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STAP/UNESCO WORKSHOP MANAGING THE SUBSURFACE ENVIRONMENT: INTEGRATED MANAGED AQUIFER RECHARGE

(Prepared by the Scientific and Technical Advisory Panel)

United Nations Environment Programme
برنامج الأمم المتحدة للبيئة • 联合国环境规划署
PROGRAMME DES NATIONS UNIES POUR L'ENVIRONNEMENT • PROGRAMA DE LAS NACIONES UNIDAS PARA EL MEDIO AMBIENTE
ПРОГРАММА ОРГАНИЗАЦИИ ОБЪЕДИНЕННЫХ НАЦИЙ ПО ОКРУЖАЮЩЕЙ СРЕДЕ
UNEP

STAP/UNESCO Workshop
Managing the Subsurface Environment: Integrated Managed Aquifer Recharge

19-22 September 2005, New Delhi, India
Workshop Report

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Preface

Groundwater is used by, and addresses the basic socio-economic needs of, more than 2 billion people. Groundwater is also important for the maintenance of river flows, water bodies and wetlands, and habitats for biodiversity. Groundwater is, therefore, important both for its development and environmental functions.

Groundwater, however, is a vulnerable source if not managed or valued properly. Groundwater can be susceptible to degradation from over-use, contamination, and other abuses, which can have a far-reaching, and often irreversible, impact.

The significance of groundwater, and its intrinsic social and economic characteristics, are insufficiently recognized and valued in national development plans, or in the administration of water resources and the environment. The Scientific and Technical Advisory Panel (STAP) was, therefore, asked by the Global Environment Facility (GEF) to identify the principal threats, and strategic issues on groundwater.

In response, STAP convened a workshop on strategic priorities and options in groundwater resources in April 2004. The workshop recognized that Managed Aquifer Recharge (MAR) is integral to the management and sustainability of groundwater resources. Furthermore, the workshop acknowledged that MAR technologies can help address threats to groundwater (e.g. aquifer degradation due to salinization and seawater intrusion).

The GEF, therefore, asked STAP to convene a second workshop on managing the subsurface environment, with a focus on MAR. The purpose of the workshop was to assess the effectiveness of MAR, including, and in combination with related technologies, such as water reuse, in a range of hydrogeological and environmental settings. These included: transboundary water impacts in international waters, the impacts of extreme climatic events on groundwater recharge/storage, and groundwater management for sustaining groundwater-dependent ecosystems.

STAP and UNESCO-IHP (International Hydrological Programme) organized a technical workshop in New Delhi, 19-22 September 2005 to discuss thoroughly these issues. STAP specifically discussed and reviewed how and in what ways the GEF could integrate groundwater management, in particular MAR, in and across the GEF focal areas of biodiversity, climate change, and land degradation, and transboundary water management activities.

The workshop was attended by experts on groundwater and MAR from developed and developing countries. The workshop was also attended by STAP members Angela Cropper, Saburo Matsui, and by former STAP member Hubert Savenije. The meeting was co-chaired by Hubert Savenije, Angela Cropper, and Abdin Salih from UNESCO.

I hope very much the following analysis, workshop conclusions, and STAP's recommendations will help the GEF as it mainstreams groundwater and MAR in the design of GEF projects.

Yolanda Kakabadse
STAP Chair

May 5 2006
Washington, DC

Executive Summary

1. Groundwater is an important source of the world's drinking water, irrigation supply, and industrial water. The benefits of groundwater relate to the large subsurface water storage volume (not affected by evaporation losses, protected from surface contaminants, and with a capacity to regulate and mitigate floods) in relation to the annual flows. Groundwater has the capacity, therefore, to secure water supply and productivity, and sustain groundwater dependent ecosystems, even in conditions of drought and floods.

2. Integrated Managed Aquifer Recharge (MAR), including with water reuse, can enhance groundwater development. MAR describes intentional storage and treatment of water in aquifers, and is often called enhanced recharge, water banking and sustainable underground storage.

3. MAR can be used to re-pressurize aquifers, which are subject to declining yields due to salinization, and seawater intrusion. MAR can also play a significant role if applied as a broad water management approach to control abstraction and restore groundwater balance.

4. However, MAR uptake has been limited by a lack of understanding of hydrogeology and/or knowledge of MAR. With appropriate training and demonstration projects, MAR has the potential to contribute to sustainable groundwater use and management, especially in semi-arid and arid regions.

5. STAP reviewed the options and strategies for integrated groundwater management, and MAR, across the GEF focal areas of biodiversity, climate change, and land degradation, and transboundary water management activities. STAP discussed these issues at a workshop, 19-22 September 2005 in New Delhi, India, co-organized with the United Nations Educational Scientific and Cultural Organization, International Hydrological Programme (UNESCO-IHP).

6. The workshop concluded that MAR, within the context of groundwater management, is a specific option to integrate water storage, reuse and liquid waste disposal, mitigate land degradation, conserve biodiversity, and address transboundary water management issues.

7. STAP recommends, therefore, the GEF supports the development of specific, groundwater, MAR, integrated demonstration projects to concurrently achieve objectives in the GEF focal areas on biodiversity, climate change, international waters, and land degradation.

8. STAP identified five priority areas of action for GEF demonstration projects:
   - Groundwater and MAR in biodiversity conservation and protected areas.
   - Groundwater and MAR as a strategic component in Climate Change.
   - Groundwater management and MAR in SIDS[1].
   - Groundwater quality management and MAR in relation to water reuse, pollution remediation, and freshening saline aquifers.

[1] STAP will convene a workshop to discuss groundwater management and MAR in SIDS. The workshop will take place 6 – 9 November 2006, in Trinidad or Tobago.

- Groundwater and MAR in land degradation – MAR for catchment water and soil conservation.

9. STAP also recommends that the GEF enhances the capacity of the Implementing Agencies and Executing Agencies in the application and integration of groundwater management and MAR across the focal areas.

10. STAP also recognizes that a successful and cost-effective MAR approach depends on social and institutional factors, such as an enabling institutional and human capacity environment at the local, regional, and global level. Furthermore, STAP acknowledges that a sustained and successful adoption/adaptation of MAR technologies will require effective mechanisms on knowledge and information exchange. Targeted knowledge management systems and policy mechanisms could be some of the tools used to achieve sustainable MAR applications.

11. STAP also reached various salient recommendations specific to groundwater and MAR integration into biodiversity, climate change, and land degradation. In biodiversity, STAP recommends to integrate MAR into projects where groundwater deterioration threatens biodiversity of wetlands and coastal lagoons, and to define actions using groundwater management with MAR and water reuse applications to: 1) control groundwater contamination, and reduce potential threats resulting from nutrient pollution and POPs in water bodies; and, 2) control degradation of coastal and estuary ecosystems harmed by salinization and saline intrusion.

12. For climate change, STAP recommends the integration of MAR technologies into adaptation to climate change activities, especially in drought and flood prone regions. Furthermore, STAP believes groundwater and climate change activities could be integrated to address the various challenges posed by sea-level rise in SIDS.

13. For land management integration, STAP recommends that MAR technologies are applied at the catchment level, with targeted interventions that promote downstream impacts. Land management and MAR integration could, therefore, provide opportunities that enhance groundwater use and management, and contribute to land and water productivity and quality throughout the catchment area. Furthermore, STAP believes that MAR integration into land-based practices can also contribute to sustainable costal management by helping to prevent salinization of costal lands.

Section 1: Introduction

1.1 Background

In April 2004, the Scientific and Technical Advisory Panel (STAP) to the Global Environment Facility (GEF) convened a workshop on strategic priorities and options in groundwater. STAP organized the workshop with UNESCO's International Hydrological Programme (IHP). As a continuation to this workshop, the GEF asked STAP to convene a second workshop on managing the subsurface environment, in particular on Managed Aquifer Recharge (MAR[2]).

STAP convened, therefore, a group of experts on groundwater and MAR from developed and developing countries, 19-22 September, 2005, in New Delhi, India. The workshop was co-organized by UNESCO-IHP. The workshop was also attended by former STAP member Hubert Savenije, (who chaired the meeting with Dr. Abdin Salih, UNESCO), and STAP members Angela Cropper and Saburo Matsui, and by representatives from the GEF Secretariat, and the GEF's Implementing Agencies (UNEP, UNDP and the World Bank). A complete listing of workshop participants is attached in Annex 1.

1.2 Purpose of the workshop

The workshop, within the objective of sustainable groundwater management, aimed at assessing the effectiveness of MAR, including, and in combination with related technologies, such as water re-use, as a versatile tool to progress water management issues in a range of hydrogeological and environmental settings. These included, in addition to transboundary impacts in international waters, the mitigation of land degradation, impacts of extreme climatic events on groundwater recharge/storage and groundwater management for sustaining groundwater-dependent ecosystems.

The workshop looked at the wide range of activities in MAR, as a proven technology with ancient traditions and widespread applications, at many different scales, and levels of sophistication, and as a strategic factor in groundwater management.

The workshop was asked specifically to consider the opportunities of integrating groundwater issues, particularly MAR, into the other focal areas of the GEF (biodiversity, climate change, international waters [transboundary water management activities], and land degradation), and to identify options for integrated groundwater demonstration projects.

1.3 Workshop organization

The workshop was organized into plenary sessions, with introductory speeches by the representatives of the GEF Secretariat and STAP, followed by presentations on two keynote papers commissioned by the STAP (Annex 2). This was followed by case study presentations on groundwater management and MAR applications (Annex 3).

The participants, in three break-out group sessions, then reviewed how the GEF should proceed to ensure that groundwater management issues, in particular MAR, are adequately reflected and

[2] MAR describes intentional storage and treatment of water in aquifers. The term 'artificial recharge' has also been used to describe this.

integrated in and across GEF projects on biodiversity (i.e. groundwater-dependent ecosystems), climate change (adaptation), international waters (i.e. transboundary water management), and land degradation (i.e. sustainable land management).

The workshop conclusions and STAP's recommendations, which evolved from the working group sessions, are detailed in the following report.

Section 2: Conclusions and Recommendations

The workshop concluded that MAR, within the context of groundwater management, is a specific option to integrate water storage, reuse and liquid waste disposal, mitigate land degradation, conserve biodiversity, and address transboundary water management issues.

Furthermore, the workshop concluded that MAR represents a practical and tangible approach to enhancing groundwater integration across the GEF focal areas: biodiversity (groundwater dependent ecosystems); climate change (adaptation); international waters (transboundary impacts); land degradation (addressing soil and nutrient conservation and prevention of coastal saline intrusion with close land – groundwater linkages), and, POPs (water quality).

In addition, the workshop acknowledged that MAR can provide opportunities to develop and implement effective water policy, and governance mechanisms that recognize the social and environmental drivers in the political economy. For a successful MAR application, the workshop recognized the importance of analysing the conditions for implementing MAR, by consolidating knowledge of MAR and reuse methods in different geographical areas. It also acknowledged the challenge of introducing MAR to the IW-TDA/SAP, and to other similar strategic approaches in the different focal areas.

The workshop, therefore, broadly recommended the following:

- The GEF should adopt a strategy for MAR pilot demonstration projects, and promote the replication of good MAR and reuse practices as they apply to the GEF focal areas on biodiversity, climate change, international waters, and land degradation. The GEF should enhance the capacity of its Implementing Agencies and Executing Agencies in the application and integration of groundwater management, and MAR, across the focal areas.

- The GEF should focus on sharing MAR knowledge through networks, which highlight successful case studies, quantitative impact evaluations, and training initiatives, including on-line resources, and targeted courses.

In addition, the workshop identified four priority areas for action for GEF pilot demonstrations. These are:

- Groundwater and MAR in biodiversity conservation and protected area management.
- Groundwater and MAR as a strategic component in Climate Change projects.
- Groundwater management and MAR in SIDS
- Groundwater quality management and MAR in relation to water reuse, pollution remediation, and freshening saline aquifers.
- Groundwater and MAR in land degradation – MAR for catchment water and soil conservation.

Furthermore, the workshop adopted detailed recommendations on: integrated groundwater and environmental management (2.1); groundwater in the GEF focal areas (2.2); and, identified options for pilot demonstration projects (2.3).

2.1 Integrated groundwater and environmental management

Groundwater accounts for about 50% of the world's drinking-water, and probably a 10-15 times larger volume is used in agriculture. The benefits of groundwater relate to the large storage volume in relation to annual flows, with the capacity to secure water supply and productivity and sustain groundwater dependent ecosystems, even under extreme conditions of drought or floods. As a result, groundwater is a strategic resource that can be used to reduce social, economic and environmental risk, eradicate poverty and support livelihoods and equity.

Integrated MAR, including with water reuse, mobilizes and enhances the social and environmental capacity of groundwater development. MAR augments natural recharge and is supplementary to incidental recharge resulting from land clearance and leaking water mains/sewers and irrigation canals, etc. MAR represents an efficient option to address a variety of environmental and social issues, such as groundwater depletion and pollution, flooding, land and ecosystems degradation, erosion, soil fertility decline, desertification and saline intrusion, and the consequent threats to productivity and biodiversity.

Effective application of MAR requires consideration of political and socio-economic realities. Groundwater development is market-driven and good management should reflect a sound relation between costs and benefits, and build on socially accepted institutional mechanisms. Policy and investments should be enabled and regulated in coherent governance systems, including appropriate institutional arrangements at acceptable realistic transition costs. Planning and development objectives and regulatory frameworks, and other incentives, should provide the right directions for efficient sustainable development and equitable use of groundwater and related land resources.

MAR implementation should be built on sound hydrogeological knowledge and recognition of opportunities to enhance water productivity and control water quality. MAR can be enhanced when supplemented with agricultural reuse and emerging filter and membrane techniques for water treatment and desalinization of brackish water.

Effective implementation and cost-efficient application of MAR, depends on appropriate enabling institutional and human capacity at global, regional and local levels. Effective mechanisms are needed to exchange experience and replicate demonstrated technology and governance mechanisms for sustainable socio-economic development with tangible impacts and environmental benefits in and across the different focal areas.

The workshop recommended that the following measures were necessary to address integrated groundwater and environmental management (see Figure 1):

Policy, institutions, governance

- Assess policy and institutional environments and governance frameworks for introduction of MAR and water reuse technology.
- Assess the use of MAR to facilitate the establishment of effective groundwater governance.

- Plan, select and design policy, institutional and technological components of MAR, and reuse pilot demonstration projects, in GEF projects.
- Review the social and economic cost-efficiency and the replicability of MAR pilot projects at the local, regional, and global scale.
- Recognize economic realities in relation to, for example, energy subsidies, and other groundwater incentives.
- Promote stakeholder participation in groundwater planning, management and monitoring activities.

MAR technology

- Evaluate MAR for enhanced water management and environmental protection in relation to local hydrological, chemical/biological, physiographic, and sociological factors that influence the potential for MAR to achieve GEF focal objectives. Special attention should be given to MAR in SIDS and in hard-rock terrains.
- Identify and develop opportunities for integration of MAR with irrigation technology and agricultural reuse, and with urban storm water and industrial water conservation and reuse.
- Enhance acceptance of waste water reuse and MAR, to protect human health and ecosystems and increase water productivity, through demonstrations of appropriate technology.

Capacity building

- Mobilize relevant global, regional and national capacity building networks, centers and programs (e.g. UNESCO-IHP, IAH-MAR, Asia G-WADI, Qanats and watershed harvesting centre in Iran, CGWB & NGOs in India etc.) to disseminate knowledge and experience in MAR applications.
- Develop knowledge management systems on MAR technology, project experience, and policy (targeting e.g. Implementing Agencies, in-country project proponents, and policy makers and managers etc.).
- Make use of present GEF learning programs e.g. IW-LEARN, and similar structured learning activities in the other focal areas, for training at demonstration sites/centers of excellence etc.
- Establish clusters of demonstration sites in regions to capture traditional MAR methodologies, evaluate their environmental and socio-economic effectiveness and promote appropriate replication.

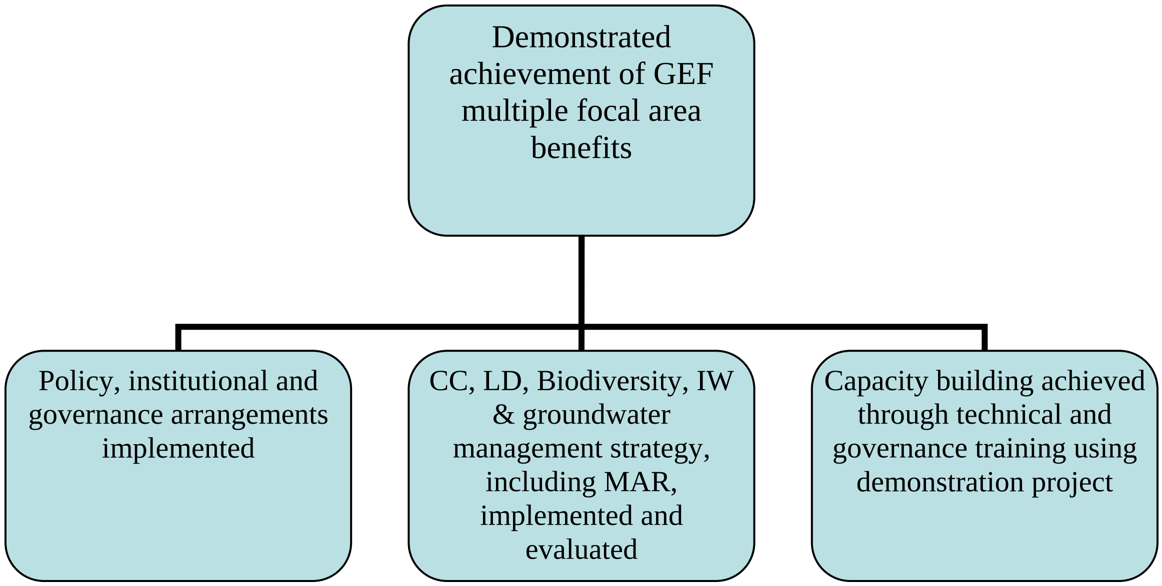

Figure 1.Demonstration projects allow assessable achievement of GEF focal area objectives with integration of governance and technology, and capacity building in both.

2.2 Groundwater in the GEF focal areas

Following the STAP-UNESCO groundwater review in 2004, the opportunity for integrating groundwater activities across the focal areas has been recognized in the GEF, and included in the programming activities for GEF 4, and in future GEF projects. The opportunities appear across the biodiversity, climate change and sustainable land management focal areas, and have been initiated as groundwater components in a limited number of the large international water basin and large marine ecosystem (LME) projects. Integrated MAR and reuse activities give the opportunity to enhance water supply and productivity, control water contamination and reduce abstraction pressures on aquifers, to sustain biodiversity, support adaptation to climate change, and combat land degradation.

Integrated MAR can help in reducing stress on surface ecosystem, in many applications, for example: (a) catalyzing policy, and sustainable institutional developments and management in protected areas, (b) mainstreaming conservation of groundwater dependent ecosystems and biodiversity in the use sectors, in particular agriculture, and (c) providing windows for innovative technologies, management approaches and demonstrations projects.

Groundwater conditions are critical for adaptation to climate change, and MAR provides a management tool to address and mitigate the effects of drought and floods and to control salinization from sea level rise and coastal storms. The application of MAR should be considered for, and targeted to regions and countries with predicted high, real and potential, increase in water stress from impacts of climatic change. A scenario is exemplified in the projections in Figure 2. This scenario shows the change in water stress due to climate change by the 2080s with controlled emissions leading to stabilisation of CO_2 at 750 ppm; a moderate scenario. Stressed countries are predicted to experience a decrease in stress (dark green), an increase in stress (red) and some countries are predicted to move into a stressed class (light green). Regional variability will, of course, be experienced within countries.

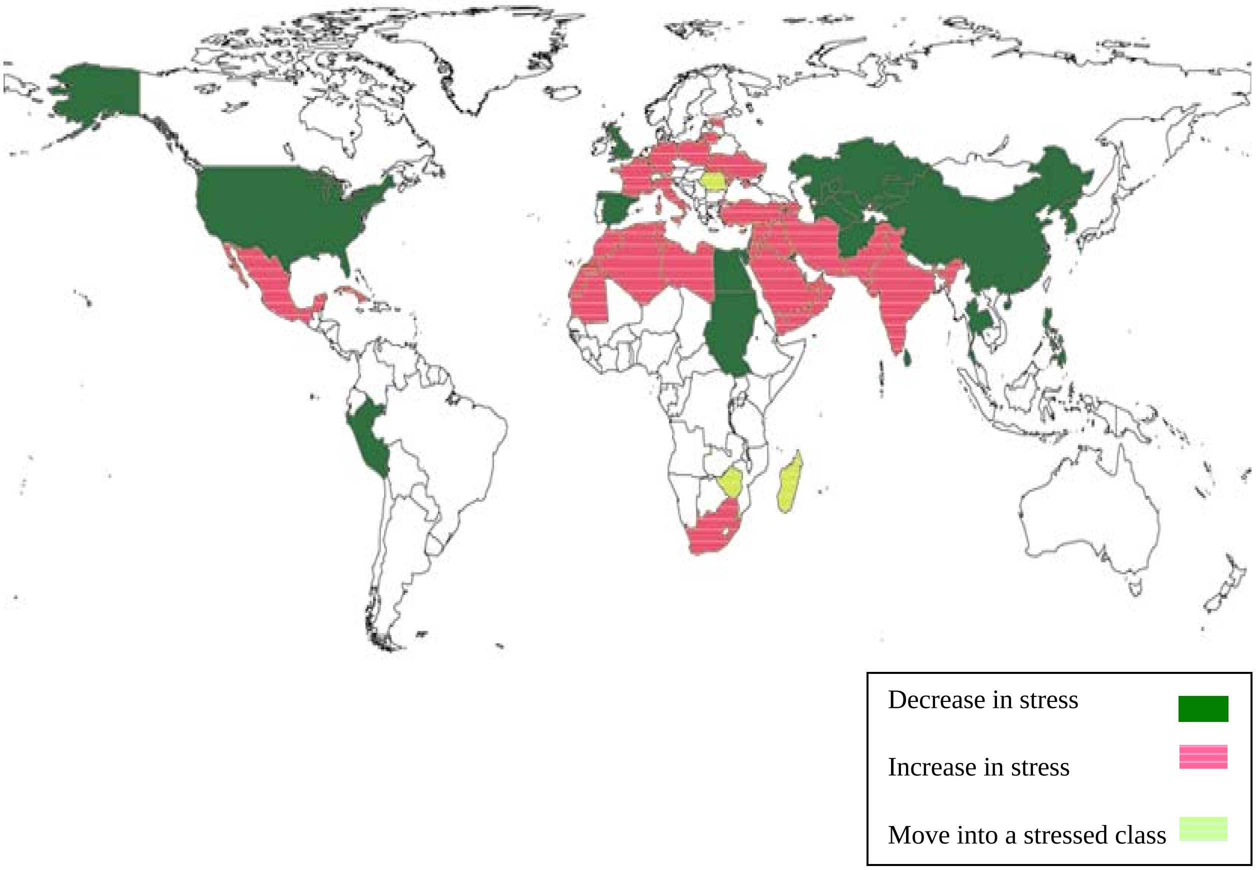

Figure 2. Climate Change: prediction of change in water stress by the 2080s.[2]
(Source: The Met Meteorological Office, Hadley Centre, Southampton University (UK)
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MAR can contribute to the management of silt, salt and salinization and plant nutrition and nutrient contamination, all in relation to soil and water productivity. MAR is a traditional practice used to enhance water supplies and control land degradation in semi-arid regions. The present understanding of MAR needs to be improved through testing and validation of current practice to ensure cost-effective, and scientifically valid application. However, the sustainability of application on a wider scale points to the need for catchment-based approaches with recognition and sensitivity to downstream water demands and potential water conflict.

The workshop recommended that the following detailed measures were necessary to effectively integrate groundwater across the GEF focal areas: Consideration should be given in national Climate Change plans, IW-TDA/SAP and other established GEF mechanisms and processes, to incorporate groundwater and MAR for environmental benefits and adaptation to climate change.

[3] As regional water stress increases, or decreases, the projected change in water stress gives an indication for planning and prioritization for management interventions, including MAR.

Biodiversity

- Assess and establish linkages between biodiversity and groundwater in aquatic and non-aquatic ecosystems.
- Ensure that groundwater of suitable quality is sustained to support, rehabilitate and enhance protected areas in groundwater dependent fresh and brackish wetland ecosystems, lagoons and estuaries.
- Identify GEF biodiversity projects where groundwater deterioration threatens biodiversity and define measures for action, including groundwater management with MAR and reuse to:
  - Control groundwater contamination and to reduce threats from nutrient pollution with eutrophication of water bodies, groundwater dependent protected areas and ecosystems, and
  - Control degradation of coastal and estuary ecosystems from salinization and saline intrusion.
- Incorporate and support groundwater management in community based protected area management.

Climate Change

- Review opportunities, including retrospective analysis of groundwater related GEF climate change projects, for MAR applications to mitigate and adapt to the impacts of climate change. Promote and demonstrate groundwater management opportunities, including MAR, for adaptation to climate change, especially in regions and countries where projected impacts (as exemplified in Figure 2) are high, including:
  - Frequent and extensive drought and floods.
  - Increased salinization (from e.g. impacts on vulnerable SIDS of climate change and sea level rise, saline water intrusion from sea water, adjacent saline aquifers, and land salinization and recharge from saline inland sinks (*chotts*).
  - Impacts on groundwater dependent services (GDEs, water bodies and river low flows, water and food security etc.).

Land Degradation

Land degradation may be viewed and addressed from the perspective of the catchment, from mountains to mid-slopes to coastal plains. Interventions should consider downstream impacts and promote groundwater management, and MAR, as part of integrated land management practices, with respect to:

- Waste water reuse, to recycle nutrients and provide irrigation water to enhance land and water productivity especially in peri-urban agriculture.
- Land management during drought conditions.
- Improved soil fertility, and infiltration based on recovery of silt from check dams.
- Saline intrusion and soil salinization of coastal land and saline inland depressions with related loss in land and water productivity.
- Impact of erosion and silt loads on marine (e.g. coral) ecosystems and tourism.
- Prevention and remediation of impacts from saline inundation (e.g. coastal surges - tsunami) to establish vegetation, and flush and reclaim soil and aquifers.
- Integrate MAR into community-based watershed and land conservation management programs.

International Waters

- Demonstrate the effectiveness of integrated MAR and reuse, in balancing water uses and reducing stresses to freshwater - coastal ecosystems in transboundary settings (watersheds, aquifers, coastal regions).
- Incorporate consideration of integrated MAR into GEF-IW methodological approaches, (e.g. TDA/SAP, M&E, project design).
- Promote integrated MAR and reuse, within land and groundwater management demonstrations replicable over a range of climatic conditions and socio-economic settings.

2.3 Pilot demonstration projects

Following from the STAP/GEF 2004 review[4], the workshop elaborated on prospective MAR and reuse pilot demonstrations, to avail, promote and enable broad replication at global regional and national scale of state-of–the-art MAR technology. The workshop identified: project selection criteria and priority applications for MAR demonstrations integrated across the GEF focal areas, (Figure 3 and Table 1), project opportunities, as activities under actual GEF projects and regional initiatives (Table 2), and identified groundwater strategy elements (Table 3).

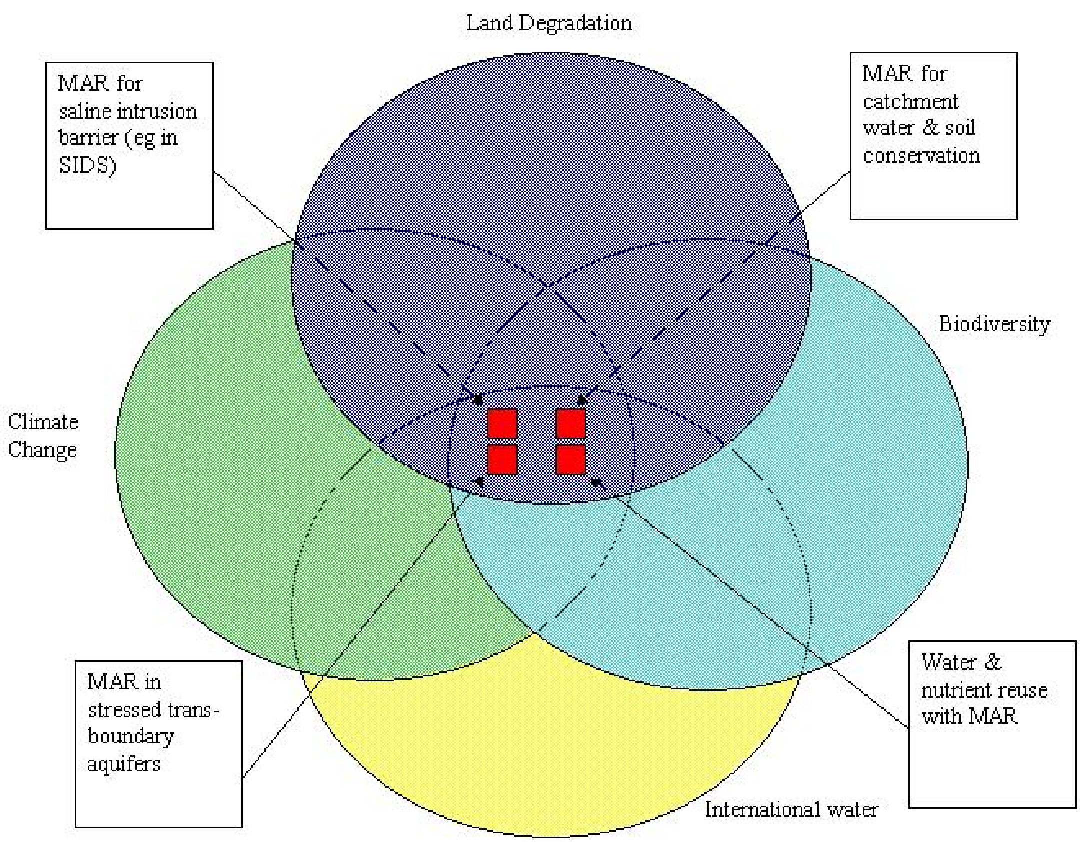

Figure 3. Integrated MAR demonstration projects to concurrently achieve objectives of several GEF focal areas

[4] With reference to the recommended priorities for demonstrations STAP/GEF report GEF/C.24/Inf.13 GEF Council November 17-19, 2004.

The workshop recommended that the identification of specific demonstrations projects should be focused on the following priority areas of action:

- Groundwater management and MAR in SIDS[5].
- Groundwater and MAR in biodiversity conservation and protected area management.
- Groundwater and MAR as a strategic component in Climate Change projects.
- Groundwater and MAR in land degradation- MAR as a driver in catchment-based soil conservation and soil fertility projects.
- Groundwater quality management and MAR in relation to water reuse, pollution remediation and freshening saline aquifers.

Table 1: MAR applications - groundwater integration in the GEF Focal Areas and International Waters

GEF Focal Area, OP	Focus, geographical zones, issues	Transboundary, IW-integration[6]	Governance institutions, socio-economic drivers
Biodiversity	Protected area management, forest, sanctuaries and natural parks, Ramsar - Valencia 2004. SIDS – coastal, marine ecosystems.	GW dependent coastal wetlands, estuaries: Mediterranean action plan, MED-MAP - SAP Bio -II, Caspian sea, Guinea Current coastal aquifers, Black Sea coastal aquifers – LME nutrient control.	Ecological values. Local benefit of the sustained products from bio-diversity.
Climatic Change	CC adaptation – COP10/2004. Drought, flood management Groundwater to address CC impacts in other focal areas.	SADC (Limpopo basin) aquifer project.	High regulation transaction costs.
Land Degradation, OP10, OP15	Arid, semiarid water scarce zones; watershed management, MAR.	Southern Asia arid plains – India, China. Coastal zone management in Caspian Sea (CEP).	Inequity, energy and agricultural subsidies.
POPs, OP14	Reuse, soil- plant nutrition, reclaimed water, soil aquifer treatment. Natural sources of water quality impairment (arsenic, fluoride).	Land based water contamination: Mediterranean action plan MED-MAP-II. Coastal zone management, Caspian (CEP).	Water quality standards, guidelines/ code of practice, ownership of reclaimed water.

[5] To be reviewed in the scope of integrated SIDS management at planned workshop in 2006.
[6]Under OP 9, *Integrated Land and Water Multiple Focal Area operational program*, and OP10, *Contaminant-based operational program*, an opportunity exists to integrate groundwater to individual multi-focal activities (biodiversity, land degradation etc.) under IW transboundary basin and LME projects and to formalize and enable implementation under the TDA/SAP process.

Table 2: Specific MAR pilot projects – integrated projects with International Waters and other GEF Focal Area benefits

Focal Area	Name, location/project objective,	Replicability	Priority criteria
Biodiversity	Sundarban, India; protected area management, with control of saline intrusion by hydrogeological technology. Integrated multi-purpose MAR and reuse coastal aquifer demonstrations MED-II; Caspian Sea. Integrated karst aquifer management – submerged gw discharge coastal/marine ecosystems. Erosion and silt deposit, marine ecosystem protection – Caribbean SIDS.	Replicable in national protected area projects. Replicable on a global scale.	Protected areas addressed under GEF- Biodiversity-protected area projects.
Climatic Change	Groundwater, coastal salinization, Caribbean SIDS (MoRSCA). Drought management – SADC groundwater project. Improved (agricultural)) water productivity.	Global replicability in coastal zones, semi-arid areas, and in agriculture-dependent economies.	Non-emission related interaction from CC adaptation. Relevance to MOD implementation.
Sustainable Land Management	Watershed and local aquifer management. Land and recharge area salinization – SASS aquifer project. Erosion and silt deposit, marine ecosystem protection – Caribbean SIDS.	Global replicability.	Water management based approaches to land degradation.
POPs	Natural geochemical impairment of water quality – e.g. Iullemeden aquifer project. GW POPs and other contamination – effects on drinking water.	Global replicability.	Reduce degradation with protection of drinking water supplies –implementation of MODs.

Table 3: Groundwater strategy elements in the GEF Focal Areas: sample activities for demonstrations

GEF Focal Area, OP/ Strategy elements	Demo: Managed artificial recharge, reuse	Demo: Interaction fresh/saline – IW	Demo: Groundwater in SIDS	Demo: Land management practices	Concrete steps: GW in global dialogue
Multi-focal area	Demonstration of inter-focal area linkages and mitigation measures.	Demonstration of inter-focal area linkages and mitigation measures.	Demonstration of inter-focal area linkages and mitigation measures.	Demonstration of inter-focal area linkages and mitigation measures.	Groundwater framework convention: Capacity building support for regional awareness and implementation. Sustainable development: MDGs and WSSD implementation.
Biodiversity	Hydrogeological wetland management.	SIDS, Coastal wetlands.	Protecting coastal and marine ecosystems.	Sustainable land management for biodiversity habitats.	Hydrogeological wetland management; technology development.
Climatic Change	GW in regional, national CC adaptation plans. Drought, flood mitigation.	Mitigating coastal aquifer and land salinization – from e.g. sea level rise, coastal surges etc.	Groundwater and CC adaptation in SIDS.	Mitigating moisture management related land conservation measures for CC adaptation.	Groundwater and land resources- risk and uncertainties. Values and costs under climatic change.
Land Degradation, OP10, OP15	Soil moisture, fertility, and conservation.	Saline aquifer resources; saline. Groundwater recharge and storage.	Terrestrial erosion and sedimentation.	Risks, uncertainties and upstream-downstream conflict in land management.	Land degradation - values and costs.
POPs, OP14	Soil and water contamination and salinization.	Rehabilitation for enhanced productivity and reduced health hazard of polluted and saline land area.	Coastal aquifer quality protection.	Risks and Code of practice for non-polluting land use.	GW contamination and contamination transport – cost and values.

Annex 1: List of participants

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Annex 2: List of workshop keynote papers

1. Management of the Subsufarce Environment for Sustainable Use and Environmental Benefits: Managed Aquifer Recharge, Bo Appelgren. Available at: www.unep.org/stapgef

2. Technical Background Report on Managed Aquifer Recharge, Ian Gale. Available at: www.unep.org/stapgef

Annex 3: List of workshop presentations

The workshop presentations can be accessed at: www.unep.org/stapgef

1. Groundwater in the GEF, Andrea Merla, GEF Secretariat
2. Scope of MAR Applications in the GEF, Bo Appelgren, Consultant
3. Managed Aquifer Recharge in Arid and Semi-Arid Regions, Ian Gale, BGS
4. Groundwater in Asia: Reflection, Bhanu Neupane, UNESCO
5. Management and Sustainable Utilization of Subsurface Environment, Mohammed El-Aryani, Ministry for Water and the Environment
6. South Africa: Artificial Recharge in National Resource Strategy, Ricky Murray, Groundwater Africa
7. Artificial Recharge System in the Transboundary Aquifer of Geneva, Gabriel de los Cobos, Geological Survey of the State of Geneva
8. Managed Aquifer Recharge Strategy to Unlock Non-Productive Investments In Irrigation Wells, Mani K.A.S., Somasekhar Rao P, FAO
9. Isotope Application for MAR and Groundwater Assessment, Pradeep Aggarwal, IAEA
10. MAR: Extending the Scope Through GEF Focal Areas, Shammy Puri, UNEP
11. Management of Artificial Recharge: Historical Background and Future Prospective, D.K.Chadha, Global Hydrogeological Solutions
12. Implementing Managed Aquifer Recharge for Water and Wastewater Treatment in Developing Countries, Saroj Sharma and Gary Amy, UNESCO
13. Groundwater and Drought Management Project Implemented by Southern African Development Community, Len Abrams, World Bank
14. Guaraní Aquifer System, Ofelia Tujchneider, El Litoral Nationa University
15. MAR in Australia, Water Quality, and Role of MAR in Groundwater Management, Peter Dillon, Chair IAH Commission on MAR & Leader, Water Use and Reuse, CSIRO Land and Water
16. Project of Managed Artificial Recharge in Binh Thuan Vietnam, Bui Tran Vuong, Division of Hydrogeology and Engineering Geology for the South of Vietnam, Phan Thi Kim Van, Institute of Geology Hanoi, Vietnam
17. Additional Information About the Pilot Project on Artificial Recharge in Binh Thuan, Vietnam, Bui Tran Vuong, Division of Hydrogeology and Engineering Geology for the South of Vietnam, Phan Thi Kim Van, Institute of Geology Hanoi, Vietnam
18. Abkhandari: An Artificial Recharge Management Technique in Iran, Mohammad Hossien Mahdian, Soil Conservation and Watershed Management Research Institute, Tehran, Iran
19. Managed Artificial Recharge in China, Longcang Shu, Hohai University