discussed here) is linked to the specific hydrogeological and socioeconomic settings involved – namely an extensive, low-storage, aquifer system that is annually recharged to varying degrees by the monsoonal rains, and whose 'manageable groundwater bodies' are exploited by fairly homogenous communities of small farmers'.

- The four Andhra Pradesh CBGWM experiences had the following shared objectives although with different emphasis on each:
  - safeguarding basic services (drinking water and ecological facilities)
  - achieving sustainable agricultural production
  - ensuring access to minimal water-supply for all
  - keeping public energy costs manageable.

  There is high potential for increasing 'internal synergy' between APWELL, APFAMGS, APDAI and APCBTMP, and a lot to be gained by interchanging experience.

- The successful design of a rounded support package for CBGWM should include :
  - facilitating better farmer understanding of the groundwater/crop-planning interrelation to encourage more balanced cropping with less high water-use crops
  - simple agricultural information and extension directly to farmers
  - promoting well sharing, piped distribution, efficient irrigation and soil-water conservation
  - implementing a combination of demand management and aquifer recharge measures
  - increasing the reliability of improvement of rural electricity services
  - ensuring the coordinated utilization of all appropriate government grants and support.

- A SWOT analysis (Table 4) is helpful in assessing and summarizing both the potential of CBGWM in Andhra Pradesh and the difficulties that continue to be encountered

Table 4: SWOT analysis on promoting CBGWM in Andhra Pradesh

STRENGTHS	WEAKNESSES
– existence of working models (APFAMGS) and very promising pilots (APDAI) – existence of substantial number of local NGOs and other organizations with ability to support such programs - many with women in a leading role – receptiveness within SG to consider required adjustment of government programs	– government outreach through extension services is weak – AP-WALTA legislation is top-down and not effectively implemented – UP-GWD has history of groundwater data collection and only recently is orientating towards resource management – public subsidy system still biased against groundwater management and dry land farming
OPPORTUNITIES	**THREATS**
– changing rural scenario (higher wages, rural-urban migration and more commercialization) – groundwater management need not come at cost of agricultural production and farm income with appropriate irrigation technology – much scope to integrate CBGWM with other programs (such as for watershed conservation, drinking water supply, electrical power improvement, etc.)	– expansion of CBGWM risks public over-expectation and causes capacity constraints – continued bore well drilling in several places and very dramatic changes in agricultur in Rajelsima areas – expansion of tree horticulture may limit possibilities to expand CBGWM

- An important lesson from the experience so far is that there is no need for a 'sacrificial attitude' to groundwater management – since groundwater demand management encourages changes in cropping patterns, irrigation techniques and soil-moisture conservation that can also lead to improved water productivity and farmer returns. At present the coverage of improved practices in Andhra Pradesh is about 30% - and there is thus considerable room for further action. The cost of CBGWM facilitation is reasonable but that ample time is required and one should not expect 100% success.

- In summary, Andhra Pradesh has available enough critical support and positive experience to up-scale and replicate CBGWM – but a phased and flexible approach will be needed while avoiding spending pressures and unwieldy operational procedures, and engaging experienced and sensitive facilitating support organizations. It would be very valuable to form a corpus of practitioners to design the up-scaling and replication process, together with the development of a 'lighthouse function' in the AP-GWD to monitor the process, and act to ensure continuity and momentum is achieved on a widespread basis.

Publication Arrangements

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