Water events and historical flood recurrences in the Vietri sul Mare coastal area (Costiera Amalfitana, southern Italy)

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Abstract This study addresses problems pertinent to the municipality of Vietri sul Mare located in the southeastern corner of the Amalfi coast (southern Italy). The physical landscape, the economic settlements, the social activity and the natural hazards characterizing this area depend particularly on water: meteoric, riverine and marine. Indeed Vietri sul Mare is located on a steep rocky coast deeply dissected by ephemeral water courses (the Stream Bonea basin) with human activities mainly developed on the narrow stream banks located at the base of steep sided valleys, or at the mouth of Stream Bonea. This exposes them to a high hydrogeological risk triggered by water events associated with heavy rain. Several historical sources report at least 22 flooding events for the Vietri area during the last three centuries, which caused severe damage. In this paper historical sources are combined with geological data in order to improve the mitigation of flood phenomena through the reconstruction of historical floods and the estimation of the associated risks.

Key words flood; historical source; hydrological risk; rocky coast; Sorrento peninsula; southern Italy

INTRODUCTION

The study area is located on the southern flank of the Sorrento peninsula (Costiera Amalfitana), west of Salerno (southern Italy). It is a steep rocky coast developed in a northeast-southwest direction, separating the Bay of Naples to the north from the Bay of Salerno to the south. This structure is the top of a submerged monocline dipping towards the northwest and southwards bordered by normal faults, with a northeast-southwest orientation, (Finetti & Morelli, 1974; Brancaccio *et al.*, 1995). It is mainly composed of Mesozoic limestone tectonically uplifted since the lower Pleistocene. The sedimentary cover includes siliciclastic deposits Miocene in age, and Quaternary volcaniclastic and alluvial deposits, which form a discontinuous mantle overlying the carbonate bedrock, prone to detachment during hydrological events. The geological structure also controls the pattern of drainage of the study area. This is characterized by ephemeral streams with high-elevation drainage areas, high-gradient transfer zones and main delivery areas into the adjacent marine shelf (Fig. 1).

Since historical times, flooding and sliding phenomena have frequently occurred in this area, suggesting rapid slope morphodynamics, (Cascini & Ferlisi, 2003; Esposito

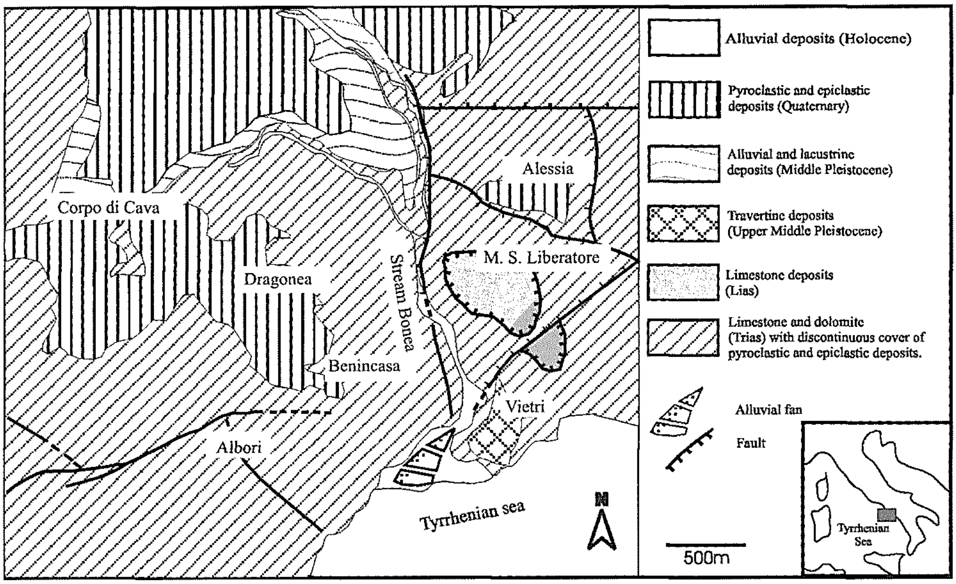

Fig. 1 Geological sketch of the Stream Bonea basin.

et al., 2003a,b; Guida *et al.*, 2003). Slides are triggered by intense rainfalls over a range of magnitudes, inducing displacement of the sedimentary covers and collapse (rock falling) of the carbonate bedrock. The slide phenomena involve a water saturated mass of material rapidly flowing down slopes including those with vegetated covers and man-made structures (earth/debris flow, Del Prete *et al.*, 1998; Cairo & Dente 2003; Calcaterra *et al.* 2003), able to expose wide areas of carbonate bedrock when caused by exceptional rainfalls. These water events also induce severe overflowing of the main streams, resulting in significant damage to property and loss of livelihood, as testified by historical analyses of past floods, a mandatory step for the evaluation of the hydrogeological hazard.

A correct approach to the study of natural disasters due to floods includes several areal analyses among which the historical reconstruction of flood dynamics and induced geological effects represent valid tools to identify geologically sensitive areas. The identification of flooded areas within the history of a region is one of the main aims for hydrogeological risk assessment, since these phenomena are characterized by recurrence in time and space.

This study uses historical data and geological investigations in order to assess natural hazards and associated damage resulting from the 1954 Vietri sul Mare flood. This event is in fact well documented in technical-scientific papers and newspapers, allowing the depiction of a detailed scenario to calibrate a model for future risk estimation based on the potential worth of the loss.

THE VIETRI SUL MARE HISTORICAL HERITAGE SITE

The Costiera Amalfitana, is considered one of the most beautiful coastal locations in Italy, both for its natural landscape and its architectural heritage. This area reached its maximum opulence during the Middle Ages (6th–11th centuries), when Amalfi became the first of the Italian Repubbliche Marinare with commercial activities all over the Mediterranean basin and acquired remarkable political and military power. Since 1997 it has been included in UNESCO's List of World Heritage Sites, being considered as an outstanding example of a Mediterranean landscape, with exceptional cultural and natural scenic value resulting from its dramatic topography and historical evolution.

Vietri sul Mare is made up of seven villages (Vietri, Molina, Raito, Albori, Benincasa, Dragonea and Marina di Vietri) covering an area of 9 km^2 with approximately 10 000 inhabitants. Several historical sources suggest it has an Etruscan origin as reported in the "Geography" of Strabo (63 BC) who locates the ancient town of Marcina in the area now called Molina di Vietri. Numerous archaeological remains have been found along the coast and inside the town. Among these, the most important are represented by graves containing pottery of Corinthian style, a Roman thermal structure and an *opus reticulatum*. Moreover, other architectural structures dating from the Middle Ages to the Renaissance occur all over Vietri sul Mare. These include an aqueduct (the Bridge of the Devil) built in 1320 with 34 arches on two levels, a total height of 19.50 m and a length of 180 m; a single span bridge, taken as an example for its stability and three 16th century towers located in strategic positions along the coast. There are numerous monumental churches and monasteries, built since the 13th century, often made precious by majolica floors, (Tesauro, 1984; D'Episcopio & Masullo, 1996). At present the economic activities are mainly tourism, handicrafts pottery and glass ware. In particular Vietri ceramics produced since the Middle Ages, are exported to the rest of Europe and to the USA.

THE VIETRI SUL MARE COASTAL ENVIRONMENT

Coastal areas are very special environments where atmospheric, oceanographic, biological and geological processes operate simultaneously and contain highly diversified systems, mainly controlled by the occurrence of water. The coast is also the location of the major human settlements, and human activities represent an important part of the environmental impacts and socio-economic developments. In this context the Vietri sul Mare coastal area offers an opportunity to experience the complexity of such a system, highlighting the importance of interdisciplinary studies within the framework of natural hazards and risk assessments.

The Vietri sul Mare municipality has developed within a small drainage basin (the Stream Bonea basin) which deeply dissects a steep rocky coast composed mainly of Mesozoic limestone deposits, with a delivery area located on the adjacent continental shelf (Fig. 1). These systems are normally characterized by a very small sediment load and low flows, with sudden and significant increases from high magnitude rainfall events, with both seasonal and larger recurrence intervals.

At present, most of the human activities and the settlement are located in the lower transfer zones of the Bonea basin (Molina di Vietri village), characterized by high-gradients of the stream channels, laterally constrained by steep-sided valleys, and at Marina di Vietri village, which is located at the mouth of Stream Bonea. The main village of Vietri rests on top of terraced travertine deposits of Pleistocene age, this position being critical for risk prevention. The smaller villages of the Vietri sul Mare municipality, including Raito, Albori, Dragonea and Benincasa, are also developed at the top of hillsides, high and away from the water courses.

The recent geology of the Stream Bonea basin is characterized by the occurrence of pyroclastic deposits derived from late Quaternary activity of Somma-Vesuvius, and other loose materials including talus breccia, alluvial and eluvial deposits, directly overlying carbonate bedrock (Fig. 1). The volcanic materials also include the air-fall deposits of the great Vesuvius eruption of AD 79. They exist as pumiceous strata, interbedded with sandy-silt volcanic ash. The overall thickness of this sedimentary mantle varies from a few tens of centimetres up to several metres, very often cropping out as pedogenic levels or heavily weathered materials. Poor consolidation and differential permeability with respect to the carbonate bedrock make them very unstable covers, prone to detachment during significant rain.

THE RECONSTRUCTION OF HISTORICAL FLOODS

A systematic investigation of historical sources was carried out on published and unpublished documents since 1700. The research was based on critical reviews of manuscripts, administrative documents, technical reports and newspapers, as well as on scientific papers, related to flooding events occurring in the Amalfi coastal area, with particular reference to the area of Vietri sul Mare.

The main sources were found at the National Archive of Naples, Salerno and Avellino. Among these the most relevant were the Protocolli Notarili (18th century), the Intendenza (19th century), and the Genio Civile (20th century), that include a variety of social, economic and politic information with an almost daily occurrence. A comprehensive revision of technical and scientific papers of the last century was also performed.

This research identified and classified 45 flood events (Table 1), with 22 of them hitting the Bonea basin. The most significant events occurred in 1773, 1899, 1910 and 1954.

Table 1 Historical floods in the Salerno province since the 18th century.

Day	Month	Year	Day	Month	Year	Day	Month	Year	Day	Month	Year
	November	1738*	01	April	1875	23–25	June	1905*		March	1960
	November	1760*	01	December	1875	01	September	1905*	16	February	1963
11	November	1773*	25	February	1879		November	1908*	25	September	1963*
24	December	1796*	01	November	1881	24	October	1910*	9	January	1968
13	September	1834	15-17	September	1882	23	January	1911	19	October	1970
18	July	1835	01	February	1885	13	November	1921		December	1971
27	September	1837*	05	May	1885	26	March	1924*			1980*
01	January	1841	01	November	1893			1929*	16–17	November	1985*
17	December	1867*			1896			1935		March	1986*
21–22	June	1868*			1898	01	October	1949			
7–12	November	1868*	7 –8	October	1899*			1951*			
11	December	1869*			1904*	25–26	October	1954*			

* Flood events affecting Vietri sul Mare (Salerno district) territory.

On 11 November 1773, a flood event caused 362 deaths and covered a wide area including Tramonti, Mercato San Severino, Nocera Superiore, Cava dei Tirreni and Vietri sul Mare. Much damage was recorded at Molina and Marina di Vietri where some factories (flour-mills, paper-mills) and cellars, alongside Stream Bonea were completely destroyed (Protocolli Notarili di Salerno and Cava dei Tirreni, 1773–1774; Amarotta, 1994).

On 7–8 October 1899 a flood destroyed an area of about 400 km^2, damaging 46 villages located both in the inner and coastal areas (Salerno district). There were 87 fatalities. There was severe flooding at Tresare and Vianuova (Molina territory) with serious damage to agriculture. A textile factory collapsed and five other factories were heavily damaged and a deck was swept away at Marina di Vietri, (Protocolli Notarili, 1773–1774; Fumanti *et al.*, 2002; Esposito *et al.*, 2003a,b).

The 24–25 October 1910 flood hit a narrow coastal area of about 70 km^2 between Salerno and Conca dei Marini, causing 200 deaths. Marina di Vietri suffered damage by flooding from the river, with the railway being struck in several points (Esposito *et al.*, 2003a,b).

Each of these reported events was triggered by a few days of steady rain followed by 6–18 h of heavy rain. The effects included extensive landslides, significant floods on the streams and changes to the coastline at the mouth of Stream Bonea. In particular, erosion was concentrated on hillsides at San Liberatore and along the Bonea valley (Amarotta, 1994; Esposito *et al.*, 2003a,b).

A widespread pattern of destruction characterized these events: serious damage to buildings and to industry, together with destruction of roads, bridges, aqueducts, sewer systems, and railways. The cultural heritage also suffered great damage. In addition, all these events caused a large number of deaths, from tens to >100. Official estimates put the economic damage to private and public property at values ranging from 2.5 to 550 million Euros.

THE 1954 FLOOD EVENT

The reconstruction of the 1954 flood is based on critical reviews of several scientific and local publications, newspapers, as well as photographs and technical notes associated with descriptions given by eyewitnesses, (Amendola, 1954; Cancellara, 1954; Lazzari, 1954; Penta *et al.*, 1954; Frosini, 1955; Rispoli, 1955; Amarotta, 1994; AVI Project, 2003). These data, combined with morphological and geological evidence derived from air photo interpretation and field analysis, allowed mapping of the many and different flood-induced geological effects, including landslide phenomena, overflow areas, temporary dams on the Stream Bonea and coastline changes (Fig. 2). Major damage to public and private buildings and structures were also mapped within the framework of current land use information, functional to economic evaluation and risk assessment (Figs 2 and 3).

The 25–26 October 1954 storm was one of the most intense and catastrophic meteorological events recorded in the Campania region. There were 318 deaths. Heavy rainfall hit Salerno and the southern flank of the Sorrento peninsula lasting about 16 h, from 13:00 h on 25 October, to 05:00 h on 26 October. The intensity of the rainfall was recorded by 13 raingauges distributed around the Salerno district. The maximum value of

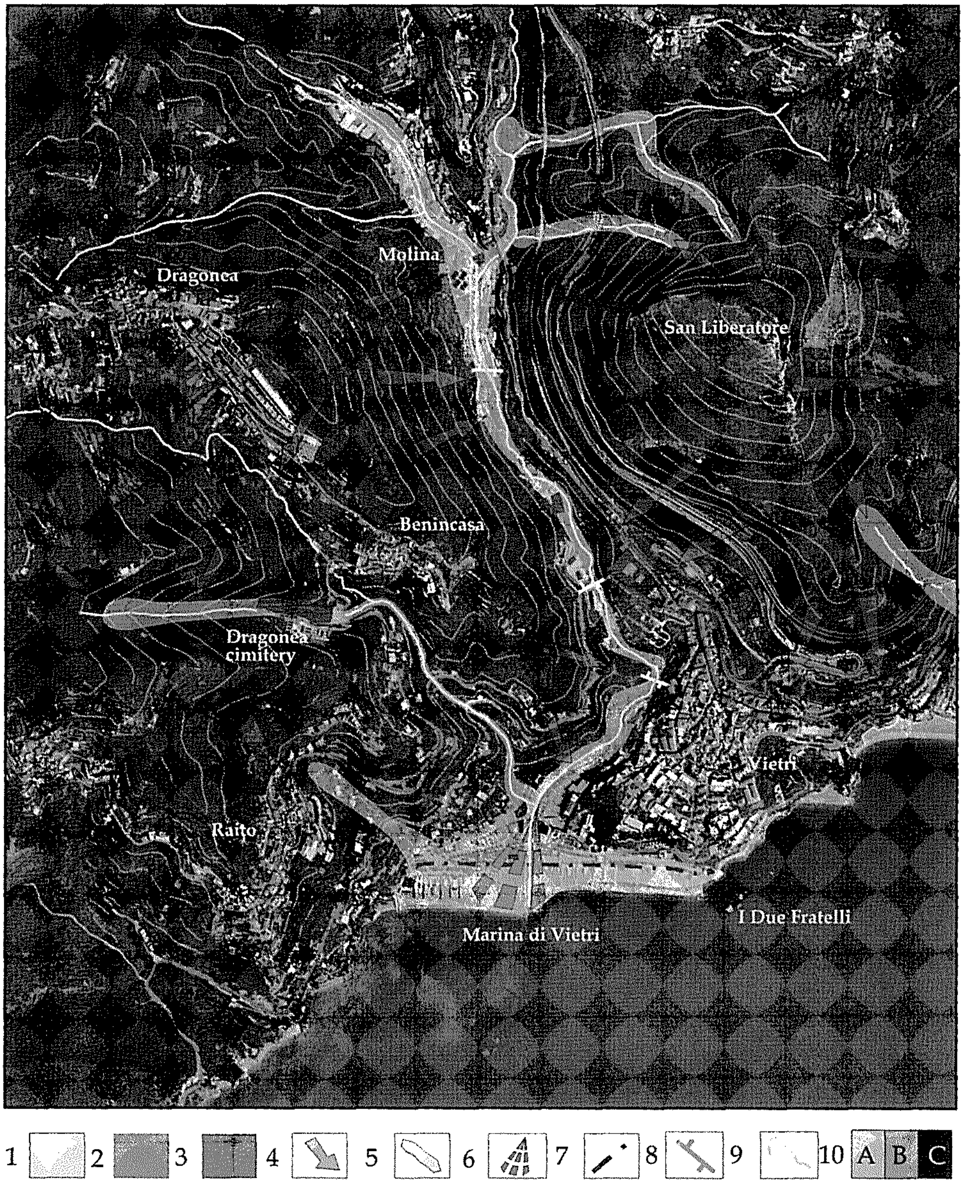

Fig. 2 Geological effects and damage pattern induced by the 1954 flood event. (1) Overflowing area; (2) mud deposits; (3) evidence of past denudation; (4) landslide phenomena; (5) channelled debris flow; (6) alluvial fan; (7) shoreline before 1954 event; (8) temporary dam; (9) drainage network; (10) damage categories: (A) heavy, (B) medium, (C) light.

precipitation was recorded in Salerno with a total of 504 mm, and a maximum intensity of 150 mm h^{-1}. The most intense precipitation was recorded at Cava dei Tirreni, north of Vietri sul Mare, between 19:00 h and 02:00 h on 26 October. During this period, 322.4 mm of rain accumulated, which was 92% of the total rainfall (348 mm) (Frosini, 1955).

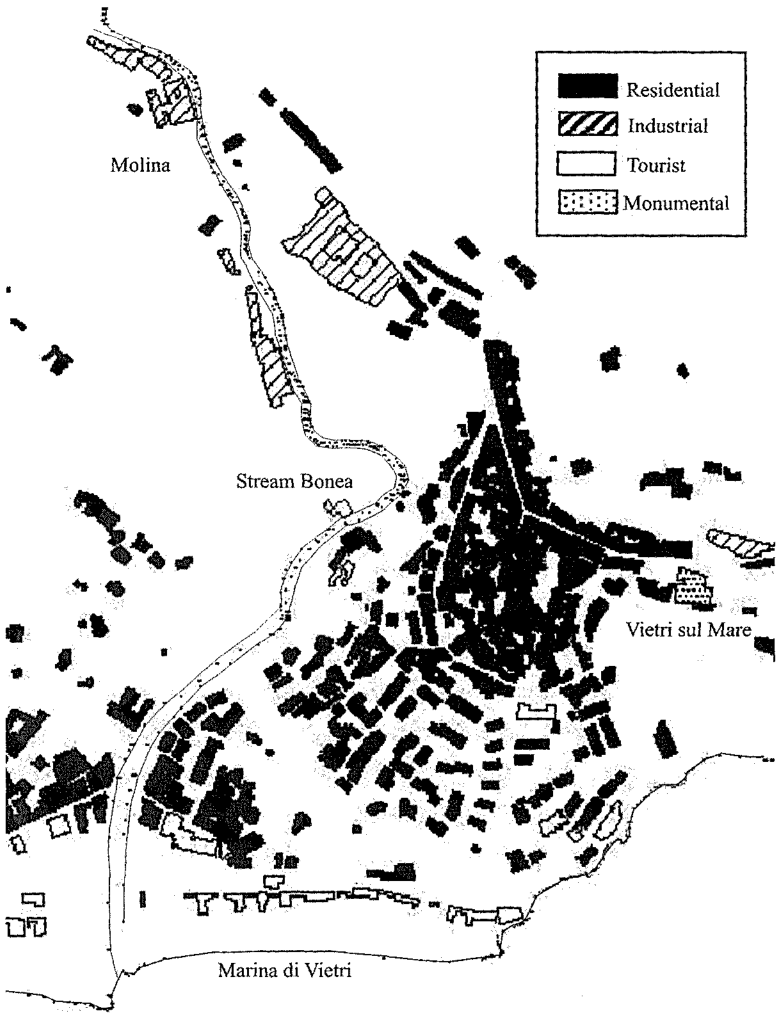

Fig. 3 Land use map of Molina di Vietri, Marina di Vietri and Vietri sul Mare areas.

Vietri sul Mare suffered the worst damage. Some 309 buildings were destroyed, 329 were damaged and 143 were rendered unfit for use. Considerable damage was observed along the railway and on State Road no. 18, while the aqueduct was completely destroyed. There were 117 deaths. Molina and Marina di Vietri suffered the worst damage. At Molina di Vietri the Stream Bonea and small tributaries flowing along the western slope of the San Liberatore hill (Figs 4(a) and 2) also overflowed along their lower courses, destroying 15 buildings, S. Maria della Neve Church and many bridges. Temporary dams developed at points where the course of the stream narrowed, 150 m downstream from Molina village and at the bridge north of Vietri village. Marina di Vietri suffered major flooding which produced a shoreline shift of about 150 m, following the creation of a delta at the stream mouth (Figs 4(b) and 2). Material was transported to the beach at Marina di Vietri by a major landslide which occurred downstream of Raito village and by severe flooding from a minor tributary of

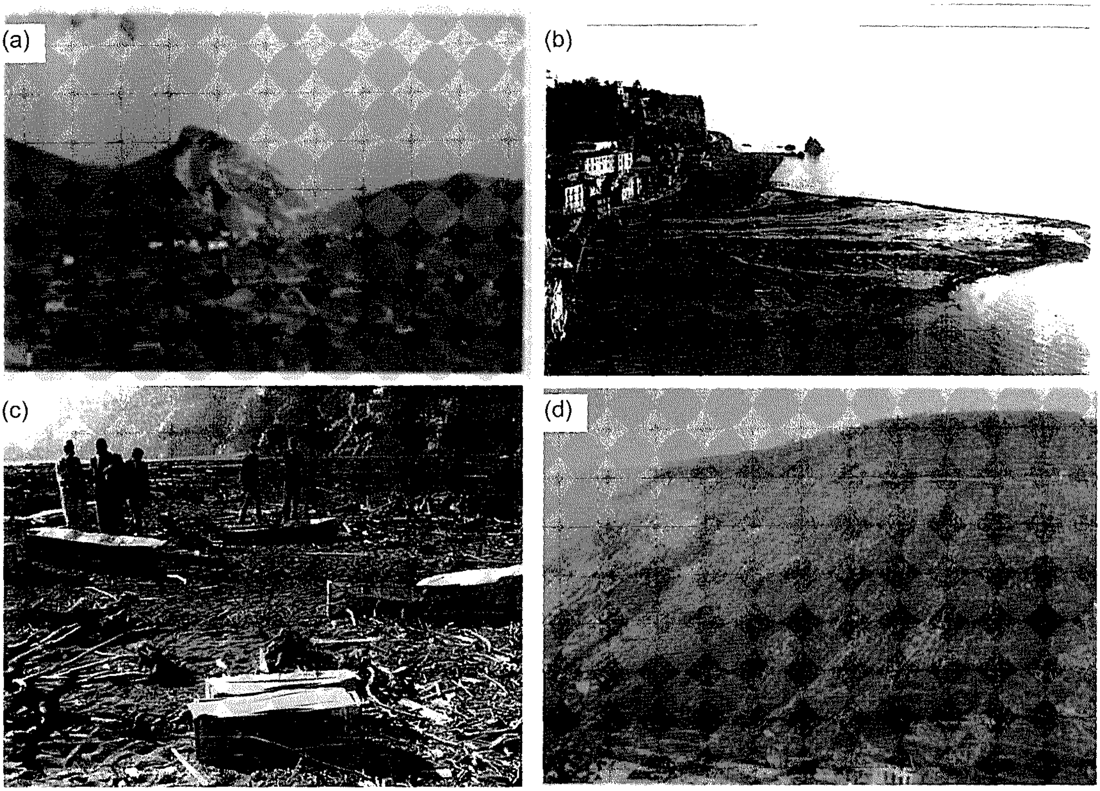

Fig. 4 Photographic documentation referred to the 1954 flood event. (a) Channelled debris flows and denudation at the northwest side of S. Liberatore Hill. Picture taken on June 1955; (b) Alluvial fan at Stream Bonea mouth after the 1954 flood event; (c) Coffins transported from the Benincasa cemetery to Marina di Vietri beach along a Bonea tributary; (d) Extensive denudation phenomena at the western side of Stream Bonea (Tresare locality, Molina di Vietri; from Penta *et al.*, 1954).

Stream Bonea, located south of Benincasa village. Here a local cemetery in the path of the water was totally destroyed, with several coffins transported about 1 km to the shore (Figs 4(c) and 2). Extensive displacement of the sedimentary covers occurred on the hillsides at San Liberatore and along the western side of the Stream Bonea at Tresaro, Dragonea and Tresare (Figs 4(d) and 2), releasing large amounts of material straight into the stream bed, raising it to augment the effect of the flood.

The geological configuration and analysis of recurrent landslides characterizing the study area led to ascribing the main mass movements which occurred in conjunction with the 1954 storm event to soil slide debris/earth flow mechanisms. Debris flows evolved from soil slips, often exposing the carbonate bedrock over wide areas of hillside (Fig. 4(d)), or developed along linear paths and tributaries, already flooded by rainfall (Fig. 4(a)). The Bonea Stream was the first place where the displaced material was delivered. Its arrival in the stream increased the destructive action of the running waters, also causing local obstructions (temporary dams) where the stream narrowed, such as at bridges, and other points where water backed up (Fig. 2). The collapse of temporary dams triggered a flood wave reaching a height eight times the usual stream depth (Lazzari, 1954; Amarotta, 1994). On the other hand, the high-gradient steep-sided river profiles prevented deposition (bypass area), so that the material was transported all the way down to the coast, resulting in an ephemeral delta at the stream mouth and hyperpicnal flows in the adjacent marine area (Budillon *et al.*, 2000; Esposito *et al.*, 2003).

FLOOD EVENTS AND DAMAGE ESTIMATION

The risk associated with historical floods in the Vietri sul Mare area results from a combination of overflows and landslide hazards. The latter, besides providing a landslide risk, also controls the extent and intensity of the induced flood wave by supplying sediment from side slopes or via tributaries to the Stream Bonea, so increasing the transported load and the water level. In this section an approach to flood wave modelling and related damage estimation is proposed, which does not account for the risk associated with the landslide phenomena. This task indicates a separate approach which is beyond the aim of this paper. The model considers the solid load deriving from displaced materials as a part of the hydrological process triggered by rainfall events, without analysing its specific contribution to over-bank flooding phenomena. In particular, the steps in developing a model for damage estimation are discussed (Fig. 5). At present it is partially applied to the study area, but for reconstruction of the described past flood event. The reconstructions here are considered within a wider framework based on a potential worth of loss, to calibrate numerical flood modelling and relative damage estimation.

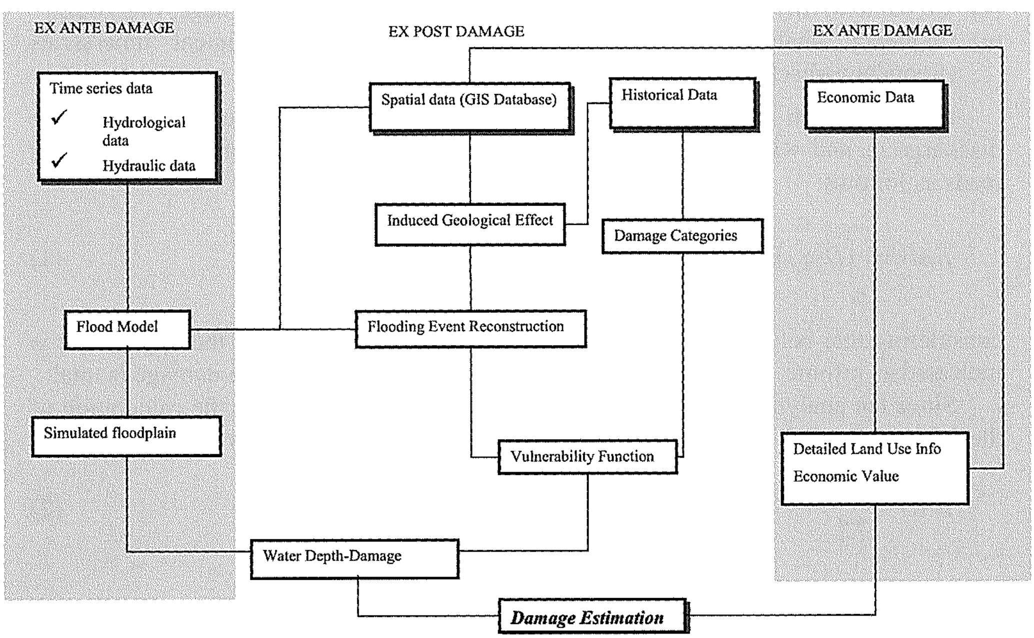

Fig. 5 Flow chart for damage estimation.

Two main approaches are typically used in the quantification of flood-wave induced damage (Penning-Rowsell & Chatterton, 1997). The traditional one is based on damage estimation resulting from the analysis of past flood events (ex-post damage). This approach is quite rigorous and allows the characterization of geologically sensitive areas, but is not sufficient for accurate damage computation. Moreover, risk management requires different scenarios in terms of time recurrence and extent of flood events. For these reasons a correct approach to flood damage estimation should also include ex-ante hydrological/hydraulic and economic analyses defining a potential worth of loss (ex-ante damage), with a ground-truth control provided by ex-post analysis (Manciola *et al.*, 2004). Historical sources combined with geological data aid computer simulations of flood dynamics and in damage estimation produced by flood waves, so defining the relations between water-depth and the percentage of properties exposed to risk (vulnerability function). In turn, the vulnerability function can be referred to different land uses (Fig. 3), derived from economic analyses. The sum of the total damage, expressed as money values, extended to all properties located in the flooded area for a given water depth, corresponds to the total damage estimation resulting from a specific flood event (Fig. 5) (Manciola *et al.*, 2004).

Further procedures for risk assessment can be based on the expected value of the damage which occurs considering floods of all possible severity, usually referred to as Expected Annual Damage (*EAD*) (Davis, 1990). Such a parameter is estimated from a damage–frequency curve (Fig. 6), resulting from a combination of the above described vulnerability function with a discharge–frequency function. In particular, the steps involved in the construction of a damage–frequency curve include:

(a) hydraulic analysis for a given flood discharge (stage–discharge analysis, Fig. 6(a));
(b) the vulnerability analysis described above (stage/water depth–damage, Fig. 6(c));
(c) frequency analysis of flood discharges based on hydrological time-series (frequency–discharge analysis, Fig. 6(b)).

Indicating with $D(q_d)$ the damage–discharge curve, with $f(q_d)$ the frequency of the discharge q_d and with $F(q_d) = 1 - f(q_d)$ the related exceedence probability, the *EAD* reads as follows:

$$EAD = \int_{q_c}^{+\infty} D(q_d) \cdot f(q_d) \cdot \mathrm{d}q_d = \int_{q_c}^{+\infty} D(q_d) \cdot \mathrm{d}F(q_d) \qquad (1)$$

considering that below the discharge q_c the damage is zero. Even if the upper limit is indicated as infinite, there should be a discharge value over which the damage is total.

Since the analytical formulation of $D(q_d)$ and $F(q_d)$ is nontrivial, the calculation of the *EAD* is obtained by numerically integrating equation (1) as follows:

$$EAD = \sum_{j=1}^{n} \frac{\left[D(q_j) + D(q_{j+1})\right]}{2} \cdot \left[F(q_{j+1}) - F(q_j)\right] \qquad (2)$$

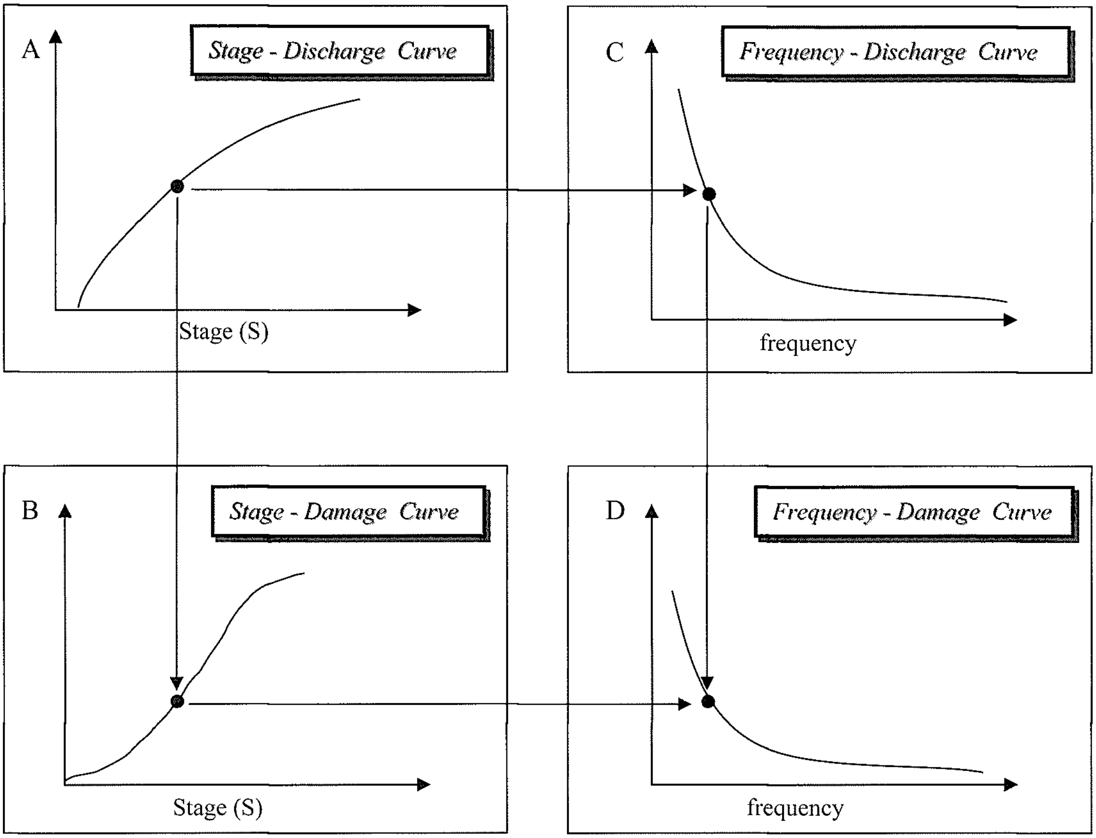

Fig. 6 Steps for construction of a frequency-damage curve. (A) Computation of water depth-stage from hydraulic and topographic analyses. (B) Damage estimation *vs* water-depth according to land use information. (C) Computation of frequency-discharge curve from hydrologic time series to estimate flood recurrence. (D) Frequency–damage curve resulting from integration of (A), (B) and (C).

FINAL REMARKS

In Vietri sul Mare the surface water drainage network and heavy rainfall events act in the same direction, dramatically increasing the hydrogeological risk. Even if the water ways offered opportunities for economic development, their exposure to natural hazard has a high impact in terms of damage and live lost. In particular, the historical flood recurrence in the Vietri sul Mare area since 1773 suggests a still present risk of flooding as testified by the latest serious event which occurred in 1954. The observed frequency of these phenomena (including minor floods) in the last three centuries is rather high, as it includes at least 50% of the total floods registered in the Salerno district.

Accurate reconstruction of the 1954 flood event led to identification of the pattern of damage and the flood-prone areas in the study area. Historical reconstructions and geological data combined with hydraulic/hydrological and economic data are desirable in order to frame the natural hazard within a risk context. The steps and methods to perform such a task, are at present still under development, including the analysis of hydrological time-series and land use mapping, which put flood modelling in a quantifiable time-recurrence perspective with an economic influence.

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2 The International Year of Freshwater: the Achievements and Successes of Similar International Initiatives

International Year of Freshwater, 2003: activities, cooperation and lessons learned

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Abstract The UN International Year of Freshwater, 2003 was intended to raise awareness of the central importance of water to development and poverty alleviation, and to improve water resources management throughout the world. The major activities were very effectively coordinated by two agencies—the United Nations Department of Economic and Social Affairs (UN DESA) and the United Nations Educational, Scientific and Cultural Organization (UNESCO), with collaboration from other members of UN-Water. The media, a website (www.wateryear2003.org), a multi-media travelling exhibit, and educational materials including a video and classroom resource guide, were used to raise awareness. The paper describes these and the focus on youth, use of national focal points, other events and cooperation with NGOs and civil society. A brief analysis of the lessons for the UN of this successful exercise is provided. Later in 2003, the UN General Assembly declared 2005–2015 an International Decade for Action—Water for Life.

Key words awareness raising; education; NGOs; the media; UN-Water; UN International Year of Freshwater 2003; youth

The International Year of Freshwater, 2003 was proclaimed by the United Nations General Assembly (Resolution 55/196 in December 2000) to raise awareness of the central importance of water to development and poverty alleviation, and to improve water resources management throughout the world.

The original initiative came from the Government of Tajikistan, because of its concern to reinforce political will and consolidate action to follow the multiple international agreements, declarations and recommendations in the area of water resources. The International Year was well timed to follow-up the action recommendations on water and sanitation from the World Summit on Sustainable Development (WSSD). The resolution encourages governments, the United Nations system and all other actors to take advantage of the Year to increase awareness of the importance of sustainable freshwater use, management and protection. It also called upon governments, national and international organizations, non-governmental organizations and the private sector to make voluntary contributions and to lend other forms of support to the Year.

The major UN activities for the Year were jointly coordinated by two agencies—the United Nations Department of Economic and Social Affairs (UN DESA) and the United Nations Educational, Scientific and Cultural Organization (UNESCO). It has been an excellent collaboration that drew in many other members of UN-Water (the group of 23 UN agencies concerned with water). The Year was launched on 12 December 2002 in two parallel acts at the United Nations Headquarters in New York and at the UNESCO Headquarters in Paris. At UNESCO, the Director-General led the proceedings at an information meeting for Permanent Delegations and presented the official website for the Year (www.wateryear2003.org). In New York, a full day event was organized for governments, NGOs, the private sector, entertainers and water experts. The event was financed by a private firm (CH2M Hill) and the Singapore Public Utilities Board. The Secretary-General of the United Nations sent out a message announcing the Year (www.un.org/events/water/).

A meeting of the Focus Group of interested Permanent Delegations to the United Nations based in New York was convened in mid-February to mobilize support for the Year at the highest political level; to encourage missions in New York to get involved with activities during the Year; and to establish channels of communications for educational and press materials at the national level in the respective countries. Although the Focus Group only met once, the interested Delegations provided support for activities throughout the Year.

The Year was marked by several important events including the Third World Water Forum in Japan, 16–23 March (www.world.water-forum3.com/), and the celebration of World Day for Water (22 March), coordinated by UNEP (www.waterday2003.org). On that day the UN system agencies, working together as the World Water Assessment Programme (WWAP), launched the first edition of the World Water Development Report: "*Water for People, Water for Life*" in Kyoto www.unesco.org/water/wwap. The title of this first edition puts people at the centre of water, and directly ties both WWAP and the report into the International Year of Freshwater.

The cooperation among the UN organizations enabled the whole system to work together to raise awareness through the media and website (www.wateryear2003.org), the multi-media travelling exhibit and educational materials, such as the video "*Water: the Drop of Life*" and the classroom resource guide, "*Every Body Counts, Every Drop Matters*". The awareness raising must have worked, because by the end of the Year the General Assembly had proclaimed an International Decade for Action—"*Water for Life*" from 2005 to 2015.

The International Year attracted widespread interest and inspired a range of actions around the world on water and sanitation issues. From the official launch of the International Year on 12 December 2002 until the present, the Year captured the imagination of international agencies and development banks, National Focal Points, governments, NGOs, the private sector, water managers and experts, entertainers, authors, painters and private citizens from many countries.

Educational and media materials

The most important accomplishment of the International Year of Freshwater was in terms of educational projects, geared towards all ages, all countries, and all professions. The Year's official website www.wateryear2003.org, was based at UNESCO and maintained by UNESCO staff. The website was an important tool to make information accessible on events happening worldwide through an up-to-date calendar of events, as well as educational material for different age levels and cultural backgrounds. Links to national websites, UN background documents on water issues, and concrete information on how to get involved were also featured.

Through the website's extensive educational material, facts and figures, activities, the newsletter, the partnerships and of course the work on a local, national and international level, the number one message was: "education and awareness-raising: a step to bringing water education into the decade".

The multi-media travelling exhibit for the IYFW (the "*Water Drop*") was financed by the government of The Netherlands and was launched by DESA at the Water Dome during the World Summit for Sustainable Development (WSSD) at Johannesburg in 2002. This excellent and informative exhibit then travelled to the Third World Water Forum in Kyoto, and then to New York during the eleventh session of the Commission on Sustainable Development (CSD-11) in spring of 2003. It then made stops in Madrid and Geneva before going to UNESCO/Paris in January 2004.

The "*World Water Development Report*" covers the full spectrum of water-related issues, from challenges to life and well-being (health, ecosystems, cities, food, industry, energy) to management challenges (managing risks, sharing water, valuing water, ensuring the knowledge base and governance). In order to reach out to people and governments to raise awareness and create a ripple effect of responses and actions, the Report places the emphasis firmly on people and governments as both the cause and the solution to today's water problems. The executive summary of the Report was released in nine separate language versions: Arabic, Bahasa Malaysian, Chinese, English, French, German, Japanese, Russian and Spanish. Translation of the full report into the six official UN languages is also foreseen.

The attractive Newsletter "*Splash*!" was transmitted electronically and featured best practices, up-coming water events and conferences and news stories from around the world. It introduced new educational material on water management and conservation issues, and drew attention to features of the Website.

A press section was maintained to support the work of interested media and journalists. The educational website of the UN's Department of Public Information (www.Cyberschoolbus.org) has hosted a range of interactive learning tools for children to gain knowledge about water and sanitation issues. The Department also issued an excellent Resource Guide on Water, "*Every Body Counts, Every Drop Matters*", late in 2003. It is envisaged that this guide will be translated into several languages for wide distribution. Additional educational materials are being developed with the assistance of the Chief Executive Officers' (CEO) Panel; the materials are to be provided to the UN, and will be widely distributed to schools in coming years.

At the beginning of December 2003, the United Nations University, in cooperation with DESA and with financing from the UN Development Account, launched an online diploma course aimed at training water-management experts in order to reach the Millennium goal to halve the number of people without access to safe water and sanitation by 2015. The 10-subject 250-hour course will be aimed mainly at current government officials and engineers, and will be initially based at three regional centres in West Africa, South Pacific and Asia. The programme, offered free of charge, will award graduates a diploma bearing the UN seal. The curriculum was developed by more than 60 academics and professionals around the world, including those from the University of Waterloo, McMaster University, and the University of Guelph. It was created over three years at a cost of $US 1.6 million from the UN's development account.

Focus on youth

It is clear that we must look to the youth of the planet to make the changes required to avert a water crisis in the next decade and to make sure people have access to safe drinking water and sanitation for basic human needs, agriculture and the maintenance of the ecosystem.

The Youth coordinator for the Year, based at UNESCO, has collected information and disseminated electronically the bi-monthly Newsletter "*Splash*!" in three official UN languages (English, Spanish and French). Youth groups contributed substantially to both the website and to the newsletter and were the focus of many of the activities carried out at the national level.

Youth represent the future generation of water users, managers, professionals, and leaders: they are the key to a future generation educated in and aware of water issues and solutions related to over-consumption, exploitation of resources, pollution etc. Youth have the energy to take action and get involved in their communities, representing an important resource and a catalyst to real change. The Year saw many countries with Youth Focal Points working on a national or local level as well as international youth NGOs becoming active in the Year.

The Year brought out an opportunity to build a culture of water, teaching people to realize the importance of water, not only in poverty reduction and in our survival, but also in our culture. Projects relating to water proverbs, water myths, the word "water" in different languages, cultural events around the world, water's value in religion, were all topics that received positive responses from the public.

National focal points

As governments play a very important role in the creation and implementation of water policies and agreements made at an international and national level, special attention was paid to what was happening in countries and the work being done by National Focal Points. There were over 69 country-nominated focal points—36 from International Hydrological Programme (IHP) committees worldwide—and almost every country around the world organized events for the Year.

In most countries, the National Focal Points appointed for the Year have provided support to activities at the national level and have been able to authorize the use of the official *WaterYear2003* logo for non-commercial purposes. In many countries, events have been organized at the municipal, provincial and national levels, in many cases supported by UN Information Centres. The IHP committees that served as National Focal Points were very active in organizing both scientific and technical events and awareness building events. The video "*Water: The Drop of Life*", produced for DESA, has been shown at many special events, as well as being broadcast on TV in many countries.

Within the www.wateryear2003.org website, a series of pages were created for each country allowing the National Focal Points to promote, in their native languages, the celebrations at a national level and to bring out activities being organized in the country. Over 90 000 "hits" were made to the country pages over the Year.

Other events

The Commission on Sustainable Development at its 2003 session selected water, sanitation and human settlements as the main themes for its first two-year cycle (CSD-12 and CSD-13, 2004–2005). Preparations for this are well underway.

A major event of the Year was the Dushanbe International Freshwater Forum held in Tajikistan (29 August–1 September 2003) www.freshwaterforum.org/index-eng.htm.

With the water and sanitation Millennium Development Goals top of its agenda, the Dushanbe International Freshwater Forum was supported by the Swiss government, the Agha Khan Foundation, UNDP, DESA and others. The Dushanbe Water Appeal called for a new "*Decade for Action: Water for Life*" 2005–2015, which was adopted by the General Assembly on 23 December 2003.

Some other important related international conferences held during the International Year took place in Moscow, Russian Federation; Kiev, Ukraine; Madrid, Spain; Boston, Los Angeles and Minneapolis, USA; Lisbon, Portugal; Paris, France; Rome, Italy; and Geneva, Switzerland; among others.

Additional important inputs to the CSD-12 agenda and the Millennium Development Goals were discussed at the Water for the Poorest conference held in Stavanger, Norway in early November and at the African Implementation Conference in Addis Ababa in December.

Cooperation with NGOs and civil society

The Year provided an excellent opportunity for the UN agencies to follow and work with NGOs, the private sector and other members of civil society. The success of the Year was due principally to the work and communication between the international NGO community and the United Nations in terms of presentation of projects, exchange of contacts and information, creation of partnerships between different NGOs, and joint activities. NGOs and civil society provided the content of the website, of the newsletter and they were the heart and energy of the Year's events. The Year's Focal Points in the UN and at the national level worked hard to encourage these NGOs to work together locally and nationally and to connect projects with NGO groups and *vice versa*. With approximately 30 emails a day coming in from NGO groups around the world, the Year was able to bring out much of the work that these groups do.

United Nations cooperative efforts

Other actions supported by UN agencies and launched during the Year were the following:

(a) A new Water Cooperation Facility was announced by UNESCO to address issues related to international watercourses, means of equitable river basin sharing and conflict resolution;
(b) UNICEF and the Water Supply and Sanitation Collaborative Council launched the WASH (water, sanitation and hygiene for all) in Schools campaign in a number of countries;

(c) UNDP launched its Community Water Initiative ($50 million for 2003–2008) and its Gender and Water Resources Guide (with the Gender and Water Alliance);
(d) UNDP and the Global Water Partnership launched a programme on effective water governance;
(e) The UN Postal Administration launched a special stamp series commemorating the International Year of Freshwater, issued in New York, Geneva and Vienna;
(f) The Secretary-General issued statements stressing the importance of freshwater on the international agenda on the occasions of the World Day for Water, World Environment Day, the Dushanbe Freshwater Forum and World Habitat Day. He also wrote the Foreword to the "*World Water Development Report*";
(g) Nane Annan dedicated her children's book, "*Tip and Top: The Adventures of Two Water Drops*" to the International Year of Freshwater. Many special issues of magazines and journals, both connected to the UN and commercial editions, were dedicated to the Year;
(h) Another full day marking the IYFW, sponsored by DESA and the Department of Public Information, was held at the UN in New York on 16 October with speakers, panel discussion and information sessions. It was very popular, with standing room only in each session. The level of interest and commitment shown by NGOs was very high.

The United Nations system agencies worked closely together throughout the Year, in a number of global activities focusing on water resources, including the celebrations of World Day for Water, World Environment Day and World Habitat Day. They also created an Interagency Gender and Water Task Force, which includes as members focal points for gender and for water from 13 UN agencies and four non-UN entities. DESA's focal point for the International Year was named Task Manager. The Task Force aims to have significant input into the work of the CSD in 2004–2005, into the work of the Task Force on Water and Sanitation of the Millennium Project and especially in the programmes for the "*Water for Life*" decade.

The collaborative work that has been carried out during the Year with partners from the UN System, governments, NGOs, institutions and the private sector has been extremely valuable in the lead up to CSD-12 and -13, and will be carried on through the "*Water for Life*" decade. The joint activities initiated jointly by DESA and UNESCO have laid a solid foundation for our expanded work in the future.

The closing ceremonies for the International Year of Freshwater took place at UNESCO Headquarters on 20 January 2004 in the presence of the Director-General, the representative of DESA, and special guests. The closing ceremony took place at the end of a two-week exhibition in the UNESCO hall of the "*Water Drop*" multi-media exhibit.

Some lessons learned

(a) The coordinating agencies were fortunate to have existing UN system-wide programmes working in the area of water resources (UN-Water and the World Water Assessment Programme) that participated in the activities of the Year. This facilitated communication and information sharing among the agencies and provided concrete information for the website and agency activities, as well as the enquiries and communication with the public, NGOs, and private sector.

(b) The public is very curious and interested in knowing what the UN agencies do. It is important that this information be presented in a way that can be understood and used by the public. The UN agencies should actively participate in joint websites to make their activities and projects accessible to the public.

(c) The UN agencies should coordinate internally well in advance of International Years (or Decades!), so that they can organise their activities appropriately.

(d) Each agency should have a Focal Point within the organization so that people know where to go for information on what is being planned. The Focal Points should send regular updates to the agency co-ordinating the Year/Decade so that this information can be made available to the public and to member States.

(e) Focal Points are also needed at the national level. These should also have contacts with the major stakeholders that are interested in the issue, i.e., youth, women, business etc. It would be useful to have a contact list for major group contact points in each country available on the website. These groups should be provided with educational materials, the logo, a webspace, etc.

(f) Materials that are appropriate and usable for youth groups should be created, including ideas for projects, stickers, posters, resources. Often such groups were interested in receiving a guide on how to get involved, what kind of projects to do, how to find funding, etc.

(g) A means (form) should be devised on the website for groups to sign up as being part of the celebrations for the Year.

(h) Guidelines are needed for National Focal Points on how to approach the private sector for funding and partnerships. These guidelines could be available on the website as well.

(i) A liaison person is needed to negotiate and secure partnerships with the private sector to provide micro-credit, scholarships, grants, etc. to groups around the world doing work at a local and national level.

(j) An upbeat electronic newsletter such as "*Splash*!" is an important tool for keeping people informed in multiple languages and also for sending people to the website. If significant work and time is being put into developing a website as a tool for groups, they need to be aware of what is new on the site.

Beyond 2003

Water continues to be a central issue in the international community going into the current cycle of the Commission of Sustainable Development (CSD-12 and -13), which will focus on water, sanitation and human settlements, and then into the International "*Water for Life*" Decade (2005–2015). The latter timetable coincides with the Millennium Development Goals in water and sanitation.

The website will continue to be available as a resource for the general public. It will be adapted to bring it into the "*Water for Life*" Decade, where the resources developed during the International Year can continue to be used and developed.

The lessons learnt, partnerships, contacts and information collected over the past year will be invaluable to kick start the "*Water for Life*" Decade. The Decade provides a new opportunity to get people more involved and to plan real, long-term projects to help us get closer to our goals and to involving all sectors of society more actively in protecting our water resources.

It is expected that the Focus Group of interested Permanent Delegations to the United Nations based in New York will be revived in relation to the "*Water for Life*" Decade. It is very important to have active support of our member States, as well as the network of NGOs and other major groups. We are looking forward to an expansion of the valuable work that has been done, and the wide dissemination of our work.

Acknowledgements Pallabee Bera, Pilar Gonzalez and Giselle Weybrecht of UNESCO and Henrike Peichert of DESA contributed to this report.

The Basis of Civilization – Water Science? (Proceedings of the UNESCO/IAHS/IWHA symposium held in Rome, December 2003). IAHS Publ. 286, 2004

Agriculture, food and water—managing water to feed a growing population

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Abstract Latent heat of evaporation represents a large outgoing component of the energy balance established at a crop-stand surface. This explains why agriculture uses approximately 70% of all the freshwater withdrawn in the world. Increasing demand for water due to population growth, competition with industrial, domestic and environmental requirements, and the decreasing quality of water, limit the agricultural capacity for food production. The Water Resources, Development and Management Service (AGLW) of the Food and Agricultural Organization of the United Nations (FAO) is carrying out activities aimed at helping country members in supporting sustainable water management to securing food for a growing population. These activities cut across the various levels of the water domain, going from the (inter)national policy level down to local-level field applications. In this article, FAO's experiences in agricultural water management are used to provide lessons from the past and indicate directions for future challenges.

Key words agricultural water management; irrigation; water policy; water productivity; water resources; water use

INTRODUCTION

Water and agriculture are intimately linked as fundamental conditions for human development. Agriculture is by far the largest user of the world's freshwater resources, accounting for 70% of water withdrawals and for >90% of water consumption (FAO, 2002a). This large water consumption by agriculture is, for a large part, the consequence of the energy balance establishing over a crop-stand. For instance, from April to August, fields in Mediterranean latitudes may receive approximately 30–35 × 10^6 MJ ha^{-1} as solar radiation. This energy is equivalent to the heat developed by the burning of around 10 t gasoline, and the plants on the field dissipate this heat via the transpiration process. In this way, 1 ha of a spring–summer crop like maize or tomato "consumes" some 6000–9000 m^3 of water.

With the world population projected to grow from roughly 6 billion to >8 billion in 2030, water withdrawals for irrigation are projected to grow by 14% for developing countries (FAO, 2003a). Moreover, meeting the demand for improved diets for a growing world population requires ever more food production, which further stretches the growing demand for water. These trends pose huge challenges as the competition for water resources is already increasing and water scarcity is becoming a concern in more and more parts of the world.

This paper discusses the role of the Food and Agriculture Organization (FAO) of the United Nations in addressing the challenges in agricultural water management as styles and patterns of agricultural production change. It reviews FAO's experiences in creating sustainable water management for agricultural production as it strives to satisfy demands for food and fibre. Some key conclusions are drawn and an argument for a better understanding of the water variable in agricultural futures is established. The paper draws upon lessons learned in the latter half of the 20th century which has seen the passage of the "Green Revolution" and the transformation of agricultural systems with a whole host of second order problems related to food quality, equity and environment.

FAO's ROLE IN THE FIELD OF WATER AND FOOD SECURITY

FAO and water management: unlocking the potential of water in agriculture

FAO was established in 1945 with the mission to help build a world where all people can live with dignity, confident of food security. FAO's mandate is to raise levels of nutrition, improve agricultural productivity, better the lives of rural populations, and contribute to the growth of the world economy. Within this mandate, FAO's activities comprise four main missions: provide technical assistance to member countries, serving as a knowledge-network bringing knowledge to professionals and farmers in the field, sharing policy expertise, and providing a forum for nations.

In line with FAO's general mandate and its main activities, a specific area of work is in the field of natural resources of which water is perhaps the key agent of production. However, while a large part of agricultural water consumption is inevitable due to the basic physical processes, there is also significant room for improvement in managing the demand for irrigation water. The improvement of in-field (hydrological and biological) efficiencies, the performance of irrigation delivery systems and the conjunctive management of surface and groundwater supplies across river basins are systemic approaches to demand reduction. These can "unlock" water resources, freeing up bulk water for use in other sectors and conserving the environmental integrity of land and water systems. But such improvements in productivity cannot be achieved without strategic investment. Both the physical and institutional means to effect a better performing water service to agriculture are required. But here it is important to stress that it is the quality of investment that is important, not the quantity.

The work of FAO in the field of water management cuts across the various levels of water domains. It ranges from the collection and analysis of information at the (inter)national policy level down to the implementation of field projects at the local level. Covering this range of activities, different areas are identified for discussion in this paper, zooming in from the general water policy level, through the water quality and management at the regional and field level, down to specific small-scale irrigation and water harvesting techniques.

Over the past years, various activities have been undertaken in these fields and the following sections focus on some of them providing interesting experiences and future challenges for the wider community of water professionals.

ACTIVITY DOMAINS OF THE WATER RESOURCES, DEVELOPMENT AND MANAGEMENT SERVICE (AGLW)

Water policy development: information management and sharing policy expertise

While agriculture has been successful in capturing the bulk of withdrawn water resources, the rationale for continued access to this resource has come under intense scrutiny from both water economists and environmentalists. A review of irrigation policy implementation in the 20th century (Burke, 2002) has indicated that irrigation sub-sector reform would have more chance of success when implemented as part of an agricultural strategy that targets farmer beneficiaries rather than irrigation systems *per se*. In this sense irrigation policy may need to avoid being subsumed under general water sector reform (FAO, 1995), but its allocation as key player in integrated water resources management on the basis of better water science and economics needs negotiation. As the trend toward precision agriculture gathers pace in developing countries the demand for more reliable water services rises—modern production systems cannot tolerate volatile inputs. Yet climatic unpredictability does not diminish and the chances for the development of new infrastructure to build more bulk storage are severely limited—in physical, economic and even ethical senses (http://www.dams.org/). Therefore AGLW is being asked to support many countries in expanding the policy and investment space in which agricultural water management can innovate to enhance and modernize the performance of the irrigation systems and their associated institutions, looking at alternatives to brute capture of yet more water resources. Much of this work is carried out with the collaboration of water lawyers in FAOs Natural Resource Law Service (FAO LEGN) and the collaboration has resulted in many national irrigation policy water legislation outputs and a range of publications to guide water resource policy and regulatory development in which stable and transparent rights in water use are seen as essential (FAO 2003b,c, 2004a).

Information about the availability and use of water in agriculture and about the impacts of past and current activities is essential for the development of policies and investment decisions that enable a sustainable and productive use of water in agriculture. Good science begets good policy. Therefore, FAO has developed its AQUASTAT programme, a global information system on water and agriculture that aims to provide policy makers and experts with the most accurate, reliable, consistent and up-to-date information on agricultural water management on the international, national and regional level. This information system uses a philosophy of building knowledge on a strong national information basis.

Examples of specific information outputs in this area are country profiles and national data on water resources and agricultural water management (FAO, 1999, 2003d), and spatial information on water resources and irrigation (FAO, 2000a). The information collected has also been used as a basis for thematic studies, such as the assessment of the irrigation potential in Africa (FAO, 1997a), water control in southern Africa (FAO, 2003e), and for the compilation of general reviews and future outlooks (FAO, 2003f; WWAP, 2003).

The experience and lessons learned in global water information management show the importance of national capacities, systematic data and information collection including quality checks, harmonized definitions, sharing of information, metadata, database management, and the combined use of tools such as GIS, modelling and remote sensing with expert knowledge. Furthermore, printed information and other information media remain important as the Internet is not yet accessible to all.

In addition to the information that is currently covered under the AQUASTAT programme, there is also a need to develop in-depth studies on key themes related to water, food and agriculture. There are several issues that are of increasing relevance, for which no good information is currently available for (inter)national level policy makers and experts. Therefore, the AQUASTAT programme plans to develop studies on issues such as the extent of urban and peri-urban irrigation, waterlogging and salinization, pressurized irrigation, and the use of wastewater in agriculture. Expanding into these new fields while improving, maintaining and updating its basic information capability, are the future challenges for AQUASTAT, along with the strengthening of information and knowledge management capacities.

Water management and irrigation systems

Water can be managed more effectively from field levels up to the catchment or river basin to raise its productivity, i.e. producing *more crop per drop* (FAO, 2002a).

Crop water management is a key area which aims to increase crop production per unit of water in order to secure an adequate food production with limited and dwindling water supplies. The basis for crop water management is an accurate estimation of crop water requirements and an assessment of crop yield responses to deficit water conditions, for which FAO has developed guidelines, methodologies and software (FAO, 1979, 1998; CROPWAT, downloadable from the FAO website). These outputs are widely disseminated and are being permanently maintained and upgraded, taking into account changes and innovations in research and technology, cropping systems, climate, etc. The challenge is to realize these updates without losing the combination of scientific accuracy and simplicity which allowed the success of the first initiatives >20 years ago.

In getting the right amount of water to the crops at the right time, an adequate operation and management (O & M) of irrigation systems is crucial. To improve this O & M, numerous modernization processes have been started all over the world. AGLW is engaged in a worldwide survey to analyse these irrigation modernization processes to derive lessons from those experiences and to be able to advise those that are planning a modernization activity. AGLW is promoting Rapid Appraisal Procedures to assess the needs for modernization, coupled with benchmarking and performance monitoring and evaluation of the schemes. Experiences from these modernization activities indicate that demand-based management, rather than the supply-based concept of previous years, is taking root slowly but surely among the irrigation community. Also, for many farmers, modernization is above all an issue of reaching cost effectiveness of irrigation investments and operation and maintenance.

The engineering perspective and the hardware are usually the starting point in the modernization of irrigation schemes, but a successful modernization requires the integration of this "hardware" with the "software" of active farmers' participation, good governance and institutional arrangements. Unless the right balance between these inputs is achieved, the irrigation systems are likely to continue to perform below their potential. Many of the countries that depend upon large scale public irrigation, particularly in Asia and Latin America, are having to review the institutional arrangements under which such schemes are operated.

Numerous countries are moving towards a decentralization of irrigation management, transferring management tasks and responsibilities from state agencies to local user groups. The expanding role of groundwater also has to be recognized as individual farmers seek to improve their productivity through development of on-demand, just-in-time supplies (FAO, 2003g). FAO develops activities to support these institutional reforms, by documenting experiences, organizing international meetings and publishing guidelines (FAO, 2004b). The experiences suggest that there is not one single model for management transfer or irrigation, but rather that the approach has to be adapted to the special conditions of the particular country. In addition, the institutional process is a lengthy one that requires full commitment of both governments and farmers. Local capacity in handling the management tasks is often weak after the handing over, and the transfer will only bring the expected outcomes if it is accompanied by strong and consistent interventions to support the development of the local institutions in managing their resources.

Land and water quality management and the environment

Land drainage is an essential water management component to prevent land degradation and increase the agricultural productivity of problem soils. By means of drainage, water-logging and soil salinity are controlled, the latter in particular in irrigated lands. Controlled drainage is also relevant for drought mitigation if the groundwater is of good quality.

FAO has provided technical assistance on land drainage in many field projects, and prepared several publications on this subject to provide practical guidance to field engineers, for example recently on drainage materials (FAO, 2000b). A forthcoming publication on drainage design is currently under preparation.

Agricultural drainage water must be properly managed to prevent deterioration of land and water resources. Water conservation, re-use, safe disposal and eventually water treatment are the major components of drainage water quality management. To promote adequate drainage water quality management, AGLW implements country projects, works on guidelines (e.g. FAO 1997b, 2002b) and exchanges experiences with other partner organizations (e.g. in the Dialogue on Water, Food and Environment).

An important area of attention related to water quality and the environment is the use of treated wastewater in the irrigation of agricultural lands. Treated wastewater re-use is seen as a valuable option in water scarce countries. It not only makes more water available for agriculture, but the nutrient content in the wastewater is also an agricultural benefit, in addition to the environmental benefit. FAO collects and disseminates information on the health risks, environmental hazards and crop production potential associated with the use of treated wastewater, through publications (e.g. FAO, 1992, 1996) and information systems, such as the *Wastewater Database*. This database contains information on wastewater production, treatment and re-use, provided by member countries and from peer-reviewed papers, proceedings, and FAO's related databases.

The link between agriculture and the environment is even tighter in wetland areas such as flood plains and deltas. The availability of water and generally fertile soils as well as the presence of an important biodiversity are creating favourable conditions for profitable agriculture. Additional revenues are obtained from traditional activities such as hunting, fishing, the collection of wood, construction materials and medicinal plants, etc. In many countries of the world, large areas can be characterized as wetlands of many different types and represent, in spite of their fragile nature, a large potential for increased agricultural production. Unfortunately, the specific problems of wetlands are either ignored, or wetlands are designated as protected areas. However, farmers are practicing agriculture in wetlands anyway and generally without proper technical guidance. Therefore, FAO is increasing the awareness of decision makers in the SADC region (South African Development Community) on the potential and the specific problems of wetlands through case studies and regional workshops, in close collaboration with IWMI (International Water Management Institute) and with IUCN (World Conservation Union). FAO contributed to the adoption of a resolution by the Conference of Contracting Parties of the Ramsar Convention on *Agriculture, Wetlands and Water Resources Management*. A number of countries are receiving direct assistance from FAO for activities in wetlands, in particular in the framework of the SPFS (Special Program on Food Security). From an inventory of ongoing training programmes in the SADC region, it is clear that there is an urgent need for specific modules at all levels for formal and in-service training on the specific aspects of wetland development and management.

Small scale irrigation and water harvesting technologies

Small-holder irrigation and rainwater harvesting are increasingly considered as alternatives to large scale formal irrigation schemes. In addition, the use of on-demand just-in-time groundwater supplies has expanded significantly as individual farmers seek to reduce their exposure to unreliable surface supplies. Investment costs are only a fraction of the large irrigation schemes and are often privately financed. In such small scale irrigation development, all operations are in one hand and conditions can be easily adapted to the local circumstances.

Several regional expert consultations and training on small-scale irrigation have been organized to exchange experience and make information available to a wider public.

In arid and semiarid regions, only a small percentage of rainwater actually benefits the crop. Large shares of the precious rainwater either flow away at the surface, infiltrate beyond the root zone or evaporate locally from the surface of the field. Water harvesting techniques, and in particular runoff farming, concentrate runoff from a larger non-cultivated area on to a smaller cropped area. A technical document on water harvesting for agricultural production has been developed (FAO, 1994) and has been used to develop training material for workshops in about 10 countries in Asia, Africa and the Middle East. A CD-ROM with the course material in the five working languages of FAO is being produced. More work on the economic aspects, particularly in relation to farmer incentives, is needed to establish the "state of the art" at policy level and to provide information and possibly decision support tools to select the most suitable areas and the appropriate techniques for water harvesting. The quantitative assessment of the contribution of water harvesting techniques to the replenishment of the shallow groundwater circulation, contributes to the economic justification of such kinds of investments.

PROSPECTS FOR THE FUTURE

Past experiences and lessons all clearly point to one important challenge that FAO faces in its work, which is putting knowledge into practice. With the existing scientific insights and available technologies, the prospects for further improvement in agricultural water management look promising. However, the practicalities of agricultural water management on the ground prove more complicated than the application of science and technology. The social and economic realities that condition the uptake of new ideas need as much attention as the control of hydraulic transients in modern canal systems. The main challenge for AGLW therefore is to bring research results into practical implementation, ensuring that they actually benefit the ultimate (local) water users in their productive capacities. Removing constraints to such implementation thorough socio-economic policy analysis and legal reform are as important as the technology, but all such interventions have to be viewed from the perspective of the farmer—the *de facto* water manager.

Addressing this challenge, AGLW will continue to work on collecting information on the experiences and status of water management in agriculture, and to make this information available to a wide range of users and to use it as a basis for policy advice. In this process, the FAO Regional, the Sub-Regional and the country-representative offices play a crucial and essential role. Training and capacity building are key elements in developing the local skills, knowledge and means to define, plan and implement action programmes in water management for agriculture. Capacity development is not a mere addition to rural and agricultural development, but rather it is a critical aspect of the development itself, and it requires judicious investment.

Finally, experience underlines that agricultural water management itself is a service to agriculture, requiring integration of other agricultural system components and continuous interaction and cooperation with the professional communities of other related disciplines.

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Isotope hydrology at IAEA: history and activities

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Abstract The International Atomic Energy Agency (IAEA) was established in 1958 as a new United Nations special organization, with isotope hydrology as part of its research and technical cooperation programme, in conformity with the mission to encourage the Peaceful Applications of Atomic Energy. Shortly afterwards the Isotope Hydrology group at the IAEA was consolidated into the Section of Isotope Hydrology. Since that time the Section has promoted and supported the development and practical applications of nuclear and isotope techniques in hydrology and related earth sciences, including oceanology and climatology. The paper highlights specific contributions of the Agency to these developments such as the establishment and operation of the Global Network for Isotopes in Precipitation (GNIP), the provision of isotope standards and reference materials, the organization of coordinated research programmes, and the support of technical co-operation projects in developing countries. The collaboration between the IAEA and other UN organizations, such as UNESCO, in hydrology and climatology is also underlined.

Key words climatology; environmental isotopes; hydrology; International Atomic Energy Agency (IAEA); radioactive isotopes; stable isotopes; United Nations Educational, Scientific and Cultural Organization (UNESCO)

THE BEGINNING

Isotope hydrology is the discipline within the earth sciences that studies the hydrological systems using techniques based on the determination of isotopic abundances and their changes in water and the environment. This scientific discipline was born in the fifties, after the development of mass spectrometers capable of measuring small isotope ratio variations and gas proportional counters capable of detecting the occurrence of radioactive isotopes at very low concentration, and the consequent publication of a number of studies and applications related to natural waters.

Since 1958, that is shortly after the establishment of the International Atomic Energy Agency (IAEA) as a new United Nations organization, isotope hydrology was included in its research and technical cooperation programme, in conformity with the mission to encourage the Peaceful Applications of Atomic Energy. The Isotope Hydrology group at the IAEA, initially led by Erik Eriksson, was then consolidated into the Section of Isotope Hydrology, headed by Bryan R. Payne until his retirement in 1987. Since then, the Section of Isotope Hydrology of IAEA has been led by

Roberto Gonfiantini (1987–1993), Jean-Charles Fontes (1993–1994), Klaus Froehlich (1994–1999) and Pradeep Aggarwal (present head).

The Isotope Hydrology Section's strategy was set up in two advisory panels convened in the early 1960s, which brought together isotope experts and their counterparts of the hydrological community. As stated in the report of the first panel:

"the panel considered that there were two possible approaches to the development of isotope techniques aimed at the solution of hydrological problems. The first might be termed an isotope technique development approach having no particular application in mind. The second approach would be to consider particular projects and then to try and find the isotope techniques which could be applied to their solution. The disadvantage of the first approach is that the isotope specialists are not always aware of the real hydrological problems, and on the other hand, consideration of only what might be called the project approach would handicap application owing to the prevailing lack of standard working techniques. The panel strongly recommended that both lines of attack should be simultaneously followed, resulting in mutual incentive to the two main groups of workers".

This dual role was then further emphasized as the work progressed.

The main focus of isotope hydrology in the fifties and early sixties was on the introduction of short-lived radioisotopes (readily available from the nuclear industry) in groundwater and surface waters, in order to obtain local parameters of hydrological systems such as mixing characteristics, transit times, storativity, porosity, transmissivity, discharge rate, etc. The new technology was rather well received by field hydrologists and applied in different parts of the world. However, the increasing difficulty of obtaining permission for the introduction of even small amounts of radioactive isotopes into hydrological systems used for water supply, as well as the limited time and space scale in which they could be employed, resulted in the gradual curtailment of the use of artificial tracers, and their replacement by isotopes of natural or anthropogenic origin distributed in the environment by natural processes. These isotopes are called environmental isotopes.

ENVIRONMENTAL ISOTOPES

The first of these isotopes to come into focus was tritium, the radioactive isotope of hydrogen with a half-life of 12.3 years. It is not only produced naturally in the atmosphere by the secondary cosmic radiation via the reaction ^{14}N (n, ^{3}H) ^{12}C, but has also been released in large amounts (about 7.5×10^5 TBq per Megaton equivalent of fusion energy) by the thermonuclear explosions. Indeed the tritium released into the environment by the atmospheric thermonuclear tests performed in the years 1961 and 1962—just before their suspension from 1 January 1963 by the Limited Test Ban Treaty between the UK, USA and the former USSR—was 1.8×10^8 TBq. This amount corresponds to about 140 times the natural inventory, and to 1300 times that naturally produced by cosmic rays during the same period. In those years, and for many years to follow, the thermonuclear tritium completely overshadowed the natural tritium signal in precipitation. During the four decades elapsed after the occurrence of its maximum value (1963), the concentration of thermonuclear tritium in atmospheric waters has been decreasing almost regularly, reaching during the 1990s values equal, or very close to, the natural, pre-bomb level. This trend was only slightly disturbed by the relatively smaller French and Chinese tests which took place from 1967 to 1980 and which introduced additional tritium pulses into the atmosphere.

The tritium injection by the atmospheric thermonuclear tests inadvertently resulted in the largest tracing experiment ever attempted of the whole hydrological cycle. The introduction and mixing of the excess (bomb-) tritium into the surface and groundwater bodies, promised hitherto unrealized opportunities for the study of the dynamics of these systems. This "tracer experiment" complemented the dating of hydrological systems by the natural cosmic-ray produced tritium as was suggested by W. Libby and co-workers in Chicago just prior to the bomb pulse. The latter obviously terminated the possibility of a straightforward dating approach based on cosmogenic tritium.

THE GLOBAL NETWORK OF ISOTOPES IN PRECIPITATION (GNIP)

The global aspect of this "tracer experiment" necessitated as a prerequisite the documentation of the tritium distribution in the atmosphere and surface waters (oceans, lakes, etc.), focusing the attention on the water cycle as a whole, especially the atmosphere–surface–groundwater continuum. Since from the very beginning an important task of the IAEA had been the monitoring of the radioactive fallout of nuclear explosions, it was only natural that the Isotope Hydrology Section was charged with the duty of measuring the tritium content in the environment. Under the assistance and advice of other scientists—among which were Robert Brown (Canada), Willi Dansgaard (Denmark), Joel R. Gat (Israel), Karl-Otto Münnich (Germany), Edgar Picciotto (Belgium), Ezio Tongiorgi (Italy)—about 150 stations out of the network of the World Meteorological Organization were selected and monthly composite samples of precipitation were collected for tritium analysis. This network was the nucleus for GNIP (Global Network of Isotopes in Precipitation).

Soon thereafter it was decided to also determine the stable isotope composition of precipitation, i.e. the $^{2}H/^{1}H$ and $^{18}O/^{16}O$ ratios, which would help to understand the general atmospheric circulation patterns as well as in applying isotope techniques in water resources assessment. Furthermore, an intensive measurement programme of tritium in rivers, lakes and groundwater, at selected sites representative of different climate zones, was initiated, yielding some invaluable information on the dynamic aspects of the water cycle, such as the residence time of water in the different hydrological reservoirs, the hydrograph separation, the exchange rate and mechanisms between the stratosphere (where most thermonuclear tritium was injected) and troposphere and between the northern and southern hemisphere, etc. By monitoring the concentration and movement of tritium and other isotopes in water molecules, hydrologists were able to determine the rate at which water moves through the hydrological cycle: from clouds to the earth surface, to rivers, underground reservoirs, aquifers or glaciers; to the ocean; and back again to clouds. In this way hydrologists could determine the origin of water and its age, the rate of precipitation and evaporation or infiltration into the ground.

Similarly, the stable isotope data on precipitation were an invaluable source of information on the global circulation patterns of atmospheric vapour and on the connection between isotopic composition and meteorological conditions and major climatic characteristics. The isotopic composition of atmospheric precipitation defines the isotopic input to the majority of the natural archives used for reconstruction of the climate in the past (palaeo-climate).

Thus, the establishment of the GNIP has to be considered a very fruitful scientific operation, which only an international body such as IAEA could have undertaken. No wonder that the scientific communities dealing with (palaeo-) climate and global circulation modelling are making increasing use of the GNIP database. Several international programmes related to palaeo-climatology have commended the relevance of the GNIP database as a primary reference for recent isotope data and as a means to validate palaeo-climatic reconstruction based on isotope records. In this context it should also be noted that, starting in 1998, the GNIP database was supplemented by a database compiling isotope and related data from water resources projects worldwide. The database is known as ISOHIS. The GNIP and ISOHIS data were recently merged in a common GNIP/ISOHIS database accessible through the Internet under http://isohis.iaea.org.

THE IAEA ISOTOPE HYDROLOGY LABORATORY

As the number of isotopic analyses required for the GNIP network and field projects for water resources assessment was large for any research laboratory, IAEA decided to set up its own Isotope Hydrology Laboratory for measuring tritium and carbon-14, which some years later was upgraded to include stable isotope measurements ($^{2}H/^{1}H$, $^{13}C/^{12}C$ and $^{18}O/^{16}O$ ratios). During the years, the equipment of the Isotope Hydrology Laboratory was gradually increased; nowadays it includes four gas proportional and five scintillation counters for low-level β-counting (tritium and carbon-14), five isotope ratio mass spectrometers for stable isotopes, a full water chemistry laboratory, and gas chromatographs for chlorofluorocarbons (CFCs) determination in the atmosphere and natural waters. Recently, a mass spectrometer dedicated to measurements of ^{3}He was acquired, which will enable combined ^{3}H and ^{3}He analyses and thus the application of the $^{3}H/^{3}He$ method to groundwater and surface water studies. Whenever possible, the analytical systems are run automatically and are able to process a large number of samples. For instance in recent years the samples processed for research and technical cooperation field projects were: 1200 for ^{3}H; 3000 each for $^{2}H/^{1}H$ and $^{18}O/^{16}O$; 300 for $^{13}C/^{12}C$; 150 for ^{14}C (carbon-14); 150 for water chemistry; and up to 100 for the CFCs.

The IAEA laboratory provides assistance to member states in establishing and operating isotope hydrology laboratories, for which it serves as reference laboratory. In addition, the laboratory provides assistance in the preparation and distribution of reference materials for isotope measurements and organizes inter-comparison and inter-calibration exercises among laboratories. In this respect, an early highlight was set by the first Advisory Group Meeting on Stable Isotope Reference Materials in 1966, which recommended the production of two water reference materials to improve the inter-laboratory comparability of measurements of hydrogen and oxygen stable isotope ratios in water samples. This led to the preparation of VSMOW (Vienna

Standard Mean Ocean Water) and VSLAP (Vienna Standard Light Antarctic Precipitation) by Professor Harmon Craig of the Scripps Institution of Oceanography, La-Jolla California, USA. In subsequent meetings the preparation of several (35) other reference materials was suggested and undertaken, materials which were calibrated through the cooperation of selected laboratories. Towards the end of the nineties, further efforts were made to improve the analytical quality of the Isotope Hydrology Laboratory and its partners worldwide and to improve the precision of the stable isotope and tritium measurements according to the new challenges by applications to climate and groundwater replenishment studies.

FIELD PROJECTS IN ISOTOPE HYDROLOGY

Having established its own isotope hydrology laboratory, the IAEA started to be involved in field projects to assess the water resources in developing countries which were financially supported by the Technical Co-operation programme of IAEA and other UN organizations such as the FAO, UNESCO, UN, and others. In fact, it soon became clear that isotope techniques can provide information on the origin, history and dynamics of water bodies which often is inaccessible by other means. In particular, isotope techniques are capable of evaluating groundwater age, that is the time elapsed since the rain or surface water infiltration recharged the aquifers, by using the radioactive isotopes tritium and carbon-14.

With carbon-14, the age is obtained by determining the decrease of the carbon-14 concentration in the dissolved inorganic carbon due to radioactive decay. Carbon-14 has a half-life of 5730 years and thus enables determination of groundwater ages of up to 30 000 years. Carbon-14 is particularly useful in arid and semiarid regions where the recharge is low (or even negligible in modern years) and where little is known about the replenishment and flow regime of groundwater. The IAEA has provided technical assistance to many member states in arid regions.

During the five decades of the existence of Isotope Hydrology, the practical applications in hydrology have increased continuously and were extended to tackle many of the categories and aspects of water problems, including: water resources assessment in arid and semiarid countries, the origin of water resources contamination, geothermal resources assessment, environmental investigations related to climate change and its impact on the water cycle, the reconstruction of palaeo-climatic conditions, the use of artificial isotopes for measuring river discharge and sediment transport, etc.

RECENT DEVELOPMENTS AND FUTURE PROSPECTS

Some early work that followed the discovery of the stable isotopes of hydrogen and oxygen had already established the depletion of the heavy isotopes of meteoric waters relative to oceans and, in contrast, their enrichment in surface waters exposed to evaporation. However, it was not until the stable isotope composition of precipitation was determined within the framework of the GNIP programme, establishing the time and space patterns of its variability, that the potential of stable isotope methodology for studying the water cycle became fully evident. Questions such as the interrelations between surface and sub-surface waters, the geographic and temporal origin of groundwater recharge, and the water balance of whole hydrological systems, especially in wetlands and evaporation-prone areas, could be addressed. Thus, the emphasis of isotope hydrology shifted from detailed and local problems to larger scales, such as that of the complete watershed, and beyond to the continental scale. This development required, however, a widening of the horizons to encompass the total environment and integrating engineering, geography, meteorology, and agricultural science in the programme of hydrological science. The IAEA isotope hydrology programme was thus thrust into the position of spearheading the transition to this new concept of hydrology. The environmental isotope applications rely on an in-depth understanding of the water cycle, in both detail and its totality and complexity. This has put great challenges at the door of the Hydrology Section, in that it had to play a dual role of initiating very basic research, as well as continuing its important function of furthering practical applications, especially in developing countries.

As a consequence, in recent years the practical problems of water resources assessment and management shifted increasingly from the supply of adequate amounts of water towards water quality protection from pollution and overexploitation. This development enhanced the importance of following up the movement of particular parcels of water in hydrological systems, on the one hand, and of identifying the origin and the geochemical behaviour of contaminants, on the other hand. Isotopes other than those of hydrogen, oxygen and carbon are used to trace contaminants, in particular those of sulphur, nitrogen, boron, chlorine and noble gases. Indeed the link with the geochemistry of water resources was strengthened, including the water–rock interaction processes.

In the 1980s concern about global warming and its impact on the world's climate began to increase. One product of this concern was growing interest in establishing models of the global atmospheric circulation of water, water vapour and other greenhouse gases, as well as of ancient climates (palaeo-climatology) as a potential key to predict future changes. Since the isotopic ratios of precipitation are closely related to climatic parameters and prevailing atmospheric circulation patterns, it is evident that proxy materials recording the isotopic composition of past precipitation, namely ice-cores, palaeo-groundwater, lake and sea sediments, cave deposits and tree rings, can be used for palaeo-climatic reconstructions. Radioactive environmental isotopes, in particular radiocarbon, have been used to provide the time-scale of these climate changes. Thus, isotope hydrology is playing a pivotal role in palaeo-climatological research. This explains the participation of IAEA in international research programmes such as: PALAEAUX-Management of Coastal Aquifers in Europe, and GASPAL-Continental Isotope Indicators of Palaeo-climate, both financed by the European Union, and ISOMAP, a special programme under the IGBP core-project PAGES (Past Global Changes). Moreover, permanent cooperation is established with scientists working in oceanography, atmospheric global circulation modelling, ecology (plant water balance studies), etc.

Another field of application of isotope techniques is the study of the greenhouse effect. Gases such as water vapour, carbon dioxide and methane, absorb part of the infrared radiation released from the Earth's atmosphere into outer space and transform its energy into kinetic energy, so causing a rise of the mean air temperature. The carbon isotopic ratio variations of atmospheric carbon dioxide and methane allow better quantification of the contribution of the various sources of these greenhouse gases and better understanding of their atmospheric cycling at the global scale. This provides a basis for improving the prediction of climate changes. The isotopic variations to be detected are small and require long-term and high-accuracy measurements. The IAEA promotes collaboration among specialized laboratories and provides support in refining the methods and assuring the quality of the measurements. In addition, since 1993 IAEA has regularly organized symposia on the use of isotopes in climate research, with an emphasis on studies related to hydroclimatic changes and their impact on catchment and surface water systems.

Recognizing the concern about "*water: a looming crisis*", which is rapidly growing—especially in developing countries—the IAEA Isotope Hydrology programme continues to place emphasis on integrating isotopes in technical co-operation projects on water resources assessment and development in member states. The programme's objectives have been defined as follows:

"*to assist, through integration of isotope techniques in applied research and practical applications, in solving practical problems related to sustainable and efficient management of water resources and to promote research and field studies related to human induced changes and hydroclimatic influences on the water cycle and its interaction with other geospheric systems*".

IAEA's Board of Governors assigns high priority to this Isotope Hydrology programme.

The IAEA has from the beginning of its Isotope Hydrology programme collaborated with several international organisations. In particular, IAEA contributes to UNESCO's International Hydrological Programme (IHP), for which it has recently supervised the preparation of a textbook on Isotope Hydrology. Through a Memorandum of Understanding signed in 1998, the co-operation between IAEA and the World Meteorological Organization in operating the Global Network of Isotopes in Precipitation (GNIP) has been strengthened. Thus, this remains a high-priority, permanent programme of the IAEA, assuring the continuous updating of a database which is readily accessible to hydrologists, climatologists, geochemists, and environmental scientists.

To fully integrate isotope techniques into national/regional water sector programmes it was deemed necessary to increase the awareness of the communities of scientists, field hydrologists, and managers, at the national and international levels. To this aim, an International Programme of Isotopes in the Hydrological Cycle (IPIHC) was initiated in 1998 in cooperation with UNESCO and WMO. The programme includes the objective of integrating isotope hydrology in: (1) national and regional water sector programmes; (2) syllabi of universities (as part of geological, hydrological and climatological sciences); and (3) climatological research (with an emphasis on climate change and its impact on drinking water availability). In April 2000 a joint UNESCO–IAEA Planning Group discussed further details and stressed the need for such a long-term inter-agency programme, which is now called the Joint International Isotopes in Hydrology Programme (JIIHP) and is included in the International Hydrological Programme of UNESCO Phase VI.

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3 The Impact of Water Resources Development and Management on Society

Water resource development and the environment in the 20th century: first the taking, then the putting back

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Abstract The purpose of this paper is to show how perspectives have shifted in the past century from the certainties of taking freshwater from the environment to produce goods and services, to a pervasive uncertainty because the environment has been degraded by too much development. The study will first trace the intellectual and philosophical inspiration, which led to the hydraulic mission approach. Second, it will outline the discursive politics, which reversed the trend in the North. The analysis will also demonstrate why the hydraulic mission is still prominent in the South, despite the advocacy of the green social movement and major international financial agencies. The role of risk awareness and the changes in such awareness will be shown to be central to any analysis of how water policy-making has been and will be made.

Key words cultural theory; economic efficiency; environmental services; freshwater; hydraulic mission; hydro-politics; risk; risk construction; soil water; valuing water; water development; water management paradigms

INTRODUCTION

The purpose of this paper is to provide what social scientists and historians call a narrative. Narratives are useful means of accessing changing perspectives on, for example, how natural resource using and policy-making communities have created the environments in which they now operate. In the case of this analysis the approach will be helpful in identifying the different perspectives which currently dominate the policy discourses in the North and in the South.

It will be shown that in the early 19th century water users, the hydraulic engineers who solved many of their problems, and the policy-makers engaged in the allocative politics of managing water resources, achieved a consensus on how water resources should be managed. By the mid-19th century, engineering "solutions", diverting and storing water to overcome seasonal variability, were successful. Engineers, water system professionals and water scientists were progressively more reinforced in their certainty that they were solving some of the most basic problems of society. This phase has come to be known as the period of the "hydraulic mission" and in the North it lasted until the late 1970s (Swyngedouw, 1999). The approach has been associated with the notion of industrial modernity. Industrial modernity was enabled by the coming together of Enlightenment Science, the development of engineering and industrial competence, the acceleration of capitalist manufacturing and markets, and a phase of imperial related global capitalism in the first half of the 19th century.

As in many other sectors, industrial modernity transformed the way resource management was approached. The allocation and management of water was profoundly impacted by these developments and by the policy options, which the new economic contexts made possible. Both the small volumes of water associated with domestic and industrial activities as well as the huge volumes associated with irrigated agriculture were combined in this period with unprecedented levels of manufactured and financial capital. One of the consequences was the progressive increase in the level that water was taken from the environment to increase the production of food.

The late 1970s will be shown to have marked the end of industrial modernity in the North. The green movement was particularly successful in the North. Those making water policy in such political-economies located in semiarid regions, for example California, Arizona, Australia and Israel, became aware of the impact of taking water out of the environment. Certainty in the hydraulic mission faltered and was replaced by the uncertainty and risk awareness (Beck, 1996, 1999) which characterizes "late modernity" (Allan, 2001). Governments introduced polices and regulations, which began to put water back into the environment to ensure that the environmental services provided by water were rehabilitated and protected.

The trajectories of water use in these northern semiarid economies has not been repeated in the South. It is important to note that the population of northern economies comprises only about one billion of the world's 6.5 billion people. Economies in the South, such as those of India, China and the Middle East and North African region—comprising over half of the population of the South—have a high proportion of the semiarid tracts of the world. Their governments have not been moved by the advocacy of the green movement on the subject of allocating water back to the environment.

There will be a brief discussion of the most recent developments in the global discourse on major hydraulic works. The World Bank (2003) has indicated its willingness to consider the financing of major hydraulic works after over a decade of not funding such projects. Many southern governments have indicated their readiness to commit to such projects.

WATER POLICIES IN THE NEO-LIBERAL NORTH AND IN THE SOUTH IN INDUSTRIAL MODERNITY AND LATE MODERNITY: CHANGING RISK PERCEPTION

Risk is socially constructed. Societies recognize or ignore risk according to their historical experience. Those who consume water and those who are responsible for water policy-making in a political economy tend to operate according to past experience. Past experience will shape decisions rather than the newly identified risks shown by scientists to be impacting water resources. In the Middle East and North Africa, for example, water policy-makers are more likely to enter coalitions with major traditional users of water in irrigated agriculture than reduce the risk of such policies by introducing measures to manage water demand. (Allan, 2001) This last could be achieved by allocating the water resource, sustainably, according to economic and environmental criteria. But it is rarely thus.

Awareness of risk in the water sector has been shown to be related to whether a political economy is involved in what is called its "hydraulic mission" (Carter, 1982;

Reisner, 1984; Swyngedouw, 1999; Allan, 2001). During 1920–1970, the northern economies managing scarce water in semiarid regions—for example the western states of the USA, Australia and Spain—were committed to taking water from the environment to raise irrigated crops. By the late 1970s the green social movement prevailed by showing that structures to generate power and irrigate land were both environmentally and economically damaging (Reisner, 1984). The building of dams and flood control structures ended in the early 1980s in the North. Water began to be put back into the environment. The process was contentious and there were serious political casualties. President Jimmy Carter was elected in 1976, just as the water discourse was in transition from the "certainties" of the hydraulic mission agenda of industrial modernity to the "uncertainty" and risk aware perspectives of late modernity. Late modernity in the water sector was influenced first by environmentalism, second by the quest for economic efficiency, and third by the recognition that participative policy making was a sound basis for policy-making in the water sector. President Carter's diaries reveal that he was unable to prevail on the old coalitions, despite the wisdom of his economic and environmental analysis:

> "Had a rough meeting with about 35 members of the Congress on water projects. They are raising Cain because we took those items out of their 1978 budget, but I am determined to push this item as much as possible. A lot of these projects would be ill-advised if they didn't cost anything, but the total estimated cost of them at this point is more than $5 billion, and my guess is that the final cost would be more than twice this amount." J. C. Diary, 770310, in Carter 1982, p. 78.

> "I had several serious disagreements with Congress, but the issue of water projects was the one that caused the deepest breach between me and the Democratic leadership. As a governor and during my campaign, I had repeatedly emphasized the need to eliminate waste and pork-barrel projects in the federal government. Some people had heard and understood what I was saying. The members of Congress had not. They were amazed when I moved to cut out the worst examples of this abuse—unnecessary dams and water projects that would cost billions of dollars and often do more harm than good. The problem was that scores of these plans were in progress, from the original conception to the final construction stage. Some of the more senior members had been waiting many years for their particular proposals to get to the top of the list. The projects represented major political plums for each district, tangible symbols of the representative's influence in Washington. For 10 or 15 years, in every congressional campaign, the promise of a new lake or canal was put forward to create temporary construction jobs, satisfy local pride, and win votes.
>
> I understood the importance of these long awaited projects to the legislators, but during the years since their initial conception, circumstances had changed, environmental considerations had increased in importance, costs and interest charges had skyrocketed, other priorities had become much more urgent, and any original justification for some of the construction had been lost forever. Still the inexorable forces toward legislative approval moved on. Other recent Presidents, graduates of the congressional system, had looked on the procedure as inviolate. I did not, and drove head first to reform it." Carter Diary, 770310, in Carter, 1982, p. 78–80.

Uncertainty and risk in water policy reform

In an analysis of risk and the water sector it is important to draw attention to a number of features of the transition from industrial modernity to late modernity. First, during industrial modernity the management of environmental resources such as water were underpinned by "certainty". The problem solving record of the engineer supported by the progressively more effective understanding of science led those combining environmental, human, manufactured and financial capital to assume that safe and effective outcomes were certain. The questioning of such certainties was central to the shift to a risk aware late modernity. Uncertainty and awareness of a wide range of newly defined risks characterized late modernity. Beck (1999) captured the risk dimensions of the 1980s and 1990s in the neo-liberal North in the following paragraphs:

> "The discourse of risk begins where the unbroken trust in safety ("progress") ends and applies so long as the catastrophe has not (yet) occurred. *The perception of threatening risks determines thought and action.*
>
> "This peculiar reality status of "no-longer-and-not-yet"—"no longer trust/security, not yet destruction/disaster"—is what *the concept of risk expresses and makes a public frame of reference. The sociology of risk is a science of possibilities.*
>
> "The sociology of risk reconstructs a tech-social event in potentiality, but in a very concrete sense. Where risks are believed as real, the foundations of business, politics, science and everyday life come into flux. The concept of risk, considered scientifically (risk = accident × probability), accordingly works itself out in the form of the calculus of probability, which we know can never rule out the worst case. This becomes significant in view of *the socially very relevant distinction between risk deciders and those who must clean up the decisions of others.*"
> (Beck, 1999 p. 75).

In this analysis it will be shown that the northern economies have, since the late 1970s, been deeply involved in their risk society approach to the management of such resources as water. Those allocating and managing the water resources of political economies in the South have been made aware of the shift in approach in the North. (World Commission on Dams, 2000). However, The northern approach is resisted as inappropriate, first for political reasons, and second on points of principle. First, the environmentally inspired, risk aware, approach of the North is associated with intolerable political costs, which the politicians in developing and especially weak economies are not prepared to pay. The political leaderships of most countries in regions such as the Middle East and North Africa (MENA) expect to be around for more than four- or eight-year terms. Second, and more importantly, the water managing establishments of the MENA region, along with those of South Asia and East Asia, do not see it to be necessary to deny themselves the economic dividends of development. They want to develop their water resources at least as intensively as did the United States and other northern economies in achieving their prosperity. Northern environmental, risk aware, wisdom would be more persuasive if the northern economies had demonstrated restraint in the development of their own water resources.

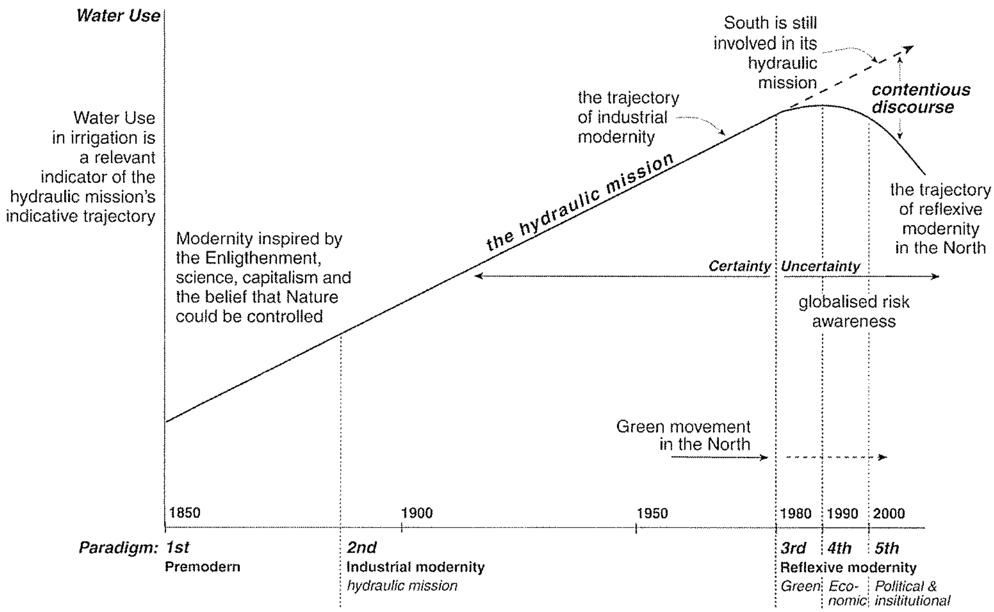

Fig. 1 The five water management paradigms of modernity and late modernity.

THE FIVE WATER MANAGEMENT PARADIGM

Water management in the North can be conceptualized as having five phases, each dominated by a different approach or paradigm. Figure 1 shows the five phases. First the pre-modern phase. Second the phase of industrial modernity, which was launched at various points in the 19th century according to the moment when a political economy began to be affected by the science, engineering and capitalist production processes and the markets stimulated by the Enlightenment. In the water sector a particularly vigorous phase of industrial modernity was launched by the state in the United States, Spain and South Africa in the early 1930s. The hydraulic mission approach was also adopted by the Soviet state in the late 1920s and it continued until terminated by Secretary Gorbachev in the testing political and economic circumstances of the late 1980s.

The end of the hydraulic mission of industrial modernity marked for the water sector the end of modernity and the transition to late modernity. Late modernity has been identified as a period of reflexiveness (Beck 1992, 1995, 1996, 1999; Beck *et al.*, 1996). Reflexiveness is a term, which captures the discursive political processes via which the preferences of a wide range of interested parties can influence outcomes. Outcomes can also be determined by a narrow group of technically experienced officials. This last approach was possible during industrial modernity, because of the certainties engendered by the early successes of hydraulic engineers.

By the end of the 1970s allocative water policy outcomes began to be influenced by the activism of green social movements that gave a voice to the role of water in the environment. This advocated that consideration must be given to the environmental services provided by water resources. The contribution of freshwater to the economy, in for example, irrigated agriculture was important but not the only priority issue.

Reflexiveness to the advocacy of the green agenda was the first water management paradigm of late modernity.

A second reflexiveness of late modernity gained currency in the North in the 1990s. This was the economic paradigm driven by the idea that water can, and some advocated strongly that water should, be counted as an economic resource. Water could and should be valued, be made subject to economic instruments such as pricing and be subject to markets and privatization with willing buyers and willing sellers. The approach was contested but made substantial currency in the North during the 1990s.

A third reflexiveness was the gradual recognition that water policy reforms would be safer and more durable if they were achieved through participative and inclusive political processes. The inclusive paradigm became evident in the late 1990s and is exemplified by the consultative process of the World Commission on Dams (WCD), which extended from 1998 to 2000. (World Commission on Dams, 2000). The WCD report advocated core values and standards, a range of design and operating criteria for dams, and the adoption of a sustainable balance of developmental and environmental principles.

These principles were adopted without much contention in the North, although the Northern dam-building interests in both the public and private sectors were disappointed. In the South the big dam building authorities in the public sectors of China and India either loudly contested the WCD report in India (Iyer, 2003) or ignored it in China. In the Middle East, Turkey, Iran and Egypt were not moved by the recommendations of the WCD report.

THE SOUTH OPTS NOT TO BE REFLEXIVE

The water policy reforms associated with late modernity in the North are reflected in the levels of use of water for irrigation. Figure 1 uses this trajectory of freshwater use to illustrate how the five paradigms have influenced water management of the one billion or so people living in the North. The diagram also illustrates how the governments overseeing the affairs of the over five billion who live in the South have opted to delay the adoption of reflexive principles, based on a precautionary approach to the environment and on the economically efficient use of water resources.

There is a significant discursive distance between the ideas in currency in the Northern neo-liberal economies and those of the South (see the top right hand corner of figure). Peoples and governments in the South are preoccupied with the challenges of meeting the needs of rising populations and improving their standards of living. They wish to follow the same upward trajectory of water utilization experienced by the Northern semiarid and arid region economies. That this approach was inconsiderate of environmental and economic principles in achieving diverse and strong economies and high living standards can for the moment be borne.

SUSTAINABILITY: A FUNDAMENTAL BUT MUCH MISUNDERSTOOD CONCEPT

Awareness of risk in the water sector is also determined by discursive hydropolitics. These same hydropolitics determine how sustainability is defined in a political economy. Sustainability has three dimensions—social, economic and environmental. Different economies arrive at a politically acceptable definition of sustainability according to the strengths of the voices contributing to the discourse. By definition, therefore, sustainability is not a condition that is constant or defined by narrow conservation or any other criteria. Sustainability will differ from one political economy to another. It will vary in the same political economy through time.

The strengths of the social, economic and environmental voices vary, first on the water resource endowment (freshwater and soil water). Second, on the extent to which a mass of basic rural livelihoods are dependent on crop and livestock production. Third, on the level of diversity and strength of the economy. And fourth, on the effectiveness of the advocacy of the green social movement in the respective political economy.

In the discursive hydropolitics generated by the contending social, economic and environmental players, the position of constructed knowledge, which can be the basis of allocative water policy is evolved. This discursive knowledge, or discursive power, reflects a form of equilibrium in the political system. Discursive power appears to be less influential than coercive power. Most political systems in the MENA region seem to be characterized by features associated with coercive power. But in the water sector most policies are determined by awareness of the political risks of affecting the livelihoods of rural communities by reducing their access to water for irrigated farming when there are no alternative livelihood options.

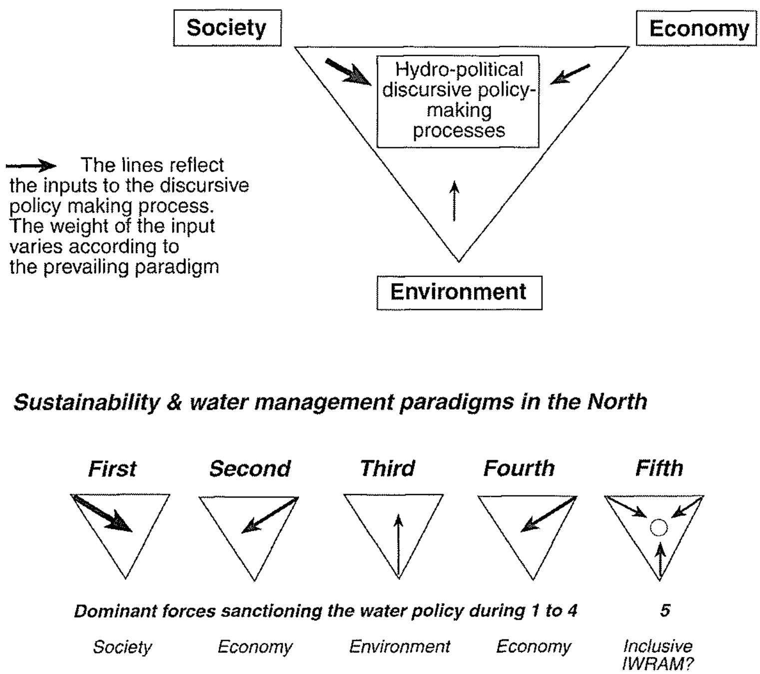

Fig. 2 The concept of sustainability and the water sector; water management as a political process and determining perceptions of the diverse values of water in the North. The third, fourth and fifth paradigms have only been very partially adopted in the South.

The five water management paradigms can be usefully mapped on to the sustainability triangle. The lower part of Figure 2 illustrates how the inspiration underpinning the meaning of sustainability has shifted in the past two centuries. Initially sustainability is a social priority achieved by using substantial volumes of water in the dominant—over 90%—livelihood, crop production. Sustainability is determined by society. Next, sustainability was determined by investment in civil works to store and transport water for irrigation. Often such activity was associated with the generation of hydro-power. Most of such activity was state sponsored whether it took place in capitalist economies, for example those of the United States, Australia, Spain or South Africa starting in the 1920s/1930s, or in South Asia, East Asia, South-East Asia or South America in the period after 1950.

With the onset of late-modernity in the Northern economies, the third voice came via the very effective advocacy of the green civil movement. The environment was given a voice at least in the North. The fourth water management paradigm, which dominated the 1990s, namely awareness of the value of water, the possibility of pricing it and distributing it through market systems, moved back to principles of economic sustainability.

The fifth water management paradigm, inspired by inclusive and participatory approaches to water allocation and use, is located in the discursive hydropolitics at the core of the sustainability triangle. It could be argued that this locus is where the approach to management should always have been mediated. That the approach has ended in discursive politics rather than having started there is explained by the relationship between the status of the water resources and the demands placed upon them. As the demands on the water resources have progressively increased in response to demographic change and socio-economic development it has become necessary to adopt different policy solutions prioritizing economic sustainability and environmental sustainability in the end via political mediation.

This political mediation can be the very effective in risk reduction. There is much evidence in the water sector, however, especially in the MENA region, that the political process is subject to constructed risk. Such constructed risk is the outcome of constantly shifting coalitions of water professionals, policy-makers and advocates of environmental protection. Their effectiveness varies with the changing political contexts—such as war, peace, or insecure economics—as well as the occurrence of windows of opportunity occasioned by emblematic environmental events—such as droughts and floods, and political events—the need to negotiate an international water agreement (Kingdon, 1984; Hajer, 1996; Allan, 2001).

SCIENCE, RISK AND WAYS OF LIFE

The evolution of the approaches to water management captured by the five water management paradigms can also be shown to relate to some fundamental features of society and politics. A very useful means of identifying those participating in contentious hydropolitics is provided by cultural theory, sometimes referred to as the grid/group theory or ways of life theory (Douglas & Wildavsky, 1982, Thompson *et al.*, 1990). Advocates of cultural theory show that those involved in the socio-activities activities of getting things done can be identified by their tendencies to fatalism, hierarchy, ethics and entrepreneurship. These identities can be observed at the level of the individual as well as at higher levels of social organization.

Figure 3 shows the basic features of cultural theory. The horizontal axis on the diagram is defined by the tendency to prefer the absence of control on the left and the preference for control on the right. The vertical axis has conformism at the top and the tendency to non-conformism at the bottom.

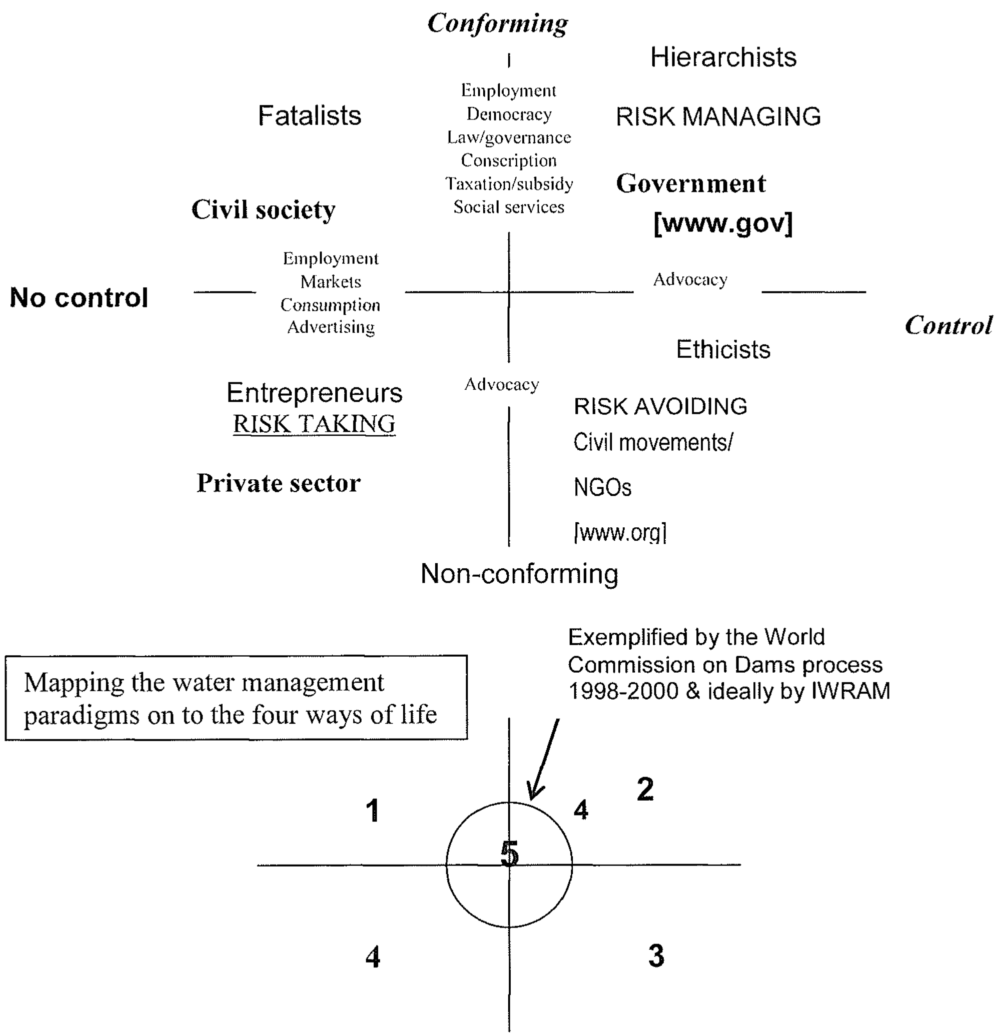

Fig. 3 The four ways of life of the Mary Douglas cultural theory (Douglas, 1970; Thompson *et al.*, 1990). And showing in the upper diagram how (1) some of the socio-economic processes through which the ways of life interact; and (2) the uncanny prediction of the internet server structure. And (3), in the lower diagram, how the sequence of water management paradigms (from Fig. 1) can be mapped on to the ways of life categories.

The four ways of life can be identified at high levels of social organization (sometimes referred to as social solidarities) by the categories—civil society, government (the state), social movements such as NGOs and by the private sector. (Dixit *et al.*, 2003). The theory relates to neo-liberal democracies in the North. The theory cannot be exported to explain the political economies that exist in the South, although some progress is being made in East Asia to show that the theory has an explanatory role there (Lee, 2003).

Figure 3 shows how the different ways of life transact their affairs. Laws, taxes, regulations, employment, pensions, subsidies, public services, conscription are at the interface of civil society and government. Markets, advertising, employment and pensions enable civil society to transact with the private sector. Civil movements and NGOs do not deploy these kinds of relationship and transactions. But it has already been shown that the green movement has been very effective through "advocacy" in influencing environmental and water policy of governments and in shifting the practices of the private sector in the way their enterprises manage water.

Some might feel that cultural theory is vague and unlikely to reflect how different groups in society actually interact. They should note, however, that the theory was being developed and published in the late 1970s and early 1980s, long before the mass utilization of the Internet. When by the 1990s the Internet servers were grouped for ease of organization and use, the main categories had been given the identities—.gov, .org, and .com—reflecting government, civil movements and the private sector.

The relevance of the ways of life theory to water science and water policy making is that the approaches to risk of those involved in water allocation, management and policy-making differ according to the way of life of the player. The two categories that get things done in a neo-liberal democratic society and bring about change are "government" and "the private sector". The other important player that can also influence policy and practice is found in the ethically driven civil movements.

The perception of risk and the science brought to bear by these three ways of life differ. Government tends to be risk managing and to deploy risk managing science. The private sector tends to be risk taking and this tendency is evident in the science it deploys. Civil movements tend to be risk avoiding and deploy risk avoiding assumptions in their science (Thompson *et al.*, 1990; Moench *et al.*, 2003) .

The message of this part of the analysis is that it is unsafe to base policy on the science of just one of the ways of life. The risk assumptions underpinning the science will tend to be biased because the sponsorship of the science or its inspiration can be managing risk, or risk taking or risk avoiding. Gyawali (Moench, 2003) argues powerfully on the basis of diverse experience of the ways of life. He was first in government as a water engineer. He was a successful activist over-turning dam building policies in Nepal, by confronting when necessary the private sector, Indian interests and the international donors.

Gyawali found that the science used by the private sector and donor engineers and economists could be used to undermine their own arguments and especially their assumptions. His phase of life as an environmental activist was followed by a year as minister of water in Nepal. On the basis of his experience as a practitioner in two of the ways of life (social solidarities)—as government official and environmental activist—along with close engagement with the private sector private, he is sure that it is only when all three types of science are making a contribution to the development of water policy can the risks associated with such policy making be safely mediated.

RISK AWARENESS AND MANUFACTURED RISK

> "One of the problems for the professionals involved in allocating and managing water is that the solutions to water scarcity in dry regions ultimately lie outside the water sector."

It is being argued in this study that water policy-making, like all policy-making, is subject to contentious discursive politics. At the same time these politics evolve in an over-arching political context determined by events outside the water sector of a particular economy and also beyond the political economy of water more generally. Regional climate events and regional hostilities as well as global economic shocks impact the policy options of a policy-making community.

In addition to these dynamic circumstances there is much evidence that the risks and awareness of them, which determines policy can be constructed. Mary Douglas (Douglas *et al.*, 1982) showed that communities select the risks of which they are aware. They readily de-emphasize many risks that scientists and economists can measure and predict. If this seems a wild comment think of how individuals take up risky habits such as smoking, over-eating and incurring debt. Allan (2001) has argued that water using communities are just as prone to denial as the credit card debtor:

> "Wise politicians know that they
> Must resist the simple (scientific) truths
> And subscribing to pervasive water lies
> Remain in power along with [Their] essential truths."
> Allan, 2003, after Goleman, 1997

One of the problems for the professionals involved in allocating and managing water is that the solutions to water scarcity in dry regions ultimately lie outside the water sector. In the MENA region, for example, which has for over 30 years left behind the era of supply management, will mainly address its water deficit, as defined by food self-sufficiency, by continuing to make good its deficit via the virtual water solution. Virtual water is for the purposes of this discussion, the water embedded in grain imports. It requires 1000 tonnes (m^3) of water to raise a tonne of grain. Water scarce regions in the second half of the 20th century avoided the economic and political stress of mobilizing an increasing proportion of their water needs—over 20% by 2000—by importing highly subsidized grain from the USA, the EU and Australia. By the middle of the 21st century the proportion imported could be 50% (Allan, 2002, 2003).

Virtual water is economically and politically remarkable for a number of reasons. First, virtual water is exceptionally large in volume at the global level. Over 20% of the water that is used to raise crops in the world enters crops that cross international frontiers in trade (Hoekstra, 2002). Second, this huge volume of virtual water is immensely flexible in terms of the destinations to which it can be conveyed. It can be used to address a short-term food emergency in Africa; a politically induced shortage in the former Soviet Union, or an increasing but variable requirement of a major economy such as China, or a region such as the Middle East and North Africa. No engineering intervention in managing surface water or groundwater has the global reach of virtual water in international trade. Hydraulic works affect areas of ten of square kilometres and occasionally thousands of square kilometres. They never directly impact users on different continents or consumers at the opposite side of the globe.

The third important characteristic of virtual water is its economic invisibility and its political silence. These qualities have remarkable impacts on the awareness of scarcity and the rational associated risks. Those making water policy can choose to make prominent this miraculous solution provided by global hydrology, mediated by trade in water intensive commodities. Or, they can opt for a stress free political existence by enjoying the invisibility and the silence. It is normal for politicians to address only the problems that are in their face. Problems that are not prominent in the current discourse can be ignored. In the case of virtual water the solution is politically invisible, yet so complete, that it enables any preferred discourse to be kept in place. This sanctioned discourse (Tripp, 1996, personal communication) in the case of water policy in the MENA region is, "all we need is a little more water, then we shall manage it more carefully and everything will be all right" (Allan, 2001).

The consequence for those advocating the underlying principles of consideration for the environmental services provided by freshwater resources, the third water management paradigm, and economic efficiency—the fourth water management paradigm, is that their arguments have little impact. In other words, the risks of impairing the environmental services of freshwater in the environment and of not achieving high levels of water use efficiency are not evident because water has been accessed outside the local watersheds. Local watersheds do not determine the volumes of water to which a political economy has access. There are solutions outside the watershed in the "problemshed".

Another very important solution that lies outside the water sector, and which also very significantly reduces the risk of water scarcity, is the diversification of an economy. More jobs per drop is a very much more important water managing principle than more crop per drop. Achieving more crop per drop can double the productivity of water in agriculture where 70–90% of the water used in a food self-sufficient economy will be deployed. Using water in industrial and service sectors can achieve 1000 times higher return to a cubic metre of water than water devoted to agriculture. Diversification of an economy is associated with an invisible and silent re-allocation of water. The equivalent re-allocation achieved by policy change in the water sector would be highly politically risky, costly and fiercely resisted.

The major message here is that water policy makers are fortunate that water scarcity in the face of increasing water demands can be, and has been, ameliorated by risk reducing processes that are economically and politically invisible. Water policy makers should recognize that the major solutions to the problems of water supply in future will be found outside the water sector.

MANAGING RISK AWARENESS IN THE MENA REGION: FOREGROUNDING AND BACK-GROUNDING RISK

Those who want to take risk into account in their analysis of water allocation and management and in the development of water policy have to recognize that risk is socially constructed (Wynne, 1989). The sociologists who have usefully identified risk as an integral element in the societies of late modernity in the North (Giddens, 1990; Beck, 1995, 1999; Beck *et al.*, 1996) have established that northern societies are much more comprehensively risk aware than in the past. The risks are also much more comprehensively in currency than at any time in the past amongst the 1.5 billion or so that live in northern, neo-liberal, political economies.

In the South the risks to the environmental services provided by water resources are much less constructed. The risks to poor communities of reducing the water available for rural livelihoods is long-standing and in much sharper focus. The need to put water back into the environment is not on the agenda. The urgency of demand management approaches to water allocation and use are not much in evidence. The role of virtual water in enabling such policies has been demonstrated above.

The theory of Mary Douglas that risk can be foregrounded and backgrounded is very relevant to the MENA region. A regional case study which exemplifies such foregrounding and back-grounding is the water policy of Israel between 1950 and 2000. From 1950 to the mid-1980s, Israeli water policy, both internally and externally, was driven first by the hydraulic mission and second by the water management paradigm principles. The aim was to mobilize more and more freshwater and increase crop production. The risks being addressed were strategic water security and food security. By the mid-1980s a number of circumstances brought about a change in emphasis. Israel experienced the advocacy of a serious environmental movement, which promoted a coalition of interests in government, NGOs and society that led to the introduction of a policy to reduce water allocated to agriculture. The purpose was partly to induce increases in productivity in irrigated farming, the achievement of cost recovery for water in agriculture and the security of the services provided by water in the environment. The years of drought immediately before 1986 provided an emblematic event that focused the discourses in science, the media and amongst the policy-makers and the public in general. This development was a third water management paradigm shift. It was assisted by the requirement of the United States that Israel reform its economy and introduce economic reforms.

The trajectory of water use in Israel indicates the reflexive response in Israel's water policy. Water use drifted upwards in the late 1980s but was sharply reduced again after a severe drought in 1990–1992. In late 1992 water policy-makers were speaking about sustaining the reduction of water in agriculture by 30% and in due course achieving a reduction of 60%. This reflected a deep commitment to the third and fourth water management paradigms based on environmental consideration and economic efficiency, respectively.

However, this commitment proved to be very reversible. The drought ended with a period of high rainfall in December 1992. All the decline since the 1997 occupation brought about by the increase in withdrawal from the Western Aquifer (of the West Bank Aquifers) was restored in the space of three weeks as a consequence of the intense rainfall and the associated reduction in pumping. Simultaneously the negotiations associated with the Middle East peace process were initiated between Jordan and Israel. Those between Palestine and Israel also became probable.

In this new international hydropolitical context the risk regime was transformed. Environmental and economic risks were immediately backgrounded. The negotiation risk was foregrounded and has remained the major risk in the Israeli water managing context. Water use in agriculture rose after 1992 and has remained at the pre-1986 levels or above ever since, until the reductions in pumping in response to drought in 2002–2003. This narrative of the shifts in Israeli water policy are of importance as they reveal the complexity of water policy making and how such policy processes are subject to the perceptions of, and the prioritization of risk.

CONCLUSION

> "This means among other things that risk statements are by nature statements that can be deciphered only in an interdisciplinary (competitive) relationship, *because they assume in equal measure insight into technical know-how and familiarity with cultural perceptions and norms.*" (Beck, 1999)

Water policy is a political process in which risk awareness can play a significant explanatory role. Water policy is subject to different pressures and ideas in the North and in the South. The progressive adoption of different water management paradigms in the North cannot be taken as an agenda for water policy reform in the South. Northern governments in semiarid regions have begun to put back into the environment some of the water formerly used to raise agricultural commodities in order to foster the delivery of water's environmental services. Southern water managers and governments are resistant to this approach until much more economic development has been achieved.

There is a very intense, contentious and predictable discourse between northern professionals advocating the adoption of the third, fourth and fifth water management paradigms in the South, and in the MENA region in particular. The risks associated with not adopting them have been widely articulated. To date they have only been adopted by Israel and then very thoroughly rejected in a political emergency, at least in the short term. Other political economies have begun to adopt the new paradigms at least partially—for example Jordan, Cyprus, Tunisia and Morocco. The political coalitions in the other MENA economies remain unconvinced of the urgency of shifting their perception of risk from that of the insecurity of their freshwater resources. As a result they continue to assume, misguidedly according to northern outsider economists, that security, that is risk avoidance, will result from the maximum utilization of freshwater in irrigated farming. Invisible and silent remedies such as virtual water and the re-allocation of water between sectors, as a consequence of socio-economic development, are not yet widely recognized in water scarce semiarid regions in the South as very effective risk reducing processes. Meanwhile the discourse on large dams and major inter-basin water transfers is gaining a new life in 2003 in the South, with the approval of the World Bank water professionals. It remains to be seen whether this new phase in water allocation and management discourse will be within a World Commission on Dams (2000) framework, or through a radical re-imposition of hydraulic mission policies blind to the environmental services of water.

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The Basis of Civilization – Water Science? (Proceedings of the UNESCO/IAHS/IWHA symposium held in Rome, December 2003). IAHS Publ. 286, 2004

Integrated water resources management for the Yellow River in China: a discussion of scientific and ethical approaches

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Abstract The Yellow River basin (YRB), the cradle of Chinese civilization, has so frequently been subjected to disastrous floods that the basin is entitled "China's Sorrow". Managing these floods was historically dominated by ethical approaches. These are now complemented, and sometimes replaced, by scientific approaches. This has prevented major flooding over the last 50 years, but the present situation is far from sustainable. In addition, drought and environmental issues have become prominent and urgent. The introduction of integrated water resources management (IWRM) is very promising, but this approach remains a scientific and technical-based approach, even if it is public participation-based and explicitly takes care of ecosystems. What seems to be lacking in the YRB is a strong ethical basis, sufficiently rooted in the society of the basin. The indigenous ethical approaches used for flood management can provide that basis, in particular Taoism. This should be re-enforced to give greater emphasis to nature in the basin and to harmonize human beings with nature.

Key words Chinese indigenous philosophy; ethical approach; flood control; integrated water resources management; scientific approach; Yellow River asin, China

FLOOD CONTROL IN THE YELLOW RIVER BASIN

The Yellow River (YR) is the second largest river in China (Fig. 1). It originates in the Yuguzonglie basin in the Tibet Plateau in the west of China and discharges into the Bohai Sea in the east. It is 5464 km in length, has an altitude difference of 4480 m and drains an area of 795 000 km^2 (8.28% of China). The frequent occurrence of extensive floods is related to its geography (stretches with low gradients, in particular in the east) and to the uneven temporal and spatial distribution of precipitation. Records since the third millennium BC show that the YR has overflowed its dikes 1590 times and changed its course 26 times. Nine of those course changes were major. The range of the course deviation covers an area of 250 000 km^2. In many floods, thousands of people were killed. The cycle of flooding and related deaths earned the YR its dubious title "China's Sorrow".

The crux of the flooding problem in the YR is its sediment load. The middle reaches flow through the Loess plateau, where annually an average 1.6 billion tons of sediment is picked up and transported to the lower reaches. One quarter of this

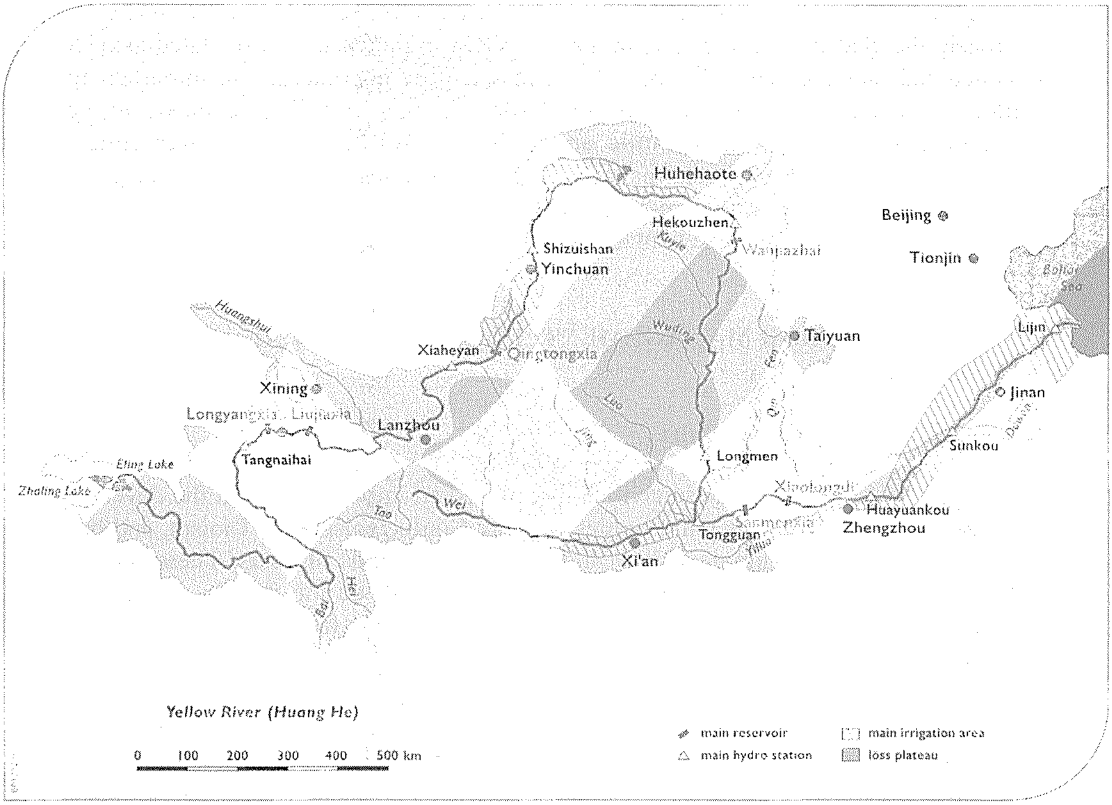

Fig. 1 The Yellow River basin in China.

sediment load is deposited in the channel. With this long term heavy deposition of sediment, the downstream river bed has gradually risen between the embankments. At present, the river bed is 3–5 m higher than the land level behind the embankments, in some sections even 10 m higher. Therefore, the lower reach of the YR is known as a "suspended" river. Consequently flood control in the YR has been the key water management issue for centuries.

Historically, when science and technology did not advance, the flood management of the YR was mainly based on ethical approaches. The two dominant ethical approaches, which were followed alternately, originated from the Confucianism and Taoism philosophies. Since 1949, by application of more advanced scientific approaches and major infrastructure investments, flooding has been successfully controlled and no major flooding has occurred since then. However, the threat of flooding remains, in particular because of the continuous rise of the downstream riverbed. At the same time the YR basin (YRB) has experienced severe water shortages as well as environmental deterioration.

To seek a sustainable solution to flooding and the other water crises in the YRB, a review of the historical and modern flood management is conducted in this paper. Attention is given to both ethical approaches and to scientific approaches. For the ethical approaches, the relationship between water management and the (indigenous/nonindigenous) philosophical basis is analysed. Generally regarded as a scientific approach, the challenging implementation of IWRM in the basin is articulated next. It is concluded that both ethical approaches and scientific approaches are important to achieve sustainable development of the YRB. To this end IWRM needs to be understood as more than a scientific approach and IWRM needs to cover ethical approaches as well. It is debated that for the YR the Chinese indigenous philosophies as ethical approaches should be re-enforced, giving greater emphasis to nature in water management, and to harmonize humans with this nature.

HISTORICAL FLOOD MANAGEMENT: FOCUS ON ETHICAL APPROACHES

Chinese indigenous philosophies

The YRB, the Cradle of Chinese civilization, played an important role in the development of Chinese indigenous philosophies, namely Confucianism and Taoism, and has deeply influenced the Chinese way of thinking for thousands of years. These philosophies also influenced the way the people of the YR tackled the flooding problems. Confucius (551–479 BC) believed that adaptation of nature to human needs could take place by following nature's rules. Humans could cause serious disruption due to ignorance, but could also restore harmony by wisdom and learning. For these reasons, Confucius advocated education, self-discipline, and investigation of natural phenomena and, at the social level, a harmonious social order. Unlike Confucianism, Taoism was a philosophy of non-interference (the founder of Taoism is believed to be Lao-Tse, a contemporary of Confucius). Taoism held the belief that all matters took nature as their law. Tao is characterized by Wu-Wei (literally "no action") and called for spontaneity and for no unnatural action or interference with a given situation, in order to allow matters to take their own course. While Confucius emphasized social order and an active life, Taoists took the view that social conventions were not natural and were destructive to humans. They believed that not to act or interfere with the course of nature was the best way to act and rule. In the following sections an analysis is made of how these two philosophies influenced flood control in the YRB.

Historical water management in the Yellow River

According to Chinese legend Yu The Great, the first "manager" of Chinese waters, (21st century BC) built the first dikes along the lower reaches of the YR. For his achievements he was appointed Emperor. Those dikes were built after the failures of his ancestors, who built barriers to block or store the water in large holding areas for long periods of time. Yu The Great's innovation was to direct flow to the sea by dikes. The first actual recorded construction of levees started in the Warring State periods (770–221 BC) when the YR was not yet "suspended".

The construction of dikes reduced the flood frequency at first, but increased the flood risk (risk = frequency × damage) due to dike failures. During the Han Dynasty (206 BC–AD 220) disasters by flood breaches and the resulting shifting of the course of the river were more overwhelming than ever before, along with more sediment deposition in the lower reaches. Erosion increased in the basin by more intensive human activities in the Loess Plateau and the lower reaches gradually became a suspended river. Because the heavy silt load of the river restricted the effectiveness of flood control, constant efforts were needed to try to maintain sediment equilibrium in the river. To tackle the flooding in the YR, the prominent water manager Jia Rang stated around 7 BC his "three measures on river treatment (flood management)". The first measure, the best option according to Jia Rang, was to return the river to an abandoned course. However, this idea proved to be impossible at that time with the limited technological capacity, as the abandoned channel was seriously silted. The second measure was to dissipate the power of the river by draining off water for irrigation in the lower reaches and diverting relatively silt-free streams into the YR to increase the silt-carrying capacity. The last measure was to strengthen the dikes to encapsulate the river. This measure was his last choice. He believed that the endless need to increase dike levels was a waste of time, labour and sources of material.

After Jia Rang, Wang Jing proposed and carried out river channel stabilization around AD 69, so effectively that no major dike breach occurred during the next 1000 years. His methods included dredging, strengthening the levees at dangerous points, digging new channels for tributaries in rough terrain, and building numerous sluice gates. In the 16th century, Pan Jixun (AD 1521–1595) was remarkable in the Ming Dynasty (AD 1368–1644). He advocated building strong dikes to closely contain the river so that it would scour its own narrow channel. This was the first forceful statement against the ancient principle of dividing the flow to dissipate the river's power. This strategy to stabilize the river in this way was also followed by Jin Fu (1633–1692) in the early Qing Dynasty (AD 1644–1922).

Although the Chinese recognized for centuries that sediment was the main cause of the floods in the lower YR, Li Yizhi (1882–1938) was the first one to argue in the early 1920s that it was necessary to focus attention on the upstream part of the basin and to attack the silt problem at its source. He believed that the most important long-range method of control was to reduce the silt content in the river through conservation measures in the Loess Plateau. Since such measures would require decades to become effective, Li also proposed that detention reservoirs be built upstream to control the maximum flood discharge.

Ethical approaches: control by "controlling" or "not controlling"

The former section explains that the two main strategies alternatively dominated in the long history of flood management in the YR. The first strategy is to confine the YR in a narrow channel by high levees (1–3 km apart). The advantage of this strategy is that the narrow channel has a high sediment transport capacity and a slow silting rate of the riverbed. It might even cause lowering of the riverbed. However, it has limited capacity to absorb major flood crests and induces rapid erosion of the dikes. The alternative strategy is to confine the river in a broad channel between widely-spaced lower levees (5–6 km apart). Between these dikes many small diversion dams (groins) can be built to keep the river in the centre of the channel. The advantage of this strategy is that wide levees enable the discharge of extreme flood flows. A disadvantage is the rapid rise of the bed level due to increased sediment deposition, especially when the river is not forced into a small bed during low flows. Furthermore, peasants moving in the riverbed to cultivate the rich silted lands between the widely spaced levees are in constant jeopardy from high flood waters.

These two strategies represent more than two different technical approaches for controlling the river. Their roots lie in different philosophical outlooks. Construction of narrowly-spaced strong dikes is associated with Confucianist tendency to curb nature, or "control by controlling". Construction of widely spaced low levees is associated with the Taoist approach of letting nature follow its own course, or "control by not controlling". In Chinese thought, Taoism has long complemented the dominating Confucianism by promoting greater understanding of the harmonious natural world and downplaying the importance of invasive human interventions.

The people who lived with floods before and during the time of Jia Rang (221 BC) represent the "Taoist" school, while Wang Jing (first century AD) and Pan Jixun (15th century) were famous representatives of the 'Confucianist' approach. Li Yizhi (at the beginning of the 20th century) returned to the "Taoist" approach. Jia Rang advocated leaving room for floods and using alternative flood control measures, such as population resettlement out of the silted abandoned course. These measures are considered as Taoism. After Jia Rang, a long period of focusing on dike construction started. Wang Jing could be called a Confucianist because he advocated strong dikes that confine the river to a narrow channel. Being more positive to controlling floods, Pan Jixun gave the first forceful statement against the ancient principle of dividing the flow to dissipate the river's power. Pan Jixun's strategy was followed until the beginning of the Peoples Republic of China (1949) by strengthening and raising the levees. The views of flood risk management that are now being studied for the YR again show more respect for nature and are looking for alternatives to dike raising. Therefore, these present ideas are more in accord with the Way (Tao) of water, or "control by not controlling". This indicates that currently Taoism is the leading direction of thinking on long term strategies for flood control for the YR.

In brief, Confucianism and Taoism philosophies guided flood control historically as the two dominant ethical approaches alternatively conducted in the basin. This is also partially due to the fact that scientific approaches were little developed or considered by the government until the last century. Not surprisingly, without proper advanced scientific and technical approaches, the YR remained as China's Sorrow for a long time.

FROM FLOOD MANAGEMENT TO IWRM WITH A FOCUS ON SCIENTIFIC APPROACHES

Nowadays scientific and technological approaches in diverse fields such as hydrology, ecology, sociology, are being applied in modern water management in the YR. Significant achievements have been obtained, for instance, no dike breach in the lower YR has occurred for more than 50 years. However, these approaches have not yet resulted in a sustainable situation. Since the 1980s, due to the decrease in inflows in the upper and middle reaches together with the increased water consumption along the

YR, zero runoff has frequently occurred in the lower reaches. Obviously, water scarcity and environmental deterioration interrelate and have become a bottleneck to the socio-economic development of the YRB, much more than the threat of flooding. An integrated approach is needed to solve these problems. The Chinese government has realized this and has started to implement the concept of IWRM. As defined by the GWP Technical Advisory Committee (GWP, 2000), IWRM is a process which promotes the co-ordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner, without compromising the sustainability of vital ecosystems. The aim of IWRM is to discard the one-sided management perspective of single interests of one sub-sector by one government agency and to strive for a participatory multi-sided management perspective including all interests in the management of water resources. Undoubtedly, IWRM broadens our understanding of water resources and its complicated connections to nature and humans. IWRM takes account of all natural aspects of the water resources, all sectional interests and stakeholders, the spatial and temporal variations of resources and demands, relevant policy frameworks and all institutional levels.

The implementation of IWRM in the YRB is taking place gradually. Research programmes and projects have been launched, including soil and water conservancy, basin wide water allocation, combined regulation of surface and groundwater, water demand management, environmental (minimum) flows, ecosystem restoration, institutional capacity building, water markets, water law, etc. With respect to flood management both structural measures and non-structural measures are being adopted. Structural measures include reservoirs, diversion structures, retention basins, embankments, dredging, channel modifications, etc. Non-structural measures include flood warning systems, telecommunication technology, land use zoning, and so on. Also, short-term flood control measures (e.g. flood control system and sediment trapping systems) are combined with long-term flood management measures (e.g. soil and water conservation in the Loess Plateau). The current flood control strategy aims at "retaining water upstream, discharging downstream and retarding in detention basins on both banks". These flood measures function in combination with a sediment treatment system based on the principle of "trapping sediment at the source, discharging sediment to the sea, depositing fertilized sediment in irrigation districts, diverting the sediment to strengthen the dikes, and dredging sediment from the main course". Moreover, institutional capacity building and participatory management is implemented accordingly step by step.

However, the first results indicate that IWRM does not necessarily result in more sustainable development for the YRB. Sometimes more problems appear than the solutions that IWRM tries to achieve. The question is why the scientific and technological approaches of IWRM do not perform adequately. The ongoing threats of flooding, water scarcity and the increasingly fragile environment call for deep reconsideration. At the turn of the 21st century, reports on the YRB started to suggest an attitude towards humans more in harmony with nature instead of trying to control ("harness") it. This recalls the old debate on flood control in the YR. It also reminds us that the historical ethical approaches should not be neglected any more.

INTEGRATING THE TWO APPROACHES TO WATER MANAGEMENT IN THE YELLOW RIVER BASIN

IWRM and its philosophical basis

As Herkert argued (1997), environmental issues raise fundamental questions of "ethics and philosophy". First, what is the proper ethical relationship between human beings and the natural environment? Second, what is the philosophical basis for this relationship? Besides a scientific approach, an "ethical approach" is also important in order to address water issues. Without either, our understanding of water crises must remain "very limited and incomplete" (Ip, 1986).

Based on the above articulation, we realize that general understanding of IWRM basically remains a scientific and technological approach. A basic principle of IWRM is the idea of caring for nature and ecosystems and this actually provides strong support for an ethical stance. It is very important to emphasize, if not extend, the understanding of IWRM by employing a reasonable philosophical basis. That is, both scientific and ethical approaches to water issues should be included in the context of IWRM. The next question thus is What is a proper philosophical basis of IWRM?

The historian Lynn White (1967) argued that many of our modern scientific and technological approaches to nature started from the Judeo-Christian perspective, which is especially anthropocentric. According to White, anthropocentrism or anthropocentric scientific approaches contribute to "our current ecological crisis". In terms of sustainable development, Canter *et al.* (1995) point out that Agenda 21 (1992) and most of the international documents on this aspect "use very traditional language from Western science, economics, and law" to describe sustainable development implementation strategies; the emerging water crisis created "a powerful challenge to Western ethical systems" because ethicists were forced "for the first time" to consider and articulate the value of species of plants and animals. Western ethical systems have been accused of failing to value anything other than human happiness or interests and consequentially to devalue animals, plants, and ecosystems. For these reasons, traditional or dominant Western philosophical and theological views on human relationships with nature seem in many cases to have contributed to environmental destruction and degradation.

As the anthropocentric Western philosophy is charged, we turn to Eastern perspectives. One common element among several Eastern perspectives, particularly when contrasted with the western view, is the de-emphasis on dualism, and the human sense of connection to nature. Eastern conceptions are bio-centric in outlook, and the "primal" peoples of the East subordinated themselves to the integrity of their biotic universe. From this point of view, we may conclude that Eastern philosophy could be an alternative to the Western philosophical basis with respect to the ethical approaches to water issues.

Nevertheless, given the well-documented ecological disasters in Eastern societies, Guha (1989) points out that Eastern knowledge about the natural world was not infallible. Tuan (1968) also argued that "Buddhism and Taoism may have precepts which promote respectful attitudes toward nature, in theory, but that did not prevent the Chinese from engaging in a long history of environmental changes and destruction".

However, Hargrove (1989) debates that "environmental values are the ideals indicating how people ought to live, rather than a description of how they necessarily always do behave". He also points out that "the gradual environmental degradation in the East may have resulted from empirical ignorance." Jenkins (2002) considered that environmental degradation in modern China can be explained "in terms of recent increases in the importance of the pragmatic over the ideal". Thus, the environmental problems observed in non-Western society may very well be due to causes other than a lack of wisdom about the proper human relationship to the natural environment. Therefore, we can conclude that to tackle water issues Chinese philosophies may provide proper bases to ethical approaches to IWRM.

Scientific and ethical approaches to IWRM in the YRB

As articulated above, neither Confucianism nor Taoism has led to the successful sustainable development of the basin without being combined with advanced scientific approaches. Neither has the recent implementation of scientifically focused IWRM given satisfying solutions. Based on extended understanding of IWRM, which should consist of both scientific and ethical approaches, the main question is how these ethical and scientific approaches can be successfully combined into successful IWRM practices for the YRB. To answer this question, first of all it is necessary to determine which philosophy can provide a proper philosophical basis for IWRM in the YRB. Compared with Confucianism, Taoism gives larger emphasis to nature and to harmonization of human beings with nature. Yet it is time to strengthen the concern for the relationship between human beings and nature and to provoke people at all levels to care for nature. As a strong vehicle towards awareness building, Taoism is preferred today to provide a proper philosophical basis to IWRM for the YRB.

Then the next question is how this Taoism dominant ethical approach can be combined into the scientific and technical approaches to deal with water issues in YRB. It is better to be illustrated by concrete water issues. At present population pressure and poverty has resulted in the flood plain of the lower reaches of the YR being increasingly used for settlements, industry and infrastructures. This has increased the flood risk and limited the options for water management. Managing a river in such a crowded flood plain requires the solution of conflicts of interests between many stakeholders. This is typically true when discussion is concerned on how to leave room for the river in the lower reaches. Here we need to discuss how Taoism as ethical approach exerts its influence, together with the scientific approaches in the context of IWRM to deal with these two issues.

Concerning the issue of room for the river, the main obstacle lies in how to persuade people to resettle away from the flood plain area where fertile silted land between embankments is tempting for farmers. Ideally, according to Taoism, people should be aware that the river and its flood behaviour have their place and human beings should allow the river to follow its natural course. Besides, with a high degree of respect for nature, the culture and values of the landscape, together with biodiversity and human security in the flood plain, are also probably recognized and considered important. It may become easier for people at the grass roots to tolerate the loss of economic benefits or life's comforts by leaving room for the river, e.g. by the widening of embankments or other interventions. In this way, the policy of resettlement of people from the flood plain and leaving room for the river would be relatively easier to implement to some degree.

As the erosion of the Loess Plateau is the crux of the flooding in YRB, it has become well known that developing soil and water conservation measures in the Loess Plateau would ultimately reduce the sediment load of the YRB. In theory, to implement this policy in the manner of Taoism will achieve a better effect. First of all, according to Taoism, people would reduce human intervention in the fragile environment. That is, individual people at the grass roots would keep their lifestyle more ecofriendly. Thus, people should be less greedy to use natural resources if the usage is not in a sustainable way or if the usage is only to satisfy their taste for luxury. Secondly, for policy makers, they would promote adjustment of socio-economic activities in the Loess Plateau to give a higher priority to nature. In this way, the industry sector would focus on the development in a less intensive way to interference with nature. Thirdly, for engineers, more ecofriendly techniques should be studied and proposed along with more innovative techniques, to make up the loss or the "pain" of human beings and nature as much as possible. When caring for nature and giving nature a higher priority becomes accepted, grassroots people, policy makers and engineers can communicate and cooperate with each other more openly and effectively to adapt human needs to nature based on Taoism. Then, YRB flood hazards would be dealt with in a more ideal way by smoother implementation of IWRM of soil and water conservation and reformation of the industrial sector in the Loess Plateau.

The Taoism philosophy of harmony with nature is not very specific for China. The same approach is also practised in some river systems in other countries, e.g. in Bangladesh (Islam, 2001), the lower Missouri (Criss & Shock, 2001), the Napa River in California (Wheeler, 1998) and in The Netherlands (Klijn *et al.*, 2001). It is not the approach as such that is advocated, but the ethical basis that influences the people's awareness and co-operation. Without such a strong ethical basis, a new approach to river management cannot be implemented in the expectation of a high degree of success.

CONCLUSIONS

By reviewing the methods of historical and modern flood management in the YR, it is argued that both ethical approaches and scientific approaches are important to achieve sustainable basin development. IWRM is a promising approach, but the present science and technology oriented concept of IWRM should be extended to cover the ethical approaches. It is concluded that Taoism, which originated in the YRB and is deeply rooted in the hearts of the Chinese people, is the preferred proper philosophical basis of IWRM in the YRB. Taoism, as an ethical approach to IWRM, might be helpful in mediating in conflicts between human beings and nature, and to facilitate more effective implementation of IWRM. Although it is a lengthy process for human beings to put ethical approaches into proper practice of IWRM in the YRB or in other regions in the world this paper is a starting point in the process of initiating people from different backgrounds and reminding others of the concern for reaching real sustainable development in the YRB.

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The Basis of Civilization – Water Science? (Proceedings of the UNESCO/IAHS/IWHA symposium held in Rome, December 2003). IAHS Publ. 286. 2004

Role of water in the development of civilization in India—a review of ancient literature, traditional practices and beliefs

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Abstract Water is an integral part of Hindu beliefs and customs and it is always given a sacred position in the centuries-old civilization of India. The civilization originated and flourished on the banks of the sacred rivers and the influence of the rivers is reflected in all aspects of life. In the hymns of the Vedas, the Puranas, the Upanishads, the epics and the great works of Vedic scholars, the importance of water is often highlighted. Ancient records show the awareness existed in India of water conservation and management. From the keen observation of the environment, several proverbs related to rain and water were developed. This paper is a review of the role of water in Indian civilization, in the ancient Sanskrit literature, in the beliefs passed through generations and in the festivals celebrated.

Key words ancient literature; civilization, India; cultural development; holy rivers; proverbs

INTRODUCTION

As in many other parts of the World, civilization in India also flourished around rivers and deltas, and rivers remain an enduring symbol of national culture. Different generations have considered rivers as sacred. The seven important rivers Ganga (the Ganges), Yamuna, Godavari, Saraswathi (underground river), Narmada, Sindhu (Indus) and Kaveri (Cauveri) cover the length and breadth of undivided India, and connect people with different life styles, languages, costumes, etc. Ancient civilizations such as those at Mohanjodaro and Harrapa in the Indus Valley, started around 4000–5000 BC. Excavations at these sites, scattered information in the old literature, and studies of the truth behind religious practices provide an idea about the role that water played in the rich cultural heritage.

WATER IN CIVILIZATION

Indus Valley civilization

The Indus Valley civilization, one of the earliest civilizations, was the world's largest in extent. Its total area covered 1×10^6 km^2, comprising north India and the present Pakistan. The first major settlements in the civilization based on Mohenjo-daro and Harappa, were found along the Indus River and its tributary, the Ravi. Exploration in recent decades has disclosed several sites along the dry bed of a huge river, now widely recognized as the legendary River Saraswati praised in the ancient literature "Rig Veda". Satellite images also show signs of channels of water in northern and western India that disappeared long ago. Some scholars have made the point that the Harappan civilization would be better named the "Indus-Saraswati civilization" (Danino, 1999). Urban centres were often planned near rivers or at the coast. The great and well planned cities provided public and private baths, sewerage through underground drains built with precisely laid bricks, and an efficient water management system with numerous reservoirs and wells. In the impressive drainage systems, drains from houses were connected to the larger public drains. Agriculture was practised on a wide scale, with extensive networks of canals for irrigation. It appears that fire and flood control measures to protect farms and villages were also practiced.

Water management and technologies

Drier climates and water scarcity in India led to numerous innovations in water-management techniques, since the Indus valley civilization. Irrigation systems, different types of wells, water storage systems and low cost and sustainable water-harvesting techniques were developed throughout the region. The reservoirs built in 3000 BC at Girnar, the artificial irrigation lake Bhojsagar in Madhya Pradesh constructed in the 11th century (it covered 650 km^2), the artificial lake fed by the Kaveri River in the same century and ancient step-wells in Western India are examples of some of the skills. Technologies based on water were also prevalent in ancient India. Reference to the manually operated cooling device "variyantra" (revolving water spray for cooling the air) is given in the centuries old writing "Arthashastra" of Kautilya, 400 BC. The "Arthashastra" and "Astadhyayi" of Panini, 700 BC, give reference to raingauges.

WATER IN ANCIENT INDIAN LITERATURE

Ancient Indian literature points towards an intuitive understanding of nature and natural processes. However, many of the ideas are presented in a philosophical manner, so skill and effort are needed to trace the meaning out of the lines. The Vedas, Upanishads, Puranas, Epics and scholarly writings such as "Mayurchitraka" "Vrihat Samhita" are vast treasure troves of scientific knowledge. Many of the hydrological concepts developed in the last few centuries were known and well documented in them by 3000 BC. Even for hydrology alone it is not possible to explain their contents in just a few pages. Only a small fraction of the scientific knowledge in them has so far been studied in detail. A valuable attempt to undertake this work was carried out by the National Institute of Hydrology (1990).

The beginnings of studies on weather and water in India can be traced back some thousands of years. Early philosophical writings contain descriptions of the Earth's revolution around the Sun, the seasons, and the processes of cloud formation and rain. Though "Indra" was worshipped as the God of rain, the ancient scholars knew that basically the energy of the Sun causes rainfall. Rig Veda says that the Sun is the cause of rainfall and water ("adityat Jayate Vrishti" or the Sun gives rainfall) that evaporates by the sun's rays moves up into the sky for conversion to clouds and rain and then is finally stored in rivers and oceans. "Arthashastra" contains records of scientific measurements of rainfall in various parts of India and its application to the country's revenue and relief work. It also classifies climates and identifies the zones suitable for agriculture. The great poet Kalidasa of the 7th century BC, in his masterpiece "Meghdoot", or the message of clouds, mentioned the date of onset of the monsoon over central India and the path of the monsoon clouds (India Meteorological Department, 2003). In the Vedic period itself the concepts of evaporation due to the sun's rays and winds, the concept of hydrological cycle, the types of clouds, the process of cloud formation and precipitation, methods of measuring rainfall, the nature of winds, the estimation of slopes from river flow, and the dimensions of meandering rivers along with velocity of flow, were well understood.

The "Vayu Purana" and the "Matsya Purana" mention the rainfall potential of clouds and the formation of clouds by cyclonic, convectional and orographic effects. The "Vishnu Purana" discusses the glorious sun that exhales moisture from seas, rivers, the Earth and living creatures. Similar verses are also found in the epic "Mahabharata". The book "Meghmala" written in AD 900 (author disputed) is on cloud-related studies. The "Thaithariya Aranyaka" classifies clouds and winds in an appreciable manner. Information on infiltration can be found in "Taitariya Samhita" and in "Mahabharata". The rivers were considered as the daughters of the Sun and cloud and the "mantras" of the "Rig Veda" denotes that creation started with the origin of water. Knowledge of Geography, Geomorphology and streamflow was developed and, according to the "Atharva Veda", rivers of a mountain origin are perennial and summer flow is maintained if the mountain is snow-covered. For several thousands of years, Indians have recognized the importance of groundwater development and utilization, as life was dependent on agriculture and because many parts of North India experienced dry climates. The Vedas mention clearly the use of water abstracted from wells. Three chapters of "Vrihat Samhita" of Varaha Mihira, of the 5th century AD, are fully on meteorology and climatology, and one chapter is fully dedicated to groundwater exploration, exploitation and equipment. Physiographic features, termite mounds, soils, flora, fauna, rocks and minerals, were used to detect groundwater. Estimation of the depth of the water table was based on the presence of termite mounds and on certain trees near them. In the famous Bhagavad-Gita, Lord Krishna in his advice, comments on sinking wells for water as great work (yagna) and highlights the role of water in the evolution of all beings (Ramakrishnan, 2000).

Methods to assess and maintain water quality and treatment methods to improve it are explained in Vedas and books on "Ayurveda". Varahamihira presented methods for obtaining potable water from a contaminated source, using plants, metals and heat. Water conservation, water use and management were given considerable importance in ancient India. There are quotations in Vedas and in early scholarly manuscripts on canal irrigation, drought management, water allocation, water pricing and even transboundary water management. As per "Yajur Veda" pure water will purify all things through rain: "may waters, like mother purify our bodies".

WATER IN BELIEFS AND RELIGIOUS PRACTICES

The physical and aesthetic properties of water give it a unique mythical-religious potential and therefore it has played an important role in myths and religious rituals. Lord Vishnu, the God of existence, is also known as "Narayan", which means one who resides in water. The origin of life from water and the development of species explained through the ten incarnations of Lord Vishnum, is a Hindu theological concept in Vedic history. The incarnations through the ages start from water as a fish and continue as a tortoise, boar and lion to a perfect human being. Importance of rivers and water bodies is highlighted throughout the epics "Ramayana" and "Mahabharata". There are several legends about water and water bodies. The epic "Ramayana" (Valmiki) explains a lot about the river Sarayu (Ganges) in which Lord Sri Rama disappeared on the way to heaven. Saints appearing in epics always lived in the vicinity of rivers, as physical purity associated with mental purity was believed a must in realizing eternal truth.

In all religious practices, the sprinkling of divine water is an inevitable part. The water is purified with "mantras", inviting the presence of the seven sacred rivers. This divine water is used to anoint the idol, which is then distributed to devotees. Associated with every Hindu temple and ashrams, there are big ponds and wells. It was a popular belief that bathing in holy rivers or drinking some drops of water from these rivers before the last breath, can help remove the sins acquired from the evil deeds during the lifetime and through the generations. In the functions following funerals and during the offerings to ancestors, bathing and dipping items for worship in holy water bodies, including the ocean, is considered of great spiritual value. Praying with a handful of water in the morning and the evening was part of daily life. There are several water bodies considered sacred in the different States of India. Cultural traditions have helped conserve many of the water resources and the forests and wetlands that maintain them.

Former generations gave due consideration to the right to use water for all creations. Open wells have been in use for centuries. Near the well, they used to construct small pits to fill water so that birds, reptiles or animals could drink. Some class of Brahmins even judged the behaviour of a newly-wedded girl by asking her to water the sacred plant "tulsi" and by watching to see if she kept some water in the bucket used to draw the water from the well for other creatures. It was a custom not to empty the bucket until sunset.

WATER IN TRADITIONAL PRACTICES AND PROVERBS

Societies and cultures have traditionally developed sustainable techniques for conserving and managing nature and natural resources. For example, making small heaps of sands before the end of the winter monsoon in the central part of Kerala was, in fact, a multi-purpose method involving water and agricultural management. Water trapped in between the heaps infiltrates to groundwater, so that there is no serious water shortage in the dry months. In addition, the weeds are removed and soil becomes loose to fit the land for agriculture. Unfortunately, because of changing life styles, the rising cost of labour and the shortage of land availability due to the increasing population, this sustainable and environment-friendly method is becoming uncommon. However, the recent water crisis is initiating a drive to improve traditional, reliable and cost-effective domestic rainwater harvesting methods.

India has a fascinating and significant ancient tradition of conserving land and water and even today, local people follow several such traditional conservation practices. They include protecting patches of forests and water bodies in the name of local deities. The "sarpa kavu" (Snake forests or sacred groves) and the miniature forest to worship holy snakes (and certain other deities) were once integral parts of agricultural plots and many households in Kerala in south India, and they still exist in isolation. This ecosystem consists of many species of trees (some of them considered sacred where some of the deities are believed to dwell), shrubs and rare herbs of high medicinal value. A well-protected pond, which helps a lot in recharging and conserving water, is an essential part of this forest. Every year, there used to be "puja" (offerings) to the snakes and deities and before offering "puja" the ponds were cleaned. The quality and quantity of water in nearby wells are largely influenced by this ecosystem. There is a proverb "cutting the kavu destroys the nation". This has become true, as the destruction of the forests and the filling of ponds has resulted in falling water tables and created serious water shortages in non-rainy months. These preserved biodiversity-related cultural phenomena exist by different local names in different parts of India.

There are several proverbs related to rainfall in the different Indian languages, the collection and explanation of them is a large task. They were developed through keen observations of nature. As examples some of the numerous proverbs existing in the southern State of Kerala, are summarized below:

(a) "Those who stands in 'kalavarsham' (summer monsoon) and those who runs in 'thulavarsham' (winter monsoon) get wet". Summer monsoon rainfall is continuous and winter monsoon rainfall is short and heavy, because of the differences in circulation pattern and types of clouds.
(b) "Clouds over pounding shed, rain is sure". Pounding shed is in the northwest corner of the house and huge winter monsoon thunderclouds appear there.
(c) "South clear, weather clear". This is related to the formation of clouds due to typical circulation pattern during summer monsoon.
(d) "Half a 'koda' (very heavy rainfall) for 1000 'venals' (hot summers)". This means that if the summer is very hot, it will be followed by heavy rain.
(e) "If planted in 'njattuvela' (break monsoon), even dry sticks will grow". The break monsoon gives rain and strong sunshine alternately several times a day, and this is a good time to plant small plants and trees.
(f) "Water should be inside 'thundams' (heaps of sand) in the 'thulavarsham' (winter monsoon)". The winter monsoon is the end of the rainy season and the detention of water enhances groundwater recharge.
(g) "Rain in 'makaram' destroys 'malayalam' (Kerala)". 'Makaram' is a month in the local calendar that falls during January–February. This is a harvest month and if there is rain, whole crops will perish.

The old farmers could even predict droughts and floods by the observation of the pre-monsoon weather. To them the position of celestial bodies, clouds, winds and the behaviour of birds and animals were indicators of the nature of forthcoming rainfall and the availability of resources.

THE INFLUENCE OF THE GREAT RIVERS ON CULTURAL DEVELOPMENTS

The influence of the great rivers is reflected in all facets of development in the civilization and the famous ancient kingdoms. Almost all major cities in India were on the banks of rivers. The most important is the River Ganga, the heavenly river that is believed to be brought down to the Earth by King Bhagirath, to wash away the sins of his forefather. Many of the holiest of Indian cities grew along her banks. There are numerous festivals and fairs held in and around rivers, the most important being the "Kumbh Mela".

Since time immemorial, the Kumbh Mela, has been the greatest of the Indian fairs and with the highest state of water symbolism, attracting the world's largest congregation of religious pilgrims. Symbolically speaking, the forces of creation are collected in one vessel (Kumbh) and a celebration (mela) ensues, which is why this event is called "Kumbh Mela". Millions of worshippers take a dip in the holy rivers to wash away their sins. The month long festival represents a time when the river is believed to turn into purifying nectar, allowing the devotees to cleanse their souls as they bathe. It is a very important occasion that takes place every 3 years at the following four locations in India:

(a) Allahabad (Prayag), at the confluence of the rivers Ganga, Yamuna and the mythical river, Saraswati;
(b) Haridwar, where the River Ganga enters the plains from the Himalayas;
(c) Ujjain, on the banks of the Shipra;
(d) Nasik, on the banks of the Godavari.

The "Ardh (half) Kumbh Mela" is held in every 6 years at Allahabad and Haridwar and the "Purna (complete) Kumbh Mela", the biggest and the most auspicious fair, every 12 years. The "Purna Kumbh Mela" is always held at Allahabad, which is exceptionally sacred because of the confluence of holy rivers. The "Maha Kumbh Mela" (Grand Pitcher Festival) occurs every 144 years. In addition, the "Magh Mela" or the Annual Mini Kumbh (in the month of Magh in the national calendar that falls during January–February) is held every year at Allahabad, except the years of "Purna Kumbh Mela" and "Ardh Kumbh Mela". It is a popular belief that a dip in the sacred waters on this auspicious day ensures salvation or freedom from the cycle of birth and death.

Two other important festivals connected to the Ganges (Ganga) are the "Ganga Dashara" and the "Ganga Dhara". Celebration of these festivals varies from city to city. In the Hindu festivals like this, there is a common theme of giving thanks to God for food, water and shelter. The legend behind this says that Lord Shiva provided water in times of extreme drought. Many legends related to the rivers are based on religious, cultural, as well as social events in history.

In short, since Vedic times, water has been enjoying the most respectable and unique status in India. Development to a modern society through the centuries was always linked to the holy rivers. The rituals and ceremonies associated with the sacred rivers still continue, sometimes more actively than in the past.

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