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44361

Number 18

Confronting the Groundwater Management Challenge in the Deccan Traps Country of Maharashtra — India

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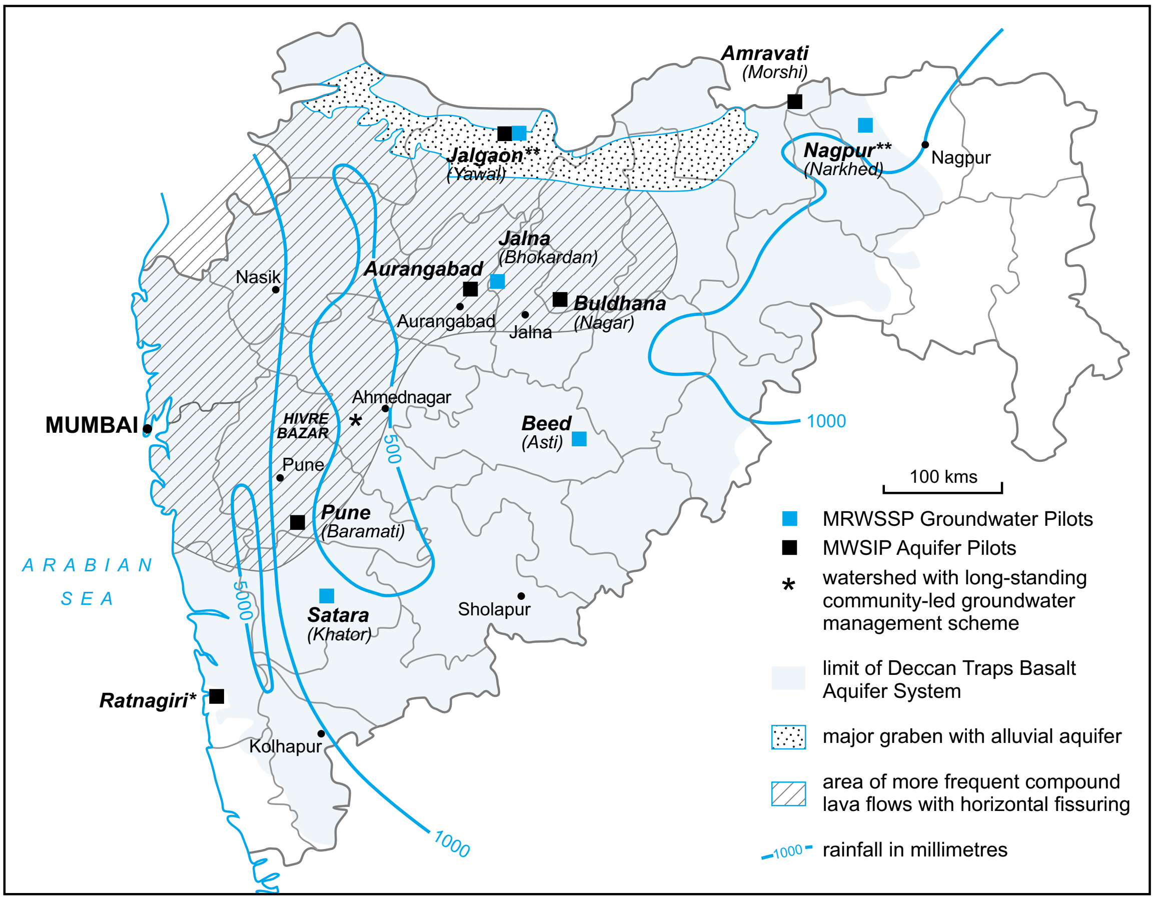
The drought-prone interior of Maharashtra State is especially dependent on groundwater resources for both rural drinking water-supply and for subsistence and commercial irrigated agriculture. Despite generally very limited potential these resources are very intensively exploited, but such development has encountered significant problems. This Case Profile summarizes the progress of, and the groundwater management approach developed for, the MRWSSP (Maharashtra Rural Water-Supply & Sanitation Project –Jalswarajya) and the MWSIP (Maharashtra Water Sector Improvement Project) – which respectively are at the phase of mid-term review and completion of 'baseline characterization'. The opinions presented here are those of the authors alone, but benefited greatly from in-depth discussion with the senior counterparts of the aforementioned projects : Mr V S Dumal (State Secretary – Department of Water-Supply & Sanitation), Dr Satish Umrikar (DWSS-MRWSSP Pilot Project Coordinator), Dr S P Bagade & Mr Vikas Kharage (Directors of Groundwater Survey & Development Agency), Mr Suresh Khandale (GSDA-Deputy Director) and Mr Shashank Deshpande (GSDA-MWSIP Pilot Aquifer Coordinator).

RESOURCE DEPLETION – REALITIES & MYTHS

Most of the land surface of Maharashtra State is underlain by the Deccan Traps Basalt (Figure 1), including the entire highly drought-prone central area with an average rainfall of less than 750 (and locally 500) mm/a. This formation gives rise to a complex low-storage weathered hard-rock aquifer system – and in the very extensive rural areas outside the command of (the few) major irrigation canals it is vital to human survival and livelihoods. But the **total available storage of groundwater in hard-rock aquifers (such as this) is strictly limited by their weathering characteristics and water-bearing properties.**

There is one part of Maharashtra State which possesses a major alluvial aquifer – this is the Tapi Gurnia 'tectonic graben' which runs approximately west-east in the northwestern part of the State (Figure 1), passing under the town of Jalgaon – the development and management of the groundwater resources of this economically-important aquifer require a different approach and are also considered here.

Figure 1: Hydrogeological map of Maharashtra State showing the extension of Deccan Traps Basalt and the location of MRWSSP & MWSIP Pilot Projects



Widespread and progressive depletion of groundwater tables in Maharashtra has become a cause of major concern over the past 10 years – in many locations this has occurred more-or-less year-on-year, except for a partial (but temporary) recovery following years of exceptionally heavy monsoon rainfall. The developmental sequence for groundwater observed since the mid-1980s has been :

- drying-up of most dug wells ever earlier in the dry (rabi) season – initially those at the margins of the main groundwater bodies (where the weathering depth was less) but subsequently stretching much more widely
- deepening of dug wells as dug-cum-borewells, but also with subsequent yield reductions
- drilling of progressively deeper bore wells, almost regardless of whether there was evidence of the existence of groundwater flow at greater depth.

Groundwater resource depletion has already had serious impacts (including a possible correlation with increasing levels of farmer suicides) and, in consequence, has received a lot of media publicity and increasing political attention. But much of this has focused on only the following two facets of what is a more complex problem (misleading for the reasons indicated) :

- **provision of highly-subsidized lump-sum electrical power for pumping** – *while energy subsidies* *should be phased out because of their dire consequences (when combined with falling water-tables) for state finances (and replaced by some other form of support targeted to the poorest farmers), energy consumption represents only a minor proportion of total crop production costs and increased energy costs are unlikely on their own to prove sufficient to curb excessive groundwater abstraction*

- **failure to conserve watersheds and encourage groundwater replenishment –** *recharge enhancement should not be regarded as a universal panacea for resource imbalance (because the land area over which recharge from monsoon precipitation can be economically enhanced is always limited compared to the potential dry-season demand from irrigated agriculture) but can be useful for sustaining drinking-water sources (provided abstraction for irrigation in the neighborhood can be controlled).*

So what are the primary causes of groundwater resource depletion? The reality is that the **total available storage of groundwater bodies in hard-rock aquifers (such as the Deccan Traps Basalt) is strictly limited by their weathering characteristics and water-bearing properties.** Moreover, this storage reduces rapidly as the water-table falls through critical horizons in the weathering zone (usually below the uppermost 2-6m of fractured bedrock which is typically situated at 5-25m bgl). It can thus be rapidly depleted by heavy abstraction, and the intensive uncontrolled borewell drilling for irrigation of rabi and jawaad (dry season) crops (which has occurred widely over the past 10-15 years) is unquestionably responsible for the observed hydrological imbalance.

Groundwater resource depletion has had a series of impacts – spiraling costs for water well and/or pumpset deepening, escalating energy consumption and losses in water pumping, serious operating and financial problems for state electricity company (since rural energy is highly subsidized), reduced availability of electricity and/or groundwater supply for irrigation with damage to dry season crops, and problems with provision of drinking water.

In the rural environment the main stakeholders in groundwater use fall into the following groups: subsistence agriculture, rural drinking water, some village industries and occasionally commercial agriculture (although well yields are only locally sufficient for this). **Resource depletion impacts the poorer farmers first by:**

- putting them in the precarious position of having to purchase water from richer farmers with deeper bore wells (whose water is often produced with free electrical energy)
- forcing them out-of-business completely with migration to the cities.

In turn many 'better-off' farmers find themselves having to negotiate larger-and-larger bank loans in their efforts to deepen water wells and to 'chase the declining water-table', whilst simultaneously facing decreased water security and crop yields. Thus although the initial use of groundwater for irrigation generated many benefits for farmers, there are **few 'winners' when its exploitation becomes uncontrolled and excessive.** Such 'winners' would appear to be restricted to water well drilling rig manufacturers, owners and operators, together with pump manufacturers and retailers (and their financiers).

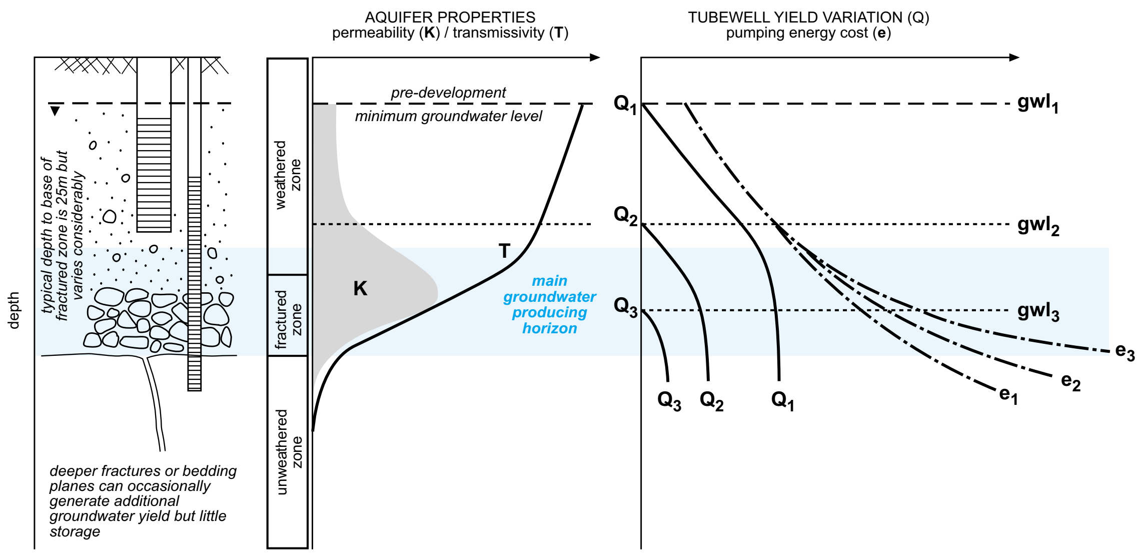
It would thus appear that a 'non-intervention policy' (allowing natural controls to constrain use) will have unacceptable social costs – including failure to meet minimum drinking water-supply requirements, increasing bankruptcy of the rural population and sub-optimal use of available groundwater for agricultural production. And practical approaches are urgently needed for mobilizing communities to adapt to groundwater resource realities by exercising constraint on groundwater extraction

Energy-supply policy (determining the level/effectiveness of rural electrification) and pricing (dictating the level of subsidy or flat-rate tariffs) have exerted a great influence on groundwater use for irrigated agriculture. In much of Maharashtra there is high coverage of rural electrification and the supply (although very intermittent) is 'sufficiently predictable overall' for farmers to rely exclusively on electric-engine pumpsets. The major electricity subsidy via 'flat-rate tariffs' related only to pump horse-power results in farmers actually paying for less than 20% of the energy supplied.

It is unlikely that flat-rate electrical tariffs are the primary cause of excessive groundwater exploitation (because this condition also widely occurs where farmers have to use diesel-engined pumpsets), but the existence of flat-rate electricity tariffs where shallow low-storage hard-rock aquifers predominate has allowed extremely inefficient practices to develop such as :

- farmers leaving pumps switched-on to obtain supply when the power-system activates (since this is not on regular time-base) and not worrying about non-beneficial energy losses
- farmers continuing to operate bore wells and pumps at groundwater levels which are far too low and at which well entry and pump friction losses are very high – this marginal extraction would be completely uneconomic if farmers felt the full-cost of electrical energy consumed (Figure 2).

Figure 2: Hydraulic characteristics of the weathered Deccan Traps Basalt Aquifer and their effect on tube well yield-drawdown-energy consumption with rapidly deteriorating performance under falling water-table



The main effect of the flat-rate electrical energy tariffs in Maharashtra groundwater conditions has thus been to impose an enormous financial burden for little return on the state electrical energy generation and distribution company. It is also evident that the large electrical energy subsidy is not benefiting the poorest farmers (because their water wells are usually less deep and are often dry early in the rabi season) and it goes to the somewhat better-off farmers who have deeper bore wells (and whose groundwater production is probably the more inefficient).

The flat-rate rural electricity tariff can be justified to some degree :

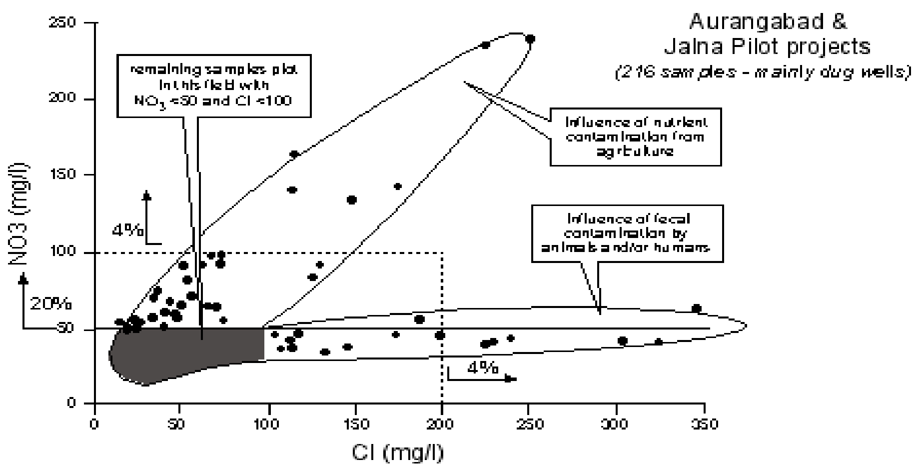
- in political terms to reduce the unjust price differential for irrigation water-supply between farmers wholly dependent on groundwater pumping compared to those in major irrigation-canal commands
- and might be manageable in technico-economic terms in higher-yielding aquifers (for which pumping energy requirements and water well energy losses much smaller)

but it is an extremely costly policy in hard-rock aquifer terrains. Thus rural electricity use-efficiency mapping is urgently needed to inform the electrical energy-groundwater policy debate and understand better the current patterns of rural use and grid distribution losses according to aquifer type and groundwater levels.

The competition for available groundwater resources between village drinking-water provision and irrigated agriculture is increasingly being recognized as a major factor in the widespread slippage (and potential non-achievement) of the UN Millenium Development Goals (MDGs) in terms of adequate sources of safe rural water-supply in the 'hard-rock country' of India.

Fortunately the groundwater of the Deccan Traps Aquifer System does not tend to exhibit elevated fluoride concentrations (like those encountered quite widely in the Weathered Granitic Complex Aquifer elsewhere in central India), and the main concerns over groundwater quality in the rural areas relate to either inadequate sanitary protection or diffuse agricultural pollution. The contrasting effects of these contamination processes is illustrated (Figure 3) from a large sample of dug wells in the adjacent PP areas of Aurangabad and Jalna Districts.

Figure 3: Evidence of groundwater contamination in the dugwells of Aurangabad and Jalna District Pilot Projects from nitrate and chloride analysis



APPROACHES TO COMMUNITY-BASED GROUNDWATER MANAGEMENT

The initial approach taken for the MRWSSP and the MWSIP was to identify a series of relatively small pilot projects (PP) areas, broadly representative of the range of hydrogeologic and climatic conditions of the State (Figure 1), in which a community-based approach to drinking-water source development and protection, and to groundwater resource management more generally, would be promoted. From the summary of PP hydrogeological characteristics (Table 1) it will be evident that the majority (6 out of 10 total) fall into the classification of 'upland Deccan Traps micro-watersheds' in the most drought-prone areas of Maharashtra, which have severe drinking water-supply problems.

Table 1: Summary of the MRWSSP & MWSIP Groundwater Pilot Projects

DISTRICT	BLOCK	AREA (km^2)	HYDROGEOLOGICAL SETTING	PROPN WITH PERENNIAL GW BODY
MRWSSP GROUNDWATER PILOTS				
Pune	Baramati +	96	upland Deccan Traps Basalt country with limited 'storage zone' on main valley floor, flanked by 'runoff zone' on the highest ground which generally has only localised groundwater	30%
Aurangabad	Aurangabad	241		20%
Buldhana	Nagar	147		20%
Nagpur	Narkhed	31	Deccan Traps Basalt with relatively high proportion of 'storage zone'	0-10% (if alluvial deposits included)
Ratnagiri *	Ratnagiri	48	dissected coastal lateritic plateau with layered very low storage and weakly-recharged discontinuous 'aquifers'	50%
MWSIP GROUNDWATER PILOTS				
Satara	Khator	198	upland Deccan Traps Basalt country with limited 'storage zone' on main valley floor, flanked by 'runoff zone' on the highest ground which generally has only localised groundwater	30%
Beed	Asti	125		20%
Jalna	Bhokardan+	50		10%
Amaravati	Morshi	61	Deccan Traps Basalt with relatively high proportion of 'storage zone'	50%
Jalgaon **	Yawal	278	major graben filled with deep alluvial deposits and flanked by supplementary recharge zone constituting a major groundwater body or aquifer system	80-100%

* *not really necessary/possible to continue as MWRSSP Pilot for technical/social reasons* ** *formerly MWRSSP Pilots*

In Maharashtra there are isolated existing examples of community self-regulation of land and groundwater use (at village level with the gram sabha playing key role in fostering participation). The most long-standing and apparently successful is Hivre Bazaar (Ahmednagar District), which occupies just under 1,000 ha of elevated Deccan Traps Basalt (700-800 m ASL) in the most arid part of the State (average rainfall around 400 mm/a) (Figure 1). Its population is around 2,000 and 80% of its area is cultivated agricultural land, but prior to 1990 irrigation wells failed well before the end of the rabi-season and hardly any groundwater was available for irrigation after the month of January until the arrival of the monsoon in June – and there were also severe problems to meet drinking-water requirements. At that time stringent soil and water conservation measures were progressively introduced through community agreement under charismatic leadership (without government support or intervention), as part of a broader package of social reform, including :

- conservation of hilly ground as woodland by banning axes and open grazing of livestock, together with measures to reduce monsoon soil erosion and to enhance aquifer recharge
- permitting only the use of dug wells for agricultural irrigation and reserving deeper bore wells for domestic water-supply – as a measure to give priority for drinking water
- encouragement of drip and microspray irrigation and only permit irrigation by these techniques in the jawaad-season – this as a measure to reduce non-beneficial evaporation
- ban on sugar-cane cultivation for sugar refineries – as a measure to conserve groundwater and look for higher productivity uses especially in the jawaad-season
- annual community groundwater resource status assessment and use audit, together with communal agreement on rabi and jawaad cropping patterns and support in crop/product marketing – as a measure to balance irrigation demand with groundwater availability and to increase groundwater productivity.

Current cropping regimes include kharif millet, sorghum and onions (on all available agricultural land), rabi wheat, vegetables and fodder crops (requiring about 150 mm of irrigation), and jawaad vegetables, pomegranates and flowers (with weekly drip irrigation on around 20% of the cultivatable land), together with a significant level of stall dairy farming (450 head of cattle). This approach has led to an increase in family incomes from I rps 830/a (US$ 100/a) in 1990 to over I rps 28,000/a (US$ 3,500/a) in 2005 – and mobilized sufficient resources to provide full coverage of pit-latrine sanitation. Hydrologically the approach has maintained water-table levels within a maximum depth of 10-15 m bgl (according to location) and assured an uninterrupted supply of drinking water from well-equipped and maintained hand-pump tube wells.

The original intention for the PPs was to define micro-watersheds, on the assumption that these would delineate the most appropriate areas for 'aquifer management' – with the implication that the entire watershed would be underlain by a continuous '**groundwater body**' capable of (and requiring) resource management.

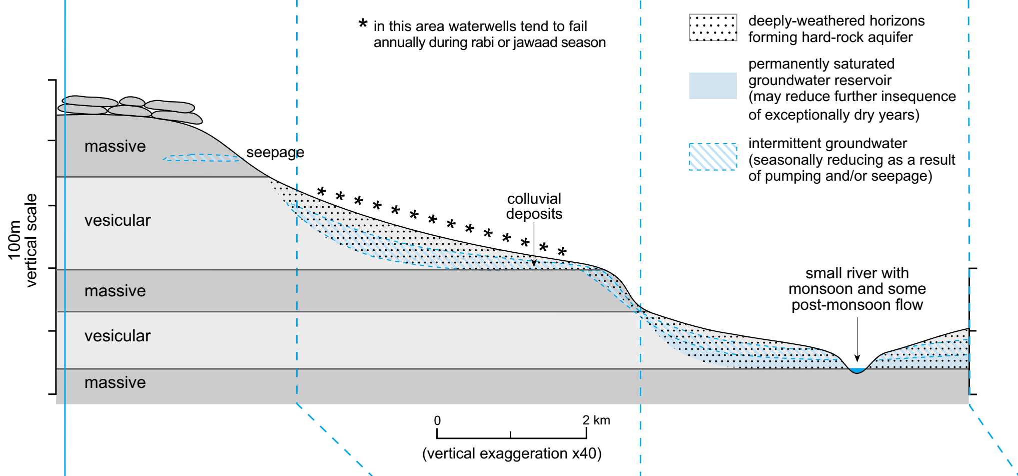
But an important lesson learnt is that it is only on the lower ground that a deep weathering profile of the Deccan Traps Basalt is generally preserved, and it is that forms a continuous **perennial groundwater body** of significant storage (this part of the aquifer system is sometimes called its '**storage zone**') (Figure 4 & Table 1). It is evident in Figure 4 that the stratification of different types of basaltic lava (vesicular to massive) also exerts some influence on the weathering process and the preservation of deeper weathering profiles – but it is only in a limited part of the State (Figure 1) that more complex brecciated lava-flows occur which may have sufficient primary horizontal permeability and porosity to form significant local aquifers.

In all other areas, up hydraulic-gradient from the 'storage zone' is the so-called '**recharge zone**' (Figure 4), which has good infiltration characteristics but whose groundwater storage tends to be seasonal and drain away during the course of the dry season. And above this again is the so-called '**runoff zone**', which has very limited groundwater infiltration and storage capacity and very little water is retained after the end of the monsoon (except for occasional disconnected weathered pockets associated with faults and along contacts between discrete basalt flows).

The **appropriate focus and scale of community participation in groundwater management should be informed by the degree to which villages share (or significantly influence) a 'common resource base'** ('**groundwater body**'), and this will vary substantially with hydrogeological setting (Table 1 & Figure 4). There may be an argument for including the 'recharge zone' (or part of that zone) with the 'storage zone' when defining the 'groundwater body' which should be subjected to community resource management, and also trying to ensure some economic reward for upstream communities who undertake recharge

Figure 4: Typical hydrogeological cross-section of a Deccan Trap Basalt micro-watershed to illustrate the occurrence of groundwater bodies with related water-supply prospects and management needs

DECCAN TRAPS BASALTIC GROUP



GROUNDWATER BODY	***'run-off zone'***	***SEASONAL ('recharge zone')***	***PERENNIAL ('storage zone')***
Groundwater Resource Potential	extremely limited - associated with localised weathered pockets and occasional thin flows of more fractured or porous basalt	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	'groundwater body' of limited extension and modest storage - but capable of useful well yields for both kharif and rabi irrigation (or perennial crop production) on significant land area
Village Water-Supply Improvement Options	scope for augmenting existing waterwells should be evaluated and groundwater pockets associated with structural features may be worth pursuing - but may be insufficient and need supplementing periodically by tanker	establish performance of existing waterwells and potential for recharge enhancement -VWSCs must protect improved sources from irrigation well construction	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
Approach to Groundwater Resource Management	not needed - but VWSC involvement for improved sanitary and pollution protection of any existing waterwells and small springs	no systematic approach necessary or feasible but VWSC's could participate in AMOR because of recharge significance of zone	form AMOR for 'groundwater body' by VWSC's and other stakeholders to regulate dry-season irrigation use, facilitate water savings and resolve conflicts
Socio-Economic Development Level	only very small villages that have difficulty in finding sufficient water for domestic needs and livestock watering, and struggle for subsistence given only dryland farming (insufficient water availability for irrigation)	occasional larger village - kharif irrigation but little rabi cropping, thus population have to migrate seasonally to work in irrigated agriculture or urban industrial areas	more densely-populated – irrigation of rabi and/or perennial crops practised on significant proportion of land area (15-25%) but competition for available storage can lead to conflicts between irrigators and drinking water supply

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

enhancement measures which increase groundwater availability immediately downstream. But there appears to be little point including villages (or VWSCs) from the (often extensive) runoff zone, and a much more simple approach to groundwater (in effect limited to source operation and protection) is advocated for this zone (Figure 4).

Given the nature of the hydrogeological regime and the low population density in the 'runoff zone', water resource management actions (such as hill reforestation to re-instate minor upland springs, developing or capturing the very limited groundwater available to improve drinking water-supply and for garden irrigation, small surface water impoundments, etc) will have little effect on other parts of the micro-watershed and can be best handled by the corresponding VWSC alone (Figure 5) (92 of which have been created by the MRWSSP). But nevertheless the runoff zone should be a high priority for investment in water-supply development in the interest of basic UN-MDG rights and poverty alleviation.

Only those areas extensively underlain by a continuous groundwater body lend themselves to community aquifer (groundwater resource) management via an AWMA or AMOR. And here, because groundwater is a 'highly decentralized resource' and one that has been mainly developed through private initiative (by very large numbers of individual users), its management and protection can only be effective through proactive social participation.

However, a responsible local government agency will often have to make the 'first move' by :
- defining 'groundwater bodies' that are capable of being managed as a 'water reservoir' (Figure 4) , and their actual and potential allocation conflicts
- establishing a 'groundwater users profile' for each groundwater body to facilitate engagement with the community and thereby understanding the socioeconomic importance of the resource and assessing the risk of 'non-action'
- selecting 'pilot areas' to try out participatory groundwater resource management and quality protection—the boundaries of such areas (and subsequent aquifer management areas) being defined on the basis of groundwater bodies with specific management needs.

An 'enabling environment' for local community participation (at groundwater body or micro-watershed level) will often need to be facilitated and sustained, which will involve bringing together subsistence farmers, commercial irrigators (where present), village panchayat leaders (representing drinking water interests and any industrial users), local administration (district inspectors, revenue officers, etc) and state government departments. In this context the promotion of community groundwater user (or aquifer management) organizations will be an important step to develop a structured dialogue and collaboration with those either owning or operating water wells, and to ensure adequate surveillance of groundwater resource status and sustainability.

The local government agency responsible for promoting groundwater management must set (in coordination with stakeholders) realistic targets for groundwater management interventions – and given the character of the limited groundwater resources of the Deccan Traps Basaltic aquifer system (which are not at risk of permanent degradation and whose shallow depth naturally restrict groundwater withdrawals) the primary objectives can be limited to :

- eliminating unproductive private investments in constructing/deepening irrigation bore wells, which have a very low chance of encountering an adequate groundwater supply (even in the short-term) and are leading to increasing bankruptcy in the rural population and bad debts for rural development banks (**in other words convincing all actors in the rural community that the logical response to observed falling water-table is never water well deepening**)
- improving the productivity of existing groundwater irrigation use, through the elaboration of realistic village crop-water plans that maximize farmer income whilst reducing groundwater use (Figure 5) by increasing water productivity with the introduction of higher-value crops (**and in particular convincing farmers that the logical response to a rise in water-table is not necessarily increasing the cropped area under irrigation**).

Figure 5: Indication of typical irrigation water demand in Maharashtra for typical crops grown in the three main cultivation seasons

MONTH		J	A	S	O	N	D	J	F	M	A	M	J
SEASON		HOT WET (kharif)				COOL DRY (rabi)				HOT DRY (jayaad)			
CROP TYPE	seasonal	millets^{0} sorghum^{0}				wheat^{1} millets^{1}				groundnut^{1} green fodder^{3}			
		rice^{0}				pulses^{1} groundnut^{1}				vegetables^{3}			
	perennial	sugar cane^{3}				orange^{2}, banana^{3}, sweet lime^{2}							
AVERAGE IRRIGATION REQUIREMENT		**50 - 150 mm** (occasional application)				**120 - 200 mm** (regular application)				**400 - 600 mm** (continuous need)			

IRRIGATION WATER DEMAND	RELATIVE CROP VALUE	WATER-TABLE DEPTH CONSTRAINT
0 low/negligable (in this season)	low	<2m - rice
1 low	high	>2m - grains, pulses, groundnut, vegetables
2 moderate		>5m - oranges and other fruit trees
3 high		

Beyond this the longer-term objectives of a community groundwater management plan will in many cases include such items as :

- specific measures to help conserve drinking water sources, in terms of restrictions on the construction and operation of irrigation water wells in their vicinity, the implementation of recharge enhancement measures where appropriate, and measures to avoid their pollution from land-use practices
- a general reduction in land area irrigated in the dry season, coupled with such policies as irrigated crop diversification, improving the productivity of livestock rearing and dry land cropping and the development of small-scale industries
- reducing the level of electrical energy consumption for groundwater pumping through somewhat

reduced pumping lifts and major reductions in system and pump losses (paradoxically improved reliability of electricity distribution would probably aid this process)
- promoting the consolidation of AMORs for relevant groundwater bodies through providing them with 'ad-hoc legal personality' both to facilitate their access to other government agencies and support programmes and to help them deal with 'user profile asymmetry'.

A small proportion of groundwater bodies in Maharashtra State, in effect mainly (or exclusively) those of the alluvial aquifer associated with Tapi Gurnia 'tectonic graben' (Figure 1), possess large enough groundwater resources to support large-scale commercial irrigated agriculture – in addition some of these groundwater bodies are susceptible to irreversible salinization if their groundwater abstraction is not adequately controlled. As such they require a somewhat different management approach in which proactive community participation is complemented by a formalized regulatory approach. In particular if groundwater use for rural water-supply and small subsistence irrigators is to be protected in such aquifers, an inevitable implication is that larger groundwater abstraction for commercial-scale irrigated agriculture (and industrial use if present) must be controlled.

Here the responsible local government agency will need to appraise the scope for regulatory measures such as individual groundwater use rights (abstraction permits/entitlements with abstraction measurement and charging) for major commercial and industrial abstractors (and communal groundwater use rights at aggregate village level for village water-supply and subsistence agriculture), But the issue of how to address heterogeneity in the groundwater 'users profile' will have to be addressed in order to ensure community support and enforceability.

A '**Groundwater Management Model Bill**' has been prepared by the Indian Union Government (2005) as a basis for state governments to develop and implement legislation on resource management and protection with appropriate adaptation to local circumstances – its strong features are recommendations:
- to constitute and empower some form of 'groundwater management agency' appropriate to local circumstances and needs
- to register and control at least the larger groundwater users in heavily-exploited 'blocks' whose groundwater resources are at risk of irreversible degradation.

But it is less clear on community participation and pollution control and there also remains a potential conflict with the **Indian Easement Act** (1882) which associated groundwater abstraction rights directly with land ownership – although that could be interpreted as restricted to only 'minimal subsistence use' on the land holding concerned (and not to apply to commercial or industrial use nor to allow the sale of groundwater).

However, the Union Government–Groundwater Management & Ownership Commission (September 2007) offers a pragmatic political and legal framework for sustainable groundwater management, by-passing the issue of legal groundwater ownership through providing a coordinated national-state government mechanism (based on a Supreme Court of Justice ruling invoking environmental considerations) to notify 'groundwater resource blocks' in 'danger of irreversible damage'. Such notification would make way for the introduction of regulatory, economic, supply-side and demand-side measures (including reduction of groundwater-irrigated areas) to reduce groundwater extraction. In Maharashtra the opportunity to pilot this approach (within the MWSIP) has arisen for the Jalgaon District—Yawal & Raver Blocks (which ate the only two 'notified groundwater areas' in the State).

Groundwater management is a major challenge in the field of natural resource administration as a result of being a widely-distributed resource affected by a plethora of local users and polluters, with the behaviour of these users and polluters being influenced by national policy decisions affecting land and water use. Thus governance arrangements, resource policy and information provision need to relate to a range of different scales, with specific attention to :

- **macro-economic policy interventions**—because groundwater demand is strongly influenced by national/state subsidies or financial support (variously for food crops, electrical energy and water well drilling) which affect groundwater-based agriculture and the rate of transition to less water-dependent livelihoods
- **local-level management measures**—to create effective institutional arrangements for groundwater (including empowered government agency, adequate legal framework, local community management partnerships, land-use constraints and where appropriate abstraction charging) to regulate and protect resources.

A key requirement for improving local groundwater management will be develop a state government agency responsible for the resource. In the Indian context, state-level agencies have some major advantages when it comes to promoting groundwater management on-the-ground, since they are best able :

- to facilitate cross-sector dialogue on groundwater resources at the all-critical (state) level
- to promote close government-stakeholder interaction (especially considering that most state government departments have operational offices at 'district-level' where many of the local management measures will need to be taken).

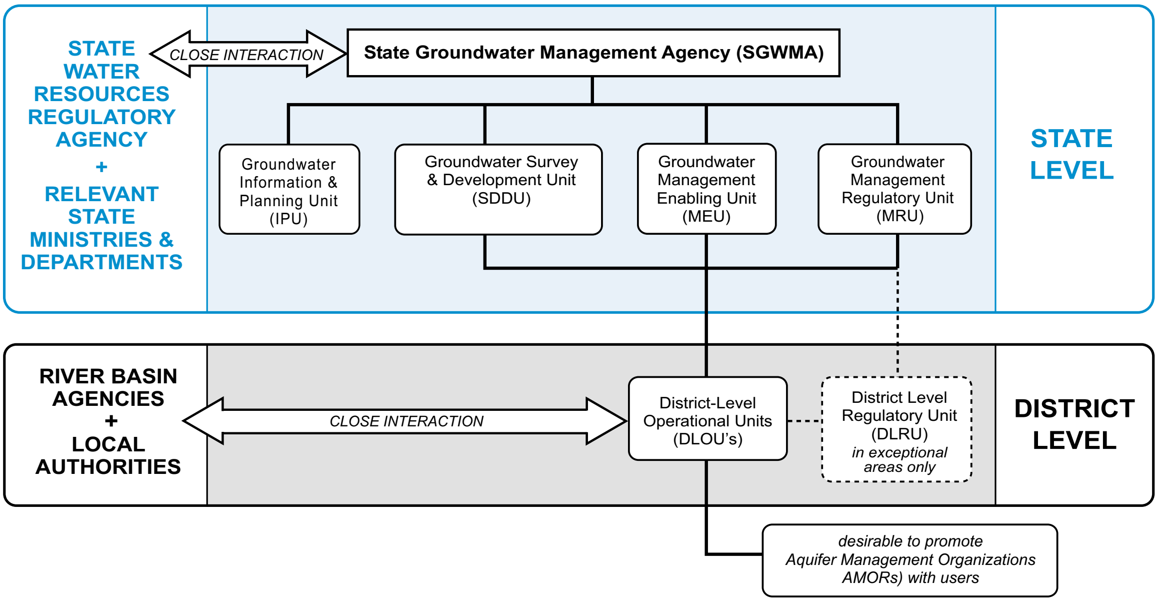
But it will be necessary to nucleate effectively the existing groundwater expertise and re-focus it on resource management.

In the case of Maharashtra the most pragmatic and attractive approach would be to transform the role of the GSDA from exclusively 'supply-development' to primarily 'resource-custodian' and 'information-provider'. But for decentralization of the groundwater resource management function to be successful there will be a substantial challenge in terms of setting the GSDA at the appropriate level in the state government hierarchy, of staffing it with appropriately-trained professionals, and of defining the relation with the surface water resource administration – the preferred structure to achieve these ends is given in Figure 6, with the following primary tasks for each of the suggested units :

- **Groundwater Information & Planning Unit:** maintaining up-dated resource and user status assessments as basis for informing related state government policy and for planning replication of management actions
- **Groundwater Survey & Development Unit:** undertaking basic field work and ensuring groundwater supply plans, recharge enhancement measures and demand management interventions are to

best practice (scientifically sound and economically effective)
- **Groundwater Management Enabling Unit:** facilitating, monitoring and supporting the success of community-based groundwater resource management initiatives
- **Groundwater Management Regulatory Unit:** working on resource monitoring, evaluation and regulation in groundwater block notified as in danger of irreversible damage (through process prescribed by the coordinated national-state government policy).

Figure 6: Proposed internal structure for the GSDA to fulfil the role of state groundwater management agency indicating necessary interactions with other state departments and river basin agencies



The GSDA will need to promote the sort of actions summarized in Table 2.—and it will be especially important for them to be proactively involved in defining the level of delegation for resource management to the community, with empowerment of District Inspectors and Village Panchyat Leaders to sanction those who persistently violate the established local rules for groundwater abstraction and use.

In refocusing around a management (as opposed to development) agenda, the GSDA will also need to put particular emphasis on :
- providing transparent, authoritative and intelligible information on groundwater resource status to both the state political/policy level and to the local groundwater user community
- evaluating the availability of resources at the onset of the dry (rabi) season (and not just the trend of groundwater table levels), which will be the central element for community awareness and mobilization
- communicating the consequences and costs of excessive abstraction
- enabling sustainable community based groundwater management.

  Such action is essential to counteract 'the pedlers of false hope' and their vested interest in continuing the vicious circle of further expenditure on water well deepening and pump lowering.

In this role the **GSDA will also need to work closely with the State Agriculture Department** in crop-water planning (so that these take full account of the availability of groundwater storage at the end of the monsoon recharge period) and in encouraging them to provide the required technical support and extension services. They will also need jointly to advocate and support macro-economic reforms to facilitate the groundwater management process such as :

- defining clear incentives to reduce (or placing actual constraints on) the cultivation of high water-demand crops (such as rice paddy and sugar cane)
- establishing greater incentives (including support prices), readily-accessible low-cost credit and commercial infrastructure for the cultivation of high-value and/or low water-demand crops
- re-directing the use of the electrical energy subsidy to support the provision of seeds, the purchase of improved irrigation technology and the marketing of lower water-use crops.

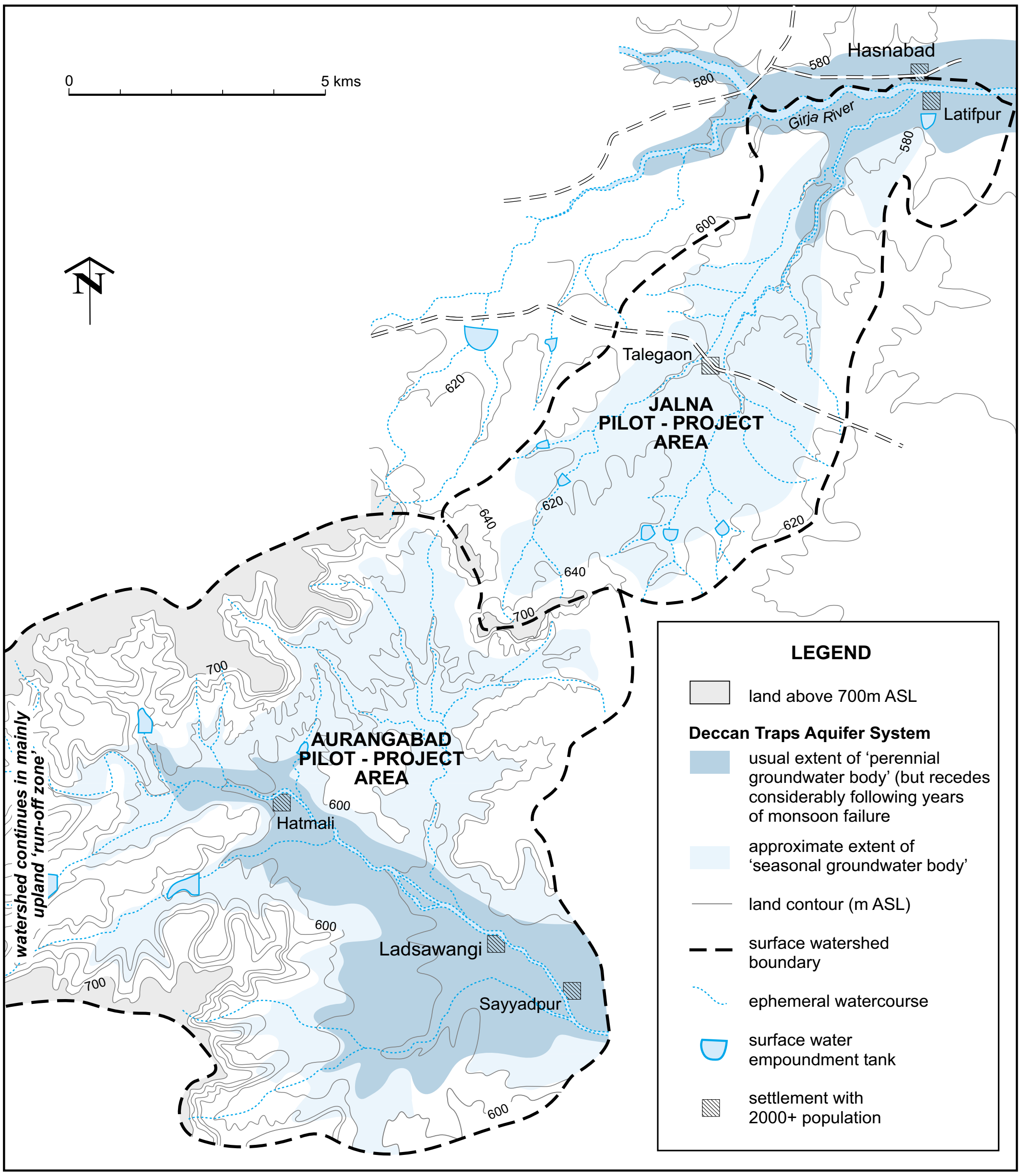
Table 2: General Scheme for Promotion of Community-Based Groundwater Management

OBJECTIVE OF INTERVENTION	MANAGEMENT PROCESSES & MEASURES
Develop a Shared Vision of Groundwater Resource Availability & Use Priorities	• boundaries of groundwater body and any external influences • average order of annual groundwater replenishment • concept of available storage at onset of dry season • potential for artificial recharge enhancement • protection of quantity and quality of village water supply • implications for crop irrigation availability
Ensure Sustainable Community Participation	• establish community groundwater management committee with village level representatives, respecting local traditions/leaders • facilitate women's participation • involve community in data gathering • ensure two-way communication based on agreed information
Set-up Flexible Management Plan with Achievable Goals	• define an agreed participatory groundwater management plan, incorporating consideration for improving groundwater productivity and making real groundwater resource saving • promote grants/subsidies for approved real water-saving measures • remove subsidies for the growing of high water-use crops in dry season (eg, sugar cane, rice, bananas, maize) • periodically monitor groundwater resource status (quantity/quality)
Establish Enforceable Rules/Regulations*	• define realistic water-user entities (individual or aggregate depending on user profiles) • establish a comprehensive groundwater users inventory with active collaboration of community • identify acceptable proxy controls on groundwater use in situation when water abstraction metering is not feasible • introduce (and enforce with community support) indirect controls on groundwater abstraction in heavily-committed aquifers (through ban on new well drilling, restrictions on well spacing and constraints on electricity connections)

DISCUSSION OF SPECIFIC PILOT PROJECTS

The pilot projects of Aurangabad and Jalna Districts are situated adjacent to one another (Figure 7) in area with an average rainfall of around 650 mm/a, but are separated by an elevated ridge of Deccan Traps Basalt 'runoff zone'. Both are characterized by a relatively limited proportion (around 10-20%) of perennially-saturated aquifer (the 'storage zone') with a considerably larger area of seasonally-saturated aquifer ('recharge zone').

Figure 7: Hydrogeological sketch map of the Aurangabad MRWSSP & Jalna MWSIP pilot project areas to illustrate the occurrence of perennially-saturated groundwater bodies



It is only in these areas that extensive (second) rabi cropping is practised – for example during 2006 in the Jalna pilot area (which on the lower ground possesses deep black fertile soils) some 3,360 ha were planted with rabi-season cotton, millet and wheat which used an estimated 6.6 Mm^3 of groundwater irrigation, following more extensive (but largely non-irrigated) cultivation of maize, cotton and sorghum during the kharif-season. In the jawaad-season the cropped area reduces markedly to a limited proportion (perhaps amounting to 20%) of the 'storage zone' only, and the main crops are vegetables, animal fodder and in the case of the Jalna District PP perennial sweet-lime trees (with an estimated 2006 abstraction for irrigation of 1.2 Mm^3 on around 120 ha).

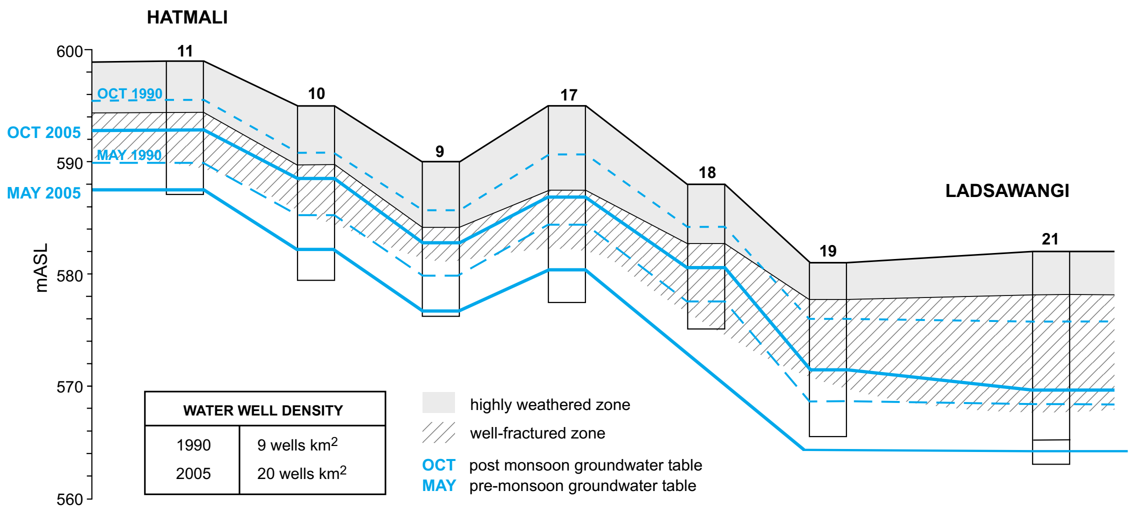
There are suggestions that :

- the extension of perennially-saturated aquifer has reduced in recent years, due to falling groundwater table (Figure 8) associated with increasing abstraction for dry-season irrigation and reducing antecedent monsoon rainfall
- the month in which the seasonally-saturated aquifer of the 'recharge zone' fails has advanced, giving less guarantee of water availability for the rabi crop.

In consequence there have also been increasing problems with the continuity of drinking water-supply in both zones – with examples of 'community requisitioning' of more reliable private irrigation water wells to supply drinking water albeit with payment of some form of financial compensation to water well owners.

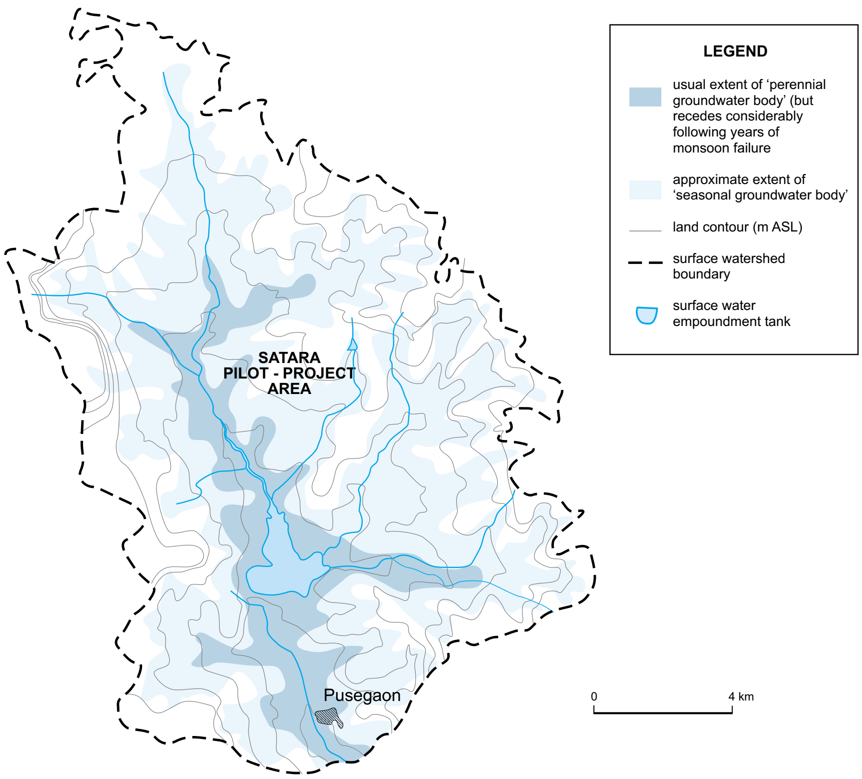
Clearly the main challenge facing the GSDA in these pilot areas, beyond the provision and protection of improved village drinking water wells wherever feasible, is working with the 'state agricultural agency' and farmers on the more sustainable and productive use of the limited groundwater resources for rabi-crop security and allowing some sustainable jawaad-season cultivation in the storage zone without compromising drinking water sources (which in this area have to serve a higher rural population density).

Figure 8: Variation of groundwater table levels in the main perennially-saturated aquifer of the Aurangabad MRWSSP pilot area during 1990-20



The Satara District PP is in many ways similar to those of Aurangabad and Jalna, although the relief at 600-800 m ASL is significantly higher and the average rainfall at 510 mm/a is somewhat lower (and can reduce to under 200 mm/a in exceptionally dry years). There is an extensive area underlain by only a seasonally-saturated groundwater body and a smaller but significant area underlain by a permanently-saturated groundwater body (Figure 9), although the limit of the latter is said to recede further (and virtually leave the PP area) in years of successive below average monsoon rainfall.

Figure 9: Hydrogeological sketch map of the Satara District MWSIP pilot project area to illustrate the occurrence of perennially-saturated groundwater bodies



In general terms the crops cultivated in this PP area are 'well tuned' to the land elevation and limited availability of groundwater for irrigation (Table 3) and there is very limited jawaad (hot dry) season cultivation. But numerous villages in the 'recharge and run-off zones' still experience significant problems of drinking-water supply during April-June in most years with tankering over distances of up to 35 km.

Table 3: Summary of current agricultural cropping and irrigated cultivation in the Satara District MWSIP pilot project area

CROP-TYPE	CROP AREA (ha) kharif	rabi	jawaad
Total Cultivated Area	**9790**	**3510**	**400**
millet	5130		
sorghum	1360	2080*	
green beans	2440		
wheat		650*	
potatoes+vegetables	430*	370*	110*
sugar-cane	250*	250*	250*

* *main crops irrigated mainly from groundwater together with a small tank*

The Tapi Gurnia Alluvial Graben Aquifer is easily the groundwater body of largest storage and highest water well yields in Maharashtra. It currently supports the irrigation of almost 30% of India's commercial banana production. Some 80% in total of the valley floor is currently cultivated with bananas (and much smaller extensions of sugar-cane and vegetables), but the aquifer is experiencing a serious long-term trend of overexploitation – Figure 10 shows the average dewatering during 1980-2005 but the dynamic water-level situation in individual irrigation water wells is far more dramatic.

Whilst subdivision of this large alluvial aquifer, and its supplementary recharge zone along the flanks of the graben, is difficult the PP area defined by GSDA is as good a place to start as any on the important task of confronting the management of this aquifer. However, consideration should be given to including all of the aquifer within both the Yawal and Raver Blocks – which are the only two blocks of Maharashtra State legally notified by (and agreed with) the CGWA as being seriously overexploited and at risk of irreversible degradation, there being a serious threat of saline up-coning from around 100 m bgl in addition to the dewatering of tube well screens with serious water well yield decline.

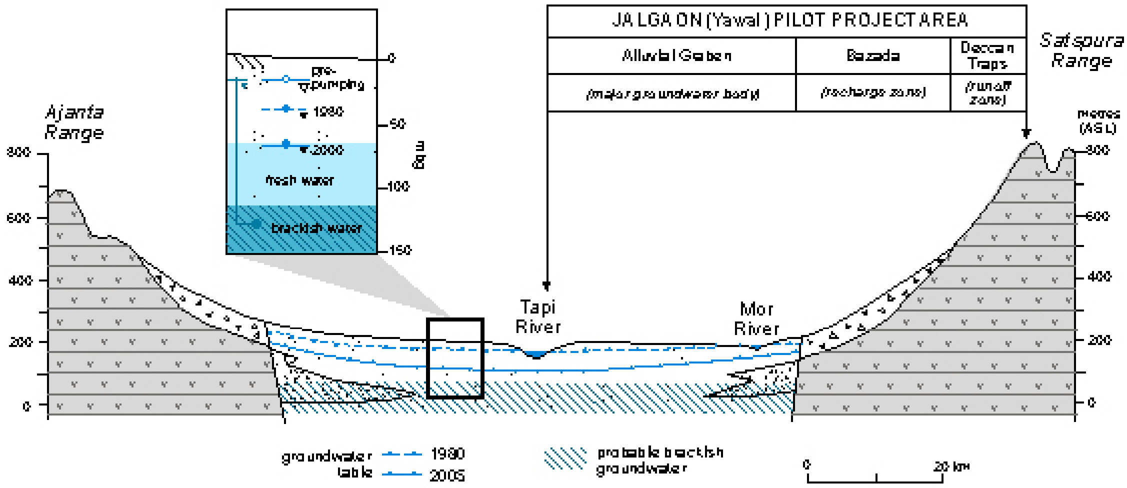
This 'legal notification' requires State Government to register all existing operational waterwells by a stated date (and declare any remaining unregistered after this date as illegal), to prohibit the construction of all new irrigation tube wells and deepening of existing tube wells by drilling contractors and land owners, to ban the sale of water abstracted from the area, and to report progress on the groundwater management measures to the Union Parliament.

But to achieve groundwater use sustainability in these blocks (and this PP) will require a major long-term effort (since the total consumptive water requirement of highly-profitable banana cultivation even when using efficient systems of drip irrigation is around 1,500 mm/a) and must include such actions as :

- mobilization of a package of agricultural demand-side management measures, including some reduction in the cropped land area under irrigation

- enforcing an 'overall ceiling' on irrigation use through a system of individual and community-aggregated groundwater rights
- promoting (and helping finance) use of excess wet-season canal flows for aquifer recharge via disused dug wells (in the recent Banmod experiment some 19 Mm^3/d of excess canal water were recharged through some 40 disused dug wells for 110 consecutive days).

Figure 10: Generalised hydrogeological structure of the Tapi Gurnia Graben alluvial aquifer system showing the location of the Jalgaon District Pilot Project



Only those micro-watersheds extensively underlain by a continuous groundwater body lend themselves to community aquifer (groundwater resource) management via an AWMA or AMOR – those with limited areas of continuous groundwater body only require this approach in a portion of the micro-watershed and in the 'runoff zone' (in particular) community participation can conveniently be restricted to the action of VWSCs in respect of source improvement, operation and protection.

There is a pressing need for Maharashtra State Government to ensure (via GSDA) the successful outcomes of the current pilot projects in terms of :

- social appreciation of (and first steps in) integrated community groundwater management in the Deccan Traps Basalt groundwater 'storage zones'
- improved water-supply sources in the Deccan Traps Basalt 'recharge and runoff zones'

for each of the current pilot projects. In this context GSDA will need to strengthen its ability to work with community NGOs (SOs) and to develop some in-house capacity in socioeconomics and agricultural water-use. They will need also to further the monitoring of groundwater abstraction, building-up a fuller profile of use and users which will require not only direct survey and inventory of irrigation wells but also their use for irrigation by :

- community self-registration with some checking and additional survey work
- satellite imagery interpreted in terms of cultivated areas, crop types and water use.

In the interest of long-term sustainability and replicability of the groundwater management pilots, it is further recommended that GSDA take on the 'lighthouse function' for state government by developing a group dedicated to monitoring (and providing a 'reference point' for) the promotion of community-based groundwater resource management and thus ensure that they do not fail because of lack of support and control (because it will take some years for the community to become leaders of an environmentally-sustainable development process).

Publication Arrangements

The GW•MATE Case Profile Collection is published by the World Bank, Washington D.C., USA. It is also available in electronic form on the World Bank water resources website (www.worldbank.org/gwmate) and the Global Water Partnership website (www.gwpforum.org).

Funding Support

GW•MATE (Groundwater Management Advisory Team) is a component of the Bank-Netherlands Water Partnership Program (BNWPP) using trust funds from the Dutch and British governments.