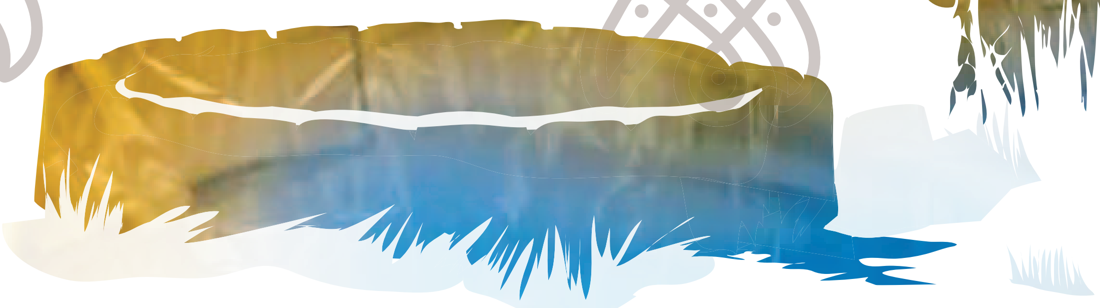
Smallholders and sustainable wells

A Retrospect: Participatory Groundwater Management in Andhra Pradesh (India)



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A Retrospect: Participatory Groundwater Management in Andhra Pradesh (India)

Samala Venkata Govardhan Das

Jacob Burke

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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Samala Venkata Govardhan Das

Jacob Burke

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Glossary

A

Adaptation: Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects. Adaptation can be carried out in response to (ex post) or in anticipation of (ex ante) changes in climatic conditions. It entails a process by which measures and behaviors to prevent, moderate, cope with and take advantage of the consequences of climate events are planned, enhanced, developed and implemented.

Adaptive capacity: The general ability of institutions, systems, and individuals to adjust to potential damage, to take advantage of opportunities, or to cope with the consequences.

Aquifer: An underground layer of water-bearing permeable rock or unconsolidated materials (gravel, sand, silt, or clay) from which groundwater can be usefully extracted using well water.

Artificial recharge: Process by which groundwater is augmented at a rate that is much higher than that of natural conditions for replenishment.

B

Base map: A map of any kind showing outlines necessary for adequate geographic reference, on which additional or specialized information is plotted for a particular purpose; a map depicting background reference information such as landforms, roads, natural drainage systems, and political boundaries, on which other thematic information can be superimposed. A base map is used for locational reference and often includes a geodetic control network as a part of its structure.

Bio-fertilizer: A large population of a specific or a group of beneficial microorganisms for enhancing the productivity of soil.

Balance, groundwater: The remaining groundwater after extracting available water by users for various purposes. It is estimated based on the difference between net recharge and net discharge.

C

Canal: An artificial channel for water.

Catchment: Refers to any structure that captures water. It is sometimes referred to as Basin or Watershed.

Check dam: A small dam constructed in a gully to decrease the flow velocity, minimize channel scour, and promote deposition of sediment.

Climate change: Refers to a change in the state of the climate that can be identified (e.g. by using statistical tests) by changes in the mean and/or variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be the result of natural internal processes or external force, or to persistent anthropogenic changes in the composition of the atmosphere or land use. Note that the United Nation's Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is additional to natural climate variability observed over comparable time periods'. The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition and climate variability attributable to natural causes.

Climate variability: Refers to variations in the mean state and other statistics (such as standard deviations, occurrence of the extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events. Variability may be caused by natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic forcing (external variability)

Community: In this note, suggests that members have some communal relations. Experiences, values and/or interests may be shared, and members may interact with each other and be concerned about mutual and collective well-being. However, this set of individuals may include diverse groups that can act collectively (organized community) or individually in order to increase climate resilience at the household level.

Crop yield: In agriculture, crop yield (also known as 'agricultural output') is not only a measure of the yield of cereal per unit area of land under cultivation; the yield is also the seed generation of the plant itself (e.g. one wheat grain produces a stalk yielding three grain, or 1:3).

Crop water budgeting (CWB): This is a critical component of the PHM activity, and is considered the final step in the chain of PHM. The aim of CWB is sustainable groundwater management by the farmers themselves. The CWB exercise involves estimation of the groundwater balance based on the total annual recharge and withdrawal. This estimation helps farmers make informed decisions on the crops to be sown.

D

Display board: Is a format used for dissemination of data to a larger audience; usually made of wood, these boards can be displayed in central locations to capture the interest of more people.

Drought: Is defined in many ways and includes the phenomenon that results when precipitation is significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land resource production systems. In the case of India, the definition of what is considered 'precipitation below normal' varies from agency to agency.

Withdrawal, groundwater: Refers to the discharge of groundwater. It is estimated based on well discharge and the total number of pumping days.

Drainage: Natural or artificial removal of surface and subsurface water from a given area. Many agricultural soils need drainage to improve production or to manage water supplies.

Drainage basin: This is an extent of land where water from rain or snow melt drains downhill into a body of water, such as a river, lake, dam, estuary, wetland, sea or ocean.

E

Ecosystem: Natural unit consisting of all plants, animals and micro-organisms in an area functioning together with all of the non-living physical factors of the environment.

Evaporation: Process by which molecules in a liquid state (e.g. water) spontaneously become gaseous (e.g. water vapour). It is the opposite of condensation.

F

Farmer Field School: Group-based learning process that has been used by a number of governments, NGOs and international agencies to promote Integrated Pest Management (IPM). The first FFS were designed and managed by the UN FAO in Indonesia in 1989.

Farmer Water School: An adaptation of the Farmer Field School approach to groundwater management. This was an initiative of the FAO-funded APFAMGS project.

G

Green revolution: Ongoing worldwide transformation of agriculture that led to significant increases in agricultural production between 1940s and 1960s. Former USAID Director, William Gaud, was the first to use the term 'Green Revolution' in 1968.

Groundwater: Water located beneath the ground surface in soil pore spaces and in the fractures of lithologic formations.

Groundwater Management Committee: A farmer institution promoting interaction among farmers in a village with an objective of groundwater management for sustainability of groundwater resource.

Groundwater recharge: The process by which external water is added to the zone of saturation of an aquifer, either directly into a formation or indirectly by way of another formation.

H

Hydrological Unit (HU): When rain falls on the ground and flows downward, it is called a first order stream. When two or more first order streams meet, a second order stream is formed. Similarly, two or more second order streams join together to form a third order stream. First and second order streams do not have defined flow paths and tend to change their movement, depending on the place where rain falls. The third order stream has a defined flow path, over a period of hundreds of years, and is clearly marked on topographic maps. APFAMGS identifies third order stream as the outlet point of a natural drainage system and refers to it as 'HU'. From the outlet point of a third order stream, the area of the drainage basin is demarcated as the area of the HU. Often HUs have local names and the HU is named by the community.

Hydrological Monitoring Record (HMR): A book used for recording data obtained from rain gauge stations, and measuring water levels.

HU Network: A farmer institution promoting interaction among farmers in the HU, comprising many villages with an objective of sustainable management of the groundwater resource.

Hydro Ecosystem Analysis (HESA): Methodology used to analyse hydrological systems for planning and prioritizing research and development activities in the fields of hydrology and groundwater resource management.

Hydrogeology: The study and characterization of water flow in aquifers.

Hydrological cycle: Also known as the water cycle, it describes the continuous movement of water on, above, and below the surface of the Earth. Since the water cycle is truly a 'cycle,' there is no beginning or end.

Hydrology: is the study of the movement, distribution and quality of water throughout the Earth.

I

Inflow: Refers to the flow of water into the HU.

Infiltration: This is the downward movement of water into the soil, which finally becomes groundwater.

Integrated Pest Management (IPM): Pest control strategy that uses an array of complementary methods: natural predators and parasites, pest-resistant varieties, cultural practices, biological controls, various physical techniques, and the strategic use of pesticides. It is an ecological approach that can significantly reduce or eliminate the use of pesticides.

Injection well: A bore well that is meant to directly recharge the aquifer.

Infiltration rate: This is the rate at which water percolates into the ground. It depends on rock and soil type.

Irrigation: Artificial application of water to the soil usually to assist growing crops.

K

Kharif crop: Is the autumn harvest. Kharif crops are usually sown with the beginning of the first rains in July, during the southwest monsoon season.

L

Lake: Body of water or other liquid of considerable size contained on a body of land. Most lakes on Earth are fresh water.

M

Monitoring: To observe a situation for any changes that may occur over a period of time.

Monitoring well: A bore well having attached devices for measuring water levels and discharge of water.

O

Organic fertilizer: Fertilizers are compounds that are given to plants to promote growth. Naturally occurring organic fertilizers include manure, slurry, worm castings, peat, seaweed, sewage, and guano.

Outflow: Refers to the flow of water out of the HU.

P

Participatory Hydrological Monitoring: Refers to the effort to sensitize the individual groundwater users on judicious use of groundwater.

Pumping water level: Refers to the water level measurement that is taken three hours after pumping water from a bore well. This time is sufficient for the well to recoup (from an aquifer) the water that has been taken out.

Potable water: Water of sufficient quality to serve as drinking water is termed potable water whether it is used as such or not.

Porosity: Is a measure of the void spaces in a material, and is measured as a fraction, between 0–1, or as a percentage between 0–100 percent.

Precipitation: Refers to any product of the condensation of atmospheric water vapour that is deposited on the Earth's surface. Occurs when the atmosphere becomes saturated with water vapour and the water condenses and falls out of solution.

R

Rabi: Rabi sowing of different crops starts in September in some areas, while it extends up to the end of November in others. Mostly, the southern districts of Coastal Andhra and all districts of Rayalaseema that receive the northeast monsoon rains have the maximum cropped area during this season. The cropping season extends up to February–March.

Resilience: When referring to natural systems, the amount of change a system can undergo without changing state. If referring to human systems, see adaptive capacity (IPCC TAR 2001).

Rain gauge: type of instrument used by meteorologists and hydrologists to gather and measure the amount of liquid precipitation over a set period of time.

Runoff: Term used to describe the flow of water from rain, snowmelt, or other sources, over the land surface, and is a major component of the water cycle.

S

Stakeholders: Any persons with interest in a particular decision, either as individuals or as representatives of a group. This includes people who influence a decision or can influence it, as well as those who are affected by it.

Stream: A body of water with a current, confined within a bed and banks.

Static water level: The undisturbed water level when the bore well is not functioning.

Surface water: Water collecting on the ground or in a stream, river, lake, wetland, or ocean is called surface water.

T

Tank: A construction to collect water.

V

Vulnerability: Is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes.

W

Water: Common chemical substance that is essential to all known forms of life.

Water cycle: Describes the continuous movement of water on, above, and below the surface of the Earth. Since the water cycle is truly a 'cycle,' there is no beginning or end.

Water analysis: This is the analysis of both drinking water and water used for irrigation. While drinking water is checked for chemical and microbial contamination, checking is also done prior to using it for irrigation.

Water level indicator: An instrument used for monitoring the water levels of an observation bore well.

Water table: Surface where the water pressure is equal to atmospheric pressure.

Well: Artificial excavation or structure put down by any method such as digging, driving, boring, or drilling for the purposes of withdrawing water from underground aquifers.

List of Abbreviations

AARDIP	Adoni Area Rural Development Initiatives Programme
ACIAR	Australian Centre of International Agriculture Research
AF	Agriculture Facilitator
AGR	Artificial Groundwater Recharge
APBW	Annual Plan and Budget Workshop
APDAI	Andhra Pradesh Drought Adaptation Initiative
APFAMGS	Andhra Pradesh Farmer Managed Groundwater Systems
APSGWD	Andhra Pradesh State Ground Water Department
APSIDC	Andhra Pradesh State Irrigation Development Corporation
APT	Agriculture Production Trainer
APWALTA	Andhra Pradesh Water Land Tree Act
APWALTA	Andhra Pradesh Water, Land and Trees Authority
APWAM	Andhra Pradesh Water Management Project
APWELL	Andhra Pradesh Borewell Irrigation Schemes
AWS	Adarsha Welfare Society
BBT	Ballot Box Test
BD	Base Document
BIRDS	Bharathi Integrated Rural Development Society
BUA	Borewell User Association
CARE	Centre for Applied Research and Extension
CARVE	Collective Activity for Rejuvenation of Village Arts and Environment
CAS	Crop Adoption Survey
CBI	Community Based Institution
CBO	Community Based Organization
CD	Compact Disc
CGWB	Central Ground Water Board
CIID	Copenhagen Institute for Interactive Design
CLDP	Comprehensive Land Development Programme
CMS	Community Mobilization Specialist
CO	Community Organizer
CRIDA	Central Research Institute for Dryland Agriculture
CRYD	Centre for Rural Youth Development
CSA	Climate Smart Agriculture
CWB	Crop Water Budgeting

CWIK	Crop Water Information Kiosk
CWS	Centre for World Solidarity
DA	Documentation Assistant
DASM	Dalit Adivasi Seva Morcha
DFC	District Field Coordinator
DIPA	Development Initiatives and People's Action
DM&HO	District Medical and Health Officer
DPAP	Drought Prone Areas Programme
DRAP	DRAP Plastics Private Limited
DRD	Department of Rural Development
DSGM	Demand Side Groundwater Management
EPHM	Extensive Participatory Hydrological Monitoring
ESRI	Environmental Systems Research Institute
EVA	Environmental Viability Assessment
FAO	Food and Agriculture Organization of the United Nations
FCS	Farmer Climate Schools
FD	Field Day
FDM	Farmer Data Management
FES	Foundation for Ecological Security
FFS	Farmer Field Schools
FMGS	Farmer Managed Groundwater Systems
FR	Farmer Representative
FWS	Farmer Water Schools
GA	Ground Water Authority
GEC	Groundwater Estimation Committee
GEF	Global Environment Facility
GF	Gender Facilitator
GI	Galvanized Iron
GIDO	Gender and Institutional Development Organizer
GIS	Geographic Information System
GM	Groundwater Management
GMC	Groundwater Management Committee
GoAP	Government of Andhra Pradesh
GOI	Government of India
GPS	Global Positioning System
GVS	Gram Vikas Samstha
GWS&DA	Ground Water Survey and Development Agency

Ha	Hectare
HDPE	High Density Poly Ethylene
HESA	Hydro Ecosystem Analysis
HF	Hydrological Facilitator
HIS	Hydrological Information System
HMN	Hydrological Monitoring Network
HMR	Hydrological Monitoring Record
HRIS	Habitation Resource Information System
HU	Hydrological Unit
HUN	Hydrological Unit Network
I&CAD	Irrigation and Command Area Development Department (I&CAD)
IAMWARM	Irrigated Agriculture Modernization and Water Resources Management
ICARRD	International Conference on Agrarian Reform and Rural Development
ICID-CIID	International Commission on Irrigation and Drainage - Commission Internationale de l'irrigation et du drainage
ID	Irrigated Dry
IDF	Institutional Development Facilitator
IJP	Indira Jala Prabha
ILRI	International Institute for Land Reclamation and Improvement
IMTI	Irrigation Management Training Institute
IPHM	Intensive Participatory Hydrological Monitoring
IPM	Integrated Pest Management
IPTRID	International Programme for Technology and Research in Irrigation and Drainage
IRDAS	Institute of Resource Development and Social Management
IRS	Indian Remote Sensing
ISI	Indian Standard Item
IWMI	International Water Management Institute
IWMP	Integrated Watershed Management Programme
JJV	Jala Jana Vedika
Km	Kilometre
LCD	Liquid crystal display
LFA	Logical Framework
LISS	Linear Self Images Scanner
LTE	Long Term Experiment
MAD	Maximum Admissible Withdrawal
mbgl	Meters below ground level
MLA	Member of Legislative Assembly

MoEF	Ministry of Environment and Forests
MS	Mild Steel
MSP	Medium-sized project
NABARD	National Bank for Agriculture and Rural Development
NAIP	National Agriculture Innovation Project
NDDE	National Dairy Development Board
NET	Netherlands
NEX	Nationally Executed
NFE	Non Formal Education
NGN	NGO level Network
NGO	Non-governmental organization
NGOC	Non-governmental Organization Coordinator
NGRI	National Geophysical Research Institute
NIIT	National Institute for Information Technology
NRM	Natural Resource Management
NRSA	National Remote Sensing Agency
NSSO	National Sample Survey Organization
PAN	Panchromatic Camera
PCM	Participatory Climate Monitoring
PGM	Participatory Groundwater Management
PHED	Public Health and Engineering Department
PHM	Participatory Hydrological Monitoring
PIF	Project Identification Form
PMT	Project Management Team
PMW	Production-cum-monitoring well
PNGO	Partner Non-governmental Organization
PRA	Participatory Rural Appraisal
PRED	Panchayati Raj Engineering Department
PRI	Panchayat Raj Institutions
PRIYUM	Priyum Advisory and Consultancy Services Private Limited
PRM	Participatory Resource Mapping
PSC	Project Steering Committee
PVC	Poly Vinyl Chloride
PWB	Participatory Water Budgeting
PWL	Pumping Water Level
RBO	River basin organization
RHGBMSS	Rayalaseema Harijana Girijana Backward Minority Seva Samajam

RIF	Recharge Infiltration Factor
RISES	Rural Integrated and Social Education Society
RNE	Royal Netherlands Embassy
SAFE	Society for Sustainable Agriculture and Forest Ecology
SAID	Social Awareness and Integrated Development
SDC	Swiss Agency for Development Cooperation
SGPL	Sumadhura Geomatica Private Limited
SHG	Self Help Group
SOI	Survey of India
SPACC	Strategic Pilot on Adaptation to Climate Change
SPANDANA	Spandana Society
SRI	System of Rice Intensification
STE	Short Term Experiment
SWL	Static Water Level
SWSC	State level Water Steering Committee
SYA	Star Youth Association
TA	Technical Assistance
ToR	Terms of Reference
ToT	Training of Trainers
TST	Technical Support Team
UGB	Upper Gundlakamma Basin
UNESCAP	United Nations Economic and Social Commission for Asia Pacific
USCID	United States Committee on Irrigation and Drainage
VC	Village Coordinator
VHS	Viral Haemorrhagic Septicaemia
WC	Watershed Committee
WCM	Water Conservation Mission
WCS	Water Conservation School
WDS	Water Development Society
WE	World Education
WIS	Well Irrigation System
WUG	Water User Group
WWF	World Water Forum

Executive Summary

1. Introduction

With 16 percent of the world's population, India has 2.45 percent of the world's land resources and 4 percent of its water resources. It is obvious that supply will barely match future demand. Around 50 percent of irrigated agriculture and 85 percent of rural drinking water comes from groundwater. Sustainable management of groundwater plays a major role in the agriculture sector, contributing to the economic development of a mainly agrarian country.

Half of farmer households in India are indebted and the average outstanding loan increases with the size of the landholding. Smallholders, who have no access to irrigation make up a major portion of the worlds' poor. In relation to operational area, the poor are well represented in groundwater irrigation. Over 60 percent of India's irrigated area is dependent on some form of groundwater source.

The people nearest the groundwater can best manage this resource, not agencies that visit every now and then. Therefore, the nature, occurrence and behaviour of aquifer systems need to be understood by those most affected by changes in the system. Local organizations, government, civil society and the private sector all have important, and often unique, roles to play in participatory groundwater management (PGM). This publication is an attempt to describe these roles as they developed during the life of a set of projects in Andhra Pradesh.

PGM is highly relevant for India's rural development, given current groundwater development practice and related institutional capacities and policy initiatives. Without some method for putting management into the hands of users, the long-term viability of many rural communities is at risk.

2. The Participatory Groundwater Management (PGM) Package

In this publication, the main components of PGM are: well irrigation system (WIS); hydrological unit [1] (HU); participatory hydrological monitoring (PHM); farmer data management (FDM); Crop–water budgeting (CWB); artificial groundwater recharge (AGR); Farmer Water Schools (FWS) and community based institutions (CBI).

[1] The hydrological unit is 'an area covered by the catchment of a stream that has influent and effluent connection with the local aquifer

A typical well irrigation system may comprise a drilled borehole or dug well that is jointly owned by a group of five smallholder families, with a well command of about 5 ha; well assembly including a submersible pump connected to the electrical grid and buried piped distribution system, with water outlets to each family field in the group.

Using the HU, as the basis for intervention, holds good at the lowest level. This is where the HU is equated with the catchment area of a third order stream in a hard-rock aquifer [2] under water table [3] conditions. In the case of a confined aquifer [4] , the HU encompasses a larger area, matching the catchment of a stream, into which the aquifer discharges. Topographic and geological maps published by the Central Government of India form the basis for generating thematic layers of the HU, using Geographic Information System (GIS) and Global Positioning System (GPS) technology. Maps generated at the HU level include: boundary; settlement; road and rail network; drainage; geology; elevation contour; hydrological monitoring stations and PGM interventions.

Participatory hydrological monitoring (PHM) comprises the hydrological monitoring network (HMN); PHM training; guidance; handing over and withdrawal. HMN involves the establishment of stations to measure rainfall, well water level, well discharge and stream discharge with representative spatial distribution within the HU. For PHM, production wells are converted to monitoring wells, including failed wells and stream gauge stations. Farmers take fortnightly measurements of water levels (static and pumping), discharge from wells and stream discharge. PHM uses four training modules to develop farmers' skills, based on demonstration and practice and exposure visits.

Trained volunteers collect PHM data from the station and store it in a booklet called the hydrological monitoring record (HMR). Other farmer data management tools are the base document (BD), Habitation Resource Information System (HRIS) and crop–water information kiosk (CWIK). The base document serves as the reference point for farmers for all PGM activities. The district level non-governmental organizations (NGOs) store the farmer-collected data in computers, using the HRIS database software. Thematic layers of the HU are stored on a GIS platform, at the NGO level, in the crop–water information kiosk, which interacts with the HRIS and GIS. Farmers share the hydrological information with others in the village using four types of display boards: HU, rainfall, water level and information.

PHM is meaningful when the interpretation of the data generated leads to sensible use of the groundwater resource. Crop-water budgeting is an exercise employed to trigger people's action, following (a minimum of) one-year's data collection through PHM. Crop–water budgeting steps are: updating of the resource inventory; estimation of groundwater recharge during June–October; estimation of groundwater withdrawal during June–October; estimation of groundwater balance at the end of October; farmer crop-plan for November–May; estimation of crop–water requirement for farmer's crop plan; projected groundwater balance at the end of the hydrological year (May); crop–water budgeting workshop and crop adoption survey.

Staff members use an Excel spread sheet for all estimations carried out as part of the crop–water budgeting exercise. Farmers are taken through the process of groundwater balance estimation before every winter cropping season. This

2 Water bearing formation

3 The upper surface of the zone of saturation, in an unconfined aquifer i.e., not confined on one side by impermeable zone (that neither has void spaces nor transmits water)

4 Water-bearing formation that is sandwiched between two impermeable layers of rock

is done during a crop–water budgeting workshop where all groundwater users in the HU are gathered. Farmers are encouraged to plan their crops suiting the estimated groundwater balance available for winter crops. The crop plans (CP), evolved during a crop–water budgeting workshop, are shared with all groundwater farmers at village and family meetings. The extent of implementation of the winter crop plan (WCP) is assessed by a crop adoption survey (CAS). Crop–water budgeting estimations are repeated after the CAS, using real-time data to arrive at the actual annual groundwater balance in the HU, after completion of the hydrological year in May.

Though the focus of PGM is on 'reduction of withdrawal', i.e. demand-side groundwater management (DSGM), essentially it incorporates supply-side groundwater management (SSGM), through artificial groundwater recharge. PGM adopts a method of blending scientific and people knowledge to derive location-specific artificial groundwater recharge (AGR) measures, wherein scientists use groundwater-modelling methods to select technology and appropriate sites for AGR structures and farmers bear part of the cost of construction.

Community capacity building is the heart of the PGM approach, offering a package of practices that impart the required skills and knowledge in the fields of hydrology, agriculture and institution management. PGM uses formal and non-formal education (NFE) methods for community capacity building, including street theatre, audio-visuals and a community newsletter. The content of formal training used for PHM, CWB and AGR forms the curriculum of the Farmer Water Schools (FWS).

FWS occur throughout the hydrological year (June–May), the 14-session curriculum matches the seasons of the hydrological year: 1) Introduction to FWS; 2) Knowing the HU; 3) PHM; 4) Groundwater recharge; 5) Estimation and projection of groundwater recharge; 6) Estimation and projection of groundwater withdrawal and balance; 7) Crop–water budgeting workshop; 8) Review of farmer crop plans and design of long-term experiments; 9) Crop adoption survey results; 10) Alternative irrigation practices; 11) Soil-moisture retention; 12) PHM data analysis; 13) Estimation of groundwater balance for winter and 14) FWS Field Day.

A four-tier community-based institutional structure is adopted for PGM: Groundwater Monitoring committee (GMC), at the habitation level; hydrological unit network (HUN), a network of GMCs at the HU level; NGO level network (NGN), an apex body of HUNs, where an NGO operates; and a State Level Water Steering Committee (SWSC), a state level network with the representation HUN leaders and nine NGO heads. PGM has a strong gender interface to keep practical and strategic gender needs at the core. Gender sensitization helps men and women understand their roles and responsibilities and broaden their thinking beyond routine assumptions. As food and nutrition, hygiene, sanitation and healthcare are mainly considered to be women's issues, these are consciously promoted for development of inclusive institutions at the grass-roots level.

3. The Path

PGM in Andhra Pradesh started with wells for smallholders in 1995, in an Indo-Dutch bilateral project called the Andhra Pradesh Borewell Irrigation Schemes (APWELL). In 2000, PHM and AGR were launched as a first step to ensure sustainability of smallholder wells. Expansion of PHM activity at the basin level began in June 2001, in the Upper Gundlakamma river basin (UGRB), with delineation of HUs within the basin. Smallholders with new well irrigation systems were the primary PHM stakeholders. PHM in Gundlakamma necessitated the inclusion of all groundwater farmers, irrespective of the size of landholding. The URGB–PHM experiment was halfway through when APWELL was formally closed in 2003.

Crop–water budgeting was conceived in 2001 as the final rung on the PHM ladder, after one-year's farmer data became available. A methodology for the crop–water budgeting exercise was evolved working with farmers and district level functionaries during the hydrological year 2000–2001. Crop–water budgeting spreadsheets were refined and field-tested at eight HUs in the 2002 winter cropping season and a final version evolved by November 2002. A crop adoption survey was carried out during December 2002 to March 2003, to assess the extent of crop changes, as a result of crop-water budgeting.

The final evaluation of APWELL was concerned with the abrupt closure of the project, while some promising pilots aiming to achieve sustainable groundwater management, were being tried out. APFAMGS was formally launched in July 2003, with direct Dutch funding. Because of the changed policy of the Government of India (GoI) opting not to consider minor funding, the Royal Netherlands Embassy in India, re-routed funds reserved for the implementation of APFAMGS, through FAO, after terminating three of its projects in March 2004. APFAMGS, with FAO support was launched in August 2004, under the new Nationally Executed (NEX) modality.

APFAMGS focused on fine-tuning APWELL approaches and field-testing of a few new approaches, which included PHM, artificial groundwater recharge and crop–water budgeting. New approaches developed and field tested by APFAMGS were: Farmer Water Schools (FWS), Habitation Resource Information System (HRIS) and the crop–water information kiosk (CWIK).

By the end of 2004, hydrological monitoring networks were established at seven of the 63 HUs, identified and delineated for APFAMGS intervention; 36 staff was trained to implement PHM activities; 27 staff possessed the knowledge and skills for tasks related to low-input agriculture; and crops suiting the groundwater balance were promoted at 11 habitations. By the end of 2005, 496 habitations were covered under crop–water budgeting and about 7 000 women and men in 661 habitations participated fully in the PHM process. Groundwater Monitoring Committee volunteers at 555 habitations were capable of collecting and recording rainfall data from 203 rain gauges. Members of 63 HUNs were trained to understand the behaviour of groundwater at the HU level. By May 2006, hydrological monitoring networks had been established at all 63 HUs. Training of volunteers for PHM Module 1 was completed at the same time as the HMN were established and all equipment and infrastructure were transferred to the respective HUN. In 2007 all HUs conducted their first crop–water budgeting exercise, which included efforts to reduce external inputs into agriculture.

Since its inception, APFAMGS has attempted to integrate the Farmer Field Schools (FFS) approach, which had been successfully tried out by FAO with integrated pest management (IPM). It was decided that the crop–water budgeting workshop, planned during October/November 2005, would try the FFS approaches. In 2005 the CWB workshop was named *Farmer Field Schools – Crop Water Budgeting* (FFS-CWB). Pleased with the success of the FFS–CWB, the Project decided to run a complete cycle of the FFS, i.e. June 2006 through May 2007. The term *Farmer Field School – Farmer Managed Groundwater Systems (FFS-FMGS)* was then adopted. By the start of the hydrological year 2007–2008, the term FFS-FMGS was replaced with *Farmer Water Schools (FWS)*. The complete session outline was revised, and 16 sessions were conducted (later reduced to 14). By May 2009, the project successfully produced 19 777 graduates: 12 315 men and 7 462 women.

APFAMGS established 555 GMCs at habitation level and 63 HUNs, at the HU level. By the end of 2007 all GMCs and HUNs had established functional links with the line department. All NGOs transferred funds to HUN accounts for running the FWS, in 2008. GMCs and HUNs emerged as lead players after their members had successfully demonstrated their capabilities as resource persons to train officers from several states in India. GMCs and HUNs developed links with various government departments and effectively mobilized funding. A total of 9 323 families from 466 habitations benefited from government programmes, as a result of these funds, which amounted to more than half a million United States dollars.

The APFAMGS FAO-NEX Project was terminated by 31 August 2009. However, because of the drought that year, FAO provided support to community-based institutions to conduct crop–water budgeting at Water Conservation Schools in 2009. This support was provided through a bridge funding arrangement for a four-month (September–December) period. APFAMGS activities in operational areas were low-key January–December 2010. Meanwhile FAO and key consultants organized incremental costs from the Global Environment Facility (GEF) to enhance environmental benefits by broadening the farmer agenda from that of ‘sustainable groundwater management’ to ‘building adaptive capacity of rural community for sustainable land and water management’.

The new project, financed by GEF, named ‘Strategic pilot on adaptation to climate change (SPACC)’ began implementation in December 2010. At the time of writing, SPACC has started implementation of its key activities: participatory climate monitoring (PCM), Farmer Climate Schools (FCS) and sustainable land and water management (SLWM) pilots.

4. The Responses

The decade-long pursuit of PGM successfully involved about half-a million women and men farmers in 661 habitations (or villages) across drought-affected parts of Andra Pradesh. About 20 000 of these farmers may now be considered barefoot water technicians, who remain committed to the sustainable use of the aquifer systems. These community-based institutions occupy a central position in the smallholder approach. Farmers are capable of collecting and recording hydrological data; they understand the seasonal occurrence and distribution of groundwater near their habitations and in the hydrological units as a whole and are able to estimate recharge, withdrawal and balance, without external support. They have understood the concept of groundwater as a common property resource and are willing to manage it for the collective benefit. GMCs and HUNs are able to mobilize resources for their members from government programmes and have taken up other activities of interest to their members such as marketing.

Physical responses

This assessment of the response of aquifer systems in 63 HUs to the PHM intervention is based on a desk study using information from the HUNs. Four HUs, showing different responses to PGM interventions were selected for a detailed survey to investigate reasons for the different responses of aquifer systems to the same intervention. The results of the survey are briefly outlined below.

The hydraulic state of the local aquifers in the HUs is an important indicator of overall sustainability – will accessible groundwater resources be available from year-to-year. The Static water levels (SWL) at 35 HUs (55 percent) showed an ‘upward’ trend; while at ten HUs (16 percent) the SWL showed a ‘downward’ trend. At the remaining 18 HUs (29 percent), SWL was ‘stable’. The SWL upward or stable trend at 86 percent of HUs indicates that aquifers were generally stable and able to buffer droughts. The groundwater balance was computed for this 6-year (2005–2011) assessment period and the ‘Stage of development’ was calculated as the percentage of withdrawal to recharge. The categorization, used by the Central Ground Water Board (CGWB) is applied to group HUs, into:

* safe (less than 70 percent development);
* semi-critical (70–90 percent development);
* critical (90–100 percent development) and,
* over-exploited (more than 100 percent development)

The analysis revealed that: fifty (79 percent) HUs fall into the category of over-exploited; seven (11 percent) HUs can be classified as safe; three (5 percent) HUs are in the critical category and another three (5 percent) HUs are in the semi-critical category.

The size of the HU, and area underlain by a permeable and transmissive aquifer was found to be a critical factor in determining the capacity of the aquifers to accept recharge. It was found that forty Hus (63 percent) are between 1 000 to 10 000 ha; ten (16 percent) are from 10 000 to 20 000 ha; eight (13 percent) are less than 1 000 ha and five (8 percent) HUs are more than 20 000 ha. In general, the larger the aquifer, the larger and more reliable, is the groundwater buffer (in terms of recharge capture and storage potential). The effect of scale has to be adequately communicated to groundwater users in the HU in order to tailor expectations and cropping plans accordingly.

Response from the people

The level of groundwater withdrawals or 'withdrawal' is influenced by the number of functional wells, well yield, pumping hours, area under well irrigation as well as crop–water requirement. It was anticipated that farmers would respond to the Project's intervention by: not constructing new wells; reducing withdrawal by planting water-efficient crops and reducing the area under well irrigation and agronomic practices. The analysis of farmer data shows that in 2010 the number of actively pumped boreholes or wells were reduced by 17 percent from 25 112 in 2006 to 21 530.

It was observed, however, that the area under groundwater sourced irrigation increased by about 62 percent (22 675.09 ha in 2006 to 36 387.16 ha in 2010), in spite of the reduction in actively pumped wells. This means farmers used fewer wells to irrigate crops over a larger area. The average area cultivated using wells was 0.90 ha in 2006, which rose dramatically to 1.69 ha by 2010, almost double that of the 2006 area. This may be attributed to crop–water efficient practices, i.e. suitable irrigation methods and water-saving devices – or simply more pumping from fewer wells. Across the 63 HUs, actually irrigated areas increased from 8 251.5 ha in 2006 to 11 922.6 ha in 2010 – a 44 percent increase across the area of intervention. This increased area under irrigated cropping certainly increased water consumed by evapotranspiration, but the expansion of irrigated area also indicates smart use of available groundwater by more pro-active matching of supply and demand over the cropping calendars, including enhancement of recharge through land-use management.

Certainly there were changes in cropping patterns and cropping choices. The main winter crops across the 63 HUs were sunflower, groundnut, rice (winter), chilli and red-gram. The area under sunflower showed a steady increase until 2009 and showed a slight decline in 2010. Groundnut cultivation became increasingly popular. Surprisingly, the area under rice cultivation also increased, probably the result of the promotion of system of rice intensification (SRI) and some of the intervention area was brought under canal irrigation (for example in Nalgonda and Kurnool). The area under sweet orange increased until 2007 and remained stable thereafter, as it is a perennial crop. Areas under other minor crops notably increased, including pearl millet, cotton, sugarcane, tomato, finger millet and sorghum, a clear indication of crop diversification.

Response from the external environment – diffusion of an idea

Unexpectedly, there has been an overwhelming response from the external environment. On the request of several states, national and international agencies, APFAMGS conducted training programmes and workshops, to share the PGM experience. In 2005, a Training/Exposure on *demand-side groundwater management (DSGM)* was organized for high-ranking officers from Afghanistan and Bhutan. There was also an International Learning Workshop on *demand-side groundwater management (DSGM)* for participants from 16 countries.

Four International students have conducted research on APFAMGS. The key consultants were invited by external agencies and forums to make presentations on PGM, including one at the Parliamentary Forum on Water, in the Indian Parliament House. APFAMGS was considered for the Japan Water Prize at the Fourth World Water Forum and was among the ten presenters at the *Bazaar of Ideas*, organized by the United Nations Economic and Social Commission for Asia and Pacific (UNESCAP). The World Bank conducted an evaluation study, mid-way through implementation of APFAMGS, in partnership with the Delhi School of Economics and the Hyderabad Central University, the results of which are published in Deep Wells and Prudence (World Bank, 2010).

The PGM approach is incorporated into the publication of the Planning Commission of *India, Faster, sustainable, and more inclusive growth: an approach to the twelfth five-year plan (2012–2017)*, under paragraph 5.10 (pages 46–47), describing ‘Stakeholder aquifer management’.

Common guidelines for watershed development projects (2008), issued by the Government of India, is currently popular, Page 7, paragraph VI – Cluster Approach, envisages a broader vision of ‘geo-hydrological units’ with an average size of 1 000 to 5 000 ha, comprising a cluster of micro-watersheds.

5. Reasons for different responses

Across the varied physical and social landscapes of Andhra Pradesh, it was not expected that the application of PGM would find consistent application or have consistent outcomes. The application and responses were naturally as varied as the projects and the people involved. Understanding this variation is important. For the purpose of this publication, four HUs were selected, one matching each of the four CGWB categories for stage of development: Chandrasagarvagu (Safe), Thundlavagu (Semi-critical), Bhavanasi (Critical), and Mandavagu (Over-exploited). A detailed famer survey investigated the reasons for the aquifer systems' different responses. After the desk study, specific questions were framed and interviews conducted to record farmers' perceptions of key issues.

Chandrasarvagu is considered 'Safe' because: 1) Conditions are favourable for good groundwater recharge (medium size; 74 percent of the area under the litho-unit favourable for recharge; a surplus balance of +25.98 million cubic metres (MCM), highest among the four HUs studied). 2) Farmers tried to limit withdrawal as shown by the 6 percent decrease in functional wells; negligible decrease (0.3 percent) in unit area using well irrigation; 8 percent decrease in area under rice; 17 percent increase in area under irrigated dry crops; 43 percent increase in area under water-saving devices and 57 percent increase in area under efficient irrigation practices; farmers attraction to higher returns for alternate crops is indicated by increased incomes reported by 100 percent of respondents. 3) The 'poor' rating of GMC is 13 percent, while that of HUN is 39 percent (highest poor rating recorded in the farmer survey out of the four HUs), indicating the lowest level of farmers' dependency on CBI advice. 4) The categorization is in line with the 'stable trend' of static water level, confirmed by 62 percent of farmer respondents.

Thundlavagu is considered 'Semi-critical' because: 1) Conditions are unfavourable for good groundwater recharge (small; only 32 percent of the area under the litho-unit favourable for recharge; a surplus balance of +16.53 MCM, next only to Chandrasagarvagu). 2) Farmers attempted to reduce withdrawal as shown: 12 percent decrease in functional wells; a whopping 240 percent increase in unit area under well irrigation; 9 percent decrease in area under rice; 33 percent increase in area under irrigated dry crops; 34 percent increase in area under water-saving devices; and 33 percent increase in area under efficient irrigation practices; farmers attraction to higher returns for alternate crops is indicated by increased incomes reported by 87 percent of those interviewed. 3) The 'poor' rating of GMC is 6 percent, while that of HUN is 27 percent (better than Chandrasagarvagu), indicating a lower level of farmer dependency on Community Based Institution advice 4) The categorization is in line with the 'stable trend' of static water level, confirmed by 100 percent farmers interviewed, as the HU is still to enter the 'critical' category.

Bhavanasi is considered ‘Critical’ because: 1) Conditions are unfavourable for good groundwater recharge (large, but only 24 percent of area under litho-unit favourable for recharge; a marginal surplus balance of +1.67 MCM, least among the three HUs showing a surplus balance. 2) Farmers attempted to reduce withdrawal as shown by: 38 percent decrease in functional wells; a whopping 122 percent increase in unit area under well irrigation; 23 percent decrease in area under rice; 10 percent increase in area under irrigated dry crops; 63 percent increase in area under water-saving devices; and 866 percent increase in area under efficient irrigation practices; farmers attraction to higher returns for alternate crops, is indicated by the increased incomes reported by 82 percent of respondents. 3) The ‘poor’ rating of GMC is 3 percent, while that of HUN is 6 percent (second best), indicating very good efforts by Community Based Institutions. 4) The categorization is NOT in tune with the ‘upward’ trend for static water level, as confirmed by 74 percent of farmers interviewed; this could be the result of structurally controlled additional recharge, or because the HU is located on the boundary of the Cuddapah basin, which was affected by tectonic disturbances in the geological past.

Mandavagu is considered ‘Over-exploited’ because: 1) Conditions are unfavourable for good groundwater recharge (very small; only 72 percent of the area under the litho-unit favourable for recharge; a deficit balance of -26.91 MCM, the only HU showing a deficit balance). 2) Farmers, however, attempted to keep the withdrawal down as shown by the 1 percent decrease in functional wells; 31 percent decrease in unit area under well irrigation; 17 percent decrease in area under rice; 24 percent increase in area under irrigated dry crops; 43 percent increase in area under water-saving devices; and 57 percent increase in area under efficient irrigation practices; farmers attraction to higher returns for alternate crops is indicated by increased incomes reported by 82 percent of respondents. 3) The ‘poor’ rating of GMC as well as HUN is zero percent, indicating high popularity. 4) The categorization is in line with the ‘downward’ trend of static water level, as confirmed by 93 percent of the farmer respondents, because the HU is in the ‘Over-exploited’ category.

This choice of cases for ex-poste evaluation gave a representative sample, because of varied representation in terms of size of HU, type of aquifer, stage of development and trend of water levels. It proved that: i) higher withdrawal and smaller size put Mandavagu in a ‘deficit’ groundwater balance, while matching withdrawal and larger size put Bhavanasi in a ‘surplus’ groundwater balance; ii) categorization based on stage of development does not always seem to substantiate the trend of water levels in the HUs; iii) 100 percent increase reported for income levels at all HUs proves that smart management of water is economically beneficial to farmers; iv) GMCs seems to be very popular because of their endowment of knowledge and easy accessibility, as shown by the very low percentage of farmers who rated GMCs as ‘poor’; and v) HUNs do not seem to be that popular in Chandrasagar and Thundlavagu, where there was no serious water shortage, while they and seem to command respect in Mandavagu and Bhavanasi, where water availability was an issue.

6. Sustainability, relevance and upscaling

Sustainability

The sustainability of an intervention may be assessed by whether its intended objectives are met and sustained after withdrawal. The original success criteria matches the high expectations of the external agencies and individuals interested in learning more about this highly acclaimed intervention. There are, however, professional biases because a policy-maker may want to see a drastic improvement in socio-economic conditions of the target communities, a scientist is concerned about the accuracy of data and methods of estimation. A social worker may expect more social control over the resource as well as more emphasis on supply-side management. The reality is the intervention had a clear-cut goal, 'platform created for community managed aquifer system'. All said and done, PGM did achieve this goal.

Sustainability of the PGM model in terms of technical interventions is has been validated as several programmes and projects have adapted the model. The terms coined in the process of implementation of the PGM model such as HU, PHM and CWB remain in current use. Further, the interest of HUNs in sustaining and carrying forward the technically burdensome activity CWB (the heart of PGM activities), is illustrated by the conduct of CBW in the 2010 winter cropping season, post the FAO project withdrawal. This also means that PHM data collection will continue.

The economic sustainability of PGM through analysis farmers' income, which seems to have been ensured, as a result of switching to more profitable crops, confirmed by responses from 89 percent of farmers. However, economic sustainability will depend mostly on national and international food and energy price policies. Nevertheless, farmers are equipped with the knowledge and decision-making tools that allow them to cope with external threats.

An assessment of institutional sustainability at the grassroots level was conducted during a *post-facto* evaluation. It was found that 82 percent of farmer respondents said they continue to be involved in GMC/HUN activities, even 2 years after APFAMGS withdrawal. Reasons given for their sustained interest are: to improve knowledge and skills (36 percent); understand CWB (20 percent); understand groundwater (19 percent); to share the platform of groundwater users (16 percent); know about water-saving methods (5 percent); hear good suggestions (3 percent); and understand Andhra Pradesh Water Land Tree Act (APWALTA) [5] (1 percent). GMCs still seem to treasure access to hydrological data and are further encouraged by the possibility of income from sale of data. Probably HUNs remain active because of the opportunity for climbing further up the leadership ladder. In addition, FWS graduates are treasured and used as resource persons in several government programmes, the State Government officially recognizes many farmers associated with PGM as 'model farmers'.

[5] APWALTA is currently popular in the state and intends to curb groundwater over withdrawal, among other initiatives.

NGOs remain active in the APFAMGS operational area, though supporting GMC/HUN may not be a priority given the variety of activities they implement, and also because of their inability to retain technical staff for a variety of reasons. A resource pool of technical NGO staff members, who are trained intensively and perfectly and oriented towards the concept and practice of PGM, are highly regarded have already moved onto similar programmes and projects.

The Technical Support Team (TST) was the backbone of PGM, and ideas generated by this think-tank ultimately found a place in the overall development paradigm. This was possible because FAO financed hiring of highly qualified and progressive professionals in the fields of water management, agriculture, institution building and gender. After dismantling of the Project, there followed a gap of one-year and nothing could hold the key members of the TST together. The company that hired these consultants is no longer active. Currently, they are placed in projects supported by different United Nations agencies and World Bank projects

Relevance

Before thinking of the relevance of any experience, it is necessary to understand the context in which the intervention took place. It is impossible to isolate the two apparently different interventions (APWELL and APFAMGS) from each other, i.e. The socio-economic thrust of APWELL would be missed if learning was limited to APFAMGS, while the opportunity to learn from the more refined PGM model is lost if APWELL is studied alone. Therefore APWELL and APFAMGS really need to be considered as one experience under the banner of participatory groundwater management and the relevance judged in that context.

PGM is relevant for addressing both the private interests of individual farmers (their year on year income levels) and the public interest in commonly shared groundwater resources. In this respect, it works toward a system of voluntary self-regulation. People’s empowerment through knowledge, strong community-based institutions and functional links with local agencies has been an important feature of the process. But the core strength of PGM is its approach to demystifying science and technology. Access to scientific information at the user level holds the key to the sustainable management of water resources. The PGM approach tried to strike a balance between the scientific management of the HU and infusing groundwater users with a sense of responsibility, thereby a professional-farmer partnership model evolved for sustainable groundwater management.

The focus on farmer engagement for the generation and sharing of knowledge about local resources is key to instilling a sense of pride and ownership of the scientific knowledge, which used to be restricted to research institutions. This is in stark contrast with many other natural resource management initiatives, where resources and efforts are concentrated on supporting physical works and creating incentives such as subsidies for water-saving irrigation techniques. For community management efforts to succeed, it is clear that information, education, and social mobilization needs to be recognized as core objectives, not subsidiary activities

The existing instruments for controlling abstraction of groundwater through direct regulation have not halted the proliferation of boreholes. A direct regulatory approach is impossible to implement, because of the lack of resources for policing and absence of substantial support for penalizing defaulters. The PGM experience suggests there is a viable option for voluntary regulation by users themselves. This needs to be driven by users' improved understanding of their aquifer systems and demonstrations of the positive impacts of improved natural resource management on livelihoods.

Upscaling

The PGM experience is a breakthrough in groundwater management and securing the livelihoods of poor farmers in India. Both are key concerns of the central Government of India, and of many State Governments, and now the PGM approach has found its place in the Twelfth Five-year Plan prepared by the Union Government. However, taking this model to scale would not be straightforward. The model has to be accepted by individual States for piloting, a technical support team needs to be assembled and retained for any piloting and implementation phases and crucially, the NGO interest and capacity has to be available to join forces with local government administration and support. However these difficulties could be overcome by establishing a PGM group at national and State level in the Central Groundwater Board and respective Groundwater Departments or State level agencies responsible for groundwater management (agriculture and potable water supply), which may include PHED. An interface with a set of qualified NGOs at national and State level would be essential. Many States have already sent their staff for training during the APFAMGS–FAO phase.

The starting point for PGM upscaling could be a district level pilot that can be scaled up at the state level. State governments can take policy action to facilitate formation of local groundwater user institutions and ensure institutional coordination among different groundwater-related departments at the level of individual aquifer.

State agencies have a much sharper appreciation of how to nurture and sustain people's institutions for managing water resources. The state agencies have an advantage in promoting groundwater management on the ground, as they are in a better position to promote government-stakeholder interaction, considering that most departments have offices at the district level, where many local management measures need to be followed to design groundwater management approaches specific to the typologies and user needs of local aquifers.

Models that were entirely funded by external resources would fail to create community ownership. On the other hand, commercial models would defeat the very purpose of PGM because the hydrological data would then become goods for sale. It is more about encouraging communities to make farm-level decisions based on self-generated scientific information. A completely voluntary up-scaling model is impracticable, because the key to success of PGM was the presence of farmers who felt the pinch of water scarcity, wells going dry in front of them and neighbours committing suicide, as they were unable to pay debts for drilling bore wells. In areas where no water stress is felt it is difficult, if not impossible, to generate voluntary action. In addition, PHM infrastructure and technical expertise will not come freely.

A combination of these three models should be in place to upscale the PGM model at the national level. Components that need to be completely funded are: PHM infrastructure, community capacity building, hiring of technical personnel and incentives to encourage farm level action. The commercial component of the model would be to provide mechanisms for marketing farmer data products, which would contribute to the sustainability of community-based institutions and PHM assets (funds for operation and maintenance). The voluntary component would be limited to the choice a community makes to engage in efforts to match the annual groundwater withdrawal with the annual recharge, in a given HU.

At the international level, FAO can use this fact to promote upscaling of PGM, with local modification worldwide. FAO is addressing this issue with this present publication, as a first step towards this end. A starting point could be to get in touch with people, located in different countries, with various capacities, to assess the level of diffusion of PGM in their respective countries and work out the ways and means of upscaling at the national or provincial level.

When attempting to take the PGM model to scale, several pre-conditions apply. First, there has to be a willingness to adopt the HU as an intervention unit. Second, the model has to suit both the local hydro-geological settings and local sociocultural conditions where the adaptations will be made. Third, the approach has to embrace full participation and be multi-disciplinary in nature. Finally, support from a national level promoter of the PGM concept is essential to ensure consistency of approach and to focus monitoring and evaluation.

The myth and the reality

Myths and misunderstanding generated by the unprecedented popularity of the PGM model, and the extent to which it is relevant are addressed briefly. First the **myths**:

- community based institutions crumbled after withdrawal of FAO support;
- farmer data is not accurate;

- no economic benefit for the farmer;
- did not interest the local State government;
- social fencing to curb over withdrawal is weak;
- there was no effort to promote groundwater recharge;
- promoted cash crops;
- the model is not affordable and scalable;
- did not ensure drinking water security at the village level;
- farmer suicides curbed as a result of PGM;
- upscaling is difficult because of the lack of training facilities;
- data collecting farmers are paid by the project, and
- conflict resolution mechanism is not in place.

The **reality**, which may be cross-checked by visiting any PGM operational area, shows that: community-based institutions continue data collection and crop–water budgeting, even after withdrawal of FAO support; farmer data is more than accurate and representative as strict scientific norms are adopted for construction and qualified professionals validate data collected; farmers directly benefited economically from access to well irrigation and tapping of government funds for efficient irrigation; PGM interested the local state government as manifested by the wide diffusion of PGM practices in several programmes; social fencing may appear weak because PGM adopted a non-coercive approach; artificial groundwater recharge formed an essential part of the management of HUs where crop–water budgeting results showed an over-withdrawal.

Farmers may have opted for cash crops, but no crop was promoted as part of PGM, except for the appeal to match groundwater withdrawal with recharge; the model is affordable and scalable at the HU followed by the basin level, however, investment is needed for capacity building and to establish hydrological monitoring networks; drinking water security is taken care of by crop–water budgeting. Although the number of new wells has definitively been reduced, and farmers are earning substantial income from alternate crops, the extent to which farmer suicides have been curbed can only be known after a specific study.

In India, many training facilities are available at the district, state or national level to address PHM upscaling needs. Data collecting farmers are NOT paid by the project, as the idea was to instil a sense of responsibility for sustainable groundwater use. Finally, conflict resolution mechanisms at the village level is the responsibility of the Groundwater Monitoring Committee, at the HU level the Hydrological Unit Network and at the basin/district level the Partner-NGO level network.

For all these reasons, the authors sense that the PGM model is replicable, if applied intelligently and with a view to 'continuous improvement'. At its heart is a simple principle of learning to play with natural processes. The knowledge to do so is not the exclusive domain of the specialist. With a little effort and knowledge all groundwater users can engage positively with groundwater – it is in their long-term interest to do so.

Chapter 1. Introduction

The term 'management', as defined by the Business Encyclopedia, is "a process that is used to accomplish organizational goals". In organizational studies, resource management is "efficient and effective deployment of an organization's resources when they are needed". In conservation, resource management is "a set of practices pertaining to maintaining the integrity of natural systems". The broad term for this type of resource management is 'Natural Resource Management (NRM)'. For water, it becomes 'water management' and when the focus is on tubewells (boreholes) or dugwells, it may be called 'groundwater management'.

In business management, the 'demand' for a certain product is assessed by a market study of several factors that may influence demand. The capacity of the production unit is matched with current and future demand to assess demand-supply status. The production capacity may be enhanced, which entails capital investment to increase production (supply), if necessary.

If one has to apply these basic principles of business management to water management, the demand could be equated with the current and projected 'needs' of water to meet human needs, while supply could be understood as 'water availability'. If the 'resource' is kept, i.e. water at centre stage, instead of human needs, the 'supply' can be equated with 'replenishment' and demand with 'use'. For groundwater management, aquifer replenishment is known as 'recharge', while use can be equated with 'withdrawal' or 'pumping from wells'. Therefore, demand-supply management, in the case of groundwater resources, may be understood as 'matching the withdrawal with recharge'.

Matching of withdrawal-recharge may be accomplished by increasing the recharge; decreasing the withdrawal; or a combination of both. Natural groundwater recharge is from percolation of rainwater into void space in the rock-formation that can hold and transmit water, referred to as an 'aquifer'. Natural recharge can be supplemented by methods of artificial recharge to increase the overall recharge. Reduction of withdrawal is possible only at the user level, using a number of technical and social instruments, which are discussed in Chapter 3.

Groundwater and economic development

At global level an estimated 70 percent of all water withdrawn for human use is used by agriculture. Groundwater alone accounts for 40 percent of that use (FAO, 2011). In India groundwater accounts for almost 60 percent of all agricultural withdrawals, reflecting the widespread adoption of groundwater drilling and pumping technology throughout the sub-continent. Since India accomodates 16 percent of the world's population, but is only endowed with 2.45 percent of the world's land resources and 4 percent of renewable water resources, the pressure on India's aquifers underlying productive farmland is intense.

It is estimated that the country's annual usable water resources are 690 km^3 of surface water and 396 km^3 of groundwater, for a total of 1 086 km^3. Current use is around 600 km^3. As a result of population growth, India's water withdrawals will rise to an estimated **900 km^3/year by 2050** to meet agricultural, municipal and industrial needs. It is obvious that supply will hardly match demand, although India is currently among the top nine water-rich countries (FAO, 2011).

India possesses almost one-fifth of total equipped irrigated land worldwide some 62 million hectares (ha) of which almost 40 million ha depend on groundwater as a sole source or a conjunctive source (Seibert *et al.*, 2011). The National Commission for Integrated Water Resources Development Plan, in its report of September 1999, placed national groundwater resources at 432 billion m3 and use at 396 billion m3.

The importance of groundwater for national life is obvious because over 60 percent of irrigated agriculture is based on access to groundwater and 85 percent of rural drinking water comes from groundwater. Even after implementation of all major and medium irrigation projects (under construction and contemplated), groundwater sources will still dominate, particularly so in drought years (GoI, 1999). Thus, sustainable management of groundwater plays a major role in the agriculture sector, which in turn contributes to the economic development of this mainly agrarian country.

Groundwater development has led to increased drought-proofing of India's agricultural economy. If one compares the drought years 1965–1966 and 1987–1988, food grain production declined by 19 percent in 1965–1966, in contrast to 1987–1988, when food grain production declined by only 2 percent. Much of this can be attributed to the spread of irrigation and of groundwater irrigation in particular. The growth of India's irrigated area, specifically irrigated with groundwater, has greatly reduced the economy's vulnerability to reduced rainfall, effectively drought-proofing national crop production and the rural economy. In contrast to surface water irrigation, groundwater irrigation in India is almost wholly self-financed. While public investment is available for large dams and surface irrigation commands, at all stages of planning, construction, operation, maintenance, there is none for groundwater sources, although they contribute to half of agricultural production.

Improved development and management of groundwater will, therefore, address the broad array of emerging resource and allocation problems in rural areas. India's ability to feed its rapidly growing population depends on its ability to increase agricultural production and, this in turn, depends on irrigation. Access to groundwater can be a major engine for poverty alleviation and economic development in rural areas. There is immense social value related to increasing rural agricultural incomes and slowing the migration of the poor to urban areas. Re-allocation must, therefore, not be at the expense of maintaining a viable agricultural economy.

Smallholders

The word ‘smallholders’ is defined as “farmers with limited resource endowments relative to other farmers in the sector” (FAO, 2003). Generally, a farmer having less than a hectare is considered to be a smallholder. The ceiling may be higher in semi-arid regions. The National Bank for Agriculture and Rural Development (NABARD), in India, defines a small farmer as “a cultivator with a land-holding of 2 ha or less; and a marginal farmers as “a cultivator with a land-holding of 1 ha or less”. However, the ceiling is flexible and the suitability of the applicant for financing depends on the opinion of the district level branch of NABARD. In this publication, both smallscale and marginal farmers are considered to be smallholders.

In India, while 76 percent of operational landholdings are small (2 ha or less), they operate on only 29 percent of the area. They comprise 38 percent of the net area irrigated by wells and account for 35 percent of the tubewells fitted with electric pumps (GOI, 1992). Thus, in relation to operational area, smallscale and marginal farmers are well represented in groundwater irrigation. The United Nations World Water Development Report (2003) states: “In India, 69 percent of people in non-irrigated areas are poor; in irrigated areas this figure falls to 2 percent”. Therefore, there is a clear link between the incidence of poverty and access to irrigation. Smallholders without access to irrigation seem to make up a major chunk of the worlds’ poor. Thus, in relation to operational area, the poor are well represented in groundwater irrigation.

Uneven distribution and unequal access to canal irrigation, and the decline of the traditional village tank system, has led to greater reliance on groundwater, which is costly for individual cultivators. Large-scale farmers can afford their own tubewells or tanks and can sell water; however, poor smallholders have no access to water for their small areas of land and prefer to live as agriculture labour.

The number of groundwater abstraction structures increased dramatically over 1951–1990. During this period, the number of dug wells increased from 3.86 million to 9.49 million, shallow tubewells from 3 000 to 4.75 million and public tubewells from 2 400 to 63 600. Similarly, the number of electric pumps increased from 21 000 to 8.23 million and diesel pumps from 66 000 to 4.35 million.

The National Sample Survey Organization (NSSO), in its Report No. 499 (2003), observed that 48.6 percent of Indian farm households were indebted. This represents a substantial increase over time, compared to 26 percent in 1991 (similar NSSO survey). Note the average amount of outstanding loans increased with the size of landholding.

Access to information

A farmer who is not connected to a communication network is usually not in a position to access data or information that would make her or him smarter when making farm-level decisions. The NSSO survey found that around 40 percent of the sample accessed such scientific information from other farmers (17 percent), input dealers (13 percent), radio (13 percent) and television (10 percent). Public agencies that are meant to deliver such knowledge to farmers had been accessed by only 8.4 percent of farmers surveyed. In Andhra Pradesh, scientific information is gathered and used, in decreasing order, by farmers (91.5 percent), input dealers (86.3 percent), extension workers (73.5 percent), television (54.7 percent), newspapers (52.5 percent) and radio (50.5 percent).

This indicates that Indian farmers are increasingly dependent on input dealers for any kind of scientific advice, making him/her vulnerable to the input dealer's possibly ill-placed advice as they promote their products. Furthermore, the huge wealth of traditional knowledge is often ignored, as is the remarkable ability of farmers to adapt and develop cultivation practices according to their own specific situation and experience. So it need not be true that all new research and knowledge, arising from various sources, always generates the best or most desirable practices.

It may also be true that the people who are closest to the groundwater can manage it best, not the occasionally visiting agencies. Therefore, the knowledge of the nature, occurrence and behaviour of aquifer systems may be better understood by people who are going to be affected by changes in the aquifer system. Though all beings need water for their survival, the group that utilizes it most, depleting groundwater in certain pockets, is the groundwater-based farmer. She or he is the principle stakeholder in groundwater management.

In this regard, priorities at the local level differ from those at the regional or national level. Therefore individuals and communities need to be encouraged to understand their options for change; choose from these options; assume responsibility for implementation of options that these choices imply and then realize their choices could radically alter the way the world uses its limited water resources. It follows that local organizations, government, civil society and the private sector all have important, and often unique, roles to play in water management and need to be encouraged.

Purpose of this publication

The Participatory Groundwater Management (PGM) model, which is discussed in this publication, attempts to institutionalize groundwater management through community based institutions, non-governmental organizations (NGOs) and local government functionaries. Sensitizing farmers and strengthening their capacity is the key to their improved knowledge of the aquifer systems they are operating within. This enables them to start thinking about demand-side management of groundwater resources. The PGM approach, which is the basis of this current work, began in 1999 and, over time, evolved several tools for groundwater management as alternatives to past approaches.

This publication recounts the journey of smallholders and groundwater professionals in Andhra Pradesh during 1999–2009 and, in the process, places PGM in the right context. The journey, traced in Chapter 2 begins with the provision of Community Borewell Irrigation Schemes – the APWELL Project, and the origin of the concept of PHM, and continues through to the termination of the Andhra Pradesh Farmer Managed Aquifer systems (APFAMGS) project. Chapter 3 brings together PGM technical and social tools, as they evolved over time. In Chapter 4, the response to different tools is assessed, apart from building a typology of responses to the PGM. In Chapter 5, four case studies are used to analyse response typologies and reasons for different responses. The relevance of the PGM model, especially in terms of the issues addressed, its sustainability and scope of upscaling is discussed in Chapter 6.

Chapter 2. The Particpatory Groundwater Management (PGM) Package

APWELL provided 3 462 borewells for use by about 14 000 small and marginal farm families, which by March 2002, placed about 14 000 ha under well irrigation. A typical APWELL system comprised a community irrigation tubewell, jointly owned by a group of 3–6 smallscale/marginal farm families, with a well command of about 3–5 ha. By the time APWELL commissioned the wells, scientists and administrators became aware that the project would contribute to the depletion of dwindling groundwater resources.

APWELL addressed this concern with twin strategies: a) site selection in virgin, or areas where there was scope for further groundwater development; and b) incorporating an entirely new model of community based groundwater management to ensure the sustainability of wells provided to the needy smallholder farmers. This approach is referred to as participatory groundwater management (PGM), in the current work. PGM not only gave poor farmers first-time access to groundwater, but also instilled a sense of responsibility, in the interest of overall sustainability of the aquifer system on which they would depend forever.

The main components of PGM are: well irrigation system (WIS); hydrological unit (HU); participatory hydrological monitoring (PHM); farmer data management (FDM); crop water budgeting (CWB); artificial groundwater recharge (AGR); Farmer Water Schools (FWS) and community based institutions (CBI). These components and a few strategies and tools are discussed in this chapter.

2.1 Group-managed borewell irrigation systems

APWELL adopted the strategy for group-managed borewell irrigation systems because: i) it is neither economically viable nor environmentally good, if a well is provided to each family that owns a small area of land; ii) scope for larger coverage in terms of number of smallholder farmers and area under irrigation; and iii) to experiment with the idea of groundwater as a common pool resource that could be better utilized for the common good by sharing it. The model is highly successful illustrated by its functionality, even a decade (at the time of *post facto* evaluation study conducted for this publication) after its creation.

Steps followed for creation of those group-managed borewell irrigation systems were: mandal [1] ranking; selection of potential areas; environmental viability assessment (EVA); participatory rural appraisal (PRA); submission of applications; formation of a water user group (WUG) and women's self-help

[1] An administrative unit below the district level, in Andhra Pradesh, two to three times smaller than the conventional 'block', a term used to denote subdistrict unit of administration in other parts of the country.

group (SHG); water-sharing agreement; collection of farmer's contributions; hydrogeological survey; clearance of drilling sites; well drilling; yield test; water-quality test; electricity connection; well commissioning; formation of borewell user association (BUA); laying of piped distribution system; one-year warranty; and handing over of the system to the WUG.

APWELL operated in seven drought-prone districts of Andhra Pradesh: Anantapur, Chittor, Kadapa, Kurnool, Mahabubnagar, Nalgonda and Prakasam. When the site-selection procedure was reviewed in August 1999, it was found that 51 percent of borewell clusters were small (less than five tubewells). To ensure that the project created a number of workable clusters, to facilitate capacity-building activities, a desk study was conducted to rank each mandal in the district. Four simple criteria were used: stage of groundwater development; groundwater potential; groundwater quality and area under surface water irrigation. As a result of this exercise, out of 413 mandals, 146 (35 percent) qualified for project intervention.

Within the priority mandals, potential areas were selected based on secondary data and maps. APWELL developed an environmental viability assessment (EVA), a tool to ensure the project drilled borewells where the stage of groundwater development provided scope for further groundwater tapping. The EVA process involved primary data collection, using specifically designed formats and data inputs entered into a spreadsheet package, which automatically gave results and recommendations. It included a module for micro-level water balancing and agronomic assessment, followed by social validation. At the end of the last drilling season (March–June 2001), 544 EVA clusters were delineated; EVAs were conducted at 535 clusters; 414 were cleared for project intervention and borewell clusters were created in 360 of these EVA clusters.

In addition a social viability assessment was carried out, using participatory rural appraisal. This comprised analysis of the socio-economic status of communities in identified EVA clusters. Villages were selected based on the outcome of PRA and villagers were advised to submit applications for the provision of a group-managed borewell irrigation system. This involved much village level action, including the formation of water user groups. Participating women were organized into self-help groups to ensure a gender balanced project intervention. Meanwhile, this provided an opportunity for the potential well beneficiaries to group together and submit an application for construction of a well. The district teams set the targets for the number of borewells, based on the applications received that qualified for APWELL intervention. These targets determined the number of clusters to be created and mandals to be covered; a workable cluster of 12 tubewells was determined.

An important step between clearance of the application and hydrogeological survey was the payment norm for the first installment of group contribution, which was 15 percent of the estimated cost of well construction. Drafting of water-sharing agreements, between the beneficiary families was mandatory before any hydrogeological survey took place.

Hydrogeologists from Andhra Pradesh State Irrigation Development Corporation (APSIDC) then conducted integrated hydrogeological and geophysical (vertical electrical sounding) investigations to select drilling points. Care was taken during the investigation not to violate the government well-spacing norm (a minimum distance of 300 m between two tubewells). The cleared sites were then drilled using APSIDC rigs. Hydrogeologists or irrigation engineers from APSIDC supervised the drilling. The hydrogeologist conducted a yield test to assess the yield from the well under different pumping conditions. A well was declared successful if it yielded more than 2 500 gallons per hour (gph) (9 464 litres). The ceiling for success was later revised to 1 500 gph (5 678 litres), in response to farmers' demands.

Water samples were collected from the newly drilled well, while conducting the yield test and sent to local government laboratories for analysis of water quality. The well was considered successful when the quality of water was not detrimental to the soil or crop. An irrigation development project, APWELL, analysed water for both irrigation and drinking water quality. The water quality analysis was carried out in partnership with local laboratories run by Panchayati Raj Engineering Department (PRED) and the Office of the District Medical and Health Officer (DM&HO). Results of the analysis were communicated to farmers and necessary support was provided to overcome quality problems, mainly by training and creating links to the line departments.

After completion of successful drilling in a cluster, usually a village, the district teams organized borehole user associations (BUA) to take care of the common interests of the new well owners, including operation and maintenance of their systems. The BUAs were also conduits for community capacity building and other village level activities related to project implementation.

Soon after the well had been declared successfully drilled, the long process of application for an electricity connection started. It is interesting to note that new connections were sanctioned for APWELL borewells, in spite of a blanket ban on electricity connections for irrigation borewells in the state. However, the time taken for electrification of wells, after successful drilling, was anywhere between 6 months to 2 years. It was often quicker for the new wells to be connected to existing electric transformers, because of long delays when ordering a new transformer. Suitable submersible pumps were selected and installed after electrification of the wells.

The last step in well commissioning was the laying of the underground pipeline distribution system, with outlets for each of the families in the WUG. APSIDC gave a warranty of 1 year, after which the system was handed over to the WUG, which became responsible for operation and maintenance of the system, and for payment of electricity bills and irrigation scheduling. Metering was introduced for the first time in the state as an experiment with APWELL farmers, which however proved to be a non-starter.

2.2 Delineation of the hydrological unit (HU)

The term ‘groundwater’ is generally used to refer to water occurring in wells and springs, while water that flows on the ground in streams and rivers is called ‘surface water’. The type of water-bearing formation or aquifer, or simply rock-type, determines the amount of water that can be stored or transmitted through the aquifer. While water flowing over the ground is visible, and easy to quantify and manage, the hidden nature of groundwater makes such quantification and management difficult. Basic knowledge of groundwater science or hydrogeology is necessary to understand the dynamics of aquifer systems in a given area. The management of aquifer systems should ideally begin before, or simultaneous to, their development for beneficial use, limiting the number of wells to draw less than the estimated annual recharge. However, groundwater is tapped with no management practice.

Aquifers (water-bearing rock formations) may have fixed geological boundaries but they show dynamic responses to the hydrological cycle. Aquifers are recharged naturally, when rain and other forms of precipitation fall, enabling the exposed part of the aquifer to uptake water through its pores and fractures. Once the aquifer is saturated groundwater can move vertically and laterally to discharge as a spring or seepage zone, often into the nearest stream or river (in a few cases directly into the sea or ocean), in the form of *base flows or low flows*. This connection between surface water and shallow groundwater circulation is dominant in the generally thin, discontinuous aquifers of Andhra Pradesh. Therefore, the practical unit for management of aquifer systems is a drainage basin where recharge and discharge areas can be readily identified and agreed with groundwater users. There may be some groundwater connection across hydrological units, but to all intents and purposes, the recharge occurring in one unit will appear as discharge in the same topographically defined unit.

In unconfined aquifer systems, upper weathered and fractured layers form the recharge zone, while the discharge zone will be associated with a watercourse that drains both surface water and groundwater, where its bed level is topographically below the water table in the surrounding catchment. However, when the water tables lie below local watercourse, recharge to the aquifer can occur along the length of a stream (indirect recharge). Indeed the water table aquifer is known to interact with the streams, either through base flows (effluent condition) or drawing surface flows for saturating its unsaturated portion (influent condition). It is found that water table aquifers usually discharge into the nearest third order stream. APWELL mostly worked in a hard rock area, which was typified by unconfined aquifers, and considered the catchment of a third order stream, which was perceived as a workable hydrological unit.

APWELL operated in eight pilot hydrological units (HU) in Bollasanduvanka (Anantapur), Alanvanka (Chittoor), Peddavagu (Kurnool), Erravagu (Kadapa), Polerammavagu (Prakasam), Bhasker Rao Kunta (Nalgonda), Mandavagu and Manne vagu (Mahbubnagar). APFAMGS expanded to 38 HUs (in six districts), operating with unconfined aquifer systems in hard rock. These were Upparavanka, Bellamvanka, Maruvanka, Mynapuramvanka, Peddavanka, Gootymaruvanka and Vajralavanka (Anantapur), Kothakunta, Diguvetigaddavagu, Rommonivagu and Nakkillavagu (Chittoor); Bokkineru, Erravagu, Mulabandalavagu, Tadaukuvagu, Tandrasilavagu and Erravanka (Kadapa); Chinneru, Rallavagu, Thundlavagu, Peddavagu, Yerravanka, Lothuvagu, Chandravagu, Buchammakonetivanka, Konetivanka, Bhavanasi and Peddavanka (Kurnool); Chandrasagar, Mallappavagu and Mandavagu (Mahbubnagar); Bhaskaraokunta, Mallappavagu, Sattammakunta, Kondesikunta, Natiganicheruvu and Nukanayanicheruvu (Nalgonda);

In confined aquifer systems, the delineation of HUs can prove challenging, particularly where the underlying structural geology is complex – characterized by faults, intrusions and fracture zones. A balance needs to be struck between the recharge and discharge areas, which may be far apart. The recharge area (the part of the aquifer exposed on the ground) of the confined aquifer should form part of the management unit. It may be essential to identify the correct stream or river into which the confined aquifer discharges. This could, in many cases, be the main river or its tributary. The catchment of such stream or river, which includes both recharge and discharge zones of the aquifer, should be the unit of groundwater management.

An entirely fresh approach is needed for aquifers that discharge directly into the sea or ocean. While they could have a clear recharge zone on land, the aquifer discharge area would have an interface with the saline water ingression from the sea front. The entire coastline may need to be considered, where aquifers discharge as an HU. Management here should be related to management of water quality rather than to quantity.

Ultimately, the overall water management unit could be the river basin, made up of several types of aquifer systems, interacting with each other. The ideal is to bring together management structures created in each of the hydrological units, under the umbrella of the river basin organization (RBO). However, building an RBO from the bottom, i.e. smallest HU to the top, at the river basin level, would be more sustainable than organizing at one go.

APWELL used topographic maps (on 1:50 000 scale), published by the Survey of India (SoI), to delineate the topographic drainage basin, i.e. the hydrological unit. APWELL clusters were marked on the map and the surface drainage around the clusters studied to decide the outlet point of the main stream in the area. The study of contours in the area of interest revealed the ridge-points (bench-marks), which were connected to obtain a proper drainage basin of the third order stream identified earlier. The area of the HU was calculated using a centimeter graph.

After installation of geographic information system (GIS) software, and procurement of handheld global positioning systems (GPS) for APFAMGS, topographic maps were digitized, along with other thematic maps prepared by the Geological Survey of India and Soil Survey of India. All Project interventions were captured in the different thematic layers, including location of PHM stations. Figure 2.1 shows the drainage of the Upper Gundlakamma sub-basin and its 25 constituent HUs.

Upper Gundlakamma sub-basin, delineated by APWELL, covers 192 villages in seven mandals. The APWELL Project was active in 19 of these villages, through the borewell programme. Within the Upper Gundlakamma sub-basin 25 independent HUs were delineated: Pulivagu, Erravagu, Lingogipalluvagu, Chinnauppuvagu, Peddanagulavaramvagu, Yadalavagu, Kanugulavagu, Mekaleru, Naidupallivagu, Tarlupaduvagu, Seetanagulavaram, Bodducherlavagu, Mittameedipallivagu, Suuddakuruvavagu, Jampaleru, Vemuleru, Kakarlavagu, Bogolu, Chavatavagu, Singaraikondavagu, Palamotuvagu, Rallavagu, Narsireddipallivagu, Uppuvagu and Peeturuvagu.

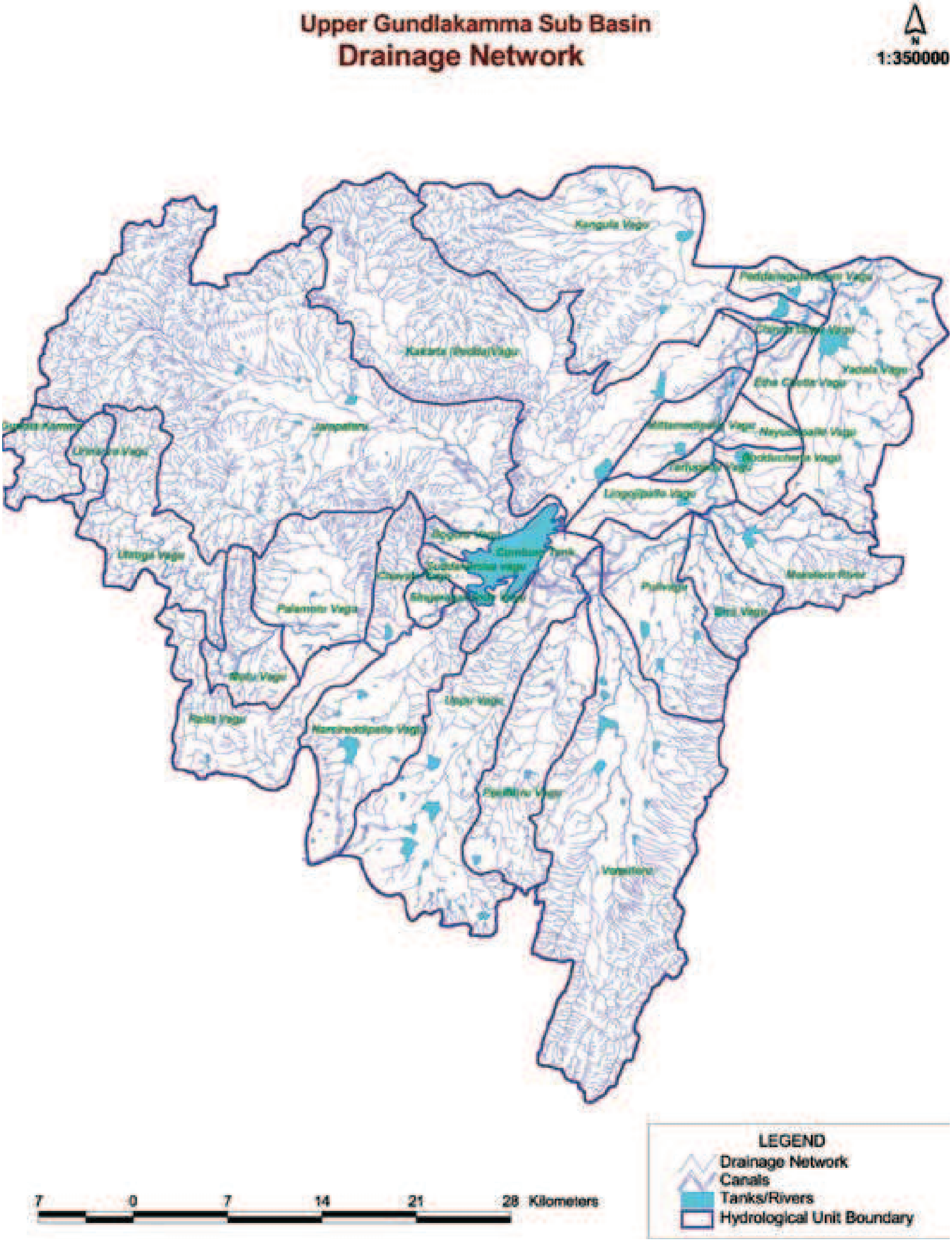
2.3 Participatory hydrological monitoring (PHM)

Prior to PHM, hydrological monitoring was largely the domain of scientists. The scientific information a farmer needs, to make informed farm level decisions, was never within his/her reach. The PHM model was path breaking not only in terms of making the needed data available at the farmer's door-step, but also for ushering in the concept of a farmer-scientist partnership to sustainably manage groundwater resources. The initial doubts about a farmer's ability, as they are not formally trained, to handle sophisticated scientific equipment and analyse hydrological data were cleared after the APWELL pilot phase. Introduction of non-formal education techniques further strengthened PHM, bringing in additional methods of farmer-friendly data analysis and sharing. Now, there is no doubt, at least in India, about this aspect, as illustrated by the influx of hundreds of visitors and trainees, including, formally trained hydrogeologists, who openly acknowledge the scientific validity of PHM.

The key PHM activity is installation of water monitoring equipment, which is essential for estimating the recharge and discharge processes in the HU. The norm for establishing a rain gauge station is one station for every 5 km^2 and one monitoring well every 1 km^2. The rain gauge station network allowed for integration of rainfall over the HU to estimate groundwater recharge. Natural groundwater discharge was measured where possible at the outlet point of the HU using already established stream gauging sites and known stage/discharge relationships. Aquifer withdrawals from pumped wells were made in half of the monitoring wells, with additional pipes and bends in the well assembly, to measure actual well discharge. The average withdrawal

Figure 2.1

Upper Gundlakamma sub-basin and its 25 hydrological units, Prakasam district (AP)



from the aquifer was then estimated based on known pumping durations. With this information, users could calculate the basic water balance for the HU, as detailed below.

Rain gauge station

A total of 203 rain gauge stations (one for every 5 km^2) were established on land donated by the farmers for APFAMGS. Listing of farmers willing to donate land for the establishment of a rain gauge was the first step in establishing a rain gauge station. Possible sites were inspected to check the site was an open space with no obstructions; the distance between the site and the nearest object was not less than twice the height of the object, in no case was the distance less than 30 m. Sites where selected on flat ground where possible. In hilly areas, where level ground was difficult to find, sites were selected to minimize any local topographic interference.

Several types of rainfall measuring instruments or rain gauges were available. A basic Symon's non-recording rain gauge was used for PHM, which comprises a cylindrical vessel measuring 127 mm internal diameter with an enlarged base of 210 mm diameter. A rain collecting glass or plastic bottle is placed inside this cylinder. Over the top of this bottle, a glass/plastic funnel is inserted. The top section of the funnel has a circular brass ring of exactly 127 mm internal diameter. The bottle can hold from 75 to 100 mm of rainfall. A cylindrical graduated measuring glass is also supplied with each rain gauge. Each graduation of this glass is marked 0.2 mm, with an accuracy of + or - 0.1 mm.

The rain gauge was fixed on a two-step square masonry base, set upon a (60 x 60 x 60) cm concrete block. The funnel rim was at least 305 mm above ground. A hole was left at the centre of the concrete bed of the rain gauge, 76.2 mm deep and 210 mm wide. The base of the rain gauge was placed in this concrete bed of 25.4 mm. Care was taken so that 50.8 mm of the bottom portion of the rain gauge remained below ground. After fixing the metal pipe of the rain gauge, other components (collection jar and funnel) were placed inside and the cap closed.

A barbed wire fence was used to establish the rain gauge station and to control stray animals and miscreants. APWELL found this ineffective and a fence was built around the rain gauge measuring (4 X 4) m, 1.5 m high, with four iron angles (0.25 gauge) 3.2 cm wide, 15.2 cm long and 6 mm thick were driven into the ground, and used as a skeleton around which a 4 mm wire mesh was arc-welded to the angles. A gate 1.5 m high and 80 cm wide was fixed in the eastern boundary for access and to display information related to the rain gauge and the HU. Plate 2.1 shows a typical rain gauge station established as part of PHM.

Plate 2.1

A typical rain-gauge station established as part of PHM

Rainfall was the first meteorological element measured by people, using the vertical depth of water accumulated and held on a level surface. To maintain a common base, and allow for comparison with data from other agencies or stations, a standard procedure was prescribed and followed for PHM rainfall data collection. The volunteer collected rainfall received at 08.00 hours, every day in conformance with Indian meteorological standards.

The rainfall was collected following the steps described: the measuring jar was carried to the rain gauge station; lock of the gate opened; lock of the rain gauge opened; conical flask removed by unscrewing it from the fixed part of the rain gauge; collection jar taken out; water collected in the collection jar carefully poured into the measuring jar; if the water collected was more than the capacity of the measuring jar, first filling was thrown away and the remaining water poured into the measuring jar; the previous step was repeated if water still remained in the jar; the number of measuring jar fillings was noted; the final water fill in the measuring jar was noted; the number of fillings of the water jar and the last reading were added together to arrive at the rainfall received on that day and the value noted.

Production-cum-monitoring well (PMW), measuring water levels

A total of 2 026 monitoring wells (one well for every km^2) were established across the project as part of the PHM network. For the purpose of PHM, which envisaged people being engaged in monitoring, the equipment used was simple and easy to operate, but gave sufficiently accurate groundwater readings to interpret as part of a local groundwater balance. Participatory resource mapping (PRM) resulted in a complete inventory of wells in the HU. After PRM, in a separate well inventory, the wells' location was marked on the topographic map. After the staff were equipped with the skills and equipment, the well's location was geo-referenced, using hand-held GPS.

Initially, social feasibility (willingness of the farmer) took precedence over technical criteria (spatial representation) in the selection of the monitoring wells. Later, the hydrological units were divided into equal grids on the topographic map and a socially feasible well was identified within the grid.

For conventional hydrological monitoring, sophisticated equipment is used by qualified scientists. To measure the water level in wells, government departments maintained a network of observation wells, the average distance between two observation wells being about 20 km. No pumping is allowed from these observation wells. When such an observation well is drilled it is generally completed with casing and screen to isolate the aquifer unit in which head or pressure changes are occurring and as such can be called a piezometer. Departmental staff took water level measurements twice a year, pre-monsoon and post-monsoon. Under the Hydrology Project [2], several piezometers were drilled to strengthen the observation well network. Some of the piezometers were equipped with automatic water level recorders.

[2] A World Bank funded project supporting infrastructure development, including strengthening of observation well network and hydrological database of the Central Groundwater Board and State Groundwater Departments.

To obtain a realistic picture under pumping conditions, clusters of production wells in the PHM were converted into monitoring wells. To monitor the un-pumped water level, failed wells were included in the monitoring well network. Care was taken to ensure representation of all parts of the HU. To identify monitoring wells the steps followed were: use of a centimeter graph, the HU was divided into 100 ha grids, 4 cm boxes made up one 100 ha grid; if one borewell (failed or successful) was available in each of the 100 ha grid, it was shortlisted for field validation with preference given to wells at the centre of the grid.

In practice, one failed borewell was always selected in each HU; if there were no borewells in the 100 ha grids dug wells, or other types of wells were selected. It was ensured that monitoring wells were equally spread throughout the HU, including the recharge area, the central and discharge area, i.e. near the mouth of the stream outlet and care was taken to ensure that the highest and lowest yielding and failed borewells were included.

The material used to convert a production well into a monitoring well included: high density poly-ethylene (HDPE) pipe of 1' diameter and suitable length; galvanized iron pipe (7' diameter with 1.25' ring, gauge 18); borewell cap (7' diameter, 1' high with closer and couplings); gate valve with Indian Standard Item (ISI) mark; brass nipple; galvanized iron connecting nipple: steel nipple;

steel connecting nipple; end cap; galvanized iron or poly vinyl chloride (PVC) L-bend; T-bend and jockey to lift the pump assembly. The hydrogeologist guided installation. Skilled and unskilled labour was obtained from the village or near by. Plate 2.2 shows a production well converted into a monitoring well to measure water levels.

Plate 2.2

A production well converted into a monitoring well to measure water levels

Installation of the conduit pipe in the monitoring wells was awkward and was commissioned prior to the commencement of the PHM activity. Welding equipment was carried to the site to make the hole in the casing cap. For wells commissioned later, the casing cap was manufactured with a pre-made hole. Farmers reported difficulties with the measuring pipe when the motor had to be lifted out for repair. The motor was not coming out smoothly on account of the small gap between the motor pipe and the mild steel (MS) coupling of the lowering pipe. Replacing the MS couplings with PVC solved the problem. Use of couplings was avoided after introduction of one-length of HDPE pipe.

After the short-listing of potential monitoring wells, the owners of the selected wells were contacted and the purpose of the monitoring well, and physical changes required to the well assembly were discussed. If a farmer was unwilling, an alternative well was selected in agreement with the owner. After the selection process was complete, wells were located on the HU map to ensure good representation throughout.

The project provided electronic water level dip-meters to measure water levels in the wells, which were monitored every two weeks by men and women farmer volunteers and by APWELL farmers. On each scheduled day, they following these steps: noted the time elapsed since the last pumping; the water level indicator was opened and checked that it was still functioning; the nipple of the insertion pipe was removed (with a spanner, if required); the probe with the measuring cable was slowly lowered into the well through the insertion pipe; lowering of the probe stopped when the beeper sounded; the measuring cable was slightly lifted and jerked, before lowering it again; the jerking and lowering repeated two or three times was to ensure that the exact water level was reached; reading on the measuring cable was noted as the static water level.

All previous steps were repeated after continously pumping from the well for four hours; just before the power was switched off, or there was an expected power cut, the water level was again measured and noted as pumping water level.

Production cum-monitoring-well (PMW), measuring water levels and well discharge

There was no need to make a discharge measurement provision for private farmers, who adopted open channel irrigation where the delivery pipe was left open. However, for farmers using pipes for irrigation, such as APWELL farmers, the pipe system was connected with the borewell, by two L-bends, one at the end of the delivery pipe and the other at the beginning of the distribution system. Simple alteration was therefore needed at the end of the delivery pipe to provide room for discharge measurements.

In borewells with piped systems, the following procedure was adopted for the discharge measurement: the entire pump assembly was lifted to a sufficient height to enable the calibrated drum to be placed underneath the delivery pipe; the borewell assembly and distribution system were detached by unscrewing the L-bends; a T-bend was placed at the end of the delivery pipe, with the leg of the T parallel to the ground surface; a 1 m pipe was fixed to the end of the T, parallel with the surface of the ground and a removable cap fixed to the end of the T. The diameter of all material used for the discharge measurement matched the diameter of the delivery pipe. Plate 2.3 shows an example of the discharge measurement.

Discharge measurements were carried out in 700 monitoring wells using the calibrated drum (100 litre capacity) method. Time was required for staff to make the discharge measurements as much work was involved. Though the alteration was simple, the staff had to go to each and every well carrying the cutting and fixing material, which they found cumbersome. This difficulty was overcome with persuasion and demonstrations. Initially, a digital sports watch was used. As the farmers found the operation a little complicated, a conventional steel-body stopwatch was introduced.

Plate 2.3

A production-cum-monitoring well to measure water levels and well discharge

Steps to measure borewell discharge were: cap of the T-bend pipe was opened; while one farmer put the calibrated drum under the pipe, another farmer pressed the stopwatch when the first drop of water fell into the drum; when the water touched the 100 litre mark, the stopwatch was pressed again; the minutes and seconds elapsed noted; the time taken to fill the known volume was noted; to arrive at the discharge in litres per minute the provided conversion table was referred to; these steps were repeated immediately after taking the second pumping water level reading.

Stream gauge station and stage-discharge relationships

During the APFAMGS Project, stream gauge stations were established at all HU outlet points. In the dry season, a calibrated wooden staff was installed at the outlet point in the streambed. Farmers were trained to use the float method, using a tree branch or wooden float, to calculate the stream discharge at a given time. The number of days/hours the stream flowed in a year gave an estimate of the quantity of water flowing out of the HU. Later, current meters were provided, instead of the float, and farmers trained how to use them, which improved the accuracy of the estimation. Plate 2.4 shows a stream gauge station and equipment used to estimate the annual stream discharge from a given HU.

As most of the streams were ephemeral and flowed for a brief period in a hydrological year, typical 'stages' of stream flow were established during the first year, and later firmed up by observations in good and bad rainfall years. This led to identification of extremely high and low stages of stream flow. The stage-discharge relationship was developed by plotting discharge measured at each of the typical stages on a 'rating curve'.

Plate 2.4

A stream gauge station for measuring outflow from the HU

Water quality monitoring

In May and October the twice-yearly APFAMGS monitoring of water quality in sample wells took place for 16 standard drinking water quality parameters. Wells with water quality problems were identified, based on statistical analysis of results of the water-quality analysis. All wells with quality problems were marked with a 'danger sign' to caution the community not to drink the well water. In preceding years (all the years APFAMGS was active), water quality analysis was restricted to the wells with reported water quality problems.

Water samples collected from wells in the project area were tested for irrigation water quality. Wells yielding saline or alkaline water were shortlisted and farmers informed of the problem. They were encouraged to adopt methods to drain excessive salts from the water using the APWAM [3] model. Visits were organized to inform farmers of the problem. In 2006, water quality testing kits were provided to Partner-NGOs.

2.4 Farmer data management

About 7 000 women and men in 661 households fully participated in the PHM process. Groundwater Monitoring Committee (GMC) volunteers in 555 households learned to collect and record rainfall data from 203 rain gauges. Members of 63 HUNs were trained to understand the occurrence of groundwater at the HU level. Farmer-collected data included daily rainfall, fortnightly water levels, fortnightly borewell discharge and daily stream flows.

The farmer data management tools used in APFAMGS attempted to elaborate and refine the APWELL experience. They included: the base document (BD); hydrological monitoring record (HMR); habitation resource information system (HRIS) and crop water information kiosk (CWIK), described below.

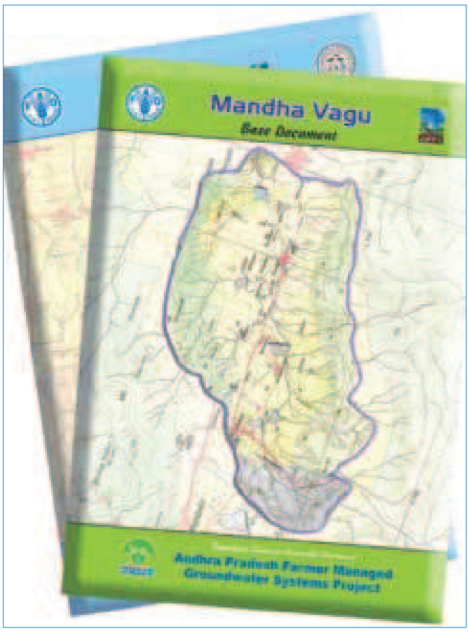
Base document

One base document was prepared for each hydrological unit. The data input for the base document came from the desk study of maps, reconnaissance, participatory resource inventory (comprising well inventory and crop inventory) and secondary data (such as rainfall, demography, etc.). The base document (Plate 2.5) served as a reference point for all farmers and staff for their activities.

The base document includes administrative details, geography, geology, geomorphology; human resources information including demography, community based institutions, government institutions, participation of women and men, literacy, habitation, history, indigenous knowledge and practices, power equations, migration, health and services; information about water resources comprising agro-climate, rainfall, drainage, surface water, groundwater, groundwater recharge structures, water management practices, knowledge system of water management and APWELL interventions; information about agriculture including land use, soil, conservation practices, cropping pattern, crop calendar, crop yield and net returns, pest and diseases, mechanization, cattle and biomass.

Plate 2.5

A base document



Hydrological monitoring record (HMR)

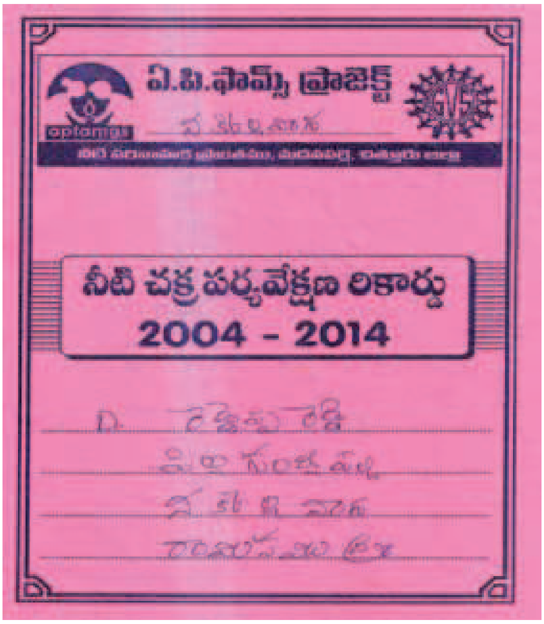
The hydrological monitoring record was a small booklet developed by APWELL; it was fine-tuned by APFAMGS for storing PHM data collected by farmers. The main components of the HMR were: cover page showing project logo, name of the HU, district and borewell user association, and later the Groundwater Monitoring Committee; the first page gives location of the monitoring well, well code and

[3] Andhra Pradesh Water Management, implemented by the Acharya NG Ranga Agriculture University, and supported by the Dutch. Their aim was to evolve a model to manage saline soils in the coastal district, using technology developed by the International Institute for Land Reclamation and Improvement (ILRI), the Wageningen University, the Netherlands. This project was re-routed through FAO and terminated 2007. The APFAMGS project established good linkages with APWAM and used their expertise for management of saline soils and measurement of stream flow.

names of farmers under the borewell; the second page kept blank for pasting the topographic map showing the location of the monitoring well, as well as location of other wells with respect to that particular well (later the thematic map showing the Hydrological Monitoring Network in the HU); the fourth page shows technical data, pertaining to drilling, pumping test and commissioning; the table on the fifth page provides space for recording the static and pumping water levels and borewell discharge; the same page was repeated ten times to accommodate 10-year's of data recording; the conversion table was provided after the water level and discharge table. The table provided space to record rainfall data for one full hydrological year (based on the conversion table), which was repeated to accommodate data for 10 years. Plate 2.6 shows the HMR.The data collected by a PHM volunteer were entered and stored in the hydrological monitoring record, at the village groundwater monitoring committee office, which shared the data with the hydrological unit networks each month, initially through Partner-NGO staff and later directly. At the Partner-NGO level, data from all hydrological unit networks were collected every month and stored as an Excel spreadsheet, designed by the consultants. Whenever necessary, the Technical Support Team (TST) accessed data held by the Partner-NGO. Later, it became mandatory to send monthly data from the HUs to the TST office. This enabled proper storage of data at different levels, providing for backup in case data were lost at any level.

Plate 2.6

Hydrological monitoring record



Display boards

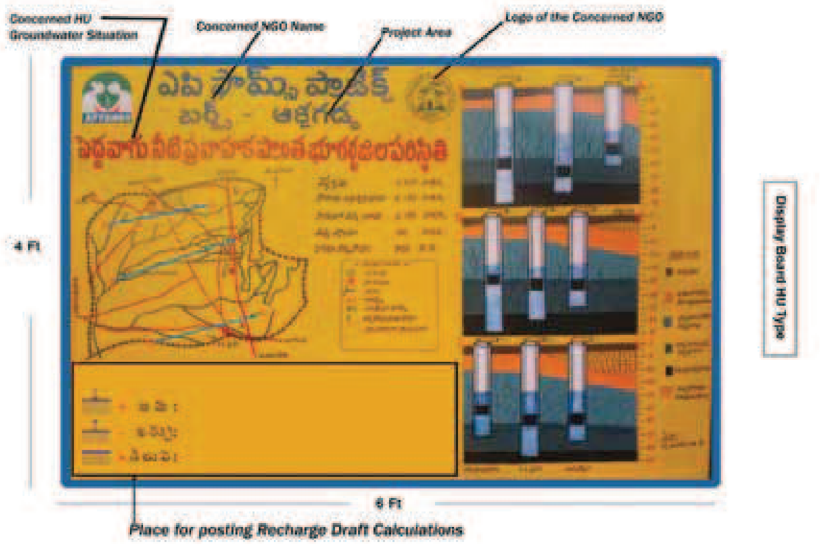
Four types of display boards were used for APFAMGS: HU, rainfall, water level and information. Around 2006, two more display boards were introduced for crop–water budgeting and crop–water economics.

The HU metal sheet and wooden display board measuring (1.8 x 1.2) m was erected at the centre of all HU villages. The HU map was transferred from the topographic map onto the board. Three vertical sections of the HU, along three different profiles covering the monitoring well network, were developed through study of structural maps and lithologs of the area. Subsurface lithology was clearly depicted in the figure, which called for good technical skills on the part of project staff.

Provision was made for enough space at the bottom of the board, which was painted black, to stick the results of data analysis. Farmers wrote in this space with a permanent marker. This type of board was erected at a centrally located road junction within the HU. The HU display boards not only facilitated a visual understanding of the hydrological regime of the HU but also initiated discussion around several technical matters related to groundwater. Plate 2.7 shows an HU display board erected in Kurnool district.

PLATE 2.7

Hydrological unit display board



In villages, where rain gauge stations were established, a board was erected at the village centre to display the rainfall received on a day-to-day basis. Provision was made for one hydrological year, after which the board was repainted. The board (a wall painting in some cases) replicated the HMR table. Plate 2.8 shows one such rainfall board.

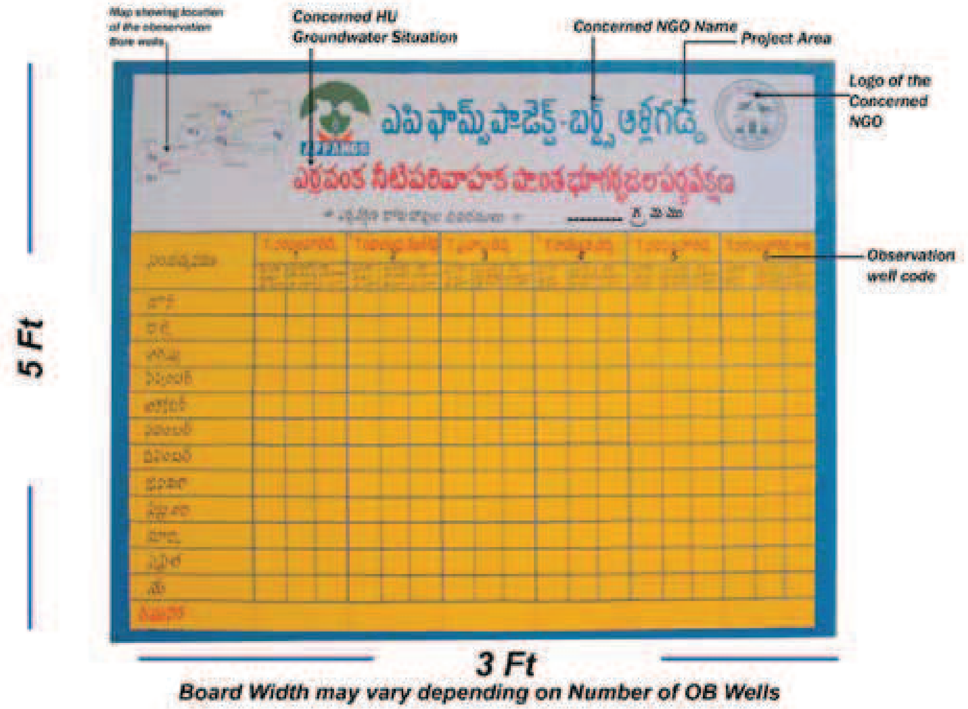
PLATE 2.8

Rainfall display board

Water level boards were erected at centrally located places such as school buildings or the Panchayat office. In some cases, the display board was a wall painting replicating the table from the hydrological monitoring record. Farmer volunteers entered data on the marked columns against each monitoring well. Provision was made for data entry for one hydrological year. Permanent markers were used to update the data, which was repainted after one year. Plate 2.9 shows one such water level display board.

Plate 2.9

Water level display board



Apart from the display boards, which were used to update the data and inform people of changes in their aquifer system, a (1 x 1) m board was erected at every HU village, to record implementation of the PHM activity. These boards were erected at strategic locations such as village centres, road corners and rain gauge stations, giving details such as the name of the HU, number and names of habitations, number of monitoring wells and rain gauge stations and number of farmer volunteers. Plate 2.10 shows an information board.

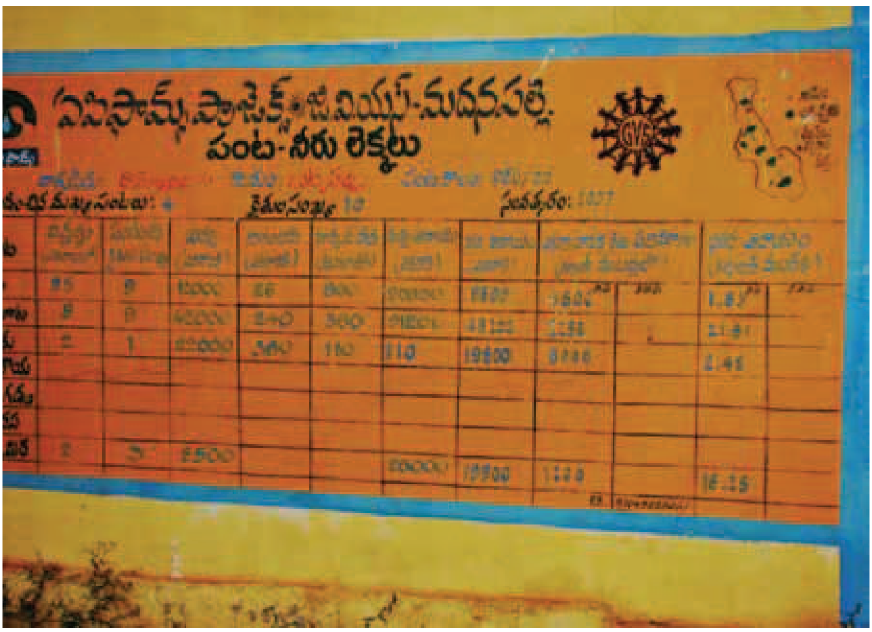
Display boards became village discussion points for issues related to drought, floods, water levels and agriculture. They attracted the attention of all those entering the village including government officials as they displayed vital information as data. It was felt that it was appropriate to exhibit the results of the CWB workshop for the general public to enhance participation in matching recharge–withdrawal. Furthermore, the crop–water economics boards were intended to promote water-use efficiency and to promote quick adoption by farmers growing crops with high water consumption. Plate 2.11 shows these boards, which were introduced at a later stage.

Plate 2.10

Information board

Plate 2.11

Crop–water budgeting results board and crop–water economics board



Habitation resource information system (HRIS)

The hydrological data collected by farmers was stored in computerized databases referred to as Habitation Resource Information System (HRIS) at the NGO level. The data stored included the names of individual farmers who could be queried at habitation and hydrologic unit level. The HRIS databases of different HUs were integrated at the NGO level. The HRIS helped organize the farmer-collected data into a computerized format to share with researchers and planners. The HRIS comprised two important modules the HRIS module and the crop–water budgeting module.

The HRIS module stored all data for the HU, including general information, infrastructure, demographic, water details, gender and institutions (including GMC), well information (including static and pumping water levels and discharge), artificial groundwater recharge structures and details of daily rainfall and training, among others. The screens were designed to organize the data in the HRIS module. The opening screen of the HRIS module displays the GIS maps. HRIS generated a standard hydrograph of the water level in conjunction with rainfall data. It provided tools for generation of time series data on water level and quality. Contour maps could be generated from water quality and water levels. Various water quality diagrams can be generated that enhance the appreciation of the data. The HRIS module was linked to the CWB module to generate graphs that could be exported to MS Word or Excel sheets. Plate 2.12 shows an HRIS window.

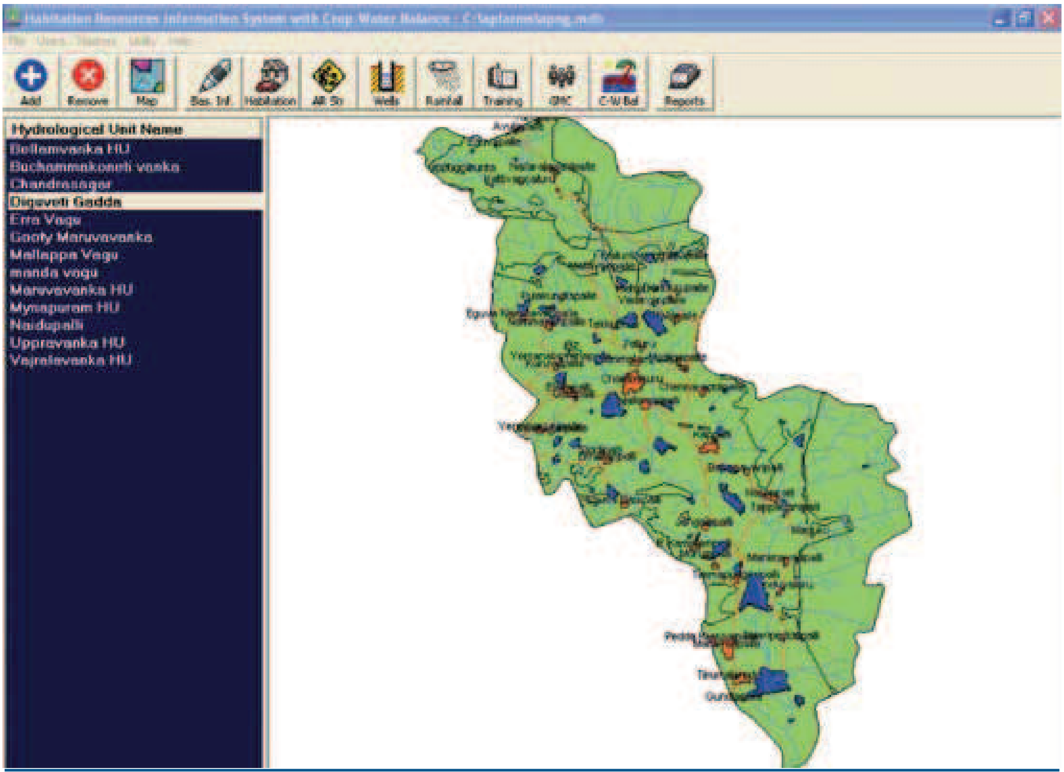
Crop–water information kiosk

"Demystification of science for sustainable development" was the official slogan of the APFAMGS Project, which created GIS datasets for all HU units, so as to make the technology directly accessible to farmers. ArcInfo was installed at the TST Office and ArcView was installed at Partner-NGO offices. While ArcInfo is used to digitize scanned maps it also transfers satellite imagery data information to a map, ArcView is used to view the generated GIS layers. A total of 36 staff members were trained to use ArcInfo/View and to handle GPS equipment.

The GIS database was comprehensive, and critical for enabling farmers' understanding of the situation in their HU. Using GPS, hydrological facilitators (HFs) collected all geo-coordinates for all monitoring wells, rain gauge stations and artificial groundwater recharge structures. Base maps were procured for all 63 HUs and digitized by the end of 2006. Spot heights were digitized as a point; drainage networks as lines; and HU, tanks, rivers were digitized as polygons. Indian Remote Sensing (IRS) Satellite image data both panchromatic camera (PAN) and Linear Self Images Scanner (LISS-III) images were procured in digital format, geo-referenced and overlaid on the digitized HU maps for generation of specific themes. Thematic maps were generated for all HUs in 2007. The project produced eight thematic maps

Plate 2.12

Habitation Resource Information System window



for each of the 63 HUs with features useful to Partner NGOs, along with additional base maps, charts, reports and technical papers.

The crop–water information kiosk was designed to help farmers access and interact with the HRIS and GIS layers. The kiosk was a touch-screen with large icons displaying limited but focused data, supported by graphics and animations. The hardware was standard configuration, not generally visible to the users. The kiosk carried out basic computations to answer various queries raised by farmers and displayed the results as animations, graphics and charts, which the users could understand and appreciate.

The kiosk had basic modelling tools to create a 'what if?' scenario. The farmers could look at their cropping plans and understand the impact of their, as well as other farmers', cropping on the aquifer system. The kiosk offered farmers the opportunity to change the cropping system on screen and immediately see the response of the changes on the overall groundwater balance in the HU. Tools were available to measure distances, calculate discharge and area. Options were available to save the results of various scenarios for which printouts could be made. Plate 2.13 shows the picture of a crop–water information kiosk.

PLATE 2.13

Crop–water information kiosk

The information kiosk was designed as a public terminal for farmers to access, and managed by self-employed youth. The hardware comprised a kiosk box, which was a large touch screen, mounted camera, computer central processing unit (CPU) housed in the box. The keypad, mouse, track ball, printer and scanner were additional available devices. The kiosk came with provision for Internet connectivity. Large fonts and pictures were used to ensure easy understanding. The default language was Telugu, with the option of switching to English. The kiosk offered a set of tools that were not prejudiced by social, economic considerations, while making available new decision-making systems that provided a long-term vision of groundwater management.

2.5 Estimation of groundwater balance and crop–water budgeting (CWB)

APWELL developed the PHM model, which turned out to be a useful tool for preparing the community for sustainable management of their aquifer systems. PHM, however, was only the 'means' to achieving community-managed aquifer systems and not the 'end'. PHM became meaningful when the interpretation of the data generated lead to sensible use of the groundwater resource. Another model called crop–water budgeting (CWB), was conceptualized and developed as an exercise to trigger people's action, following (a minimum of) one-year of PHM data collection.

The groundwater balance estimation involved updating of resource inventory; estimation of groundwater recharge during June–October; estimation of groundwater withdrawal during June–October; estimation of groundwater balance at the end of October; farmer crop plans for November–May; estimation of crop–water requirement for farmer's crop plan; and projected groundwater balance at the end of the hydrological year (May).

The crop-water budgeting exercise, in the APWELL model, comprised three key activities. These were estimation of groundwater balance, crop water budgeting (CWB) workshop, and crop adoption survey (CAS).

Updating of resource inventory

The base document gave a good picture of the status of water resources, particularly groundwater resources, before PHM intervention. This information was very useful for activities carried out during the crop–water budgeting phase. However, for several estimations of the exercise, it was essential that the available information be updated. Updating of resource inventory was carried out in September, using formats used for the baseline survey, as well as pictorials and graphs generated by participatory exercises. The information was presented to the community in small group meetings and changes were made based on their feedback. As for the base line survey, detailed inventories were carried out by the professional staff during transect walks with the farmers to update critical information on the resource. After compilation of the information collected, it was transferred to charts and validated at a meeting of groundwater users in the HU.

Estimation of groundwater balance, end of rabi

APFAMGS estimated recharge using the rainfall-area method because of its simplicity. It used standard recharge rates recommended by the Groundwater Estimation Committee (GEC) for different types of geological formations. These estimates of recharge rates were taken as general 'rule of thumb' guides to allow an initial iteration of the CWB. Over time, it is expected that recharge estimates will be refined as data for seasonal and annual water balances become available. The idea behind the CWB exercise was to try and match the annual groundwater withdrawal with the annual recharge. The rule was that the annual withdrawal should not exceed the annual recharge. The historical depletion, or supplementation, of the aquifer was ignored even though inter-annual effects can be expected. Groundwater formations and their respective recharge rates, prescribed by GEC 97 are shown in Table 2.1.

Table 2.1

Recharge rates of different groundwater formations in India (source: GEC 97)

SN	Rock formation (Aquifer)	Recharge rate as percentage of rainfall
1	Hard rock, without fractures	1
2	Phyllites and shales	4
3	Granulites	5
4	Hard Sandstone/Limestone	6
5	Soft basalt	7
6	Laterite	7
7	Soft sandstone	8
8	Granitic rock, with clay	8
9	Western coast	10
10	Granitic rock, without clay	11
11	Fractured basalt/Limestone	13
12	East coast	16
13	Indo Gangetic alluvium	22

Based on geological maps and field verifications, the area under each type of geological formation was calculated and entered into the pink cells of worksheet 1, for APWELL. For APFAMGS, the areas under each geological formation were computed by superimposing the geological layer on that of the HU base map. The hydrologist identified and classified the local geology after study of rock outcrops and well logs for the HU.

The rainfall record kept by farmers was the single most important source of information for the estimation of groundwater recharge. The rainfall received during June–October was added together and averaged where more than one rain gauge station was established, and entered in the red cell of worksheet 1 of the CWB spreadsheet. After these two data inputs, the groundwater recharge for the period June–October was computed automatically in the last row of the column-recharge (blue cell). Once pink cells were filled, only one entry was needed in worksheet 1. This means that a farmer’s entry for worksheet 1 was limited to only one cell.

Groundwater withdrawal was estimated using worksheet 2 of the CWB package. Input for worksheet 2 data were collected during the updating of the resource inventory, which included a number of functional wells during the budget season and pumping days. Daily pumping hours were interpreted from hours of fixed electricity supply. Average well discharge from borewells was extracted from the resource inventory. After the data input, the spreadsheet automatically calculated the total withdrawal during June–October. Groundwater withdrawal was calculated by multiplying the number of functional wells, average well discharge, daily pumping hours and number of pumping days. The number of red cells was highest in this worksheet, denoting requirement of large data input. This was necessary, as all parameters were dynamic and subject to change during any part of the hydrological year.

Worksheet 3 of the CWB package was designed to estimate the groundwater balance at the end of October. No entries were needed in this table as all values were automatically generated once data entry was completed in worksheets 1 and 2. The end rows of worksheets 1 and 2 served as inputs to the first two rows of worksheet 2. Recharge came from worksheet 1, while withdrawal came from worksheet 2. Balance was automatically computed.

The balance was shown in the cell adjacent to *Surplus*, if the recharge was more than withdrawal. If the withdrawal was more than the recharge, i.e. negative balance, it was shown in the cell adjacent to *Deficit*. Groundwater, available for use for the rest of the monsoon year, was computed automatically in the last row. The balance was automatically taken as zero (0) if the type of balance was deficit. For a surplus balance, 80 percent of the balance was computed as groundwater available for agriculture for the rest of the monsoon year. The remaining 20 percent was reserved for other purposes such as domestic and industrial use.

Projecting groundwater balance, end of hydrological year

Apart from updating the resource inventory, crop plans (November–May) were collected from the farmers during small group meetings at the village level. The crop-planning exercise was a regular feature of the APWELL Project, even before initiation of the PHM activity, and was continued with APFAMGS. The crop-planning exercise was conducted twice a year. While in kharif, the exercise was carried out during June/July. The rabi crop-planning session took place October/November, depending on the district or area agriculture calendar. The plan covered the command area under all wells in an HU.

During APFAMGS, the crop plans for CWB were collected only for the rabi season, because of apparent high use of well water during that season. Later, the period was extended until the end of May, covering both rabi and the summer season. Groundwater users, other than APWELL farmers, were met and their crop plans collected during this exercise. Collection of individual crop plans was a detailed exercise and staff needed to keep to a tight schedule for the fieldwork. It was found that 500 ha was the ideal area that could be covered by one team.

The crop-planning exercise was carried out in small groups using participatory tools of rural communication. The farmer's data was cross-checked using secondary data sources such as the Village Land Record (Pahaani), Village Cadastral Map and Agriculture Statistical Abstracts. Another strategy adopted for crop planning was to plan at the level of water source, i.e. well. Names of farmers' owning or leasing land under each source were gathered from villagers as well as village records. This proved to be a very useful exercise for both farmers and project staff, as data collected was a one-time exercise and only needed updating in the following crop-planning seasons.

Worksheet 4 of the CWB package was used to compile crop-plan data. In the first column of worksheet 4, all sources were numbered serially, in the order of type of well (borewells, in well bores and dug wells). Column 2 showed the type of well. Column 3, listed the farmers under each source. Survey numbers against each farmer were listed in column 4. Columns after the fourth were marked for entering the name of the crop. The last three columns were left blank for entering a new crop name in the future and a few rows were left blank for future additional sources. The results of farmers' crop planning were entered into the appropriate cells against the farmer's name and under the crop name. The last column automatically summed the total crop area planned by each farmer under each source. The last row summed the planned area under each crop by each farmer and gave the total area under each crop in the HU. The colour scheme for worksheet 4 was the same used for all other worksheets in the CWB package.

The crop–water requirement for the farmer's crop plan was estimated in worksheet 5. Crops listed in worksheet 4 were in exactly the same order as for worksheet 5 (column 2). If the crop name was changed in worksheet 4, it was automatically copied to column 2 of worksheet 5. Once each farmer had entered the area under each crop in worksheet 4, these values were automatically copied to column 3 of worksheet 5. The area was automatically converted into hectares and square meters, in column 4 and 5 respectively. Column 6 listed standard crop–water requirements recommended by the Acharya NG Ranga Agriculture University in Hyderabad.

It was often found that the same land area had more than one source of irrigation. Worksheet 6 estimated the quantity of water available for land under wells from sources other than groundwater. Worksheet 6 was comprised of four repeated tables, one beneath the other, to finally sum the total amount of water available from other sources in an HU. The first row of the table was marked for entering the name of the source, while the second row computed *ayacut* under the source in square meters, and the third row was used to enter the data pertaining to the average water depth in the source. The fourth row was marked for computing average water spread area in square meters. The fifth row of the table computed the amount of water available from the source. The last row of the worksheet automatically computed total water available, once data pertaining to all the sources were entered.

Column 7 was marked for one-time entry by the field level agriculture professional. Bearing in mind the suggested ranges (column 6), s/he had to come up with a realistic value that represented the soil-crop-water relationship in the area. In column 8, the total water requirement for irrigating the area under each crop was computed automatically. In the last row of the table, each cell automatically summed the values in its column. The last cell of the last column/row, gave the total water requirement for the farmer's crop plan.

Worksheet 7 was the replica of worksheet 1, except that it computed the expected groundwater recharge based on expected rainfall during November–May, in contrast to the actual groundwater recharge in worksheet 1. The expected rainfall in the rest of the monsoon year was arrived at through a study of historical rainfall data from the nearest rain gauge station. The 10-year rainfall data for November–May was averaged to arrive at the figure used in worksheet 7.

Projected groundwater balance at the end of the hydrological year (May) was computed in three worksheets (6, 7 and 8) of the CWB package. With inputs in worksheets 6 and 7, worksheet 8 was automatically generated. Worksheet 8 was important from the viewpoint of understanding the situation of the aquifer after adoption of crop planning. A negative value was indicative of a deficit balance, meaning over withdrawal. No entries were made in worksheet 8, as all the cells were linked to cells in the previous worksheets that automatically produced values.

The last two worksheets (9 and 10) of the CWB package were very important, as they indicated the relationship between water levels and recharge-withdrawal-balance. Worksheet 9, which is the source for graphs generated in worksheet 10, was named 'monthly' and contained five tables in which data entry were made on a monthly basis. The format used for table 1 was the same as that used for worksheet 1, while the format for table 2 was the same as worksheet 2. Twelve tables were provided for monthly data entry for one hydrological year. However, only the first five tables of both 1 and 2 types were used before the CWB workshop. Table 3 was designed to generate the monthly recharge, withdrawal and balance. Values in this table were automatically generated once data was entered in type 1 and 2 monthly tables. While table 4 of the worksheet named 'monthly' was marked for entering data on static water levels that farmers had collected from the monitoring wells, while table 5 was used for data entry of pumping water levels.

Crop–water budgeting (CWB) spreadsheet

APWELL evolved a spreadsheet, using Microsoft Excel software for use in the crop–water budgeting exercise. The spreadsheet was in the local language, as the end users were farmers. The Excel package contained ten worksheets. While the first eight worksheets contained one table each, the ninth contained several tables of source data for graphs generated in the tenth worksheet.

Different colours were used for all worksheets to indicate the nature of the cell. Staff members at the field level were not to touch the yellow cells, which indicated that the entry was a one-time exercise. Pink cells were also for one-time input, but at the field level. Red cells were designated for periodic entries. Sky-blue and blue cells were automated and the values appeared in the relevant cells once entry was made in the other coloured cells. Blue cells were the product of the computations in the worksheet. The purpose and use of each of the CWB Excel spreadsheets are discussed in the following section.

Crop Water Budgeting Workshop (CWBW)

The main feature of the CWB exercise (Plate 2.14) was to take farmers through the process of estimating groundwater balance at two stages of the monsoon year. Preparations made at the field level to set the stage for CWB included: collection and compilation of information concerning individual wells and crop plans, covering the entire irrigated area in the HU, for the

Plate 2.14

Crop–water budgeting workshop

period November–May; detailed inventory of functional wells (during June–October); inventory of other water sources and estimation of the water that would be available for irrigation during November–May; collection and compilation of PHM data (rainfall, borewell discharge, static and pumping water levels) and other relevant secondary hydrological data; data entry in the CWB table spreadsheets; meeting of PHM team with farmer volunteers, on the penultimate day of CWB workshop to ensure a thorough understanding of the topic and for practice.

Graphs were used in the CWB workshop, as were all worksheets in the CWB package. On the eve of the CWB workshop, staff and farmer volunteers met at the field office and discussed the tables and graphs generated in the CWB package. During the meeting it was decided who was to present the various parts of the CWB package. Other responsibilities relating to the CWB workshop were agreed upon at the same meeting. A mock presentation was made to make necessary changes in the presentation method and content of the CWB workshop.

The CWB workshop brought together all groundwater users in the HU onto one platform. During the previous steps the staff, and farmer volunteers, listed each groundwater user and all were invited to the CWB workshop. Needless to say, the welfare of the groundwater was in the hands of the people at the CWB workshop. Any action decided at the workshop, or later in the small group or individual family meetings, would result in efficient management of the groundwater resource. The attempt was made for 100 percent attendance at the CWB workshops, which was achieved at only a few HUs.

CWB Workshop Session 1 – the APWELL District Field Coordinator (DFC) and APFAMGS NGO Coordinator, formally introduced staff and other resource people to the farmers. This was followed by an exercise to enable participant farmers in the HU to get to know each other and to estimate the percentage of people attending the workshop against the total number of users. This was done with the help of the list of farmers, which was prepared based on the crop-planning and resource inventory updating exercises. Names listed were called out so participants could get to know each other. Each farmer gave details of his/her irrigation source, including type of well, whether it was self-financed/financed by others, functional/non-functional and reasons for its non-functional status. This exercise generated discussion of the causes of the declining status of groundwater sources.

Picking issues from the discussion generated in the introductory exercise, the HUN President, who is the anchor of the CWB workshop, gave a briefing about the reasons why the CWB workshop was needed. This began with the general status of the groundwater situation in the HU and the need for farmer-managed aquifer systems was emphasized. Activities taken up under the PHM programme were explained to establish the right background for the exercises that followed. The briefing concluded with the introduction of farmer volunteers who were actively participating in data collection and other PHM-related activities.

Session 2 – began with a farmer presentation, which visually demonstrated the topography, geology and boundary of the HU to the participants. The presentation was given with the help of a display board, later with large cotton banners, as transportation of boards became troublesome. This presentation was usually made by the President of the Groundwater Monitoring Committee (hosting the CWB workshop) or by one of the village opinion leaders. The boundaries of the HU were described using locally used terms and vocabulary, followed by a description of the surface drainage. The cross-sections across the watersheds were drawn on display boards, and used to explain the subsurface lithology and well yields. The location of monitoring wells, rain gauge stations and other features concerning PHM activity were shown on the map.

The farmer volunteer, who had been collecting the rainfall data, was invited to share his/her experience about the work. The presentation included the results of data collection as well as the farmer volunteer's opinion about collection of rainfall data by semi-literate farmers. Another farmer then built upon the previous presentation on rainfall data and linked rainfall, static and pumping water levels in the monitoring wells. The relationship between well discharge in monitoring wells and water levels was then linked, and another farmer volunteer explained this phenomenon. In all farmer presentations in Session 2, data collected between June and October was dealt with in greater detail, often leading to discussion.

The Hydrogeologist, later the community leader, summed up the proceedings of the session adding his/her remarks and explained the recharge-withdrawal-water level relationship with the help of an liquid crystal display (LCD) projector (later with banners). The graph generated by the last worksheet in the CWB package was used for this purpose.

Session 3 – a farmer volunteer presented the results of water balance estimation using worksheets 1–3 of the CWB package. Description of worksheet 1 began with a general briefing of the geological formations underlying the HU and their respective recharge rates (as recommended by GEC 97). Total rainfall received during June–October was entered in the relevant cell of worksheet 1 and the resulting recharge shown to the participants. The Hydrological Facilitator explained the working principle and purpose of assigning different colours to different cells of the worksheet.

The computed recharge during June–October was shown to participants. The session concluded with the explanation that entries for worksheet 1 were limited to one cell to ensure farmer volunteers were confident about handling the CWB package.

Worksheet 2 of the CWB package, dealing with estimation of withdrawal (June–October), was then presented. Reference was made to the farmers' interaction while collecting the data for input to the worksheet. After brainstorming, values were entered in the red cells of the worksheet and the resulting withdrawal shown.

Worksheet 3, which was fully automated, was presented. The source cell, for each of the values derived in the worksheet, was demonstrated by returning to worksheets 1 and 2. Computing procedure for the balance at the end of October was explained. Participants were invited to identify whether the balance was surplus or deficit. If the balance was surplus, the reason was explained why 80 percent of the balance should be made available to agriculture for the rest of the monsoon year. If the balance was negative, the reason was explained why the available groundwater was shown as zero. Session 3 ended with the summing up of the results of worksheets 1–3 and the status of groundwater availability for the rest of the monsoon year.

Session 4 – was lead by the Agriculture Facilitator, later by a member of the HUN, and presented by a farmer volunteer. Worksheets 4 and 5 of the CWB package were used for the Agriculture Facilitator's briefing on the crop-planning exercise. Farmer volunteers then presented worksheet 4, showing the first row and reading the names of the crops planned. The volunteer then showed the rows containing the names of each farmer and the crops they planned for November–May. Then the last row of the worksheet was read, detailing the total area planned under each crop.

The relationship between worksheet 4 and 5 was explained. By returning to worksheet 4 the source cells of columns 2 and 3 in worksheet 5 were demonstrated. Automated computation of worksheet 5 was explained. Session 4 was concluded with a description and explanation of the meaning of the last row of worksheet 5, which gave the total area planned for cropping, and total water requirement for the planned crops.

Session 5 – dealt with the projected groundwater balance at the end of the monsoon year (May). A farmer volunteer, assisted by the Hydrological Facilitator and the Agriculture Facilitator used worksheets 6–8 in this session. Worksheet 6 was discussed first, which gave the data pertaining to other water sources. The computation process was explained, followed by an explanation of data entry and the source of data. When participants suggested changes to the values, these were accepted immediately. In the last row of the worksheet, water available from other sources (during November–May) was shown. While presenting worksheet 7, an explanation was given as to how to project rainfall (November–May). The computation method for recharge estimation was explained. In worksheet 8, the automation process was clarified by switching between the sheets. The resultant row of worksheet 8 was presented.

At the end of Session 5, participants were invited to work with worksheets 1–7 to change the situation in worksheet 8. It was observed that farmers mostly changed numbers in worksheet 4 (crop-plans). They began by reducing the area under water-intensive crops and proceeded to remove one crop or add a new crop. Other worksheets used were worksheets 6 and 7, changing the rainfall and water from other sources.

Session 6 – participants were invited to give their opinions about the groundwater situation in the HU. It was observed that active farmers found this to be a good platform to demonstrate their leadership qualities. Moderation by the facilitators was needed to focus the discussion on the topic of groundwater management. After discussion at the follow-up meetings at the household and family level and crop adoption survey, a time schedule was evolved, before the CWB workshop was concluded with a vote of thanks by a community leader.

Crop Adoption Survey

One of the main activities taken up after the CWB workshop was the crop adoption survey. This was carried out in November–December, by which time farmers had sown the seeds in their fields. The objective of the survey was to document the impact of the CWB workshop in terms of change of crops planned and actually sown. The format used for worksheet 4 was used to collect the data during small group meetings and farm visits.

2.6 Artificial groundwater recharge (AGR)

Though the focus was ‘reduction of withdrawal’, i.e. demand management, artificial groundwater recharge (AGR) was taken up on an experimental basis, both for APWELL and APFAMGS, to enhance natural rainfall recharge in identified depleting aquifers. The AGR pilots attempted to evolve a suitable methodology for artificial groundwater recharge using a blend of scientific and layperson actions. While the scientific studies were of utmost importance when selecting the best sites for artificial groundwater recharge, people’s participation held the key to the sustainability of the structures.

The AGR technique, which directly filled the deeper, unsaturated parts of the unconfined aquifer, was considered to be a quicker method of recharging groundwater as compared to watershed development activities, such as check-dam and percolation pond.

Under APWELL, in collaboration with the National Geophysical Research Institute (NGRI), an AGR pilot was established to evolve a method of scientist–farmer partnership. A team of scientists from NGRI carried out preliminary field investigations, and the NGRI team selected two villages Kalugotla (Veldurthy mandal, Kurnool) and Mulakala Cheruvu Thanda (Tanakal mandal, Anantapur), to pilot the AGR intervention. The scientific activity carried out by NGRI and outputs generated are summarized in Table 2.2.

TABLE 2.2

Scientific activities related to outputs, as part of the AGR pilot in APWELL

SN	Scientific activity	Outputs
1	Rainfall data analysis	Natural recharge estimated
2	Geophysical surveys	Aquifer thickness mapped
3	Pump tests	Transmissivity and storage coefficient estimated
4	Infiltration tests in dried dug wells	Feasibility of converting dried wells dug into artificial recharge shaft assessed
5	Setting up hydrological monitoring systems	Response of aquifer systems in terms of water level and borewells discharge in a given rainfall situation monitored
6	Interpretation of remote sensing maps	Agricultural activities mapped in time domain
7	Tracer studies	Groundwater flow direction, velocity apart and aquifer interconnection found
8	Water quality analysis	Groundwater quality understood

Apart from the above-mentioned activities, APSIDC completed the reduced level survey and provided the information to NGRI. Technical information available for APSIDC such as resistivity data, lithologs and pump test results were also shared.

Primary data collection (rainfall, withdrawal and water levels) started in June 2000. The information gathered during the studies, and the hydrological data for one full hydrological year, were utilized by the NGRI for groundwater modelling, which was useful for prediction models in each village. At the end of 2001, physical works were prioritized in terms of their technical and financial feasibility. The works started under the artificial recharge pilot were: one storage tank with recharge shaft and two check dams with injection borehole in Kalugotla, a subsurface barrier in Mulakala Cheruvu Thanda.

The AGR work was then extended under APFAMGS to supplement demand-side management targeting HUs, where annual groundwater withdrawal exceeded recharge. Two hydrological facilitators were closely associated with the AGR pilot, and later formally trained by NGRI in AGR became APFMAGS resource persons. The AGR activity had three simple steps: identification of over-exploited aquifers, construction of AGR structures and impact monitoring.

Identification of over-exploited aquifer zones was largely carried out during the groundwater balance exercise, as and when CWB workshops were conducted for the first time in an HU. On the whole, 38 HUs, out of 63, showed a deficit water balance. Scientific studies, on the lines of NGRI methodology, were conducted in the HUs showing deficit groundwater balance, to study the technical feasibility of constructing an AGR structure.

AGR constructions were installed at five over-exploited aquifer zones, identified in 2004, to serve 11 habitations. Another four HUs, covering 22 habitations were targeted for AGR intervention in 2005. Under APFAMGS, by the end of 2007, additional recharge potential was created at 15 other habitations, thus covering a total of 18 over-exploited aquifer zones. No AGR work was undertaken after 2007, owing to the high estimation costs for construction. AGR structures constructed in APFAMGS are shown in Table 2.3.

Table 2.3

APFAMGS – artificial recharge structures

SN	HU	Constructed AGR structures
1	Yerravanka	Seven diversion channels into dug cum borewells; and De-siltation of Lingareddy and Pendlimarri tanks
2	Mallappavagu	Check dam with injection well; and recharge pit with injection borewell
3	Pulivagu	Two injection wells; and de-silting of one tank
4	Mekeleru	Four injection wells
5	Mittamedipallevagu	De-silting of one tank
6	Maruvavanka	Check dam with Injection well
7	Vajralavanka	De-silting of one tank; and repairs and improvisation of existing check-dam
8	Palmotivagu	De-siltation of tank; and Injection well
9	Peeturuvagu	Injection well
10	Vemuleru	De-siltation of tank; and check-dam with Injection well

Farmers were selected to monitor and collect data on water levels, which was analysed and compared with other monitoring wells, located at a distance from the AGR structures. The results were shared with other farmers in the GMC, HUN and other farmer meetings. Plate 2.15 shows some of the AGR structures constructed during the AGR pilots.

An impact study conducted in 2006 showed that the injection well sites had become popular among villagers; irrigation tanks of comparable sizes in non-AGR areas overflowed in good monsoon years, while those influenced by AGR structures did not overflow, probably because of increased groundwater infiltration; static water level gain in wells in the area influenced by the AGR

Plate 2.15

Artificial groundwater recharge structures

was 3.4 m greater than in wells in non-AGR areas; seven seasonally defunct wells became operational throughout the year in the AGR influence area, while those in non-AGR areas remained seasonally defunct; and additional recharge related to AGR was an estimated 304 250.7 m^3, which irrigated an estimated additional area of 40 ha.

Water quality analysis carried out prior to (June 2005) and after (April 2006) AGR intervention, in wells located within area of AGR influence, revealed that: pH remained the same; values of electrical conductivity, total dissolved solids, total hardness, calcium (as $CaCO^3$), chloride (as Cl), and fluoride (as F) decreased; and alkalinity (as $CaCO^3$) and nitrates showed a slight increase in their respective values.

2.7 Community capacity building

Community capacity building was the key intervention to empower community members with the required skills and knowledge in hydrology, agriculture, gender and institution management. Training activities were planned for the different components of the project. These activities were timed in relation to the hydrological year. In addition, needs-based training was conducted. Formal and informal techniques were used based on the topic and nature of the target group. These capacity-building techniques included kalajatha (street theatre); audio-visuals; community newsletters; training and exposure and farmer water schools.

Kalajatha (street theatre)

The initial intention of APWELL was to use the medium of Kalajatha to popularize the overall approach of the project. The themes covered included the APWELL objectives, implementation process, environmental pollution, depleting groundwater, organic farming, etc. During the early phases of the *Kalajatha* performances, it was found that the performers made a few mistakes when passing on the messages, because they had to digest so much new scientific knowledge. To address this situation, consultants regularly tracked the performances and gave guidance to correct the mistakes. When PHM was expanded to cover a larger area, the need for specific *Kalajatha*, focusing on the PHM concept was realized. Accordingly, the troupe developed a 3-hour package on PHM. Plate 2.16 shows a *Kalajatha* performance.

Plate 2.16

Kalajatha (street theatre)

Audio-visuals

Initially, flipcharts with colour pictures were used to explain the intricacies of the hydrological system. Later, a live glass model was used for more effective communication. An audio cassette/CD was produced by the project to highlight the disadvantages of groundwater overuse and how to curb wastage. A well-liked lyricist Mr G. Venkanna, winner of two State level awards, wrote songs that became very popular with the farming communities and were later used in folk shows. Audio-cassettes and CDs, containing the recorded songs and other *Kalajatha* programmes, documented these excellent means of mass communication. Audio-visuals (Plate 2.17) were played at the meetings, training and other occasions. It was found that these could disseminate PHM messages more effectively than training and other conventional methods of rural communication.

Plate 2.17

Audio-visual aids

Community newsletter

Another important tool, successfully used during the project, was the quarterly newsletter (Neella Mucheta) (Plate 2.18) published by the project in the local language. To ensure that dialect and language were clearly understood, farmers or contributors were encouraged to write articles or success stories in their own dialect. Furthermore, subject experts and project staff used the newsletter from time-to-time to communicate technical information concerning geology, aquifer systems, agriculture, irrigation and other relevant topics. Several farmers contributed their success stories to the newsletter recounting their experience of the project.

PLATE 2.18

Community newsletter

Farmer training (PHM Module 1, 2, 3 and 4):

Based on the experience of APWELL farmer training, fully developed PHM modules were used during the APFAMGS Project.

PHM Module 1 – was a one-day module organized in a village, with the necessary infrastructure and all equipment was provided to farmers. The module was scheduled before the monsoon set in and all physical work had been completed. A total of 25–30 farmer volunteers, from a cluster of four to five habitations were trained in each group. Four professional staff, concerned Village Coordinators and the Documentation Assistant conducted training. Morning sessions were in the form of lectures, wherein the facilitators shared scientific information aided by training materials and visual aids. The morning session was used to share scientific information about hydrology, geology, hydrogeology and geochemistry; introduce the concept and content of PHM; and share the working principles of PHM equipment/material. During the afternoon session, participants were divided into three groups and sent to three different sites such as a rain gauge station, monitoring well to measure static and pumping water levels and a monitoring well to measure well discharge.

PHM Module 2 – lasted one day and was organized in a village where there had been regular data collection for at least three months and display boards had been erected. Training material included: the hydrological monitoring record and display boards for water level, rainfall and the HU; marker pens/paints; microphone set and stationery. In the morning session, HMRs were reviewed and HMR data entry skills were demonstrated interactively, followed by practice. In the afternoon session the trainees were taken to where the different types of display boards were erected. At each display board data entry was demonstrated, followed by practice sessions.

PHM Module 3 – lasted one-day to complete GMC formation in a village surrounded by three to four habitations where the Groundwater Monitoring

Plate 2.19

PHM training

Committee was active. Trainers included four professionals and other field staff, as well as specifically invited resource people, usually an NGO head. Training material included minutes book; accounts book; hydrological monitoring record; different types of display boards; marker pens/paints; microphone set; stationery material; mechanical tool kit and copies of Laws, Acts, success stories.

In the morning session, a meeting was held and general and technical book-keeping was demonstrated interactively, followed by practice and sharing of material related to water legislation in India. In the afternoon session trainees were taken to places displaying the different types of display boards. At each display board data entry was demonstrated, followed by a practice session.

PHM Module 4 – lasted one day and was organized at a central location in an hydrological unit, after formation of the HUN and successful completion of the CWB process. Trainers included subject experts, four professionals and other field staff. Training materials included a computer; CWB package (in Telugu); farmer hydrological data; rabi resource inventory data; crop-plan data; LCD projector; stationery; mechanical tool kit and copies of Laws, Acts, success stories.

Topics covered in the morning session included: how to conduct a rabi resource inventory, collection of farmer level crop plans for rabi and an introduction to the CWB package. In the afternoon session, the trainees were familiarized with the methods used in the CWB package; presenting CWB results at a workshop; how to conduct a rabi crop adoption survey and how to influence farmer crop choices.

Farmer water schools (FWS)

The specific objectives of FWS were to empower farmers with the knowledge and skills to measure recharge and discharge of groundwater; sensitize farmers to the need for collective action for effective groundwater management; sharpen farmers' abilities to make critical and informed decisions regarding crop plans so as to match the available groundwater resources; sensitize farmers to new ways of thinking and resolving issues of groundwater management and assist farmers organize themselves for sustainable groundwater management.

Farmer water schools were scheduled throughout the hydrological year (June–May), unlike the farmer field schools, which lasted one crop season. Farmers met once a fortnight to participate in a total of 14 sessions, which evolved during a curriculum development workshop. The specific goals of the FWS were to empower farmers with the knowledge and skills to measure recharge and discharge of aquifer systems; sensitize farmers to the need for collective action for smart management of groundwater; sharpen farmers' abilities to make critical and informed decisions concerning crop plans in order to match the availability of water to the rabi season; encourage famers to innovate and resolve issues related to groundwater management and motivate farmers to organize themselves at the HU level.

To reach a large number of farmers, and tap their existing knowledge and skills, the project adopted a multiple cycles approach. After having participated in the session, the farmer participants formed into pairs to facilitate an FWS at their respective habitations with other participating farmers. Thus in 2006–2007, NGO staff conducted 34 FWS, while farmer participants from the first cycle organized 272 FWS, reaching about 10 000 farmers. Since the hydrological year 2007–2008, farmer institutions and facilitators have led the management and implementation of FWS, while project staff have supervised and monitored the process.

The year-long FWS cycle's 14 sessions covered: 1) Introduction to FWS; 2) Knowing the HU; 3) PHM; 4) Groundwater recharge; 5) Estimation and projection of groundwater recharge; 6) Estimation and projection of groundwater withdrawal and balance; 7) CWB Workshop; 8) Review of farmer crop plans and design of a long-term experiment; 9) Crop adoption survey results; 10) Alternative irrigation practices; 11) Soil moisture retention; 12) PHM data analysis; 13) Estimation of groundwater balance for rabi; and 14) Farmer Water School Field Day. Session content is briefly explained below.

Session 1 – started with a game to introduce the participants to each other. The objectives of the FWS were presented, which included 'levelling of expectations' wherein the participants' list of expectations is revisited to see how, or if, they matched the FWS curriculum. A puzzle was used to draw the participants' attention to the issues of groundwater management and options. A Ballot Box Test (BBT) [4] was conducted to document the current level of knowledge, skills and farmers' groundwater management practices. The Session ended with the formation of small learning groups and the establishment of the norms for FWS participation.

[4] Each participant is allocated a specific registration number and given a ballot slip with the same number. The number of ballot slips should be equal to the number of participants. Each question has three options: 'Yes', 'No', and 'No Idea'. Three envelopes are pasted beneath each question with each representing one of the three options. The participant answers the question by placing his/her ballot in one of the envelopes.

Session 2 – was designed to familiarize participants with the physical characteristics of the HU, referred to as the hydro ecosystem analysis (HESA). Before the session began, participants were taken out for a transect walk in a selected cross-section of the HU. Participants were familiarized with the boundaries' geological formations, soil types, etc. The issues discussed, while on the transect walk, included the HU water cycle; factors influencing rainfall in the HU; how rainfall occurs; rock and soil types; drainage patterns; runoff and transpiration; potential recharge zones and over-exploited zones. Farmers' observed favourable and unfavourable factors, which were listed, analysed and collective action plans were evolved to address the unfavourable factors.

Session 3 – dealt entirely with the concept, content and practice of PHM. Farmer data, carried to the session by one of the PHM volunteers, was discussed. Participants learned about the equipment and the measuring procedure for the parameters of rainfall, water level, well and stream discharge. Real

PHM equipment was used for the demonstration. Later, data storage and dissemination methods used for PHM were discussed, using the hydrological monitoring record and display boards.

Session 4 – dealt with aspects related to groundwater recharge, both natural and artificial. Discussion was generated using models of how natural rainfall recharge occurs and the factors influencing groundwater recharge; different methods of artificial groundwater recharge; recharge rates recommended by GEC; water-bearing formation of the HU and the participants' area and the additional rate of recharge through watershed development.

Session 5 – participants learned how to estimate groundwater recharge. Using models and posters, participants were encouraged to think about the rainfall–recharge relationship, how rainfall recharge is estimated and calculation of the HU area using a centimeter graph.

Session 6 – groundwater withdrawal and balance were estimated and tables from the CWB package were used for demonstration and practice sessions.

Session 7 – was timed to coincide with the CWB workshop. An exhibition was organized where various visuals and models were used to disseminate the concept and practices of sustainable groundwater. Visuals developed for the HU concept covered: recharge, withdrawal and estimation; projecting recharge, withdrawal and balance and crop–water requirement. Models were developed to estimate the HU area; inflow and outflow of the HU; recharge; quantification of water; crop–water requirement; projecting rainfall and discharge measurement using a calibrated drum.

Session 8 – reviewed farmer's CWB crop plans and developed the design for long-term experiments. Information on crop–water requirements was shared. Participants were encouraged to discuss agricultural inputs for conventional and alternate crops such as seeds, fertilizers, pesticide, labour costs and water and electricity consumption. This was followed by a discussion about returns from conventional and alternate practices. Participants were encouraged to design their own long-term experiments by engaging in critical thinking, exploring alternate best practices and testing new ideas.

Session 9 – was scheduled to coincide with the completion of the crop adoption survey (see Section: Crop adoption survey, below) and compilation of its results. First, cropping during rabi was shared with participants who were encouraged to estimate the potential groundwater withdrawal, using the crop–water requirement method. The participants were encouraged to think about the percentage of farmers who make their decisions based on crop–water budgeting.

Session 10 – dealt with alternate irrigation practices. A discussion was initiated about conventional methods of irrigation, in the 'good old days' and how this has changed over time with the advent of modern agriculture. Current irrigation practices were discussed, leading to a logical question: Are there any alternative practices that can reduce water use? Facilitators were ready with the information on alternative irrigation methods and tools, which they shared with the participants. The participants were encouraged to draw their own conclusions as to the suitability of the methods with respect to crops they grew and probable cost-benefits.

Session 11 – focused on the methods and techniques of soil moisture retention. First different methods were introduced on how to retain soil moisture over longer periods. These included mulching and application of farmyard manure/organic manure and vermin composting. Methods were explained, of how to use audio-visuals that had been developed by governmental and non-governmental organizations. Often, during this Session there were visits to farmers' fields.

Session 12 – the art of PHM data analysis using a CWB spreadsheet was covered and water savings related to alternate crops and irrigation techniques were highlighted.

Session 13 – familiarized participants with estimation of groundwater balance in the particular hydrological year, building on previous projections. A ballot box test was repeated to document participants' post-FWS knowledge, skills and practices and to compare the results with the pre-FWS ballot box test. This Session was used as a preparatory meeting for the 'bid' day, i.e. graduation ceremony or FWS Field Day.

Session 14 – the final session was considered the FWS Field Day and was organized as a big event, often at project level, with the participation of FWS graduates across seven districts. The venue was festive, with attractive models and interesting visuals in specifically-designed stalls that presented basic information on the HU and hydro-ecosystem analysis; concepts of sustainable groundwater management; water-saving techniques and methods; methods of soil moisture retention; organic pesticides and AGR structures. The Field Day started with a prayer and ended with the distribution of certificates, after which guests addressed the graduates. APFAMGS produced 19 777 graduates of these 12 315 men and 7 462 women.

Plate 2.20

A field used as part of a Farmer Water School

2.8 Community based institutions (CBI)

Several people's institutions already existed in the villages, because of the intervention of both government and non-governmental organizations. These institutions were groups with an activity-specific objective. For example, the women's development programme had self-help groups, a watershed development programme and a watershed committee. Apart from these issue-specific institutions, there was the three-tier Panchayat Raj body, which was elected by adult franchise at the village, mandal and district level.

In addition, APWELL organized its target farmer groups into water user groups (WUG) at the borewell level and borewell user associations (BUA) at village/cluster level. A typical WUG was made up of eight to ten members, two from each family. The WUG was responsible for the operation and maintenance of the borewell and other material provided by the project, as well as the equitable sharing of water. Water user groups in a village were formed into a borewell user association.

Based on deliberations, involving all stakeholders, a five-tier community based institutional structure was finalized for APFAMGS.

1. Groundwater Monitoring Committee (GMC) – at habitation level
2. Hydrological Unit Network (HUN) – a network of GMCs at HU level
3. NGO level network (NGN) – for the operational area of each NGO partner
4. District/basin level Apex Body
5. State level water steering committee (SWSC) – a state level network with the representation opinion leaders from the operation area of all seven Partner-NGOs.

Groundwater Management Committees (GMC)

The Groundwater Management Committee (Plate 2.21) was conceived as the PHM torchbearer for sustainable groundwater management. The formation of GMCs was delayed because it was not clear that a separate community institution was needed, as well as the borewell user associations, organized by APWELL earlier. As non-APWELL farmers had to be invited in because of PHM, it was felt that GMCs, which specifically carried out PHM and CWB (later FWS), were necessary for creating a sense of responsibility among farmers about the sustainability of groundwater. However, many GMCs had a strong membership presence as part of the executive bodies of the borewell user associations.

APFAMGS established 555 GMCs at habitation level, which were responsible for data collection, promotion of water efficient crops and implementation of actions at the village level. GMCs are informal institutions, working under the leadership of the HUN. However, GMCs established links with various government agencies and mobilized around 60 schemes in 625 villages. On withdrawal of APFAMGS, PHM assets (equipment and infrastructure) were handed over to the GMCs, with the understanding they would share data with the HUN.

Plate 2.21

Groundwater Monitoring Committee meeting

Hydrological Unit Networks (HUN)

Institutional strengthening peaked with the registration of all 63 HUNs in 2007, after which they became legal entities for the project operation, maintenance and mobilization of resources from government and other external agencies. HUNs took responsibility for collecting data, analysing and conducting CWB workshops and FWS across the project. Project support for activities was reduced as Farmer Facilitators took over conduction of the FWS and CWB. The details of currently active HUNs are found in Annex 1.

By 2008, the HUNs emerged as sovereign institutions to implement demand-side groundwater management (DSGM) in 637 villages. NGOs slowly made way for the HUNs to take over all critical decision-making and management of finances. All NGOs transferred funds to HUN accounts to run the FWS in 2008. This was a momentous step in strengthening the capability of people's management of groundwater resources, as well as establishing a new approach to its governance. The HUNs emerged as lead players, after successfully demonstrating their capabilities as resource persons, for training the officers from several states in India (See Plate 2.22).

HUNs developed links with various government departments and could effectively mobilize large amounts of funding. A total of 9 323 families from 466 habitations benefited from government programmes, mobilizing INR 30.4 million of funding, mainly in the form of water-saving devices such as drips and sprinklers.

Plate 2.22

Hydrological Unit Network meeting

NGO level network (NGN)

Nine NGO level networks (NGN) were formed during the concluding phases of APFAMGS in all nine Partner-NGO operational areas, with the membership of two representatives from each of the HUNs (one male and one female) handled by an NGO. All the NGNs were to be legally registered under the Societies Registration Act. The role envisaged for the NGN was coordination of the NGO and HUN for implementation of the CWB and FWS; sharing of data and experience across the NGO operational area; building links with local governmental and non-governmental agencies to benefit groundwater farmers in the Partner-NGO area; and together with the NGO playing an arbitrator role in conflict resolution between the HUNs and the GMCs. However, NGN registration did not materialize because of the emergence of strong HUNs and the presence of an NGO that was also a registered body.

NGNs met twice a year in February/March and in September/October. At the first meeting, decisions taken in the previous CWB were reviewed in light of the crop adoption survey, and the status of PHM data collection was appraised. Information about government programmes, and methods used to access them, were shared and discussed. The NGN meeting, in September/October, focused on the conduct of CWB in the Partner-NGO operational area, including the scheduling of CWB workshops; a tentative list of resource people; strategy for preparation of workshop material; and the roles and responsibilities of

CWB workshop event management such as printing of invitations, press-note, transportation arrangement for resource people and food arrangements.

Basin level apex body: Upper Gundlakamma sub-basin

Much of the APFAMGS intervention took place in the Upper Gundlakamma sub-basin in Prakasam district, where three NGOs shared the task of organizing communities. The plan was to bring together 25 HUNs to form a basin level apex body. This did not materialize, because of operational difficulties, except for the organization of a Field Day (as part of FWS), once in 2006.

State Level Water Steering Committee (SWSC)

The State Level Water Steering Committee (SWSC) was considered to be the ultimate people's institution to take care of groundwater management at the state level, initially with members of APFAMGS, NGNs and later farmers invited from other districts. It was decided that the steering committee would be named '*Jala Jana Vedika*' (JJV) meaning 'people's water forum'. This proved to be a non-starter because of lack of time in the concluding phases of APFAMGS. In 2011, nine NGOs came together and registered an NGO network *Association Promoting Farmer Managed Groundwater Systems (APFAMGS)*, to carry forward the PGM mission.

Gender

APWELL and APFAMGS had a strong gender interface to retain practical and strategic gender needs at the core of PHM. Gender was seen as a cross-cutting issue, encompassing all components and processes. The project approach was to bridge the gender gap and help establish self-esteem and confidence. The gender approach implied that attitudes, roles and responsibilities of men and women were taken into account. It was recognized that both sexes did not necessarily have the same access to, or control over, resources or benefits and impacts may be different for both groups. The APFAMGS gender approach created open mindedness and aimed for the fullest participation of both women and men.

Gender sensitization helped men and women understand their roles and responsibilities and broadened their thinking outside their routine assumptions. One of the project's greatest achievements was the support men gave to women's participation. Other influencing family members were sensitized using different gender modules, which extended their support by assisting women to take the space and time to attend to aspects of the common good; this starting point has been crucial.

Illiterate women formed a major segment of participants, through participatory training these women came to understand the technologies and face the challenges of PHM. Even though women's education level varied from illiterate to post graduate, the project's highly technical component proved attractive. The project addressed both practical gender needs, such as improving women's conditions through the provision of water and sanitation close to their houses, as well as strategic gender needs: improving women's position in society by increasing awareness of her situation and her capacity to take decisions and influence change.

Food Security – is considered a women's issue and was prioritized by APFAMGS. Midway through the project, in 2007, a food and nutrition survey was conducted, data were analysed and the results shared with farmers in the project area. Health care practices were encouraged by raising awareness and training was given in hygiene and sanitation.

Chapter 3.
The Path

The search for a suitable model for PGM in Andhra Pradesh started with wells for smallholders. In this chapter, the path and experiences are traced across the set of APWELL, APFAMGS and SPACC project landmarks. These are wells for smallholders (under APWELL); the afterthought; Particpatory Hydrological Monitoring (PHM) pilot; Crop Water Budgeting (CWB); PHM in Upper Gundlakamma sub-basin; the transition period; launch of the APFAMGS Project; withdrawal of the Royal Netherlands Embassy; the transition period; transfer of APFAMGS to FAO; building on PHM and CWB; the APFAMGS extension; termination of APFAMGS; one-year gap and the SPACC project.

3.1 Wells for smallholders (1995–2002)

In 1987, the Government of India submitted a preliminary proposal to the Royal Government of the Netherlands requesting financial assistance for minor irrigation schemes in Andhra Pradesh. After several studies by the Missions, commissioned by the Royal Government of the Netherlands, a final Project Document was prepared and submitted in 1993. Consequently, the 'Andhra Pradesh Groundwater Borewell [5] Irrigation Schemes (APWELL)' Project was approved in 1994. APWELL was implemented in seven drought-prone districts of Andhra Pradesh: Anantapur, Chittoor, Kadapa, Kurnool, Mahbubnagar, Nalgonda and Prakasam.

[5] A well of 7' diameter, constructed by drilling rigs is called a borewell, which differs from a tube-well, which has a tube (with screen of perforations of desirable diameter), running throughout the well depth. In a borewell, the tube (casing pipe) is inserted only to a depth equivalent to the depth of the upper loose soil that could collapse.

APWELL was implemented as part of the Indo-Dutch bilateral cooperation in India. The Royal Netherlands Embassy in New Delhi, through its Development Support Division, provided funds for project implementation. The executing agency, representing the Government of Andhra Pradesh, was APSIDC, which received funds from the Royal Netherlands Embassy. Arcadis Euroconsult (the Netherlands) provided technical assistance. International consultants were organized by Euroconsult, national consultants by the Institute of Resource Development and Social Management (IRDAS), a Hyderabad based NGO, initially and later by Priyum advisory and Consultancy Services Private Limited Company (PRIYUM), an Indore-based consultancy firm.

APSIDC executed groundwater surveys, drilling, pumping tests and construction of distribution systems; the Executive Engineer guided the technical staff. Social, institutional, gender, agricultural and eco-development project components were implemented by field staff comprising Agriculture Production Trainers (APT), Gender and Institutional Development Organizers (GIDO), Community Mobilization Specialists (CMS) and Community Organizers (CO) who were employed through district specific NGOs (see Table 3.1 for details). The District Field Coordinator (DFC), who was part of the Consultant's team, supervised the work in each district.

Table 3.1

NGOs involved in APWELL at the district level

District	Name of the NGO	Acronym
Anantapur	Rural Integrated and Social Education Society	RISES
Chittoor	Gram Vikas Samstha	GVS
Kadapa	Rayalaseema Harijana Girijana Backward Minority Seva Samajam	RHGBMSS
Kurnool	Bharathi Integrated Rural Development Society	BIRDS
Mahbubnagar	Centre for Rural Youth Development	CRYD
Mahbubnagar	Adarsha Welfare Society	AWS
Nalgonda	Dalit Adivasi Seva Morcha	DASM
Prakasam	Spandana Society	SPANDANA

Box 3.1

Nagi, the achiever and motivator

Nagamma, fondly called Nagi by her family and friends, was married into Dadaluru village of Kanaganipalli mandal in Anantapur district, Andhra Pradesh. She lived with her husband and three children and eked out a living working as an agriculture labourer on other people's farms, even though the family had 1 ha of dry land, which provided additional farm income in good monsoon years. Achamaiah, a rich and influential farmer in the village, often asked Nagi and her husband to tend his field during the seeding and harvesting seasons. The family found it very difficult to meet the basic minimum requirements for a decent living with the family income, let alone send their children to school.

In 1998, Eshwaramma, Nagi's colleague, who also worked on Achamaiah's farm, suddenly stopped working on other's fields. Eshwaramma told Nagi that the scheme implemented by APSICD had provided a borewell and there was no need for her to work on other people's fields. Eshwaramma invited Nagi to take part in the meeting, organized by APWELL, so that she could learn more about the scheme. This was a turning point in Nagi's life. She persuaded her husband, and they jointly applied for the APWELL borewell irrigation scheme, along with five other farm families who had land adjacent to her 1 ha of dryland. Her application was passed and she ended up having a secure irrigation source to cultivate land, along with others. Given the pro-active nature of Nagi, she soon became popular not only within her own community but also with APWELL staff and underwent training in several subjects. After attending training for 'dairy management', she pestered her husband to apply for a bank loan and became the proud owner of two buffaloes.

The income from the dairy dramatically changed the outlook of Nagi's family bringing them financial stability, allowing them to send their children to school. On the social front, she began to command respect for her achievements and was recognized as a leader among the women in the village. She became the leader of the Self Help Group in the village and became effective at motivating other women to achieve success in their own endeavors.

The ultimate goal of APWELL was to increase agricultural productivity in farms that had no access to canal water supply (so called 'dry land'). This was challenging given that those benefiting from APWELL were smallscale or marginal farmers, who had never had the advantage of an assured irrigation facility. To meet this end, APWELL focused on farmer capacity building, covering a wide array of topics including soil, crop and water management practices.

The APWELL training programme encouraged farmers to grow irrigated 'dry' (such as groundnut, sunflower, vegetables, bengalgram, castor, and SRI paddy) under the new irrigation source, as opposed to the cultivation of 'wet' crops, notably rice, which would be more commonly associated with an assured irrigation supply. At the end of the APWELL project, it was estimated that about 95 percent of the APWELL borewell command was under irrigated dry crops. Mainly this was attributed to training and metering of electricity, which was charged for based on units consumed. The bottom-line was that for a smallholder or marginal family access to the water source was like a dream come true and several rags-to-riches stories resulted from the APWELL Project, see Box 3.1.

3.2 The Afterthought (1999)

The APWELL Project was conceived in the mid-1980s as a groundwater development project, providing borewell irrigation facilities to smallscale and marginal farmers, which was extremely relevant at the time. When the project was launched in 1995, the state of Andrah Pradesh's aquifers had drastically changed because of mushrooming rapid expansion in the number of borewells and groundwater withdrawals. Everyone realized the importance of the steps required to ensure sustainability of aquifer resources. Keeping this in mind, APWELL stated its objective of 'environmentally sound interventions', and incorporated the necessary modifications needed to address the changed scenario, including limiting drilling to areas with the highest potential (in many cases areas whose aquifers had not been developed).

APWELL was concerned about the sustainability of the borewells provided to the smallscale and marginal farmers. However, the sustainability of borewells was governed by factors outside the influence of the project. This required that the project broaden its horizon beyond smallscale and marginal farmers to the entire groundwater user group and from a narrow focus on borewell construction to management of the groundwater resource. In its annual plan for 2000, APWELL proposed several pilot activities with the objective of groundwater sustainability including: participatory hydrological management (PHM), artificial groundwater recharge and the revitalization of failed borewells, for which PHM proved to be the most relevant and successful.

3.3 Participatory hydrological monitoring (PHM), the Pilot (1999–2003)

APWELL, in its original proposal, foresaw the need for hydrological monitoring by state agencies to ensure that the groundwater irrigation systems, created as part of the project, remained usable for a reasonable period by smallscale and marginal farmers. This was perceived more as a technical component, which did not takeoff until 1999, because the Technical Assistance Team lacked the technical expertise. After hiring the Consultant Hydrogeologist, this task was discussed and it was decided that the Pilot would be more sustainable if the users themselves carried out hydrological monitoring. The term participatory hydrological monitoring' or 'PHM' was coined to describe the monitoring of water levels in wells by the users. The long-term objective of PHM was: *"to create a platform for farmer-managed aquifer systems"*.

The ultimate aim of piloting the PHM approach was to build the capacity of farmers to record hydrologic data, interpret and use it for more informed management of their aquifer systems. To trigger the process, it was necessary to strengthen the capabilities of community workers and the Hydrogeologist. Indeed it was imperative that the main PHM actors were farmer representatives, community organizers, agriculture production trainers, district field coordinators and the APSIDC District Level Hydrogeologist. After implementation of the pilot activity for one full hydrological year, the project was expected to gain insights into the possibility of replication and adaptability of the concept.

Box 3.2

PHM activity quenches villagers' thirst in Regumanipalle village

Regumanipalle is a remote village in Pada Araveedu mandal, Prakasam district where APWELL drilled 21 successful borewells. One of the 25 villages in the district qualified for extensive participatory hydrological monitoring. There are seven observation wells in the village and a water level indicator was provided to measure the water levels in these observation wells.

The village received a drinking water supply scheme from the government in 2001. After hydrogeological investigations, a borewell was drilled north of the habitation. The borewell was declared failed as the driller reported he had observed only slight signs of under-saturated rock while drilling. The scheme was stalled at the initial stage because the source was considered insufficient for supplying drinking water to the entire village. Villagers were left with no option except to solve the severe water shortage. As a result of the PHM intervention, villagers had both the skills and equipment to measure water levels in borewells. Before thinking of other alternatives, villagers wanted to make sure the borewell had really failed. They used the knowledge and equipment provided by the project to test the borewell.

When the water level indicator probe was inserted into the borewell, it beeped at a depth of 12 mbgl. Villagers informed the government authorities of the results of the water level measurement and pressured them to conduct a full-scale yield test. To the surprise of the government staff, the yield test revealed that the safe yield of the borewell was 2 000 gph. Responding to public demand, and the result of the yield test, the government completed the drinking water supply scheme, which involved construction of an overhead tank, laying of pipe lines and stand posts. Currently, the scheme supplies drinking water to about 200 families.

This story of how farmers measured the water level made the rounds of nearby villages and the PHM concept is well accepted in this area. As a result, villagers have planned to keep track of the water level in the drinking water source.

The APSIDC Hydrogeologist, by virtue of his academic qualification and field experience, was the only groundwater management expert at the district level. He was thus the resource person who provided the inputs to delineate the HU/aquifer system, train farmers, identify monitoring wells, install scientific equipment, support services to grass-root level functionaries, as well as guide data collection, interpretation and use. His role was of utmost importance in compiling the base document and its dissemination to the communities. Box 3.2 presents an account of the benefits of PHM at the village level.

The District Field Coordinator was the main link between the project stakeholders, making his involvement inevitable for PHM. He was able to identify issues that needed to be sorted out at the project or district level. Furthermore, because of his academic background, and field experience in handling issues related to community mobilization, he acted as a catalyst between the scientific and the social staff.

PHM was implemented on two scales, i.e. extensive and intensive, subdividing the activity under two broad headings: extensive participatory hydrological monitoring (EPHM) with the objective '*discussion triggered in the village about water level-rainfall-yield relationship*' and intensive participatory hydrological monitoring (IPHM) with the objective: *'water use plans are evolved based on the estimate of utilizable groundwater reserves in the HU*'. While IPHM was expected to develop tools for PGM, EPHM was perceived as a pre-cursor to IPHM.

Towards the end of the APWELL Project, it was considered essential that the IPHM pilot be implemented on a basin or sub-basin level, because aquifer systems, in some cases, directly discharge into large streams. It was found that Gundlakamma river, which drains into the sea, covers a relatively small area, when compared to other river basin systems in the State; it was therefore identified for the basin-level IPHM. APWELL activities concentrated in the southern and central areas of Prakasam district, which forms the upper part of the Gundlakamma basin. The basin level initiative, under IPHM, was therefore limited to the Upper Gundlakamma basin (UGB).

Extensive participatory hydrological monitoring (EPHM)

All well clusters, with more than ten successful borewells drilled under APWELL, were targeted for EPHM intervention and, in 2000, a total of 89 clusters were covered. Later in the year, 11 additional clusters qualified making the total 100. By project end, 122 well clusters were covered by EPHM.

The EPHM intervention was simple, limited to providing owners of selected monitoring wells with water level indicators and imparting the skill of measuring water levels in the wells. The idea was to measure the early morning water level (more or less representing the static water level) and water level after the pump had been running for 4 hours (pumping water level or stabilization point). It was expected that farmers would appreciate the difference in drawdown after four hours, in various monitoring wells and come to understand the health of the aquifer in comparative terms. Physical inputs provided by APWELL for the EPHM pilot were: a) conversion of production well into production-cum-monitoring well (described in Chapter 2) and b) one water level indicator for each cluster of ten wells.

Intensive participatory hydrological monitoring (IPHM)

The steps for implementation of IPHM in 2000 were: staff and farmer training; identification of pilot districts/clusters; delineation of aquifer systems/HUs; selection of monitoring wells; preparation of base document; *Kalajtha*; procurement of equipment; installation of equipment; training – PHM Module 1; data collection and storage; training – PHM Module 2; field support and monitoring; scientific interpretation of data; development of participatory data interpretation tools; field testing and finalization of participatory tools; formation of GMC; and documentation of the experience.

Once data collection started, there was a rigorous follow-up at the field level by the Consultant Hydrogeologist, APSIDC Hydrogeologists and District Field Coordinators. In 2001, private hydrogeologists were hired and the position of Hydrological Facilitator was created as part of the NGO team. The aim was to provide technical guidance and motivation to farmer volunteers involved in PHM data collection: rainfall, water level and well discharge.

In 2000, the Groundwater Management Committee (GMC) was conceived as the torchbearer for sustainable groundwater management for IPHM watersheds. GMCs were only formed in 2002, when it was understood that a

> **Box 3.3**
>
> **Low-yielding borewell becomes functional in Nalgonda as a result of IPHM**
>
> Poor tribal farmers inhabit Vasram thanda, near Adavidevulapally a town in Nalgonda district. This is one of three villages in Bhasker Rao Kunta HU, under intensive participatory hydrological monitoring. Of 22 borewells drilled by APWELL, 13 were declared successful, based on the project norm of a yield of 1 500 gph and above. However, after declaration of the failure of their borewell, Panchakoti, Panthulu and Meshya continued rainfed farming. Drilling yield had been reported at 308 gph with a static water level of 6.9 meters below ground level (mbgl).
>
> As part of the IPHM activity these farmers learned how to measure the water level, borewell discharge and rainfall. One of the monitoring wells belonging to Mr Swamy is located near the failed borewell. Panchakoti and his friends became interested spectators when Mr Swamy routinely took water level measurements in the monitoring well. They learned much about the IPHM activity through other volunteers and the display boards.
>
> This group of farmers became curious about the water level and discharge of their failed borewell. With the help of project staff, PHM volunteers in the village, and a local mechanic, they conducted a yield test of the borewell. The safe yield of the borewell was calculated at 1 200 gph. This would still put the borewell under the failed category as per APWELL norms. But, in comparison to the drilling yield, the borewell had improved, probably because of cleaning of pores and fracture zones as a result of continuous pumping during the yield tests. On their own, the farmers installed a submersible motor and pump. Encouraged by the developments, the farmer group investigated purchase of a sprinkler or drip irrigation system so that all members of the borewell user association could benefit from borewell irrigation. They also sought the assistance of project staff to identify improved varieties of irrigated dry crops.

separate community institution was required, in addition to the borewell user associations, organized with membership of APWELL beneficiaries at the village level. Non-APWELL farmers were invited, because of IPHM, so it was felt GMCs were essential for the PHM activity. Box 3.3 presents a short narrative on the impacts of IPHM activities.

IPHM in Upper Gundlakamma basin (UGM)

Expansion of PHM at the basin level started in June 2001 in the Gundlakamma river basin (see Figure 3.1). While delineating the hydrological boundaries of Gundlakamma basin, it was found that its upper part covered the area in Prakasam district, where APWELL was active. Delineation of the Upper Gundlakamma basin and its hydrological units was completed and well inventory and societal analysis carried out in the villages. PHM in the Gundlakamma basin began in APWELL villages and was later expanded to non-APWELL villages.

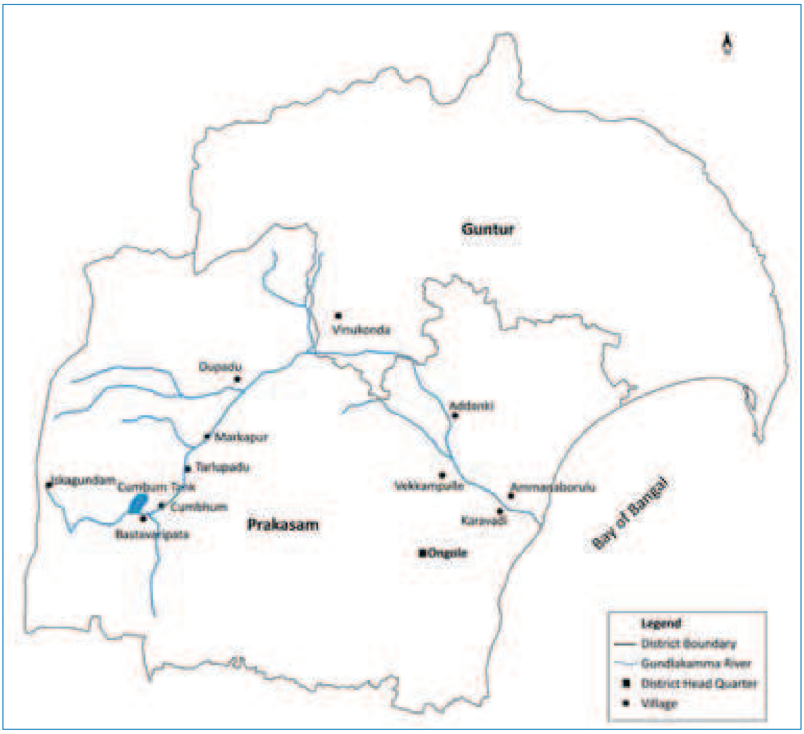
When the APWELL Project was extended for one additional year (April 2002–March 2003), the unspent budget under the Gudlakamma Pilot went into the general pool and a separate budget was prepared to cover staff salaries and overheads. Physical activities suffered because of lack of funds; however, minor costs were met by the regular APWELL budget. The PHM teams worked relentlessly to meet the targets defined at the Annual Plan Workshop at the end of 2002. The UGB–IPHM pilot was only halfway through when APWELL was formally closed. This meant that only software had been completed, leaving the entire hardware component, including establishment of PHM stations and data collection, incomplete. Activities accomplished by the UGB–IPHM pilot, at the end of the APWELL project, in March 2003, included: participatory exercises; well inventory; installation of one rain gauge station; procurement of ten rain gauges and identification of PHM volunteers.

Participatory/Crop Water Budgeting (2001–2003)

As IPHM was experimental, farmers' data was scientifically scrutinized for data gaps and calculation errors in 2000. It was found that the data could be used for discussion with the communities at the HU-level workshop. Before

Figure 3.1

Map of upper Gundlakamma basin



doing this, data was used to roughly estimate the groundwater balance, based on the norms of the GEC 97. Participatory Water Budgeting (PWB) was conceived as the final step for IPHM. PWB was to trigger people's action, following a minimum of one-year of IPHM data collection. The aim was to work out an annual water use plan based on estimated groundwater balance.

The borewell user association decided on the type of crops that could be cultivated in the HU and suggested the permissible limits for areas under each crop. Precision irrigation techniques such as a piped water distribution system, drip, sprinkler and rain-gun were demonstrated. During a farmer meeting, opinion leaders from all HU villages decided they would return to their respective villages to decide rabi plans with the farmers. They also promised to inform the GMC about the farmers who had adopted water saving irrigation methods (ridge and

Box 3.4

PHM volunteer takes responsibility for data collection at the Drought Prone Areas Programme (DPAP) rain gauge station

Pandillapalli village is in Peeturuvagu watershed, forming part of Upper Gundlakamma sub-basin. Existence of a rain gauge station (established by DPAP) came to light during the PRM exercise and other PHM activities. Following APWELL Project, DPAP was contacted and an agreement was reached to organize farmer volunteers to collect data from the rain gauge station.

Subsequently, Kasi Reddy and Venkatanarayana Reddy volunteered to take responsibility for data collection. They, along with other farmers were trained by APWELL for 'rainfall measurement, display and information sharing'. Since then, they have regularly collected rainfall data, and shared it with other villagers using the data display board and informal interactions. The information is regularly left with DPAP.

Kasi Reddy became a member of the Farmer Training Team because of his excellent performance.

furrow; alternative furrow; and check-) techniques (ploughing across the slope; compost application; alternate wetting and drying; border strip; and critical irrigation). The President of the GMC released the water utilization plan for the rabi season in October 2001. It contained the crops, water saving methods (such as check-basin method and sowing across the slope) adopted, water balance in normal situations and water balance after dissemination of PHM results.

One important regular APWELL activity was crop planning. Crop-planning sessions were conducted twice a year at the beginning of kharif (June–October) and rabi (October–March) seasons, which was facilitated by the Agricultural Production Trainer, with an occasional visitor from the local agricultural research institute or agriculture department. Taking advantage of this practice, it was suggested at a consultant's meeting that linking the crop-planning exercise to the estimated groundwater balance needed to be explored. In 2001, during the kharif participatory water budgeting, it was realized the exercise was more meaningful for rabi plans because, during that season, crops solely depended on groundwater. In October/November 2001, four IPHM HUs experimented with participatory water budgeting, after which it was re-named crop–water budgeting (CWB), which specifically involved planning of crops rather than the entire water use plan.

A methodology was evolved for working with farmers and district level functionaries during the hydrological year 2000–2001. An Excel spreadsheet was evolved by September 2001, ready for field-testing for participatory water budgeting, in that rabi season.

The CWB workshop formed the backbone of the entire CWB process. This daylong workshop, involved the participation of men and women farmers, the District Field Coordinator, Agriculture Production Trainer, Hydrological Facilitator, Community Mobilization Specialist and Community Organizer. In October/November 2002, CWB workshops were organized at all eight IPHM Units, to experiment with the CWB spreadsheet and to influence farmer's crop plans, based on estimated groundwater balance.

Different approaches were adopted at each of these IPHM clusters, to vary instruction and adapt to the field situation. The CWB spreadsheet was refined and field-tested at eight IPHM clusters in the 2002 rabi. In November 2002, a final version, on the Microsoft Excel platform was evolved, at the end of field validation in Mulakala Cheruvu Thanda, Anantapur district. A Telugu version was developed, using the Telugu Lipi Editor software, available on line and sent to field units for their future use. Based on the experiences of the CWB exercise, at all IPHM HUs, consultants finalized the CWB methodology and package, which was communicated to the districts towards the end of 2002.

Follow-up actions were listed after a post-CWB workshop consultant's meeting. These included a crop adoption survey (CAS), essential for comparing crop plans before CWB and crop changes after CWB, during January–March 2003; complete inventory of groundwater users, to link each farmer's final result and cropping-pattern changes; subdivision of the UGB into small workable HUs, to facilitate more interactive CWB workshops; the addition of a pictorial form of the CWB package for community interaction; if possible, a 'Simputer' could be provided to each GMC to store hydrological data and run the CWB format on their own. It was proposed that a detailed account of the experiences gained from the CWB workshops be described in a separate chapter of the PHM publication. Box 3.5 relates the experiences of PHM in Gottipadiya.

Box 3.5

People of Gottipadiya check borewell drilling after PHM intervention in the village

Gottipadiya is a remote village in Markapur mandal of Prakasam district, in the foothills of eastern Nallamalais. It is about 15 km west of Markapur town, accessible only in the dry season, and located in the northeastern part of the Upper Gundlakamma sub-basin. The main stream flowing across the village is Erra vagu, which feeds an irrigation tank in the east at Vemulakota. Surplus water in the tank flows into the Gundlakamma river.

The PHM team contacted this village in March 2002, with a Kalajatha performance. In June, well inventory was carried out, which proved a good platform for interaction between the professional staff and farmers. While staff learned about the groundwater situation in the village, farmers gained insight into the complex working of the hydrological cycle operating in their village. The villagers report that discussions were triggered around the groundwater situation in the village at all levels of society, as a result of PHM initiative. Project staff facilitated some of these discussions. Gali Ramaiah and Kasi Reddy explained, "As additional groundwater is drawn from more borewells, the water level falls. Though every year rain recharges the groundwater, it takes more time to reach the groundwater level thereby the additional rainwater is not available for immediate use".

Based on the participatory rural appraisal exercise and inventory of well data it was found that out of an estimated 1 000 borewells drilled in the village, about 400 were functional and another 150 seasonal. Static water level ranged between 28 and 80 mbgl. Time line analysis carried out by the project staff indicated drilling depths in 1985 ranged between 30 and 45 mbgl, while current ranges were between 120 and 135 mbgl. The analysis revealed that about 60–80 new borewells had been drilled every year, over the past five years. As a result of PHM, villagers realized that drilling more borewells was not good for anybody. Marereddy Chenchu Reddy, Sarpanch of the village, observed: "What is needed are measures to increase groundwater recharge, which should be done with the able guidance of the APWELL project". As a result of project interventions the villagers reported only three new borewells had been drilled in the last drilling season.

Lessons from the PHM Pilot

Community participation

It was assumed it would be easier to convince farmers about supply-side management, because his/her contribution was limited to receiving investments for physical structures. Moreover, this could be perceived as an opportunity to increase groundwater withdrawals. On the other hand, demand-side management seemed to be unattractive, as the farmer could not see any reason to control water losses, learn about crop–water requirements, change cropping patterns, or close borewells. In quantitative terms the farmer had no idea what would happen over time if the present level of withdrawals continued. PHM could describe the situation in a particular aquifer system, under projected recharge/withdrawal conditions. Whether supply or demand management, it was important that the user knew what s/he was doing with the groundwater resource. This was where the PHM pilot played a major role.

It was not difficult to enlist the support of villagers, since APWELL had already made a difference to the lives of smallholders by providing an irrigation source. Because of the popularity of the APWELL Project, people received the project staff warmly whenever they entered a new village. The ease with which the Project could identify farmer volunteers, select monitoring wells, select sites for rain gauges, was an indicator of people's positive response.

Youth (men and women) and children participated enthusiastically in PHM. As an experiment, the topic of sustainable groundwater management was incorporated in the curriculum of schoolchildren, with the excellent cooperation of schoolteachers. It was realized that involvement of teachers in PHM was crucial to ensuring future citizens understood the sustainability of this scarce groundwater resource. As village elders were contacted first, their participation in PHM was also high.

Though there was no direct material benefit for farmers, they wholeheartedly participated in the pilot project, as illustrated by the incoming data, attendance at training camps and increasing demand for water level indicators. Participation may have been linked to farmer's gratitude for the 85 percent grant they received for the borewell and its benefits. The willingness of APWELL farmers to participate in the PHM pilot was apparent because eight rain gauge stations were established in APWELL on land owned by farmers. People also asked farmer volunteers about the rainfall received on a particular day, the water level in a particular well and discharge of a particular borewell. Farmers who did not receive any benefit from the project borewells also offered to monitor their water levels.

To further increase the participation of non-APWELL farmers in the PHM pilot, the project involved them in training to improve agriculture techniques, pump mechanism and vermi-compost. This approach worked well and helped the project select a representative to monitor the well network. Later, some became very active and became GMC office bearers.

It was difficult for farmers in rich groundwater areas such as Polerammavagu HU to understand the rationale behind PHM as they had plenty of water. Here, the project organized awareness-raising visits as part of the training of farmer volunteers. They were taken to a village called Regumanipalle, where the high-yielding borewells failed after one single drought year. This was enough to convince them of the importance of PHM.

PHM teams

The need was felt for district level PHM teams to take up the task of PHM and PWB in the new districts. Eight district level PHM teams (two in Prakasam district for Gundlakamma) were formed that included a Hydrological Facilitator, an Agriculture Production Trainer, and a Community Mobilization Specialist (CMS). After district level PHM teams had been created, a two-day 'training of trainers' was conducted to prepare them for their tasks.

One lesson learned from the training was that the staff needed to understand the type of physical action they needed to make. They had many doubts about the details of their activities. For example, they did not know what the display board should look like. Or how big a rain gauge station should be. It was not possible to discuss these details with staff members in all districts, at the same time.

To address this situation, consultants standardized all specifications and documented them in a reference document. This was circulated to all districts and proved useful to all district level staff for checking details. This also resolved any disagreements pertaining to specifications. The reference document drastically reduced enquiries from the district, which were then limited to the monthly project level meetings.

Interaction of multi-disciplinary team members, on a common platform, not only brought out the linkage between each of the subjects, but also created an atmosphere in which farmers from different crop cultures were able to discuss the water requirements of each crop.

Equipment

For the purpose of hydrological monitoring under the APWELL Project, APSIDC manufactured its own brand of water level indicator. Except for the first batch, supplied to IPHM villages, most others had quality problems and failed. Because of this, the farmer-training schedule suffered in all districts, apart from delays in starting the water level measurement. PHM suffered badly in 2000, because of the poor quality of the water level indicators. After discussions between the Technical Assistance Team and APSIDC, it was decided to procure water level indicators on the open market. All non-working water level indicators were returned to APSIDC and bulk manufacturing was stalled. In the second quarter of 2001, procurement of water level indicators on the open market solved the problem of data gaps related to non-functioning water level indicators. Mr Jangamappa of Anantapur district fabricated a low-cost water level indicator and received praise from the project authorities. However, his prototype failed to withstand the rigours of PHM.

PHM stations

Barbed wire fencing was used to establish the perimeter of the rain gauge station but was found to be ineffective in controlling the activities of miscreants. The project switched to iron wire-mesh mid-way through the implementation of the PHM pilot.

The APWELL project team selected production wells as monitoring wells despite their limitations in reflecting the actual piezometric surface of the aquifer. Monitoring of what might be only partially recovered water levels was justified on the basis of coverage and frequency of readings. At the beginning of the PHM pilot, the project had been skeptical about the participation of non-APWELL farmers. To enlist their support the project included villages under the borewell programme, which automatically became APWELL partners. Inclusion of borewells owned by non-APWELL farmers, in an APWELL village, became inevitable for ensuring the monitoring well network was representative.

Installation of the ‘conduit pipe’ in the monitoring wells was awkward. These were commissioned before the start prior to PHM activities. Gas welding equipment needed to be taken to the site and a hole made in the casing cap. Sometimes, the entire pump assembly was lifted out. For wells commissioned later, the manufactured casing cap came with a pre-made hole. Farmers reported difficulties because of the measuring pipe. When the motor needed to be lifted out for repair, it did not come out smoothly because of the small gap between the motor pipe and the mild steel coupling of the lowering pipe. Replacing this steel coupling with PVC solved this problem. Later, the sturdier, high-density polyethylene (HDPE) pipe was chosen.

Staff found it took a lot of time and work to make the discharge measurements. Though alteration was simple, staff had to go to each well with the cutting and fixing material, which they found burdensome. With persuasion and demonstration this difficulty was overcome. Initially, a digital sports watch was used. Later, as farmers found the operation complicated, a conventional steel-body stopwatch was introduced.

Kalajatha (street theatre)

At the start, APWELL intended to use *Kalajatha* performances to popularize the Project. The themes included APWELL objectives, implementation process, environmental pollution, depleting groundwater, organic farming, etc. During the early phases of the *Kalajatha* performances, the artists made mistakes passing on the messages, because they had to digest so much new scientific information. To overcome this, consultants tracked performances and corrected mistakes.

It was a Herculean task for the *Kalajatha* troupe to cover the vast target area of the APWELL Project. It took about a year to complete the programmes at all APWELL target villages. When the PHM activity was expanded to a larger area, there was the need for specific Kalajatha performances that focused on PHM. Accordingly, the troupe developed a three-hour package on PHM. However, the area was vast and spread across the entire state; in the Gundlakamma basin alone, there were about 200 villages. As *Kalajatha* was used as an entry point into these PHM villages, it was decided to make videos and recordings on CD of the *Kalajatha* performances.

Farmer training

Flipcharts with colour pictures were first used to explain the intricacies of the hydrological system. Later, glass models were used, which resulted in more effective communication. Practice sessions resulted in participants, especially women farmers, becoming more serious about the challenging task of handling equipment. The need for a second training was realized, once farmers started collecting data. Based on the evaluation of training conducted at the HU level, the Farmer's Hydrological Record was introduced.

During farmer volunteers' training, the potential of each participant was identified. Accordingly, farmers were entrusted with tasks and timing of data collection. During the evaluation session at the training some farmer volunteers expressed how empowering they found it was to be the holder of the information on water in their village. Working with the communities, it was found that many expressed enthusiasm for attending meetings or training to update their knowledge. When it came to accepting responsibility, however, only a few remained in the boat. Those who did remain played a key role in the successful implementation of the pilot project.

Farmer data

The borewell owners closest to the rain gauge station took responsibility for the rainfall data, which had to be collected at 8.00 hours every day. Owners of the monitoring wells were responsible for collecting water level data from respective borewells every two weeks; one or two active farmers were entrusted with the job of helping if needed. Discharge measurements were also recorded every two weeks.

Measuring PHM parameters was not hard because farmers had enthusiastically participated in the pilot. In some cases, proper recording of data proved difficult for those who were unable to write their information in the hydrological monitoring record. To overcome this, farmers identified an educated youth or school-going child, which ensured data recording was regular and accurate throughout the HU area targeted for PHM.

The HU map was transferred onto a huge, skillfully painted, display board for each of the PHM HUs. These boards were periodically updated. Any difficulties were overcome by putting a separate board in each village and updating the main HU display board twice a year, at the beginning of kharif and rabi.

In some cases, it was found that data was not authentic, resulting in much primary data collection, which delayed the preparation of the base document. This base document, covering four IPHM Hus, could only be compiled one year after the start of PHM. Learning from this experience, APWELL timed data collection, for the Gundlakamma basin, before the start of any activities. With the introduction of further participatory rural appraisal (PRA) tools for data collection, gaps in secondary data were covered.

During the data collection period, it was found farmers carried out PHM activities because of their gratitude rather than for serious concern for groundwater sustainability. Further, they were not sure about how the collected data could help make crop-related decisions. The project had focused on data collection and ignored the need to explain the link, because it wanted to use farmer's data to interpret the groundwater situation in a given HU.

The need for participatory data analysis was realized only during the implementation stage of the PHM pilot. The need for a common methodology for interpretation was appreciated, after the project found district staff followed different methods. In some cases, fresh data were being collected from primary and secondary sources for spreadsheets. This could have been avoided if the methodology for data collection and recording had been standardizing at the start.

For the first three months, project staff regularly attended the farmers' fortnightly data recording. This was necessary to provide assistance and guidance if required. Later, farmers recorded the data on a piece of paper and brought this to the district level project office and staff helped them enter the data into the farmer's hydrological record. After a year of data collection, farmers were able to carry out measurements and record them on their own.

APWELL's plan, at the launching of the PHM pilot, was to wait until farmers had collected hydrological data for one full hydrological year before initiating any participatory data analysis. During the implementation stage, however, it was found farmers were curious about how the HU fit into the overall picture. PHM staff began to discuss the reasons for different situations in various parts of the HU. Later, it was felt that the mid-way brainstorming on fresh data was useful for retaining farmers' interest.

Topics arising during interactions between project staff and farmers were: failed wells and static water levels that were similar to nearby wells; wells in the discharge areas yielded more than those in the recharge areas; failure of nearby wells was possible when the borewell did not strike the fracture zone; static water level gradually declined after rains stopped, because of little or no rain, but continued pumping in rabi; though fresh rains came in June, static water levels started building up only in July; drawdown (difference between static and pumping water levels) was more in the lean season than the monsoon season; low-yielding wells had more drawdown than high-yielding wells and few borewells had reduced discharge and more drawdown in summer.

It was apparent farmers understood the utility of measuring rainfall, water levels, and discharge at least when comparing performance related to well location and season. It is suggested that agencies interested in adopting the PHM approach conduct this type of intermediate data analysis with farmers.

Though the reference document provided a procedure for calculating borewell discharge, it was found that project staff had to assist farmers. The project immediately prepared conversion tables and supplied them to the farmers. The initial recommendation of a 200-litre drum was found impractical, as it was too heavy to carry and farmers preferred 100-litre drums. The conversion tables for 100-litre drums were prepared and supplied to farmers using the 100-litre drums.

Crop–water budgeting

There were several reasons for APWELL's development of the environmental viability assessment (EVA) package. This was conceived as a one-time exercise to record the water balance before drilling. The need for repeating EVA annually was realized when the PHM pilot had started. A completely new Excel spreadsheet was evolved, through extensive interaction with field level functionaries and farmers, to suit the needs of annual crop–water budgeting.

Participatory water budgeting (PWB) proved to be an eye-opener not only for the farming community but also for the implementing agency. It became clear that much more could be done to tackle the problem of groundwater depletion from the demand-side. The need for annual repetition of participatory resource mapping (PRM) and PWB was realized at the time PWB data were interpreted. This proved an effective and rapid method to update baseline data. Lessons learned, after the PWB exercise, were: water balance estimation should be based on the proposed rabi crop plans and PHM data; crop changes were easier for villages where there were only APWELL borewells and structural controls in an aquifer system had to be studied in detail before attempting water balance estimation.

APWELL farmers repeated PRM at the beginning of each rabi season, which was basically the updating of the output of baseline PRM. The staff and farmers sat together with the earlier PRM map (on chart) and worked by segment. They discussed any changes during the last year related to additional wells and cropping pattern changes. In the plenary, the map was updated and kept ready for use as an input for EVA.

Farmers from four IPHM clusters (2001) were invited to provide assistance along with Project staff. Farmer participation at all eight CWB worships was excellent, especially those who were not benefiting from the project. The interactive method at the workshops effectively generated ideas about sustainable groundwater management. Participation of women at the workshops was very high, as indicated by their number and level of ideas contributed.

Computers and projectors were used at the field level to enable farmers to come up with ideas. By incorporating their ideas into the spreadsheets, facilitators explained the meaning of water levels. Farmers could see what could happen if the current rate of pumping continued under conditions of constant recharge.

Participatory water budgeting was useful for deeper understanding of the crop–water requirement and possible changes in cropping patterns. This inter-disciplinary interaction was essential not only for farmers but also for professionals who came to better appreciate the work of others. It is suggested that participatory water budgeting be carried out by all agencies interested in adopting the PHM methodology.

3.4 APWELL Final Evaluation (April–June 2003)

The Final Evaluation of the APWELL Project was conducted in April/May 2003. The Mission found that:

> *"APWELL showed that provision of irrigation facilities through borewells to smallscale and marginal farmers was possible; the step-wise selection and construction process supported by intensive social facilitation worked; sharing water in groups of three to five without major conflicts was observed, even in times of water scarcity; the irrigation system would depend on availability of electricity; while improving the economic status of smallholders, the farmers cultivating cash crops were left exposed to market risks; there was no doubt that both farmers and other stakeholders in APWELL were concerned with the future of groundwater availability and therefore the future of the borewells; considerable work remained to be done, to enable institutions organized by APWELL to counter over-extraction by others; and APWELL was considered by many to be an innovative project and a source for new approaches to be adopted by others and for ideas for policy development."*

The Mission was concerned about the abrupt closure of the project, while a few promising pilots supporting sustainable management of groundwater were being tried. Supported by the Royal Netherlands Embassy, APWELL lobbied the Government of Andhra Pradesh, specifically the Water Conservation Mission (WCM), under the Department of Rural Development (DRD), for the continuation of PHM activities. This did not materialize, so the Embassy, in April 2002, decided to fund key APWELL activities, mainly PHM and CWB through a network of NGOs. As it was impractical to enter separate contracts with each of the NGOs, the Embassy identified a 'Nodal' NGO from among the APWELL partner NGOs, through which Embassy funds could be routed.

Based on a thorough Institutional analysis, and results of a comprehensive audit ranking NGOs partnering APWELL, Bharathi Integrated Rural Development Society (BIRDS) of Kurnool district was found suitable on account of its financial credibility and its central location in the APWELL operational districts. The Embassy asked the APWELL Consultant Hydrogeologist to draw up a project proposal for direct funding by the Royal Government of the Netherlands to the NGO network, through BIRDS, for further development of the PHM model. The consultant prepared a project proposal *Andhra Pradesh Farmer Managed Groundwater Systems (APFAMGS)*, which was submitted to the Embassy in September 2002. Approval was delayed because of the uncertain situation at the national level, with regard to policies related to foreign funding. The APFAMGS Project was then formally launched, with an Inception Workshop in July 2003, with funding from the Royal Netherlands Embassy.

During the period between the closure of the APWELL Project in March 2003, and approval of the APFAMGS Project in July 2003, APWELL staff continued to work voluntarily at the field level, foregoing their salaries. BIRDS and Priyum

Advisory and Consultancy Services Private (PRIYUM) provided the minimum funding required supporting these voluntary efforts.

3.5 APFAMGS–Royal Netherlands Embassy Phase (July 2003–April 2004)

The Development Objective of APFAMGS was stated as: *Farmers in Andhra Pradesh manage their aquifer systems based on annual recharge-withdrawal conditions*. The stated Project Purpose/Goal was: *Stage is set for enabling the farmers to manage their aquifer systems in about 500 villages in seven drought prone districts of Andhra Pradesh by the year 2005*.

After the Royal Netherlands Embassy Project was approved, BIRDS entered a partnership agreement with six Partner-NGOs (see Table 3.2). Each Partner-NGO became responsible for project activities at about 70 habitations, assisted by a team of professionals. The Project Management Team (PMT) guiding the field teams for project implementation was subcontracted to PRIYUM. World Education, India, was subcontracted to provide critical inputs related to non-formal education. SUMADHURA Technologies Private Limited was subcontracted to provide support to the project for demystifying groundwater science, using GIS.

Table 3.2

Partner NGOs during APFAMGS-RNE phase

District	Name of the NGO	Acronym
Anantapur	Gram Vikas Samstha	GVS
Chittoor	Gram Vikas Samstha	GVS
Kadapa	People's Activity for and Rural Technology Nurturing Ecological Rejuvenation	PARTNER
Kurnool	Bharathi Integrated Rural Development Society	BIRDS
Mahbubnagar	Centre for Applied Research and Extension	CARE
Nalgonda	Centre for Applied Research and Extension	CARE
Prakasam	Collective Activity for Rejuvenation of Village Arts and Environment	CARVE
Prakasam	Development Initiatives and People's Action	DIPA

A Project Steering Committee (PSC) was created to steer the project in the right direction and assist making appropriate policy decisions. A three-day Annual Plan and Budget Workshop, was conducted in November to plan activities for January–December 2004.

The Project Management Team comprised a Project Leader, four Subject Experts (water management, institutional development, agriculture, and gender in water). Multi-disciplinary teams were formed at the district level comprising an NGO Coordinator (NGOC), Hydrological Facilitator (HF), Agriculture Facilitator (AF), Gender Facilitator (GF), and Institutional Development Facilitator (IDF), Village Coordinators (VC) and Documentation Assistant (DA).

Project Staff orientation took place during the APFAMGS Induction Workshop held in September 2003. Partner-NGOs held two training/workshops for staff on participatory tools. After the supply of the GIS software, the National Institute for Information Technology (NIIT) gave three training sessions for Project staff to familiarize them with the products.

The consultants communicated 'technical specifications' for the conversion of production wells into monitoring wells, which was completed at 473 habitations (17 HUs), and 26 rain gauge stations were established. Each of the Partner-NGOs identified one HU in their operational area to pilot the GIS experiment, and procured village cadastral maps and village records (Pahani) to prepare thematic maps. The order was placed for purchase of satellite data from the National Remote Sensing Agency (NRSA) for seven Pilot HUs.

In villages, where there was an immediate need to supplement rainfall recharge of depleted aquifers, 16 artificial recharge structures were constructed. Monitoring wells were established to assess the impact of these structures in areas they influenced.

Habitation level Groundwater Management Committees (GMCs) were formed; members were men and women farmers from 152 project habitations. Opinion leaders were identified for all 506 habitations of the Project. Social feasibility studies were completed to finalize monitoring wells at 477 habitations. The identification process was completed at 505 habitations. During the Royal Netherlands Embassy phase, 362 Gram Sabha meetings were conducted and 152 GMCs formed.

One-day of training was held in March 2004 on gender mainstreaming for all Gender Facilitators (GFs), to discuss strategies for the gender component of the project. A Gender Assessment Survey was carried out as part of a larger socio-economic survey, covering 448 habitations. Women's participation in project activities was generally good: women farmers measured water levels at 138 habitations, rainfall data was collected at 34 habitations and women's membership in 132 GMCs was higher than 35 percent.

Given the nature of the project, which called for scientists to work with the attitude of a social worker, this was crucial for building staff capacity for community mobilization. Therefore, staff orientation for the *learning systems*' approach was taken up at the beginning of the Embassy phase. World Education, an NGO pioneering non-formal education, upgraded the skills of project staff.

3.6 The transition to APFAMGS, the FAO NEX [6] Project (August 2004–August 2009)

Because of the changed policy of the Government of India, which opted not to engage in minor funding, the Royal Government of the Netherlands, through the Royal Netherlands Embassy in India (New Delhi) decided to phase out its funding for three projects, then operational. The Embassy formally closed direct funding to the APFAMGS project in April 2004. The funds reserved for Project implementation were re-routed through the FAO.

A new APFAMGS Project document was submitted to FAO in March 2004. However, three months elapsed between the close of the Embassy-phase, before the agreement was formally signed in August 2004. BIRDS, PRIYUM and Partner-NGOs maintained contact with each other and the communities and raised funds internally.

APFAMGS, in the FAO NEX Phase, was guided by the 'Logical Framework' in the project document, which clearly defined, the project goal, immediate objectives, objective verifiable indicators and their means of verification, as well as external factors required for achievement of project objectives.

The Project Goal, as stated in the logical framework was: *Stage is set for enabling farmers to manage their aquifer systems in about 650 villages in seven drought prone districts of Andhra Pradesh by the year 2008*. Four 'immediate objectives' were required to reach this goal: 1) About 3 000 men and women farmers in a position to understand aquifer systems within which they are operating at about 650 habitations in Andhra Pradesh, in a scientific manner, by the year 2008; 2) Hydrological database using GIS platform is developed for use by Groundwater Management Committees, covering 650 habitations, by 2006; 3) About 6 500 farm families enabled for adoption of alternative agricultural practices suiting availability of groundwater, by 2008; and 4) Community based institutions established for alternative management of groundwater resources with equal representation/participation of men and women, covering 650 habitations, by 2008.

Institutional arrangements made during the Embassy-phase were continued for the FAO–NEX phase, except for the renaming of the Project Management Team as the Technical Support Team (TST). In addition, three more NGOs: Star Youth Association (SYA), Social Awareness for Integrated Development (SAID), Adoni Area Rural Development Initiatives Programme (AARDIP) were taken on board for Anantapur, Prakasam and Nalgonda districts. After one and half years of association with APFAMGS, AARDIP withdrew its partnership because its head office in Kurnool district was too far away from the field unit in Prakasam district. In the Plan and Budget 2006, a new Partner NGO, Society for Sustainable Agriculture and Forest Ecology (SAFE) replaced AARDIP.

[6] Nationally Executed Modality: Under NEX agreements, FAO has no direct implementation responsibility. It only assists national implementing institutions in making appropriate choices.

Three Netherlands Assisted (NET) Projects were the first NEX projects, approved by the FAO Conference in 2003. NEX projects have only two budget lines: contracts and FAO support costs.

Programme support to NEX programmes in India was funded by a fourth project, which provided funding *inter alia* for a National Land and Water Officer based in the FAO India Office, New Delhi and technical backstopping from FAO Headquarters through Missions.

APFAMGS continued to work in the same districts, as they were drought prone and fast depletion of groundwater resources had been recorded. Borewell clusters, created as part of APWELL, were central to the identification and delineation of HUs for APFAMGS. PHM for APWELL was implemented as a multi-disciplinary process, placing groundwater management at the centre; sustainable groundwater management remained the focus during the APFAMGS-FAO Phase.

The APFAMGS-FAO phase focused on fine-tuning APWELL approaches and field-testing new approaches. Key APFAMGS approaches were PHM; artificial groundwater recharge; CWB; Farmer Water Schools; community based Institutions; the crop–water information kiosk and policy advocacy.

Participatory hydrological monitoring

APFAMGS established the first hydrological monitoring network (HMN), operated and maintained by the community. All Partner NGOs agreed on specifications and procurement was carried out in strict adherence. The hydrological equipment needed for project infrastructure included: water level indicators, insertion pipes and accessories, rain gauges, stopwatches, calibrated drums, staff stream gauge, current meter and other accessories. Establishment of the HMN required a rain gauge station, water level monitoring well, water level discharge monitoring well and stream gauge, purchases adhered to technical specifications issued by the Technical Support Team, supervised by the Hydrological Facilitators.

At the end of 2004, HMNs were established in seven HUs and completed at all 63 HUs by May 2006, creating a platform for farmers' collection of hydrological data. Training of volunteers for PHM Module 1 was completed during establishment of the HMNs. All equipment and infrastructure developed as part of HMN were transferred to the respective HUNs in 2007. About 7 000 women and men at 661 habitations participated in the PHM process. GMC volunteers at 555 habitations became proficient at collecting and recording rainfall data from 203 rain gauges. Members of 63 HUNs were trained to understand the occurrence of groundwater at the HU level.

Farmer-collected data included daily rainfall, fortnightly water levels, fortnightly borewell discharge and daily stream-flows. Volunteers stored the data collected in a booklet, referred to as the hydrological monitoring record. The farmer's data were exhibited on display boards maintained at strategic locations throughout the HU.

The adoption by APFAMGS of the hydrological monitoring record, data display boards and the base document, for specifically storing PHM data helped improve upon the APWELL experience. APFAMGS introduced computer-based Habitation Resource Information System (HRIS) for data storage at the Partner-NGO level. CWIK, the crop–water information kiosk, developed towards the end of APFAMGS, was designed to store data and for interactive groundwater management. These data management tools are discussed in Chapter 2.

Global information system (GIS) and global positioning system (GPS)

The Industry standard GIS, ArcInfo, was installed at the Technical Support Team Office during the Royal Netherlands Embassy-phase, ArcView was installed at seven Partner-NGO offices. During the FAO-NEX phase, two more sets of ArcView software were procured from the National Institute for Information Technology (NIIT)-Environmental Systems Research Institute (ESRI) and installed at two new Partner-NGO offices in 2005. The Technical Support Team and Sumadhura developed a suitable GIS platform for the project. While the Technical Support Team used ArcInfo, to digitize scanned maps and transfer satellite imagery data onto a map, the Partner NGOs were supplied with ArcView so they could view the generated GIS layers; 36 staff was trained to use ArcInfo by mid-2005. All staff learned to handle the GPS equipment during on-site training. In addition to the farmer-collected data and secondary data, the project developed six spatial layers for the entire project area. Satellite imagery was procured for three time periods and land-use changes were assessed.

Base maps for all 63 HUs were procured and digitized by the end of 2006. Spot heights were digitized as points, drainage network as lines and HU, tanks, rivers were digitized as polygons. Indian Remote Sensing (IRS) Satellite image data, both panchromatic camera (PAN) and Linear Self Images Scanner (LISS-III) image were procured in digital format, geo-referenced and overlain on the digitized HU maps to generate specific themes. Thematic maps were generated for all HUs in 2007.

Crop–water budgeting

During implementation of the APFAMGS Project, from 2004, the project promoted crops that required less water (such as SRI paddy, horticulture, sunflower and castor) in 11 habitations where the groundwater balances indicated a need to reduce pumping to maintain acceptable aquifer levels. By the end of 2005, 496 habitations were covered by CWB; all 625 habitations were covered by 2007. Efforts to reduce agro-chemical inputs through integrated pest management (IPM) and organic fertilizer production were carried out simultaneously with the CWB exercises. At the end of 2004, twenty-seven staff-members had the knowledge and skills for low-input agricultural tasks. By 2005 this number had risen to 36.

Farmer Water Schools (FWS)

Since its inception, APFAMGS attempted to integrate Farmer Field Schools into its approach. This had been successfully tried out by FAO with IPM. FAO conducted season-long training of trainers (ToT) courses at Farmer Field

Schools – IPM for vegetables May to July in 2005. The course, coordinated by FAO, was to create a pool of master trainers for the FFS methodology. A vegetable crop, *Bhendi* (lady's finger or okhra), was chosen for the training because there was no such experience in India; a number of FFS had been held for crops such as rice, cotton, groundnut and pulses.

A preliminary workshop was conducted in June 2005 to deliberate the possibility of adapting the FFS approach to groundwater management. The Subject Expert, Water Management, prepared a concept note: *Farmer Field Schools* – Groundwater Management (FFS-GM), based on these deliberations. The goal was to:

"Integrate Farmer Field School methodology with the PHM process to enable farmers (men and women) to identify problems beset by groundwater management, search for local solutions, take collective decisions, and implement these decisions and measure impacts generated, ultimately to manage their hydrological system scientifically, with the participation of all stakeholders including the community based institutions, government departments and other developmental agencies."

Favourable factors for the adaptation of FFS methodology were identified in the concept paper, including hydrological monitoring, established infrastructure; adequately trained farmer volunteers; readily available PHM training modules; no additional financial resources required for the adaptation of FFS to groundwater management; periodical or sequential input of groundwater management concepts through experiential and discovery learning process enhanced the ownership of the learning process and effective management of groundwater resources and the feasibility of social harmony created by joint management of scarce water resources.

The challenges identified were: limited field-testing for groundwater and water testing results are not immediately visible as they are for agriculture.

Strategies were listed bearing in mind the favourable factors and challenges required for implementation of Farmer Field Schools–Groundwater Monitoring (FFS–GM: FFS would be year long; sessions would be organized fortnightly and each session would last 4 hours; there would be a training of trainers workshop; participants in the FFS-GM would include farmer volunteers (both observation wells and rain gauge stations), owners of observation wells and rain gauge station sites, GMC office-bearers, a few progressive farmers and landless poor and HU participants limited to 30, with equal representation of men and women farmers.

It was decided that the CWB workshop, planned for October/November 2005, would try the Farmer Field School approach and the CWB workshop of 2005 was named *Farmer Field Schools* – Crop–water budgeting (FFS-CWB); 15 sessions were conducted as part of the FFS-CWB. Pleased with its success, the decicion was made to run a complete cycle of the adaptation, i.e. June 2006 through May 2007. The term *Farmer Field School – Farmer Managed Groundwater Systems (FFS-FMGS)* was then coined. By the start of the hydrological year 2007–2008, the term FFS-FMGS was replaced with the words *Farmer Water Schools (FWS)*. There was a complete revision of the session outline and 16 sessions were conducted.

To reach a large number of farmers, and tap farmers' existing knowledge and skills, the project introduced the multiple cycles approach. After participating in the session, the farmers paired up to assist at Farmer Water Schools at their respective habitations with other farmer participants. Thus in 2006–2007, NGO staff conducted 34 FWS, while farmer participants from the first cycle organized 272 FWS, reaching about 10 000 farmers in all. Farmer institutions and facilitators led management and implementation of FWS from the hydrological year 2007–2008, while project staff supervised and monitored the process.

In the hydrological year 2008–2009, FWS planning workshops were organized to enable HUN members and farmer facilitators to manage FWS on their own. Funds were transferred to HUNs to conduct FWS. HUNs and GMCs showed increased ownership and initiative for the management and implementation of FWS. HUNs proved to be more proactive in forging new links with government departments and local political representatives.

By mid-2008, the project successfully completed the second year of FWS and initiated third-year sessions across all project areas. The significant feature of the new session was that the responsibility for running the school was handed over to the registered HUNs. In the FWS's second year it was attended by over 9 460 farmers at 300 schools.

In June 2008, at the end of rabi cropping season, Field Days were successfully initiated at all nine Partner-NGOs. Farmers conducted these field days by themselves. The representative farmers from different GMCs participated in the field day, which served as a platform for evolving a sound and farmer-friendly water-use programme for the rabi cropping season. The CWB workshop results enabled farmers to adopt cropping systems that matched groundwater availability. Innovative physical models and cultural media were successfully used to deliver the message of the field day to all farmers. Farmers adopted a number of resolutions to save water, improve water-use efficiency and adopt environmentally friendly practices. By May 2009, the project successfully produced 19 777 graduates of which 12 315 men and 7 462 women.

In 2008–2009 FWS went into their third year, attended by over 5 142 farmers at 174 schools. FWS had tremendous impact at the grassroots level in six months. Graduates of previous FWS led FWS 08-09; their increased involvement has very much enhanced the participatory approach.

Community based institutions (CBI)

APFAMGS established 555 GMCs at habitation level and 63 HUNs, at the HU level. These community based institutions occupied a central position in the APFAMGS approach, for data collection, decision-making and implementation of activities related to sustainable management of groundwater in the project area. All GMCs and HUNs had established functional links with the line department by the end of 2007.

GMCs established links with various government agencies and mobilized around 60 schemes in 625 Project villages. In view of the withdrawal of the Project, PHM assets were handed over to the respective GMCs, which conducted monthly meetings. HUNs took over responsibility for data collection, analyses and conduction of CWB workshops and FWSs across the project. Project support for activities was reduced as Farmer Facilitators took over the conduction of the Farmer Water Schools and crop–water budgeting.

All NGOs transferred funds to the HUN accounts in 2008 to run FWS. This was a significant step in strengthening the capability of people's management of groundwater resources as well as establishing a new approach for governance. GMCs and HUNs emerged as lead players after successfully demonstrating their capabilities as resource people for training officers from several states in India. GMCs and HUNs developed links with various government departments and effectively mobilized funding; 9 323 families from 466 habitations benefited from the government programme. Funds mobilized amounted to INR 30.4 million used to procure water-saving devices.

Other key APFAMGS activities

As food security is perceived to be the responsibility of women, APFAMGS made this a priority. In 2007, mid-way through the project a food and nutrition survey was conducted, data were analysed and results shared with farmers in the project area. The project promoted trials of SRI (system of rice intensification) varieties to test the scope for reduced groundwater pumping under alternate wetting and drying as opposed to continuous rice basin flooding. Production and application of vermi-compost was carried out in all Partner-NGO areas to encourage organic agriculture in the project area. Healthcare practices were encouraged in all Partner-NGO areas and hygiene and sanitation awareness training provided.

In 2007, the Project encouraged the adoption of organic agriculture and farmers were trained to prepare compost, botanical extracts and regenerate biomass. They received training in water-saving techniques (such as check-basin method or irrigation and sowing across the slope), SRI paddy and micro-irrigation equipment such as drip and sprinklers. Women were trained to cultivate kitchen gardens, in food and nutrition and creation of nurseries for medicinal and aromatic plants. Schoolchildren learned about PHM activities and water management at the GMC level.

In 2006, health-care practices were encouraged in all Partner NGO areas where, in the same year a food and nutrition survey was carried out. Documentary films were produced covering different themes related to project activities in all Partner-NGO areas. Videos, documenting project activities, were made by all Partner-NGOs to showcase the process and the impact of various activities implemented and to capture farmers' insights and opinions.

3.7 Beyond APFAMGS

The APFAMGS FAO-NEX Project ended in August 2009. However, because of the critical drought that year, FAO continued to provide support to the community based institutions for crop–water budgeting and for water conservation schools (WCS) in 2009, with a bridge funding arrangement for a four-month period September–December. Activities in APFAMGS operational area remained low-key during the period January–December 2010. FAO and key consultants meanwhile organized funding from the Global Environment Facility (GEF) for additional environmental benefits to broaden farmers' agenda to include sustainable groundwater management, and build the rural communities' adaptive capacity for sustainable land and water management. FAO-BIRDS accessed funds for a climate change/variability adaptation project from GEF. By the closure of the APFAMGS Project, the Project Identification Form had been approved by the GEF Secretariat and the Withdrawal Project Document for this medium-sized project had been endorsed by the Ministry of Environment and Forests (MoEF), Government of India (GoI).

The gap between APFAMGS and the GEF project (January–December 2010)

Activities in the APFAMGS operational area remained low-key during the gap period January–December 2010, between termination of APFAMGS and the start of the GEF project. APFAMGS key staff members, awaiting the start of the GEF Project, were absorbed by other projects, some based on the APFAMGS model, and therefore they were unavailable for service when the agreement was signed in December 2010. The GEF Project suffered badly from this brain drain, as APFAMGS had spent much time and energy building their capacities.

Strategic Pilot on Adaptation to Climate Change (SPACC)

Building on the experience of APFAMGS, SPACC aimed to minimize the impacts of climate change/variability through a package of mass awareness generation, skill development and the evolution of location-specific technologies and methods of climate-smart agriculture and water management. In the business as usual scenario, FAO would have continued to support the NGOs' development of community capacity for sustainable groundwater management, through the key activities: participatory hydrological monitoring; Farmer Water Schools; crop–water budgeting; strengthening of community based organizations and policy advocacy.

GEF funds brought in additional environmental benefits to the ongoing FAO initiative by broadening the agenda of community capacity for sustainable groundwater management by building the adaptive capacity of the rural community for sustainable land and water management. Implementation of the GEF-financed project *Strategic pilot on adaptation to climate change (SPACC)* began in December 2010. Key activities include participatory climate monitoring, Farmer Climate Schools (FCS) and sustainable land and water management (SLWM) pilots.

Chapter 4. The Response

The decade-long pursuit of PGM successfully involved an estimated half-million women and men farmers in 661 habitations. About 20 000 can be referred to as barefoot water technicians, who are committed to the sustainable use of groundwater systems. In addition, 555 GMC and 63 HUNs were formed. These community based institutions occupy a central position in the smallholder approach. Farmers collect and record hydrological data and understand the seasonal occurrence and distribution of groundwater in their habitations and HUs. They estimate recharge, withdrawal and balance without external support and understood that groundwater is a common property resource and are willing to manage it for the collective benefit. GMCs and HUNs mobilize resources for their members from government programmes, and are involved in activities of interest to their members such as marketing.

Farmers, particularly smallholders benefitting from the APWELL interventions, have taken collective action to ensure their wells are sustained and provide them with acceptable economic returns. The aquifer systems have responded variously in the different HUs, controlled by physical conditions and changes in people's behaviour. In this Chapter, the response of these aquifer systems is considered; followed by understanding the efforts made by communities to understand how they contribute to the system's response and finally the response from the external environment.

4.1 Aquifer system response

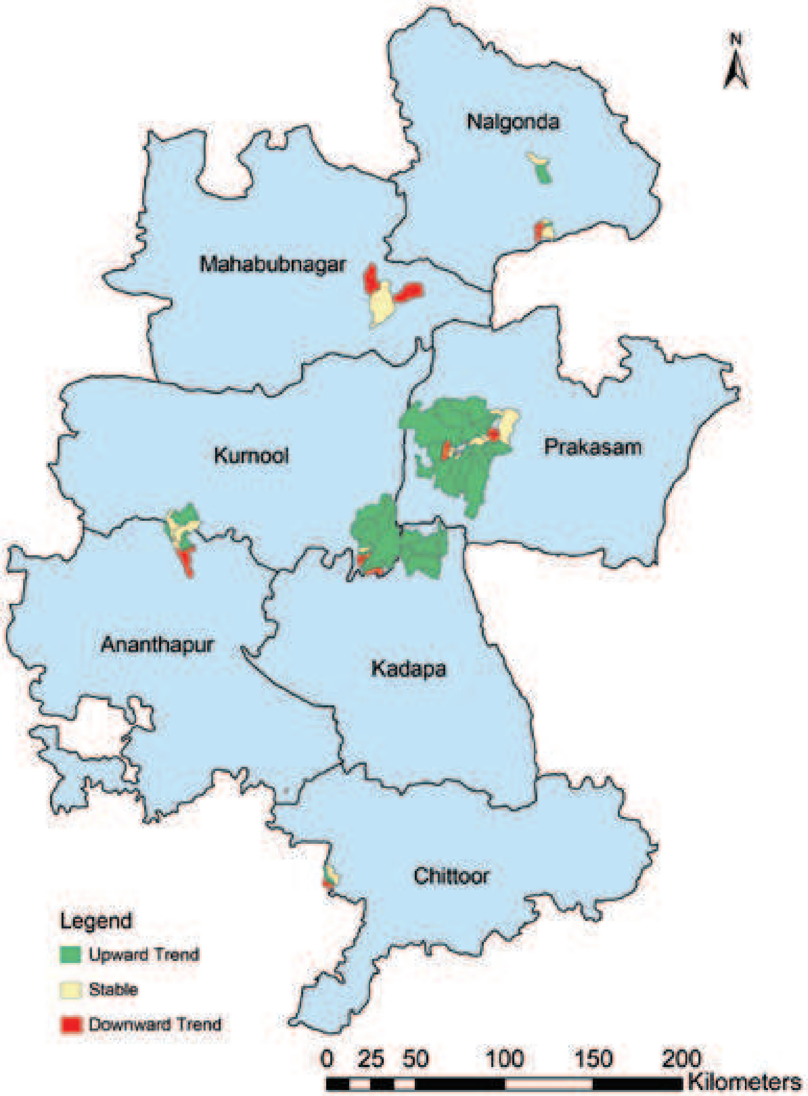
The response of the aquifer systems in the 63 HUs was assessed during a desk study based on information from the HUNs. A typology of HUs was developed and four HUs, showing different response to the PGM intervention, were selected for a detailed questionnaire survey to investigate the reasons for the groundwater systems' various responses after the same intervention.

Static water levels

Farmer data for 2005–2011 was used to follow how water levels behaved during the period. Static water levels recorded in the production-cum-monitoring wells at 63 HUs were analysed, independently, plotting the recorded static water level against the date registered on spreadsheets. A trend line was assigned to facilitate understanding of the behaviour of the upward and downward water level trends. Water levels not showing any difference of plus or minus 1 m were classified as stable. Annex 2 gives a summary of results obtained from HUs for water level and stage of development.

Figure 4.1

Location of HUs showing different water level trends for 2005–2011



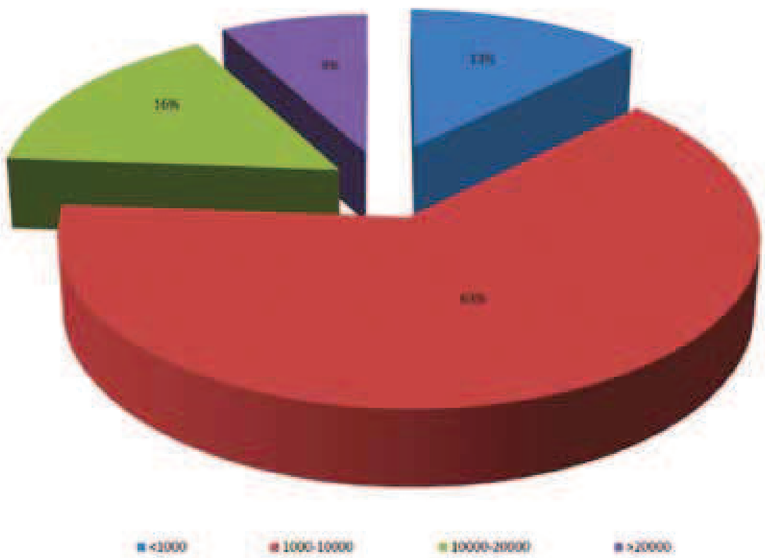
Static water level at 35 HUs (55 percent) shows an 'upward' trend; while at ten HUs (16 percent) a 'downward' trend was observed. At the remaining 18 HUs (29 percent), static water level was found to be 'stable'. The upward, or stable, static water level trends at 86 percent of the HUs indicate aquifer systems were receiving recharge in the monitoring period, a legacy of the generous monsoons in those years. In general the small number of aquifer systems exhibiting downward trends can be explained by poor infiltration capacity of the aquifer and/or its location in the rain-shadow area.

Estimating the annual groundwater balance

Recharge estimation: The size of the HU, and area underlain by a relatively better aquifer, is critical in terms of the recharge potential. It was found that 40 Hus (63 percent) are between 1 000 to 10 000 ha; ten (16 percent) are in the range of 10 000 to 20 000 ha; eight (13 percent) are very small, less than 1 000 ha and five (8 percent) HUs are very large, more than 20 000 ha.

FIGURE 4.2

Pie-chart showing categories of HUs in the PGM area



Farmers estimated rainfall recharge annually for use in the CWB exercise (see Section 2.5). The simple method for estimation was evolved by APWELL. Rainfall received is multiplied by the area under each type of geological formation, under each CGWB category. The product is again multiplied by the recharge infiltration factor to arrive at the recharge for each geological formation in the HU. Adding together the estimated groundwater recharge for each type of geological formation gives the total rainfall recharge in the HU, for a given period (monsoon/winter season or annual). The following equation is used for PGM:

[7] The percentages are recommended by the Groundwater Estimation Committee 1997

Recharge from rainfall (MCM) = area of the HU ($m^{2)}$ x Rainfall received (m) x Rainfall infiltration factor [7] (percent)

The equation is re-written as:

Annual groundwater recharge (ignoring additional recharge from all other sources =

(Area under litho-unit 1 x Rainfall received during June–September x Rainfall infiltration factor) +

(Area under litho-unit 2 x Rainfall received during June–September x Rainfall infiltration factor) +

(Area under litho-unit 4 x Rainfall received during June–September x Rainfall Infiltration Factor)

The PGM method used to estimate recharge is illustrated in the following section using an example from Bhavanasi HU (Kurnool district). The area underlain by different litho-units (LU) in the HU was calculated using the geological layer. In Bhavanasi HU, farmers collected rainfall data from three rain gauge stations, established as part of PGM. Rainfall data collected at C. Ahobilam was used for LU1; Nagallapadu for LU2; and Muthyalapadu for LU4. For example, the groundwater recharge estimated for the period June–September for Bhavanasi HU is shown in Table 4.1.

Table 4.1

Estimation of groundwater recharge (June–September 2007) in Bhavanasi HU

Code	Litho-unit classification of GEC 97	Area (m^2)	Rainfall (m)	RIF (%)	Recharge (m^3)
1.	Massive poorly-fractured rock	243 540 000	1.17	1	2 859 160
2.	Phyllites and shales	1 669 000	1.17	4	783 762
4.	Consolidated sandstone, quartzite, limestone (except cavernous)	57 870 000	1.17	6	4 076 363
	Totals	318 100 000			7 719 285

Estimation of secondary recharge, related to the return flow and addition of 2 percent to the recharge infiltration factor, in areas watershed development activities are implemented, is recommended by the Groundwater Estimation Committee. These additions are not made to estimate recharge in PGM, mainly to allocate this part of recharge to domestic and industrial needs and to simplify the estimation method.

Annual groundwater recharge in 63 HUs is estimated, as the product of area, rainfall received and recharge infiltration factor recommended by the

Groundwater Estimation Committee. Annual recharge estimated at 58 HUs, for the hydrological years 2006–2011 is used for this analysis, while recharge estimation for 2010–2011, is carried out for five HUs because of the lack of reliable data.

Groundwater withdrawal estimate: Two methods were used in the PGM approach to estimate groundwater withdrawal the well census method, to estimate monsoon withdrawal (June–September), and the crop–water requirement method for the winter and summer cropping season (October–May). This estimation is based on crop planning information for projected groundwater withdrawal in the winter and summer cropping seasons, for use by the CWB workshop. After completion of the crop adoption survey, the actually cropped area was used to estimate groundwater withdrawal during October–May, replacing the projections. Addition of monsoon withdrawal and winter/summer withdrawal gives the total withdrawal in the hydrological year.

For the well census method, withdrawal is calculated using the following equation:

Withdrawal (MCM) = Number of functional wells x Pumping hours x Average well discharge (m^3/hr).

Withdrawal is estimated using the crop–water requirement method, with the following equation:

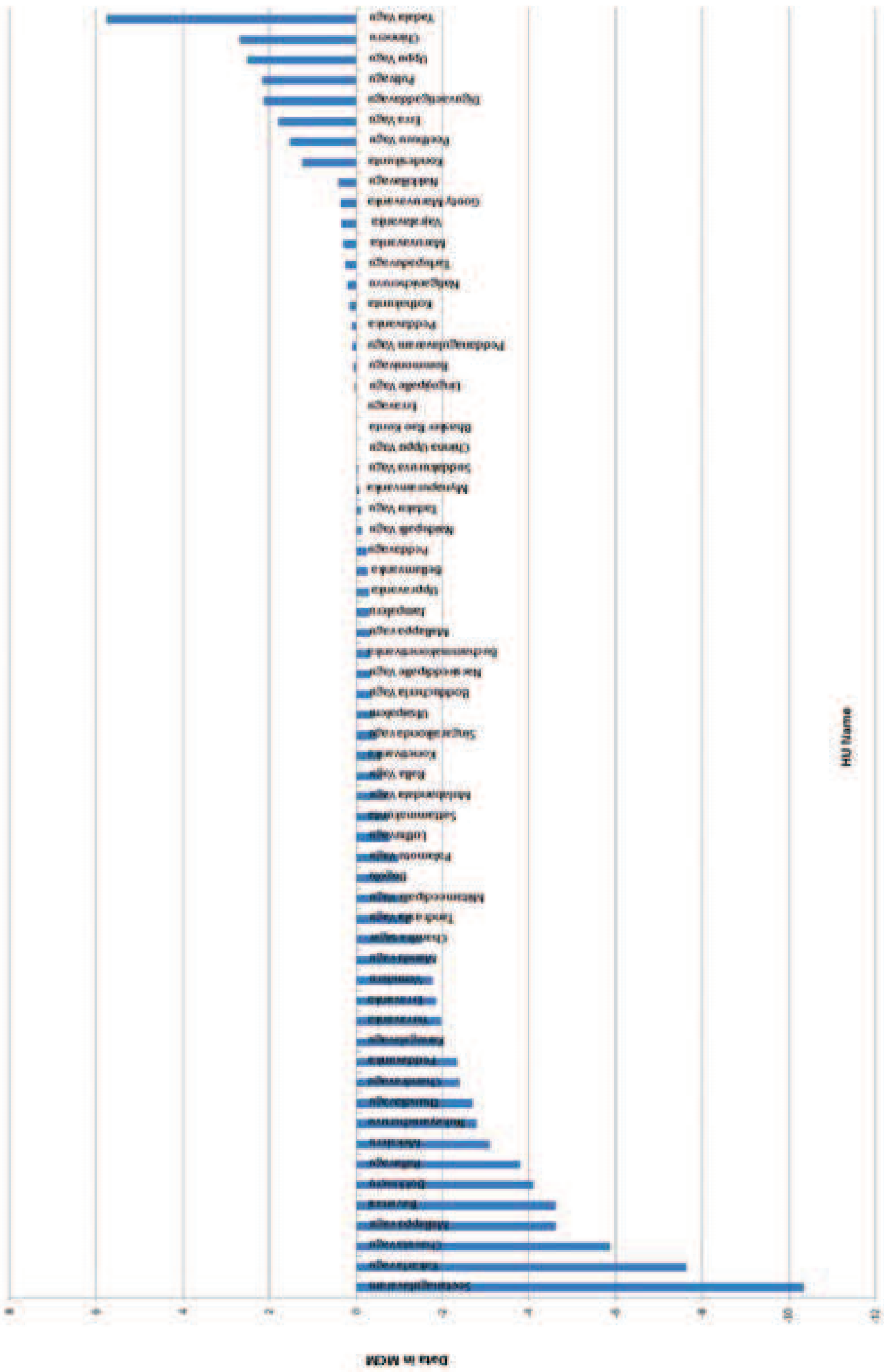
Withdrawal (MCM) = Crop 1 x Area (m*2*) x Crop-water requirement (m) + Crop 2 x Area (m^2) x crop–water requirement (m) + Crop 'n' x Area (m^2) x crop–water requirement (m).

As for the recharge estimation, the range of crop–water requirements recommended by Acharya NG Ranga Agriculture University is used as the basis for arriving at a suitable quantity of actual requirement, based on local soil and climate conditions. The agriculture scientist derives the value for each crop in consultation with local research institutions and farmers.

Annual withdrawal estimated for the hydrological years 2006–2011 is used for this analysis. First CWB was conducted at 34 HUs in 2005–2006, at 25 HUs in 2006–2007 and at four HUs in 2007–2008. The first year of CWB workshops is considered as the base year for this analysis. The average of the withdrawal recorded in later years is taken as the value of the assessment. The base assessment value is deducted from the base value, which tells us if the withdrawal has increased or decreased in a particular HU. Figure 4.3 shows the summary.

FIGURE 4.3

Graph showing average withdrawal during assessment years with respect to the base year



Of the 63 HUs, 43 show a decrease in the withdrawal during the assessment period, compared to the base year, while the remaining 20 show an increase. The withdrawal decreased by more than 50 percent at four HUs; 13 showed a decrease of 50–20 percent; 27 a decrease of 20–0 percent; ten HUs showed less than a 20 percent increase in withdrawal; seven showed an increase of 20–100 percent; and the remaining two HUs recorded an increase of more that 100 percent withdrawal. Withdrawal remained almost the same (+ or – 0.1 MCM) at another HU.

An estimation of groundwater balance is made using the crop adoption survey data and the results presented to farmers at a specifically organized workshop at the HU level in May. Estimation of balance requires using the actual values of recharge and withdrawal.

Withdrawal is influenced by the number of functional wells, well yield, pumping hours, area under well irrigation, as well as crop–water requirement. It is expected that people respond to the intervention by: not constructing new wells, reducing withdrawal by planting water-efficient crops and reducing the area under well irrigation; improving irrigation practices; use of water-saving devices and crop diversification.

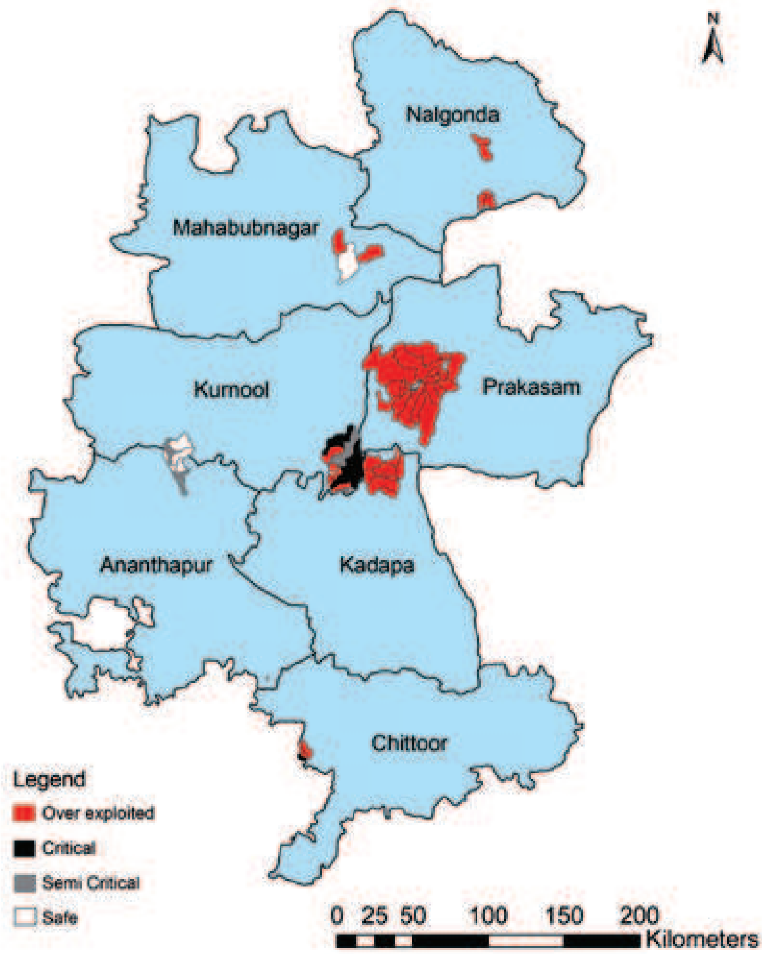
If the recharge is more than the withdrawal, the product has a positive value, referred to as a 'surplus'. On the other hand, if the withdrawal is more than the recharge, the product has a negative value, denoting a 'deficit'. Plus or minus 1 MCM difference of recharge and withdrawal is considered as 'matching' groundwater balance. See Annex 2 for the summary of results.

Groundwater balance is computed for a 6-year (2005–2011) assessment period and the 'Stage of Development' is calculated as a percentage of withdrawal to recharge. The categorization used by the CGWB is applied to group HUs, into 'Safe' (less than 70 percent development); 'Semi critical' (70-90 percent development); 'Critical' (90–100 percent development); and 'Over exploited' (more than 100 percent development).

The analysis reveals that: 50 (79 percent) HUs fall into the category of 'Over-exploited'; seven (11 percent) HUs can be classified as 'Safe'; three (5 percent) HUs are in the 'Critical category' and another three (5 percent) HUs are in the 'Semi-critical' category. Annex 3 shows categorization of HUs based on the stage of development. Figure 4.4 shows the location of HUs and their categorization in terms of stage of groundwater development.

FIGURE 4.4

Location of HUs showing different categories of 'stage of groundwater development'



HUs categorized as safe are: Chandrasagarvagu, Vajralavanka, Lothuvagu, Bellamvanka, Guthi-maruvavanka, Upparavanka, and Mynapuramvanka. HUs in the semi-critical category are Maruvavanka, Peddavanka and Thundlavagu. Under the critical category are the HUs Bhavanasi, Chinneru and Nakkillavagu. The remaining 50 HUs are in the over-exploited category.

HU typologies for in-depth studies

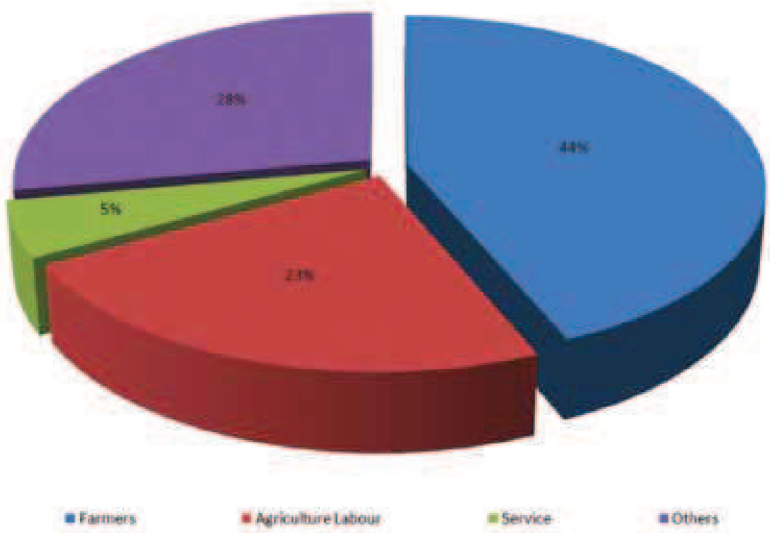
Four HUs were selected that match each of the four CGWB categories for stage of development. These are Chandrasagarvagu (Safe), Thundlavagu (Semi-critical), Bhavanasi (Critical), and Mandavagu (Over-exploited), which were chosen for the detailed farmer survey to investigate reasons for different responses of the groundwater systems. After the desk study, specific questions were framed and interviews conducted to record farmer's perceptions of the key issues.

4.2 People's response

Of an estimated total population of 600 421, in the PGM operational area, 67 percent depend on agriculture as their principle source of livelihood, across 63 HUs. While about 14 percent are landless, 3.5 percent are employees, 15 percent have other forms of livelihood sources (fishing, pottery, weaving, livestock rearing and masonry). There is a practice of farmers offering their services as farm labourers in other farmers' fields free of charge, which is reciprocated as and when required. Of agriculture-based farm families 39 percent are smallscale and 26 percent are marginal. While 18 percent of the population depends on agricultural work as their main source of income, 17 percent are classified as large-scale farmers (owning more than 5 ha). Figure 4.5 shows the breakdown of livelihoods in the PGM project area.

Figure 4.5

Pie-chart showing breakdown by main source of income in the PGM area



There is extensive outward migration from the PGM project area, involving around 59 percent of the population, specifically from Prakasam district. The next worst hit district was Kadapa, with 22 percent of its population migrating outwards. Other districts recording out-migration are Kurnool (8 percent), Mahbubnagar (4 percent), Anantapur (3 percent), Nalgonda and Chittoor (2 percent).

Construction of new wells

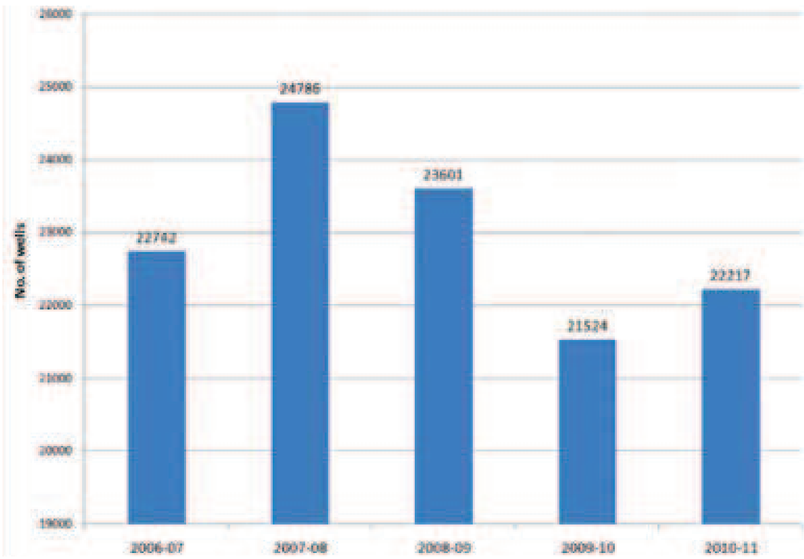
Shallow dug-wells, which are the lifeline of well irrigation, are drying up because of the lowering of the water table, which forced farmers to depend on shallow borewells and, in the following years, deeper borewells. Figure 4.6 shows the number of functional borewells across 63 HUs. Clearly there has been a consistent decrease of around 17 percent in the number of functional wells, from 25 112 in 2006 to 21 530 in 2010. Generally, this can be attributed to the lowering of the water table, causing marginal wells to fail. Partly, however, this may be the result of awareness generated by the project, which empowered farmers to make wise choices and to grow suitable crops with the water available.

Area under well irrigation

As mentioned, the demand for well irrigation is found to be highest during the rabi cropping season, and the project tried out its 'demand-side management of groundwater' to reduce water demand during this season.

Figure 4.6

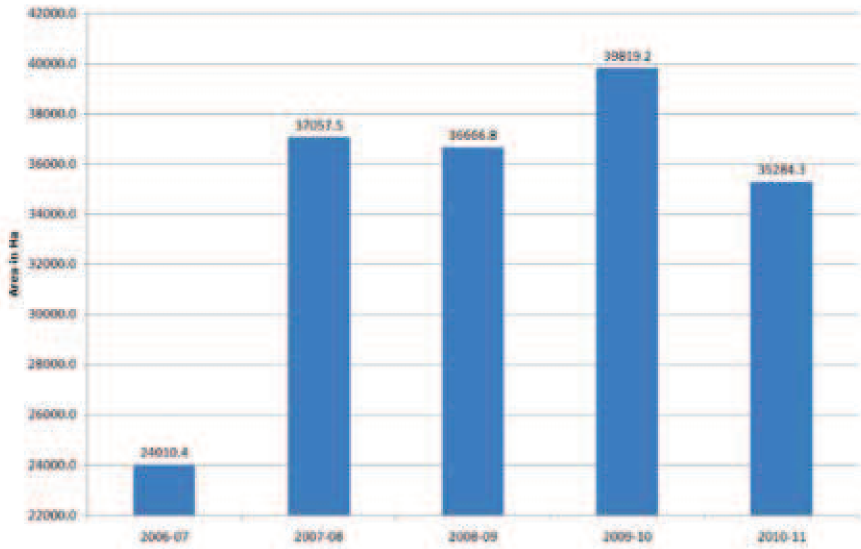
Number of functional borewells in PGM area 2006–2011



Note that the area covered by well irrigation increased by about 62 percent (22 675 ha in 2006 to 36 387 ha in 2010), in spite of the reduced number of functional borewells (Figure 4.7). Clearly this means farmers used fewer borewells to irrigate crops over a larger area by adopting crop-water efficient measures. The average area cultivated using borewells was 0.90 ha in 2006, which rose dramatically to 1.69 ha by 2010, almost double the area in 2006.

Figure 4.7

Hectares irrigated from borewells, in PGM area 2006–2011



Crop diversification

Across the 63 HUs the main winter crops are sunflower, groundnut, rice (winter), chilly and redgram. The area under sunflower increased steadily in 2009 and declined slightly in 2010. The popularity of groundnut increased substantially. Surprisingly, the area under rice cultivation also increased, probably because SRI was promoted and some intervention areas were brought under canal irrigation, for example Nalgonda and Kurnool. The area under sweet orange increased until 2007 then stabilized thereafter, as it is a perennial crop. There was a notable increase in areas under other minor crops including pearl millet, cotton, sugarcane, tomato, finger millet and sorghum, clearly indicating crop diversification (Figure 4.8).

Area under precision irrigation

Another important activity promoted by PGM was the use of water-saving devices such as drip systems, sprinklers, rain-guns; helped by links with ongoing government programmes. Moreover, the project promoted water-saving irrigation methods such as check-basin, etc.; these initiatives aspired to 'more crop per drop'.

Figure 4.8

Hectares under major crops in rabi season in the PGM area 2006–2010

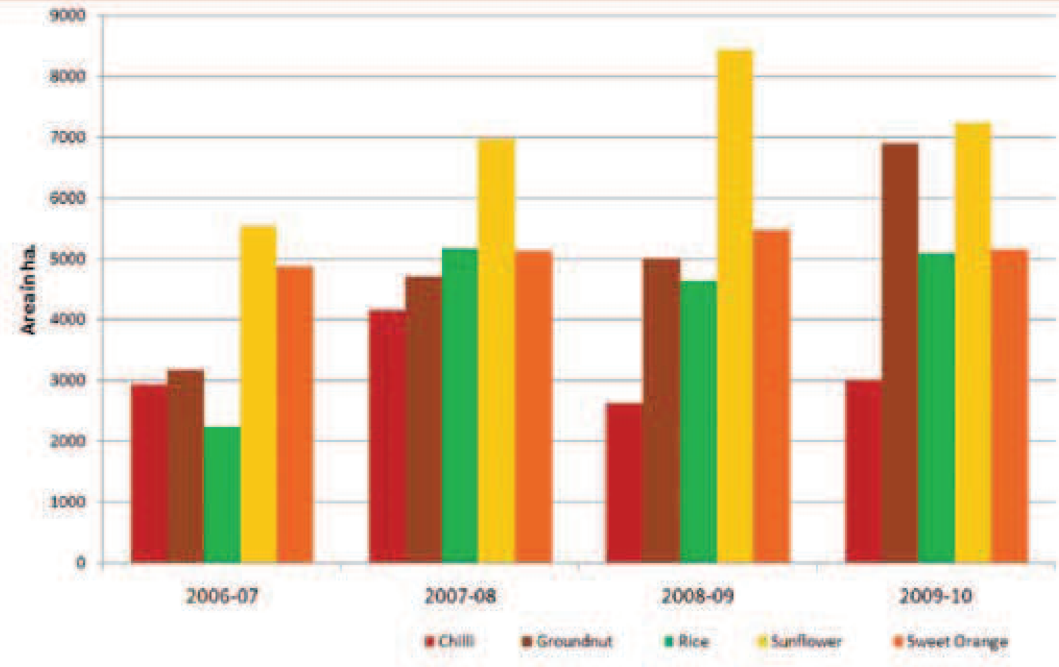


Figure 4.9 shows the area across 63 HUs under precision irrigation methods in rabi season increased from about 8 252 ha in 2006 to around 11 923 ha in 2010. There was a peak in 2007 of 14 364. The year after, farmers seemed to have switched back to flood irrigation, probably because of a good monsoon. The area was more or less maintained under precision irrigation methods in the following years. In 2010 about 30 percent of the total area irrigated with water from wells used efficient irrigation methods. In the same year, the area under water-saving irrigation increased by 44 percent across the project, as compared to 2006.

Figure 4.9

Hectares under efficient irrigation methods 2006–2010

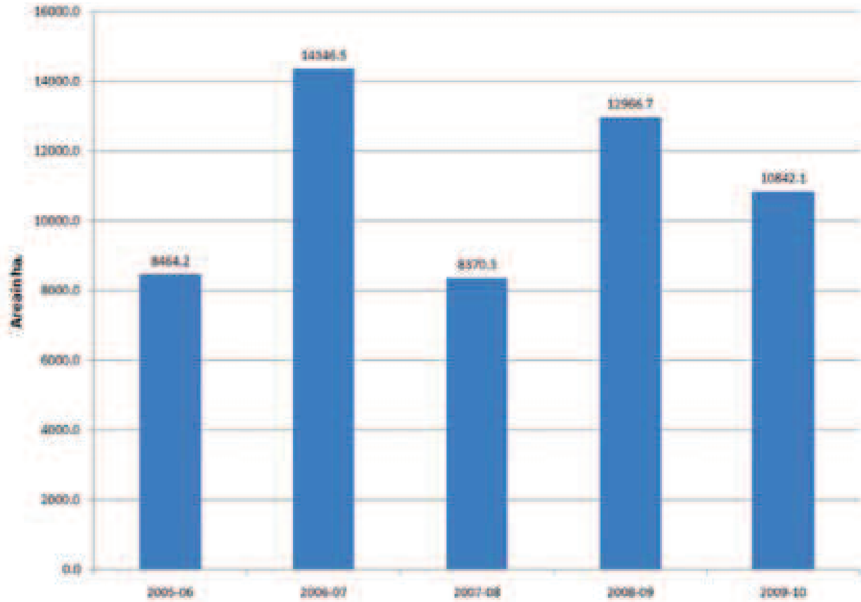


Figure 4.10 shows the area across 63 HUs under sprinkler irrigation, used mainly for sunflower, chilly and groundnut. The area under sprinkler irrigation increased from 551 ha in 2006 to 916 ha in 2010, an increase of about 58 percent.

Figure 4.10

Hectares under sprinkler systems in rabi season in the PGM area 2006–2010

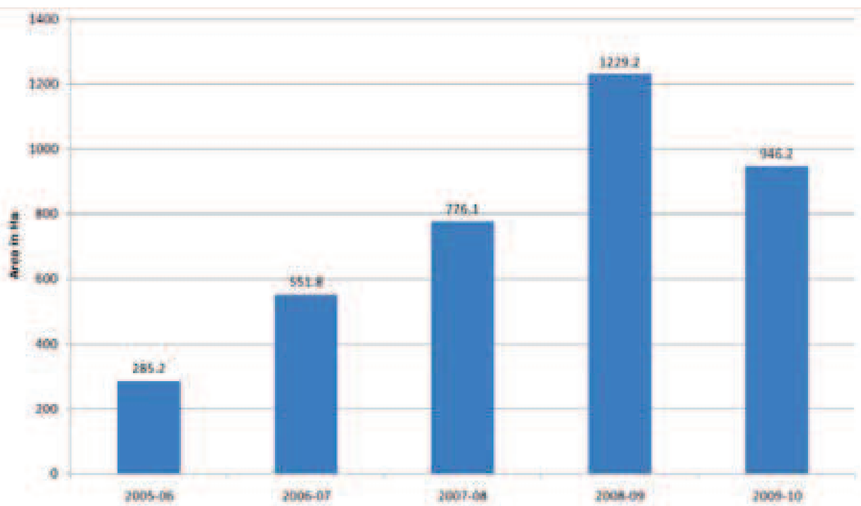
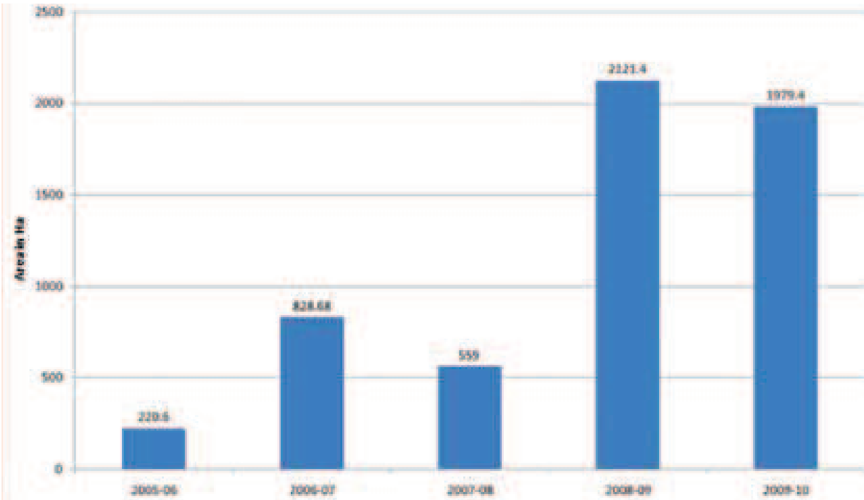


Figure 4.11 shows the area under drip irrigation, used for cultivation of horticulture crops such as sweet orange and mango, across 63 HUs. The area under drip irrigation increased from 804 ha in 2006 to 1 910 ha in 2010, an increase of 137 percent.

Figure 4.11

Hectares under drip systems in rabi season in the PGM area 2006–2010



As stated elsewhere in this publication the GMCs make decisions about the management of groundwater resources, mobilizing resources from government programmes for their members and engage in activities benefiting their members. In a number of cases, GMC members were elected members of the Panchayat Raj Institutions (PRI). These links benefited the entire groundwater farming community when funds were accessed not only for water-saving devices but also for general community development work. This brings to the fore the role GMCs can potentially play in overall local development.

HUN members are at the forefront of all development activities, thanks to their links with external institutions, built up over time. All 63 HUNs were legally registered by 2008. They play a critical role in dissemination of knowledge from the Project to the larger community of farmers beyond the project area. These institutions, exhibit a strong presence of women farmers, who have been trained to collect and analyse hydrological data. The literacy level does not hinder the community's capacity building, since there is a strong component of non-formal education.

Both HUNs and GMCs developed the confidence to request services from the government and, at the same time, were recognized as 'easy to reach and work with' interlocutors for service providers. Most community-based institutions continue to perform their tasks with distinction, their roles and responsibilities, based on the PGM model, as shown in Table 4.2. However, PGM was unable to build these institutions' capacities for marketing, market linkages, post-harvest management and processing.

Table 4.2

Roles and responsibilities of community based institutions

Activity	Responsibility of GMC	Responsibility of HUN
Data	Collection	Monitoring
	Storage	Analysis
	Dissemination	Storage and reports preparation
Meetings	Organize	Monitoring
Training	Organize FWS sessions	Monitoring
	Organize experiments	Planning and monitoring
	Organize CB training	Planning and monitoring
Workshops	Mobilize	Planning and organizing CWB, Field Day, World Water Day, World Food Day, and World Women's Day
Assets	Maintenance	Monitoring
Renewal		
Improved seeds	Implementation	Monitoring
Linkage	Identify, obtain	Identify, obtain
Resource mobilization	Identify, collection	Identify, collection

Farmers who collect and record hydrological data, understand the seasonal occurrence and distribution of groundwater in their habitations and HUs overall and can estimate recharge, withdrawal and balance, without external support. They have grasped the concept of groundwater as a common property resource and are willing to manage it for the collective good. This has been achieved through focusing on investment in capacity building and by demystifying science, without compromising the basic principles that empower farmers and community based institutions.

Community based institutions succeeded in establishing a clear correlation between groundwater availability and crop plans, thereby reducing the risks associated with conventional cropping. They provided a platform for farmers to collectively estimate the water balance at the HU level. They did not promote any type of crop, respecting farmer's traditional knowledge and his/her ability to make decisions beneficial to the health of the aquifer. Farmers take smart decisions to reduce groundwater withdrawal, without compromising profitability.

Demand for farmers' hydrological data had not been foreseen, although research and other agencies may be interested in purchasing data from the GMCs. The PGM phase was not able to prepare the community based institutions for this demand since, as the project had ended by the time the need was articulated by the research institutions, such as National Geophysical Research Institute (NGRI). It would be worth handling this issue cautiously, because money is involved, and management of community based institutions' finances could become an important function. NGOs have been mediating between the potential data buyers and HUNs for exchange of data. Sale of data was promoted to generate funds for operation and maintenance of PHM assets. It was not clear, at the time of writing, how far NGOs have been able to facilitate this data sale activity.

4.3 Response from the external environment

During implementation of the APWELL Project, policy advocacy was limited to the state level. APFAMGS, during its implementation, focused on popularizing project concepts and practices at all levels starting with the field, to district, state, national and international levels. The 'copy-left' strategy means all information generated by the project was immediately available on the Internet.

Field level

Several training and field visits were organized by Partner-NGOs at the district level for a variety of visitors from within the state, such as other states, national and international agencies. Among the distinguished visitors were His Excellency, Dr Bob Hiench, Ambassador, Netherlands Embassy; Theo. J.J. Groothuizen, Counselor, Head of Science and Technology Department at the Netherlands Embassy and Mr Hans Wolff, Agricultural Consultant, Mr Y. Rajasekhar Reddy, Honorable Chief Minister of Andhra Pradesh and Mr Shekhawat, Honourable Speaker of the Legislative Assembly of Rajasthan (Plate.4.1).

Plate 4.1

Photo of visitors

State level

APFAMGS, at the state level, was involved in the capacity building of state level agencies by conducting dedicated training programmes on demand-side groundwater management (Plate 4.2). This helped diffuse project components across several states in India. Among others, APFAMGS trained the Andhra Pradesh State Groundwater Department (APSGWD); Rural Water Supply and Sanitation Department, Andhra Pradesh; Irrigated Agriculture Modernization and Water Resources Management (IAMWARM), Tamil Nadu; Irrigation Management Training Institute (IMTI), Tamil Nadu; Groundwater Department, Government of Rajasthan; Water Supply and Sanitation Department, Government of Maharashtra; Department of Water Resources, Government of Orissa and 15 Members of the Legislative Assembly and the Honourable Speaker of the Legislative Assembly, Government of Rajasthan.

The key consultants made presentations at the State Level Workshop, under the European Union State Partnership Programme, organized by the Ground Water Department, Ministry of Water Resources, Government of Rajasthan and the Workshop on *Drinking water security and sustainability in Maharashtra*, Groundwater Survey and Development Agency (GWS & DA), Government of Maharashtra.

National level

Policy Advocacy at the national level was organized through participation at national workshops, papers were distributed, presentations were made and new partnerships were created.

A paper *Participatory Hydrological Monitoring (PHM) – An effective tool for community managed groundwater systems*, was presented at the National Conference on Land Resource Management for Food, Employment and Environmental Security. The workshop was sponsored by the Department of Land Resources, Ministry of Rural Development, GOI, and organized by the Soil Conservation Society of India. The paper is included in the main theme session – *Implementation, monitoring and evaluation*. The paper was published by the organizers in the Volume, *Advances in land resource management for the twenty-first century*. This publication connected the PHM pilot, for the first time, to the outside world.

The key consultants participated in national level workshops at the Watershed Summit, Chandigarh, under the World Bank Integrated Watershed Development Project, organized by the Department Agriculture, Government of Haryana (India); GEF National Dialogue in India, Ministry of Environment and Forests (MoEF), Government of India; Drinking Water Security Pilot Programme Workshop, Pune, organized by the Government of India, Ministry of Rural Development, Department of Drinking Water Supply; National conference on land resource management for food,

Plate 4.2

Demand-side groundwater management (DSGM) training

employment and environmental security, Soil Conservation Society of India, New Delhi.

The APFAMGS approach to community involvement attracted the attention of many national and international agencies. An invitation was extended to make a presentation to the Parliamentary Forum for Water on the methodology and achievements of the APFAMGS Project. The hour-long presentation was followed by discussion. The parliamentary forum on water involved distinguished parliamentarians who have handled this subject over the years. Based on the presentation, enquiries about the project have arrived from the State Governments of Bihar and Gujarat.

International level

Policy advocacy at the international level was organized through international training and workshops; guiding international research students; participation at global events; sending papers; making presentations and forging new partnerships.

In 2005, Training/Exposure to *Demand-side management of groundwater* was organized for 18 high-ranking officers from the Government of Afghanistan. The International Learning Workshop on community-led groundwater management was organized for participants from 16 countries. Demand-side management of groundwater was presented to four high-ranking officers from the Royal Government of Bhutan, and four International students, working on community based groundwater management, worked with APFAMGS.

Another important method used by APFAMGS was to invite the participation of key consultants to international events including the *Dialogue on water for food and environmental security*, Colombo, Sri Lanka; the Fourth World Water Forum (Mexico); Fifth World Water Forum (Turkey); Sixth World Water Forum (France); the IPTRID Secretariat, FAO (Malaysia); International Conference on Agrarian Reform and Rural Development (ICARRD): *New challenges and options for revitalizing rural communities, 7–10 March 2006, Brazil; Workshop on monitoring and evaluation of capacity development strategies in agriculture water management*, the International Programme for Technology and Research in Irrigation and Drainage, FAO (IPTRID) Secretariat, FAO, Rome, 2007; 2–4 December 2009, at the *Bazaar of Ideas*, supported by the Committee on Environment and Development, Bangkok, organized by the United Nations Economic and Social Commission for Asia and Pacific (UNESCAP), Thailand; the United States Committee on Irrigation and Drainage (USCID) Fourth International Conference on Irrigation and Drainage, International Commission on Irrigation and Drainage (ICID)–Copenhagen Institute for Interactive Design (CIID), Sacramento, California, United States; World Water Week (Sweden) and the international symposium on agro-meteorology and food security, organized by the Central Research Institute for Dryland Agriculture (CRIDA), India', which provided an opportunity for showcasing the success of the PGM model worldwide (Plate 4.3).

The World Bank conducted an evaluation study, mid-way through the implementation of APFAMGS, in partnership with the Delhi School of Economics and the Hyderabad Central University. The results of the study were published as *Deep wells and prudence* (World Bank, 2009), which became a reference point on APFAMGS for many global players in the water sector.

Diffusion

During the implementation period, APFAMGS focused efforts on popularizing project concepts and practices at the field, district, state, national and

Plate 4.3

Participation in international events to showcase PGM model

international levels. The ‘copy-left’ strategy guaranteed all information generated by the project was immediately posted on the Internet. Copy-left proved effective for promoting project ideas with other programmes and projects, which ensured their diffusion as they were being generated. Some are briefly described below.

There has been an overwhelming response from the external environment. The PGM approach has been incorporated into the publication of the Planning Commission of India, with the title: *Faster, sustainable, and more inclusive growth: an approach to the Twelfth Five-year Plan* (2012-2017), under paragraph 5.10 (pages 46-47), describing stakeholder aquifer management. Common guidelines for watershed development projects (2008), issued by the Government of India, which is presently popular, page 7, paragraph VI – Cluster approach, envisages a broader vision of ‘geo-HUs’ of the average size of 1 000 to 5 000 ha, comprising a cluster of micro-watersheds.

The Andhra Pradesh Community Based Tank Management Project (APCBTMP), funded by the World Bank, was implemented by the Irrigation and Command Area Development Department in association with the Andhra Pradesh State Ground Water Department (APSGWD). The Project adopted the PHM approach for its programme, which rehabilitated 2 000 medium irrigation tanks that irrigate an additional 2 500 ha.

The PHM component of this programme replicates the PHM approach, which established 281 rain gauge stations, 1 500 observation wells using PHM technical specifications; three PHM training modules were adapted to strengthen the capacity of groundwater users in the tank command and zone of influence. The borewell user associations, based on the APWELL model, are formed by representatives who are also members of the tank water user associations, by Government Order 160; twenty-eight government officers from APSGWD, who were trained by APFAMGS in Demand-side management of groundwater, currently hold key positions for project implementation; 12 Training Resource Persons (TRPs), six Assistant Project Directors, and one State Coordinator, employed by the Project, worked and was trained by APWELL/APFAMGS.

The Community Managed Hydrological Monitoring and Water Management Programme is supported by NABARD in association with the Foundation for Ecological Security (FES), established by the National Dairy Development Board (NDDB), working in 16 districts (439 watersheds) in Andhra Pradesh. This programme involved the watershed community and promoted understanding and monitoring of changes related to watershed development, based on the PHM approach; adaptation of suitable cropping pattern, based on the CWB approach and hired three APWELL/APFAMGS staff.

The World Bank funded, *Andhra Pradesh water sector improvement project* was launched to pilot the concept of conjunctive use of surface and groundwater, implemented by the Irrigation and Command Area Development Department (I&CAD), Government of Andhra Pradesh (GoAP). This project incorporates the PGM tools including PHM and crop–water budgeting, in Nagarjuna Sagar canal command in Guntur, Nalgonda and Khammam districts.

The pilot programme on *Vulnerability assessment and enhancing adaptive capacity to climate change in semi-arid areas* is supported by the Swiss Agency for Development and Cooperation (SDC) uses PHM and crop–water budgeting for adaptive use of groundwater, which is implemented in two villages in Mahbubnagar district.

Andhra Pradesh Drought Adaptation Initiative (APDAI), implemented in 14 villages in Mahbubnagar and ten villages in Anantapur, is a World Bank project, which extensively uses PHM and CWB tools, assisted by three personnel trained by APFAMGS.

National Agriculture Innovation Project (NAIP), through the Central Research Institute for Dryland Agriculture (CRIDA) is guided by two people trained by APFAMGS, in the use of PHM and CWB concepts in one Gram panchayat (five habitations) in Medak district.

The European Union funded sustainable agriculture and groundwater management is implemented by the Centre for World Solidarity (CWS), using PHM and CWB tools to mainstream unauthorized tapping of electricity for agriculture and to provide support for the laying of power lines and installation of transformers, assisted by one person trained by APFAMGS.

Moreover, other initiatives in the pipeline, being developed based on the key PGM tools, include the new AP Groundwater Bill, which draws heavily on the PGM approach; the World Bank Water and Sanitation Programme for *Village water security plan* and the Rural Development Department of GoAP is contemplating the introduction of PHM and CWB approaches into the Integrated Watershed Management Programme (IWMP) and Comprehensive Land Development Programme (CLDP), referred to as Indira Jala Prabha (IJP).

Chapter 5: Specific Responses

The general response of aquifer systems and aquifer users to PGM described in Chapter 4 masks many local variations, conditioned as much by the geology and recharge characteristics as the variability in the socio-economic capacity of users. To refine this assessment of the impact of PGM in Andhra Pradesh, a short survey based study was undertaken in 2012 to illustrate the variability across the State. As a first step, the farmer databases were accessed and a desk study carried out. Four HUs were selected, one matching each of the four CGWB categories for stage of development Chandrasagarvagu (Safe), Thundlavagu (Semi-critical), Bhavanasi (Critical), and Mandavagu (Over-exploited) were chosen for a detailed farmer survey to investigate the reasons for the varied responses of the groundwater systems. Specific questions were framed and interviews conducted to record farmer's perceptions of the key issues by means of a *post facto* farmer survey (see the questionnaire in Annex 4), to investigate reasons for the various responses of the groundwater systems. After a description of each of the case study HUs, this Chapter presents a summary analysis.

5.1 Chandrasagarvagu: 'Safe' category

The Chandrasagarvagu HU (Figure 5.1) is located in the eastern part of the Mahabubnagar district of Andhra Pradesh. It lies between the northern latitudes 16° 26′ 00′ and 16° 11′ 16′ and eastern longitudes 78° 35′ 42′and 78° 43′ 58′, and forms part of the Survey of India topographic maps 56 L/11 and L/12 (scale 1:50 000). The HU covers a geographical area of 20 650 ha of nine Gram panchayats: Choutapally, Gumpenapally, PN Laksmapur, Bolgatpally, Nadimpally, Polisettipally, Banala, Lakshmipally and Kondnagula. The first five Gram panchayats form part of Achampet mandal, while the second group of four falls under Balmoor mandal and the last Kondanagula is part of Amarabad mandal.

Figure 5.1

Map of Chandrasagarvagu hydrological unit

The highest elevation in Chandrasagarvagu HU is 875 m above mean sea level (msl), located to the southeast, while the lowest is about 400 m above msl, located north of Nadimpally village. On the western plains, the slope is less than 1 to 2 percent, while slopes of 40–20 percent are common to the east. Chandrasagarvagu originates in the hill ranges to the southeast, covered by the Nallamalla Reserve Forest and flows roughly in a northeasterly direction, for about 26 km, before merging into Chandrasagarvagu, northeast of Kondanagula village. The stream flows to meet Dindi, a tributary of the

Krishna river. Chandrasagarvagu gains from the flows of small streams with local names: Jabbunivagu konakuntavagu, Kadudulla, Amudalavanmpu, Yerrakunta vanmpu, Mutchalavanmpu, Chakalonivanmpu, Varakasaguvanamp, Thelsakuntavagu, Ipplavagu, Peddabavikuntavagu and Ruthukunta vagu.

The surface flow of Chandrasagervagu is intercepted by 14 small irrigation reservoirs, one of which, Rusul Cheruvu, is located in the southern part of the HU, and serves a command of about 3 000 ha. The remaining 13 tanks in the HU are located in the western part of the HU (see Figure 5.2 for the drainage map).

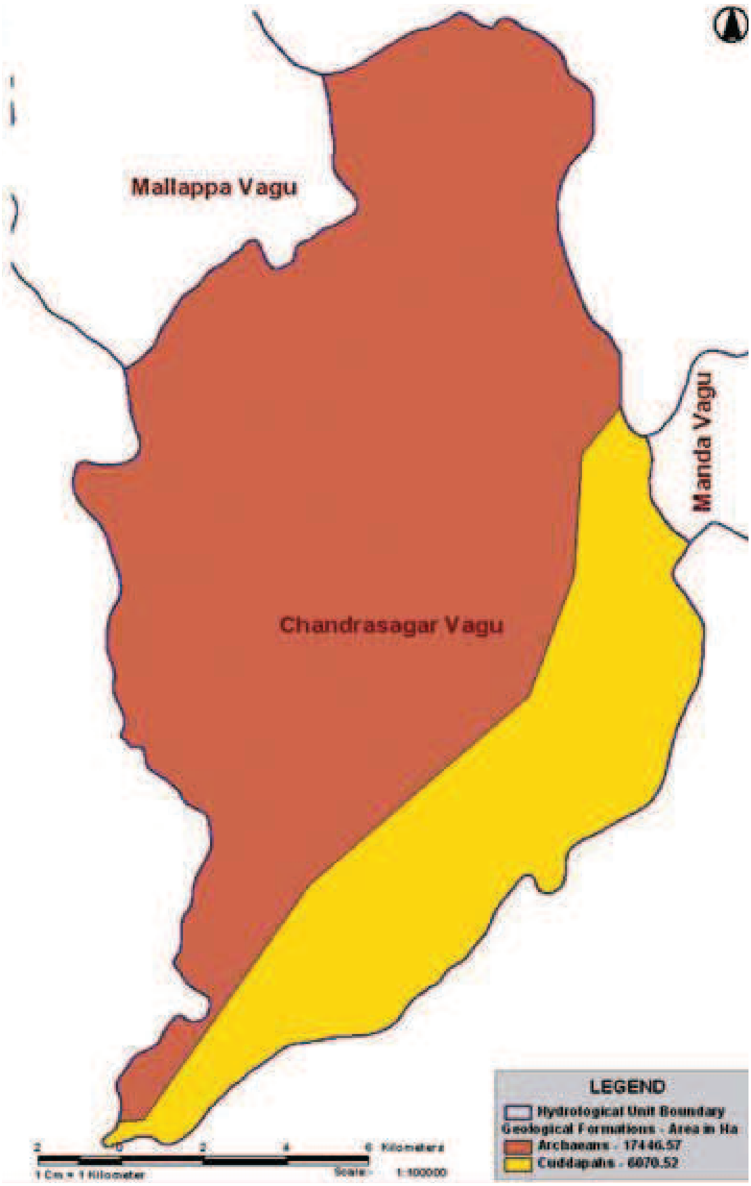
Figure 5.2

Drainage map of Chandrasagarvagu hydrological unit

The Chandrasagarvagu HU is underlain by Archean crystalline rocks of the Dharwar Group, belonging to the azoic age, comprised of granites, gneisses and schists, in the northwest (see Figure 5.3 for the geological map of the area). The rocks of the Dharwar Group are subjected to fracturing and jointing and are traversed by intrusions of quartz veins. The southwestern part of the HU is underlain by Shrishailam quartzite of the Kurnool group of the Proterozoic age, striking in a NNE-SSW direction and dipping towards the east at an angle of 35 to 40°.

FIGURE 5.3

Geological map of Chandrasagarvagu hydrological unit



Both the granitic as well as quartzitic rocks lack primary porosity. In granites, the recharge is determined by the extent of weathering and fracturing. As groundwater occurs mostly in unconfined, sometimes semi-confined conditions in granites, the thickness of weathered and fractured zone become very important in terms of their recharge capacities. The shallow aquifer in the HU has a weathered mantle of crystalline rocks ranging from 1 to 25 mbgl. The majority of the aquifer zone encountered is within the depth range of 15 to 25 mbgl. The shallow aquifer system is generally tapped for irrigation by wells dug down 12 to 20 m and dug-cum-bore wells to 40 mbgl. The yield of dug wells ranges between 180 and 250 m^3/day. The transmissivity values range from 15 to 50 m^2/day.

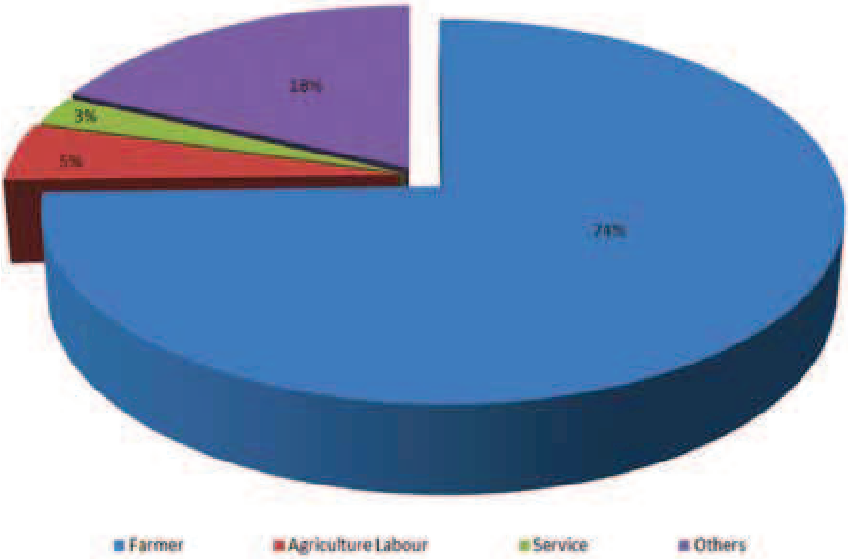
Direct processes dominate the recharge pattern in the HU, i.e. deep percolation and soil moisture drainage. The indirect recharge processes such as: transmission losses through deep-cut canals; and secondary recharge through intensive irrigation (mainly because of standing water in rice cultivation) are negligible, in the HU. The Groundwater Estimation Committee (1997) gives a recharge rate of 11 percent for "weathered granite, gneiss and schist with low clay content". Quartzites are massive/hard with no, or minimal, joints. GEC 97 gives a recharge of rate of 1 percent for "massive poorly fractured rocks". Therefore, the recharge area in Chandrasagarvagu is restricted to its northwest, where granitic rocks occur, covering an area of 20 650 ha.

The deeper aquifers are developed, in Archean crystallines, by constructing bore wells to a depth of 100 m. The deep exploratory drilling revealed that fractures are vertical to subvertical and horizontal in their disposition. It is observed that about 80 percent of major aquifer zones are encountered between 25 and 70 m; and 15 percent of fracture zones are encountered from 70 to 150 m depth. Deeper than 150 m aquifers are rare, except along major lineaments and deep valleys. Discharge from successful wells ranges from between 3 to 5 litres/s.

The total population inhabiting Chadrasagarvagu HU is 23 911, of which 12 126 women and 11 785 men, with a sex ratio of 1 029 women for every 1 000 men. Of the total geographic area, only 63 percent is arable, 6 percent wasteland and the remaining 31 percent is covered by forest. The main source of livelihood is agriculture (74 percent) and agriculture labour (5 percent). Figure 5.4 shows the breakdown of livelihood sources in the HU. APWELL provided 39 community borewell irrigation schemes to eight villages in the Chandrasagar HU (source: Base document).

Figure 5.4

Pie-chart showing breakdown of livelihoods by main source of income in Chandrasagarvagu HU



A total of 24 farmers, including eight women, covering five habitations in Chandrasagarvagu, were interviewed. Of these 37 percent of respondents said they benefited from APWELL, while 87 percent were borewell owners, 63 percent of farmers constructed wells on their own. Further, 13 percent of respondents did not have borewells for irrigation, but leased a well to irrigate their land. A desk review reveals the number of functional borewells in Chandrasagarvagu increased from 644 in 2005–2006 to 682 in 2010–2011, amounting to a 6 percent increase overall in the number of functional wells. There were 16 non-APWELL borewell owners, while 38 additional borewells were drilled.

Average well discharge, in Chandrasagar vagu, seems to have remained stable at about 0.50 litres/s in 2006–2009. Well discharge peaked during 2005–2006 and 2009-2011 at about 2.3 litres/s. Chandrasagarvagu began with an average of 840 annual pumping hours in 2005–2006, which drastically reduced to 720 hours per annum in 2006–2007, which remained constant, probably for the same reasons as for Mandavagu (See Section 5.4).

A total of 96 percent of respondents said they participated in crop–water budgeting, while 92 percent said they changed crops after participating in PGM under the APFAMGS project. Crops grown prior to participation in crop–water budgeting included rice 20 percent; groundnut 11; castor 23; sorghum 21; maize 12; millets 7 and other crops 6 percent. The cropping system changed greatly after participation in crop–water budgeting, October 2006. The area under rice cultivation and sorghum decreased from 20 to 12 percent and from 21 to 5 percent, respectively; the area under groundnut increased from 11 to 28 percent; cotton increased from 2 to 23 percent and maize increased from 12 to 25 percent. The area under other crops slightly increased from 6 to 7 percent. The desk study revealed that the main rabi crops in 2005–2006 were rice 24 percent, groundnut 74 and other 2 percent. There seems to have been a clear shift in cropping pattern in 2010–2011, where the area under rice drastically decreased from 24 to 13 percent; groundnut cultivation slightly reduced from 74 to 70 percent and farmers clearly shifted to other crops from 2 to 17 percent.

Reasons given for changing crops were: 1) to reduce groundwater withdrawal (29 percent); 2) benefit from good market price for the new crop (27 percent); 3) mono-cropping is harmful to the soil and crop yield (24 percent) and 4) unable to manage pests (20 percent).

The farmer survey revealed annual incomes ranged from INR 3 000 to 80 000 per annum, before changing crops and increased dramatically ranging between INR 15 000 and 300 000 per annum after. All farmer respondents reported a general increase in their income level as a result of crop changes. A two to three-fold increase in income was reported by 45 percent of the respondents, while 21 percent reported a three to four-fold increase; 17 percent of respondents reported a two-fold increase and an equal percentage said their income increased by more than four-fold.

To the question: What was the general water level in your village, prior to CWB? Farmers' responses fell into two groups: 17 percent said the water level was less than 6 mbgl, while 83 percent grouped water levels in the class 6–18 mbgl. The farmer survey revealed that for the perceived current water levels, 17 percent perceived the level as below 10 mbgl; 75 percent 10–20 mbgl; and 8 percent said 20–30 mgbl. This may be interpreted as, water levels in general remained stable between 6–20 mbgl. Static water levels recorded in 45 production-cum-monitoring wells, measured in May (the driest month of the hydrological year), and in October (the start of the monsoon crop season) also showed a 'stable' trend.

Respondents stating that pumping did not cause water level depletion were 71 percent, while 29 percent took responsibility for general water level depletion in the HU. The responses to the question: What are the reasons for water level depletion? Were: 1) reduction in rainfall received (56 percent); 2) over withdrawal (30 percent) and 3) deforestation (14 percent).

When asked, What are you doing to reduce pumping from wells? Responses were: 1) using sprinklers and drip (43 percent) and suitable irrigation practices such as check-basin, ridge and furrow and mulching (57 percent). To the question: How much money did you save through water-saving measures [8]? The response was: 1) can't say (53 percent); INR 10 000 to 40 000 (29 percent);

8 Here water saving measures discussed in the survey included: sowing across the slope; ridge and furrow; alternative furrow; check-basin, compost application, and green manure application.

3) INR 40 000 to 80 000 (14 percent) and 4) INR 80 000 to 120 000 (4 percent). While 75 percent of respondents believed their wells would be sustainable in a drought year, the remaining 25 percent were skeptical.

It is interesting to note from the desk study that the area irrigated from wells increased by 4 percent (955 ha in 2005–2006 to 985 ha in 2010–2011). This may be because of a 6 percent increase in the number of functional wells. Average area cultivated under borewells was 1.48 ha in 2005, which was almost the same (1.44 ha) in 2010.

A total of 14 percent of respondents said they were engaged in APFAMGS as PHM volunteers, 5 percent in HUN, while 62 percent took part in GMC activities, 19 percent were involved with both GMC and HUN. To the question: Do you continue to get involved in GMC/HUN activities? 89 percent said yes and 11 percent said no. To the question: What are your interests in supporting GMC/HUN? The responses were: 1) to improve our knowledge and skills (36 percent); 2) crop–water budgeting (15 percent); 3) improve my understanding of the groundwater system (8 percent); 4) stage of information sharing (23 percent); 5) agriculture practices (13 percent); and 6) to promote implementation of the APWALTA Act (5 percent).

The GMC was given a ‘good’ rating by 30 percent of respondents, while 57 percent rated it as ‘average’, and the remaining 13 percent considered performance as GMC ‘poor’. Then 22 percent of respondents gave a ‘good’ rating for HUN, while 39 percent rated it as ‘average’, and the remaining 39 percent considered HUN performance ‘poor’.

Chandrasarvagu is considered ‘Safe’ because: 1) Conditions are favourable for good groundwater recharge (medium size; 74 percent of the area is under the litho-unit favourable for recharge; a surplus balance of +25.98 MCM, highest of the four HUs studies). 2) Chandrasagarvagu recorded a 14 percent decrease in withdrawal during 2006–2007, compared to the base year; 2005–2006: 6 percent decrease in functional wells; negligible decrease (0.3 percent) in unit area under well irrigation; 8 percent decrease in area under rice; 17 percent increase in area under irrigated dry crops; 43 percent increase in area under water-saving devices and 57 percent increase in the area under precision irrigation practices; farmers’ attraction to higher returns from alternate crops are indicated by increased income, reported by 100 percent of respondents. 3) The ‘poor’ rating for GMC was given by 13 percent of respondents, and HUN 39 percent, which is the highest poor rating recorded for the farmer survey for the four HUs, indicating farmers’ lowest level of dependency on community based institution advice. 4) The categorization is in line with the ‘stable’ trend for static water level, confirmed by 62 percent of farmer respondents.

5.2 Thundlavagu: 'Semi-critical' category

The Thundlavagu HU is located in the southeast of Kurnool district, Andhra Pradesh. It lies between the northern latitudes 15° 20′ 55′and 15° 6′ 5′ and eastern longitudes 17° 44′ 45′and 17° 32′ 30′, and forms part of the Survey of India topographic maps 57 I/11 and I/12, mapped on the scale of 1:50 000. Figure 5.5 shows the location of the Thundlavagu HU, which covers a geographical area 17 487.5 ha with four Gram panchayats: Narasapuram, Chittarenipalli, Alamur and Mittapalle. The first three GPs form part of Rudravaram mandal, while the last is part of Allagadda mandal, in Kurnool district of Andhra Pradesh.

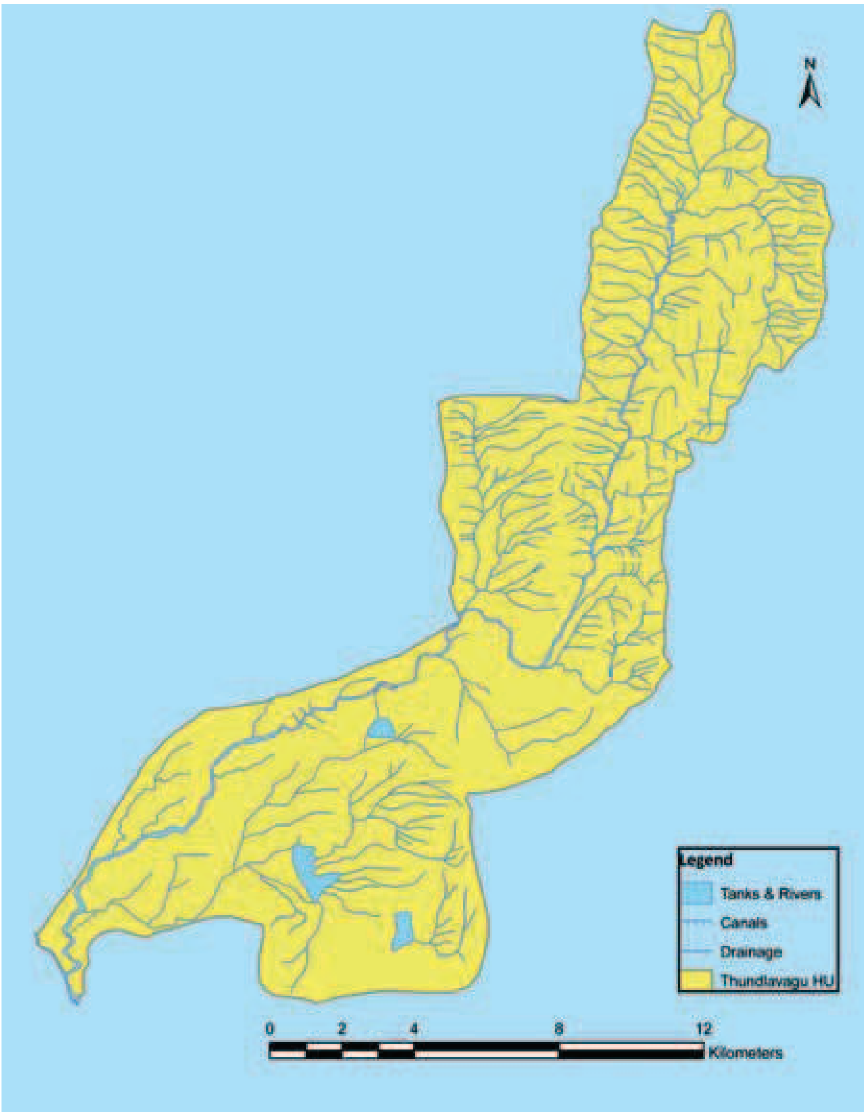
Figure 5.5

Map of Thundlavagu hydrological unit

The highest elevation in Thundlavagu HU is 785 m above msl is in the northeast, while the lowest is about 164 m above msl, located southwest of Kalugotlappalle village. The general slope is towards the southwest, and on the southern plains, the slope is less than 1 percent, while slopes of 40–20 percent are common in the northern hills. Thundlavagu stream originates in the southern hill ranges, covered by the Sirvel Reserve Forest and flows roughly towards the southwest, merging with the Vakkileru stream (near Yadawada village), which ultimately meets Kunderu, a tributary of the Pennar river. The surface flow of Thundlavagu is intercepted by three reservoirs: Yerracheruvu, Mittapallecheruvu and Alamurucheruvu (serving a command of about 120 ha). The other two major tanks in the HU are located in the southwestern corner of the HU, referred to as Yerracheruvu and Vanipentacheruvu, serving commands of 150 ha and 250 ha, respectively: Figure 5.6 shows the drainage of Thundlavagu stream.

FIGURE 5.6

Drainage map of Thundlavagu hydrological unit

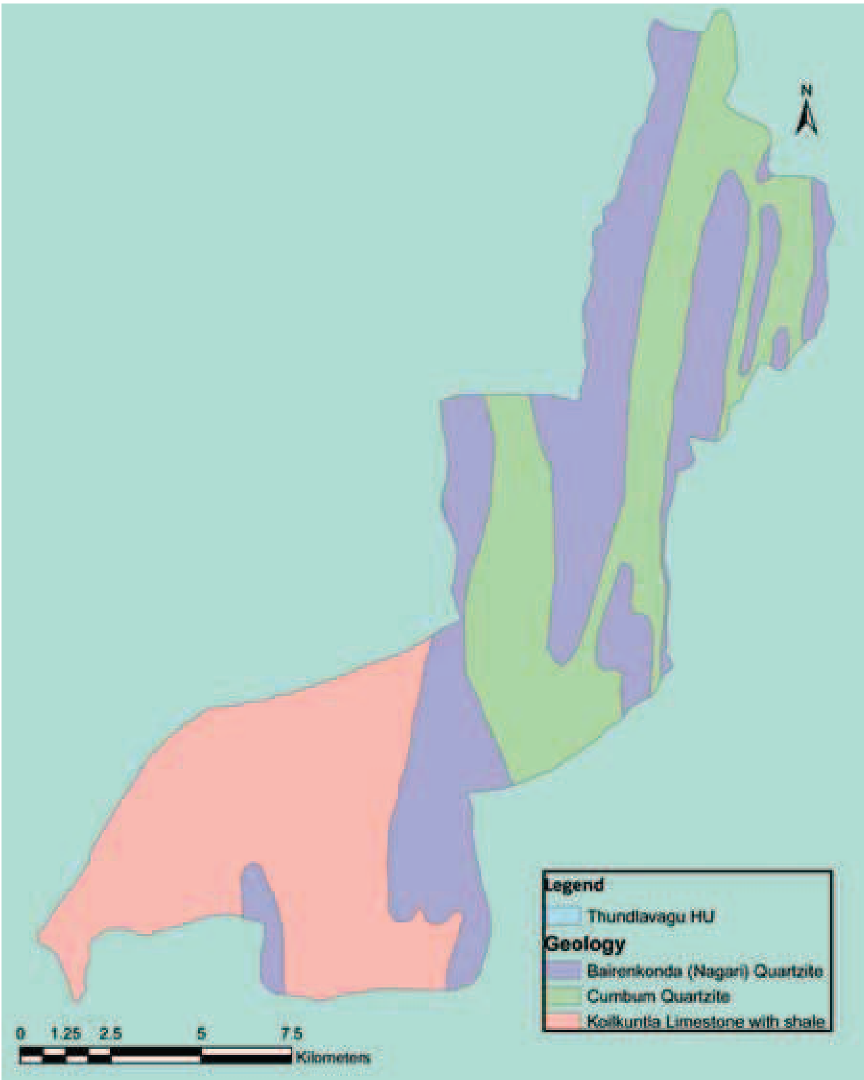


The Thundlavagu HU is underlain by the Cuddapah Group of rocks of the Proterozoic age and Kurnool Group belonging to the Late Proterozoic period. The geology of Thundlavagu is further detailed in Figure 5.7, derived by superimposing the geological layer of the Geological Survey of India over the boundary layer extracted from the Survey of India toposheet. The Cuddapah Group rocks in the HU are represented by the Nallamalai suite of rocks, which make up the lower Bairenkonda (Nagari) formation and the upper Cumbhum (Pullampet) formation. The Kurnool Group of rocks lie uncomformably over the Nallamalai group represented by the upper members of the Group, the Koilakunta and Nandyal formations.

The Bhairankonda formation is made up of quartzites with shale intrusives, the formation is about 4 000 m thick. The Cumbhum formation in the HU is represented by quartzites. Kurnools underlie the western part of the Thundlavagu HU, comprised of Koilakuntla limestone with intercalations of shale, exposed mainly in the central part, followed by Nandyal shale forming the western tail of the HU. Average thickness of Koilakuntla limestone with shale varies from 15–50 m, while Nandyal shale is between 15–100 m thick.

Figure 5.7

Geological map of Thundlavagu hydrological unit



The Cuddapah and Kurnool Groups are categorized as hard rocks that lack primary porosity and permeability and the occurrence of groundwater is dependent on the extent and thickness of secondary permeability developed in the superficial weathered and fracture zones. In the Thundlavagu HU, the area underlain by quartzites is confined to uplands and hilly areas under forest cover. Groundwater in Koilakuntla limestone-shale and Nandyal shale occur under unconfined conditions in the top weathered, fractured and karstified zones. The presence of karstic caverns and conduits in this limestone can result in very high yields from some wells.

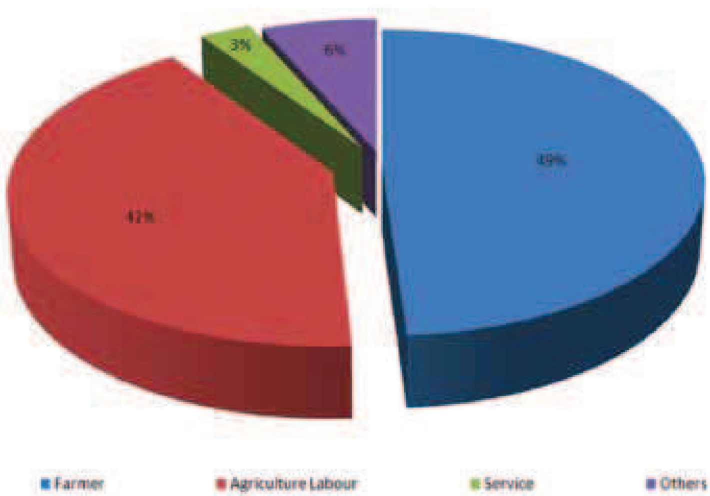
Exploratory drilling by CGWB in Koilkuntla and Nandyal formation, in the range of 27 to 74 mbgl, yielded between 3.5 to 13 litres/s, with a drawdown of 0.56 to 13.3 m. Transmissivity of these formations range between 67–1 910 m^2/day. The regolith of shale is red clayey soil, while black soil is the result of limestone weathering. Red sandy soil is seen in the foothills of the quartzite hills or plateaus. Mixed red and black soils are common in Koilkuntla limestone-shale areas.

Direct processes dominate the recharge pattern in the HU, i.e. deep percolation and soil moisture drainage. The indirect recharge processes such as: transmission losses through deep-cut canals; and secondary recharge through intensive irrigation (mainly because of standing water in rice cultivation) are negligible in the HU. The Groundwater Estimation Committee (1997) gives a recharge rate of 8 percent for “consolidated sandstone, quartzite, limestone (except cavernous)”. The recharge area in Thundlavagu, where such rocks occur, cover 5 842 ha. Quartzites are massive/hard with no or minimal joints. GEC 97 gives a recharge of rate of 1 percent for “massive poorly fractured rocks”. The recharge area in Thundlavagu, where such rocks occur, cover 12 283 ha. The total area of recharge in Thundlavagu is thus an estimated 18 125 ha.

The total population inhabiting Thundlavagu HU is 8 510, of which 4 157 women and 4 353 men, with a sex ratio of 955 female for every 1 000 male. Of the total geographic area, only 27 percent is arable, 3 percent wasteland and the remaining 70 percent is under forest cover. The main source of livelihood in the HU is agriculture (49 percent) and agriculture labour (42 percent). Figure 5.8 shows the breakdown by main source of income in APFAMGS project area. APWELL provided 49 Community Borewell Irrigation Schemes, in four of the seven villages making up Thundlavagu HU (source: Base document).

Figure 5.8

Pie-chart showing breakdown by main source of income in Thundlavagu HU



In Thundlavagu, 16 farmers (2 women), covering 3 habitations were interviewed. Of these 62 percent of respondents said they benefited from APWELL, 87 percent were borewell owners, 15 percent of farmers constructed wells on their own. Of those interviewed 13 percent of the respondents had no borewell irrigation facility, but leased a well to irrigate their land. The desk review showed that the number of functional borewells, for the period 2006–2007 (660) increased in 2007–2008 (754), which accounts for private drilling in that year. However, there was a 12 percent overall decrease in the number of functional wells, between 2006–2007 (660) and 2010–2011 (584). This can be attributed to the awareness generated by the project, discouraging farmers' investment in the construction of new wells.

Average well discharge in Thundlavagu, varies with each ensuing year, ranging between 1.65 to 2.10 litres/s. In 2005–2007, the average well discharge was about 1.7 litres/s, sharply increasing to stabilize at about 2.1 litres/s in 2007–2008, then gradually decreasing to 1.84 (more than the baseline value) in 2009–2010, again increasing to about 2 litres/s in 2010–2011. Well discharge seems to have peaked during 2005–2006 and 2009–2011 to about 2.3 litres/s. Unlike other HUs, Thundlavagu started low, with an average of 125 annual pumping hours in 2007–2008, which increased to 250 in 2008–2009 and has remained constant.

All respondents said they participated in CWB and changed crops after participation. Crops grown prior to participation included: rice (28 percent); groundnut (20 percent); sorghum (14 percent); redgram (13 percent) and other crops 25 percent. The cropping system seems to have largely changed, after participation in CWB (in October 2006). The area under rice cultivation decreased from 28 to 17 percent; area under groundnut increased from 20 to 27 percent; sorghum and redgram gave way to bengalgram 17 percent and cotton 16 percent; area under other crops slightly increased from 25 to 27 percent.

The desk study revealed the main rabi crops in 2006–2007 were: rice (58 percent), groundnut (18 percent), sunflower (7 percent) and other (17 percent). There was a clear shift in cropping pattern 2010–2011, the area under rice drastically decreased to only 31 percent of the total cropping area; groundnut cultivation reduced to 6 percent; area under sunflower reduced by 3 percent. Clearly farmers shifted to other crops (mainly cotton and bengalgram), 60 percent of the area under other crops was irrigated from wells.

The reasons given for changing crops were: 1) mono-cropping is harmful to soil and crop yield (31 percent); 2) to reduce groundwater withdrawal (21 percent); 3) unable to manage pests (21 percent); 4) to reduce input costs (15 percent); and benefit from good market price for the new crop (12 percent).

The farmer survey revealed annual incomes range between INR 8 000 and 75 000 per annum, before changing crops. Incomes increased to INR 20 000 to 200 000 per annum, after changing crops. All farmer respondents reported a general increase in income level as a result of crop changes. A two-fold increase in income was reported by 37 percent of the respondents, while 25 percent reported an increase of three to four-fold and 18.5 percent reported an increase of more than four-fold, an equal percentage reported a two to three-fold increase in income after crop changes.

To the question: What was the general water level in your village, prior to crop–water budgeting? Farmers' responses fell into three groups: 88 percent said the water level was 8–12 mbgl; 6 percent said 12–16 mbgl, while 6 percent said 16–20 mbgl. According to the farmer survey, current water levels are: 50 percent 16–20 mbgl; 12 percent 20–25 mbgl; and 13 percent 25–30 mbgl. This may be interpreted as: water levels have increased by more than 16 mbgl. However, farmer data for the period 2004–2011 revealed static water levels recorded in 32 production-cum-monitoring wells, measured in May, which is the driest month of the hydrological year, and October, the start of the monsoon crop season, showed an 'upward trend', contrasting with farmers' responses.

Respondents answering that pumping did not cause water level depletion were 69 percent, 31 percent took responsibility for water level depletion in the HU. To the question: What are the reasons for water level depletion? The responses were: 1) reduction in rainfall received (35 percent); 2) increase in number of borewells (30 percent); 3) no water harvesting structures (20 percent); 4) cultivation of water-intensive crops (10 percent) and 5) no watershed treatment (5 percent)

When asked: What are you doing to reduce pumping from wells? The responses were: 1) using sprinklers (34 percent; 2) switching to irrigated dry crops (33 percent) and suitable irrigation practices such as check-basin, ridge and furrow and mulching (33 percent). To the question: How much did you save through water-saving measures? The responses were: 1) can't say (56 percent); INR 10 000 to 20 000 (25 percent); and 3) INR 20 000 to 40 000 (19 percent). While 75 percent of respondents believed their wells would be sustainable in a drought year, the remaining 25 percent were skeptical

Note the desk study revealed the area under well irrigation increased by 240 percent (661.4 ha in 2006–2007 to 1 581.4 ha in 2010–2011), in spite of the reduced number of functional borewells. This clearly means farmers used fewer borewells to irrigate crops on a larger area, adopting precision irrigation measures. Average area irrigated by borewells was 1 ha in 2006, which rose dramatically to 2.71 ha by 2010.

Thirteen percent of respondents said they were engaged in APFAMGS as PHM volunteers, while 62 percent took part in GMC activities, 25 percent were involved with both GMC and HUN. To the question: Do you continue to get involved in GMC/HUN activities? 75 percent said yes and 25 percent no. To the question: What are your interests in supporting GMC/HUN? The responses were: 1) to improve our knowledge and skills (41 percent); 2) crop water budgeting (21 percent); 3) improve my understanding of the groundwater system (19 percent); and 4) get good suggestions (18 percent). GMC was given a 'good' rating by 38 percent of respondents, 56 percent rated it as 'average', and 6 percent considered GMC performance 'poor'. No respondents gave a 'good' rating for HUN, while 73 percent rated it as 'average', and the remaining 27 percent considered HUN performance 'poor'.

Thundlavagu is considered 'Semi-critical' because: 1) conditions are unfavourable for good groundwater recharge (small size; only 32 percent of the area under the litho-unit favourable for recharge; a surplus balance of +16.53 MCM, next only to Chandrasagarvagu. 2) Thundlavagu recorded a 20 percent decrease in withdrawal during 2006–2007, compared to the base year; 12 percent decrease in functional wells; a whopping 240 percent increase in unit area under well irrigation; 9 percent decrease in area under rice; 33 percent increase in area under irrigated dry crops; 34 percent increase in area under water-saving devices; and 33 percent increase in area under precision irrigation practices. The number of farmers attracted to higher returns from alternate crops is indicated by the 87 percent reported increase in income. 3) The 'poor' rating of GMC was 6 percent, while that of HUN 27 percent (better than Chandrasagarvagu), indicating fewer farmers are dependent on the advice of community based institutions. 4) The categorization is in line with the 'stable trend' of static water level, confirmed by 100 percent farmers interviewed, as the HU is still to enter the 'critical' category.

5.3 Bhavanasi: 'Critical' category

The Bhavanasi HU is in the southeast of Kurnool district, Andhra Pradesh (see map Figure 5.9). It lies between the northern latitudes 14° 58′ 0′and 15° 16′ 30′ and eastern longitudes 17° 41′ 30′and 17° 56′ 30′, and forms part of the Survey of India toposheet 57 I/9, I/11, I/12, and J/9, mapped on the scale of 1:50 000. Bhavanasi HU covers a geographical area of 29 625 ha with six Gram panchayats Bachepalle, China Ahobilam, Muthyalapadu, D. Vanipenta and Kalugotlapalle. The first two form part of Allagadda mandal, while the latter are part of Chagalamarri mandal, in Kurnool district, Andhra Pradesh.

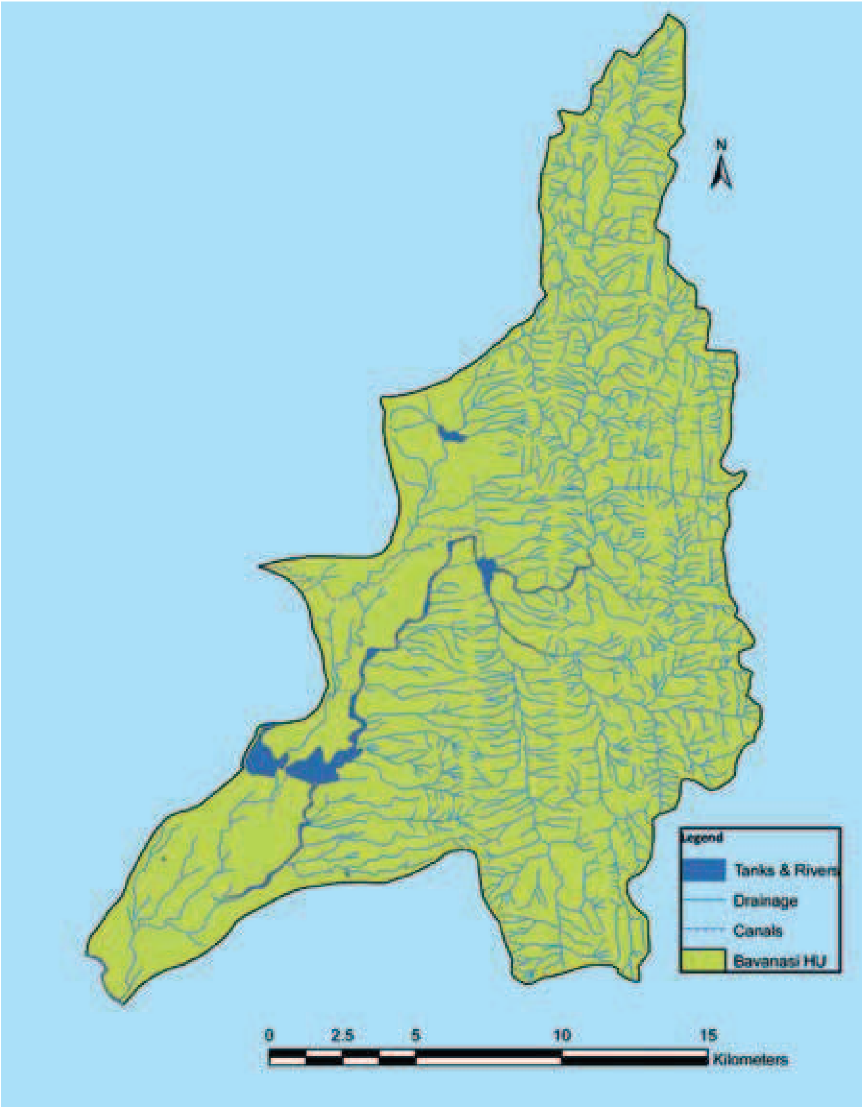
Figure 5.9

Map of Bhavanasi hydrological unit

The highest elevation in Bhavanasi HU is 852 m above msl, located in the east, while the lowest is about 153 m above msl, is southwest of Kalugotlappalle village. On the western plains, the slope is less than 1 percent, while slopes of 40–20 percent are common to the east. Bhavanasi stream originates in the hill ranges of the northeast covered by the Sirvel Reserve Forest and flows roughly towards the southwest for about 45 km, before merging with Vakkileru stream, southeast of Kalugotlapalle habitation. Vakkileru flows in a southerly direction to meet Kunderu, a tributary of the Pennar river. Bhavanasi gains from the flows of small streams with local names: Dommarivagu, Nallavagu, Perrurvanka, Pasupurevuvanka, Pitarivanka, Chavitivanka, Nerellavagu, Tellakunta, Bandalavanka, Poturajuvanka, and Bhavanasi. The Bhavansi surface flow is intercepted by five tanks, of which three are major. Malanicheruvu, is in the centre-west of the HU in the foothills of the protected forest, serves a command of about 240 ha. The other two major tanks in the HU are in the southwestern corner of the HU, referred to as Yerracheruvu and Vanipentacheruvu, serving commands of 150 ha and 250 ha respectively (Figure 5.10).

Figure 5.10

Drainage map of Bhavanasi hydrological unit

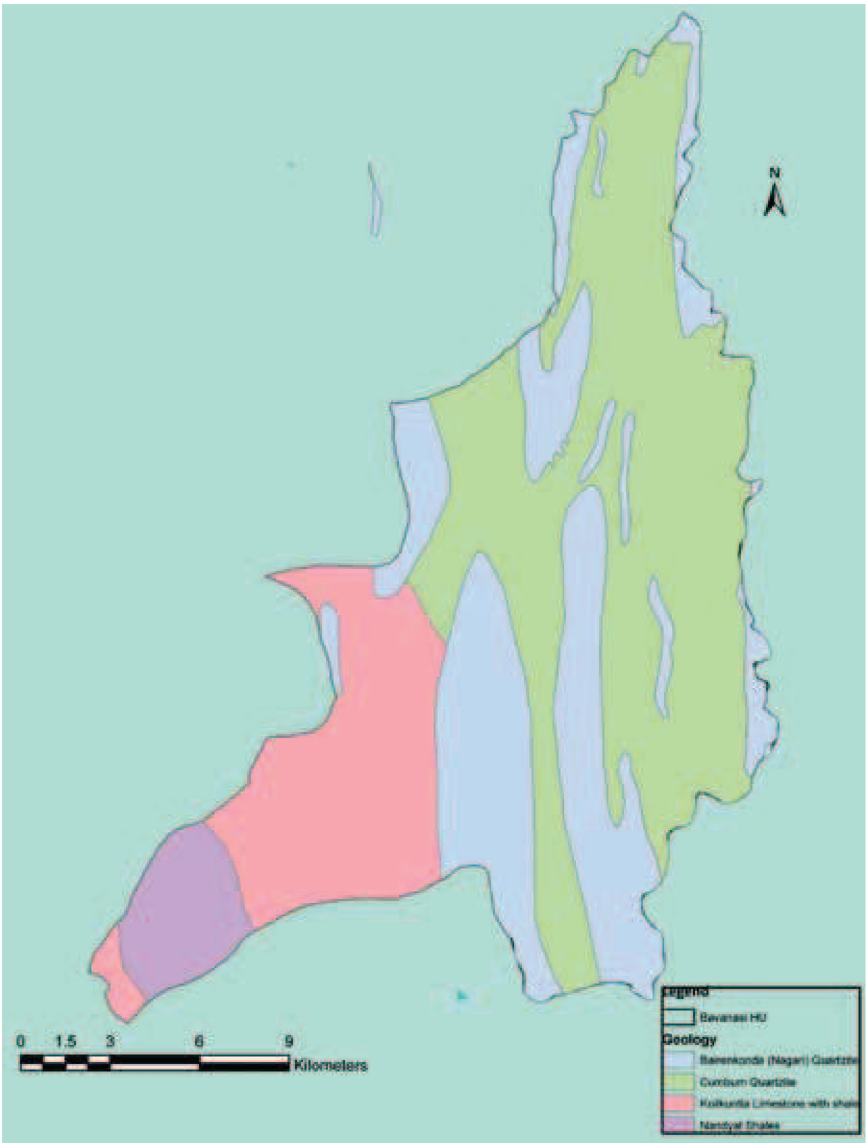


To the east the Bhavanasi HU is underlain by the Nallamalai Group of rocks that are made up of the lower Bairenkonda (Nagari) and the upper Cumbhum (Pullampet) formation (Figure 5.11). The upper Shrishailam formation is missing in the HU. The Kurnool Group of rocks lie uncomformably over the Nallamalai Group, represented by the upper Kurnool members, i.e. Koilakunta and Nandyal formations. The lower Kurnools: Banaganapalle, Narji, Auk and Panyam are not present in Bhavanasi HU. Bhairankonda formation is comprised of quartzites with shale intrusives, with a general formation about 4 000 m thick. The Nagari quartzite, occurring in the Tirumala hills, the abode of Lord

Venkateshwara, is the same as the Bairankonda formation. The Cumbhum formation is predominantly represented in the HU by quartzites and other rock types such as phyllites and dolomites; shales are absent. Kurnools underlie the western part of the Bhavanasi HU, comprised of Koilakuntla limestone with intercalations of shale, exposed mainly in the centre, followed by Nandyal shale forming the western tail of the HU. The average thickness of the Koilakuntla limestone with shale varies from 15–50, while the Nandyal shale is between 15–100 m thick.

Figure 5.11

Geological map of Bhavanasi hydrological unit



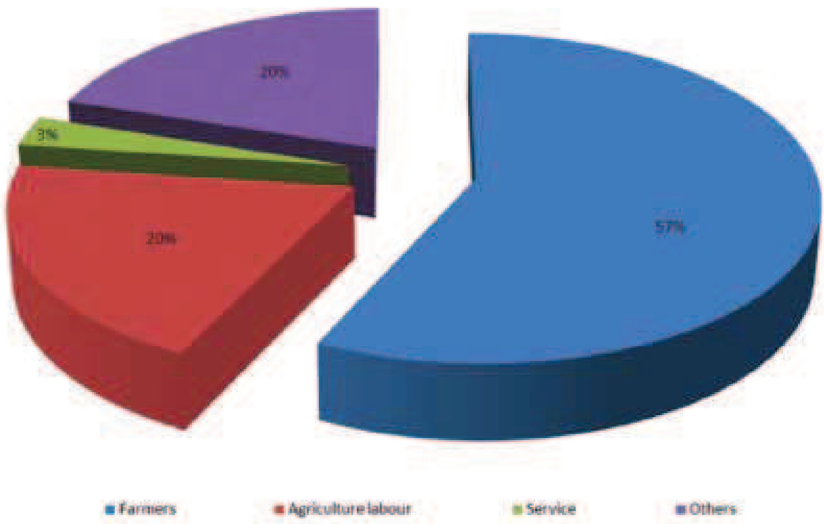
The recharge pattern in the HU is dominated by direct processes, i.e. deep percolation and soil moisture drainage. The indirect recharge processes such as: transmission losses through deep-cut canals; and secondary recharge through intensive irrigation (mainly because of standing water in rice cultivation) are negligible in the HU. The Groundwater Estimation Committee (1997) gives a recharge rate of 8 percent for "consolidated sandstone, quartzite, limestone (except cavernous)". The recharge area in Bhavanasivagu, where such rocks occur, cover 5 787 ha. Phyllites and shales are very poor aquifers with occurrence of groundwater restricted to bedding planes and weathered zones. GEC 97 gives a recharge of rate of 4 percent for "phyllites and shales". The recharge area in Bhavanasivagu, where such rocks occur, cover 1 669 ha. Quartzites are massive/hard with no or minimal joints. GEC 97 gives a recharge of rate of 1 percent for "massive poorly fractured rocks". The recharge area in Bhavanasivagu, where such rocks occur, covers 24 354 ha. The total area of recharge in Bhavanasivagu is thus an estimated 31 810 ha.

The total population in the Bhavansi HU is 15 279, of which 7 210 female and 8 069 male, with a sex ratio of 893 female for every 1 000 male. Of the total geographic area, only 21 percent is arable, and the remaining 79 percent is under forest. The main source of livelihood is agriculture (57 percent) and agricultural labour (20 percent). Figure 5.12 shows the breakdown of livelihoods in Bhavanasi HU. APWELL provided 32 community borewell irrigation schemes, in one of the 12 villages making up Bhavanasi HU (source: Base document).

The survey interviewed 33 farmers (11 women), covering six habitations in Bhavansi. Those benefitting from APWELL were 12 percent, 88 percent were borewell owners, 63 percent of farmers constructed their own wells. Those with no borewell irrigation facility amounted to 12 percent, who leased a well to irrigate their land. The desk review revealed that the number of functional borewells, in Bhavanasi during the period 2006–2007 was 735, which decreased in 2007-2008 (711). However, there was 37.8 percent overall decrease in number of functional wells, between 2006–2007 (735) and 2010–2011 (457). This can be generally attributed to the awareness generated by the project, discouraging farmers' investment in construction of new wells.

FIGURE 5.12

Pie-chart showing breakdown by main source of income in Bhavanasi HU



Average well discharge in Bhavanasi, varies each year between 1.23 and 1.69 litres/s. In 2005–2007, the average well discharge was about 1.5 litres/s, increasing to stabilize at about 1.65 litres/s in 2007–2008 then gradually decreasing to 1.33 litres/s (more than the baseline value) in 2009–2010, again increasing to about 1.69 litres/s in 2010–2011. Well discharge peaked during 2007–2008 and 2010–2011 at about 1.69 litres/s. Unlike other HUs, Bhavanasi began low with an average of 120 annual pumping hours in 2005–2006 and increased to 240 in 2010–2011.

CWB participants amounted to 91 percent, 9 percent did not participate; 91 percent changed crops after participation in CWB. Percentage of crops grown prior to participation in CWB included: rice 20; groundnut 16; cotton 9; jowar 12; redgram 11; sunflower 3; bengalgram 4; korralu 4; banana 6; cereals 3; turmeric 2; sugarcane 2 and other crops were 8 percent. The cropping system seems to have changed after participation in the CWB workshop in October 2006.

The area under rice decreased from 20 to 8 percent; and jowar decreased from 12 to 6 percent; area under groundnut decreased from 16 to 13 percent; cotton increased from 9 to 15 percent; blackgram increased from 4 to 18 percent; korralu increased from 4 to 8 percent and sunflower increased from 3 to 8 percent; the area under other crops increased from 8 to 12 percent. The desk study revealed that the main rabi crops in 2006–2007 were rice (28 percent), groundnut (24 percent), sunflower (16 percent) and other (32 percent). There seems to have been a clear shift in cropping pattern in 2010–2011. The area under rice drastically decreased, forming only 5 percent of the total cropping area; groundnut cultivation reduced to 20 percent; sunflower increased to 32 percent and other crops increased to 43 percent. Clearly farmers shifted to other crops so that 17 percent of the area under other crops was irrigated by wells.

The reasons for changing crops were: 1) benefit from good market price for the new crop (31 percent); 2) mono-cropping is harmful to soil and crop yield (31 percent); 3) unable to manage pests (18 percent); 4) to reduce input costs (10 percent) and 5) to reduce groundwater withdrawal (10 percent);

The farmer survey revealed that annual incomes ranged between INR 7 000 and 200 000 per annum before changing crops. Income increased to INR 12 000 to 400 000 per annum, after changing crops. Those reporting an increased income were 82 percent of the farmer respondents, 12 percent reported a decrease and 6 percent said there was no change. A one to two-fold increase in income was reported by 52.9 percent, a four-fold increase reported by 17.6 percent, another 17.6 percent reported an increase of two to three-fold. The remaining 11.76 percent reported an increase of three to four–fold.

To the question: What was the general water level in your village, prior to CWB? The farmers' responses fell into three groups: 50 percent said the water level was <30 mbgl; 47 percent reported 30–60 mbgl and 3 percent 60–90 mbgl. According to the farmer survey, current water levels are: 70 percent <30 mbgl; 15 percent 30–60 mbgl; and 15 percent 60–90 mgbl. This can be interpreted as water levels have increased but most are less than 30 mbgl. However, farmer data for 2004–2011 revealed that static water levels recorded in 43 production-cum-monitoring wells, measured in May (the driest month of the hydrological year), and October (the start of the monsoon cropping season) showed a 'rising' trend.

Respondents stating that pumping did not cause water level depletion were 76 percent and 24 percent took responsibility for water level depletion in the HU. To the question, What are the reasons for upward trend of water level? The responses were: 1) water-saving devices (48 percent); 2) rainfall received (21 percent); 3) additional recharge related to release of canal water (18 percent) and 4) decreased number of bore wells (14 percent).

When asked: What are you doing to reduce pumping from wells? The responses were: 1) crops with lower water consumption (2 percent); 2) suitable irrigation practices such as check-basin, ridge and furrow and mulching (77 percent); and 3) can't say (17 percent). To the question: How much did you save with water-saving measures? The responses were: 1) can't say (39 percent); INR 30 000 to 60 000 (40 percent); and 3) INR <30 000 (21 percent). While 15 percent of respondents believed their wells would be sustainable in a drought year, the remaining 85 percent were skeptical.

It is interesting to note that the desk study revealed the area under irrigation from wells increased by 122 percent (964.4 ha in 2006–2007 to 1 346.4 ha in 2010–2011), in spite of the reduced number of functional borewells. Clearly this means farmers used fewer borewells to irrigate crops on less area, adopting precision irrigation measures. Average area cultivated under borewells was 1.31 ha in 2006, which increased dramatically to 2.9 ha by 2010, by almost 1.59 ha.

Six percent of respondents said they were engaged in APFAMGS as PHM volunteers, 67 percent took part in GMC activities, 15 percent were involved with both GMC and HUN; 12 percent were involved with both GMC and PHM. To the question: Do you continue to get involved in GMC/HUN activities? 84 percent said yes and 16 percent no. To the question: What are your interests in supporting GMC/HUN? The responses were: 1) to improve our knowledge and skills (48 percent); 2) crop–water budgeting (18 percent); 3) improve my understanding of the groundwater system (16 percent); and 4) Stage of information sharing (18 percent). GMC was given a ‘good’ rating by 44 percent of respondents, 53 percent rated it as ‘average’, and 3 percent considered GMC performance ‘poor’. HUN got a ‘good’ rating from 23 percent of respondents, 59 percent rated it as ‘average’ and 18 percent considered HUN performance ‘poor’.

Bhavanasi is considered ‘Critical’ because: 1) conditions are unfavourable for good groundwater recharge (large size but only 24 percent of the area is under the litho-unit favourable for recharge; a marginally surplus balance of +1.67 MCM, least among the three HUs showing surplus balance. 2) Bhavanasi recorded a 26 percent decrease in withdrawal during 2006–2007, compared to the base year; 38 percent decrease in functional wells; a 122 percent increase in unit area under well irrigation; 23 percent decrease in area under rice; 10 percent increase in area under Irrigated dry crops; 63 percent increase in area under water-saving devices; and 866 percent increase in area under precision irrigation practices. The number of farmers attracted to higher returns for alternate crops was indicated by increased incomes reported by 82 percent of respondents. 3) those rating GMC as ‘poor’ were 3 percent, while that of HUN is 6 percent (second best), indicating very good efforts by community based institutions. 4) The categorization is NOT in line with the ‘upward trend’ for static water level, confirmed by 74 percent of farmers interviewed. This could be the result of structurally controlled additional recharge, because the HU is on the boundary of the Cuddapah basin, which underwent tectonic disturbances in the geological past.

5.4 Mandavagu: ‘Over-exploited’ category

Mandavagu HU is in the central-eastern part of Mahbubnagar district, Andhra Pradesh, between the northern latitudes 16° 25′ 12′ and 16° 18′ 59′ and eastern longitudes 78° 43′ 11′and 78° 53′ 07′, and forms part of the Survey of India topographic maps 56 L/11 and L/15, mapped on the scale of 1:50 000. Figure 5.13 shows the location of the Mandavagu HU, which covers a geographical area of 11 143.61 ha with 20 habitations that form part of eight Gram panchayats Mannanur, Venkteshwarla Bavi, Macharam, Amrabad, Kalumalonipalli, Madhavonipalli, Kummaronipalli and Jangireddypalli, all falling under Amrabad mandal.

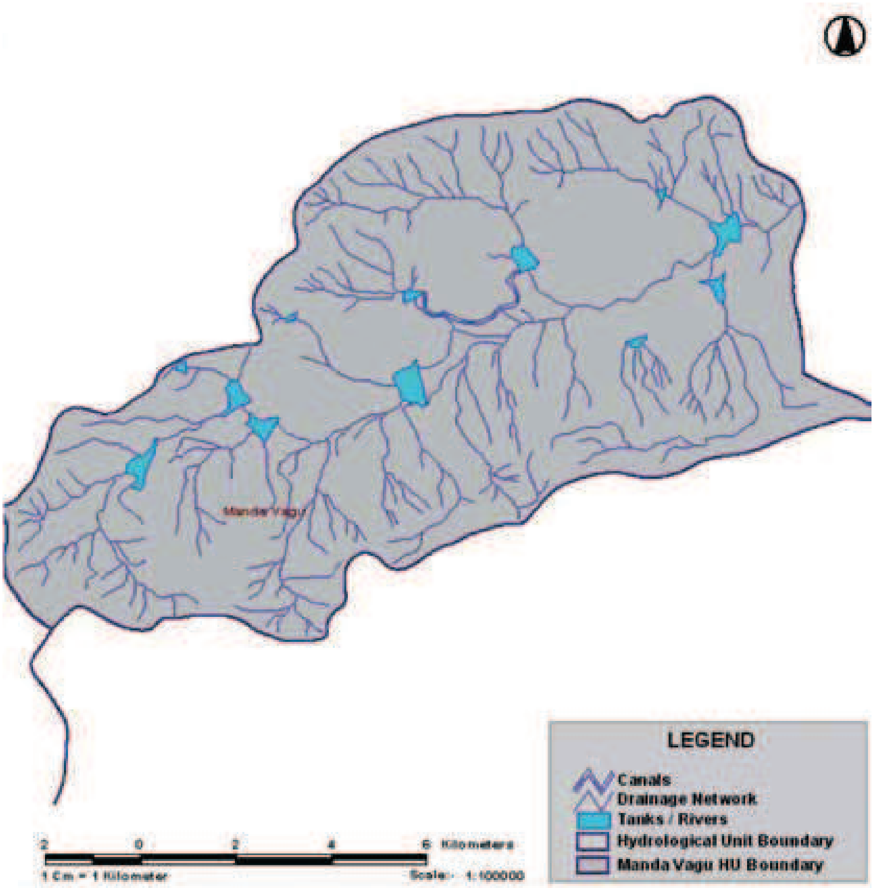
Figure 5.13

Map of Mandavagu hydrological unit

The topography of the basin controls the course of drainage (Figure 5.14). The highest elevation in Mandavagu HU is 790 m above msl, located to the west, while the lowest is about 594 m above msl, located northeast of Kummaronopalli village. The central plateau exhibits a slope of about 1 to 2 percent, while the slopes of 40–20 percent are common to the west. Mandavagu stream originates in the hill ranges in the west, covered by the Nallamalla Reserve Forest and flows roughly towards the northeast, merging with the Narsimhulu stream, a tributary of the Krishna river, near Kummmaronipalli village. Mandavagu gains from the flows of small streams with local names: Mathimadugu vagu, Yerravagu and Madhavani kuntavagu, intercepted by eight small irrigation reservoirs.

Figure 5.14

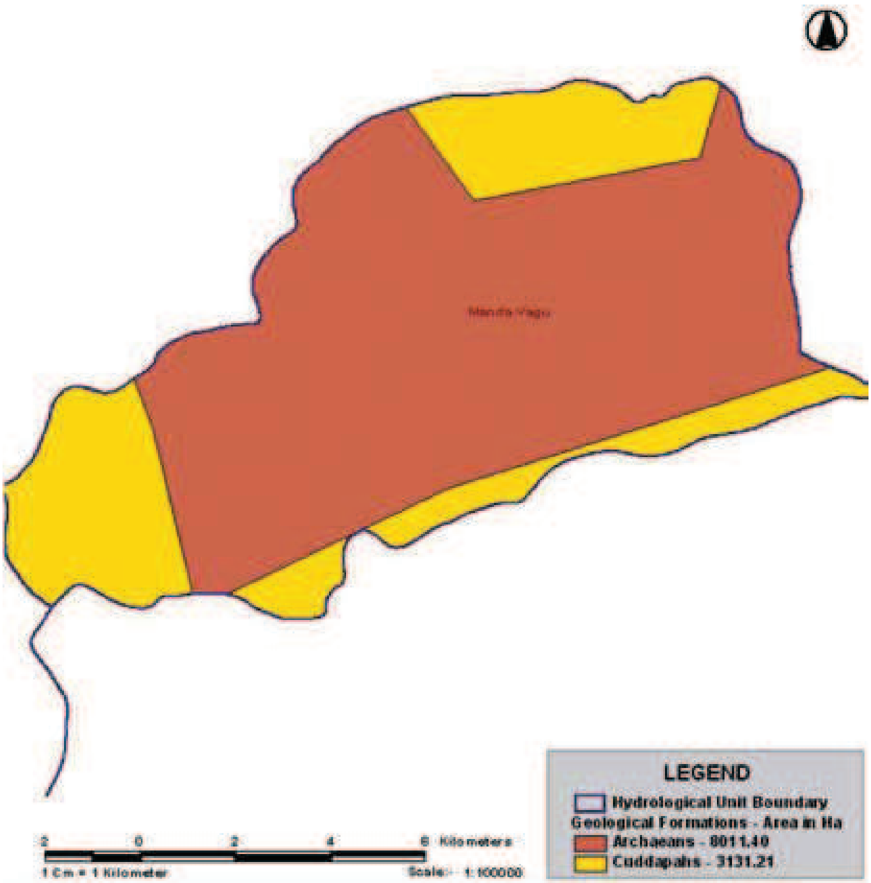
Drainage map of Mandavagu hydrological unit



Mandavagu HU is underlain by Pre-Cambrian Archean crystalline rocks of the Dharwar Group, belonging to the Azoic Era, which are comprised of granites, gneisses and schists, in the centre (Figure 5.15). The Dharwar Group of rocks has been subjected to fracturing and jointing and is traversed by quartz veins. The extreme northeast, southwest and south parts of Mandavagu are underlain by Shrishailam quartzite of the Kurnool Group of the Proterozoic, which are found striking in a NNE–SSW direction and dipping towards the east at 35 to 40°.

Figure 5.15

Geological map of Mandavagu HU

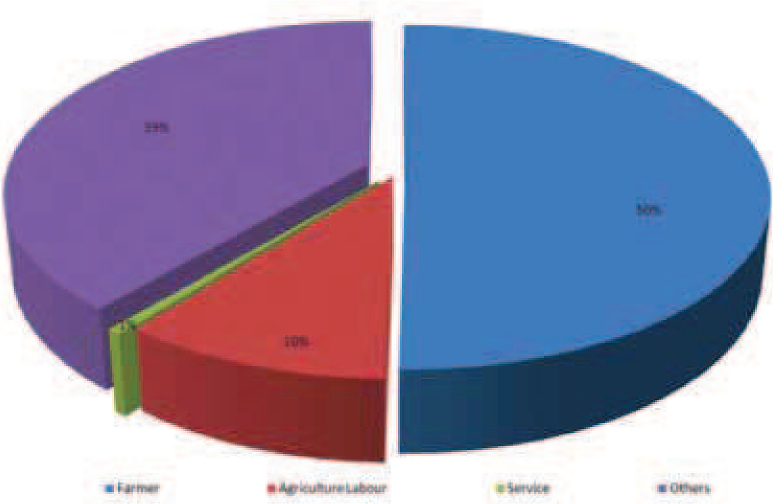


The occurrence of groundwater in the Archean rocks is controlled by the depth and degree of weathering and fracturing (often intruded by quartz veins). The recharge characteristics in Mandavagu are similar to that of Chandrasagarvagu is restricted to the north and northeast, where granitic rocks occur, covering 9 725 ha. The discharges from the shallow bore wells range from 3 to 4 litres/s and transmissivity values range from 20 to 40 m^2/day.

The total population of Mandavagu HU is 23 855, 11 868 women and 11 987 men, with a sex ratio of 933 female for every 1 000 male. Of the total geographic area, only 27 percent is arable, 44 percent wasteland and the remaining 13 percent is under forest. The main source of livelihood is agriculture (50 percent), agriculture labour (10 percent). Figure 5.16 shows the breakdown of livelihood in the APFAMGS Project area. APWELL provided 182 community borewell irrigation schemes, in 20 of the 16 villages of Mandavagu HU (source: Base document).

Figure 5.16

Pie-chart showing breakdown by main source of income in Mandavagu HU



As part of the survey questionnaire, to analyse reasons for the different responses of groundwater, 27 farmers (8 women), covering five habitations in Mandavagu, were interviewed. Of all respondents 81 percent said they benefited from APWELL, 83 percent owned borewells, 2 percent constructed their own wells. Nineteen percent of respondents did not have a borewell for irrigation, but leased a well to irrigate their land.

The results of the desk review (Figure 5.17) show the number of functional borewells in Mandavagu during the period 2005–2006 (851) increased in 2007–2008 (876), which accounts for private drilling in that year. However, there was a 1 percent overall decrease in the number of functional wells, between 2005–2006 (851) and 2010–2011 (842). Generally this can be attributed to the awareness generated by the project, discouraging farmers from investing in the construction of new wells.

It is important to note that the desk study revealed the area under well irrigation decreased by 27.4 percent (1 203.51 ha in 2005–2006 to 873.6 ha in 2010–2011) and the average area irrigated by borewells reduced from 1.41 ha in 2005 to 1.03 ha by 2010, a reduction of 32 percent.

However average well discharges have increased from 0.65 litres/s in 2005–2006 to 0.9 litres/s in 2006–2007. Discharge gradually returned to close to initial discharge by 2009–2010. Well discharge seems to have again increased dramatically during 2010–2011, this time peaking at 2.2 litres/s.

Mandavagu started with an average 840 annual pumping hours in 2005–2006, which was drastically reduced to 720 hours per annum 2006–2007, since then it has remained constant, probably related to the fixed hours of electricity supply, which worked out as an average of 2 hours/day, which may change based on the cropping season.

Eighty-five percent of respondents said they participated in CWB, while the remaining 15 percent did not; 74 percent of the farmers participating in CWB changed crops. Crops grown prior to crop–water budgeting included rice (27 percent); groundnut (18 percent); castor (20 percent); cotton (19 percent); millets (6 percent); maize (5 percent); sunflower (2 percent), redgram and vegetables (1 percent). The cropping system changed, as a result of their participation in CWB in October 2006. Area under rice cultivation decreased from 27 to 10 percent and castor decreased from 20 to 17 percent; area under groundnut increased from 18 to 29 percent; sunflower increased from 2 to 8 percent; redgram and vegetables increased from 1 to 5 percent; area under cotton remained the same (19 percent).

The desk study revealed that the main rabi crops in 2005–2006 were rice (14 percent), groundnut (65 percent) and other (21 percent). There seems to have been a clear shift in cropping pattern in 2010–2011, wherein the area under rice decreased to 8 percent of the total cropping area; groundnut cultivation increased to 68 percent; area under other crops increased to 24 percent. Clearly farmers decreased the area under rice and shifted to groundnut and other crops, which meant some reduction in groundwater withdrawal.

Reasons for crop changes were: 1) to reduce groundwater withdrawal (39 percent); 2) benefit from good market price for the new crop (23 percent) 3) mono-cropping is harmful to soil and crop yield (18 percent); 4) unable to manage pests (10 percent) and to reduce input costs (10 percent).

The farmer survey revealed that annual incomes ranged from INR 20 000 to 250 000 per annum, before changing crops. Incomes increased to INR 20 000 to 196 000 per annum, after changing crops. All respondents reported a general increase in income level as a result of crop changes, of which 82 percent reported a two-fold increase after crop changes. While 14 percent reported a two to three-fold increase, 4 percent reported an increase of three to four-fold.

To the question: What was the general water level in your village, prior to crop–water budgeting? Farmers responses fell into three groups: 11 percent said the water level was 6–12 mbgl; 53 percent said 12–18 mbgl and 36 percent said 18–24 mbgl. The farmer survey revealed that water level reported by 15 percent of respondents was less than 30 mbgl and 85 percent reported water levels of 30–60 mbgl. This may be interpreted as water levels have fallen below 30 mbgl. The desk study revealed during 2004–2011, static water levels recorded in 41 production-cum-monitoring wells measured in May (driest month of a hydrological year), and in October (start of the monsoon crop season) show a ‘falling trend’, supporting the results of the farmer survey.

Half of the respondents said their pumping did not cause water level depletion and 50 percent took responsibility for water level depletion in the HU. To the question: What are the reasons for water level depletion? The responses were: 1) reduction in rainfall received (47 percent); 2) increase in number of borewells (33 percent); 3) over withdrawal (14 percent) and 4) no water harvesting structures (6 percent).

When asked: What are you doing to reduce pumping from wells? The responses were: 1) using sprinklers and drip (43 percent); and suitable irrigation practices such as check-basin, ridge and furrow and mulching (57 percent). To the question: How much did you save through water-saving measures? The responses were: 1) can't say (53 percent); INR 10 000 to 40 000 (29 percent); 3) INR 40 000 to 80 000 (14 percent); and 4) INR 80 000 to 1 20,000 (4 percent). While 81 percent of respondents believed their wells would be sustainable in a drought year, the remaining 19 percent were skeptical.

Respondents engaged as PHM volunteers were 7 percent, 22 percent in HUN, 45 percent took part in GMC activities, 26 percent were involved with both Groundwater MC and HUN. To the question: Do you continue to get involved in GMC/HUN activities? All replied yes; to the question: What are your interests in supporting GMC/HUN? The responses were: 1) to improve our knowledge and skills (24 percent); 2) crop water budgeting (26 percent); 3) improve my understanding of the groundwater system (38 percent); 4) Stage of information sharing (16 percent); and 5) agriculture practices (6 percent). A 'good' rating was given by 58 percent of respondents, and 42 percent considered GMC performance 'average'; 26 percent gave a 'good' rating for HUN and 74 percent considered HUN performance 'average'.

Mandavagu is considered to be 'over-exploited' because: 1) conditions are unfavourable for good groundwater recharge (very small; only 72 percent of the area under the litho-unit favourable for recharge; a deficit balance of -26.91 MCM, the only HU showing a deficit balance). 2) Mandavagu recorded a 14 percent decrease in withdrawal during 2006–2007, compared to the base year; 1 percent decrease in functional wells; 31 percent decrease in unit area under well irrigation; 17 percent decrease in area under rice; 24 percent increase in area under irrigated dry crops; 43 percent increase in area under water-saving devices (such as check-basin irrigation, ploughing across the slope and SRI paddy); and 57 percent increase in area under precision irrigation practices; farmers attraction to higher returns for alternate crops is indicated by increased incomes, reported by 82 percent of the respondents. 3) the 'poor' rating of GMC as well as HUN is zero percent, indicating high popularity. 4) The categorization is in line with the 'downward' trend of static water level, confirmed by 93 percent of farmer respondents and the HU is in the 'over-exploited' category.

5.5 Summary of the analysis

Table 5.1 shows the summary of results of the combined analysis of the desk-study of farmer-collected hydrological data and results of the farmer questionnaire survey.

Table 5.1

Summary of Case Study results

Activity	Mandavagu	Chandrasagar	Thundlavagu	Bhavanasi
Area covered under the HU (ha)	11 142	23 517	18 125	31 810
Extent under Archean rocks	72 percent	74 percent	0 percent	0 percent
Extent under Cuddapah/Kurnool quratzite	28 percent	26 percent	68 percent	76 percent
Extent under Kurnool limestone/shale	0 percent	0 percent	32 percent	24 percent
Estimated recharge (June 2005–May 2011)	37.82 MCM	82.88 MCM	70.65 MCM	68.47 MCM
Estimated withdrawal (June 2005–May 2011)	64.74 MCM	56.90 MCM	54.11 MCM	66.80 MCM
Estimated balance (June 2005–May 2011)	-26.91 MCM	+25.98 MCM	+16.53 MCM	+1.67 MCM
Stage of development	171 percent	68.6 percent	76.6 percent	97.6 percent
Central Ground Water Board Category	Over-exploited	Safe	Semi-critical	Critical
Measures taken by farmer to reduce withdrawal:				
Increase/decrease in No. of functional wells	1 percent decrease	6 percent increase	12 percent decrease	38 percent decrease
Increase/decrease in unit area under a well	31 percent decrease	0.3 percent decrease	240 percent increase	122 percent increase
Increase/decrease in area under rice	17 percent decrease	8 percent decrease	9 percent decrease	23 percent decrease
Increase/decrease in area under ID crops	24 percent increase	17 percent increase	33 percent increase	10 percent increase
Extent of water saving irrigation practices and techniques	43 percent increase	43 percent increase	34 percent increase	63 percent increase
Extent of precision irrigation practices	57 percent increase	57 percent increase	33 percent increase	866 percent increase
Extent of farmers with increased income	100 percent	100 percent	100 percent	100 percent
Percentage of Rating of GMC as ‘poor’	0 percent	13 percent	6 percent	3 percent
Percentage of Rating of HUN as ‘poor’	0 percent	39 percent	27 percent	6 percent
Water level trend	Falling	Stable	Slight rise	Rising

Bhavanasi is the largest HU, in terms of geographic area, while Mandavagu is the smallest; 32 percent of Thundlavagu and 24 percent of Bhavanasi is underlain by Kurnools, made up of limestone and shale. While Shrisailam quartzite of Kurnool and Bairankonda quartzite of Cuddapah form the upper ranges in Bhavanasi (69 percent) and Thundlavagu (76 percent), only Shrishalam quartzite comprises the upper parts of Mandavagu (28 percent) and Chandrasagarvagu (26 percent). Further, 72 percent of Mandavagu and 74 percent of Chandrasagar is underlain by Archeans.

Exploratory drilling by the CGWB in Koilkuntlas and Nandyals (Kurnool Group), in the range of 27 to 74 mbgl, yielded between 3.5 to 13 litres/s. The borewells in Shrisahailam Quatzites have a depth of 45 to 60 mbgl with a discharge of 3 to 5 litres/s. The shallow aquifer system in Archean rocks yields 3 to 4 litres/s, while the yields of deeper aquifers 70–150 mbgl ranges between 3–5 litres/s. This means that Kurnool Group (limestones and shales) lithologies yielded better than the Cuddapah Group or the Archean rocks.

The HU areas studied that lie under the more favourable Kurnool limestones and shales were 32 percent in Thundlavagu and 24 percent in Bhavanasi. Kurnool limestones and shales were absent in Mandavagu and Chandrasagarvagu. The comparatively less favourable Archeans comprise 72 percent of Mandavagu and 74 percent of Chandrasagarvagu. The most unfavaourable litho-unit, Cuddapah/Kurnool Quartzite was present in all four HUs covering: 76 percent of Bhavanasi; 68 percent of Thundlavagu; 28 percent of Mandavagu and 26 percent of Chandrasagarvagu. Therefore, all four HUs had more or less comparable geological attributes.

Estimated groundwater **recharge** for the period June 2005 to May 2011, based on farmer collected data for Mandavagu, Chandrasagarvagu, Tundlavagu and Bhavanasi in MCM was: 37.82; 82.88; 70.65 and 68.47, respectively. This is probably because of the size of the HU, Bhavanasi being the largest and Mandavagu the smallest. The size also seems to have influenced the estimated recharge for Thundlavagu and Chandrasagarvagu.

Estimated groundwater **withdrawal** for the period June 2005 to May 2011, based on farmer collected data, for Mandavagu, Chandrasagarvagu, Tundlavagu and Bhavanasi in MCM was: 64.74; 56.90; 54.11 and 66.80, respectively. Here again, the size of the HU does not seem to have made the difference. Bhavanasi is the largest and Mandavagu the smallest had only minor difference in withdrawal. Perhaps, the number of functional wells is important here. While decrease in percentage of number of wells was highest (38 percent) at Bhavanasi, Mandavagu recorded the lowest (1 percent).

Higher withdrawal and smaller size put Mandavagu in a 'Deficit' groundwater balance, while matching withdrawal and larger size put Bhavanasi in a 'Surplus' groundwater balance. However, the stage of development placed

Mandavagu into the category of ‘over-exploited’, while Bhavanasi managed a ‘critical’ category. Thundlavagu fell into the ‘Semi-critical’ category, while Chandrasagar could be classified under the ‘Safe’ category. This covers the entire range of CGWB categorization of HUs, based on stage of development.

However, categorization based on stage of development does not always seem to be substantiated by the trend of water levels in the HUs. The Mandavagu, with falling water levels, confirmed that over-exploitation leads to water level depletion. Though categorized as critical, Bhavanasi farmers are puzzled about rising water levels. While water levels at Chandrasagar were stable, in line with the categorization of ‘Safe’, Thundlavagu showed a slight build up of water level, in spite of being in the ‘Semi-critical’ category. It is worth noting that parts of the area in both the Bhavanasi and Thundlavagu HUs are underlain by Kurnool limestone/shale. It is suspected that a combination of recharge propensity (ability to accept recharge), transmissivity of the limestone lithologies and structural controls or impediments are responsible for this variation.

The unit area irrigated under each well is generally a good indication of higher water use because of increased evapotranspiration and lower recharge or return flow to the aquifer from the irrigated area. A large 240 percent increase is seen at Thundlavagu, followed by 122 percent increase at Bhavanasi, areas classified by CGWB as ‘critical’ and ‘semi-critical’. But in both cased, groundwater levels were observed to rise in the period 2005–2011. In contrast there was a 31 percent decrease of unit area under well irrigation at Mandavagu, indicating falling well yields, for the most part in highly metamorphosed Archean rock formations. Well yields did not seem to be affected in the Chandrasagarvagu HU, as the unit area irrigated by a well remained more or less constant over the monitoring period 2005–2011 (decreased by 0.3 percent).

The area under irrigated dry crops increased at all four HUs, highest (33 percent) recorded at Thundlavagu, followed by Mandavagu (24 percent). This could be interpreted as the result of farmers increased awareness at Thundlavagu, Bhavanasi and Chandrasagar and low yields at Mandavagu. The greatest decrease in area under rice (23 percent) was recorded at Bhavanasi, followed by Mandavagu. This could be the effect of awareness raising at all HUs. Generally across all HUs there was a significant increase in the use of water-saving devices and precision irrigation practices. An abnormal area increase of 866 percent was observed at Bhavanasi after adoption of precision irrigation practices, which may be, in part, a response to rising water levels and improved accessibility to existing pump infrastructure. Indeed, it should be noted that across all HUs, the availability of subsidized electricity and precision irrigation equipment may have contributed greatly to this observed increase in water productivity.

There was 100 percent increase reported for income levels at all HUs, a low percentage of farmers rated GMCs as 'poor'. HUNs do not seem to be that popular at Chandrasagar and Thundlavagu.

Unlike surface water, a pre-requisite for groundwater use in the state is power supply. Therefore, an important consideration, or controlling factor of 'water use patterns', is the farmer's access to power supply. The government policy was a 7-hour a day, free of charge, power supply to the farm sector. However, the real power supply hours, as reported by farmers, hardly met this norm, and many a time the power supply was at night. This could have influenced farmers' choice of low-water consuming crops, to avoid the risk of an unreliable power supply. The bottom line is that the farmer emerged as 'winner', as shown by the definitive improvement in family income.

Chapter 6. Sustainability, Relevance and Upscaling

What should be clear from the previous chapters is that what started as an initiative to address equitable access to groundwater, ended by working with smallholders to ensure long-term sustainability of boreholes and wells constructed for their economic benefit. In this sense the PGM approach described in this publication should be seen as a ‘community empowerment model’. The underlying guiding principle is a commitment to build the capacity of groundwater users to manage the aquifers upon which they depend. Monitoring aquifer behaviour and planning cropping patterns has helped sustain yields and incomes from year-to-year. In other words, the entire effort has been dedicated to improving the resilience of groundwater users in view of their continued exposure to the risk of drought.

In the past PGM faced much criticism, not all of which was based on authenticated information. Questions have been raised about the post-withdrawal sustainability of the intervention and difficulties related to upscaling. This chapter discusses sustainability, relevance and the prospects for upscaling PGM. It attempts to separate the myth from reality and establish a practical scientific framework for management of what might otherwise appear to be a somewhat ‘mysterious’ resource.

6.1 Sustainability

The sustainability of an intervention may be assessed in terms of whether its intended objectives are achieved and sustained after implementation. The level of publicity that has been attracted by this particular PGM approach makes this difficult. The original success indicators could hardly match the high expectations. There are professional biases as well. A policy-maker may want to see drastic improvements in the target communities’ socio-economic conditions, while a scientist will be concerned about the accuracy of data and estimation methods. A social worker may expect the resource to be a public health or livelihoods priority with more emphasis placed on supply-side management. In practice this PGM intervention had a set of clear-cut objectives to achieve.

Technical sustainability

Sustainability of the PGM model’s technical interventions is evident, because of their adaption by several programmes and projects (see Section 4.3). The terms coined during implementation of the PGM model such as HU, PHM and CWB are now being used unhesitatingly. Furthermore, HUNs continue to be interested in sustaining and carrying forward CWB, the heart of PGM activities, although being a technically burdensome PGM activity, as revealed by CWB during the 2010 winter cropping season. This means PHM data collection continues.

Economic sustainability

Economic sustainability of PGM should be seen from the viewpoint of farmers' incomes, which seems to have been ensured, as a result of switching to more profitable crops. This was confirmed by farmers' responses in the post facto survey, wherein 89 percent reported increased incomes (see Chapter 5). However, economic sustainability will depend largely on national and international food and energy price policies. Nevertheless, farmers are equipped with knowledge and decision-making tools that mostly allow them to cope with external threats.

Environmental sustainability

Environmental sustainability, in the context of groundwater management, would mean maintaining the natural recharge-discharge relationship of groundwater and streams. In PGM terms, this is understood as maintaining the withdrawal from aquifer systems at equal to, or less than, the expected recharge. This would ensure that a minimum balance is maintained in the aquifer systems, even during dry periods, apart from ensuring minimal base flows into the discharge areas (streams), at least in years of plenty. This would also stabilize the aquifer movement – attenuating volatility in groundwater levels to maintain accessibility.

Crop-water efficiency, promoted on a large-scale in PGM does not seem to be enough to control withdrawal beyond replenishment, as it also depends on the size of the HU, structural controls of the aquifer systems, number of wells, pumping hours and area under irrigation (under wells or otherwise) and class and regional disparity of access to surface water irrigation. Currently, the emerging concept is 'Maximum Admissible Drawdown (MAD)', which came up for discussion at the Sixth World Water Forum in 2012. However, this should be seen as a step-ahead for the PGM experiment, which may involve community action for learning about MAD in the HUs and restricting groundwater withdrawal to the MAD limit. Indeed, this is expected to happen only when the cultivable area matches the recharge capacity of the aquifer system. When this happens, either the MAD limit can be mutually respected or withdrawals relaxed or planned depletion of aquifer storage simply continues.

Institutional sustainability

The *post facto* evaluation, based on a questionnaire survey, looked at institutional sustainability at the grass-roots level, i.e. GMCs and HUNs. It is evident that 82 percent of farmers continue to be involved in GMC/HUN activities, even two years after withdrawal of FAO support. They seem to have good reasons for doing so. GMCs still seem to enjoy the power of their access to hydrological data and are further encouraged by the possibility of income from data sales. HUNs continue to be active, as much because of the opportunity to climb further up the local leadership ladder, as the opportunity to be seen as the 'Saviour' of sustainable groundwater use. The farmers trained as part of PHM and FWS are valued by local government entities that involve them as trainers and resource persons in other programmes. GMC/HUN members also have a free-pass to higher officials for accessing government funds as their reputation for putting funds to good use is exceptionally good.

NGOs remain active in the APFAMGS operational area, though supporting GMC/HUN may not be a priority given the variety of activities they implement, and because of their inability to retain technical staff for a variety of reasons. A resource pool of technical NGO staff, trained intensively and perfectly oriented towards the concept and practice of PGM, now find shelter in similar programmes that adapt the PGM tools. However, from the viewpoint of technical staff, they are left with no option except to tread a different path in search of a livelihood. APWELL/APFAMGS staff members have been instantly absorbed into other water-related programmes implemented by State governments and bilateral projects.

The positive aspect, in relation to institutional sustainability, is retention of few staff at all levels for implementation of another FAO-supported project, financed by the GEF, which is attempting to extend the range of climatic variables monitored by communities to build resilience to climate change. This may provide a period of consolidation for sustaining and upscaling the PGM intervention at national and even global levels.

6.2 Relevance

PGM has something to offer to people from every walk of life. For a politician it is safer to implement a people-friendly model rather than coercive regulation. A policy-maker is happy because a live model is available at the field level from which s/he can learn and adapt it to relevant situations. Groundwater professionals should be happy because of increased employment opportunities. NGOs would have an opportunity to work on a subject close to the heart of the rural population. PGM provides enough material for researchers to involve them in building upon its components. Academicians will gain ideas about how to create practical and useful courses. This section discusses the methods and tools developed as part of PGM implementation that may help shape future policy response. Table 6.1 shows how the PGM approach taken in Andhra Pradesh differs from more conventional approaches.

Table 6.1

How the PGM approach is different from conventional approaches

SN	Issue	Conventional approach	PGM approach
1	Mysterious part of hydrological cycle	Further mystify, taking advantage of technological development	Demystify so that it can be understood by lay people
2	Unit of assessment/ management	Administrative boundary	Hydrological Unit, starting with catchment of a third order stream
3	Scarcity of representative data; water professionals; and user access to data/information	Introduction of sophisticated equipment; and produce super-specialists; and inter-departmental data sharing	Motivate users to collect data, with fair gender representation; and create a pool of bare-foot water technicians, and back-up teams of professionals at local level; and sharing data/ information at the community level for farm-level decision making
4	Estimation of groundwater recharge and groundwater withdrawal	Controlled by departments and disseminated in reports	Farmers encouraged to use non-formal education methods to estimate and disseminate the results in annual crop water budgeting workshops
5	Risks related to groundwater development: augmenting natural recharge; over withdrawal; meeting agriculture water demand; groundwater pollution; and base flows	Supply management (intensive recharge of aquifers); regulate through water and energy pricing; promote water-efficient crops through markets and privatization of power transmission; polluter pays; legislation	People controlled withdrawal and scientific methods of AGR; Social fencing through community- based institutions; Create platform for interaction of local stakeholders in annual Crop Water Budgeting workshop; Trained community based institutions lobby for closure of polluting units; social fencing
6	Equity and Social Justice; Policy; Public funding; Water stress basins; Food security; Water security	Conflict between concepts of 'human right' and 'economic good'; Pay and use; Substantial for surface water reservoirs and no or little for groundwater development and management; Inter-basin transfers; Produce enough for country's population; Reduce the food footprint on water	Community wells for a group of smallscale and marginal farmers, with clear water-sharing agreements; Provide for basic human needs and then talk of pay and use; Financing Community borewell irrigation schemes for small and marginal farmers; Demand-side management of groundwater for self-sufficient HUs; Produce enough at local level and make sure that it reaches the hungry; Prioritize water use for food production rather than industrial

The PGM experience is relevant, in the context of overall groundwater development and management, because it provides insights into some practical issues faced by community management of groundwater resources. The key issues and policy responses that the PGM could possibly bring about are: i) de-mystifying groundwater circulation; ii) determining the unit of groundwater management; iii) overcoming scarcity of hydrological data and user access to scientific information iv) estimating groundwater recharge and groundwater over withdrawal; v) addressing risks in groundwater development; and finally vi) the whole issue of equity and social justice that arises when aquifers are accessed and groundwater is allocated.

De-mystifying groundwater circulation

Groundwater, apart from being an important component of the Earth's water cycle or hydrological cycle, is difficult to understand because it is invisible, unlike the dramatic but variable rainfall and runoff events that occur during monsoons. In addition, the subject of groundwater is interlinked with understanding of other sciences, geology, topography, hydrology, physics and chemistry. Groundwater management entails understanding of its relation with other components of the hydrological cycle, particularly rainfall and stream flow. Therefore, understanding groundwater, and the inter-dependent components of the hydrological cycle, becomes a starting point for development and management.

Precise scientific understanding of the behaviour of different types of aquifer systems, including calibration and validation of aquifer water balances with groundwater models will remain. This is because of the need for reliable and representative hydrological data. Geology controls the nature and occurrence of groundwater, and a thorough understanding of the local geology and groundwater circulation is essential for informing the community based management plan.

There is no overall policy in public education programmes to address this issue. Indeed the current approach seems to further mystify, taking advantage of the recent developments in technology. This is apparent from the heavy equipment being introduced into data collection, limiting the use of published material by the groundwater agencies to policy-makers and other elitist groups. A farmer, who is at a great distance, has little or no value for the invaluable information being generated at the higher levels.

The core strength of PGM is in its approach to demystifying science and technology. Access to scientific information holds the key to sustainable management of water resources. The PGM approach tried to strike a balance between the scientific management of the HUs and infusing a sense of responsibility into groundwater users, thereby evolving a professional-farmer partnership model for sustainable groundwater management.

Rural Folk Art played a major role in generating awareness in the community about the key concepts of groundwater management. This form of communication is the most powerful and efficient, apart from being interesting to people. Thus, use of rural folk art is recommended for any kind of developmental activity, not only to ensure transparency but also to enlist willing participation of communities in the intended programme.

Farmer Water Schools provided another method of demystifying science for sustainable development, enriched with scientific information and skill development modules. This is also a fully developed model, ready for replication anywhere, with local adaptations.

Determining the unit of groundwater management

Determining the appropriate unit of management for a community based groundwater management approach was challenging. While it might be clear that the natural object of management should be the aquifer unit, the conventional unit of development is usually political and administrative, determined among other things by distance to headquarters, accessibility and revenue opportunities, in spite of the periodic cautions of the scientific community.

For instance, the watershed management programme approach is focused more on the area of treatment and specifies the size of the watershed, changing from time-to-time. The boundaries of the so-called 'watersheds' seldom match the boundary of the natural drainage basins at the micro-level. Moreover, a micro-watershed of 500–5 000 ha may not be always suitable as the unit of management for a groundwater system or other parts of the hydrological cycle.

The categorization of the stage of groundwater development is based on the data collected from the established network of observation wells, apart from data from other departments. The Government of India (Ministry of Water Resources) revised the prescribed norms for groundwater resource estimation in 1997. These norms, referred to as Groundwater Estimation Committee (GEC) norms guide the assessment. GEC recommended a natural drainage unit as the 'assessment unit'. Currently assessments are made for administrative as well as a drainage basin, identified by the state groundwater agencies.

The PGM unit of management for groundwater systems is a drainage basin, with established recharge and discharge areas. In unconfined systems, often this is similar to catchment of a third-order stream, referred to as the *Hydrological Unit (HU)* in this publication. A balance needs to be struck for confined aquifers between the recharge and discharge areas, which could be vast distances apart. Probably a river basin tributary could be suitable for this purpose. An entirely fresh approach is needed for aquifers discharging directly into the sea or ocean, with its recharge area on land and discharge into saline water, forming an ingress cone of saline water. Ultimately, the ideal is to bring together management structures created in each of the HUs under the umbrella of a River Basin Organization (RBO), which would be more functional and effective in discharging its duties, than creating the RBO as a separate entity.

Overcoming scarcity of hydrological data

A pre-requisite for assessment of any groundwater system is time-variant hydro-geological data, which is unfortunately rare or non-representative. Additionally, several sets of spatial and temporal information are needed to manage groundwater systems. Therefore periodic hydrological monitoring (comprising collection, analysis and storage of a range of data) becomes non-negotiable.

Governmental organizations, CGWB at the centre and APSGWD at the state level systematically collect water-level data through a network of observation wells. Under the Hydrology Project, these departments strengthened their observation well network, by constructing piezometers (some equipped with automatic water-level recorders). The data generated was stored using dedicated software – Hydrological Information System (HIS), developed by the Hydrology Project.

Currently, the observation well network is limited if one compares the geographic area of an administrative unit. In India, there is one observation well for every 20 km^2 area and one rain gauge station at intervals of about 50 km^2. Stream outflow measurement is scarce, as is the measurement of well discharge. Though, the current hydrological monitoring network is sufficient to draw conclusions at a regional scale, the data may be unfit for drawing conclusions at a micro level, given the fact that rainfall is known to vary within short distances (few kilometers) and wells within the same village in hard rock terrains show great differences in well yields.

Monitoring was on a regional scale and provides a general picture of a large area. Watersheds within this area might show quite a different picture when analysed separately. The scientific community mainly used the results of hydrological monitoring to predict water table depletion, natural disasters, weather forecasting and drought forecasting.

The *Participatory hydrological monitoring (PHM)* tool evolved after long experimentation in the field and should provide answers to major issue such as scarcity of hydrological data. PHM could assist CCWB and state level scientific agencies to adapt the scientist-farmer model of data sharing so that it is of mutual benefit. The interval between the stations, as evolved for PGM, could be adopted by groundwater agencies so as to obtain more representative data, thereby improving water-balance estimations. The designs of rain gauge stations, monitoring wells and stream gauges, as well as methodology of construction, data collection, storage, display and dissemination strategies that worked for PGM could solve the issue of access to data and introduce transparency of available data (for a cost) in the public domain. From the technical viewpoint, use of production wells to monitor water levels should be seen as a paradigm shift, which again addresses the issue of data scarcity. PHM training modules are fully developed and should address the issue of community capacity-building for sustainable groundwater management.

Local organizations, local government, local civil society and the local private sector all have important, and often unique, roles to play in water management and their participation needs to be encouraged. Priorities at the local level differ from those at the regional or national level. However, several micro-interventions have common local issues that need to be scaled-up to higher policy levels. Enabling individuals and communities to understand their options for change, so they can select these options, assume responsibility for these choices, and realize their choices could radically alter the way the world uses its limited water resources. Recently, NGOs have played a major role in accelerating developmental initiatives, not only in the traditional community organization but also in the land and water sector.

As stated in other sections of the publication, people nearest the groundwater can best manage this resource, not the occasionally visiting agencies. Therefore, knowledge of the nature, occurrence and behaviour of groundwater systems should be understood by local people who will be affected by changes to the system. Though all beings need water for their survival, the groups using it the most, thus depleting groundwater in certain pockets, are groundwater-based farmers who are the principle stakeholders in groundwater management. The PGM model institutionalized groundwater management using *community based institutions*, specifically focusing on the sustainable use of groundwater. Sensitizing and capacity building of farmers was the key to improving their knowledge of the aquifer systems. This enabled them to start thinking about demand-side management of groundwater resources.

Scarcity of right groundwater professionals: A major issue is the scarcity of the right type of groundwater professional. University students study ‘Hydrogeology’ as a specialization in geology and seem more confused than lay people, when they take up the task of well siting and other groundwater-management tasks. What is taught at the university is pure theory, which is difficult to relate to situations at the field level. Other groundwater-management professionals are geophysicists, hydrologists and civil engineers. These professionals usually lack a good understanding of groundwater science, as the topic is treated as a subsidisary subject

It is unlikely that a university degree can produce professionals that are adequately equipped to take up the task of managing groundwater systems at the field level. With a ‘brain drain’ towards information technology and mining industries, only a few groundwater professionals will be left to handle the tasks of data collection, storage, analysis and publication of research results for use by policy-makers.

Given the small number of staff in the line departments, an increase in the number of observation wells and rain gauge stations only adds more worries to already overburdened staff. The same would be the case with the introduction of the concept of keeping track of specific yields from different types of aquifer systems. With the brain drain toward software and mining industries, youth seem to have little or no interest in choosing groundwater management as a career. Even if some are interested, not many institutions seem to offer a comprehensive package, to ensure s/he goes to the field well equipped to face challenges related to this mysterious form of water source.

A pool of professionals benefited from association with the implementation of the PGM process. Those who underwent intensive training and exposure were mainly from the academic backgrounds of geology, agricultural sciences, sociology and social work. These professionals are much in demand on the job market and simply walk in to any type of agency dealing with water. This addressed the employment issue to a certain extent, at a time when there was no recruitment of professionals in the government service.

Data management strategies such as the hydrological monitoring record, Habitation Resource Information System and information kiosk, though not completely developed, could provide a starting point for similar initiatives to address data scarcity and access. Linking of the Habitation Resource Information System with the databases of groundwater agencies remains to be tried and could prove mutually beneficial. The information kiosk should be seen as an attempt to build a prototype for an interactive, user-friendly, crop–water information base. This could be a good investment and would solve the issue of data access at the farmer level. Thematic maps generated by PGM experiments for use by professionals and farmers should be seen as a sincere attempt to demystify the science of rural development. It is expected that GIP and GPS, along with mobile phone technology, could bridge the gap between a practicing scientist and groundwater farmers, which would be in the overall interest of sustainable groundwater management.

Estimating groundwater recharge and groundwater withdrawal and user access to scientific information

The norms of the Groundwater Estimation Committee (GEC 97) are being used by the CGWB and APSGWD. However, the practical application of these norms for estimation of groundwater recharge, withdrawal, and ultimately the balance, is left to state level agencies. Though these norms serve as good reference material, a computer-based application to run estimation at regular intervals, for a given hydrological unit, is currently missing.

The crop–water budgeting spreadsheet, developed as part of PGM, should be seen as an attempt to use recommended norms for sustainable groundwater management. The steps evolved could be a starting point for building a more robust methodology of crop planning suiting groundwater availability in the hydrological year. Technically, there is much scope for improvement, but there is no denying that this is a starting point. Crop–water budgeting was a key activity that linked hydrogeology with agriculture. The lesson learned is that partnership between scientists from different academic backgrounds is essential to any initiative aiming for sustainable groundwater management.

User access to scientific information: The scientific and semi-scientific staff in government departments' such as Meteorology, Groundwater (state and central) and Agriculture undertook hydrological monitoring and the results used by the scientific community for predicting water table depletion, natural disasters, weather and drought forecasts. The results of scientific assessments to classify 'assessment units' into different categories, based on stage of groundwater development, are mostly confined to the file-racks and never reach the groundwater user, who would benefit greatly from the information. A farmer is caught unaware when his/her well goes dry or poor water quality manifests itself in the form of disease (e.g. fluorosis).

A scientist's understanding of the status of development in a certain aquifer system may only result in publication of papers. If there is no political will to take measures to control groundwater extraction, this scientific analysis may be a worthless exercise. Therefore, the only alternative to controlling indiscriminate pumping from an aquifer is to ensure communities realize the enormity of the problem. It is important to note that the sustainability of borewells is governed by factors that may not be in the hands of elitist groups, and are best controlled by the activities of local people. Indiscriminate drilling by individual farmers was one such factor in the overall context of State groundwater management. One option was to raise awareness among users so they voluntarily took up the task of managing their groundwater systems.

The farmer is the ultimate guardian of the groundwater system. Legislation and improved recharge conditions could have only helped him/her and not the control of her/his actions. It is impossible to take appropriate action unless the farm community gains knowledge of annual groundwater recharge and withdrawal. An external agency may provide information about groundwater balance to illustrate the consequences (both short-term and long-term), under different withdrawal/crop/irrigation conditions, as well as the relationship of how the number of borewells can influence total groundwater withdrawal in the HU.

It is obvious, however, that farmers are in the best position to take preventive measures and thus escape the consequences of drought. It has been proved that drought forecasting by scientists could only help by documentation and could not save the farmer from misery. Further, groundwater users can best control depletion of this resource. The role of scientists and administration, therefore, should be to empower people with the skills to monitor and manage their own groundwater systems.

PHM empowers farmers with simple tools for recording hydrological aspects and interpreting them for their own benefit. As the words participatory hydrological monitoring suggest monitoring is participatory, involving all stakeholders including the scientific community and borewell users. PHM is only a tool used to trigger community action for sustainable use of aquifer systems. The idea is to generate the data to enable the community to understand the dynamics of the groundwater system.

Addressing risks in groundwater development

It is estimated that 64 percent of irrigated areas in India is serviced by groundwater (Burke, FAO, 2012). The main crops grown with groundwater are rice and wheat. While it is essential that a nation can produce enough food for its population, it is important that it is also cautious with its use of groundwater, especially in states such as Punjab and Haryana, where hydrostatic pressure head (water table) seems to be dropping at an abnormal rate, owing to annual withdrawal exceeding the recharge. However, the role of alluvial aquifers in the 'green revolution', and converting a hungry nation into a food surplus country, need not be undermined.

Until the mid-twentieth century, groundwater was tapped from shallow wells, mainly for domestic consumption and critical irrigation. The annual groundwater withdrawal, in most groundwater systems was only a fraction of the annual recharge, as a result not only the wells were perennial, but also streams flowed throughout the year, receiving base flows from the saturated zone. The advent of drilling rigs, in the seventies, paved the way for construction of deep wells. With the establishment of the Water Development Society (WDS), Hyderabad has become the centre for rig manufacturing. It became very easy for farmers who wanted to drill borewells, as the only thing s/he has to do is to hire a rig. With the intention of increasing agricultural production, developmental agencies encouraged drilling and power connections came easily to farmers who drilled borewells successfully. When the dug-wells started drying up everybody woke up and realized that borewells not only withdraw water from deeper layers of the aquifer but also the submersible pumps take out the water at alarmingly faster rates.

Advances in pump technology, especially the submersible pump, allowed high groundwater abstraction and allowed food crops such as rice and wheat to be cultivated using well irrigation. The role groundwater-based food crops cultivation had in turning hungry nations into food-surplus countries need not be over-emphasized here. Just before the turn of the millennium, unplanned development (with no concept of management) of the groundwater resource, lead to mushrooming of wells, resulting in annual withdrawal far exceeding the annual recharge, rendering many wells and stream flows seasonal.

In hard-rock areas, the quest for more water for crops, made farmers venture into tapping of deeper level aquifers, as the first layer (usually an unconfined aquifer) went dry/seasonal. The areas where there was no second layer of aquifer (e.g. in a basement complex), farmers gambled with construction of new wells at the beginning of every monsoon year, often leaving them debt-ridden, and sometimes driving them to suicide. This grim situation would have been avoided, only if the farmer and the policy-makers understood how groundwater systems work and what could be done to use the resource smartly.

While groundwater development contributed to improved agriculture production, lack of proper understanding of the system, led to a serious situation of groundwater depletion. The focus is on groundwater development rather than management. The main reason being the notion that groundwater is infinite. Elements of groundwater management are loosely understood and a half-hearted attempt is being made to manage groundwater.

The number of boreholes drilled under government programmes are few, when compared to those drilled by individual farmers. Site selection, in these cases depends on the awareness level of the individual farmer. While some farmers hire private geologists to locate a suitable site for drilling, in rural areas many depend on unprofessional practitioners (dowsers), who use forked sticks, coconuts and clapping methods. Some farmers go ahead with drilling without any site selection process at all. These are risks borne by the farmer or shared with the drilling contractor, but 'blind' prospecting in some geological settings rarely makes good economic sense.

In the eighth and ninth decades of the twentieth century, hydrogeologists played a major role in the successful construction of wells, often where use of groundwater for agriculture was uncommon. Their focus was the 'success rate'; they never looked at how many wells could be sustained by a particular groundwater system. One successful well in a non-conventional groundwater tapping area drives others in the village to invest blindly in well construction.

Many groundwater systems operate with an unsustainable number of wells, contributing to over withdrawal (withdrawal more than recharge). There is no strict scientific procedure for site selection even it is carried out by a professional. They depend on their academic knowledge and geophysical instruments, and the success rate of drilling varies from individual-to-individual depending on his/her technical skill.

Technical procedure for short-listing viable areas for groundwater development: The PGM model addressed the issue of unplanned groundwater development by deriving a standard technical procedure for construction of group managed borewell irrigation systems, including EVA and priority ranking of mandals. By suggesting a scientifically correct unit of intervention for groundwater management, PGM addressed the confusion that existed about the right unit of intervention for water resources management. The hydrological unit should alert the CGWB, as to the most appropriate groundwater assessment unit, and could help convince policy-makers.

Supply-side management of groundwater has found favour with policy-makers, historically, as it talks about putting more water into the ground. However, it should be understood that the water-bearing formation, into which additional recharge is directed to supplement natural recharge, does not have an infinite capacity to absorb. Not all aquifers can take in water and not all are able to transmit or yield the same amount of water, even after artificial recharge.

Artificial Groundwater Recharge (AGR): Current policy seems to promote standard methods disseminated by scientific agencies that do not specialize in groundwater sciences. The focus seems to be more on construction rather than understanding groundwater systems. The construction sites are never chosen based on technical viability, and the target setting for district level functionaries does not help to establish appropriate measures are taken so that artificial groundwater recharge suits local groundwater conditions.

Moreover, artificial groundwater recharge should be carried out in specific areas, where the surface or subsurface conditions are suitable for recharge, definitely not on the massive rock-bed, where there is no scope for infiltration, but better chance of increased evaporation. The standard methods of artificial groundwater recharge that are sometimes promoted by reputable agencies would not work everywhere. The artificial groundwater recharge plan for the HU should be based on extensive study of the area so as to understand the nature and occurrence of groundwater and where to locate the sites best suited to artificial groundwater recharge, both in terms of quality and quantity.

PGM also evolved a more scientific, but people-centered method, of artificial groundwater recharge. This should address the issue of groundwater over withdrawal, from a supply-side management method. The farmer-scientist partnership model provides a starting point for many future initiatives. By design, this would remove the ambiguity of artificial groundwater recharge and its benefits for improving the groundwater situation. Watershed development agencies could adopt this strategy of measuring the impact of watershed treatment on the groundwater regime.

Ensuring equity and social justice in water use

People need water for survival, basic needs and productive activities (mainly agriculture). No one is bothered about the form of water, whether ground or surface, as long as it can be accessed. The first Prime Minister of India, Pandit Jawaharlal Nehru observed, ‘Dams are modern-day temples of humans’. In the post-independence era, dam construction was taken up aggressively to bring parched lands under the commands serviced by surface water reservoirs built across several major rivers.

While, vast amounts of public money have been spent on construction of large surface water reservoirs, groundwater development is promoted as a private enterprise. In post-independence India only the prosperous, and those in important positions, were able to ensure their regions benefited from public-funded surface water reservoirs while, in other regions, the rich were satisfied with the freedom to invest and benefit from groundwater sources. This limited access to water for a few, i.e. only the powerful could access water from dams without spending a rupee, and the rich took pride in ownership of wells developed to tap groundwater. The large-scale farmers with wells prospered and constructed more wells and bought more land under irrigation. This situation continues even today.

While those with wells continue to enjoy the benefit of their access to groundwater, because of their economic status, the ones without (have-nots or poor) still remain in miserable conditions, because of their inability to invest in well construction. The regional disparity in water-based development is another important equity issue. It is no wonder that there is a high rate of groundwater use in regions that could not benefit from dams. The smallscale and marginal farmers (smallholders), who had to rely on unreliable rainfall patterns, could not access the groundwater resource and, if rains failed, they were sometimes pushed to end their own lives. There was no mechanism to incorporate the concept of equity into groundwater use or, for that matter, water in any form.

Farmers depend on groundwater for agriculture not by choice but by absence of any other form of water. Given a chance, s/he would definitely want sustainable use of water, either ground or surface. Rampant groundwater use in non-command areas is testimony to the helplessness of the farmer. The surface water user benefits from huge public funding for the construction of irrigation systems, they pay almost nothing for water. In contrast, the groundwater user invests in well construction, commissioning, operation and maintenance, as well as having to pay electricity bills.

The Directive Principles of the Indian Constitution provides for the supply by the Government of a safe drinking water supply for every citizen. Water is subject to the State as is its development, utilization, monitoring and responsibility for water resources planning, storage and use of its water resources. The water resources of the interstate rivers are governed by the allocation of water between States by tribunals set up by the Government of India. Several Government Departments/Agencies, NGOs and people’s institutions are involved in water development, use, monitoring and regulation.

This following provides a brief institutional framework of the water sector.

In 1985, the Supreme Court of India passed a judgment requiring the Government through the Ministry of Environment and Forests to address groundwater over withdrawal problems. In response, the Ministry of Environment and Forests issued a notification on 14 January 1997, creating the Central Groundwater Authority (CGWA), and designating the Central Groundwater Board (CGWB) with the administrative responsibility of the Ground Water Authority (GWA) with the mandate to regulate and control groundwater extraction. Subsequently, complementary authorities have been created at the state level.

Various states have passed legislation intended to enable groundwater regulation, which include: the Maharashtra Water Act, Madras mini-act, Gujarat amendments to the irrigation act, and the Andhra Pradesh Water Land Tree Act (APWALTA), based on the model bill circulated by CGWB. The Governor of Andhra Pradesh promulgated Andhra Pradesh Ordinance No. 15 of 200 on 15 December 2000, under Article 348 (3) of the Constitution of India. Under this Ordinance, the state government constituted the Andhra Pradesh Water, Land and Trees Authority (APWALTA).

Farmer Management of Irrigation Systems Act, 1997, by which the maintenance of irrigation systems and management of irrigation water was transferred to farmers by establishing water-user associations, distributaries and project committees. The policy of participatory irrigation management only applies to surface water and leaves out groundwater irrigation.

Transfer of power to local levels was a key component of the Panchayat Raj Act (the Seventy-third Amendment to the Constitution). Water was listed as one of the several functions of the Panchayats. The real management of water, however, was still to change hands from the Government Departments to Panchayats. Given the complexity, it was important to recognize that effective institutions would not emerge overnight and that processes enabling the development of institutions and capacity building were essential.

In general, the state only talked about enforcement and legislation to stop drilling in water stressed areas, which would be in the interest of the large-scale farmers, already benefitting from the groundwater resource. It would have further enabled them to have unscathed control over the resource. It was doubtful whether legislation could close some of the existing borewells to match the annual water balance. As long as groundwater was seen as inseparable from land ownership, the legislation was not going to address either the issue of equity or sustainability.

Well registration was a time consuming process that provided scope for corruption. Moreover, it was not easy to keep track of what happens at the village level. Water policing was a concept that could not be digested by an

Indian farmer. When drilling rigs were available on the open market, it was difficult to expect that everybody would seek permission from the suitable authority appointed by the Ground Water Authority. When there was a question of closure of wells, the selection criteria for wells to be closed was not clear.

As mentioned earlier, historically the approach to water resource development has been to construct large dams, river-diversions, large water supply and waste treatment works. Then, in the late eighties came the champions of globalization and privatization, criminalizing the groundwater users for its indiscriminate use, and introducing the concepts of water as an economic good; water-use efficiency; water markets; water pricing and water-energy nexus.

These concepts are still popular and being discussed globally. However, farmers depend on groundwater for agriculture, not by choice but because there is no other form of water. Given a chance, farmers would choose sustainable use of water, either ground or surface. Rampant groundwater use in non-command areas is evidence of the powerlessness of the farmer. In contrast to the surface water user, who benefits from vast amounts of public funding for the construction of irrigation systems and pays next to nothing for water use, the groundwater user invests in well construction, commissioning, operation and maintenance and also pays for electricity.

International agencies have recently become vocal in their trashing of groundwater users. They seem to think groundwater users are committing a great crime as pumping requires so much electrical power that could be utilized for ventures that make more profit than agriculture. Industries, including those bottling water, have become the main users of water, threatening the primary position of the agriculture sector.

Under common law in India (derived from English common law), groundwater extraction rights are chattel to land (MOWR, 1996). Extraction of percolating waters, with no limit on quantity is the right of every landowner (Sinha and Sharma, 1987). Landowners generally regard wells as their own and view others, including the government, as having no right to restrict or otherwise control their right to extract water. Despite the well-established common law position, the easement and irrigation laws proclaim the absolute rights of government to all natural water (Singh, 1990).

As long as the landowner owned the groundwater under the law, and the resource remained in the hands of rich farmers, smallscale and marginal farmers (smallholders), who rely on uneven rainfall patterns, could not access the groundwater resource and, if the rains failed, some killed themselves. There was no mechanism to incorporate the concept of equity into groundwater use or, for that matter, water in any form.

The National Water Policy (2012) of India undermines the concept of 'water as a human-right', and its dislike of the groundwater user (who is dependent on electricity) is evident. The policy does use the word 'equity', but fails to propose any concrete strategy to address this huge issue. It hints at absolving the state of its responsibility for ensuring a fair share of water to each of its citizens, and assumes that a profit-making company will be interested in the welfare of the deprived sections and will ensure that everybody gets a minimum quantity of water, required for life-support. Ideally, water allocation for agriculture should be made, keeping in view the food needs of the populations living within a natural drainage basin. Logically, per capita water rights should include the amount of water for agriculture, in addition to water for life. Needless to say those per-capita water rights should ignore the form of water, to give a fair deal to groundwater users.

The National Water Policy (2012) of India is clear in its differential treatment of surface water and groundwater sources as two independent systems, ignoring the fact that they operate within and are part of a single hydrological cycle. It singles out over withdrawal as the main cause of groundwater depletion, but does not offer any strategy to bridge the huge difference in spending of public money on construction of medium-sized projects, leaving groundwater development entirely in the hands of private investors. Following this policy it seems that electricity for agriculture is currently under-priced and there is support for charging for the cost of production based on water pricing. Electricity forms the heart of the matter for agriculture irrigated from wells and this policy is detrimental to the interests of groundwater farmers, who are already paying high prices for electricity, while the publicly-funded surface water reservoir farmer enjoys access to water almost free.

6.3 Upscaling

Currently there are two schools of thought that drive the opinion on how public water should be managed. The first, and the most powerful, consider water to be an, 'economic good', while the most vocal second group advocates 'common good' approach. The economic good group advocates the efficient use of water, through regulatory mechanism, both direct (water pricing and formal water markets.) and indirect (raising electricity prices). The 'common good' school is concerned about the reach of municipal production that can impact aquifers in surrounding rural areas. PGM is highly relevant in the context of the current conflict. As an instrument of people's empowerment, PGM can address the concern of the 'commons'school, through building strong community based institutions, made sustainable through functional linkages with all local agencies. In this sense it offers an alternative model for efficient water use in place of a regulatory model, which may prove unpopular and difficult to implement.

The core strength of PGM was its approach to demystifying science and technology. Access to scientific information, at the user level, holds the key to sustainable management of water resources. The PGM approach struck a balance between the scientific management of the hydrological units and giving groundwater users a sense of responsibility, thereby evolving a professional-farmer partnership model for sustainable groundwater management.

With an ever-increasing number of aquifers facing overexploitation, various government agencies see the need for exploring new approaches in managing groundwater decline. Agencies have been forced to seek successful approaches because of the absence of credible successful models for groundwater management. Empowerment of communities through knowledge, capacity and skills is seen as a necessity. A number of initiatives are in the advanced stages of discussion for replicating the model in different hydrogeological and socio-economic settings.

PGM provides a starting point for groundwater management in areas where aquifers are under stress. It covered only a small part of these areas, leaving others to the governmental and NGOs. It is these areas they should attempt the PGM model, whicle remembering its successes and failures.

Upscaling in India

Under the Indian Constitution, States are primarily responsibile for managing and ensuring the sustainability of groundwater resources. In addition to their constitutional mandate, state agencies have an advantage in promoting groundwater management on the ground. State agencies have a much sharper appreciation of how to nurture and sustain people's institutions for managing water resources. They are in a better position to facilitate cross-sectoral coordination of groundwater resources at the most critical (state) level, promote 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), design groundwater management approaches specific to the typologies and user needs of local aquifers.

The existing instruments for controlling abstraction of groundwater through direct regulation have not halted the proliferation of boreholes. The lack of resources for policing and absence of substantial support for penalizing the defaulters have made a direct regulatory approach impossible to implement. The PGM experience suggests that there is a viable option for voluntary regulation by stakeholders themselves. This needs to be driven through improved understanding of their aquifer systems and demonstrations of the positive impacts of improved natural resource management on livelihoods.

Arguably, the PGM experience has been breakthrough in the management of groundwater and has secured the livelihoods of poor farmers in India. Since thesere are key concerns of the central Government of India and of many State Governments, the PGM approach has found a place in the Twelfth Five-Year Plan. However, there would be some difficulties in upscaling, the most important being: dissipation of Technical Support Teams; absorption of highly trained technical staff elsewhere and not every state is willing to adopt the model. However, these difficulties could be overcome by establishing a PGM think-tank; hiring of PGM technical staff by CGWB or State level agencies responsible for groundwater management (alternatively NGOs with a scientific outlook); and negotiating with the states that sent their staff for training, during the APFAMGS-FAO phase of the Project.

The first pre-condition for upscaling of the PGM model, is the existence of a driving force, i.e. a national level institution that could perhaps bring together knowledgable people in the water sector (both NGOs and individuals). The Technical Support Team was the backbone of PGM and where ideas were generated, because FAO hired highly qualified and progressive professionals in water management, agriculture, institution building and gender. After dismantling of the Project, there was a one-year gap and nothing could hold these people together. The company that had hired these consultants was no longer active. Currently, they are employed by projects supported by different United Nations agencies.

The PGM model can be upscaled at the district level, through a quick pilot, preferably in the districts where PGM CBOs are active. After a two-year pilot, the model could be upscaled at the state level (with different intervention methods and management options in different locations within the state as well as other states). The government officers (and community leaders in some cases) of Andhra Pradesh, Maharashtra, Orissa, Tamil Nadu, Gujarath, and Rajasthan, were trained in this approach and replication is being carried out that suits the needs of their states. The sharing of State level experiences is expected to lead to a lively discussion.

The hydrological unit, which was selected as the unit of intervention and for creating community based institutions, is replicable in dry land areas that are supported by groundwater irrigation. Even for large alluvial aquifers, the unit of intervention can be delineated by mapping of the aquifer system, and by defining the boundaries of the aquifer, thereby developing community based institutions at the aquifer level.

Participatory hydrological monitoring for APFAMGS was limited only to those scientific and socio-economic parameters that control the usage of the groundwater resource. Notwithstanding, with this limitation, the set of parameters can be redesigned to suit the requirements. The bottom line is to empower communities with the skills and knowledge for collecting, collating, understanding the implications of their current actions and to trigger discussions about possible options before taking action at the farm level.

Crop–water budgeting at the beginning of the rabi season is crucial for groundwater farmers. It has been observed that pumping reaches its peak because of the low, or no, rainfall during this cropping season. However, with the necessary changes in methodology, the concept of crop–water budgeting can be replicated even in command areas.

Farmer Water Schools proved to be a powerful tool because of their approach to the experiential learning cycle. This tool is useful for educating and empowering communities with the knowledge and skills, on any topic.

Upscaling in other countries

At the international level, organizations such as FAO can promote upscaling of PGM in its member countries with local modifications to the packageFAO is addressing this issue with this present publication, which may be considered a first step. A starting point may be to contact people in different countries, with various capacities, to assess the level of diffusion of PGM in their respective countries and to define ways to upscale at the provincial or national level.

Some pre-conditions, learned during implementation of PGM, should be borne in mind while upscaling the PGM model. These are a willingness to adopt the HU as the intervention unit; technical modifications to the model should suit the local hydrogeological situation; adaptations should be made that suit local socio-cultural conditions; a think-tank should be established at the national level; multi-disciplinary teams at all levels and there should be faith in participatory approaches.

At the implementation level, implementers should have faith in participatory approaches; adaptation is required in non-hard rock areas; NGOs should be willing to recruit professional staff; multi-disciplinary teams should be willing to learn from each other; there needs to be expertise in non-formal education, socio-cultural practices; existence of willing NGOs and a core support team needs to be established.

Completely funded models would fail to create community ownership. A commercial model will defeat the very purpose of PHM, because the hydrological data would then become goods for sale. With PHM, communities are encouraged to make farm level decisions based on scientific data/information, mainly generated by themselves.

A completely voluntary model is impracticable, because the key to the success of PGM was the presence of farmers who felt the pinch of water scarcity, wells going dry in front of their eyes and neighbours who had committed suicide because they were unable to pay debts acrued from drilling borewells. In areas where there is no water stress it is difficult, if not impossible, to generate voluntary actions. Furthermore, PHM infrastructure and technical expertise will not come freely.

A combination of these three models should be in place for upscaling the PHM model at the national level. Components that need to be completely funded include PHM infrastructure; community capacity building; hiring of technical personnel and incentives to encourage farm level action. The commercial component of the model would be to provide mechanisms for marketing farmer data products, which would contribute to the sustainability of the community based institutions and PHM assets (funds for operation and maintenance). The voluntary component would be limited to the choice of individuals In the community to engage in efforts to match the annual groundwater withdrawal with the annual recharge, in a given hydrological unit.

6.4 Myth and reality

It is observed that many people worldwide, as well as within India, have some misconceptions and misunderstanding about the extent to which the PGM model applied in Andhra Pradesh is relevant and meaningful. Some of these 'myths' are captured in this section, and set against the observations of the project team. They are presented here 'without comment' just to leave an impression and caution against accepting any popular announcement without checking sources and facts.

Myth 1: Community based institutions crumbled after projects were completed

Reality: In spite of there being no support from FAO, the HUNs successfully conducted crop–water budgeting considered to be the heart of APFAMGS activities, for rabi 2010. This means there is no discontinuity of PHM data collection. Partner-NGOs remain active in their respective areas of operation and continue to provide skeletal technical support. Hundreds of farmers continue to provide their expert services to several government programmes, as Resource Persons.

Myth 2: NGOs collect PHM data

Reality: PHM data is not collected by NGOs, but by Community Based Organizations (Groundwater Monitoring Committee at habitation level and Hydrological Unit Networks at the Hydrological Unit level). In fact CBOs coordinate the data collection and storage while the data is collected by PHM volunteers. The data is not collected just to fulfil the mandate of a project, but to use it in decision-making at the hydrological unit level.

Myth 3: Farmer data is not accurate and scientific

Reality: Data does not need to be collected by a post-graduate in geology or hydrology, as any school finalist with required training can take up the task of data collection. If it relates to the sincerity of the data collector, there is no reason to believe that a farmer will compromise on prescribed norms, while a scientist will follow them strictly. Monitoring stations are established per national/international norms and data collection is carried out per international standards. The farmer-generated data is used by several academics and research institutions including the Australian Centre of International Agriculture Research (ACIAR), International Water Management Institute (IWMI) and the World Bank. The farmer data is verified by qualified professional staff (post-graduates of geology or hydrogeology), and stored in a computer database. Data is used for decision-making at the lowest level, i.e. habitation, mainly sustainable groundwater management and agriculture in their hydrological unit, which is made up of 5–20 habitations.

Myth 4: PGM did not try supply management

Reality: Artificial groundwater recharge was also a part of the APFAMGS project. The focus is on demand-side management for two reasons: 1) the Groundwater Estimation Committee recommends an additional recharge of 2 percent for computing artificial groundwater recharge through whatever physical structures; and 2) artificial groundwater recharge structures were costly. Artificial groundwater recharge (supply-side) activity has slowed and then stopped, because it was not wise to invest so much in an activity with a low projected impact.

Myth 5: PGM did not promote conjunctive use

Reality: Where there are surface water sources, it is obvious groundwater is unimportant. This was illustrated by Nalgonda district, where farmers became disinterested in PHM after they began to receive canal water. The issue of surface water institutions is different from those that are groundwater based. While surface water institutions fight for water in the desired quantity and on time, groundwater-based institutions discuss how they can sustain their dwindling resource. In our experience, the idea of conjunctive use of water has remained limited to papers and publications. Thus far no field model has demonstrated that this concept has worked.

Myth 6: PGM did not address supply-side management of groundwater

Reality: Artificial groundwater recharge formed an essential part of management in HUs where crop–water budgeting results showed an over withdrawal.

Myth 7: Participation solves everything

Reality: PHM and CWB did solve the problem of over withdrawal, in the majority of HUs because of voluntary community action, as they realized they needed to solve their own problems such as wells going dry; outsiders (scientist, bureaucrat and politician) cannot safeguard the groundwater in their wells; it is for the users to either use or misuse the resource; outsiders can at best provide support to the community in understanding the reason for the behaviour of water in their wells. So not only do the communities participate in groundwater management but outsiders as experts and technicians participate in farmers' groundwater management.

Myth 8: No economic benefit for the farmer

Reality: There was a direct economic benefit for the farmer in terms of access to well irrigation; tapping of government funds for efficient irrigation and switching to more profitable crops, as demonstrated by the discussion in the previous chapters.

Myth 9: PGM did not interest the local government

Reality: PGM interested the local state government as illustrated by the extent of the diffusion of PGM practices to several of their programmes, as described in the Section Diffusion.

Myth 10: Social fencing to curb over withdrawal is weak

Reality: Social fencing may appear weak as PGM adopted a non-coercive approach, but in reality is pervasive, and based on collective decision-making, as shown by the little or no increase in the number of functional wells and the proliferation of water-efficient agricultural practices.

Myth 11: PGM promoted cash crops

Reality: Farmers might have opted for cash crops but no crop was promoted as part of PGM, except to appeal to match groundwater withdrawal with the recharge.

Myth 12: Upscaling of PGM is difficult because of lack of training facilities

Reality: There are many training facilities at any level (district, state or national) in India.

Myth 13: PGM model is not affordable and scalable

Reality: The model is affordable, even though investment is required for capacity building and to establish hydrological monitoring networks that are scalable at the HU level, followed by basin level. These require expertise that evolved during implementation of PGM creating several tools for the scientific understanding of aquifer systems and community capacity building.

Myth 14: It did not ensure drinking water security at the village level

Reality: Drinking water security is taken care of by crop–water budgeting as recharge is not added through secondary sources. Additional recharge through watershed treatment amounts to a mere 2 percent of the rainfall received. There is the example of Nalgonda, where PGM farmers permitted connection of a village, where the water source had failed, to the water supply grid.

Myth 15: Farmer suicides are curbed because of PGM

Reality: Though there is definitive reduction in number of new wells and high economic returns from alternate crops, the extent to which farmer suicides are curbed could only be known after a specific study.

Myth 16: Farmers are paid by the project for collection of data

Reality: Farmers are NOT paid by the project for data collection, as the idea was to instill a sense of responsibility for sustainable groundwater use.

Myth 17: Conflict resolution mechanism not in place.

Reality: The conflict resolution mechanism at the village level is the responsibility of the Groundwater Monitoring Committee; at the level of the HU it is the responsibility of the HU Network; and at the basin/district levels it is the NGO Network.

Myth 18: Production wells are not suitable as monitoring wells

Reality: Non-pumping wells are specifically constructed, because pumping depletes the water level not giving the well time to recuperate and regain its original water level. It has been observed, however, that after pumping is stopped, especially in hard rock aquifers, the well regains its pre-pumping water level within a few minutes, except for the last few millimeters. PGM did not bother about the fraction of a centimeter and instead relied on a larger number of monitoring wells in a representative grid.

Myth 19: Energy pricing is better than PGM

Reality: APWELL was the first platform in India, where metering of electricity was introduced, and the farmers committed to pay according to electricity consumed. Somehow, this was left out along the way. There were also 'transformer committees' that maintained the transformer and wells it serviced, especially the cluster of borewells provided by APWELL. The notion of energy pricing being better than PGM arises from the notion that electricity is under-priced in India.

However, pricing is more in the interest of the private companies that run the business of electricity in India. From a social justice angle, groundwater farmers will loose out with this policy. It is more acceptable that agriculture water is priced, instead of singling out wells that solely depend on energy supply. Surface water facilities also depend on electricity for pumping, but costs are borne by the state because state agencies are still involved in distribution from the head-works.

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Annex 1. List of Hydrological Unit Networks (HUNs) currently active in Andhra Pradesh

SN	HU Name	District	President
1	Chinneru	Kurnool	A. Srinivasulu
2	Rallavagu	Kurnool	Sreedevi
3	Thundlavagu	Kurnool	Krishnaiah
4	Peddavagu	Kurnool	G. V. Konda Reddy
5	Lothuvagu	Kurnool	L. Ramasubba Reddy
6	Chandravagu	Kurnool	K. Nageswara Rao
7	Buchammakonetivanka	Kurnool	B. Nagireddy
8	Konetivanka	Kurnool	P. Lakshmi Narasimha
9	Bhavanasi	Kurnool	T. Pullaiah
10	Yerravanka	Kurnool	M. Pedda Narasimhareddy
11	Peddavanka	Kurnool	Y. Nrayana Reddy
12	Chandrasagarvagu	Mahaboobnagar	S. Shivamma
13	Mallappavagu	Mahaboobnagar	B. Jayamma
14	Mandavagu	Mahaboobnagar	Jangi Reddy
15	Bodicherlavagu	Prakasam	K. Naarayana Reddy
16	Chinnauppuvagu	Prakasam	T. Vijaya Lakshmi
17	Erravagu	Prakasam	Ch. Peddanna
18	Kanugulavagu	Prakasam	D. Prabhudasu
19	Lingojipallivagu	Prakasam	M. Guruvaiah
20	Mekaleru	Prakasam	G. Subbaiah
21	Mittamidipallivagu	Prakasam	R. Lakshmi Reddy
22	Peddanagulavaramvagu	Prakasam	P. V. Subbaiah Sasthri
23	Pulivagu	Prakasam	Ch. Venkataramaish
24	Sitanagulavaramvagu	Prakasam	M. Venkateswarlu
25	Tarlupaduvagu	Prakasam	G. Bhaskar Reddy
26	Naidupallivagu	Prakasam	M. Venkata Seshi Reddy
27	Yadalavagu	Prakasam	B. Ch. Narasimha Reddy
28	Narisireddypallivagu	Prakasam	M. Ranga Reddy
29	Palamotuvagu	Prakasam	P. V. Lakshmi Prasad
30	Peeturuvagu	Prakasam	S. Narasimha Reddy
31	Rallavagu	Prakasam	K. Nagarjuna Rao
32	Uppuvagu	Prakasam	K. Narsireddy
33	Diguvetigadda	Chitoor	J. Sankara
34	Kothakunta	Chitoor	B. Krishna Naik
35	Rommonivagu	Chitoor	G. Srinivasulu Reddy

36	Nakkilavagu	Chitoor	C. Ramakrishna
37	Bokkineru	Kadapa	N. Chenchi Reddy
38	Erravagu	Kadapa	D. Maddi Redy
39	Erravanka	Kadapa	S. Ramasubba Reddy
40	Mulabandla	Kadapa	Narasimha Reddy
41	Tadukuvagu	Kadapa	A. Eshwaraiah
42	Tandrasilavagu	Kadapa	K. Narayana Reddy
43	Jampaleruvagu	Prakasam	N. Chenna Reddy
44	Vemuleruvagu	Prakasam	V. Hariprasad
45	Kakarlapeddavagu	Prakasam	K. V. Ranga Reddy
46	Chavatavagu	Prakasam	Y. Venkataiah
47	Sudhakurvavagu	Prakasam	R. Ch. Venkata Reddy
48	Singarayakondavagu	Prakasam	J. Swamy Ranga Reddy
49	Bogoluvagu	Prakasam	N. S. Ranga Reddy
50	Bhaskarraokunta	Nalgonda	Gunda Sitaramaiah
51	Kondeshikunta	Nalgonda	Maryada Venkat Reddy
52	Mallappavagu	Nalgonda	K. Balu Naik
53	Nathiganicheruvu	Nalgonda	Gade Venkat Reddy
54	Nukanayanicheruvu	Nalgonda	K. Indra Reddy
55	Sattammakunta	Nalgonda	Panugothu Fakeera
56	Ulsaipalem	Nalgonda	Ancha Sambashiva Rao
57	Bellavanka	Ananthapur	K. Ramadasu
58	Gootymaruvanka	Ananthapur	D. Prabhavathi
59	Maruvanka	Ananthapur	K. Nagendara
60	Mynapuram	Ananthapur	V. Thirupal Naik
61	Upparavanka	Ananthapur	K. Venkataramaiah
62	Vajralavanka	Ananthapur	P. Venkateswrlu
63	Peddavanka	Ananthapur	T. Narayana

Annex 2. Summary of results obtained from HU level analysis of water level behavior

SN	Name of HU	Behavior
1	Kothakunta	Downward trend
2	Nakkillavagu	Downward trend
3	Buchammakonetivanka	Downward trend
4	Konetivanka	Downward trend
5	Peddavanka	Downward trend
6	Mallappa vagu	Downward trend
7	Naidupalli vagu	Downward trend
8	Tarlupaduvagu	Downward trend
9	Chavata vagu	Downward trend
10	Manda vagu	Downward trend
11	Uppravanka	Stable trend
12	Peddavanka	Stable trend
13	Gooty Maruvavanka	Stable trend
14	Diguvaetigaddavagu	Stable trend
15	Lothuvagu	Stable trend
16	Chandra sagar	Stable trend
17	Bhasker Rao Kunta	Stable trend
18	Mallappa vagu	Stable trend
19	Sattammakunta	Stable trend
20	Nukayanicheruvu	Stable trend
21	Erra vagu	Stable trend
22	Lingojipalle vagu	Stable trend
23	Peddanagulavaram vagu	Stable trend
24	Yadala Vagu	Stable trend
25	Seetanagulavaram	Stable trend
26	Bodducherla Vagu	Stable trend
27	Suddakuruva Vagu	Stable trend
28	Singaraikonda vagu	Stable trend
29	Bellamvanka	Upward trend
30	Maruvavanka	Upward trend
31	Mynapuramvanka	Upward trend
32	Vajralavanka	Upward trend
33	Rommonivagu	Upward trend
34	Bokkineru	Upward trend
35	Erravagu	Upward trend

36	Mulabandala vagu	Upward trend
37	Tadaku Vagu	Upward trend
38	Tandrasila vagu	Upward trend
39	Erravanka	Upward trend
40	Chinneru	Upward trend
41	Rallavagu	Upward trend
42	Thundlavagu	Upward trend
43	Peddavagu	Upward trend
44	Yerravanka	Upward trend
45	Chandravagu	Upward trend
46	Bavanasi	Upward trend
47	Ulsaipalem	Upward trend
48	Kondesikunta	Upward trend
49	Natiganicheruvu	Upward trend
50	Pulivagu	Upward trend
51	Chinna Uppu vagu	Upward trend
52	Kanugalavagu	Upward trend
53	Mekaleru	Upward trend
54	Miitameedipalli vagu	Upward trend
55	Palamotu vagu	Upward trend
56	Ralla Vagu	Upward trend
57	Narsireddipalle vagu	Upward trend
58	Uppu vagu	Upward trend
59	Peethuru vagu	Upward trend
60	Jampaleru	Upward trend
61	Vemuleru	Upward trend
62	Kakarla vagu	Upward trend
63	Bogolu vagu	Upward trend

Annex 3. Categorization of HUs based on stage of development

SN	HU	Recharge	Withdrawal	Balance	Percentage of development	Categorization
1	Singaraikonda vagu	1.17	7.42	-6.25	636.43	Over-exploited
2	Ulsaipalem	2.16	12.25	-10.08	566.05	Over-exploited
3	Palamotu vagu	12.84	71.14	-58.30	553.96	Over-exploited
4	Sattammakunta	2.62	13.90	-11.28	530.44	Over-exploited
5	Lingojipalle vagu	4.15	21.60	-17.45	520.66	Over-exploited
6	Chavata vagu	2.20	11.13	-8.93	505.54	Over-exploited
7	Mulabandala vagu	20.48	100.02	-79.54	488.35	Over-exploited
8	Seetanagulavaram	3.86	17.85	-13.99	462.31	Over-exploited
9	Bodducherla vagu	0.79	3.66	-2.87	461.12	Over-exploited
10	Bogolu	1.56	6.68	-5.12	427.11	Over-exploited
11	Naidupalli vagu	1.13	4.62	-3.49	409.65	Over-exploited
12	Tandrasila vagu	7.72	31.51	-23.79	407.95	Over-exploited
13	Erravagu	13.29	53.78	-40.49	404.66	Over-exploited
14	Natiganicheruvu	21.65	80.73	-59.07	372.80	Over-exploited
15	Tarlupaduvagu	2.77	10.25	-7.47	369.30	Over-exploited
16	Jampaleru	42.16	151.25	-109.08	358.71	Over-exploited
17	Kakarla vagu	35.41	125.86	-90.45	355.42	Over-exploited
18	Erra Vagu	7.16	25.32	-18.15	353.39	Over-exploited
19	Vemuleru	35.94	122.20	-86.26	340.04	Over-exploited
20	Yadala vagu	22.97	74.82	-51.85	325.67	Over-exploited
21	Peethuru vagu	18.11	57.40	-39.29	317.02	Over-exploited
22	Erravanka	21.33	66.73	-45.40	312.79	Over-exploited
23	Ralla vagu	7.93	24.50	-16.58	309.16	Over-exploited
24	Mallappa vagu	9.27	27.97	-18.70	301.78	Over-exploited
25	Narsireddipalle vagu	16.25	47.77	-31.52	294.04	Over-exploited
26	Bokkineru	21.43	57.81	-36.38	269.81	Over-exploited
27	Uppu vagu	27.29	70.50	-43.21	258.34	Over-exploited
28	Nukayanicheruvu	21.88	55.16	-33.28	252.10	Over-exploited
29	Bhasker Rao Kunta	11.39	25.46	-14.07	223.59	Over-exploited
30	Mallappa vagu	31.60	70.08	-38.47	221.73	Over-exploited
31	Pulivagu	19.86	41.62	-21.76	209.55	Over-exploited
32	Chandravagu	9.76	20.32	-10.56	208.17	Over-exploited
33	Kothakunta	1.33	2.75	-1.42	207.09	Over-exploited
34	Tadaku vagu	20.52	42.30	-21.78	206.14	Over-exploited

35	Yerravanka	17.98	35.98	-17.99	200.08	Over-exploited
36	Diguvaetigaddavagu	22.61	40.33	-17.73	178.43	Over-exploited
37	Chinna Uppu vagu	3.61	6.43	-2.82	178.16	Over-exploited
38	Peddanagulavaram vagu	4.56	7.83	-3.26	171.53	Over-exploited
39	Manda vagu	37.82	64.74	-26.91	171.15	Over-exploited
40	Peddavagu	19.70	33.53	-13.83	170.18	Over-exploited
41	Buchammakonetivanka	5.23	8.55	-3.31	163.36	Over-exploited
42	Rommonivagu	10.30	16.46	-6.16	159.81	Over-exploited
43	Kanugalavagu	27.94	43.09	-15.15	154.23	Over-exploited
44	Konetivanka	11.80	17.63	-5.83	149.44	Over-exploited
45	Miitameedipalli vagu	12.56	18.50	-5.94	147.33	Over-exploited
46	Mekaleru	16.69	23.83	-7.13	142.72	Over-exploited
47	Suddakuruva vagu	4.07	5.33	-1.26	131.01	Over-exploited
48	Kondesikunta	7.47	9.48	-2.01	126.91	Over-exploited
49	Rallavagu	60.35	70.32	-9.97	116.52	Over-exploited
50	Peddavanka	35.57	37.90	-2.33	106.56	Over-exploited
51	Bavanasi	68.47	66.80	1.67	97.56	Critical
52	Chinneru	98.98	96.22	2.76	97.21	Critical
53	Nakkillavagu	8.13	7.68	0.45	94.45	Critical
54	Maruvavanka	19.37	15.54	3.83	80.23	Semi-critical
55	Peddavanka	19.40	14.93	4.47	76.96	Semi-critical
56	Thundlavagu	70.65	54.11	16.53	76.60	Semi-critical
57	Chandra sagar	82.88	56.90	25.98	68.65	Safe
58	Vajralavanka	31.41	20.56	10.84	65.48	Safe
59	Lothuvagu	8.22	5.13	3.09	62.36	Safe
60	Bellamvanka	14.89	6.71	8.18	45.06	Safe
61	Gooty Maruvavanka	8.62	3.72	4.90	43.16	Safe
62	Uppravanka	24.26	8.73	15.53	35.99	Safe
63	Mynapuramvanka	7.31	2.33	4.98	31.84	Safe

Annex 4. Post facto farmer survey questionnaire

Name of the HU		
Name of the habitation		
Name of the Respondent		
Gender	☐ Male	☐ Female
Are an APWELL beneficiary?	☐ Yes	☐ No
Do you have a borewell?	☐ Yes	☐ No
Are you associated with APFAMGS	☐ Yes	☐ No
If yes, in which way	☐ PHM Volunteer	
	☐ GMC Member	
	☐ HUN Member	
Have you participated in CWB workshop	☐ Yes	☐ No
Have changed crops after CWB	☐ Yes	☐ No
What crops did you grow prior to CWB?		
What was your annual income on crops, then?	INR	
What crops did you grow after participating in CWB?		
What was your annual income on crops, now?		
What are the other reasons for changing crops?		
What was the general water level in your village, earlier?	MBGL	
What is the general water level in your village, now?	MBGL	

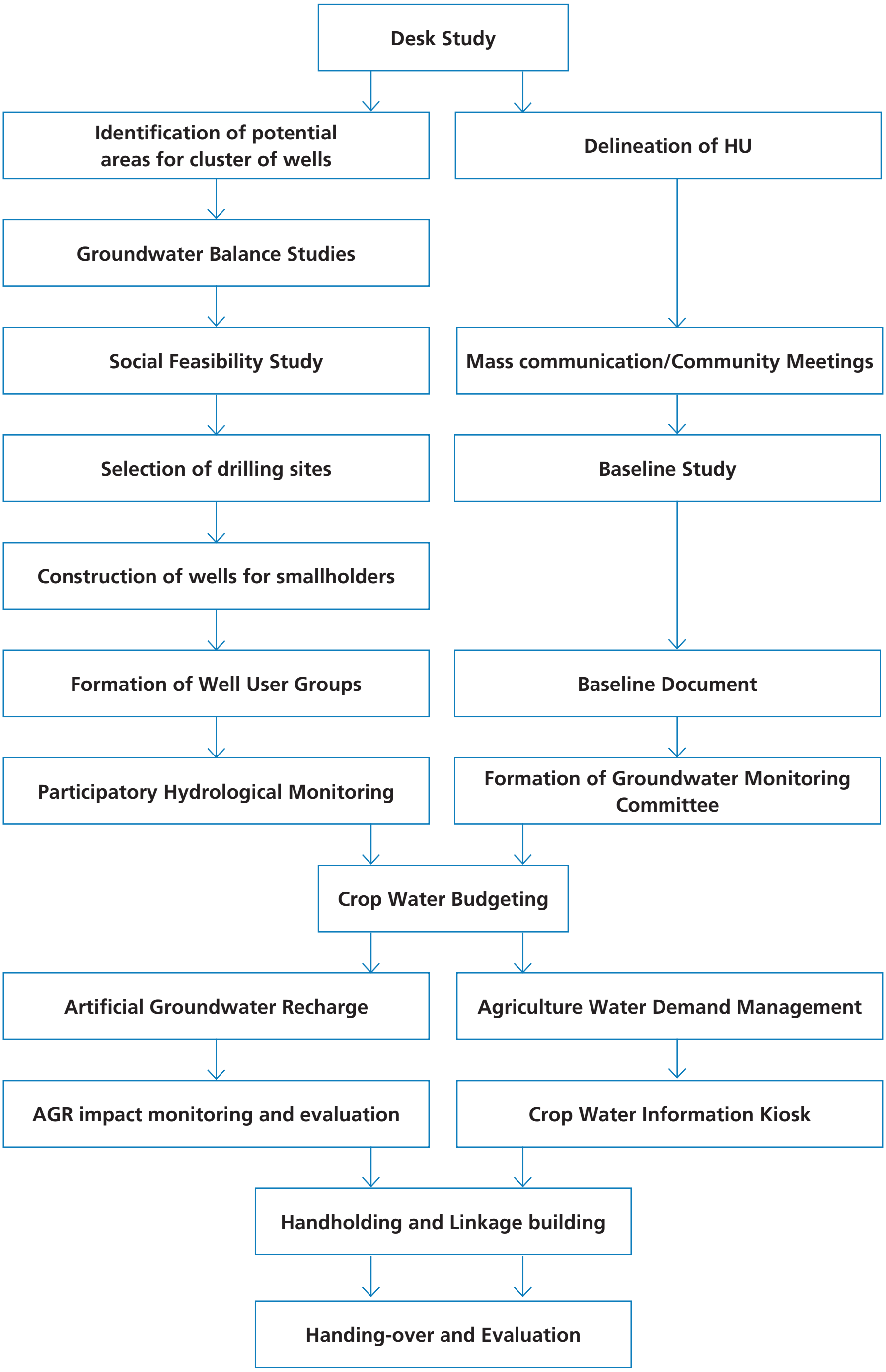
What are the reasons for increase/decrease in water level?	1.
	2.
	3.
Is your pumping causing unacceptable decline in water level?	☐ Yes ☐ No
If yes, what are you doing to reduce pumping?	1.
	2.
	3.
How much money do you save through these measures?	1.
	2.
	3.
Do you believe your well will sustain in a drought year?	☐ Yes ☐ No
Do you continue to be involved with GMC/HUN?	☐ Yes ☐ No
What are your interests in supporting GMC/HUN?	1.
	2.
	3.
What is your rating of GMC on a 1-10 scale?	☐
What is your rating of GMC on a 1-10 scale?	☐

Name of the interviewer: ....

Date: ....

Signature: ....

Annex 5. Emerging model of Participatory Groundwater Management



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