

Progress report: Regional and Country Scale Water Resource Assessment; Informing Investments in Future Water Supply in the Asia Pacific Region – a Decision Support Tool

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The Water for a Healthy Country Flagship aims to achieve a tenfold increase in the economic, social and environmental benefits from water by 2025. The work contained in this report is collaboration between CSIRO, Marjorie Sullivan at AusAID and Caroline Sullivan at Oxford University.

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EXECUTIVE SUMMARY

This is a progress report which describes the results of the current stage of research conducted as part of the *Regional and Country Scale Water Resource Assessment: Informing Investments in Future Water Supply in the Asia Pacific Region – a Decision Support Tool* project for the CSIRO-AusAID Alliance. The Alliance has been established to direct activities into developing research products required by AusAID and provides a basis for collaboration and integration of effort between management staff at AusAID and scientists in CSIRO.

The goal of this project is to inform decisions on provision of adequate and safe water supplies and appropriate sanitation where countries and regional areas are most in need. The geographical scope of the project is the Asia and Pacific regions; focussing primarily on a list of 29 countries. For these regions, there is currently a large and unmanageable amount of information from various sources on the current status, future demand and impact of climate change on water supply and services. To support decisions for targeted interventions by Australia, a decision support tool will be developed for AusAID over a preliminary three year term using available evidence and information. The development of a transparent, valid decision-making process will provide a variety of potential uses for AusAID including, access to reliable data sources and information, knowledge management, and encouragement of collaborative efforts with water managers in partner countries.

The report describes the initial stage of the project where a process has been developed to assess the relative priority and scale of future water supply challenges in a range of countries using global data sets and other sources of information. The process builds on an existing indicator methodology, the Water Poverty Index (WPI), to enable fast and efficient communication of water related information. The process has been designed to incorporate data to suit the priorities and perspectives of its users; taking into consideration that there are often multiple and varying priorities. To mitigate the risk of simplifying complex issues and relationships to a single number, the use of indicators will be embedded in a wider process of engagement and further in-depth exploration to support a collective learning process as the project progresses. This process will be designed to identify data gaps and a qualitative approach will be designed to access additional and appropriate data from non-quantitative perspectives for smaller countries and at local levels, depending in this initial stage, on the suggestions from AusAID as to their requirements. This will be a participatory process, inclusive and iterative in nature.

This report has three main sections, the literature and data review, the methodology description, and the initial results. The literature and data review will be used to inform decisions on suitable methodologies and reliability and accessibility of data for use in intervention decisions, as described in the methodology section. The preliminary results section describes the application of relevant and reliable data for the calculation of indexes, indices and components. Indicators have been applied on a national scale for 29 countries and in a case study region, i.e., the Mekong River Basin. A prototype display has been developed using ArcGIS Server software for a web-based display of the Water Need Indicator. Additional information on the choice of indices, indicators, components and sub-components are discussed and presented in the appendices. During the course of this project, indices will be finalised, mapped data updated and comprehensive metadata information will be linked to the mapping web page.

As a progress report developed for the purposes of communicating research thus far, the authors hope that it will generate feedback and discussion. In this way, we feel this report will be instrumental in ensuring alignment between project activities and AusAID needs.

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ACRONYMS, ABBREVIATIONS AND DEFINITIONS

ADB Asian Development Bank
AusAID Australian Agency for International Development
CEISIN Center for International Earth Science Information Network Columbia University
EPI Environmental Performance Index
ESI Environmental Sustainability Index
EVI Environmental Vulnerability Index
FAO Food and Agriculture Organisation (AQUASTAT Database)
GLAAS Global Annual Assessment on Sanitation and Drinking-Water
HDI Human Development Index
HDR Human Development Report
IMF International monetary Fund
IPPC Intergovernmental Panel on Climate Change
IWRM Integrated Water Resources Management
JMP WHO/UNICEF Joint Monitoring Programme on Water Supply and Sanitation
MRB Mekong River Basin
MRC Mekong River Commission
MDGs Millennium Development Goal Indicators
SDI Sustainable Development Index
SOPAC South Pacific Applied Geoscience Commission
WCU World Conservation Union
WB World Bank
WHO World Health Organisation
WNI Water Needs Index
WPI Water Poverty Index
WRI World Resources Institute
WWDR – United Nations World Water World Water Development Report
WWDR2 United Nations World Water Development Report 2
UNDP United Nations Development Programme
UNESCO United Nations Educational Scientific and Cultural Organization
UN-WWAP United Nations World Water Assessment Programme

1. INTRODUCTION

The Australian Government¹ funds water and sanitation projects in a large number of countries in Asia and the Pacific, including East Timor, Indonesia, India, China, Kiribati, Tonga and Vietnam. In order to achieve maximum impact with the available funds, the diverse needs of different locations need to be prioritised in a rational manner. We claim that such prioritisation requires knowledge, data, analysis and dialogue at a number of scales. However at present, there is a large amount of unmanageable information from various sources on the current status, future demand and impact of climate change on water supply and services in Asia and Pacific regions, and there is no single tool available that can draw this information together holistically to inform future investment decisions. This project will provide a decision support tool with evidence-based information to support decisions for targeted interventions managed by AusAID. The preliminary time frame for delivering a state of the art decision support tool is 3 years.

Prioritising development investments in a number of countries in Asia and Pacific regions in light of climate change and predicted changes to rainfall has been explored by Lukasiewicz, Minchin & Kirby (2008). The report outlined the current situation of water supply and availability of water used for drinking and sanitation and suggested future threats to water supplies. In response to these findings, and in light of implications for policy and programming, AusAID suggested further research into (i) approaches to the analysis of water supply and implications of climate change, (ii) sanitation requirements, (iii) comparison of aid investments into water and sanitation in areas of identified water stress, (iv) reliability and robustness of data sets, (v) use of temporal and spatial scales, (vi) costing of infrastructure and operation and maintenance, (vii) climate change predictions at the sub-national level and (viii) implications of uncertainty.

Methods to inform AusAID's future investment strategies will be considered in this project, '*Regional and Country Scale Water Resource Assessment: Informing Investments in Future Water Supply in the Asia Pacific Region – a Decision Support Tool*'. The *decision support tool* will be designed to assess the relative priority and scale of future water supply challenges in a range of countries. This will require a process for incorporating relevant data sets and future projections for water resources, infrastructure costs and changes to populations and climate. However, at the first level of analysis, infrastructure costs and/or costs of other interventions cannot be included as these costs will vary for each context, often requiring more detailed assessments and interactive, participatory processes.

The intent is to develop and support a process for incorporating data to be used in an adjusted Water Poverty Index (WPI) to suit the diverse priorities and perspectives of Australia. Issues of climate change, poverty reduction, food policy and health will be taken into account in the construction of the index. Research has shown that increased participation levels, awareness, education and sufficient human resources often enable successful aid initiatives (Chambers 1994). Conversely, limited ability to pay for services, legislative barriers and difficult physical conditions often act as barriers to successful implementation. This report details initial progress on the development of the *decision process* based on readily available global data sets (quantitative approach) and development of inclusive qualitative approaches to data gathering which addresses many of the research challenges.

¹ The aim of Australia's international water-related assistance is to: *Help reduce poverty and raise living standards in developing countries through promoting the efficient, equitable and sustainable use of water resources.* Australia's water-related aid program in the Asia Pacific regions delivered through AusAID is designed to ensure (i) poor have access to water, (ii) appropriate pricing policies are implemented, (iii) environmental and use practices resulting in inadequate water quality and availability are addressed, (iv) infrastructure is maintained, and (v) user groups are encouraged to participate in developing and operating water services http://www.ausaid.gov.au/publications/pdf/ausaid_water.pdf.

The first question guiding this research is:

How to design a valid and transparent process for high level assessments of water needs; that can be applied at several scales, provides interactive knowledge management and supports collective learning processes?

The research question will guide the development of a transparent, valid decision-making process that has a variety of potential uses. Access to reliable data sources and information about these sources will also provide a form of knowledge management, accessible to users of the methodology such as AusAID staff, contractors and partner country water managers. The decision support tool will be designed to provide:

- a first broad brush assessment and comparison of national and regional needs (used mainly by funding agencies)
- communication with political leaders and policy makers (used mainly by funding agencies)
- more interactive planning and knowledge management at local level; e.g at government departments, community level, water utilities, river commissions etc – involving a wider range of stakeholders such as local NGOs, community leaders, etc (used mainly at local level)
- identification of locations where further participatory assessment is needed (used mainly by agencies)
- users with the capability to undertake assessments independently without a consultant – (perhaps involving a facilitator)
- support for adaptive governance.

To enable fast and efficient communication of water related information, the use of indicators has been chosen as the methodology; whilst acknowledging the intellectual danger of simplifying complex issues and relationships to single numbers. To mitigate such risk, the use of indicators will be embedded in a wider process of engagement and further in-depth exploration to support a collective learning process. Based on a review of existing water related indicators, it has been found that limited modifications to the Water Poverty Index (WPI) can be used as a starting point to construct the decision support tool. The ultimate project deliverables will be:

- developing a decision support process which informs future investment decisions in water supply and other information needs including
 - a decision support software application
 - an engagement methodology for selection of appropriate data sources and indicator structure
 - a database with relevant data sources
 - an uncertainty and knowledge gap evaluation methodology
- applying the decision support process to the relevant countries at a national scale
- applying the decision support process to the Mekong River Basin, and one Pacific nation at a sub-national level
- providing a list of countries where further information is recommended on the basis of needs and diversity
- ensuring the software tool is structured to enable additional data to be incorporated at later date.

Initially, the tool will be applied on a national scale for the following countries:

South Asia: Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka

East Asia: Cambodia, China, Indonesia, Laos, Mongolia, Myanmar, Philippines, Thailand

Pacific: Cook Islands, East Timor, Fiji, Papua New Guinea, Niue, Samoa, Solomon Islands, Vanuatu

Subsequently, an application will be made at a more detailed level for the Mekong River Basin and for a small island nation in the Pacific region. Once the decision support tool has been approved for use by AusAID, CSIRO will provide in-house training to staff for tailored search and evaluation tasks and on ways to update and incorporate new data sets.

2. LITERATURE AND DATA REVIEW

This literature and data review describes findings in literature and describes relevant available data. The purpose of the review is to provide an ongoing document describing current knowledge. At this stage of learning, the authors have also found it appropriate to include elements of personal synthesis and relevant conclusions.

2.1 Research rationale: Impact of climate change on water supplies

Globally, water supplies are often stretched to their limit as demand is increasing and water quality and availability has markedly reduced in many locations inducing water scarcity (Falkenmark, 1998). Generally, international experts agree that water supplies are increasingly subject to climate change. In addition, seasonal variability is of considerable concern in many locations with continuing threats of floods and droughts.

Many towns and cities are growing rapidly commonly through unplanned or informal rural-urban migration. Consequently, water services are lagging behind and there is little capacity for adequate service provision. Increasingly, global populations are resident in slums and are experiencing ongoing poverty with limited access to quality water and sanitation services. According to a recent UN report (2006) very limited progress has been achieved in reaching the Millennium Development Goal of *halving the population with inadequate service provision* (Appendix 1; Goal 7). Satterthwaite (2000) argues that the core problems are usually economical, political and administrative rather than environmental factors that influence the supply of adequate water. Lundquist (1998) adds that there is a growing environmental impact with the global threat of pollution, causing water to become unusable, in many cities. Consequently, there is a need for adequate sanitation and environmental protection of water supplies to prevent water pollution.

Food security is pertinent, with rapidly growing global populations and increasing expectations amongst the population, there is an increasing need for food and water. Falkenmark (1998) suggests the water needed to produce food for one person on a nutritionally acceptable level is 1,600 m³/person/year, (in a strictly average, sufficient and approximate sense). Falkenmark (1998) suggests that increasing provision of food and water will lead to significant depletions in river flows and groundwater. Indeed, increasing water demands and apparent climate change often leads to reduced environmental flows. In such conditions, protecting ecosystems and natural environments from further damage is of considerable human interest, not least in order to avoid irreversible damage such as species loss, desertification and salinization.

Climate change is projected to impact on the environment, food production, water services provision and also has implications for access to suitable sanitation (Cook & Gichuki 2006; HDR 2007; IPCC 2007). For example, projected climate change scenarios in tropical areas of Asia suggest (i) strengthening of monsoon circulation, (ii) increases in surface temperature, (iii) increases in the magnitude and frequency of extreme rainfall events, and (iv) sea-level rise (IPCC 1997; 2007). Such changes are projected to have major impacts on regional ecosystems and biodiversity; hydrology and water resources; agriculture, forestry, and fisheries; mountains and coastal lands and human settlements and human health (Hoanh et al. 2003).

Ohlsson (1999) also discusses the issues of water related conflicts and argues that water scarcity in fact often leads to an escalation of conflicts between groups within countries, which sometimes escalate to international conflicts (often to avoid further conflicts within countries). Consequently, conflict resolution is necessary and important particularly in situations of resource scarcity. Essentially, solutions are required that are perceived as fair, rather than justified in terms of financial efficiency or for political convenience.

According to Cook and Gichuki (2006), water related poverty is experienced when communities are (i) without dependable water resources, (ii) lack capacity to access and use water resources, (iii) have insufficient land or degraded land, and (iv) have poor access to markets, capital or development opportunities. According to projected climate change trends, communities in tropical Asia and the Pacific Islands will generally experience greater hardship with increased exposure to risk and vulnerability. Targeted and contextually sensitive interventions ensuring access to quality water supplies and sanitation will be necessary to ensure that livelihoods, local culture and quality of life will remain protected.

2.2 Informing international development through the use of indices

Concerns of a pending 'global water crisis' are reflected in global and national development agendas and have prompted interest in the usefulness of indices as a means of conveying valuable and pertinent information to assess water issues and to relatively rank country or regional 'needs' (Mollinga 2008).

Global and regional data sets are readily available from which to select data to aggregate and form indices. Indices are based on a series of assumptions and consideration of proxy measurements and are used to provide a ranked indication of countries according to the intention of the measurement of the index. Indices can also provide an indication of the need for intervention and effectiveness of international aid for countries in need. International organisations collect and disseminate information and global data sets (e.g. ADB, CEISIN, FAO, SOPAC, UNDP, UNESCO, WB, WCU, WHO, WRI) and various indices (i.e., HDI, MDG, and WDI). For example, the UN World Water Assessment Programme attempts to highlight the state of water resources under different physical, climatic and socio-economic conditions and at various scales; however details on the key areas/countries of interest to this project are not reported (UN-WWAP 2003; 2006). The Global Annual Assessment of Sanitation and Drinking Water is designed to be another key reference for international water policy decisions (Properzi & Swann 2008). An holistic approach that accounts for other contributing factors to water availability and accessibility is required to understand the implications and contextual situations in remote, smaller communities for which there is scant data.

2.2.1 International institutions

The Global Statistical System involves international agencies and all national statistical systems and uses a range of tools to support the collection, analysis, and use of statistics at both the national and international levels (ADB 2004). Internationally acceptable statistics and indicators are based on standardised definitions or concepts. International agencies, particularly bilateral and multilateral donor institutions, assist with in-country capacity building to develop reliable standardised statistical measures (ADB 2004). Reference manuals and guidelines have been used to clarify concepts, classifications, and definitions, for national data sets. However, data gaps do exist and countries unable to produce reliable data have poorly informed policy and often less effective development initiatives (ADB 2004). The International Monetary Fund (IMF), World Bank (WB), Asian Development Bank (ADB) and bilateral aid agencies assist collection and compilation of timely and reliable data from various countries (ADB 2004).

Availability of data has assisted in formulation of economic and social policies, to assess investment options, and to monitor and track economic and social change (ADB 2004). In addition, statistical indicators have been used to direct socio-economic programs designed to enhance welfare and reduce poverty. The ADB's poverty database primarily contains data obtained from established data sources. Where required, additional data is sort through cooperation of the countries concerned and other involved agencies. Such gaps in available data require additional strategies and processes for collection and assessment of reliability. The data informs ADB's investment strategies for indebted countries which attempt to make

a positive contribution to improving socio-economic situations of the poor, improved governance and promote successful aid programs.

In 1999 the IMF established the Poverty Reduction and Growth Facility (PRGF) to make the objectives of poverty reduction and growth more central to lending operations in its poorest member countries². The IMF used a range of statistical data to inform the PRGF and continues to publish information on statistical implications for future international aid investments. When appropriate, the IMF draws on WB expertise in designing PRGF-supported programs. The WB advises the authorities in the design of poverty reduction strategies in areas such as poverty assessments, monitoring, structural and sectoral issues, social issues, and costing priority poverty-reducing spending. Low-income countries (per capita gross national income of \$1,025 or less) are eligible for PRGF assistance with loans to under the PRGF carry an annual interest rate of 0.5 percent³.

The United Nations Development Programme (UNDP) strategies and policies for poverty reduction include macroeconomic and structural policies, employment strategies, public resource management, and improved access to information and communication technologies⁴. International statistical databases are used to develop these strategies and policies.

A primary source of international statistical data is held in the United Nations Statistics Division, which has developed a central repository of country profiles of statistical systems and provides numerous specialised international data sources for all available countries and areas⁵. In addition, there are many tailored approaches to providing data that reflect changes to human condition in relation to the Millennium Development Goals (MDGs) (Appendix 1). An approach by the WB is the use of World Development Indicators (WDI), based on the components of a primary database which are selected and used to compare development data from different countries⁶.

The Asian Development Bank maintains a database forming a variety of development indicators that serve the purposes of informing development investment decisions aligned with MDGs⁷. In order to achieve many of the MDGs goals, people need access to sufficient and safe water. Consequently, an indirect measurement of a country's progress towards the MDGs can be an assessment of their water situation (United Nations Millennium Declaration 2000). To facilitate assessments of availability of water resources, water quality and access to water and sanitation, several approaches have been taken.

2.2.2 Water resources

Indicators have been developed as a means to quantify water resources in conventional water-resources assessments. The United Nations has produced the World Water Development Report as a knowledge base of indicators, and case studies to assist in development decisions⁸. In addition, information from WHO/UNICEF Joint Monitoring Programme on Water Supply and Sanitation (JMP) monitor global progress towards the

² <http://www.imf.org/external/np/exr/facts/prgf.htm>

³ <http://www.imf.org/external/np/exr/facts/prgf.htm>

⁴ <http://www.undp.org/poverty/propoor.htm>

⁵ <http://unstats.un.org/unsd/databases.htm>

⁶

<http://web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS/0,,contentMDK:20535285~menuPK:1192694~pagePK:64133150~piPK:64133175~theSitePK:239419,00.html>

⁷ <http://www.adb.org/Statistics/default.asp>

⁸ <http://www.unesco.org/water/wwap/wwdr/>

Millennium Development Goals (MDG) on water-supply and sanitation and is mainly based on nationally-representative household surveys and censuses⁹. A Global Annual Assessment on Sanitation and Drinking-Water (GLAAS) is designed to indicate capacity of countries to progress towards the MDG water and sanitation targets and on the effectiveness of external support agencies to facilitate this process. These reports offer a broad global picture, however data are not available for some countries selected in this study.

2.2.3 Water availability and accessibility indices

Water indicators have been used to represent the physical availability of water (Available Water Resources) at a national level in respect to the population and in reference to the hydrological cycle, known as comparative hydrology (Molle & Molling 2003). Falkenmark and Chapman (1989) report on comparative hydrology at various scales as a means of dealing with the complexity of water availability. There have been many thematic iterations to account in various ways for; (i) water withdrawals, (ii) water effectively used (runoff), (iii) amount required for domestic needs, (iv) demand for food production, (v) groundwater availability, (vi) environmental needs, (vii) estimations of water stress, (viii) alternatives to using water e.g. food imports, (ix) provision of water and sanitation facilities, (x) water stress and scarcity, (xi) social adaptive capacity, and (xii) poverty (Molle & Molling 2003).

Water availability and accessibility indicators can be calculated by integrating diverse information types such as hydrological and social data into a single number for a particular location. There are a number of different types of indicators, such as the Water Poverty Index (WPI) developed at Oxford University and the Environmental Vulnerability Index (EVI) developed by the South Pacific Applied Geoscience Commission (SOPAC). Such information can be useful for informing policy makers, donor agencies as well as local water managers about water related needs, which can in turn inform investment, development and intervention decisions. It should be noted that water assessments are reliant on available data sometimes “*of dubious quality or at the wrong scale*”, hence the reliability and robustness of data sets must be considered (Sullivan, Meigh & Lawrence 2006 p. 413).

Reliable data on indicators that focus on water scarcity and availability are difficult to obtain, while the more complex approaches to systemic water issues are challenged by complexity and fluctuating hydrological processes or a myriad of social implications (Molle & Molling 2003; Molle, Mollinga & Meinzen-Dick 2008). However, some proxies can be used for taking into account social complexities; and Ohlsson (1999) for instance claims that the Human Development Index¹⁰ is suitable for evaluating the adaptive capacity required by a society facing water scarcity, which he uses to evaluate a Social Water Stress Index (SWSI) in combination with other measures of water availability (carried out for the 159 countries for which data is available)¹¹.

Savenije (2000) warns about blind use of water scarcity indicators and says that the choice of appropriate scale and inclusion of temporal and spatial variability is absolutely critical. In terms what type of water ought to be included in water availability assessments, Savenije (2000) also considers it of critical importance to take into account all types of water resources (in particular green and blue water). Savenije (2000) uses the definition that blue water is that which exists in rivers, lakes and aquifers; while green water is that which is mainly stored in the soil.

Chenoweth (2008) claims the naturally available water resources of a country do not have a significant effect on the ability of that country to meet the basic needs of its population. Contrasts of national development data and resources data provided by UNDP and FAO

⁹ http://www.unwater.org/downloads/UNW_brochure_EN_webversion.pdf

¹⁰ <http://hdr.undp.org/en/statistics/>

¹¹ http://humandevlopment.bu.edu/dev_indicators/show_info.cfm?index_id=192&data_type=1

refute the assumption that available water resources per capita should be used as a standard indicator of water scarcity.

2.2.4 Indicator methodology- limitations, reliability and robustness

As pointed out in previous sections, there is no single definition of an indicator or the constituents of an index. Rather, there are many standardised approaches using accepted guidelines and definitions, as well as non-standardised index approaches. Each methodology and assessment requires a number of assumptions and these are not always transparent when using index applications. For a review of indicators, their usefulness and pitfalls refer to Chaves and Alipaz (2006); FAO (2003a); FAO (2003b); Feietelson and Chenoweth (2002); Molle and Molling (2003); Molle, Mollinga and Meinzen-Dick (2008); Mollinga (2008); Sullivan (200); Sullivan, Meigh, and Lawrence (2006) and Sullivan et al. (2006).

A useful indicator should be measurable, constituted by accessible data, quantified either by measuring or monitoring and highly correlated or causally related to the complex issue under investigation (Feietelson & Chenoweth 2002). There are numerous indices constructed from selected key variables or sub-components as appropriate measures or proxies of an attribute. Indices are constructed using mathematical formula or by addition of sub-component values. Some indices are standardised to represent a value between 0-1. An example is represented in Figure 1, where the Gini Coefficient is the most commonly used indicator of inequity, ranging in value from 0-, and computed using the equation in Figure 1.

$$Gini = \frac{1}{2n^2 y} \sum_{i=1}^n \sum_{j=1}^n |y_i - y_j| = \frac{-(n+1)}{n} + \frac{2}{n^2 y} \sum_{i=1}^n i y_i$$

Recipients/individuals are ordered from lowest income to highest.

y_i = income of recipient/individual i .

y = average income.

n = total number of recipients/individuals.

Figure 1 Calculation of Gini Coefficient

Source: ADB (2004 p. 32¹²)

Values of key variables and sub-components are usually determined from datasets (where available). The choice of dataset is dependant on (i) suitability; (ii) implications of the value, (iii) representativeness, (iv) scale of reference i.e. city, region, province or country, and (v) temporal reference i.e. seasonal difference, accuracy, timeframe, transferability (Molle & Mollinga 2003). Consideration of dataset issues in the selection of appropriate data will reportedly add to the reliability and robustness of the variables used to construct an index (Sullivan 2002).

Each dataset available on the internet or in books and reports has a unique presentation of data and a variety of ways of describing the data that constitutes particular indices. For example the Asian Development Bank provides a *Development Indicators Reference Manual*, outlining concepts and definitions, published by the Economics and Research Department¹³. The World Water Assessment Programme cites details of the indicators used in the second United Nations World Water Development Report (WWDR2). An example of an Indicator Profile Sheet can be viewed at

<<http://www.unesco.org/water/wwap/wwdr/wwdr2/indicators/pdf/CH01-IPSFinalEdits.pdf>>.

¹² <http://www.adb.org/Statistics/pdf/Reference-Manual.pdf>

¹³ <http://www.adb.org/Statistics/pdf/Reference-Manual.pdf>

The absence of reliable or standardised data reduces the usefulness of index methodology. Use of an index method may not take into account overlay and interactions between key variables. Another inherent problem associated with using index methods is that variability is often not considered, as average values are often used in calculations for countries or regions. Average values do not always reflect the diversity of situations, or spatial and temporal variability. Situational and contextual understandings and participatory assessments may be required to better design interventions. Issues of scale are important to understanding the costs of appropriate interventions e.g., technology and infrastructure costs can not be considered at the larger scale as this is largely dependent on the appropriate intervention.

Indicators are used for a variety of purposes. Lindholm, Greatorex & Paruch (2007, p.78) conclude that the use of indicators, and weighting and normalisation methods for sustainability analysis of alternative sewerage systems can be problematic. Bias in the selection of indicators and weighting methods can confirm that *“virtually any infrastructure system is more sustainable than any other alternative system”*. They suggest that honest and objective appraisals of critical parameters are essential to inform selection and interpretation of analysis when using indices for any purpose. Chaves & Alipaz (2006); FAO (2003a, 2003b); Fietelson & Chenoweth (2002); Molle & Mollinga (2003); Molle, Mollinga & Meinzen-Dick (2008); Mollinga (2008); Sullivan (2002); Sullivan, Meigh, & Lawrence (2006); Sullivan et al. (2006) cite many examples of problems of the use of indicators arising from:

- choice in data sets, often too much data available and the need to simplify to key variable
- data gaps-for many South Pacific nations and islands are not readily available
- data only available from in-country reports or held by ‘experts’
- remote regions with few people are less likely to have representative data
- poorer nations with less capacity, less likely to have available data
- data from countries involved in conflict not readily available and probably less reliable
- data represented as a range of values, may differ from other representations
- data represented at different and inappropriate scales
- available data of dubious quality
- difficulty in evaluating validity of data, often a subjective process
- lack of data available on specific issues e.g. land degradation data for Mekong River Basin
- collection issues where local customs/practices influences the quality of data
- little capacity to collect and store data
- seasonal fluctuations not taken into ‘average’ value
- intellectual property concerns over sharing data; data not available from organisations that are at least partly commercial or research
- duplication of efforts as well as difficulty in evaluating the validity of data and methodologies
- considerable overlap between indices
- number of variables used to construct an index
- in-country heterogeneities.

)
Molle & Mollinga (2003) illustrate the complexity and difficulties of developing and defining multidimensional indicators. The information iceberg depicted in Figure 2, emphasises the issues of defining and using appropriate data to construct such an indicator, the Sustainable Development Index (SDI). Construction of representative indexes requires expertise in subjective decision making and access to various layers of statistical data. In order to reduce complexity and uncertainty, results are used to compare computed index values of countries that have sufficient data for calculation. There are many challenges inherent in this methodology, particularly in relation to reaching consensus on what ‘good performance’ might actually mean.

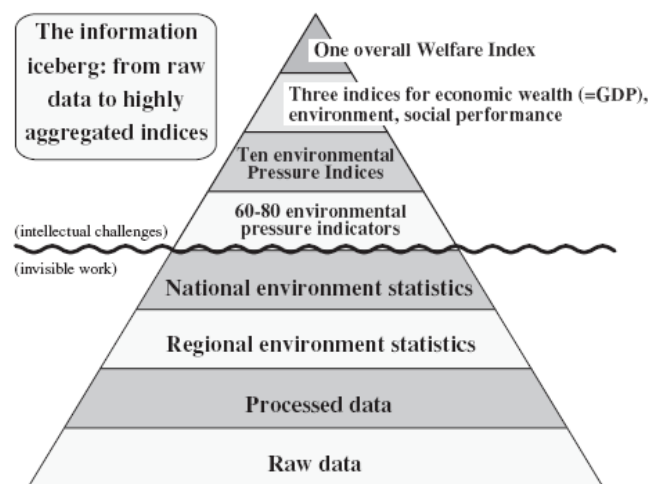


Figure 2 The Information iceberg example of the difficulties inherent in constructing the Sustainable Development Index (SDI).

Source: Jesinghaus (1999) cited Molle & Mollinga (2003 p. 533)

Molle & Mollinga (2003) also suggest the number of variables used to construct an index could be problematic in terms of data collection and the relative impact of a variable on the whole. They conclude that;

In sum, indicators tend to be marred by problems ranging from inadequate quality of data, arbitrariness of weights, incommensurability of values and incorporation of judgments/ standpoints, to classical loss of information in the aggregation process as well as in the construction of composite indices. For all these reasons, they are prone to become black boxes, making it difficult for outsiders to unravel calculations, assumptions and meanings.

Molle and Mollinga (2003) suggest that indicators are a quintessential attempt at legibility and simplification by centralised bureaucracies and provide a means to reduce a “social hieroglyph into a legible and administratively more convenient format” (Scott 1998). Lawrence, Meigh and Sullivan (2002) concede that an index may have a political rather than statistical purpose, while Streeten (1994) claims the benefit of indices is to simplify and focus attention on an issue. However, indices can be useful in de-politicising and de-contextualising problems, rather indices can be used to infer undertaking appropriate actions to initiate research, investment or reforms (Srinivasan 1994).

Molle, Mollinga and Meinzen-Dick (2008) and Lenton, Lewis and Wright (2008) suggest taking an Integrated Water Resources Management (IWRM) approach for holistic management of competing aspects of use of (i) land and water resources, (ii) surface water and groundwater, (iii) upstream and downstream uses, (iv) sectoral approaches, (v) economic production, (vi) environmental sustainability and (vii) inclusion of state and non-state stakeholders. Molle, Mollinga and Meinzen-Dick (2008) claim that IWRM attempts to reconcile goals of economic efficiency, social equity and environmental sustainability while incorporating negotiations with stakeholders. IWRM can be approached through the use of datasets and development of indices and also require interactive participatory processes.

Although there are many concerns over the use of indicators, they do provide a means of relatively ranking countries according to situation and need and as such remains a powerful tool to inform investment strategies.

2.2.5 Graphical representation of indicators and data

Increasingly, Geographical Information Systems are used as a relatively simple means of displaying the data and indices. Several examples are;

1. WaterAid uses innovative mapping programs to display data about access to water and sanitation in developing countries. The display allows for easy visualisation of data embedded in the programs. WaterAid uses the data and mapping displays to direct international aid to those most in need¹⁴. The scope is still limited and WaterAid continues to scale up mapping capability and data availability to enhance decision making.
2. FAO¹⁵ Water, Development and Management Unit have developed an interactive mapping site that focuses on climate change, water and food security. Maps provide visualisations of climate change impacts and suggest response options for agricultural water management in selected agricultural systems. Data is embedded in the program and supporting documents are accessible. Layers of information available in these maps can be used to assess and establish linkages between water and rural livelihoods and the possible impact of climate change.
3. Water Systems Analysis Group (WSAG) has developed “A Global Rapid Indicator Mapping System for Water Cycle and Water Resource Assessment (Global-RIMS)”¹⁶. The development of interactive mapping is used to reflect critical global change issue of water systems and their alteration by anthropogenic activities. Integrative studies of hydrology, biogeochemistry, and human-water interactions are used to analyse the full dimension of anthropogenic change at local, regional, and global scales.

2.3 The relationship of poverty and water

There is as yet no internationally accepted definition or prescribed guidelines for measures of poverty (ADB 2004). The WB’s *World Development Report*¹⁷ and the United Nations Development Programme’s *Human Development Report*¹⁸ use concepts and definitions pertaining to poverty, its measurement and interpretation. ADB (2004 p.27¹⁹) defines poverty as;

Poverty is the deprivation of essential goods, services, and opportunities to which every human being is entitled. Underlying this deprivation is lack of income and the inability to take advantage of opportunities for advancement. Poor people in general lack daily sustenance, suffer from poor health and inadequate education, and do not have the ability to participate meaningfully in making decisions that affect their lives. Poverty is thus measured in terms of food and nutrition, basic education, health care, water and sanitation, political participation, and income and wages.

Consequently, planning and implementation of effective poverty alleviation and poverty reduction programs implies the need for material, financial and scientific resources and information (ADB 2004).

Access to water is recognised as a human right and as such it is inextricably linked to poverty (Molle & Mollinga 2003). Issues of water availability, efficiency of use, water

¹⁴ http://www.wateraid.org/australia/about_us/newsroom/6719.asp?dm_i=310228261

¹⁵ <http://www.fao.org/nr/water/>

¹⁶ <http://rbis.sr.unh.edu/>

¹⁷ World Development Indicators (various editions); The World Bank Atlas (various editions); The World Bank Web site, <http://www.developmentgoals.org/> and <http://devdata.worldbank.org/dataonline/> (Millennium Development Goals); Global Development Finance.

¹⁸ United Nations Development Programme: *Human Development Report* (various editions).

¹⁹ <http://www.adb.org/Statistics/pdf/Reference-Manual.pdf>

productivity and allocation should be approached by planners and researchers in such a way as to ensure human needs are satisfied. The complexity of spatial and temporal variability of water supplies and demand require that decision tools inform decision making (Molle & Mollinga 2003).

2.3.1 Water Poverty Index

Sullivan and colleagues have attempted to quantify “water poverty” and capture a more comprehensive picture of the water-management challenge by constructing a Water Poverty Index (WPI) (Sullivan & Meigh, 2003; Sullivan, Meigh, & Giacomello 2003; Sullivan, Meigh & Lawrence 2006). Water poverty has been defined by Sullivan (2002) as the ability to access adequate or efficient water supplies. The relationship between the physical availability of water, its ease of abstraction, and the level of welfare of the population is estimated using the WPI. The WPI has been used to identify communities with poor water endowments and poor adaptive capacity. The WPI aims to be a holistic policy tool incorporating physical and social sciences and used to understand the physical, economic and social drivers linking water and poverty (Sullivan 2002; Sullivan et al. 2003). In addition, the WPI was designed to assist national decision makers and donor agencies to determine the priorities for interventions in the water sector.

The purpose of developing a WPI is for development agencies, researchers, practitioners and other stakeholders to determine priorities for action and to monitor progress towards development targets²⁰. The WPI is a mechanism to prioritise water needs and provides a means to enable monitoring of progress towards the MDGs²¹.

Water resource assessments which include ground and surface water are used in the development of the WPI. The WPI is considered an holistic water management tool applicable at several spatial scales, i.e., nationally, or at basin, catchment or community scales. By incorporating measures of water use by industry and agriculture, the WPI does not neglect the importance of water needs for food and other productive purposes.

2.3.2 WPI components

The WPI index has been developed as an holistic tool to measure water stress at the household and community levels. (Sullivan et al. 2003). The index combines into a single number a cluster of data directly and indirectly relevant to evaluating water stress. Component variables in the WPI have been identified through extensive consultation (Sullivan, Meigh & Lawrence 2006, p.415). The main components of the WPI include:

- *resources* – how much water is available, taking into account seasonal and inter-annual variability and water quality
- *access* – how well provisioned the population is, including domestic use and irrigation
- *capacity* – *how* to manage water resources, based on education, health and access to financing
- *use* – captures the use made of the water and its contribution to the wider economy (domestic, food, productive purposes)
- *environment* – attempts to capture the environmental impact of water management to ensure long-term ecological integrity.

Figure 3 illustrates the derivation of the WPI. The weightings shown in the WPI formula in Figure 3 can be used to emphasize a particular component of the WPI structure. Sullivan, Meigh & Lawrence (2006) suggest that the relative importance of variables should be a political decision rather than predetermined by researchers with limited local knowledge. As

²⁰ <http://ocwr.ouce.ox.ac.uk/research/wmpg/wpi/>

²¹ <http://ocwr.ouce.ox.ac.uk/research/wmpg/wpi/>

long as the variable definitions and means of measurement are standardised, inter-regional comparisons can be made. The inclusion of weights in the structure allows for adjustment for local utilisation, through a transparent process of consultation with local stakeholders, their needs and priorities. Weighting allows for generic applicability. While the WPI can be applicable to a range of scales, its most useful application is likely to be at the watershed or municipal level. The WPI has been applied at a range of different spatial scales including the community, basin, district and national levels (Sullivan, Meigh & Lawrence 2006).

The WPI is derived from the weighted average of the five components **Resources (R)**, **Access (A)**, **Capacity (C)**, **Use (U)**, and **Environment (E)**.

$$WPI = \frac{w_r R + w_a A + w_c C + w_u U + w_e E}{w_r + w_a + w_c + w_u + w_e}$$

where WPI is the Water Poverty Index value for a particular location, and w is the weight applied to each of the components. Each of the five main components is made up of a number of sub-components, and a weighting can be applied to indicate the importance of each variable. Components are standardized to fall in the range 0 to 100, giving a final WPI value between 0 and 100. The highest value, 100 is taken to be the best situation, with 0 being the worst. To avoid problems of subjectivity, a base line value of the WPI should first be calculated with these weightings set equally.

Figure 3 Derivation of the Water Poverty Index

Source: Sullivan, Meigh & Lawrence. (2006, p.26)

In this research application, an additional component described as vulnerability/resilience/climate change as been included as an important factor in assessing the relationship between poverty and water resources. A 'Water Need' Index (WNI) has been constructed using the Water Poverty Index (WPI) framework to form the basis of a decision-making process and decision support tool. The WPI has a number of other advantages: ease of understanding for policy decision-makers, transparency of the process, empowerment of local communities and adaptability to a variety of local situations and scales (Sullivan et al 2005). The WNI is a further adaptation of the WPI framework and accounts for additional impacting factors in relation to vulnerability, resilience and the implications of projected climate change.

2.4 Summary of literature and data review

Climate Change

- Water supplies are insufficient to meet increasing demand inducing water scarcity in many countries and water supplies are increasingly subject to climate change.
- Intensifying efforts to maintain food security will lead to significant depletions in river flows and groundwater.
- Targeted and contextually sensitive interventions ensuring access to quality water supplies and sanitation will be necessary to ensure that livelihoods, local culture and quality of life will remain protected.

Water and poverty

- Access to water is recognised as a human right and as such it is inextricably linked to poverty.
- Water availability, efficiency of use, water productivity and allocation should be sufficient to ensure human needs are satisfied.
- Water poverty is a measure of the ability to access adequate or efficient water supplies.
- The complexity of spatial and temporal variability of water supplies and demand require that decision tools are used to inform decision making.

Indices

- Effective indicators of water availability are required to support demand management decisions and maintenance of sustainable water supplies.
- Indicators can be used to inform policy makers, donor agencies, and local water managers about water related needs, and to inform investment, development and intervention decisions.
- International institutions collect and collate data which can be used for development of indices.
- Each dataset has a unique presentation of data and a variety of ways of describing the data that constitutes particular indices.
- Indicators have been developed as a means to quantify water resources in conventional water-resources assessments and relatively rank country or regional 'needs', e.g. Water Poverty Index (WPI) and Environmental Vulnerability Index (EVI).
- Reliable data on water scarcity/availability indicators are difficult to obtain.
- Indicator methodology can be problematic, i.e. limitations, reliability and robustness.
- Geographical Information Systems are used as a relatively simple means of displaying the data and indices.
- The complexity of spatial and temporal variability of water supplies and demand require that decision tools inform decision making.

3. METHODOLOGY

A 'Water Need' Index has been constructed using the Water Poverty Index (WPI) framework to form the basis of a decision-making process and tool. Furthermore, the capability of the decision-making tool will be enhanced using engagement methodology through a collective learning process. Indicators have been applied on a national scale for the following countries:

South Asia: Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka

East Asia: Cambodia, China, Indonesia, Laos, Mongolia, Myanmar, Philippines, Thailand

Pacific: Cook Islands, East Timor, Fiji, Papua New Guinea, Niue, Samoa, Solomon Islands, Vanuatu

An application will be made at a more detailed level for the:

Lower Mekong River Basin: Vietnam, Cambodia, Laos, Thailand, with consideration of the upstream impacts of Myanmar and China.

Papua New Guinea: Lihir, where a mining development has put stresses on the local environment

Kiribati: Tarawa where a major urban area is situated on a low-lying atoll with inadequate environmental management

Training of staff for tailored search and evaluation tasks and on ways to update /incorporate new data sets will be conducted.

3.1 Process overview

A model of the process used to select suitable components to include in the calculation of a 'Water Need' Index is depicted in Figure 4. The left of the model describes a qualitative process of selection of appropriate indicators/variables to include in the framework. This involves a variety of techniques to gain opinions from field 'experts', and includes methods such as workshops, surveys, semi-structured interviews and internet conversations forming a deliberative process for the selection of indicators. The right of the model depicts the selection process used to access appropriate data sources to develop indicators. These processes deal with quantitative data, further informing the study by assessing the validity and reliability of the data sources. After initial calculation of the Water Need Index using the WPI framework depicted in Figure 5, further research activities will be invested in developing recommendations to overcome local barriers and facilitate enabling conditions to address water demand management in specified countries or areas. Identification of data gaps and approaches to accessing reliable data and suitable information will follow. Finally, comparisons of the Water Need Index will be conducted for confirmation of the validity and reliability of the methodology.

Potential parameters for use in the construction of a comprehensive and integrated Water Poverty Index are described in Appendix 2. The Water Need Index and database will be graphically represented and is described in detail in 4.1 of the results section.

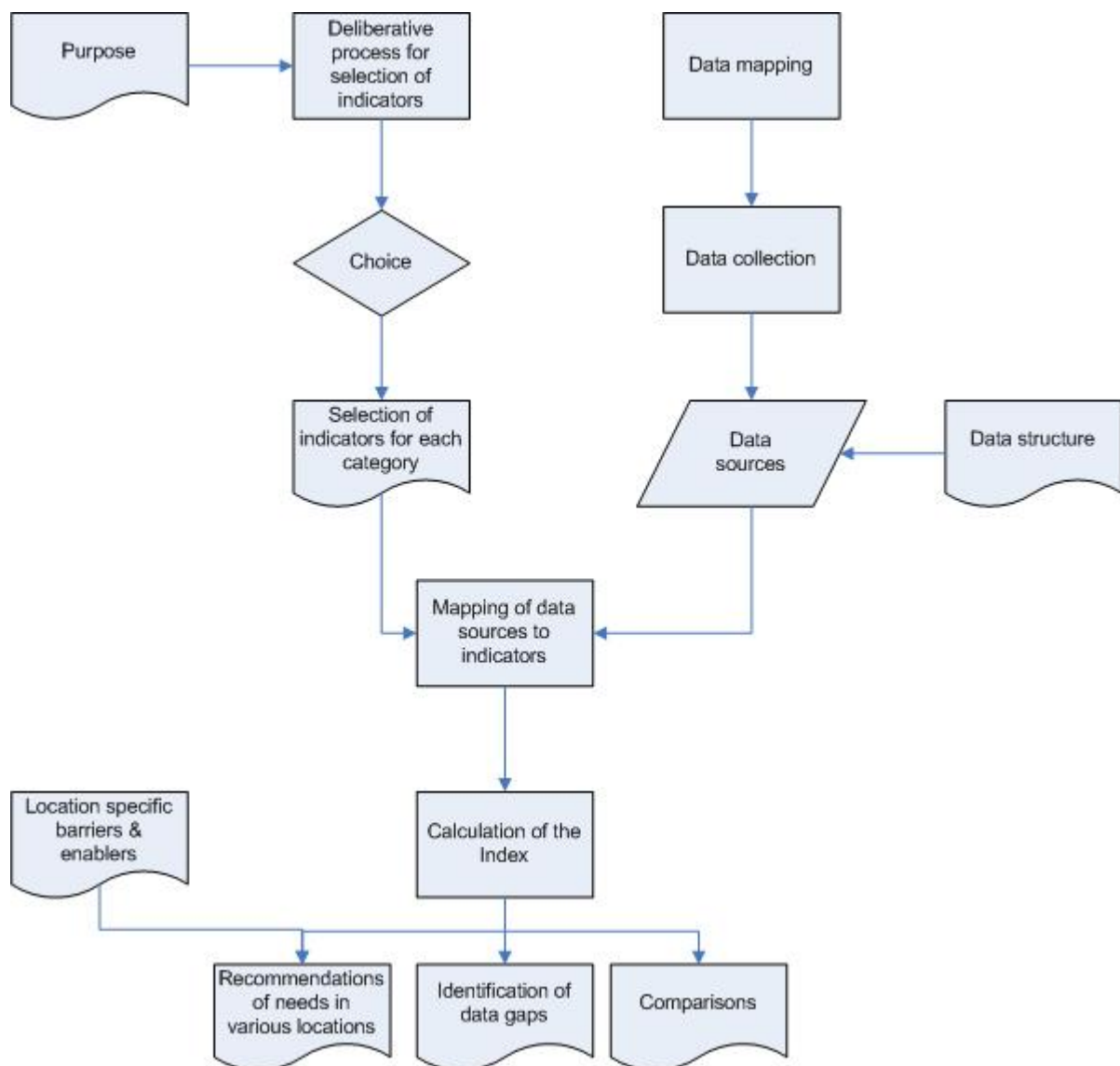


Figure 4 Overview of process used to calculate a Water Need Index

Furthermore, the approach to be used in developing the Water Need Index follows the Water Poverty Index (WPI) framework and is depicted in Figure 4.

3.2 Using case examples

It is hoped that the Water Need methodology and tool will be applied to a number of different types of situations (as described in the Project steering document). Primarily, the methodology and tool will be designed with the following use cases in mind:

- communicating with stakeholders about recipient country needs
- supporting donor agency decisions in investment decisions
- helping local water managers understand local water needs.

3.2.1 Communicating with politicians and stakeholders

Indicators are instruments used to communicate simplified, synthesised information to policy makers and to the general public. The process requires quantification of a problem, simplification of social, environmental, and economic data, and communication to galvanise decision makers into action (Fietelson & Chenoweth 2002). Effective indicators of water availability are required to support demand management decisions and maintenance of sustainable water supplies. Improving water availability is often affected by structural

impediments so indices can be a means of facilitating policy responses to supply problems (Fietelson & Chenoweth 2002; Sullivan 2002). Effective policy making is supported by rigorous interdisciplinary science and accurate monitoring (Sullivan 2002).

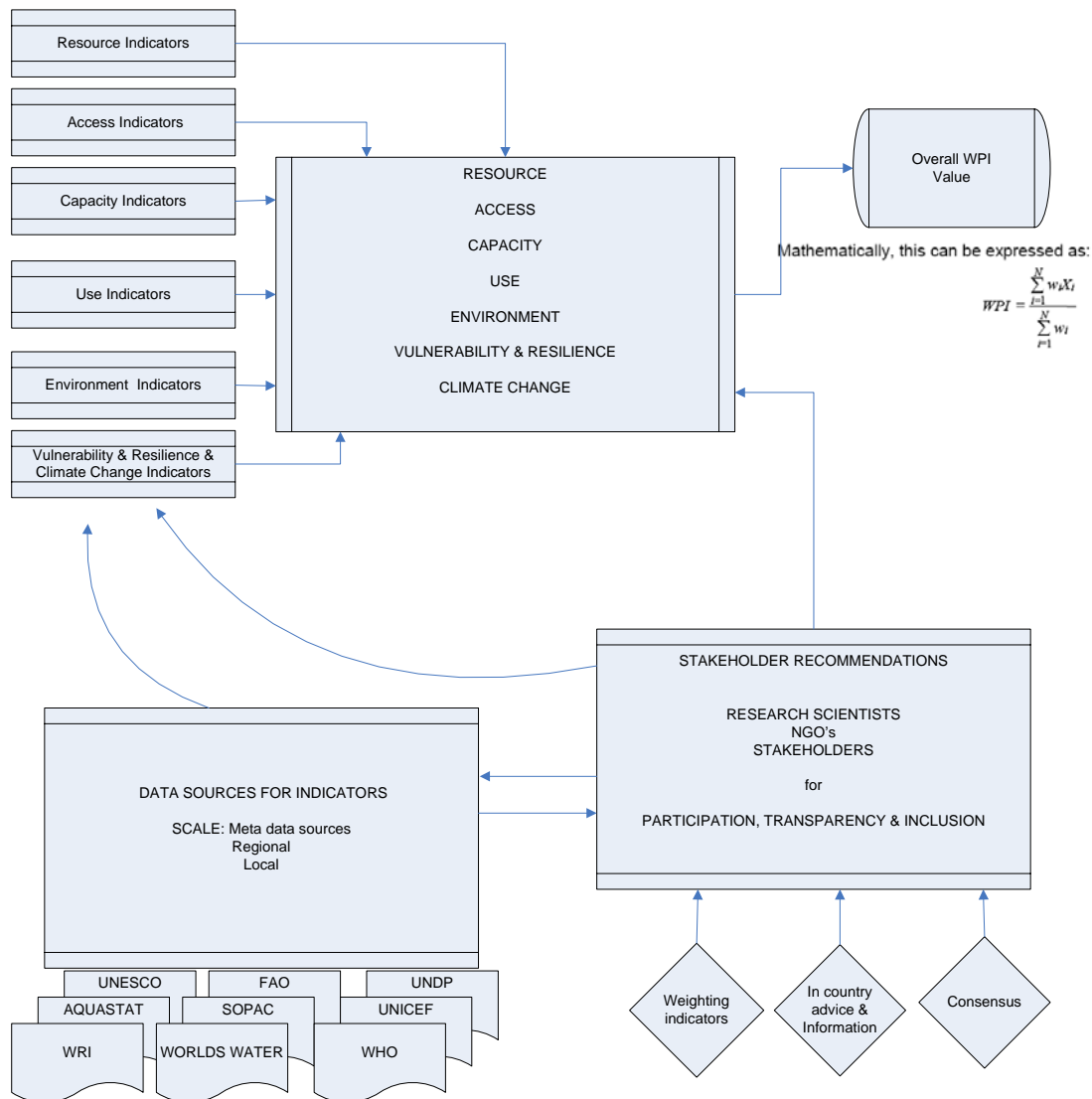


Figure 5 Approach to developing Water Needs Index using the Water Poverty Index (WPI) Framework

3.2.2 Supporting donor agency investment decisions

Indicators provide international comparisons of countries and regions and identify trends over time (UK Department of the Environment 1996). Indicators provide a first pass assessment of where to invest donor funds. However, the underlying assumption is that the donor agency knows what types of *need* its organisation wants to address. The focus may also change over time. Therefore, to allow flexibility and adaptive capacity, the methodology ought to include a mechanism for changing research and development focus. To deal with changing situations, and adaptive management decisions, the methodology used will include an engagement process, which in turn informs the structure and components of the Water Need Index. After the first assessment of ‘*need*’, it is envisioned that there will be further exploration of local issues and possible interventions, in order to make a more informed assessment of cost efficiency in interventions. Finally, interventions will be explored in a more participatory manner with local water managers and stakeholders. In other words, the methodology will have sequential activities listed below that follow processes depicted in Figures 4 and 5.

1. Collaborative choice of investment focus
2. Selection of components and structure of Index
3. Calculation of the Water Need Index
4. Identification of focus locations
5. In-depth exploration of local contexts in target locations
6. Preliminary evaluation of cost-efficiency and subsequent prioritisation
7. Participatory design of interventions

3.2.3 Understanding local water needs

Identification of communities that require provision of a basic water supply is needed, often in the poorest and least developed countries. The WPI has been used in urban and rural African communities, and has been useful in identifying the comparative state of the water sector with some degree of accuracy (Sullivan, Meigh & Lawrence 2006). Variables for this research project will be constructed using proxies for missing or incomplete data and involve subjective quantitative approaches i.e. key informant interviews or household surveys. The methodology will allow for index computation, though is subject to scrutiny in relation to research rigour, reliability and validity.

4. INITIAL RESULTS

4.1 GIS display of Water Need Indicator maps-WPI Prototype

The ArcGIS Server software from ESRI has been chosen as a relatively simple way of displaying the Water Need Indicator, component maps and a case study of available data for the Mekong River Basin. This software allows users to take an existing ESRI ArcMap project displaying the desired spatial data, publish it as a map service and then create a web application that is visible on the internet. Within this interface users can zoom in and out, change the visible layers, and view attribute information for selected countries/catchments. The web page will be accessible via a web address that will require a username and password.

The prototype has been developed using the following processes;

1. Data preparation and display using ArcInfo and ArcMap for indices and components at the national and Mekong Basin catchment scales
2. Publication of the ArcMap projects using ArcGIS Server
3. Creation of a web application based on the published map services from step 2 using ArcGIS Server

Additional steps will be the finalisation of the indices, updating of the mapped data, and assignment of comprehensive metadata linked to the mapping web page. The current version of the prototype web page can be seen in Figure 6. Metadata documenting sources and processing for the mapped datasets will be accessible via a link on the web page. This prototype is under construction, with completion date September 2008.

4.1.1 Data Sources

There are 29 Asian countries that need to be displayed for this project, with 28 of the 29 country boundaries sourced from the 'country' shapefile from the ESRI projections training datasets dated 2003. The remaining country boundary (East Timor) was sourced from <http://biogeo.berkeley.edu/gadm/>. The geodatabase version of the country boundaries 'gadm_v0dot9.mdb' was downloaded. The Mekong catchment boundaries were supplied in the form of a zipped shapefile²². Data for indices were collated by project members. The spatial data were converted to consistent formats, the index and component information was attached to the attribute tables, then the ArcMap projects were created for the national and Mekong Basin versions.

4.1.2 Example of choices for indicators and their components

Figure 6 depicts a display of information from global and regional data sets for the 29 selected countries developed using ArcInfo compatible versions of the various national scale index and component data. The display includes:

- Water Need Index (WNI)
- WNI components (resources, capacity, access, use, and environment)
- Environmental Vulnerability Index (EVI)
- EVI components (climate change, natural disaster, biodiversity, desertification, water, agriculture and fish, and human health)
- Environmental Sustainability Index (ESI)
- Environmental Performance Index (EPI)
- Water Poverty Index (WPI)
- Human Development Index.(HDI).

²² CSIRO Challenge Program

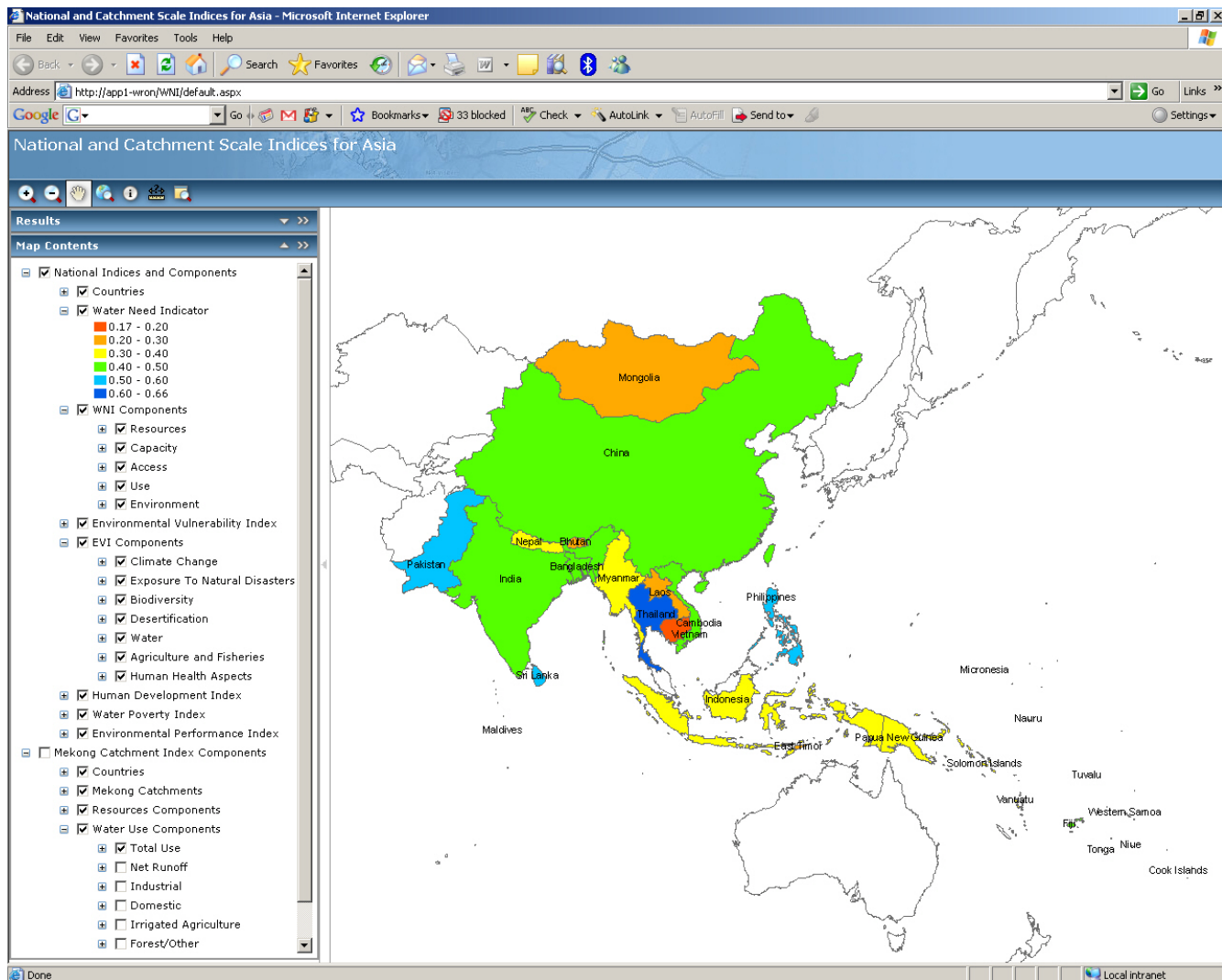


Figure 6: Single screen user interface with lists for selection of index and components.

The application shown in Figure 6 includes indices at a national scale and at a regional scale, including sub-components. The calculation is a weighted average, where the selection of components and weights vary depending on user choices. In the current application flat weights have been used and the components are shown in the second indented tick box list.

For the national scale assessments, the indicator values have been pre-calculated in an Excel spreadsheet. In the regional application (i.e., for the Mekong), the calculation involves using shape files at a number of scales, such as national, province, and catchment scales, with values for each polygon feeding into a weighted average calculation.

For the national scale application, this software will take pre-calculated values in an input file:

- The format of the input file is an Excel spreadsheet converted to a csv²³ file.
- Each of the indicators will have a value between 0 and 1.
- Ranges of values are displayed using different colours (as shown in Figure 6).
- Each indicator has a number of components and these can be displayed by using the tick boxes in the second indented list (as per Figure 6).

At scales other than the national scale, the process will be similar, but the values in the input file (also a csv file) need to correspond to the polygons in a chosen geographical layer.

Within the current stage of the project, additional functionality to be added to the software will be:

²³ A “comma separated values” file.

1. User interface providing the ability to add data relating to pre-existing geographical layers; including meta-data.
2. User interface providing the ability to add new geographical layers; including meta-data.
3. As the application is web-based it will be critical to create a “user log-in” functionality in order to limit the number of users that can access it.
4. User interface to allow the creation of a new indicator by selecting components and weights at different scales.

For future versions of the software tool, to patch up data gaps when data values are missing for particular countries (or another type of geographical entity), it is envisioned that the software will allow the user to specify “similarity rules”. This means that the missing value, say for Environmental Vulnerability, is replaced with an average of the values in the countries which have been identified as “similar”. It is envisioned that such similarity rules will be developed using a process of expert consultation.

4.2 National scale assessments

The choice of perspective will impact on what data and weights that are used. For the prototype depicted in Figure 6, three different perspectives will be taken; that of (i) reducing poverty, (ii) improving health and (iii) increasing food production. The **‘Resources’** component of the WNI will be measured by the following sub-components:

- reducing poverty- TARWR per person
- improving health- Water quality indicator
- increasing food production- TARWR per person.

The **‘Environment’** component will be measured by:

- deforestation – annual change rates (%)
- land degradation (unfortunately suitable data has not yet been found).

The other sub-components of the WNI for **‘Access’**, **‘Use’** **‘Capacity’** and **‘Vulnerability’** are yet to be determined for the national scale. Appendix 2 lists a selection of potential components for use in construction of a comprehensive and integrated Water Need Index. Appendix 3 describes information on the compilation of the meta-data and data source information on previously constructed indexes. Compilation of meta-data information will allow for a greater understanding of the indexes depicted in the WNI prototype and is essential for web based applications. The data in appendices will be further defined and refined during the course of the project. More detailed descriptions of components and sub-components to be used in the WNI are depicted in Appendix 4.

4.3 Regional scale assessments

4.3.1 Mekong River Basin

Several spatial units will be considered for mapping of the Mekong River Basin indices as data is not always available.

‘Resources’ component will be measured using resource availability and variability values for catchments described in the Challenge project i.e.

- basin water use summary
- water availability
- annual available water
- annual water withdrawals
- domestic water total
- domestic surface water
- domestic groundwater

- industrial total
- industrial groundwater.

'Use' component will be measured using resource availability and variability values for catchments described in the Challenge project i.e.

- rain-fed agriculture
- woodland/grassland
- forest + other
- irrigated agriculture
- domestic
- industrial
- net runoff
- total.

Data are also available at the provincial scale according to the Social Atlas²⁴ (Hook, Novak & Johnstone 2003) for the following components:

'Access' component will be measured by:

- access to safe water (%)
- access to sanitation (%).

'Use' component will be measured by:

- infant mortality rate (per 1000)
- child malnutrition (%)
- poverty rate (%).

'Capacity' component will be measured by:

- male literacy rate (%)
- female literacy rate (%)
- GDP per capita (\$PPP).

Data is available for deforestation at a national basis as a measure of Environmental factors

'Environment' component will be measured by:

- deforestation – Annual change rates (%)
- land degradation (unfortunately suitable data has not yet been found).

'Vulnerability' component will be measured by:

- annual population increase
- proportion of population aged 0-14
- distance from ocean (i.e., further downstream is more vulnerable than further upstream)
- changes of mean temperature (from 1961 to 2010).

4.3.2 Pacific case study:

Tentatively, Lihir in Papua New Guinea and Tarawa in Kiribati will be piloted as representative case studies of the Pacific region. The case studies will be discussed in final report, September 2008.

²⁴ http://www.mrcmekong.org/download/free_download/Social-Atlas/introduction.pdf

5. DATA SOURCE ISSUES

The literature and data review suggested various factors will influence the usefulness of indicator methodology i.e. limitations, reliability and robustness of data source. Consequently, information on the sources of data to be selected for development of the Water Need Index is crucial to the rigour of this methodology. Appendix 4 provides details of indicators and data sources used to develop the Water Need Index. The following sections deal with data source issues.

In order to select the most appropriate data for use in the Water Need Index data sources are scanned for details about the data source such as:

- suitability
- representativeness
- method of collection, frequency of data collection, date of collection
- original source, e.g. FAOSTAT, 2000
- implications of the value what does data claim to measure
- reliability
- scale of reference i.e. city, region, province or country
- temporal reference i.e. seasonal difference, accuracy, timeframe, transferability,
- geographical limitations, e.g. what areas are not covered
- level of subjectivity, e.g. how subjective is the evaluation?
- average values do not always reflect the diversity of situations, or spatial and temporal variability
- Q-type; “fully quantitative”, “categorized”, “converted qualitative”, etc.

5.1 Scale concerns

Data are often produced at different scales according to the purpose of the data and dependant on the organisation collecting data. For example, the Mekong River Basin data is available at national, provincial and catchment scales. Practically, the data cannot be directly compared, rather used with other similarly scaled data. Generally, data are available at national scale, though this is not the case for many Pacific countries in this study. When developing intervention strategies it is essential to use data at an appropriate scale, to understand the ultimate cost of implementation.

Sullivan, Meigh & Lawrence (2006) suggest large scale data sets and models are purely deterministic approaches to water assessment and often information and data at smaller scales would better inform investment decisions. Problems occur when the data is of dubious quality and/or presented at an inappropriate scale. Although data can be scaled up or down, this can generate inaccuracies and decrease the reliability of the approach (Sullivan, Meigh & Lawrence 2006). In addition, models built from data representing average conditions do not represent the actual conditions found in most places.

The benefit of using an index such as the WPI is to inform at various spatial scales. In this study data at several spatial scales are used.

5.2 Dealing with the ‘Information Iceberg’

As mentioned in the literature and data review, Molle & Mollinga (2003) illustrate (Fig.2) the complexity and difficulties of developing and defining multidimensional indicators. They emphasise the need for expertise in subjective decision making about suitable statistical data and consideration of the number of variables used to construct an index. Consequently, transparency of calculations, assumptions and meanings is essential for this project. Transparency and inclusivity in decisions about the raw and processed data and the statistics to be used to develop the overall Water Need Index will ensure a robust participatory process. Field ‘experts’ will also be involved in advice on the appropriate data for development of indices, i.e., the intellectual challenges.

5.3 Dealing with data source gaps

The formulation of an index and associated components is dependant on available data. Existing data may not have established metrics for specific variables. For example, complex variables that describe threats, linkages and underlying global water systems, may not have available or measurable data in existing data sets (Sullivan et al. 2006).

5.4 Dealing with data gaps

Incomplete global data sets are problematic for this research. Typically, countries in the Pacific region are geographically remote, small and have few residents and data is often not available in accessible global data sets. Variables for this research project will be constructed using proxies for missing or incomplete data and involve subjective quantitative approaches i.e. key informant interviews or household surveys. The methodology will allow for index computation, though is subject to scrutiny in relation to research rigour, reliability and validity. In the future data gaps may benefit from increasingly available remote sensing data, typically used to access environmental data. Regular updates by new satellite data imagery will aid the reliability of such data.

5.5 Inclusion of social data

Socio-economic data is available from numerous global data sets and for regional areas such as the Mekong River Basin (ADB;FAO;IMF;MRC;UNESCO;UNDP;WB;WHO). More specific data on gender related activities is not readily available, nor is there appropriate methodology for inclusion in an index. Participatory methodologies will be developed with local communities to access reliable data for inclusion in this project.

5.6 Infrastructure costs

Problems are expected with costing of infrastructure as solutions are dependent on local contexts and available infrastructure, geography, and present water supplies. Qualitative, participatory processes will augment these decisions and be used to glean insights and additional information.

5.7 Selection of weightings

Initially the Water Need Index will have a flat calculation structure which will not adequately account for the importance or possible interactions between variables. Data will be scrutinised and weightings developed as the data is refined and the framework developed.

6. CONCLUSION

The purpose of this preliminary study is to highlight the complexity and uncertainty, yet the usefulness of index methodology to inform international investment decisions. Accordingly, the review of literature and data sources suggested the need for careful consideration of methodology and data selection. Accessing relevant and reliable data, development of indexes, indices and components will be an ongoing process in this project. The WPI framework has been selected to guide the development of the decision support tool.

The initial GIS mapping application will display the Water Need Indicator, and component maps for the 29 countries of interest. In addition, a case study of available data for the Mekong River Basin has been constructed. The decision support tool will be refined and further developed, data sources identified and information on their reliability, availability and limitations assessed. Additional steps will be the finalisation of the indices, updating of the mapped data, and assignment of comprehensive metadata linked to the mapping web page.

The deliverables for the project will be completed by September 2008 which will include a fully functional decision support tool capable of accessing available data embedded in the application data base. This will be accessible to AusAID staff after development of a manual outlining the capability of the application and a training workshop is delivered.

Ongoing project activities will identify data gaps and a qualitative approach will be designed to access additional and appropriate data from a non-quantitative perspective for smaller countries and at local levels, depending on the suggestions from AusAID staff as to their requirements. This will be a participatory process, inclusive and iterative in nature.

6.1 Future recommendations

The following issues that are not included in the project scope at this stage and will be considered for inclusion in follow-on projects:

- determination of infrastructure and technology costs because this depends largely on the context
- gender - there is lack of data and no appropriate methodology for inclusion in an index
- the index has a flat calculation structure which doesn't take into account interactions of variables
- details of the contents of the training manual.

The expectation of Aus AID staff is to have a successful research Alliance between CSIRO and AusAID which produces a tested, world class leading edge tool which is scalable and practical and will be used in policy and program development for Watsan (Water and Sanitation)²⁵. To achieve these outcomes subsequent research and development projects will be conceptualised to aid international investment strategies.

In addition to the development of the specialised application for water and sanitation, several other options for research and development will be considered including:

- Bayesian methodology to take into account reliability of data sources and structure of interactions between key variables (i.e. poverty, health, wealth, etc)
- methodology for collecting gender-water information to incorporate into the methodology, acknowledging women's need to access water and their role in decisions.

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<http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTWAT/0,,contentMDK:21706928~menuPK:4602430~pagePK:148956~piPK:216618~theSitePK:4602123,00.html>

REFERENCES

- ADB (2008). Database and Development Indicators. Retrieved 08/06/2008, from <http://www.adb.org/Statistics/default.asp> updated May 2008
- ADB (2004). Development Indicators Reference Manual Concepts and Definitions. Retrieved 08/06/2008 (update November 2004), from <http://www.adb.org/Statistics/pdf/Reference-Manual.pdf>
- Asia-Pacific Human Development Report 2006. (2006). Human Development Index. from <http://www.pcij.org/blog/wp-docs/HDR2006/Prelim.pdf>
- AusAID Australian aid: Approaches to managing water resources. Retrieved 08/06/2008 from http://www.ausaid.gov.au/publications/pdf/ausaid_water.pdf
- Chambers, R. (1994) Shortcut and Participatory Methods for Gaining Social Information for Projects. Cernea, M, ed. Putting People First. Sociological Variables in Rural development. 2nd ed. Oxford University Press: World Bank; 1994
- Chaves H. M.L. & Alipaz, S. (2006). An Integrated Indicator Based on Basin Hydrology, Environment, Life, and Policy: The Watershed Sustainability Index. *Water Resource Management DOI 10.1007/s11269-006-9107-2*.
- Chenoweth, J., (2008). A re-assessment of indicators of national water scarcity. *WATER INTERNATIONAL*, 33(1), 5-18.
- Cook, S. & Gichuki, F. (2006). Analyzing water poverty: Water, agriculture and poverty in basins. Basin Focal Project Working Paper No. 3. URL: http://www.waterandfood.org/fileadmin/CPWF_Documents/Documents/Basin_Focal_Projects/BFP_restricted/Paper_3_14JY06.pdf
- Falkenmark M, & Chapman T (1989) Comparative hydrology: An ecological approach to land and water resources. (UNESCO: Paris, France)
- Feitelson, E. & Chenoweth, J. (2002). Water poverty: towards a meaningful indicator. *Water Policy [Water Policy]*, 4(3), 263-281.
- Food and Agriculture Organization of The United Nations (FAO). (2003a). Review Of World Water Resources by Country. Retrieved 07/05/2008, from www.fao.org/landandwater/aglw/aquastat/water_res/index.stm
- Food and Agriculture Organisation (FAO). (2003b). *Choosing a method for Poverty Mapping*. Agriculture and Economic Development Analysis Division. Rome: Retrieved 08/04/2008 from <http://www.fao.org/DOCREP/005/Y4597E/Y4597E00.HTM>
- Federico Properzi, W. & Peregrine Swann, E. (2008) UN-Water Global Annual Assessment. Global Annual Assessment of Sanitation and Drinking-Water (GLAAS), CSD-16 Side Event
- HDI 2007 Asia-Pacific Human Development Report 2006
- Hook, Jacob; Novak, Susan & Johnston, Robyn, 2003. Social Atlas of the Lower Mekong Basin. Mekong River Commission, Phnom Penh. 154 pages. ISSN: 1727-1800
- IPCC. (2007). Climate Change 2007- Impacts., Adaptation and Vulnerability Contribution of Working group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. In M.L. Parry, O.F. Canziani, J.P. Palutikof, P. J. v. d. Linden & C.E. Hanson (Eds.). Cambridge, UK: Cambridge University Press.

- Hoanh, C. T., Guttman, H., Droogers, P. & Aerts, J. (2003) Water, Climate, Food, and Environment in the Mekong basin in southeast Asia Final Report.
- Laurence, P., Meigh, J., & Sullivan, C. (2002). *The Water Poverty Index: An International Comparison* Keele, UK: Keele University
- Lindholm, O., Grotarex, J. M., & Paruch, A. M. (2007). Comparison of methods for calculation of sustainability indices for alternative sewerage systems--Theoretical and practical considerations. *Ecological Indicators*, 7(1), 71-78.
- Lukasiewicz, A., Minchin, S. & Kirby, M. (2008) Investment in Future water Supply in the Asia-Pacific region- An Overview of Issues. A Report to AusAID. Canberra, CSIRO
- Molle, F., & Mollinga, P. (2003). Water poverty indicators: conceptual problems and policy issues. *Water Policy* 5 529–544.
- Molle, F., Mollinga, P., & Meinzen-Dick, R. (2008). Water, Politics and Development: Introducing Water Alternatives. *Water Alternatives*, 1(1), 1-6.
- Mollinga, P. P. (2008). Water, politics and development: Framing a political sociology of water resources management. *Water Alternatives*, 1(1), 7-23.
- Sullivan, C. (2002). Calculating a water poverty index. *World Development*, 30(7), 1195-1210.
- Sullivan, C., Meigh, J. & Lawrence, P. (2006) Application of the water poverty index at different scales: A cautionary tale. *Water International*, 31, 412-426.
- Sullivan, C., & Meigh, J. (2003). Considering the Water Poverty Index in the context of poverty alleviation. *Water Policy [Water Policy]*, 5, 5-6.
- Sullivan, C. A., Meigh, J. R., & Giacomello, A. M. (2003). The Water Poverty Index: Development and application at the community scale. *Natural Resources Forum, UN [Nat. Resource. Forum, UN]*, 27(3), 189-199.
- Sullivan, C., Vorosmarty, C., Craswell, E., Bunn, S., Cline, S., Heidecke, C., et al. (2006). *Mapping the links between Water Poverty and Food Security. Report on the Water Indicators workshop held at the Centre for Ecology and Hydrology, Wallingford, UK, 16 to 19 May, 2005. GWSP Issues in GWS Research, No 1. GWSP IPO, Bonn. www.gwsp.org*
- Srinivasan, T. N. (1994). Human development: a new paradigm or reinvention of the wheel? *American Economic Review* 84(2), 238-243.
- Streeten, P. (1994). Human Development: means and ends. *American Economic Review*, 84(2), 232-237.
- UK Department of the Environment. (1996). *Indicators of sustainable development for the United Kingdom*. London: Department of the Environment
- UNESCO (1987) edited by Malin Falkenmark and Tom Chapman- **need reference**
- United Nations Development Programme. (2007). Fighting Climate Change: Human Solidarity in a Divided World. The 2007/2008 Human Development Report. Retrieved 09/06/2008, from <http://hdr.undp.org/en/>

United Nations Millennium Declaration. (2000). Retrieved 08/06/2008, from <http://www.un.org/millennium/declaration/ares552e.htm>

United Nations World Water Assessment Programme UN-WWAP. (2003). Retrieved 07/06/2008, from <http://www.unesco.org/water/wwap/wwdr/>

United Nations World Water Assessment Programme UN-WWAP. (2006). Retrieved 08/06/2008, from http://www.unesco.org/water/wwap/wwdr/wwdr2/pdf/wwdr2_ch_14.pdf

UN-Water. A Guide to UN Water. Retrieved 07/06/2008, from http://www.unwater.org/downloads/UNW_brochure_EN_webversion.pdf

United Nations (2006) 'Water a shared responsibility. The United Nations World Water Development Report 2.' New York.

World Bank. (2008). Retrieved 08/06/2008, from <http://web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS/0,,contentMDK:20535285~menuPK:1192694~pagePK:64133150~piPK:64133175~theSitePK:239419,0.html>

APPENDIX 1
OFFICIAL LIST OF MILLENNIUM DEVELOPMENT GOALS AND INDICATORS

Millennium Development Goals (MDGs)	
Goals and Targets (from the Millennium Declaration)	Indicators for monitoring progress
Goal 1: Eradicate extreme poverty and hunger	
Target 1.A: Halve, between 1990 and 2015, the proportion of people whose income is less than one dollar a day	1.1 Proportion of population below \$1 (PPP) per day* 1.2 Poverty gap ratio 1.3 Share of poorest quintile in national consumption
Target 1.B: Achieve full and productive employment and decent work for all, including women and young people	1.4 Growth rate of GDP per person employed 1.5 Employment-to-population ratio 1.6 Proportion of employed people living below \$1 (PPP) per day 1.7 Proportion of own-account and contributing family workers in total employment
Target 1.C: Halve, between 1990 and 2015, the proportion of people who suffer from hunger	1.8 Prevalence of underweight children under-five years of age 1.9 Proportion of population below minimum level of dietary energy consumption
Goal 2: Achieve universal primary education	
Target 2.A: Ensure that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling	2.1 Net enrolment ratio in primary education 2.2 Proportion of pupils starting grade 1 who reach last grade of primary 2.3 Literacy rate of 15-24 year-olds, women and men
Goal 3: Promote gender equality and empower women	
Target 3.A: Eliminate gender disparity in primary and secondary education, preferably by 2005, and in all levels of education no later than 2015	3.1 Ratios of girls to boys in primary, secondary and tertiary education 3.2 Share of women in wage employment in the non-agricultural sector 3.3 Proportion of seats held by women in national parliament
Goal 4: Reduce child mortality	
Target 4.A: Reduce by two-thirds, between 1990 and 2015, the under-five mortality rate	4.1 Under-five mortality rate 4.2 Infant mortality rate 4.3 Proportion of 1 year-old children immunised against measles
Goal 5: Improve maternal health	
Target 5.A: Reduce by three quarters, between 1990 and 2015, the maternal mortality ratio	5.1 Maternal mortality ratio 5.2 Proportion of births attended by skilled health personnel
Target 5.B: Achieve, by 2015, universal access to reproductive health	5.3 Contraceptive prevalence rate 5.4 Adolescent birth rate 5.5 Antenatal care coverage (at least one visit and at least four visits) 5.6 Unmet need for family planning
Goal 6: Combat HIV/AIDS, malaria and other diseases	
Target 6.A: Have halted by 2015 and begun to reverse the spread of HIV/AIDS	6.1 HIV prevalence among population aged 15-24 years 6.2 Condom use at last high-risk sex 6.3 Proportion of population aged 15-24 years with comprehensive correct knowledge of HIV/AIDS 6.4 Ratio of school attendance of orphans to school attendance of non-orphans aged 10-14 years
Target 6.B: Achieve, by 2010, universal access to treatment for HIV/AIDS for all those who need it	6.5 Proportion of population with advanced HIV infection with access to antiretroviral drugs
Target 6.C: Have halted by 2015 and begun to reverse the incidence of malaria and other major diseases	6.6 Incidence and death rates associated with malaria 6.7 Proportion of children under 5 sleeping under insecticide-treated bednets 6.8 Proportion of children under 5 with fever who are treated with appropriate anti-malarial drugs 6.9 Incidence, prevalence and death rates associated with tuberculosis 6.10 Proportion of tuberculosis cases detected and cured under directly observed treatment short course
Goal 7: Ensure environmental sustainability	

Target 7.A: Integrate the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources	7.1 Proportion of land area covered by forest 7.2 CO2 emissions, total, per capita and per \$1 GDP (PPP) 7.3 Consumption of ozone-depleting substances 7.4 Proportion of fish stocks within safe biological limits
Target 7.B: Reduce biodiversity loss, achieving, by 2010, a significant reduction in the rate of loss	7.5 Proportion of total water resources used 7.6 Proportion of terrestrial and marine areas protected 7.7 Proportion of species threatened with extinction
Target 7.C: Halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation	7.8 Proportion of population using an improved drinking water source 7.9 Proportion of population using an improved sanitation facility
Target 7.D: By 2020, to have achieved a significant improvement in the lives of at least 100 million slum dwellers	7.10 Proportion of urban population living in slums**
Goal 8: Develop a global partnership for development	
Target 8.A: Develop further an open, rule-based, predictable, non-discriminatory trading and financial system Includes a commitment to good governance, development and poverty reduction – both nationally and internationally	<i>Some of the indicators listed below are monitored separately for the least developed countries (LDCs), Africa, landlocked developing countries and small island developing States.</i> <u>Official development assistance (ODA)</u> 8.1 Net ODA, total and to the least developed countries, as percentage of OECD/DAC donors' gross national income 8.2 Proportion of total bilateral, sector-allocable ODA of OECD/DAC donors to basic social services (basic education, primary health care, nutrition, safe water and sanitation) 8.3 Proportion of bilateral official development assistance of OECD/DAC donors that is untied 8.4 ODA received in landlocked developing countries as a proportion of their gross national incomes 8.5 ODA received in small island developing States as a proportion of their gross national incomes
Target 8.B: Address the special needs of the least developed countries Includes: tariff and quota free access for the least developed countries' exports; enhanced programme of debt relief for heavily indebted poor countries (HIPC) and cancellation of official bilateral debt; and more generous ODA for countries committed to poverty reduction	<u>Market access</u> 8.6 Proportion of total developed country imports (by value and excluding arms) from developing countries and least developed countries, admitted free of duty 8.7 Average tariffs imposed by developed countries on agricultural products and textiles and clothing from developing countries 8.8 Agricultural support estimate for OECD countries as a percentage of their gross domestic product 8.9 Proportion of ODA provided to help build trade capacity
Target 8.C: Address the special needs of landlocked developing countries and small island developing States (through the Programme of Action for the Sustainable Development of Small Island Developing States and the outcome of the twenty-second special session of the General Assembly)	<u>Debt sustainability</u> 8.10 Total number of countries that have reached their HIPC decision points and number that have reached their HIPC completion points (cumulative) 8.11 Debt relief committed under HIPC and MDRI Initiatives 8.12 Debt service as a percentage of exports of goods and services
Target 8.D: Deal comprehensively with the debt problems of developing countries through national and international measures in order to make debt sustainable in the long term	8.13 Proportion of population with access to affordable essential drugs on a sustainable basis
Target 8.E: In cooperation with pharmaceutical companies, provide access to affordable essential drugs in developing countries	8.14 Telephone lines per 100 population 8.15 Cellular subscribers per 100 population 8.16 Internet users per 100 population
Target 8.F: In cooperation with the private sector, make available the benefits of new technologies, especially information and communications	

Source Official list <http://mdgs.un.org/unsd/mdg/Resources/Attach/Indicators/OfficialList2008.doc> accessed 08/06/2008 All indicators should be disaggregated by sex and urban/rural as far as possible. Effective 15 January 2008

The Millennium Development Goals and targets come from the Millennium Declaration, signed by 189 countries, including 147 heads of State and Government, in September 2000 (<http://www.un.org/millennium/declaration/ares552e.htm>) and from further agreement by member states at the 2005 World Summit (Resolution adopted by the General Assembly A/RES/60/1, <http://www.un.org/Docs/journal/asp/ws.asp?m=A/RES/60/1>). The goals and targets are interrelated and should be seen as a whole. They represent a partnership between the developed countries and the developing countries "to create an environment – at the national and global levels alike – which is conducive to development and the elimination of poverty".

* For monitoring country poverty trends, indicators based on national poverty lines should be used, where available.

**The actual proportion of people living in slums is measured by a proxy, represented by the urban population living in households with at least one of the four characteristics: (a) lack of access to improved water supply; (b) lack of access to improved sanitation; (c) overcrowding (3 or more persons per room); and (d) dwellings made of non-durable material

APPENDIX 2

POTENTIAL COMPONENTS AND DATA SOURCES FOR USE IN CONSTRUCTION OF A COMPREHENSIVE AND INTEGRATED WATER NEED INDEX

Potential parameters for use in the construction of a comprehensive and integrated Water Need Index

Component	Sub-component	Sources
<p>Resources</p> <p>Indicators of water supply & variability</p>	<ul style="list-style-type: none"> assessment of surface water and groundwater availability using hydrological and hydrogeological techniques: TARWR quantitative and qualitative evaluation of the variability or reliability of resources :Variability = 90p - 10p / 50p annual rainfall percentiles (as per BOM) quantitative and qualitative assessment of water quality <ul style="list-style-type: none"> a)Nitrogen in groundwater, b)Arsenic in groundwater, c) Faecal coliforms in groundwater access to alternative water sources* evidence of groundwater over-extraction* 	<p>WPI Water Resources and Freshwater Ecosystems -- Freshwater Indices: Water Poverty Index http://earthtrends.wri.org/searchable_db/index.php?step=countries&cID%5B%5D=31&theme=2&variable_ID=1299&action=select_years</p> <p>TARWR: Review of water resources statistics by country: AQUASTAT collects statistics on water resources and data on water resources obtained from national sources are systematically reviewed to ensure consistency in definitions and between countries sharing the same river basin. http://www.fao.org/nr/water/aquastat/water_res/index.stm</p> <p>Water quality indicator values in selected countries* Water quality indicator chart WWDR_chart2_eng.pdf ASIA-PACIFIC HUMAN DEVELOPMENT REPORT 2006 Statistical annexes: Renewable water resources in the world by country</p>
<p>Access</p> <p>Indicators of access to good quality water</p>	<ul style="list-style-type: none"> access to clean water as a percentage of households having a piped water supply reports of conflict over water use access to sanitation as a percentage of population % of water carried by women time spent in water collection, including waiting access to irrigation coverage adjusted by climate characteristics 24 hour access or not* Ability and willingness to pay* 	<p>2007 Pacific Institute: Access to Safe Drinking Water, by Country, 1970 to 2002 Access to Sanitation, by Country, 1970 to 2002 (2006 update) http://www.who.int/docstore/water_sanitation_health/Globassessment/GlobalTOC.htm.</p> <p>Joint Monitoring Programme (JMP) for water supply and sanitation WHO & UNICEF 2006 http://www.wssinfo.org/en/welcome.html</p> <p>Improved water source & sanitation (% of population with access)</p> <p>Millennium Development Goal Indicators: Proportion of the population using improved drinking water sources, total, rural , urban, sanitation http://mdgs.un.org/unsd/mdg/Data.aspx</p>
<p>Capacity</p> <p>Ability of community to afford and manage quality water</p>	<ul style="list-style-type: none"> expenditure measured by ownership of durable items (wealth proxy) under-five mortality rate educational level membership of water users associations 	<p>Millennium Development Goal Indicators Population below poverty line (\$1 a day) (% of total), Share of income or consumption (%) - poorest 20%, Ratio of richest 20% to poorest 20%, Gini index, MDG Population under-nourished, Children underweight for age (% under age of 5) http://mdgs.un.org/unsd/mdg/Data.aspx</p> <p>Asia-Pacific Human Development Report 2006 Human Development Index</p>

	<ul style="list-style-type: none"> • % households reporting illness due to water supplies • % of households receiving a pension/remittance or wage • success of previous projects* • existence of informal water management arrangements* • capacity of NGOs* • integrated planning (i.e. functional water board, or similar)* • corruption levels* • quality and quantity of data* • level of involvement of community and stakeholders in planning process* • use of adaptive policy making* • framework for negotiation between different users at times of constraints* • reliance on aid for funds (percentage of GDP)* • social capital (based on experimental economics)* • economic equality – Gini coefficient* • infrastructural capacity to store and control water* 	<p>Statistical Annexes http://www.pcij.org/blog/wp-docs/HDR2006/Prelim.pdf</p> <p>ASIA-PACIFIC HUMAN DEVELOPMENT REPORT 2006, Life expectancy at birth, total (years), Infant mortality rate (per 1000 live births), Children under age 5 mortality rate (per 1000 live births), Maternal mortality ration (adjusted per 100000 live births), Malaria cases (per 100,000 people), Tuberculosis cases (per 100,000 people), http://www.pcij.org/blog/wp-docs/HDR2006/Prelim.pdf</p>
<p>Use</p>	<ul style="list-style-type: none"> • domestic water consumption rate • agricultural water use, expressed as a measure of irrigated land as a percentage of total cultivated land • livestock water use, based on livestock holdings and standard water needs • industrial water use, based on people reporting that they used water for purposes other than domestic and agricultural • community gardens* • food self-sufficiency* 	<p>Agricultural water withdrawal (10⁹ m³/yr)</p> <p>Domestic water withdrawal (10⁹ m³/yr)</p> <p>Industrial water withdrawal (10⁹ m³/yr)</p> <p>Total water withdrawal (summed by sector) (10⁹ m³/yr)</p> <p>Agricultural water withdrawal as % of total water withdrawal (%)</p> <p>Domestic water withdrawal as % of total withdrawal (%)</p> <p>Industrial water withdrawal as % of total water withdrawal (%)</p> <p>Total water withdrawal per capita (m³/inhab/yr)</p> <p>AQUASTAT</p>

		http://www.fao.org/nr/water/aquastat/data/query/results.html
Environment	<ul style="list-style-type: none"> • people's use of natural resources • reports of crop loss during last 5 years • % households reporting erosion on their land <p>(Note: In the absence of any acceptable figures to represent environmental integrity or environmental water needs, proxy data were used.)</p> <ul style="list-style-type: none"> • damage of aquatic ecosystems; i.e. atolls etc* • water uses interfering with subsistence living* 	Environmental Performance Rankings: File: 2008 EPI _rankingandscores-23Jan Environmental sustainability index: File endnotes
Vulnerability & Resilience Climate Change	<ul style="list-style-type: none"> • risk of water borne disease epidemic* • plan for providing water at time of disaster* • risk of sea level inundation* • evacuation/migration options (within or outside country)* • increased risk of drought* • social resilience* 	<p>Environmental Vulnerability Index http://www.vulnerabilityindex.net/EVI_Country_Profiles.htm</p> <p>The 50 indicators been selected to measure environmental vulnerability are detailed below. Each indicator is classified into a range of sub-indices including the three aspects of hazards; resistance and damage and into policy-relevant sub-indices including:</p> <ul style="list-style-type: none"> • Climate Change = CC • Biodiversity = CBD • Water = W • Agriculture and fisheries = AF • Human health aspects = HH • Desertification = CCD • Exposure to Natural disasters = D
Dealing with data gaps	<ul style="list-style-type: none"> • identify most similar country with respect to a given indicator* • use "equivalent" data but from a different source* • do not include in ranking* 	<p>Source: http://192.171.153.213/sections/hrr/documents/WPI4pageleaflet_000.pdf * parameters added for integrated WPI measurement</p>

APPENDIX 3

META-DATA INDICE REQUIREMENTS

Meta-data

The following information represents a compilation of metadata including definitions of the index, values/units and implications, the source, web address and manipulation/calculations used in formulation. Once meta-data has been finalised it will be posted as a webpage and linked to the mapping web page.

Environmental Vulnerability Index (EVI)

Organization: SOPAC, UNEP

Components: Climate Change, Biodiversity, Water, Agriculture and fisheries, Human health aspects, Desertification, Exposure to Natural disasters

Calculation: The 50 indicators been selected to measure environmental vulnerability for listed components. Each indicator is classified into a range of sub-indices including the three aspects of hazards; resistance and damage and into policy-relevant sub-indices. Each indicator is also accompanied by a short form key name, detailed definition, keywords and a description of the main signals for which it is a proxy as well as the indicator's policy relevance.

URL: <http://www.vulnerabilityindex.net/> http://www.vulnerabilityindex.net/EVI_Country_Profiles.htm
Description of Indicators 2004 SOPAC
<http://www.vulnerabilityindex.net/Files/EVI%20Descriptions%202005.pdf>

Purpose:

Environmental Vulnerability Index is presented as a country score, with the percentage of data held for the 50 EVI Indicators and provides an indication of vulnerability or resilience of the country. Environmental vulnerability has been characterised by three components or sub-indices. These sub-indices focus on ecosystem integrity and how it is threatened by anthropogenic and natural hazards. To be able to capture the complexity of these aspects of environmental vulnerability requires the development of a variety of indicators that target different spatial and temporal scales and hierarchical levels of the ecosystem. International initiatives to measure environmental condition or change range have developed anywhere from 4 to 260 indicators with increasing numbers being used to assess sustainable development progress or state of environment.

The EVI utilises 50 'smart indicators' to capture the key elements of environmental vulnerability. The term 'smart indicators' has been used to define EVI indicators which aim to capture a large number of elements in a complex interactive system while simultaneously showing how the value obtained relates to some ideal condition. The indicators selected for use in the EVI are based on the best scientific understanding currently available and have been developed in consultation with international experts, country experts, other agencies and interest groups. Some important environmental vulnerability issues are not yet measured because relevant data or robust measurement techniques are not yet available. However with new technological advances especially in the area of remote sensing further indicators may be developed for use in the EVI. The refinement of indicators and search for more appropriate smart indicators is on-going.

Human Development Index (HDI)

Organization: UNDP: Asia-Pacific Human Development Report 2006 Human Development Index Statistical Annexes <http://www.pcij.org/blog/wp-docs/HDR2006/Prelim.pdf>

Components: The Human Development Index (HDI) measures the achievements in human capacities or their absence and facilitates the classification of countries based on their progress in regard to the three most fundamental dimensions indicated by the components of leading a long life (Life Expectancy Index), being knowledgeable (Education Index) and enjoying a decent standard of living (GDP Index).

HDI and a country's ranking may change from year to year depending on internal and external developments.

Calculation:

URL: <http://www.undp.am/docs/publications/publicationsarchive/nhdr00/?param=annex2.htm>

Purpose: The HDI analysis by components reveals the state of affairs in a country within specific spheres and proves that the link between economic prosperity and human development is not automatic. Countries with similar income can have different HDI values (and vice versa) depending on the accumulated human capital.

Water Poverty Index (WPI)

Organization: Oxford University Centre for the Environment

Components & Calculation:

The WPI is derived from the weighted average of the five components **Resources (R)**, **Access (A)**, **Capacity (C)**, **Use (U)**, and **Environment (E)**.

$$WPI = \frac{w_r R + w_a A + w_c C + w_u U + w_e E}{w_r + w_a + w_c + w_u + w_e}$$

where WPI is the Water Poverty Index value for a particular location, and w is the weight applied to each of the components. Each of the five main components is made up of a number of sub-components, and a weighting can be applied to indicate the importance of each variable. Components are standardized to fall in the range 0 to 100, giving a final WPI value between 0 and 100. The highest value, 100 is taken to be the best situation, with 0 being the worst. To avoid problems of subjectivity, a base line value of the WPI should first be calculated with these weightings set equally.

URL: <http://ocwr.ouce.ox.ac.uk/research/wmpg/wpi/>

Purpose: The Water Poverty Index (WPI) was developed by a team of researchers, practitioners and stakeholders, led by CEH, to help to determine priorities for action and to monitor progress towards targets. The WPI is a holistic water management tool that is mainly relevant at the community level, but can also be applied at any spatial scale up to the basin or national levels.

- It provides a better understanding of the relationship between the physical availability of water, its ease of abstraction, and the level of welfare;
- It is a mechanism to prioritise water needs;
- It is a tool for monitoring progress in the water sector (e.g. towards the Millennium Development Goals);
- The WPI is mainly designed to help improve the situation for the one to two billion people facing poor water endowments and poor adaptive capacity.

Water Wealth Index (WWI)

Organisation: The development of the Global Rapid Integrated Monitoring System (Global-RIMS) has been funded in part by the National Aeronautics and Space Administration (NASA), the United Nations Educational, Scientific, and Cultural Organization (UNESCO) and by the United Nations Environment Programme (UNEP)

Components: Global Rapid Integrated Monitoring System (Global-RIMS)

The system includes a broad suite of spatial and statistical data encompassing point scale and gridded socioeconomic and biogeophysical products for data exploration and download. This data are organized according to water indicator themes and is presented in the spatial context of the river basin to analyze the changing nature of water in relation to human needs and activities at the global, regional and case study scales.

Calculation:

URL: <http://rbis.sr.unh.edu/>

Purpose: Conceptualisation of the WWI (Sullivan et al 2006 p 26)

A GLOBAL RAPID INTEGRATED MONITORING SYSTEM FOR WATER CYCLE AND WATER RESOURCE INDICATOR ASSESSMENT (Global-RIMS)

The development of the Global Rapid Integrated Monitoring System (Global-RIMS) has been funded in part by the National Aeronautics and Space Administration (NASA), the United Nations Educational, Scientific, and Cultural Organization (UNESCO) and by the United Nations Environment Programme (UNEP). The original proto-type was implemented as the Data Synthesis System for World Water Resources (DSS) with funding from the World Water Assessment Program (WWAP) supported through the UNESCO's International Hydrological Programme. The DSS (<http://www.wwap-dss.sr.unh.edu>) is an operational, digital information system for water resource assessment cast within a geographic information system framework accessible via the World Wide Web. The system includes a broad suite of spatial and statistical data encompassing point scale and gridded socioeconomic and biogeophysical products for data exploration and download. This data are organized according to water indicator themes and is presented in the spatial context of the river basin to analyze the changing nature of water in relation to human needs and activities at the global, regional and case study scales.

The DSS framework was utilized in the development of the global River Basin Information System (RBIS) prototype, which was commissioned in 2001 by the UNEP Division of Early Warning and Assessment (DEWA) to identify impacts and challenges of global change within selected, key watershed of the world. Using a common framework and methodology, the RBIS was cast to analyze the impacts to natural resources from global change using a variety of spatial perspectives including the capability to analyze global, continental, regional, river basin and country conditions. It thus provides a framework to perform comparative broad-scale assessments while also serving to enrich country-level and case study work. RBIS, version 1 (RBIS v1) was intended as a preliminary phase in exploring global change impacts and challenges on a limited scale, focusing initially on selected, key basins and a subset of relevant data themes derived from the TYGRIS (Typology of Global River Systems) toolbox. RBIS v1 operates at a 30' (latitude x longitude) for the global sub-domains. The most recent RBIS version (RBISv2, <http://rbis-unesp.sr.unh.edu>) offers a 6' (latitude x longitude) resolution as well as dynamic and interactive functionality for assessing the contemporary state of African river basins. RBISv2 offers expanded functionality including zooming capabilities, interactive map query, display and calculation of upstream basin statistics, data layer calculator for user-generated calculations, generating upstream statistics ?on the fly?, time series animations and graphs, maps of monthly and annual climatologies, and names and locations of major cities.

The current Global-RIMS system expands RBISv2 data holdings to include regional, continental and global datasets at resolutions from 6' to 1 degree (latitude x longitude) and utilizes a display pyramid approach.

Climate Vulnerability Index (CVI)

Organization: Center for Ecology and Hydrology (CEH), UK

Components: The CVI links water resources modelling with human vulnerability assessments to contribute to a meaningful assessment for generic use Geospatial (G): what are the particular geographical characteristics of the location that make it vulnerable ? Water resources (R): what is available ? Access to water (A): what is the extent of coverage ? Use (U): how effectively is water used ? Capacity (C): what is the capacity to manage water ? Environment (E): what are the environmental impacts ?

Calculation: The CVI combines components into a composite index structure

$$CVI = (rR + aA + cC + uU + eE + gG) / (r + a + c + u + e + g)$$

Where: R, A, C, U, E and G are the sub-components

and r, a, c, u, e and g are weighting factors (possibly subjective)

URL: <http://www.unesco.org/water/wwap/wwdr/wwdr2/indicators/pdf/CH10-IPSEFinalEdits.pdf>

Purpose

Water-related hazards: floods and drought

Water availability, for ecosystems, food production and health
Integrated vulnerability assessment as a combination of physical (natural) and socio-economic data
Identify zones of present and likely future water stress
Identify geographical types likely to be vulnerable
Collect and collate relevant data for sample locations
Select scenarios of change: social, economic and environmental conditions
Calculate CVI scores for the present and expected future situations
Provide results at a range of spatial scales, with indication of uncertainty

APPENDIX 4

DETAILS OF INDICATORS INFORMING THE WATER NEED INDEX

Water Need Index Component	Resources
Indicator name	Total Actual Renewable Water Resources (TARWR)
Prepared by	UNESCO-IHP* http://www.unesco.org/water/wwap/wwdr/wwdr2/indicators/pdf/CH04-IPSEFinalEdits.pdf accessed 10/06/2008: UNESCO indicator sheets Data from FAO, 2003
Example	WWDR2, Chapter 4, Table 4.4
Challenge area	State of the Resource
Rationale/aspect of the challenge area	The amount of potentially available water resources is important knowledge for planning in all sectors.
Position in the DPSIR chain	State
Definition of indicator	The annualised total actual renewable water resource is the theoretical maximum annual volume of water resources available in a country. According to FAO 2003 www.fao.org/landandwater/aglw/aquastat/water_res/index.stm ftp://ftp.fao.org/agl/aglw/docs/wr23e.pdf Total actual renewable water resources (TARWR) (km ³ /year): The sum of internal renewable water resources and incoming flow originating outside the country. The computation of TARWR takes into account upstream abstraction and quantity of flows reserved to upstream and downstream countries through formal or informal agreements or treaties. It is a measure of the maximum theoretical amount of water actually available for the country.
Underlying definitions and concepts	The maximum theoretical amount of water actually available for the country is calculated from: (a) sources of water within a country itself (b) water flowing into a country (c) water flowing out of a country (treaty commitments). Availability, defined as the surface and ground water resource volume renewed each year in each country, is how much water is theoretically available for use on a sustainable basis. Exploitability is a different matter. While availability undoubtedly exceeds exploitability, there is unlikely adequate data to define the degree of exploitability at this stage. In more specific terms TARWR is: The sum of: <ul style="list-style-type: none"> • external water resources entering the country • surface water runoff (SWAR) volumes generated in the country • ground water recharge (GAR) taking place in the country Less: <ul style="list-style-type: none"> • the volume in the country of the total resource effectively shared as it interacts and flows in both the groundwater and surface water systems. Not to subtract this volume would result in its being counted twice. FAO refers to it as "Overlap" (5) and, • the volume that flows to downstream countries based on formal or informal agreements or treaties.
Specification of determinants needed	The specific determinants required are: (1) Actual/natural: indicates whether it corresponds to a natural situation, i.e. a measure of the water balance without human influence, or an actual situation, i.e. the conditions at a given time taking into account human influence either through uptake abstraction of water or through agreements or treaties. Natural conditions are considered stable over time while actual situations may vary with time and refer to a given period. (FAO, 2003, p xi.) (2) Renewable water resources: Total resources that are offered by the average annual natural inflow and runoff that feed each hydrosystem (catchment area or aquifer). (FAO, 2003, p xi.) (3) Internal renewable water resources (km ³ /year): Average annual flow of rivers and recharge of aquifers generated from (endogenous) precipitation that originates within the countries borders. (FAO, 2003, p xi)

	<p>(4) External renewable water resources (km³/year): That part of the country's renewable water resources which is not generated in the country which includes inflows from upstream countries (groundwater and surface water), and part of the water of border lakes or rivers. (FAO, 2003)</p> <p>(5) Overlap between surface water and groundwater resources (km³/year): Overlap defines the part of the country's water resources that is common to surface waters and to aquifers. Surface water flows can contribute to groundwater as recharge from, for example, river beds or lakes or reservoirs or wetlands. Aquifers can discharge into rivers, lakes and wetlands and can be manifest as base flow, the sole source of river flow during dry periods, or can be recharged by lakes or rivers during wet periods. Therefore, the respective flows of both systems are neither additive nor deductible.</p>
Computation	<p>TARWR (in km³/yr) = (External inflows + Surface water runoff + Groundwater Recharge) - (Overlap + Treaty obligations)</p> <p>TARWR PC = (TARWR / population) 109 m³/km³</p> <p>Calculation The method used to assess renewable water resources by country was first described in FAO/ BRGM (1996). It consists of a set of rules and guidelines leading to the calculation of the IRWR, the total renewable water resources (TRWR), and the country's dependency ratio. The method is based on a water resources accounting approach. The TRWR of a country consist of the IRWR plus the external water resources. The IRWR are the amount of water generated inside a country, and the ERWR are the amount of water generated in countries upstream. To avoid double counting, the IRWR is the only variable that can be aggregated for regional or continental assessments.</p> <p>In order to calculate ERWR, a distinction has been made between natural and actual ERWR. The natural ERWR refer to the amount of water flowing to a country from upstream under natural circumstances. The actual ERWR refer to the amount of external water resources actually available to the country taking into consideration upstream water abstraction and possible agreements with upstream and/or downstream countries.</p> <p>The TRWR are generally not equal to the amount of water available for use. Therefore, where possible, a compilation has been made of estimations of exploitable water resources per country and included in the country results. The calculation of renewable water resources is based on long-term averages as available in existing, preferably national, literature. Figure 4 illustrates the hydrological cycle and the components of the country water resources calculations.</p> <p>The data used in computing water resources originate from multiple sources, including grey literature. Most of the data originate from national sources (priority is systematically given to national sources over international reports). A major part of the data originates from the country surveys carried out for 150 countries within the Aquastat programme between 1993 and 2000. A compilation of the individual sources by country is available on the Aquastat Web site (www.fao.org/ag/agl/aglw/aquastat/main/index.htm). ftp://ftp.fao.org/agl/aglw/docs/wr23e.pdf</p>
Unit of measurements	<p>Total Annual Volume: km³/year Per capita measure: m³/capita/year All the elements of the water balance are expressed in km³/year. Area: 1 km² = 100 ha Volume: 1 km³ = 1 x 10⁹ m³ = 1 000 x 10⁶ m³ = 1 000 million m³.</p>

Data sources, availability and quality	<p>Source: FAO, computed on the basis of available country water resources data sheets and country water balance computational spreadsheets. TARWR-FAO, 2003. <i>Review Of World Water Resources By Country</i> Availability: 2005 - Latest version online. Updates done in concert with FAO. Quality: FAO refers to the data as the "Best Estimate" and updates the data when further information is provided.</p> <p>Criticisms Prior to the calculation, the information collected through the surveys was evaluated, mostly through cross-checking and by comparing the level of detail of the estimates. However, the methodologies behind the estimation of the individual components of the water balance were not always well documented. This made the evaluation more complex. Finally, the information in this review stems from multiple sources, with different periods of reference that might vary from country to country. Moreover, the original data were acquired through different methodologies and assumptions, and they might have been extrapolated in time and space. Such variations complicate attempts to determine comparable outcomes.</p>
Scale of application	Data available at country level.
Geographical coverage	Global
Interpretation	<p>This indicator provides an estimate of the maximum theoretical amount of water resources in a country. The available water resources will be less according various factors but it is an overall measure of the country's resources which is also normalized to provide an average annual per capita volume available to individuals within the country. Within the indicator are five important dependencies which relate to each nation's TARWR as to how much of that water resource volume is:</p> <ul style="list-style-type: none"> • flowing from outside the country (a security issue) • generated surface water runoff (a precipitation issue) • generated groundwater recharge (a sustainability issue) • shared in both the groundwater and surface water regimes • committed to downstream nations. <p>Limitations on the indicator:</p> <ol style="list-style-type: none"> 1. See extensive notes from FAO in publication and at web site. 2. Does not yet apply at the level of basins or hydrographic units although some work in this regard has been started by FAO. (Africa, Asia partial) 3. Does not include non-renewable groundwater. 4. Size of large countries can mask high range in variability. 5. Quality of data is variable by country as qualified in FAO database and country datasheets. 6. In the determinant "External renewable water resources", groundwater outflows through transboundary aquifers can be substantial in some countries even if they in general are small compared with surface water flows. Transboundary groundwater flows are difficult to quantify. Suggested future modifications: <ul style="list-style-type: none"> • Determine ratio by country where shared basins exist (significant number) • For the largest area countries (the 12 over 2 million km² or the 30 over 1 million km²) break down the distribution according to the next lower level of administrative governance. (e.g. Canada & China, Provinces, USA, Russia – States) • Breakdown into smaller (significant) sub-basins to assess basin-wide variability.
Linkage with other indicators	<p>Precipitation (FAO data is calculated from IPCC data unless considered not representative. Approximately 80% of FAO's precipitation data originates from IPCC).</p> <p>Water use (WU) by different sectors (is included as part of the AQUASTAT Data base)</p>
Alternative methods and definitions	<p>FAO collected statistics on water resources for most of the developing countries within the AQUASTAT programme. Data on water resources were obtained from national sources and reviewed by FAO to ensure consistency in definitions. A methodology was developed and rules were established to compute the different</p>

	elements of national water balances. From those data, FAO has compiled a comparative analysis of available country water resources data.
Related indicator sets	FAO's AQUASTAT
Sources of further information	http://www.fao.org/waicent/faoinfo/agricult/agl/aglw/aquastat/water_res/index.stm (lv 05 Feb 2006)
Other institutions involved	*This indicator was originally developed by FAO NOTE: WRI has this information on web site with link and credit for the data to FAO.

Water Need Index Component	Access
Indicator name	Access to Sanitation, by Country, 1970 to 2002 (2006 update) Total
Prepared by	http://www.unesco.org/water/wwap/wwdr/wwdr2/indicators/pdf/Ch06-IPSFinalEdits.pdf UNICEF
Example	WWDR2, Chapter 6, Map 6.2
Challenge area	Water and Health
Rationale/aspect of the challenge area	<p>Access to adequate excreta disposal facilities is an important requirement if adverse health effects of poor sanitation are to be avoided. This indicator thus provides a measurement of both the potential exposure of the population to infectious agents associated with poor sanitation, and of the action taken to improve domestic sanitation. The indicator can be used:</p> <ul style="list-style-type: none"> • to help target and plan efforts to improve access to sanitation and to monitor progress of such measures • to assess levels of social inequality and deprivation • to help investigate associations between sanitary conditions and specific health effects.
Position in the DPSIR chain	Impact
Definition of indicator	The proportion of the population (total, urban and rural) with access to an improved sanitation facility (for defecating).
Underlying definitions and concepts	<p>An improved sanitation facility is defined as a facility used for excreta disposal whereby the human excreta are hygienically separated from human contact or their immediate environment, thus reducing the risk of faecal-oral transmission to its users. Such facilities include:</p> <ul style="list-style-type: none"> • toilet with sewer connection or septic tank • pour flush toilet/pour flush latrine to sewer, septic tank or pit • Ventilated Improved Pit (VIP) latrine • latrine with a slab • ecological sanitation. <p>A shared or public facility is a facility regularly used by members of more than one household (extended families living on the same compound, plot or yard are generally considered one and the same household). Shared or public facilities are not considered improved for reasons of poor cleanliness and lack of privacy. Definitions used for urban and rural areas are those defined by individual countries.</p>
Specification of determinants needed	<p>Information on what toilet facility members of a household usually use. Household sizes are computed into population figures. National population figures used are those provided by the UN-Population Division. Population projections used are based on medium variant population growth rate. Definitions for urban and rural areas are those defined by individual countries.</p>
Computation	Population based data about the use of an improved sanitary facility, obtained from nationally representative household surveys, are used to calculate the proportion of the population with access to basic sanitation. Results of several household surveys are plotted against a time scale. A linear regression line is drawn through these points to estimate the coverage for a certain year. As a rule projections from the last data point are made up to a maximum of six years.
Unit of measurements	Proportion of the population with access to an improved sanitary facility
Data sources, availability and quality	<p>The data sources used to calculate this indicator are nationally representative household surveys. Worldwide, an estimated average of 25-35 of such surveys are conducted annually, with occasional peak years. Most surveys are done in low- and middle-income countries. As a result higher-income countries are data poor. The frequency of all surveys combined amounts to one survey conducted per country in every 3-4 years. This frequency is adequate to determine actual changes in access to basic sanitation. Data sources include household surveys, such as:</p> <ul style="list-style-type: none"> • The Demographic and Health Surveys (DHS) • Multiple Indicator Cluster Surveys (MICS)

	<ul style="list-style-type: none"> • National Censuses • Reproductive Health Surveys • World Health Surveys (WHS) • Health and Nutrition surveys • Living Standards and Measurements Surveys (LSMS).
Scale of application	<p>At national and global level For urban and rural areas By service level or facility type By household income level, determined by the wealth index – a composite of household assets and characteristics of the dwelling.</p>
Geographical coverage	Urban, Rural, National, Regional and Global
Interpretation	<p>The question in the main household surveys specifically asks about what toilet facility members of the [your] household usually use. Unused or broken toilet facilities are therefore not recorded in household surveys. Whether usage includes usage all the time, by all members of households for both defecation and urinating is not assessed, but assumed.</p> <p>The improved sanitation types identified by the WHO/UNICEF JMP, by nature of their design should ensure a clean and healthful environment. Where wastewater from a public sewer ends up and if it is being treated, however, is not monitored systematically and can not be assessed by a household survey.</p> <p>It is up to every individual country or programme to monitor access to basic sanitation in more detail, taking into account gender aspects and important issues like privacy and cleanliness. Doing so at global scale would be too costly as lengthy observation and inspection times are required to adequately assess these parameters.</p>
Linkage with other indicators	<p>Though not directly a basic need for survival like drinking water, indirectly indiscriminate defecation and improper excreta disposal are principal determinants for both morbidity and mortality. The use of a sanitary facility is closely linked to appropriate hygiene behaviour, and availability of clean drinking water. These three interventions combined maximize the positive effect in health. The indicator relates to most other health indicators, in particular those on water and sanitation related diseases, as well as the under-five mortality.</p> <p>Recent studies show the importance of safe drinking water and sanitation for the survival of people living with HIV/AIDS.</p>
Alternative methods and definitions	<p>UN-Habitat in the WWDR-I proposed a definition for safe and convenient sanitation specifically designed for people in urban slum and other high-density poor neighbourhoods: A provision for defecation that eliminates their (and others') contact with human excreta and wastewater that are convenient, clean, easily accessed and affordable by all. UN-Habitat does not rule out public facilities that are often the only hygienic option in high-density areas, with limited space for individual hygienic facilities and without a central sewer system. Although Sulabh International operates several hundreds of thousands well maintained public facilities in India, there are currently no monitoring instruments to allow to separate well-maintained and hygienic public or shared facilities from the inadequate unhygienic ones.</p> <p>The UN-Millennium Project has defined basic sanitation as: Access to, and use of excreta and wastewater facilities and services that provide privacy and dignity while at the same time ensuring a clean and healthful living environment both at home and in the immediate neighbourhood of users.</p> <p>There are too many variables in this definition to be monitored cost-effectively at national and global level and to be interpreted unambiguously. Each variable needs to be further defined and likely requires a series of questions or observations to assess privacy, dignity or cleanliness. It is useful to have an ideal conceptual definition of what constitutes access to basic sanitation as a design standard or an ultimate goal to work towards to. But for national and international monitoring an operational definition or indicator is needed that is measurable in a cost-effective way and that provides a good approximation to</p>

	the ideal definition.
Related indicator sets	Access to safe drinking water Incidence of diarrhoeal disease in children under five years of age Under-five mortality Prevalence of stunting in children under five years of age Prevalence of underweight children under five years of age
Sources of further information	WHO/UNICEF Joint Monitoring Programme (JMP), 2004. <i>Meeting the MDG drinking water and sanitation target. A mid-term assessment.</i> WHO/UNICEF JMP, 2000. <i>Global Water Supply and Sanitation Assessment 2000</i> WHO/UNICEF JMP website: www.wssinfo.org UN-HABITAT, 2003. <i>Water and Sanitation in the World's Cities.</i>
Other institutions involved	WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation UN-Habitat

Water Need Index Component	Access
Indicator name	Access to Safe Drinking Water, by Country, 1970 to 2002 (total)
Prepared by	UNICEF http://www.unesco.org/water/wwap/wwdr/wwdr2/indicators/pdf/Ch06-IPSFinalEdits.pdf
Example	WWDR2, Chapter 6, Map 6.1
Challenge area	Health
Rationale/aspect of the challenge area	Contaminated drinking water is a major cause of illness and mortality, as a result of exposures both to infectious agents and to chemical pollutants. Inadequate access to water in the home is also a source of economic disadvantage by requiring large commitment of human resources to fetching and carrying water. This indicator provides a proxy measure both of exposure, in terms of access to safe drinking water and the effectiveness of actions to improve access.
Position in the DPSIR chain	Impact
Definition of indicator	The proportion of the population (total, urban and rural) with access to an improved drinking water source as their main source of drinking water:
Underlying definitions and concepts	Drinking water is defined as water for ingestion, basic personal and domestic hygiene and cooking. It excludes water for clothes washing, an activity that frequently happens at the water source, water point, in rivers or streams. An improved drinking water source is defined as a type of drinking water facility or water delivery point that by the nature of its design protects the drinking water source from external contamination, particularly of faecal origin. An improved facility would include any of the following: <ul style="list-style-type: none"> • piped water into dwelling, plot or yard • public standpipe/public tap • protected dug well • protected spring • rainwater Definitions used for urban and rural areas are defined by individual countries.
Specification of determinants needed	The use of the main source of drinking water for a household. Household sizes are computed into population figures. National population figures used are those provided by the UN-Population Division; Population projections used are based on medium variant population growth rate.
Computation	Population based data regarding the use of the main source of drinking water, obtained from nationally representative household surveys are used to calculate the proportion of the population with access to safe drinking water. Results of several household surveys are plotted against a time scale. A linear regression line is drawn through these points to estimate the coverage for a certain year. As a rule projections from the last data point are made up to a maximum of six years.
Unit of measurements	Percentage
Data sources, availability and	The data sources used to calculate this indicator are nationally representative

quality	<p>household surveys. Worldwide, an estimated average of 25-35 of such surveys are conducted annually, with occasional peak years. Most surveys are done in low- and middle-income countries. As a result higher income countries are data poor. The frequency of all surveys combined amounts to one survey conducted per country in every 3-4 years. This frequency is adequate to determine actual changes in access to safe drinking water. Data sources include household surveys, such as:</p> <ul style="list-style-type: none"> • The Demographic and Health Surveys (DHS) • Multiple Indicator Cluster Surveys (MICS) • National Censuses • Reproductive Health Surveys • World Health Surveys (WHS) • Health and Nutrition surveys • Living Standards and Measurements Surveys (LSMS)
Scale of application	<p>At national and global level For urban and rural areas By service level or facility type By household income level, determined by the wealth index – a composite of household assets and characteristics of the dwelling.</p>
Geographical coverage	Urban, Rural, National, Regional and Global
Interpretation	<p>According to the definition of the WHO: Safe drinking water implies that the water meets accepted drinking water quality standards and poses no significant threat to health. Determining the micro-biological and chemical safety of drinking water of each household is too costly and practically and technologically too challenging. The use of an “improved” facility type as a proxy for the safety of drinking water is therefore accepted as the best alternative given the current information available. With regard to access:</p> <p>(1) The questions in household surveys specifically ask about the use of a source to obtain drinking water. Broken hand pumps or public standpipes that no longer provide water are thus not counted in household surveys and therefore not reflected in the indicator.</p> <p>(2) In addition to good quality of water, accessibility to water as defined in the Right to Water includes a continuous supply of a minimum amount of water sufficient for drinking, personal and domestic hygiene, for an affordable price, within a reasonable distance. These issues like continuity (including seasonality), quantity, affordability and distance to a source are not taken into account in the current indicator. The reasons for this are the following:</p> <p>Non-availability of historic data Questionable reliability of data collected through household surveys assessing the available water quantity or actual quantity used per person per day. Non-availability of data on continuity combined with the lack of a definition for continuity and the difficulty of interpreting continuity when e.g. intermitted supply is dealt with through storage at household level</p>
Linkage with other indicators	<p>Safe water being a basic need for survival as well as a determinant of health, should be considered with the use of sanitary facilities and practices of appropriate hygiene behaviour if positive health outcomes are to be maximized. The indicator relates to most other health indicators, in particular those on water related diseases, as well as the under-five mortality. Recent studies show the importance of safe drinking water and sanitation for the survival of people living with HIV/AIDS.</p>
Alternative methods and definitions	<p>According to WHO basic access can be defined as the availability of at least 20 litres of drinking water per person per day within a distance of not more than 1 km of the dwelling, corresponding to a maximum water hauling round trip of 30 minutes. While this definition is deemed adequate for rural areas, it does not apply to urban areas where the distance to a source is usually not a problem. In such densely populated areas, a water hauling trip of 30 minutes or less, including</p>

	<p>queuing time would be a more appropriate indicator of access.</p> <p>The MDG target is formulated in terms of sustainable access. Though officially not further defined, sustainable access refers to a continuous and affordable drinking water supply. There is no widely accepted standard of what is an affordable drinking water supply, neither is continuity sufficiently defined yet, as to make it measurable</p>
Related indicator sets	<p>Access to basic sanitation</p> <p>Incidence of diarrhoeal disease in children under five years of age</p> <p>Under-five mortality</p> <p>Prevalence of stunting in children under five years of age</p> <p>Prevalence of underweight children under five years of age</p>
Sources of further information	<p>WHO/UNICEF Joint Monitoring Programme (JMP), 2004. <i>Meeting the MDG drinking water and sanitation target. A mid-term assessment</i></p> <p>WHO/UNICEF JMP, 2000. <i>Global Water Supply and Sanitation Assessment 2000</i>.</p> <p>WHO/UNICEF JMP website: www.wssinfo.org</p> <p>UN-HABITAT, 2003. <i>Water and Sanitation in the World's Cities</i>.</p>
Other institutions involved	<p>WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation</p> <p>UN-Habitat</p>

Water Need Index Component	Use
Indicator name	Mortality rate of children under-five years of age
Prepared by	WHO http://www.unesco.org/water/wwap/wwdr/wwdr2/indicators/pdf/Ch06-IPSFinalEdits.pdf
Example	
Challenge area	Health
Rationale/aspect of the challenge area	Many of the water-related diseases are especially relevant to children and the database for estimating child mortality is much better developed than for adult mortality. This provides a strong rationale for using the under-five mortality rate in the context of monitoring the burden of water-related diseases.
Position in the DPSIR chain	impact
Definition of indicator	Probability of dying between birth and exactly five years of age expressed per 1000 live births.
Underlying definitions and concepts	Under-five : between birth and exactly five years of age
Specification of determinants needed	Number of deaths of children under five years of age for a particular year Number of live births in the same calendar year.
Computation	The direct way to measure the probability of dying between birth and age five would be to follow a cohort of births and record the proportion of children in that cohort who die before their fifth birthday. However, usually an indirect form of calculation is used: the number of deaths of children under five years of age and the number of live births are obtained in the same calendar year. The assumption in this indirect calculation is that the number of live births does not change significantly from one year to the next.
Unit of measurements	This indicator is a proportion: x per thousand
Data sources, availability and quality	UNICEF: http://www.childinfo.org/cmr/revis/db2.htm (lv 03 Feb 2006) and the annual publication State of the Worlds Children. At the national level, the best source of data is a complete vital statistics registration system – one covering at least 90% of vital events in the population. Such systems are uncommon in developing countries, so estimates are often obtained from surveys. Surveys estimating deaths require large samples. Often, indirect or modelling approaches are used with data from censuses or demographic surveys.
Scale of application	Global
Geographical coverage	Global
Interpretation	The under-five mortality rate is one of the most important social indicators of development. It is an indicator of quality of life, including income and education of parents, efficacy of health services, access to safe drinking water and sanitation etc. Under-five mortality is part of a chain of indicators, with poverty as the driving force.
Linkage with other indicators	None reported.
Alternative methods and definitions	None reported.
Related indicator sets	A related indicator is the infant mortality rate, which is a less suitable indicator than the under-five mortality rate in the context of water-related diseases.
Sources of further information	None reported.
Other institutions involved	UNICEF, United Nations Population Division, United Nations Statistical Division, World Bank, US Bureau of Census



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