ECOHEALTH AND WATERSHEDS

Ecosystem Approaches to Re-integrate Water Resources Management with Health and Well-being

Dr. Margot W. Parkes, Dr. Karen E. Morrison,
Dr. Martin J. Bunch, Dr. Henry D. Venema

A research paper by the
Network for Ecosystem Sustainability and Health
for the International Institute for Sustainable Development,
Winnipeg, Canada
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CCME	Canadian Council of Ministers of the Environment (www.ccme.ca)
CSAT	Current State and Trends, Volume 1 of the Millennium Ecosystem Assessment Global Assessment Reports
ecohealth	The name of an emerging transdisciplinary field and academic subject.
Ecohealth	The abbreviated name of a Program Initiative of the International Development Research Centre, entitled "Ecosystem Approaches to Human Health" (see www.idrc.ca/ecohealth)
EcoHealth	Used by the International Association for Ecology & Health in its logo and international peer-reviewed journal *EcoHealth*, published by Springer (see www.ecohealth.net)
EGS	Ecological Goods and Services
GEO	Global Environment Outlook (www.unep.org/geo/geo4/media)
GWP	Global Water Partnership (www.gwpforum.org)
IDRC	International Development Research Centre (www.idrc.ca)
IISD	International Institute for Sustainable Development (www.iisd.org)
ISDR	International Strategy for Disaster Reduction (www.unisdr.org)
IPCC	Intergovernmental Panel on Climate Change (www.ipcc.ch)
IWRM	Integrated Water Resources Management
MA	Millennium Ecosystem Assessment (www.millenniumassessment.org)
PR	Policy Responses, Volume 3 of the Millennium Ecosystem Assessment Global Assessment Reports
UNESCO	United Nations Educational, Scientific and Cultural Organization (www.unesco.org)
UNEP	United Nations Environment Programme (www.unep.org)
UNU-INWEH	United Nations University, International Network on Water, Environment and Health (www.inweh.unu.edu)
UNWWAP	United Nations World Water Assessment Programme (www.unesco.org/water/wwap)
USEPA	United States Environmental Protection Agency (www.epa.gov)
USNAS	United States National Academy of Sciences (www.nasonline.org)
WG II/WG III	Working Group II and Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change
WHO	World Health Organization (www.who.int)

Executive Summary

The links between ecosystem approaches to health, natural resource management and poverty reduction are being identified as important and relevant across an increasing number of disciplines and institutions. However, specific implementation guidance is scant. One promising approach to addressing this gap is the integration of two emergent approaches to environmental management: *Ecohealth*, which argues that human health and well-being are not only dependent on ecosystems but are also important outcomes of effective ecosystem management; and *Watershed-based integrated water resources management (IWRM)* which is based on the premise that watersheds are appropriate units for managing ecosystems.

Over the past century, the dominant scientific approach to environment and health relationships has been to examine cause and effect relationships between "proximal" environmental exposures and their health effects. Much progress has been made with this kind of work, but the complex, reciprocal interactions among ecosystems, society and health demand a more integrated and systemic approach. Recent convergence of research, policy and practice that re-links the social and ecological context for health lead us to understand that: in coupled social-ecological systems the same driving forces can result in combined social and environmental health inequities, hazards and impacts; policies that decrease social inequities and improve social cohesion have the potential to improve health outcomes and also to minimize and offset the drivers of ecosystem change; and linked social-ecological actions that address both biophysical and social environments have the potential to create a "double-dividend" that improves health by addressing both its socio-economic and environmental determinants, while also promoting sustainable development.

Traditionally, our understanding and management of human health has been organized spatially on the basis of human constructs such as municipalities, counties, health authorities, and provinces or states. While these boundaries do influence environmental and resource management, they often overlook the structure and function of ecosystems, and create a disjuncture between the objects of management and biophysical processes (e.g., between health and nature). A wide range of international reports have now created a demand and imperative to identify specific ecosystem-based contexts in which linkages among health, ecosystems, development and poverty alleviation can be operationalized.

One response to these challenges has been to recognize and prioritize watersheds as appropriate spatial units around which to organize management for natural resources and health. Watershed management and ecosystem approaches offer useful approaches to water management within the physical "place" of the watershed or catchment. Using key management concepts such as resilience, such approaches have the potential to improve our ability to reduce vulnerability to natural hazards, maintain ecological flows of water and the provision of other ecological services, and to promote the long-term sustainability of coupled human and natural systems. Ecosystem approaches and IWRM almost always cite collaborative decision-making and adaptive institutions as central to their approach. Mechanisms to operate such approaches must navigate overlapping jurisdictions, conflicting mandates and multiple interests, while at the same time adapting and responding to new information and operating in contexts of uncertainty.

The challenge remains to establish frameworks and processes that speak not only to public health professionals, but also to ecologists, water managers, planners and the development community. Despite the potential value in explicitly addressing concerns about human health and well-being on a watershed basis, a myriad of challenges exist—many of which reflect the limitations of restricting focus on separate parts of social-ecological systems rather than the interconnections of human and natural systems. These include the challenges of working across jurisdictions and sectors; of integrating academic disciplines and multiple worldviews; of spatial-temporal scale and the relationship between systems defined at different scales; and of the complexity of issues pertaining to each aspect of these social-ecological systems (including climate

and atmospheric processes, land uses, ecological processes, social networks, livelihoods and lifestyles). The table below summarizes key issues identified by this report and offers directions for further work.

	Research	Policy	Outreach
Governance Challenges and Opportunities	Evaluating the role of watersheds as a placebased context in which to govern for both health and sustainability.	Call for health in all policies, poses new opportunities to link IWRM and public health.	Communities could benefit from increased integration of services to achieve multiple objectives.
Spatial-Temporal Scale	Watersheds offer a meso-scale unit of analysis that reflects ecosystem processes.	Watersheds as a new meso-scale setting for action to improve social and environmental determinants of health.	Watersheds as a scale to which communities can relate, and enable a re-integration of social-ecological issues
The Paradox of Promoting Health	"Attribution" of specific health improvements to watershed changes is challenging.	Success in health promotion can be considered "invisible" or a "non-event" and is harder to measure than strategies focused on diseases.	Health gains as a result of watershed actions may be difficult for the public to identify and recognize.
Ecological Goods and Services (EGS) on a Watershed Basis	Potential to link the research agendas relating to EGS, livelihoods and social determinants of health.	Valuing ecological goods and services within a watershed context may help drive more integrated intersectoral approaches.	EGS could assist with communication about health impacts of watersheds.
Poverty and Watersheds	Linking research agendas across health, ecosystems and society (especially in relation to reducing inequities).	Potential to link services and policies across health, sustainability and disaster reduction objectives.	Initiatives to sustain ecosystems and livelihoods, and increase social equity could have profound health benefits.
"New-generation" Policy Instruments	A focus on watersheds as a setting to link and integrate tools—including impact assessments, indicators, risk and surveillance.	Policy leadership will be necessary to encourage proactive instruments and integration between approaches at the watershed scale.	Public demand for accessible and community-relevant policy instruments might drive policy innovation and integration at the watershed scale.
Building Capacity for a Paradigm Shift	Conceptualizing and managing complex adaptive social ecological systems for human health.	Policy may need to drive and demand new approaches to training and knowledge translation. Mechanisms for crossing jurisdictional barriers need to be implemented.	Watershed-based ecohealth case studies can support extension of the approach to governmental actors and other stakeholders. Communities of practice and funded training in ecohealth are required.

1.0 Introduction

Over the past three or four decades, a number of related and non-exclusive approaches have emerged that employ an understanding of general and complex systems theory, expressed in the concept of "ecosystem," to manage coupled human and natural systems. Change circled text to: These include various expressions of 'the ecosystem approach' first developed by the International Joint Commission for Management of the Great Lakes and by the Convention on Biological Diversity (Allen *et al.*, 1993; Secretariat of the Convention on Biological Diversity, 2001); 'resilience' and related approaches (including adaptive management and adaptive co-management); ecohealth; ecosystem management; and integrated water resources management. We consider these approaches to be variations on a theme—members of a family of ecosystem approaches (Bunch *et al.*, 2008).

The links among ecosystem approaches to health, natural resource management and poverty reduction are being identified as important and relevant across an increasing number of disciplines and institutions. As we shall see in this report, ecosystem approaches are gaining currency as an organizing framework for ecologists, health professionals and those interested in human development and security.

Despite the level of attention and agreement regarding the important linkages among ecosystem management, human health, development and poverty alleviation, specific implementation guidance is scant. This document is intended as a response to this gap; its purpose is to examine the ecosystem context for improving research, implementation and action with respect to human health and well-being. Our approach integrates two emergent approaches to natural resources management that have been collectively identified as a new problematique:

- *ecohealth*, which argues that human health and well-being are not only dependent on ecosystems but are also important outcomes of effective ecosystem management; and
- *watershed-based integrated water resources management (IWRM)*, which is based on the premise that watersheds are appropriate units for water governance and managing ecosystems.

Both are variations of an ecosystem approach that is rooted in systems thinking, operated using collaborative processes, and that focuses on relationships among an interconnected and evolving web of actors and elements.

1.1 Linking "Upstream" Determinants of Health

Despite the converging interest in linking the upstream social and environmental determinants of health (Parkes *et al.*, 2003), the fields of "environmental health" and "social determinants of health" have tended to remain conceptually and operationally distinct. In this section we highlight important international developments that reinforce, expand on and integrate approaches to determinants of health linking health, ecosystems and society.

In 2005, The Millennium Ecosystem Assessment (MA) argued that human well-being (key components of which are health and freedom from preventable disease) is fundamentally dependent on ecosystems, due to the provisioning, cultural and regulating services they provide. The MA elevated the concept of the ecosystem by characterizing it as fundamental for human development. Indeed, a multi-country study by the World Bank (2007) found that maintenance and access to ecosystem services was consistently associated with better health and economic outcomes. The MA drew on the combined knowledge of over 1,360

experts to provide important insights into the consequences of ecosystem change for human health and well-being. The conceptual framework of the MA pays particular attention to the supporting, provisioning, regulating and cultural role of ecosystems that affect health directly and indirectly (Corvalan *et al*., 2005, see Figure 4). Using the language of well-being (as compared to that of environmental hazards and disease), the MA provided new evidence to understand the varied ways that ecosystems influence "upstream" determinants of health—and supports attention to the common ground among public health, ecosystem sustainability and natural resource management (Butler, 2006; Waltner-Toews, 2004). It articulates the ways in which ecosystem change influences social determinants of health and exacerbates health inequities. These links were also clearly made by the late Lee Jong-Wook, Director General, World Health Organization, in his foreword to the Health Synthesis of the Millennium Ecosystem Assessment:

> *"Health risks are no longer merely the result of localized exposures to 'traditional' forms of pollution—although these still certainly exist. They are also the result of broader pressures on ecosystems, from depletion and degradation of freshwater resources, to the impacts of global climate change on natural disasters and agricultural production. Like more traditional risks, the harmful effects of the degradation of ecosystem services are being borne disproportionately by the poor. However, unlike the more traditional hazards, the potential for unpleasant surprises, such as emergence and spread of new infectious diseases, is much greater…"* (Jong-Wook in Corvalan *et al*., 2005, p.iii)

The significant link among ecosystem change, social inequalities and health has also started to influence those whose primary focus is the social determinants of health. These determinants have tended to focus on health inequities in relation to social gradient, stress, early life, social exclusion, work, unemployment, social support, addiction, food and transport (Wilkinson and Marmot, 2003). While at first glance these themes may seem unrelated to the themes of ecosystems and health, connections are beginning to be made. For example, the WHO Commissioner on the Social Determinants of Health clearly identified the links between the social determinants of environmental change and the effect of environmental change on health inequities:

> "*Putting all these levels in context is the natural environment, and the macro-level to micro-level effects of environmental change. Risks to health include heat waves and other extreme weather events, changes in infectious disease patterns, effects on local food yields and freshwater supplies, impaired vitality of ecosystems, and loss of livelihoods. If present trends continue the adverse health effects from human-induced environmental changes will be distributed unequally. The poor, the geographically vulnerable, the politically weak, and other disadvantaged groups will be most affected…* ***Addressing the intersection between social determinants of environmental change and the effect of environmental change on health inequities will benefit sustainable ecological and population health alike****.*" (Marmot, 2007, p.1156, emphasis added)

The Commission on Social Determinants of Health is thus demonstrating a new level of recognition of the role of ecosystems in relation to the "causes of the causes" of health inequities (Marmot, 2005). It is calling for a better integration of ecosystems and health as explicit parts of both the development and poverty-alleviation agendas. Commission reports have highlighted the links between ecosystem degradation and health in both urban environments (e.g., in their 2007 report *Our cities, our health, our future*) and as root causes of health inequities (Marmot, 2007). The United Nations Environment Programme echoed these concerns in the GEO-4 Assessment which argued that "[p]reventive or proactive solutions for many contemporary health problems need to address the links among environment, health and other factors that determine well-being" (UNEP, 2007, p.347).

The need to prioritize environment and health in discussions related to development and poverty alleviation was reiterated at the Poverty Environment Partnership meeting in November 2007. Proposals to respond to the nexus of poverty, environment and health include a call by the World Resources Institute for

a "Commission on Macroeconomics and Ecosystem Services for Poverty Reduction," noting that the earlier "Commission on Macroeconomics and Health" was an important precedent, but had overlooked the fundamentally intertwined nature of health and ecosystem management as development objectives (Ranganathan & Irwin, 2007, p.347). This attention has been prompted in part by the growing awareness of the impact of environmental risk factors on the global disease burden (Prüss-Üstün & Corvalan, 2005). Ecosystem management offers a strategy for what McMichael *et al* (2008) describe as "true primary prevention" by reducing or eliminating the human pressures on the environment that create disease and health inequities, as well as lessening existing health risks for vulnerable communities.

The combined emphasis of a wide range of international reports has created both a demand and imperative to examine more closely the specific ecosystem-based contexts in which linkages among health, ecosystems, development and poverty alleviation can be operationalized. This paper proposes the watershed as one such context.

1.2 Watersheds as Management Units

Traditionally our understanding and management of human health has been organized spatially on the basis of human constructs such as municipalities, counties, health authorities, and provinces or states. While these boundaries do influence environmental and resource management, they often overlook and override the structure and function of ecosystems, and create a disjuncture between the objects of management and biophysical processes—in this case a disconnect between health and nature. Water has long been recognized as a common, fundamental necessity for the health—and survival—of both humans and nature. Falkenmark and Folke note that "the deep and multiple involvement of water, in its function as the bloodstream of both the anthropogenic world and the non-human natural world, suggests that goal conflicts related to water may be numerous…" (2002, p.2). The essential role of water for nature and society has led to recognition of water governance as a catalytic entry point to reduce poverty and address environmental sustainability (UNDP, 2004). One response to these challenges has been to recognize and prioritize watersheds as appropriate spatial units around which to organize management for health and natural resources.

Watersheds, also referred to as catchments or river basins, are areas defined by the heights of land that separate river systems. On either side of a height of land (also known as a divide, or water parting) water that falls as precipitation will flow in opposite directions, making its way into different streams. Watersheds are organized hierarchically. For example, a watershed will contain sub-watersheds, and may itself fall within a larger drainage basin.

Our increasing understanding of the links between ecosystems and human well-being leads us to believe that management of determinants of health using watersheds as management units may be appropriate and useful. Hence, our exploration in this document of the integration of IWRM and Ecohealth approaches.

1.3 Integrating Ecohealth and IWRM: Organization of This Document

In pursuit of this exploration we first present below models for conceptualizing relationships among human health, ecosystems and society (Section 2). In Section 3 we review the rationale for management on the basis of watersheds, and introduce integrated water resources management (IWRM). In Section 4 we explore the role of watershed management in buffering environmental hazards and disasters, and as the settings for governance, social learning and well-being (health). We conclude in Section 5 by identifying challenges, gaps and opportunities in the integration of ecohealth and IWRM.

2.0 Conceptualizing Relationships among Health, Ecosystems and Society

Understanding the relationships between environment and health has been an important feature of society for millennia. Many indigenous peoples structured their societies and culture along these lines, and the environmental context for health is evident in the earliest documentations of western scientific tradition, such as Hippocrates' famous treatise on health entitled "Airs, Waters, Places" (Hippocrates 400 BCE, in 1983 translation). Over the past century, the dominant scientific approach to environment and health relationships has been to examine cause and effect relationships between "proximal" environmental exposures and their health effects. While considerable progress has been made with this kind of work, the complex, reciprocal interactions among ecosystems, society and health demand a more integrated and systemic approach. The last decade has therefore witnessed a re-emphasis on the environment as context for health, including proposals for a "socio-ecologic systems perspective" for epidemiology (McMichael, 1999) and a convergence of research, policy and practice seeking to re-link social and ecological understandings of health (Parkes *et al.*, 2003).

It is not our goal in this document to revisit the evolution of understanding in environment-health relationships that can already be found elsewhere in the literature. Rather, we will review some general categories and outline informative developments in how relationships between environment and health are conceptualized while highlighting two important trends:

i) an increasing emphasis on the environment as "ecosystem" (including watersheds as a social-ecological systems); and

ii) recognition of the links between social and environmental determinants of health.

Drawing on conceptual models and important international initiatives, we provide an overview of the growing awareness of the health implications of ecosystem change, and the social processes required to prevent and respond to these changes.

2.1 Ecohealth: New Developments Linking Health, Ecosystems and Society

The recent research and policy innovations described in Section 1 (including the Millennium Ecosystem Assessment and WHO's work on Social Determinants of Health) have reinforced a growing body of research, practice and policy that is increasingly grouped under the banner of "ecohealth." Drawing on anthropology, epidemiology, public health science and systems ecology, the emerging field of ecohealth has involved researchers focusing on "ecosystem approaches" to health and sustainability (Forget & Lebel, 2001, Kay *et al.*, 1999; Lebel, 2003; Waltner-Toews, 2001, 2004). These initiatives have been supported and complemented by groundwork in the field of "ecosystem health" in the 1990s which sought, in particular, to create an interface among the social, natural and health sciences (Rapport *et al.*, 1998). Ecohealth has also been cultivated through recognition of the common ground with the field of "conservation medicine" (Aguirre *et al.*, 2002) and what is sometimes described as "One Health"—linking human and animal health with increased attention to ecosystem context (Zinsstag *et al.*, 2008).

A critical insight from the field of ecohealth is that human health and well-being are important outcomes of effective ecosystem management. This presents researchers, practitioners and policy-makers with the challenges of integrating knowledge from multiple disciplines and demands, and has reinvigorated attention to cross-disciplinary, intersectoral and multi-stakeholder governance strategies that harness the common ground between public health and sustainable development (Brown *et al.*, 2001; Brown, 2007a; Soskolne *et al.*, 2007; Waltner-Toews *et al.*, 2004).

An important feature of the emergence of ecosystem approaches to health is that they have developed in a variety of contexts beyond the academic and university context in "developed" countries. For example, Canada's International Development Research Centre's "Ecosystem Approaches to Human Health (Ecohealth)" Program Initiative has funded a growing body of Ecohealth research and projects in Africa, Asia, Latin America and the Middle East (De Plaen and Kilelu, 2004; Lebel, 2003), and has more recently progressed into the development of Communities of Practice in EcoHealth.

The launch of the journal *EcoHealth* (Wilcox *et al.*, 2004) has given further impetus to the emerging field, providing an integrated, international platform for dissemination, peer-review and scholarly development across of a range of systemic approaches to addressing health, environment and development concerns. The journal has been the official publication of the "International Association for Ecology and Health" since its formation in 2006 (see www.ecohealth.net). The Association's journal, biennial conferences and related events—including collaboration in hosting the 2008 International Ecohealth Forum—exemplify the progressive development of the field.

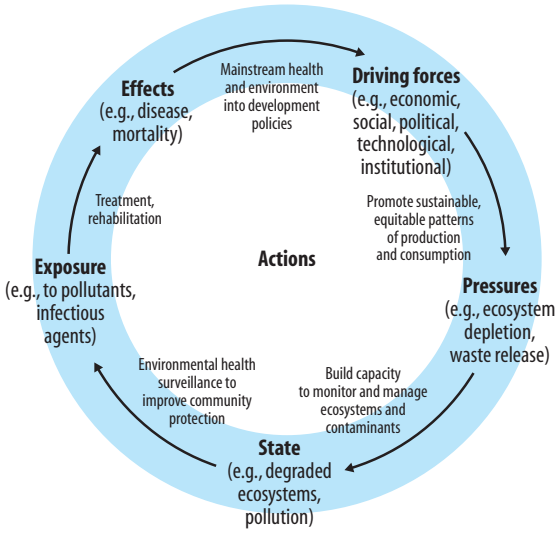
Ecohealth therefore can be seen as a platform for integration and innovations in research, policy, practice and education for a range of health and environmental issues and for a growing body of work that spans disciplinary, sectoral and cultural boundaries. The ecohealth and watersheds focus of this research paper is one specific example of these broader trends and development in the field of ecohealth.

2.2 Conceptual Models Linking Health, Environment and Social Processes

The emergence of the field of ecohealth has been supported and informed by developments in theory, methods and practice that link health, ecosystems and society, as well as conceptual models that seek to frame the relationships between environmental and social determinants of human health. Here we briefly review several models that demonstrate developments in thinking about the relationship among health, environment and social processes and offer the reader some conceptual constructs to inform understanding of the material presented in later sections of this report.

The simplest framework we present is the DPSEEA framework (pronounced "deep sea") that was developed as part of the HEADLAMP (Health and Environment Analysis for Decision Making) Project, a collaboration of the World Health Organization, the United Nations Environment Programme and the United Nations Environmental Protection Agency in the early and mid-1990s. DPSEEA stands for Driving forces, Pressures, State, Exposure, Effects and Actions. This model is often presented graphically, and unlike Figure 1 below, organized vertically in a linear fashion, from Driving forces (top) to Effects (bottom),with actions feeding in at all levels of the process. The adaptation by Carniero (2006) provides a useful reminder of the feedback, cycles and interactions that characterize health and environment relationships.

Figure 1: The DPSEEA model



(Source: Carneiro *et al.*, 2006, adapted from Corvalan *et al.*, 2000).
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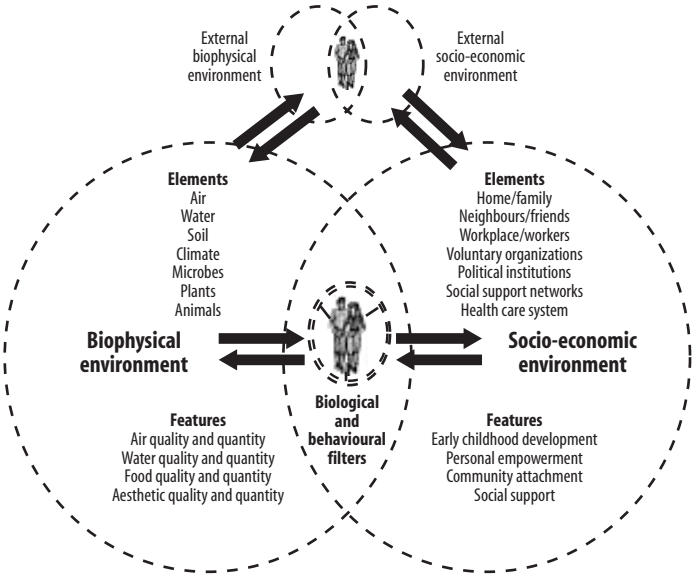
This model is useful in at least two ways. First, there is a clear derivation of the model from the Pressure-State-Response framework that is ubiquitous in environmental management fields. This greatly facilitates communication of environment and health relationships to that particular audience. It brings environment and health into the professional comfort zone of practitioners of, for example, environmental impact assessment and environmental monitoring. Second, it is organized in a hierarchical manner while at the same time emphasizing action. This makes the point that intervention in environmental contexts to improve human health can be targeted at a variety of scales, and that choice of scale is important. The DPSEEA model, however, is simplistic and requires much clarification about the sequence of—and feedbacks within—any particular set of relationships.

The DPSEEA framework and many related models of environment and health express human health as the end point in a series of relationships that cascade across a set of scales. These tend to be expressed in a linear manner. While this has the advantage of conceptual clarity, it is somewhat misleading and overly simplistic. Health is more accurately conceived as an emergent property of the overall set of interrelating social and environmental relationships in a system. Such systems are complex, not simply complicated (e.g., as described by Kay *et al.*, 1999; and Hansell *et al.*, 1997), being characterized by feedback loops that lead to resilience and stable domains of behavior, but also the possibility of rapid and surprising change.

The "Butterfly" model of health for an ecosystem context (VanLeeuwen, 1998; VanLeeuwen *et al.*, 1999) and the "Prism" Framework of Health and Sustainability (Parkes 2003a, Parkes *et al.*, 2003) seek to depict the interactions within environment-and-health systems. Furthermore, both models are couched in a discussion of the evolution of our understanding of the meaning of health and its determinants, the influence of ecological thinking, and the need for management of human health at the interface of biophysical and socio-economic environments.

A primary advantage of these models is that they place human beings more explicitly within the system rather than external to it. Humans are the focal points and participants in the relationships that influence their health, and not simply the object of consequence for outcomes of biophysical or socio-economic processes. This type of thinking has implications for our approach to managing such systems.

Figure 2: Butterfly model of health for an ecosystem context



(Source: VanLeeuwen, 1998).

In the Prism Framework (Figure 3), Parkes *et al*. (2003) emphasize "the need for integrated approaches to research and policy, methods that can engage with the synergies between the social and physical environment, and the incorporation of ecosystem principles into research and practice." Thus, the management of social-ecological systems for human health will be multi-layered, requiring the synthesis of knowledge across a broad spectrum of scientific, professional actors and private sector, governance and lay stakeholders.

The integrated conceptual models of Parkes and VanLeeuwen reinforce the need for social-ecological approaches to health promotion and protection that date back to the Ottawa Charter (WHO, 1986), and its important guiding principle of "reciprocal maintenance," that is "*to take care of each other, our communities and our natural environment*" (WHO, 1986). By reconnecting with the concept of reciprocity between biophysical and socio-economic environments (ecosystems and social systems), Parkes and VanLeeuwen make an important and explicit distinction from the ideas presented in the DPSEEA model. Instead of viewing social processes as actions "in response" to driving forces, pressures, the state of the environment, exposure and health effects, Parkes and VanLeeuwen's frameworks explicitly re-couple the biophysical and socio-economic environment and encourage thinking and approaches which recognize that:

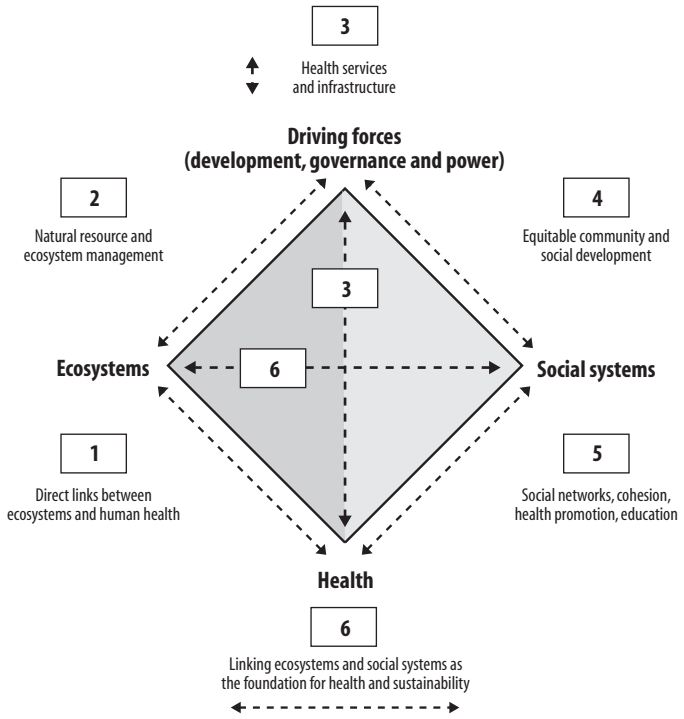
i) the same driving forces and pressures can result in combined social and environmental health inequities, hazards and impacts (McMichael *et al.*, 2008);

ii) policies that decrease social inequities and improve social cohesion have the potential to not only improve health outcomes (Marmot, 2007; Stansfeld, 2006), but also to minimize the drivers of ecosystem change; and

iii) linked social-ecological actions that promote reciprocal maintenance (*to take care of each other, our communities and our natural environment*) have the potential to create a "double-dividend" that improves both the socio-economic and environmental determinants of health, as well as achieving the goals of sustainable development (McMichael, 2006; Parkes *et al.*, 2003).

The application and implications of these integrated approaches will be discussed in more detail in Section 4 in the specific context of watersheds and public health.

Figure 3: Prism Framework of Health and Sustainability



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Depicts: 1. Direct links between ecosystems and human health (traditional environmental health); 2. natural resource and ecosystem management (including land and water use); 3. health services and infrastructure (including water and sanitation services); 4. equitable community and social development (including socio-economic determinants of health); 5. social networks, cohesion, health promotion and education (including social capital); 6. linked social;-ecological systems (synergies between the environmental and socio-economic determinants of health can arise when social processes generate health benefits through empowerment, justice and social cohesion while also enhancing ecosystems) (Source: Parkes *et al.*, 2003).

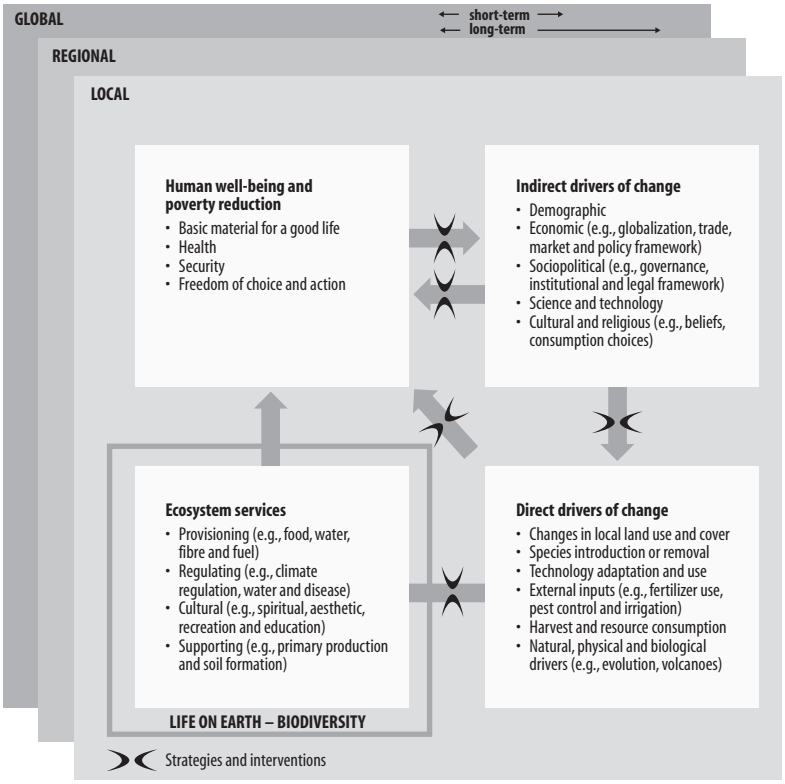
The final model reviewed here is the conceptual framework of the 2005 Millennium Ecosystem Assessment (Millennium Ecosystem Assessment Board, 2005). The relationships depicted in Figure 4 complement the models of Parkes and VanLeeuwen by explicitly linking human well-being with a suite of significant "ecosystem services." This anthropocentric approach makes a clear argument for environmental policy in human terms. It incorporates a broad definition of human well-being, which includes not only health, but also the basic material for a good life (good social relations, security, and freedom of choice and action) and notes that strategies and actions are needed at almost all points in the framework. The concept of ecosystem services is elaborated in further detail in Section 3.

The Butterfly model, the Prism Framework and the MA framework (Figures 2, 3 and 4) help us to understand that health is an expression of the condition of the overall system of interacting ecological and human relationships. By going beyond the linear depictions that characterize health or illness as a consequence of exposure to defined environmental hazards, these frameworks allow us to more easily conceive of human health as a lens through which to view social-ecological systems that are complex and evolutionary. This,

however, does not negate the usefulness of the DPSEEA framework or other models such as those referred to in later sections of the document.

Each model presented here has advantages and disadvantages and for this reason we take the position that these models should be studied and understood as a family. An important example of complementary concepts that have contributed to the "family" of ecosystem approaches to health can be found in the theories related to resilience and complexity— where applications in ecological and human development sciences have informed fields ranging from natural resource management, to disaster response and recovery. These themes are introduced briefly here, prior to focusing our attention on the specific ecosystem context of watersheds in Section 3.

Figure 4: Millennium Ecosystem Assessment's Conceptual Framework



Changes in the indirect drivers of change can lead to changes in drivers that directly influence ecosystems. The resulting changes in ecosystems are reflected in changing ecosystem services, which in turn affect human well-being. These relationships operate concurrently at a number of scales, including the local, regional and global scales. Source: Figure B in Millennium Ecosystem Assessment, (2005).

2.3 Resilience and Complexity

We understand ecosystems and social systems to be complex adaptive systems. The most useful expression of this comes from resilience theory, and is expressed in a large and growing literature with roots in complexity science and adaptive management. Complex adaptive systems are characterized by processes that act as causal morphogenic feedback loops (Kay *et al.*, 1999). That is, in these systems a bundle of key relationships operate in a way that leads them to self organize (and maintain organization) within a limited domain

of behaviour (known in complexity science as an "attractor"). Such systems are resilient— they maintain structure and functioning despite changes to their internal and external environments. However, these systems also undergo rapid and surprising change, often running through a cycle in which they repeatedly build structure and then collapse as described in Buzz Holling's famous "figure-8" schematic (see Gunderson & Holling, 2002). At the release and reorganization stage of this cycle such systems demonstrate the capacity for adaptation and innovation (and in the case of human systems, learning).

Understanding phenomena from the perspective of resilience and complexity provides insight into the management of complex adaptive systems. For example, we understand that because systems are resilient they may resist external pressure for long periods of time, then undergo sudden and surprising change (Regier & Kay, 2001; Sendzimir *et al.*, 2004). We also gain an appreciation that uncertainty related to the complex nature of the phenomena we attempt to manage is irreducible. This requires a change of perspective in management. Instead of attempting to design and implement a "system," we encourage the evolution of a complex adaptive system through strategic intervention such that the likelihood of systems evolving toward potential desirable attractors is maximized. Approaches such as adaptive co-management (e.g., Armitage, Berkes & Doubleday, 2007; Olsson, Folke & Berkes, 2004;) and the adaptive ecosystem approach (Bunch, 2003; Kay *et al.*, 1999) have been informed by the kind of understanding enabled by resilience and complexity theory.

Practical application of resilience and complexity theory to address issues that involve both ecosystems and health has been exemplified by the development of AMESH: An Adaptive Methodology for Ecosystem Sustainability and Health (Waltner-Toews & Kay 2005, Waltner-Toews *et al.*, 2004). There has also been increasing recognition of the potential of "resilience" as an integrating concept that bridges health and sustainability concerns across scales from individuals, to communities and ecosystems—with application to contexts as varied as agro-ecosystem health (Waltner-Toews and Wall, 1997), individual resilience in rural communities responding to drought, hailstorms and bushfire (Hegney *et al.*, 2007), community responses to environmental toxins (Morrison, 2008; Morrison *et al.*, 2009) and disaster preparedness and recovery (Masten & Obradović, 2008).

Masten and Obradović (2008 p.9) highlight the convergence of themes and ideas to address common challenges in the face of uncertainty and complexity, noting that:

> "*Ecological resilience and development resilience both focus on changes that preserve viability and adaptive flexibility for an uncertain future in which adaptive success in the face of major challenges requires change and some responsive flexibility for a system to survive or flourish. Both also recognize the role of human judgment in defining desirable or undesirable regimes or outcomes.*" (Masten & Obradović, 2008)

In addition to links between ecological and developmental resilience, strategies to "reduce vulnerability" and "build resilience" have emerged in a range of fields and sectors with a preventive and proactive orientation. Examples include community development, disaster preparedness, sustainability and public health (Arnold, 2005; ISDR, 2007, 2008a; Pearce 2005; Ryff & Singer, 2003; Turner *et al.*, 2003; Woodward *et al.*, 1998).

In the following sections we revisit these themes in the specific context of watersheds and watershed management—addressing the interrelationships between ecosystems, health and resilience, and the social processes required to integrate these considerations across multiple spatial and organizational scales.

3.0 Watersheds: A Place-based Approach to Integrated Water Resources Management

In this paper, the links among ecosystems, health and society are being explored in the context of a physical place defined by the movement of water over and through land. The boundaries of this "place" can be defined at a variety of scales (e.g., sub-watershed, watershed, river basin, lake basin) and encompass a wide spectrum of human activity, social organization and ecological processes. In the sections below, key ecological concepts related to water management are discussed. These concepts provide the ecological framework for a broader discussion of watersheds as "settings" supporting human-ecological actions at a variety of scales.

Watersheds are dynamic landscape constructs that are driven by what Falkenmark (2003) describes as a "hydrological imperative." Indeed, these settings are heavily influenced by both climate (long-term) and weather (short-term)—the link between the broader hydrologic cycle, local hydrological conditions, biotic/abiotic interactions and land uses is fundamental in predicting possible future states for a watershed setting. Global climate changes will create "hydrological imperatives" that require adaptation and management on a variety of scales. These imperatives have important links to public health, environmental justice and human security due to their influence on the wide variety of ecological goods and services provided to humans by watershed ecosystems.

3.1 Integrated Water Resources Management, the Ecosystem Approach

The Global Water Partnership (GWP, 2000) defines integrated water resources management (IWRM) as "a process which promotes the co-ordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems." The concept of IWRM emerged in reaction to the social, political, economic and environmental tensions that resulted from the prior emphasis on the "development" of water resources in much of the developed and developing world. IWRM embodies a shift in emphasis away from "development" and toward the long-term "management" of water resources in a more holistic sense. It promotes the three E's of: economic efficiency, environmental sustainability and social equity (Falkenmark, 2003).

One of the challenges of IWRM lies in the pervasiveness of water as a social, cultural, economic, ecologic, technical and political construct. Water resources management is, among other things, a(n):

- livelihood issue;
- land use issue;
- industrial and agricultural development issue;
- aesthetic and spiritual issue;
- social equity issue;
- climate change issue;

- environmental issue;
- governance issue;
- urban issue; and a
- health issue.

The numerous interrelated and sometimes conflicting perspectives associated with these issues influence the way in which water resources are developed, managed and valued. There is an increasing recognition that effective water resources management requires the development and implementation of a compromise position among a wide variety of stakeholders which serves to meet the needs of human populations while safeguarding the long-term viability of the water resources themselves.

While the conceptual development of an IWRM approach to water management may appear at first glance to be both viable and achievable, the implementation of this concept has proven to be quite complex. Chief among the challenges of IWRM is the decision of what, in fact, to integrate and how to decide if a management strategy is integrative "enough." As can be seen from the list of potential issues above, the scope of activity and the vast array of stakeholders included under the IWRM umbrella is itself a challenge to effective water management. Added to the challenge is the diverse number of institutions that are involved, directly or indirectly, in water management activities which also operate at a variety of ecological and administrative scales.

One way of operationalizing the IWRM concept has been through the promotion of catchment management (popularly known as watershed management in North America). Watershed management is discussed briefly in the following section.

3.1.1 Focus on the Watershed

A watershed is a boundary of land that separates different drainage basins from each other. This boundary is related to the elevation of land, and so the boundaries of a watershed tend to be smaller in hillier areas and larger where land is more flat. The catchment is the area of land drained by a watercourse within its watershed boundaries, or to use Falkenmark and Folke's (2002) description "[w]ater's flow in the landscape defines the spatial unit through its linking of upstream and downstream activities in the catchment" (2002, p. 4).

Watershed management offers a particular approach to water management within the physical "place" of the watershed or catchment and—drawing on the insights of IWRM—can provide an integrated unit for water, land and natural resource management. Scale is a significant issue in watershed management, as the concept of a watershed can be defined for small streams and tributaries, as well as large rivers and lakes. At larger scales watershed management may be referred to as river basin management (e.g., the Red River Basin or the Danube River Basin), or with regard to a lake or inland sea (e.g., the Aral Sea basin). The scale of the watershed in question plays a significant role in determining the kind of issues that are discussed—smaller basins tend to have more localized concerns. The area of interest can be defined at different scales, and the interactions of the surface and groundwater may not be fully captured by the surface water boundary.

The process of watershed management can be ad hoc and isolated, or it may be guided by a set of publicly negotiated goals, objectives and planning processes. The social processes involved with watershed planning are outlined in more detail in Section 4.1, below. Watershed management can be reactive, often in response to a crisis or disaster, such as drought, flooding or a severe weather event (see Section 4.1) or linked to a watershed planning process (see Section 4.2). Reactive management tends to lead, in the short term, to technical fixes to key problems (e.g., dams, other infrastructure), but may also catalyze the development of a proactive management strategy designed to mobilize broader participation in efforts to better manage

water resources. Due to the different scales involved with watersheds, watershed management strategies will ideally be "nested" with the management of smaller watersheds oriented to issues within their jurisdiction, but also located within a larger river basin management framework. Core principles of watershed management include:

1. Watersheds are natural systems with which we can work.
2. Watershed management is continuous and needs a multi-disciplinary approach.
3. A watershed management framework supports partnering, using sound science, taking well-planned actions and achieving results.
4. A flexible approach is always needed (USEPA, 2006).

In some cases, tensions between upstream and downstream water users can make this scenario challenging to implement, and in other cases, these concerns become international issues when the larger hydrological unit transcends national boundaries—i.e., the Great Lakes/St. Lawrence Basin. Watershed management thus provides a framework in which to discuss a significant and challenging topic: that of upstream and downstream water management. This issue often has significant political dimensions, as downstream users are often urban, whereas upstream areas are typically rural. Upstream users often also include resource intensive water users and polluters such as the forestry, mining and petroleum sectors.

3.2 Key Ecological Concepts Related to Watersheds

While watershed management is an inherently anthropocentric activity, there are several key ecological processes that drive the water management system and which should be explicitly considered in any IWRM process. Chief among these concepts are:

i) The hydrologic cycle;

ii) Green and blue water;

iii) "Ecological" or baseline water flows; and

iv) Biomes.

In addition, numerous other ecological considerations come into play when attempting to "manage" water, including: nutrients and chemicals; carrying capacities and pollution; erosion and sedimentation; and the notions of variability and resilience. The key ecological processes identified above are briefly reviewed in the sections that follow.

3.2.1 The Hydrologic Cycle

The hydrologic cycle is a fundamentally important concept in water resources management and is likely to become increasingly relevant to water managers in the future. At its most basic level, the hydrologic cycle links water processes on the ground to atmospheric processes and changes. The relationships between water resources and global climate changes are therefore inseparable. Water managers are becoming increasingly cognizant of the challenge of managing water resources in a changing climate. Previous successes in using design storms[1] based on past climatic records are proving less reliable in an era of more frequent extreme

1 A design storm is a selected storm event that informs the design of drainage and flood control strategies. An x-year design storm reflects the probability of the storm occurring once in x years in a given area.

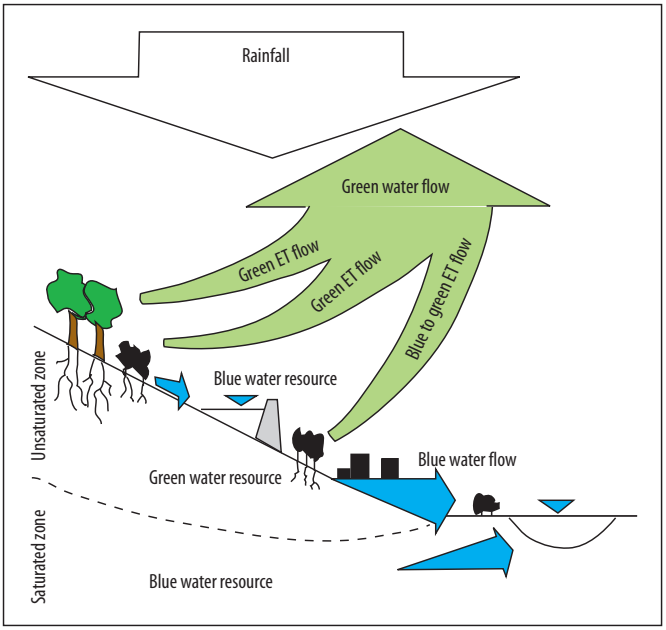
weather events (both floods and drought). This has implications not only for the design of water infrastructure but also for the adaptive management of water resources. Our limited ability to forecast weather and climate conditions in both the short and long term thus also limits our ability to accurately predict the future conditions of water resources in any given place.

Besides the climatic link between water resources and atmospheric processes, problems are caused by long- and short-range transportation and deposition of contaminants, such as acid rain, mercury, persistent organic pollutants and other compounds which move through the ecosystem via the hydrologic cycle.

3.2.2 Green and Blue Water

Whereas the hydrologic cycle is important in highlighting the linkages between atmospheric processes and water management, the concept of green and blue water (Figure 5) helps illustrate the fundamental connection between land and water management.

Figure 5. Blue and green water flows.



Source: Falkenmark, 2006

Blue water accounts for 40 per cent of the world's freshwater supply and is the water that runs off into rivers and lakes and that recharges groundwater supplies. Blue water is concentrated in discrete flows and is easily "harvested" for human uses, such as consumption and hydroelectric energy production.

Green water, on the other hand, accounts for approximately 60 per cent of the world's fresh water supply. This is the water held in soil and plant material which enters the system as precipitation and returns to the atmosphere through the processes of evaporation and transpiration (evapotranspiration)—i.e., from the respiration of plants and animals and from exposed surfaces. Green water cannot be piped or drunk, but is the water in the soil that supports the growth of plants, bacteria and other life forms. Levels of green water in the soil are affected by changing land uses, particularly those related to changes in soil permeability, vegetation and runoff generation (Falkenmark, 2003, 2006).

Indeed, land uses are linked to both blue and green water flows through their influence on the infiltration capacity of the land, as well as through the release of potential contaminants (e.g., nutrients, pathogens, persistent organic chemicals, heavy metals, pesticides, herbicides) into local ecosystems. Even small changes in land uses (e.g., changes to particularly sensitive areas like wetlands) can have dramatic impacts on blue water resources through their influence on groundwater and runoff levels as well as changes in the amount of water stored in the soil (and hence in the local water system) over time. Thus it can be seen that land uses within a watershed and their impact on both green and blue water flows are linked to public health issues like food security, water and soil pollution and the provision of habitat for potential pathogens.

High levels of arsenic in blue water in Aberjona (Box 1) provide an informative case of interactions between different types of blue water in a watershed. Concerns regarding the burden of disease from exposure to arsenic (Prüss *et al*., 2002) in other parts of the world demonstrate other interrelationships. In Bangladesh, contamination of some sources of blue water (surface water in rivers and lakes), led to harvesting of groundwater as a proposed safe alternative, and created unprecedented problems due to high levels of (naturally occurring) arsenic in the groundwater source (Bhattacharya & Mukherjee, 2001; Chowdhury *et al*., 2000; Smedley & Kinniburgh, 2002)

Box 1

Arsenic in Groundwater

In a study on the movement and distribution of arsenic in an urban industrialized watershed in eastern Massachusetts, Hemond (1995) found that "the patterns of arsenic distribution and speciation … show that it is necessary to consider the entire watershed to assess the behaviour of this contaminant."

In the late 19th to mid-20th centuries, the Aberjona Watershed was the site of several leather and chemical manufacturing industries. These industries released large quantities of heavy metals (including arsenic) into the watershed; one part of which is now the Industriplex Superfund site. Arsenic persists in an aqueous state and can be absorbed by biota. It is acutely toxic to humans in amounts as small as 70 to 170 mg/kg.

In the Aberjona Watershed, arsenic has migrated from the headwaters of the watershed to the groundwater and sediments of the area. Concentrations of several hundred mg/kg can be found in sediments throughout the watershed, which is far above the cited lethal dose of arsenic for humans. This case highlights the dynamic links between surface water, groundwater and sediment pollution in a watershed.

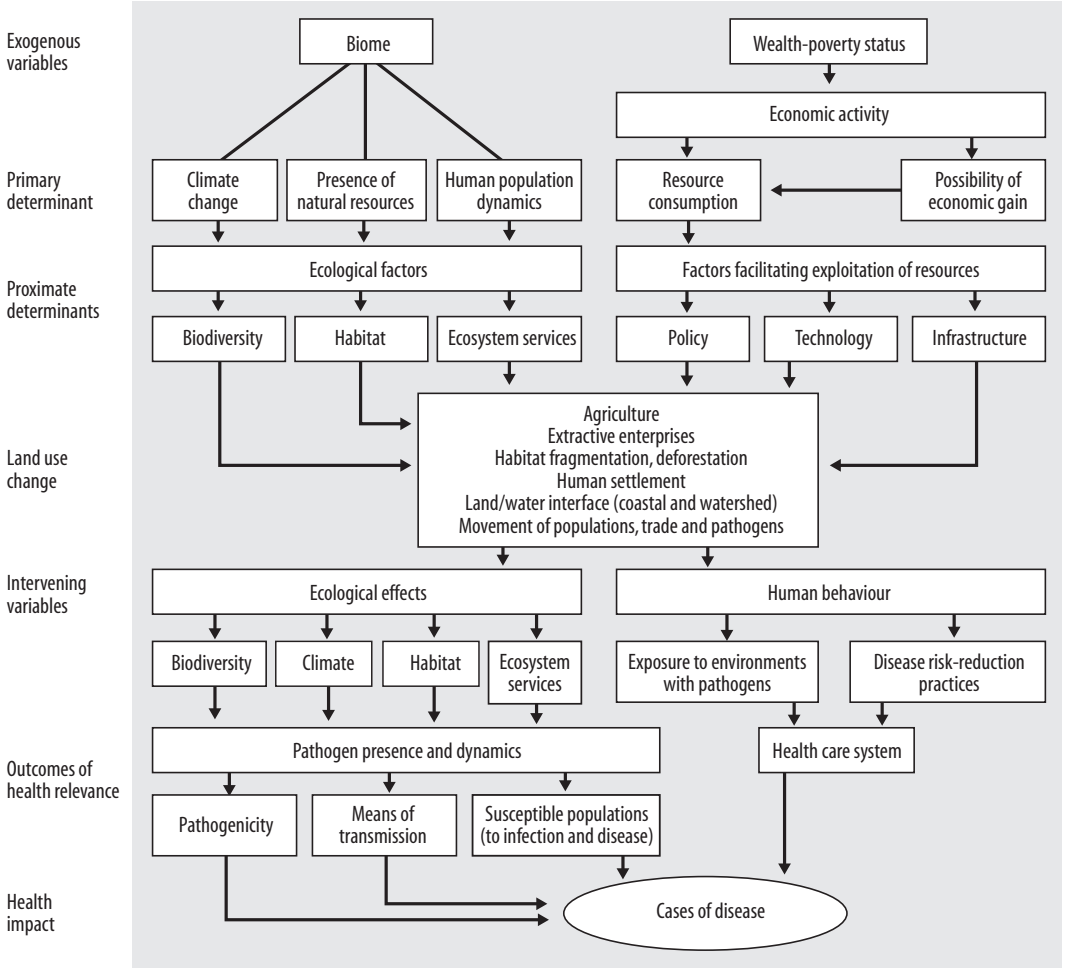
3.2.3 "Ecological" Flows of Water

The ecological flow of water through a watershed system is the amount of water required to maintain that system in a desired state. The concept of ecological flows is therefore related to the ideas of resilience and complexity in social-ecological systems as well as to that of baseflow levels for streams and rivers. Simply put, in order to maintain a water system in a desired state, a certain level of precipitation is required, captured and/or transported through surface and groundwater flows in a given watershed area. If these flows are not forthcoming (or are too large) over a period of time, the ecological system in question may shift to another state that is better suited to the new hydrological imperative. This shift may have significant and irreversible consequences for the biota that live in the watershed, as well as the viability of certain land uses, such as agriculture, and certain food supplies, like fish and waterfowl. There is a clear link between ecological flows of water and human health through both the human need for reliable water supplies, food security, the carrying capacity of water (i.e., the ability to dilute pollution) as well as the emotional, aesthetic and cultural links between human beings and viable waterbodies.

Some countries, such as South Africa, have instituted regulatory protections on river flows in order to maintain viable water systems. Reserve water flows are defined in South Africa's National Water Act (1999) as containing both a basic human needs reserve of 25 litres/person/day as well as an ecological reserve that protects the aquatic ecosystem. In other countries, a lack of such protection has meant that some large rivers, like the Columbia River in Canada and the U.S., are used in their entirety and no longer reach the sea. However, setting reserve flows of water is a difficult task given the natural variability in water systems and the need to understand the relative contributions of both surface and groundwater flows.

3.2.4 Biomes

Box 2
A Systems Model of Land Use Change that Affects Public Health



This model shows relationships between drivers of land use change and subsequent levels of environmental change and health consequences. Various levels of investigation and intervention are evident and range from specific risks factors and determinants of population vulnerability to larger institutional and economic activity (Source: Patz *et al.*, 2004).

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A final ecological concept that is important to mention in the context of IWRM has to do with the notion that many ecological constructs are not beholden to watershed or catchment boundaries. The concept of biomes helps demonstrate this concept, which is applicable to a number of ecological systems at a variety of scales. Biomes are ecological regions that are characterized by their dominant forms of vegetation and are maintained in a place over long periods of time by landscape and climatic conditions. In Canada, the boreal forest is a significant biome, as are the temperate grasslands and the Arctic tundra. These significant land use designations do not correlate directly with the boundaries of major drainage basins. Thus, sometimes the terminology of a "problemshed" is a more appropriate way to describe the geographic focus of a particular environmental issue, which may cross several watershed boundaries. While the watershed is not always the optimal unit of organization for all environmental issues, the presence of watershed governance groups at multiple-scales provide a forum for tackling other issues "on the ground."

An example of the biome as the starting point from which to consider a cascade of interacting biophysical and socio-economic variables in a systemic and hierarchical framework is provided in Box 2. In their systems model of land use change that affects public health, Patz *et al.* (2004) provide a point of reference to examine land use change as the outcome of a range of social and ecological factors, and also as a driver of disease emergence. The figure highlights many ways in which solutions to other socio-ecologic "problems" (such as habitat protection or pathogen management) will intersect with watershed-based land use planning and water management issues. Relationships between watersheds and water-related illnesses are discussed further in Section 4.

3.3 Watersheds as Settings for Health and Well-being

A complementary perspective on watersheds is enabled by viewing the ecosystem-based units as settings for promoting health and well-being. The statement that "*health is created and lived by people within the settings of their everyday life; where they learn, work, play and love*" was a central tenet of the Ottawa Charter for Health Promotion (1986), and provided the basis for the settings approach to health promotion (St. Leger, 1997). Healthy settings have been noted for their "ecological" and systemic perspectives (Green *et al.*, 1996; Poland *et al.*, 2000; Dooris, 2005).

Despite the intended ecological and systemic orientation of healthy settings approaches, such initiatives—whether healthy cities, schools, workplaces or hospitals—often overlook the specific ecosystems in which they are placed or situated. This results in the incongruous situation of initiatives that are place-based and conceptually "ecological," but blind to the processes, functions and populations of local ecosystems. A healthy settings approach that is unrelated to ecosystems is inconsistent with recognition of ecosystems as a basis for framing and informing health promotion (Butler, 2006; Cole *et al.*, 1999) as well as the growing body of knowledge about the relationships between ecosystems and public health outlined in Section 2.

Parkes and Horwitz (in press) argue that watershed-based water resources management provides fertile ground to rethink the settings approach and envision new "settings" for health and sustainability. Not only does consideration of water orient public health to the systemic relationships underpinning health and well-being, but it could also help overcome the missed opportunity to focus on the commonalities between health promotion and sustainable development (Butler, 2006; von Schirnding 2005) and the themes of the Millennium Ecosystem Assessment. Focusing on watersheds as a setting for health and sustainability encourages a view of health-water relationships that goes beyond traditional focus of water management on drinking water supply, sanitation and contaminants. Watersheds are also the basis for livelihoods, employment, food and service provision, and culture. Watershed ecosystems not only affect the causes of health inequalities but also provide a setting for intersectoral action to improve health. These themes will be elaborated further in Section 4.

3.3.1 Ecological Goods and Services Provided by Watershed Ecosystems

Explicit attention to the ecosystem goods and services provided by watershed ecosystems deepens and extends the relevance of watersheds as settings for human health and well-being. Ecosystem services and human health are directly linked in the Millennium Ecosystem Assessment (Section 2.1) which defines ecosystem services as:

> "*…the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services, such as regulation of floods, drought, land degradation and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious and other nonmaterial benefits.*"

Water resources provide key provisioning, regulating and cultural services. The question of what elements of the ecological system qualify as "goods and services" is a normative one, which includes both "use" and "non-use" values. Use values include both the consumptive (i.e., water supply) and the direct and indirect non-consumptive uses (i.e., transportation, habitat support) of water resources, while nonuse values are related to broad concepts like existence, biodiversity and cultural heritage (U.S. National Academy of Sciences, 2004).

The concept of "ecological goods and services" can be applied in watershed management. This approach would seek to manage catchment areas "as an asset that delivers a bundle of water and ecological goods and services" (Falkenmark, 2003). In the context of managing ecosystems for human health and well-being, the relationships between health and the environmental goods and services provided by watershed ecosystems is an important research question. Brauman *et al.* (2007) define hydrologic services as "encompass[ing] the benefits to people produced by terrestrial ecosystem effects on freshwater." They organize these services into five categories: improvement of extractive water supply; improvement of in-stream water supply; water damage mitigation; provision of water-related cultural services; and water-associated supporting services, and pay particular attention to the variability of water supplies in both space and time. An overview of potential ecological goods and services provided by watersheds is elaborated in Table 1 (following Moburg & Folke's [1999] matrix for coral reefs). This summary is complicated by the fact that not all land- and fresh-water based goods and services can be understood using a watershed ecosystem perspective defined at multiple scales. The table is, therefore, only a rough overview of potential ecological goods and services.

In Figure 6, the link between short-term goods and services and the longer-term sustainability and adaptive capacity of freshwater ecosystems is linked to a variety of driving forces operating at different spatio-temporal scales. The combination of the quantity of water entering a watershed through the hydrological cycle (i.e., the flow regime of the watershed) and the quality of the water (which is related to both natural features in the area and anthropogenic inputs of contaminants from the land, water and air) circulating through it lay the foundation for functional aquatic ecosystems. Changes in these driving forces influence the assemblage of species found in a given freshwater ecosystem.

Under some conditions, such as those associated with the cultural eutrophication of waterbodies, the assemblage of species is such that fewer ecological goods and services are available to human populations to support their health and well-being. Cultural eutrophication is enhanced biotic productivity (particularly algal growth) due to the addition of nutrients into natural systems beyond their original state. It is often associated with human actions such as changing land uses. The subsequent death and decay of algae blooms can led to hypoxic conditions in the local environment which have detrimental effects on other life forms, including humans (see Carpenter *et al.*, 1998).

Table 1. Overview of Ecological Goods and Services provided within Watersheds

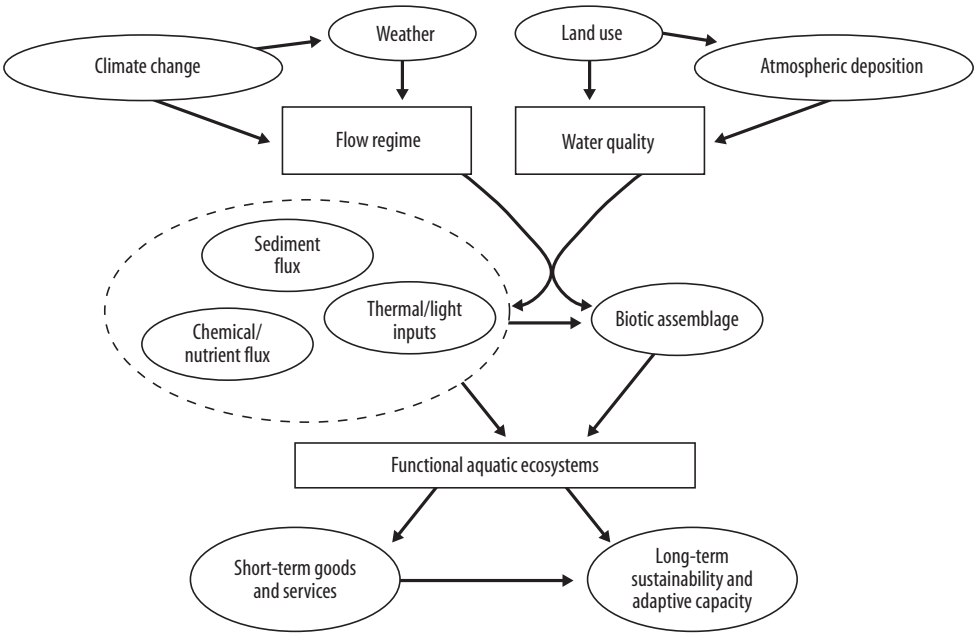
Goods		Ecological Services					
Renewable Resources	**Non-renewable Resources**	**Physical Structure Services**	**Biotic Services Within Ecosystems**	**Between Ecosystems**	**Biogeo - chemical Services**	**Informational Services**	**Social and Cultural Services**
Agricultural and forestry products Municipal and industrial water and other resources Wildlife Freshwater fishery resources Ecological flows of water Groundwater and rainwater Hydroelectric power Fertile soil Nearshore marine resources Ornamental resources	Ore including aggregate Soil generation Oil and gas	Shoreline/ river bank creation and erosion Land drainage Moderate weather extremes	Maintenance of habitats Maintenance of biodiversity and a genetic library Regulation of ecosystem processes and functions Biological maintenance of resilience	Biological support through links to ecozones and biomes/ maintenance of large-scale habitats Export of organic production to other areas' food webs Biological control/ regulation of pathogens	Nutrient cycling Primary production CO_2 regulation/ carbon cycling Oxygen production Waste assimilation Detoxification of wastes Water purification	Monitoring and pollution record Climate record	Mitigate drought, floods, landslides Support recreation and ecotourism Aesthetic values and artistic inspiration Sustaining the livelihood of communities/ urban areas Support of cultural, religious and spiritual values

The nested hierarchy of watersheds defined at different scales provides flexibility for action to follow the subsidiarity principle (i.e., management at the lowest possible scale). The localized nature of watershed actions allows watershed management groups to tackle issues from the surrounding "problemshed" while increasing local and regional resilience through good governance, adaptive management and social learning processes. Watershed boundaries, defined at different scales, provide a place-based focus for discussions pertaining to integrated water resources management and provide a social-ecological "setting" in which to develop our understanding of human health and well-being.

Drawing on these ideas, the following sections examine the proposal that watershed management can provide a useful framework for action that relates to both environmental concerns and the social determinants of health. Using the lens of social-ecological resilience, we examine the potential of watershed governance processes to influence not only the provision of the range of ecological goods and services described in Table 1, but also the socio-economic factors in the communities dependant on them, as well as the broad-

er processes of social capital formation, collective learning and social engagement. The combined social-ecological perspective helps to identify the value of watershed management as a strategy to improve health by addressing both its environmental or social determinants.

Figure 6: Conceptual model of driving forces that influence freshwater ecosystems.



Source: Adapted from Baron *et al.* (2002)

4.0 Social-ecological Resilience in Watersheds

Combining insights from the discussion of ecosystem approaches to human health (in Section 2) and watershed-based integrated management (Section 3) leads us to the observation that human health can be an objective of watershed management. In making this observation we perceive the watershed as a social-ecological system in which the scale and nature of human activity impact the nature, condition and quantity of ecosystem services and in which biophysical ecosystem components and social processes combine to support human well-being (including physical and mental health, livelihoods and socio-economic well-being). We are interested not only in the health impacts of freshwater ecosystem change, but also the social processes required to prevent and respond to these changes.

In managing watersheds, human health can be seen as both an objective for management and an indicator of the overall state of the ecosystem. Management of the watershed, particularly key components such as water, is management of the social and environmental context that leads to human health and well-being. Managing water and land is important for both preventing exposure to environmental hazards and in promoting the social determinants of health and well-being. An important concept in such management is that of resilience—the ability of the system to maintain its organization (structure and processes) in the face of shocks and stressors.

By linking to the frameworks and ecosystem concepts presented in the previous section, in this section we make the case that watershed management processes (if done well) have the potential for a cascade of positive effects including:

a) Prevention and buffering of water-related hazards—from water provision to disasters;

b) Providing a ecosystem-based context for multi-stakeholder governance and social learning;

c) Improvement of social determinants of health through social processes that encourage more equitable distribution of resources and enhance social engagement, social networking and trust; and

d) Increased resilience in social-ecological systems at multiple (nested) scales—ranging from individuals through families, communities, sub-catchments, river-basins and bioregions and the global biosphere.

4.1 Buffering Exposure to Environmental Hazards through Watershed Management

An important and fundamental component of the links between ecosystems and health is the potential for ecosystem disruption to create new environmental hazards—whether chemical, (micro) biological or physical. Whereas other authors have contributed to a growing body of evidence about hazards and risks arising from ecosystem change and the environmental burden of disease (e.g., Aron & Patz, 2001; Corvalan *et al.*, 2005; Prüss-Üstün & Corvalan, 2005) our intention here is to focus on increased awareness of and opportunities to prevent and buffer environmental hazards through proactive watershed management.

4.1.1 Watersheds and the Burden of Water-related Disease

Any discussion about watersheds as buffers to health hazards, must start by recognizing that provision of poor quality water poses one of the major threats to human health in the world. Recent WHO reports have paid particular attention to the role of water in the environmental burden of disease (Prüss-Üstün *et al.*, 2004; Prüss-Üstün & Corvalan, 2005), estimating that 88 per cent of all cases of diarrhoea globally were attributable to water, sanitation and hygiene (Prüss-Üstün *et al.*, 2004). The risk factor was defined as "drinking-water, sanitation and hygiene behaviour," as well as aspects of food safety that are related to water, sanitation and hygiene (i.e., food contamination by unsafe water, or the lack of domestic hygiene). This is a profound impact, considering diarrhoea alone amounts to an estimated 4.1 per cent of the total global burden of disease as measured in DALYs (Disability Adjusted Life Years) and is responsible for the deaths of 1.8 million people every year (WHO, 2004).

Drawing on updated information from the World Health Organization (2004) indicators of the severity of global morbidity (illness) and mortality (death) identified as "water-related" included:

- *Trachoma* – 500 million people globally are at risk and 146 million are threatened by blindness. Improving access to safe water sources and better hygiene practices can reduce trachoma morbidity by 27 per cent.
- *Schistosomiasis* causes tens of thousands of deaths every year, mainly in sub-Saharan Africa, and is strongly related to unsanitary excreta disposal and absence of nearby sources of safe water. Man-made reservoirs and poorly designed irrigation schemes are main drivers of schistosomiasis expansion and intensification.
- *Intestinal helminthes* – Access to safe water/sanitation facilities and better hygiene practice can reduce morbidity from ascariasis by 29 per cent and hookworm by four per cent.

Globally, there have also been major water-related epidemics of toxoplasmosis, cryptosporidia, giardiasis, hepatitis, *E. coli* and Campylobacter, cyclospora—many of which have been implicitly attributed to poor watershed management and its links with municipal drinking water supplies, (lack of) sewage treatment (Bowie *et al.*, 1997; Wu *et al.*, 1999).

The ongoing imperative of water-related mortality and morbidity and its contribution to the global burden of disease has been well addressed in a range of international projects and publications (see for example, Prüss-Üstün *et al.*, 2004; Prüss-Üstün & Corvalan, 2005). Our intent in here is to build on this knowledge to highlight that water-related diseases are only one component of a range of direct and indirect health impacts related to water resources (see Section 4.2).

In particular, we point to sustainable watershed management as critical to ensuring the availability of the ecosystem services that are a non-negotiable basis for providing water and sanitation services, with a range of implications for social determinants of health and well-being. For example, in many developing countries, providing access to improved drinking-water sources has the potential to considerably reduce the time spent by women and children in collecting water and trigger a range educational and economic benefits that improve the social determinants of health. In similar settings providing access to improved sanitation and good hygiene behaviours would help break the overall cycle of faecal-oral pathogen contamination of waterbodies, yielding benefits to health, poverty reduction, well-being and economic development (Prüss-Üstün & Corvalan, 2005). Furthermore, taking an "upstream" perspective both of these provisions (drinking water and sanitation) are dependent on the integrity and sustainability of the watershed, and influenced by the resource management decisions occurring upstream and downstream.

In addition, we underscore the importance of the dynamics of the watersheds, land-use change, and ecosystem service provision, in relation to new and (re)emerging infectious diseases. Attention to environmental change in watersheds and its potential to influence presence of and exposure to water-related pathogens and associated outbreaks of disease has been raised in a variety of contexts including: analysis of waterborne disease outbreaks following extreme weather events in the United States (Curriero *et al.*, 2001); trends in water-related diarrhoea following road-development in Ecuador (Eisenberg *et al.*, 2006); and understanding of the social and ecological dynamics of Leptospirosis (Barcellos & Sabroza, 2000; Roberts *et al.*, 2001; Vinetz *et al.*, 2005).

It is important to note that relationships between water and emerging infectious diseases are not always due to direct exposure to contaminated water. Box 3 provides a valuable reminder of the ways in which watershed and land-use management, including use of hazardous chemicals, are intertwined within and through the watershed. Here we are reminded of the health impacts of ecological and social processes at the level of the biome (see Box 2) may well be mediated through upstream and downstream relationships of water.

Box 3

West Nile, Land Use and Watershed Management

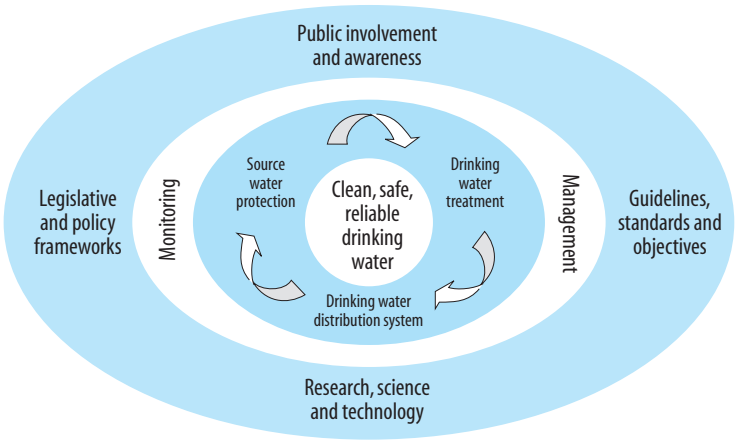
Recent outbreaks of West Nile virus in the northeastern U.S. and southern Ontario have supported a geographically-based management approach to the management of this disease. For example, spraying programs to control mosquito populations in New York City were guided by the ZIP codes of areas in which dead birds had tested positive for the virus (Karpati *et al.*, 2004); in Massachusetts, a two-km radius around infected dead birds was used for management of the disease, which included the application of pesticides. These pyrethroid pesticides also have health impacts on human populations. Managing the risk of the West Nile virus involves a number of social, ecological, and economic factors. An understanding of seasonal hydrological cycles and flooding, as determined by the unique characteristics of a given watershed, as well as the characteristics of the local biota can help predict the location and distribution of potential breeding habitats for both mosquitoes and potentially affected bird populations. Existing watershed management councils in New York State have access to a range of partners and resources to aid in West Nile virus mitigation programs.

4.1.2 Multi-barrier Approach to Drinking Water Provision

The protection of potable water supplies is a key element of most watershed planning activities. The need for attention to be paid to source water protection was reaffirmed in Ontario during the Walkerton water crisis, which killed seven people and left hundreds others sick (Box 4). Part 2 of the Report of the Walkerton Inquiry, which examined the crisis, highlighted the need for multi-barrier protection to safe drinking water supplies, beginning "on the land" and continuing through to the customer's tap (O'Connor, 2002). The Walkerton Inquiry dramatically changed the context for water planning and management in Ontario: "It advocated a multi-barrier approach to the protection of drinking water supplies, which would begin with source area protection" (Shrubsole, 2004, p. 8). In the Walkerton report, watershed protection and source evaluation are considered integral parts of the multi-barrier approach.

The multi-barrier approach to source-water protection "is an integrated system of procedures, processes and tools that collectively prevent or reduce contamination of drinking water from source to tap in order to reduce risks to public health" (CCME, 2005). As indicated in Figure 7, below, this involves not only clear policy guidance, but also public involvement and awareness, research, science and technological solutions. The multi-barrier approach is based on the precautionary principle and includes source protection, treatment, a secure distribution system, monitoring programs and responsive management (O'Connor, 2002).

Figure 7: Components of the multi-barrier approach



(Source: CCME, 2005)

A key strength of the multi-barrier approach is that it minimizes the potential negative impact of the failure of one or more barriers. In that way, it is similar to the Hazard Assessment and Critical Control Point program used in the food services industry. Underlying this strength is a shift from rather narrow management for a single component (e.g., potable water), to a more ecosystemic understanding in which the relationships among components and elements are monitored and managed.

Box 4

The Walkerton disaster through a social-ecological lens

In May, 2000, following several days of heavy rainfall, the municipal water supply in Walkerton, Ontario became contaminated with *E. coli* O157:H7, which entered into the water supply from a livestock farm adjacent to the municipal water well field (Ali, 2004; Shrubsole, 2004). Over a period of several days, hundreds of people within the Walkerton community sought hospital treatment for such conditions as bloody diarrhoea, vomiting, and severe stomach cramps. By the time the cause of the illnesses was discovered, seven people had died, and over 2,300 had become ill. It was one of the worse public health tragedies experienced in Canada.

Initially, the cause of transmission of the pathogen to the water supply was attributed to the unusually heavy rainfall events that had occurred several days earlier. It was argued that municipal water well supplies received excessive runoff from adjacent agricultural fields, which are often fertilized with manure which can be a source of this particular strain of .*E. coli* (Ali, 2004; Auld *et al*., 2004). However, Ali has provided a range of additional insights through a broader spatial, temporal and socio-economic analysis of the disaster (2004). Of particular note is an increased production of animal waste associated intensification of livestock operations in the region that was not matched by subsequent improvements in the municipal sewage treatment regulations. Ali notes that the 50,000 tonnes of waste produced by a feedlot of 25,000 cows is equivalent to the waste produced by about 250,000 humans but that "although intensive livestock operations produce as much waste as small cities, they do not have the rural equivalent of an urban sewage treatment facility" (p. 2605). As a result, livestock waste is collected into manure storage lagoons and then spread on agricultural fields as fertilizer. This may not pose too great a risk on a small scale, but when livestock operations are intensified and concentrated into a small region, as in Walkerton, the agricultural fields become supersaturated with waste, and are subsequently not fully absorbed. The rural counties that surround Walkerton have the highest density of livestock farms in Ontario. Ali also found that, following the outbreak, local health officials reported that all but two of 13 livestock farms located within a four-km radius of Walkerton had contaminated manure. Thus, the heavy rainfall events are more accurately posited as a catalyst to the Walkerton disaster, not as the direct cause.

Traditional epidemiological studies have tended to adopt a downstream approach, thereby downplaying important temporal and spatial considerations that may reveal how ecological changes influence the occurrence and transmis-

sion of pathogens (Ali, 2004). Inquiry into this disaster demonstrated that potential threats to Ontario's drinking water systems needed to be monitored on a more regular basis, with considerations of climatological conditions, land-use practices, and multi-stakeholder accountability being at the forefront (Auld *et al*., 2004). Elements of such outbreaks events usually include a source of contamination, transport of the contaminant from source to drinking water supplies, inadequate treatment, detection and reporting of outbreaks. These elements can be most effectively tracked and managed on a watershed-basis because they are inherently spatially distributed (Auld *et al*., 2004).

Downstream - Upstream

	Micro level	Meso level	Macro level
Ecological dimension	1 Individual water well; extreme weather event	2 Regionalized factory; farm setting	3 Evolution of new and (re)emerging diseases; processes of global climate change
Social dimension	4 Operator failure; individual farmer	5 Public utilities company; government agencies (MOE, public health); private lab testing	6 International political economy (neoliberalism); agribusiness

Source: Ali, 2004

4.1.3 Disaster Prevention, Watersheds and Public Health

There has been surprisingly little attention given to integrated and proactive approaches to health promotion, disaster preparedness and sustainable development, despite the common social-ecological context of the fields, and a converging interest in building "resilience" (as outlined in Section 2). In this section we examine the opportunity for linking preventive and proactive approaches to disaster reduction, health and sustainability, highlighting the relevance to water resource management. Water tends to become a critical issue in most disasters due to its essential contribution to all life. Water-related hazards include floods, drought, hurricanes, tsunamis and tidal waves, landslides, erosion, extreme weather/storms, heat waves, water-borne infectious diseases, technological disasters such as hazardous material spills, pollution, dam failures and more.

There has also been growing awareness of the importance of healthy ecosystems in disaster reduction, including hazard buffer zone protection from wave and storm action, flood protection, water recharge, water purification, and disease mitigation. Disaster risk reduction is recognized as a key component of IWRM and sustainability (UNWWAP, 2006). This is reflected in the common themes identified in the Dublin Principles for IWRM and Yokahama Strategy and Plan for Action for a Safer World. Hartnady and Hay (2004) identified the common principles between IWRM and disaster reduction as:

- integration of (resource) development-planning and risk-assessment processes;
- prioritization of prevention and preparedness;
- emphasis on cooperation and communication at all levels;
- importance of building human capacity; and
- an implicit need for conflict resolution.

The conceptual and practical overlaps extend beyond water management and disaster reduction to include health. An assessment of health impacts of floods (Ahern *et al.*, 2005) highlights the short and potential long-term health impacts of water related disasters. Ahern *et al.* found that most flooding deaths were due to drowning, injuries occurred when trying to remove oneself, family or possessions from affected areas, upon return and during cleaning up. As well as the expected evidence of oral-fecal, vector-borne and rodent-borne diseases, mental health issues were important—including post traumatic stress, depression, anxiety and suicides, with potentially profound impacts to long-term community health and well-being. Mould (with associated respiratory impacts) is another major public health issue in water-related disasters.

Even if water was not the hazard underlying the disaster, water and health concerns become tightly coupled after a disaster. Water is intimately involved with both of the dominant public health concerns after disasters, described by Noji (2005) as (1) Environmental Health, including Water, Sanitation, Hygiene and Vector Management (with a focus on providing adequate water supply, and excreta disposal and appropriate shelter for victims of disaster); and (2) Communicable Disease Control and Epidemic Management, where the focus is on controlling epidemics, disposal of dead bodies, immunization and adequate nutrition. Furthermore, even in the absence of specific natural or technological hazards, the extent of inadequate water and sanitation and water-related illnesses can—and arguably should—be seen as chronic public health disasters (Ajinkya, 2005; ProVention Consortium, 2007).

One reason for the lack of integrated and proactive approaches to water resources management, health promotion and disaster preparedness, is a persistent bias in each field toward "response" rather than prevention, and the paradox that "success is a non-event" (Rose, 1985) for both public health and disaster preparedness. Just as the larger proportion of health funding is invested in clinical care (sometimes known as sick-care), the majority of disaster management resources are spent in responding to a disaster, in building capacity to respond, and on equipment for emergency relief. Similarly, the public health links with the disaster preparedness field are often a reactive rather than proactive approach to health and well-being. That is, the focus is on emergency relief and water-related disease management, and little attention is paid to longer-term impacts on determinants of health.

Yet, the scale and impact of catastrophic events such as the 2005 Asian Earthquake and tsunami, Hurricane Rita and Katrina, and the ongoing Australian drought have begun to highlight in unprecedented ways the links between disaster, health and sustainability. These point to "chronic and widespread" contributing factors such as globalization and macro-economic policy, social exclusion, organizational inertia and global environmental change (O'Brien, 2006). O'Brien makes a powerful case for the need to reframe global environmental change and vulnerabilities to hazards in terms of "human security"—moving beyond the uncertainties of science to focus on addressing vulnerabilities and challenging the processes that undermine human security. Such a focus is intended to encourage recognition of the links between different types of security (environmental-, economic-, energy-, water- and food-security), as well as making issues of equity, power, justice and rights more visible (O'Brien, 2006). Of particular note is the way in which water (and the water cycle) is a linking mechanism between these "security" issues (Falkenmark & Folke, 2002).

This type of thinking is finally being reflected in more proactive approaches to disaster management, including refinement of processes of risk, hazard, impact and vulnerability assessment (Arnold 2005; Douglas and David, 2001) and shift in attention toward resilience. The Hyogo Framework on Risk Reduction and its focus on "Building Resilience of Nations and Communities to Disasters" (ISDR, 2007), is a prime example of this shift, providing the following informative definitions:

> *Vulnerability:* "The conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards" (ISDR, 2007, p.156) and

> *Resilience:* "The capacity of a system, community or society potentially exposed to hazards to adapt by resisting or changing in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organizing itself to increase this capacity for learning from past disasters for better future protection and to improve risk reduction measures." (ISDR, 2007, p.59)

Vulnerability and resilience have become cross-cutting themes for disaster reduction, irrespective of the type of hazard, and also provide a platform for practical, collaborative purposes, i.e., the understanding of complex issues as a function of social, economic, ecological, cultural, physical factors and that demands the input of various disciplines and various types of knowledge. The widespread applicability and relevance of vulnerability and resilience is also indicated by their increasing use in a range of other contexts, including notable overlaps with the fields of IWRM and public health. Recent work has started to build evidence of these links, gathering evidence of how disaster risk reduction can be integrated into poverty reduction and, vice-versa, to help reduce the vulnerability of the poor and protect their livelihoods and development gains (ISDR, 2008b).

To highlight this convergence, Table 2 provides an indicative sample of the range of international assessments and reports that identify the overlapping themes of vulnerability/resilience, water management, health, governance and sustainability. This converging attention provides an opportunity to integrate and harmonize multiple understandings and actions for multiple objectives of poverty reduction, equity and sustainable development (Downs, 2007).

Insight into the causes of disasters is often revealed in retrospect, from what is left out both in the management, planning and research. Ali's public "autopsy" of the Walkerton "disaster" (2004, see also Box 4) reinforces the need for greater awareness of the upstream, socio-political causes of disaster. Yet although socio-political analysis is a step forward, ongoing lack of analysis of ecological context in disaster management frameworks highlights an ongoing lack of integration—and the missed opportunity for proactive sharing, learning and exchange in the aftermath of disasters and also to build resilience (Bunch *et al.*, 2005).

Benefiting from the converging insights and common ground identified in recent disasters and translating these topical insights into practice requires settings where integration is possible. Watersheds provide an important context for proactive, integrated approaches to water resources, disaster reduction and public health.

Table 2: Overlapping agendas for health, freshwater management and sustainability: international assessments and agreements

International assessments/ agreements	The United Nations World Water Assessment Program (World Water Development Report)	The World's Water 2006-2007: The Biennial Report on Freshwater Resources	International Strategy for Disaster Reduction: Implementation of Hyogo Framework for Action 2005–2015	International Panel on Climate Change 4th Assessment Working Groups II and III	Millennium Ecosystem Assessment Statement from the Board and Full Report
Source	**UNWWAP, 2006**	**Gleick, 2006**	**ISDR 2007**	**IPCC, 2007a and b**	**MA Series, 2005**
Cross-cutting emphasis	'Water: A Shared Responsibility' (Water and Development)	State of freshwater resources	'Words into Action…Building the resilience of communities and nations to disasters'	'Impacts, Adaptation, Vulnerability' (WG II); 'Mitigation of climate change' (WGIII)	'Ecosystems & Human Well-Being: Current State & Trends' (CSAT) 'Policy Responses' (PR)

International assessments/ agreements	The United Nations World Water Assessment Program (World Water Development Report)	The World's Water 2006-2007: The Biennial Report on Freshwater Resources	International Strategy for Disaster Reduction: Implementation of Hyogo Framework for Action 2005–2015	International Panel on Climate Change 4th Assessment Working Groups II and III	Millennium Ecosystem Assessment Statement from the Board and Full Report
Source	**UNWWAP, 2006**	**Gleick, 2006**	**ISDR 2007**	**IPCC, 2007a and b**	**MA Series, 2005**
Freshwater/ ecosystems/ IWRM	Ch 4: 'The state of the resource' Ch 5: 'Coastal and Freshwater ecosystem'	Ch 2: 'Going with the Flow; 'Preserving and Restoring Instream Water Allocations'; Ch 3: 'An update on desalination'	Ch 2: 'Improving risk Information and early warning'; Ch 3; 'Building a culture of safety and resilience'; Ch 4, 'Reducing risks in key sectors'	WGII – Ch 3: 'Fresh Water Resources and their Management' WGII – Ch 4: 'Ecosystems their Properties, Goods and Services'	CSAT – Ch 7: 'Freshwater Ecosystem Services' CSAT – Ch 16: 'Regulation of Natural Hazards' PR – Ch 7: 'Water'
Resilience and vulnerability	Ch 10: 'Managing Risks: Securing the Gains of Developmen't; Ch 13 'Enhancing knowledge & capacity'	Vulnerability and Water systems in Ch 1: 'Water and Terrorism' Ch 4: 'Floods and Drought'	As above. See also ISDR (2008b) linking disaster risk reduction with poverty reduction, and protecting livelihoods.	WGII – Ch 19: 'Assessing Key Vulnerabilities and Risk from Climate Change'	CSAT – Ch 6: 'Vulnerable People and Places' PR – Ch 15: 'Integrated Responses'
Determinants of health	Ch 6: 'Protecting and Promoting Human health'	Ch 5: 'Environmental Justice and Water'	As above, with implied links between community resilience, poverty reduction and the social determinants of health.	WGII – Ch 8: 'Human Health'	CSAT – Ch 5: 'Ecosystem change & Human , Well-being' Ch 14: 'Human Infectious Disease Agents' PR – Consequences for.. human health (Ch 16); poverty reduction, ecosystem services and human well-being (Ch17)
Governance and sustainability	Ch 2: 'The Challenges of Governance'; Ch 11: 'Sharing Water'; Ch 12: 'Valuing and Charging for Water' Ch 15: 'Case Studies Moving towards an Integrated Approach'	Governance challenges in all themes e.g. legal frameworks & policy (Ch 2, 5), risks to business & industry (Ch 6).	Ch 1: 'Making Risk Reduction a priority'; Ch 5: 'Strengthening preparedness for response' See also ISDR (2008a) resilience in national platforms for Risk Reduction	WGII – Ch 14: Regional on Climate Change & Sustainability'; foci e.g., North America; Ch 20: 'Perspectives WGIII – Ch 13: 'Policies, instruments & cooperative arrangements'	PR – Ch 18: 'Choosing Responses' (decision-making, policy and governance processes)

4.1.4 Watersheds as a Context to Enhance Livelihoods and Reduce Poverty

> "The challenge ahead for water resources management is to strike a balance between the use of the resources as a basis for the livelihood of the world's increasing population and the protection and conservation of the resource to sustain its functions and characteristics" (GWP 2000, p.12).

The previous sections have examined the role watershed management plays as a buffer to environmental hazards in relation to water-related disease, multi-barrier protection for drinking water and disaster prevention. Here we introduce the idea of watershed management as a buffer against poverty through its potential to enhance sustainable livelihoods. The emerging attention to sustainable livelihoods makes a strong case for "inextricable links between poverty reduction and natural resources management" (World Bank, 2007) and with explicit recognition of the impacts of natural resource management on livelihoods and employment, down to the household level (Ashley, 2000; Singh & Gilman, 2002). A livelihoods perspective brings to life the important socio-economic implications of the ecosystem goods and services of Table 1, especially in agricultural and resource-based economies dependent on sustainable provision of green and blue water (Figure 5).

An important argument in favour of watershed management is therefore its potential to enhance the livelihoods of the people living both within the boundaries of a watershed, and—depending on the scale—potentially "downstream" as well. A wide range of technical options and good management practices have been developed that can have significant impacts on the quality of the local watershed ecosystem. They include, for example: fencing of common land to allow for its regeneration; the construction of check dams and contour trenches; the protection of wetlands and buffer (riparian) zones along waterways; no-till farming; and the promotion of soil and water conservation.

Bearing in mind the multi-faceted implications of initiating and sustaining these "technical" options, participatory watershed management processes are moving away from the traditional "top-down" focus on the biophysical environment toward a more bottom-up approach to community sustainable development (Turton, 2000). The link between social and ecological policy is clearly shown by the multiple objectives that guide watershed development strategies. In India, the Ministry of Rural Areas and Employment guidelines include the following priorities (as cited in Turton, 2000):

- Productive (optimum utilization of the watershed's natural resources);
- Social (employment generation and development of other economic resources);
- Ecological/environmental (easy, affordable solutions building on indigenous knowledge); and
- Equity (emphasis on improving the economic and social condition of the resource poor).

Participatory watershed management approaches seek to empower local communities through the creation of watershed councils that represent community stakeholders; programming that works with them to respond to their interests; the provision of leadership training and the creation of structural and institutional conditions that can lead to early (often technical) successes (Hinchcliffe *et al.*, 1999; Liu *et al.*, 2008; Turton, 2000). This support tends to involve a range of local, regional and/or national stakeholders, including government agencies, NGOs and community groups.

Despite the potential for multi-faceted social benefits, the challenges and contradictions of participatory watershed management should not be overlooked. While short-term successes related to water and soil conservation are relatively easily implemented, creating the infrastructure to support longer-term community and household commitments is much more difficult (Bouma *et al.*, 2007). In relation to alleviating poverty and enhancing livelihoods of the poor, participatory watershed management processes may even perpetu-

ate tensions within a watershed area. Watershed management activities that target poverty alleviation must make a concerted effort in this regard or the benefits of watershed management risk perpetuating inequalities within watershed settings (Box 5).

Box 5

Poverty Alleviation and Participatory Watershed Development in India

In India, participatory watershed development programs documented by Turton (2000) had a number of positive local impacts. These included: increased cropping intensity and yields; reduced threat of drought; increased milk production; enhanced groundwater recharge; reduced downstream sedimentation; improved fodder production; enhanced investment in stall-fed livestock production; year-round availability of drinking water; employment opportunities for landless peoples' labour; and the diversification of village economies.

Despite these gains, however, research into the specific impacts of these improvements on the poor showed less impressive results. This was partially due to the fact that many of the benefits were "land-based" and thus were gained by landowners. The landless poor gained some benefits from employment opportunities, but these tended not to be sufficiently secure to reduce their dependence on migrant labour. This migration away from the watershed for months at a time also affected the ability of this segment of society to participate in local "participatory" activities. Turton (2000) also found that the dependence of the rural poor on common pool resources within the watershed (such as fuel, fodder and some food) were disproportionately affected by the watershed management activities, particularly through limiting access to those lands so that they could regenerate. In addition, the rehabilitation of degraded CPR lands created a new threat: that more powerful actors would encroach upon these "improved" lands, to the detriment of the very poor. These challenges highlight the need for an explicit focus on poverty alleviation to be central to watershed development mandates, if they are to explicitly address both social and ecological goals.

Participatory watershed management processes therefore face the challenge of engaging groups that are often systematically excluded from political and social processes within the watershed (Swallow *et al.*, 2006). In order to create an enabling environment to engage with marginalized stakeholder groups, Ravnborg (2006), for example, recommends making relevant hydrological assessments widely available; fostering broad-based and inclusive public hearing processes; enhancing legal capacity, particularly among the poor; and providing dispute-resolution mechanisms, such as a water ombudsman, who is widely available and easily accessible, especially to the poor. Thus, while poverty reduction and the creation of pro-poor watershed management policies is certainly achievable through the participatory watershed management processes, it is not inherently a part of the equation. Specific, targeted and committed action is required to create conditions that specifically target poverty alleviation priorities within watershed areas.

Attention to equity—of access and benefits—will be essential for participatory watershed management to fulfill is potential role in poverty alleviation and to potentially improve social determinants of health and well-being. In contrast, inequitable water resources management processes have the potential for serious negative consequences—exacerbating power discrepancies and drivers of environmental and social disruption which may also compound health disparities.

4.2 Watersheds as Settings for Governance, Social Learning, Equity and Well-being

The case for IWRM to be based on watersheds, catchments or river basins, was introduced in Sections 2 and 3. We noted that watersheds are effective units in which to link our discussion of water and health management because of the function of water as the "bloodstream" of both the anthropogenic world and the non-human world (Falkenmark & Folke, 2002). As such, the watershed provides a particularly useful venue

in which to discuss the upstream and downstream considerations of water quality and quantity, as well as provision of and access to ecosystem services. We also noted, however, that the watershed is not always an ideal unit for water management discussions, particularly with respect to groundwater dynamics and in some cases, coastal zone management activities. Nonetheless, part of the value of the watershed management paradigm is the ability for both key stakeholders (such as government, industry) and the public at large to relate to, and understand, the concept of water management through the visible and logical natural hydrological boundaries that the watershed model provides.

This section of the paper focuses on the collective, often multi-stakeholder processes that characterize watershed governance, and how these social processes have the potential to fulfill both ecosystem management and public health objectives. Drawing on themes from earlier sections, we examine watershed management as a social process that should involve adaptive management (Allen, 1997; Habron, 2003), social learning (Keen *et al*., 2005; Pahl-Wostl, 2005) and, often, collective decision-making (Brown, 2007a; Brown, 2007b). We focus on the characteristics of watershed management as a planning process and on the challenges of watershed governance processes that are applicable at multiple scales, and may also include different stakeholders at each of these scales. We also examine the potential for watersheds to provide a place-based setting for social learning and action that transcends boundaries between sectors, disciplines, communities and cultures. We argue that if these processes are conducted in a way that builds trust, social cohesion and reduces inequities, watershed management can not only reduce environmental hazards but also improve environmental and social determinants of health.

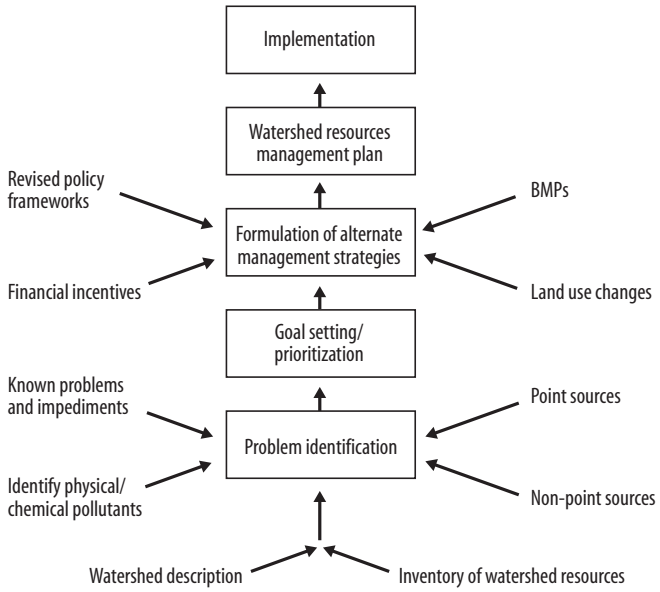
Real world challenges and opportunities of an evolving river-basin initiative in the Taieri River Catchment of New Zealand are used to exemplify and illustrate the dynamics of linking watershed management and health. Further information about this initiative can be found in Parkes (2003a, 2003b), Parkes & Panelli (2001) and Parkes *et al*. (2004).

4.2.1 Watershed Planning and Watershed Management

As with any social process, there are many entrance and exit points for watershed management. Watershed planning, like other public policy initiatives, can be state-directed, guided by the "iron triangle" of government, industry and bureaucratic interests, or it can involve a wider set of stakeholders. There are myriad different approaches that fall within this spectrum and the approach taken in any given place depends on many factors, including the size of the watershed, whether or not it crosses provincial, national and/or international boundaries, patterns of land ownership and settlement within the area, the location of the watershed in a larger watershed context (i.e., upstream or downstream of an urban centre or a key industry) and the major issues confronting the area (i.e., water quality, quantity, access, etc.). Given this diversity, it is difficult to elaborate any particular planning process, besides the "plan, do, review" formulation. That said, it is useful to identify steps and features common to many watershed planning processes. The generic overview of a watershed planning process provided in Figure 8 provides a point of reference for further discussion of watershed planning and management.

The process summarized in Figure 8 proposes that one of the first steps in watershed planning is defining the boundaries of the watershed in question. In the case of a surface water body, such as a river or a lake, this is a relatively simple exercise. In the case of groundwater, the boundaries of the aquifer in question may be more difficult to determine. Once the hydrological boundaries have been established, an inventory of the characteristics of the watershed is compiled, using both hydrological models and land use maps. Models are generated to predict the response of the waterbody to changes in precipitation, climate and land uses. Significant natural, cultural and historical features of the watershed may also be identified. In the past, watershed planning tended to focus on supply-side management approaches such as the construction of new dams or the location of water intake and effluent pipes; in some cases, this remains the extent of watershed planning exercises.

Figure 8: Proposed steps in a Watershed Committee Action Process



(Source: CCME, 2005)

Over the past several decades, however, the purpose and processes for watershed planning have changed. The many and often conflicting public and private interests in water resources on one hand increased recognition of the important social dynamics of watershed management and on the other highlighted the limits of the biophysical, technical and planning emphasis of supply-side management models such as depicted in Figure 8. Watershed planning has become a process of negotiation among stakeholders with different values and perspectives.

Building on the growing awareness of the social implications of watershed management initiatives (including those introduced in Section 4.1.4) it is now widely understood that sustainable watershed management efforts requires the engagement and participation of a wide range of public and private actors in both supply and demand management activities. Another way of characterizing approaches to water management is Brooks' soft and hard water path analysis whereby soft paths "rely on a multitude of geographically distributed, relatively small-scale sources of supply coupled with ultra-efficient ways of meeting end-use demands" (Lovins, 1977 in Brooks, 2005) and hard paths are those which "rely on large-scale capital intensive sources of supply and centralized management" (Brooks, 2005).

The successful engagement of a wide variety of stakeholders in an ongoing, adaptive and responsive process is what differentiates ad hoc and highly technical watershed management plans that languish on office shelves (no one actor can manage a watershed alone) from robust planning frameworks that support the activities a wide range of social, cultural, political and technical activities. The question of *what* a watershed is being managed *for* becomes increasingly important as more and more stakeholders engage in the management process. As mentioned in previous sections, watershed management is linked to the literature on adaptive management, which was first developed based on the experience and challenges of managing the Tennessee Valley Authority to respect multiple social and environmental objectives in the face of a great scientific uncertainty (Lee, 1993). An adaptive watershed management approach emphasizes the role of social learning in building effective and resilient management structures (Lee, 1993; Habron, 2003; Pahl-Wostl,

2005). A key question of this research initiative is what watershed management would look like if it explicitly engaged with the social and environmental determinants of human health and well-being across spatial and temporal scales.

4.2.2 Watershed Governance as a Multi-stakeholder, Multi-scale Process

As noted in previous sections, watershed management has increasingly become a forum for public engagement in, and discussions about, water and land management issues. This emphasis has come about through the recognition that no one actor or institution can make very significant inroads into the complex and multifaceted issues related to water. A wide range of engaged and empowered partners are needed, even at the smallest scales. Most watersheds are comprised of both public and private land, and so the active participation of landowners is needed to help implement watershed management plans, particularly in more heavily developed watershed areas such as those dominated by agricultural, urban and/or peri-urban interests.

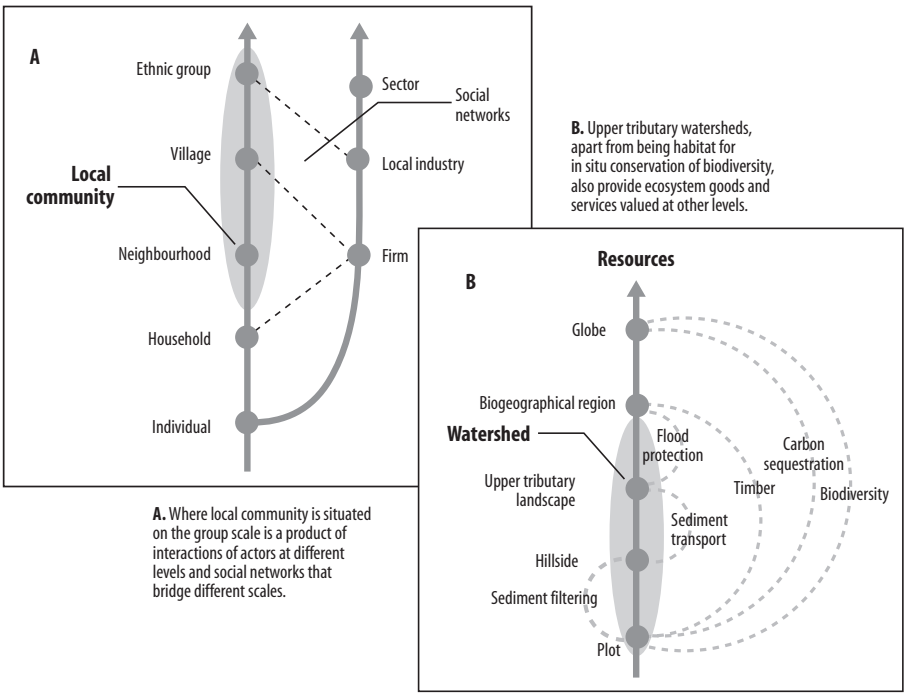
Involvement of diverse stakeholders is not unique to watershed management, but has provided a tangible context in which to understand both success factors and barriers to successful natural resource management, as well as complementary "added-value" and social benefits of participation (Pretty & Ward, 2001). The quality, nature and processes for multi-stakeholder involvement have been seen as critical to the success of watershed management (Mullen & Allison, 1999) and have provided new insights into the value of an integrated understanding of social and ecosystem dynamics in watersheds (social-ecological systems) (Sneddon *et al.*, 2002).

Recent work has also shed light on the value of translating understanding of the hierarchically nested nature of watersheds into the social processes of watershed management. This is consistent with the case made by Marshall (2008) that community-based natural resource management programs that succeed in solving large group and otherwise complex problems of collective action in an enduring way tend to be "organized in multiple layers of nested enterprises"(Marshall 2008, p.76, citing Ostrom, 1990).

The "multiple layers of nested enterprises" to which Marshall refers highlights the issue of scale. This is a central challenge of watershed governance. Both human social systems and the coupled natural systems with which they interact are organized as sets of nested hierarchical systems. This issue is examined in the context of the management of watershed tributaries in South East Asia and usefully depicted by Lebel *et al.* (Figure 9), who note that social networks have the capacity to not only create livelihood opportunities but also form the basis for environmental movements (including involvement in watershed management) across different hierarchies. This type of work is indicative of innovative approaches that seek to explicitly address and prevent inequities across different spatial scales and social contexts, such as those presented in Box 5.

A choice must be made about the appropriate level or scale within these hierarchies for management of the system(s). This choice is complicated by that the fact that nested hierarchies observed from any particular viewpoint (e.g., social, economic, agricultural, ecological) do not necessarily map spatially (nor their processes correspond temporally) to other interrelated sets of systems. Furthermore, the issue of different viewpoints or interests leads to the question of who is responsible for managing situations in an "integrated" manner—agencies, ministries or departments of Environment? Agriculture? Public Health? Energy? Natural Resources? Municipal Affairs? The question quickly leads to jurisdictional conflict.

Figure 9: A multi-level perspective on conserving with communities.



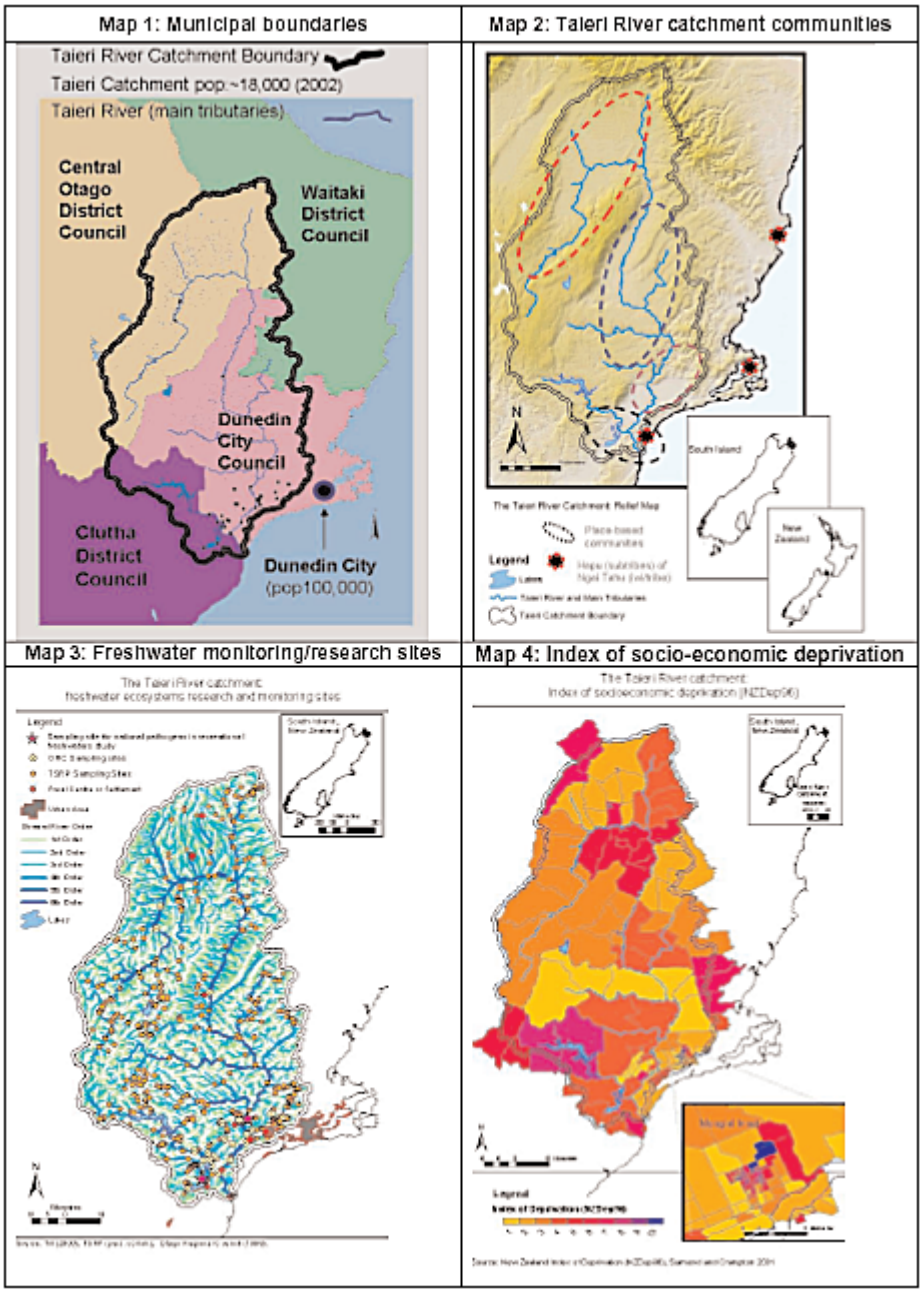
Source: Lebel *et al.* (2008, Figure 2 and 3)

The context specificity of the issues at different scales within a watershed is useful to consider in relation to specific examples. Four different maps depicting the Taieri River Catchment of New Zealand, provide an example of the different factors interacting within one river basin, spanning community, governance, environmental and social concerns (Box 6). The Taieri River is the third longest in New Zealand, draining a catchment area of 5,650 km^2 and hosting a population of approximately 18,000 people. The notably low-volume river has its origins in dry range and basin landscapes, and progresses through fertile alluvial plains, coastal lakes and estuarine flats, which were an important source of food for Māori in pre-European times (Tipa, 1999). In the past 150 years these same ecosystem characteristics provided for rapid development of farming (including dairy, cattle, sheep, deer farming, cropping and market gardening) and forestry. The Taieri River provides for irrigation, hydroelectricity, mining and recreational uses as well as surface and groundwater contributions to the drinking water supply for the municipality of Dunedin—a city of 100,000 which overlaps with but whose metropolitan hub lies outside the catchment area (Otago Regional Council, 1999).

Maps 1 and 2 speak in particular to the interplay of social dynamics within any catchment, enabling comparison between the river catchment boundary and municipal boundaries (Map 1), and their relationship with the different place-based communities located in this largely rural catchment. Maps 3 and 4 provide a juxtaposition of scale and disciplinary and thematic focus. Map 3 presents ecological research and monitoring sites in different tributaries and sub-catchments within the catchment. Map 4 depicts the index of socio-economic deprivation, an essential tool in social epidemiology in New Zealand, as calculated at the smallest unit for census analysis in New Zealand (Salmond & Crampton, 2001).

Box 6

Different views on ecosystems, community and determinants of health. Source: Parkes (2003a)



This interplay of issues at different scales and from different perspectives is one of the reasons that Biswas (2004) complains that while IWRM (read also the "ecosystem approach" in general) at meso- and macro-scales is conceptually attractive, in reality it is difficult to implement because complication and complexity of social and natural systems increase with scale (including numbers of stakeholders and jurisdictional conflicts). At larger scales there is a greater chance of neglecting localized issues and important interactions

(Blomquist & Schlager, 2005). On the other hand, management at smaller scales can discourage integration neglecting, for example, consideration of local effects on larger systems and downstream stakeholders, as well as problems manifest at the local level that originate at larger scales. Blomquist & Schlager (2005) note that this is partly an issue of drawing boundaries, which is ultimately a political decision. Questions must be resolved, such as: Who has a stake in the issue? Who participates? What are the rights of non-local affected communities?

Ecosystem approaches and IWRM almost always cite collaborative decision-making and adaptive institutions as central to the approach. Mechanisms to operate such approaches must navigate overlapping jurisdictions, conflicting mandates, multiple interests, while at the same time they must respond to new information and be able to operate in contexts of uncertainty. Cortner *et al.* (1998) noted that a primary problem in ecosystem management is that "institutional mechanisms for managing across jurisdictions under an ecosystem approach are largely unknown and have uncertain effects" and that "the adoption of ecosystem management as a management philosophy may require internal organizational change, and new arrangements among resource management agencies and the public." The nature of new arrangements may depend on the planning processes involved and the level of formality and funding provided.

Building on the information introduced in Box 6, the following section examines the interplay between watershed management and public health concerns in an evolving multi-stakeholder processes in the Taieri River Catchment of New Zealand. Conceptual frameworks presented in Section 2 are revisited, along with themes of resilience, uncertainty, and adaptive capacity.

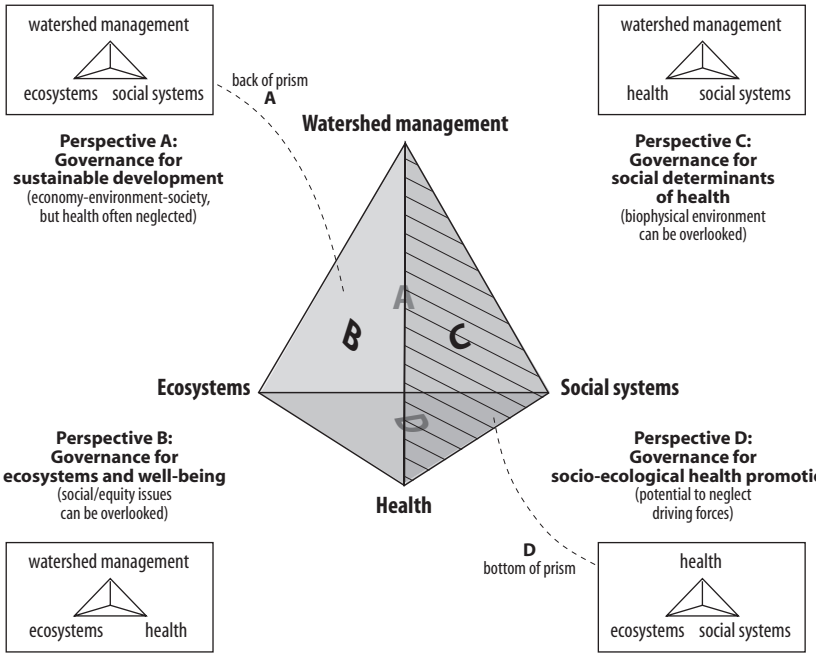
4.2.3 Linking Watersheds with the Determinants of Health and Well-being

While water has always been a fundamental concern for public health, the focus has tended to be on the provision of drinking water and sanitation services, and of water as a source of direct environmental hazards (through microbial and chemical contamination). Viewing water at the scale of watersheds or river basins, provides a broader view of the links between water and health. Building on the themes introduced in previous sections, we can see that degradation of water quality, lack of access and extremes of water quantity (drought, floods) can threaten livelihoods, compound existing inequalities, and undermine essential services—with profound implications for the social determinants of health. Focusing on the social determinants of health requires us to shift attention to the "causes of the causes" of health inequalities and a recognition that the root causes of many health challenges lie outside of the health sector.

Although intended for generic application, the Prism Framework (Figure 3) was developed in the context of water resources management, as a tool to examine interactions between, health sustainability and freshwater resources in the specific context of the Taieri River Catchment in New Zealand (see Parkes, 2003; Parkes *et al.*, 2003a). The framework draws attention to development, governance and power as drivers of both ecosystem and social change, and the implications of these changes for the environmental and social determinants of health. In the context of a watershed or river basin the Prism Framework can be used as a heuristic tool to examine how water resources management could serve to both promote ecosystem sustainability and improve the social determinants of health.

Where Figure 3 drew attention to six "axes" of relationships, Figure 10 highlights the three-dimensional character of the Prism—drawing attention to four complementary "perspectives" on governance. The Prism offers a framework to systematically consider watershed governance for "sustainable development," "ecosystems and well-being," "social determinants of health" and "social-ecological health promotion." While each perspective can be considered in isolation, their combination offers a multi-faceted vision of watershed governance with the potential to build social-ecological resilience and improve the determinants of health.

Figure 10: The Prism Framework: Four "perspectives" on governance for ecohealth and watersheds



The three dimensional Prism Framework depicts four governance 'perspectives' from which to understand the links between watershed management and the determinants of health. (Text in brackets highlights the limitation of each perspective and the need to see Prism as a whole)

Perspective A: Governance for Sustainable Development – focuses on the 'triple-bottom' line of economy, society and environment within a watershed, catchment or river basin. (Limited by a lack of awareness that criteria for sustainability are also 'upstream' drivers of the determinants of health);

Perspective B: Governance for Ecosystems & Wellbeing – focuses on the physical environment and the freshwater ecosystem good and services provided living systems, including buffering against direct environmental hazards. (Tends to overlook social/equity issues);

Perspective C: Governance for Social Determinants of Health – recognizes that water resources influence social equity, livelihoods and the socioeconomic determinants of health; values equitable, multi-stakeholder processes for water management. (Biophysical issues, and ecosystem processes can be overlooked);

Perspective D: Governance for Social-Ecological Health Promotion – recognizes watersheds as a setting for a health promotion "double-dividend," linking the benefits of sustainable freshwater ecosystems with equitable social processes and enhancing social-ecological resilience. (Needs to ensure upstream drivers of social and ecosystem change are not overlooked, since these are the "causes of the causes" of health inequities).

The Prism Framework was developed alongside and informed by the concepts and priorities of the local catchment communities involved in the participatory research project entitled the "Taieri Catchment and Community Health Project" (see also Box 7). Community participants in the project elaborated on their recognition and interest in the links between the river and community health, to identify the three integrating concepts of "lifestyles, livelihoods and living systems" as a description of their motivation for engaging with whole-of-catchment activities. This was reinforced by the formation of a collaborative, community-oriented catchment management group called the TAIERI Trust (Taieri Alliance for Information Exchange and River Improvement)—which entitled its first symposium "Taieri Waterways: Sustaining Our Lifestyles, Livelihoods and Living Systems" (TAIERI Trust, 2004).

The different perspectives of the Prism Framework offer complementary ways to view watershed governance, and to recognize the potential of watersheds to offer a tangible context within which to link ecosystems and equity, to improve the social-ecological foundation for health, and to prevent impacts of ecosystem degradation in relation to:

i) *living systems* or life-support systems, resulting in microbiological or chemical contamination/pollution of ecosystems and disruption to ecosystem services;

ii) *livelihoods* disruption of capacity to "earn a living" from ecosystem-dependent industries, especially agriculture, food production and tourism. (This is closely linked with concepts of sustainable communities and livelihoods, introduced in Section 4.1); and

iii) *lifestyles* or lifescapes, including quality of life, identity, sense of place, cultural and recreational benefits (see for example Horwitz *et al.*, 2001);

Each perspective of the Prism Framework in Figure 10 prompts new consideration of established concepts in the specific context of watersheds. Perspective A provokes consideration of population health as the "real" bottom line of sustainable development (McMichael, 2006). Perspectives B and C highlight the links between the Commission of Social Determinants of Health (see for example Marmot, 2005 and 2007), and the five interrelated aspects of human well-being defined by the Millennium Ecosystem Assessment (see Figure 4: i. health; ii. basic material for a good life; iii. good social relations; iv. security; and v. freedom of choice and action). Finally, Perspective D prompts consideration of the watershed as a 'setting' for socio-ecological health promotion and to foster social-ecological resilience (WHO, 1986; Parkes & Horwitz, in press).

Drawing on the Prism Framework's six axes (Figure 3) and four perspectives (Figure 10), another way to describe the inter-relationships between ecosystems, health and well-being is in relation to direct and indirect impacts:

> *Direct impacts* are associated with risks and hazards from direct exposure to the physical environment. These impacts can be understood in relation to the ecosystem services required, for example, for water and sanitation and the ecological determinants of water-related disease—including emerging and re-emerging infectious disease.
>
> *Indirect impacts* are associated with the "side-effects" of ecosystem disruption and their influence on the social determinants of health and well-being. These impacts are understood by seeing freshwater ecosystem services as a foundation for most resource-based economies and communities, with loss or degradation of ecosystems as a driver of poverty—with far-reaching implications for livelihoods, socio-economic status, income, inequalities and social cohesion.

Rural and agriculturally dependant communities—where the sustainability of a water resource is a fundamental requirement for the viability of agricultural livelihoods and communities—are particularly sensitive to the links between freshwater ecosystems and the social determinants of health. Conversely, they also serve to benefit from integrated approaches to promoting *both* health and ecosystem sustainability. An example of the interplay between these multiple objectives in a largely rural watershed context is provided by the evolving multi-stakeholder catchment-based processes that unfolded over several cycles of social learning in Taieri River catchment (Box 7).

Box 7

A multi-stakeholder process linking catchment and community health, Taieri River, New Zealand

1998 • Interdisciplinary Research Symposium in the Taieri River Catchment convened by the Ecology Research Group, University of Otago, Dunedin.

1999 • Major drought, Taieri River Catchment Monitoring Report (Otago Regional Council 1999)

PHASE I 1999–2001 **Taieri Catchment and Community Health Project**, Doctoral research led by M.W. Parkes, (see Parkes, 2003; Parkes & Panelli, 2003 in collaboration with research focused on public heath implications of *campylobacter spp* in the Taeri River Catchment (Eyles *et al*., 2003 ; Parkes *et al*., 2004, Eyles *et al*., 2006).

2000 (June to Sept.) • Catchment residents attend meetings in four place-based communities (Box 6, Map 2). Meeting focus on the links between the river and community health. Community reference groups choose to exchange interests and concerns through a cross-catchment meeting.
➔ *Referred to as "Participation" of individuals within community reference groups.*

2000 (Oct.) • Cross-catchment group meeting identifies principles, processes and priorities for future multi-stakeholder, whole-catchment activities—linking upstream-downstream concerns.
➔ *Described as "Collaboration" across different community reference groups.*

2000 (Nov.) • Cross-catchment representatives invite University of Otago researchers to a meeting to improve communication and exchange around collective priorities for river and community. Objectives identified for interim funding of a Community-University Partnership.
➔*Described as "Partnership"* between *cross-catchment groups and university.*

2001 (March) • Application to New Zealand Ministry for Environment's Sustainable Management Fund as *TAIERI Trust "Taieri Alliance for Information Exchange & River Improvement."*
➔multi-stakeholder collaboration *between* university researchers and community with "in kind" support from agencies and iwi was formed as an *"Alliance"* and *"Trust."*

PHASE II 2001–2004 **TAIERI Trust (1st Stage)**, launched September 2001, to establish a representative community-based catchment forum to: (i) enhance existing relationships and partnerships between communities, researchers and agencies; (ii) establish an information exchange system for effective communication, to include a website, newsletters and events; (iii) implement actions for environmental improvement, to include catchment classification, practical enhancement initiatives and education; and (iv) design reflection and evaluation strategies to enable ongoing review and dissemination of the catchment approach.

2003 The TAIERI Trust awarded New Zealand's Ministry for the Environment "Green Ribbon Award" and Otago Regional Council "Environment Award" for its work in community information exchange and riverine enhancement.

Phase III 2004–2006 **TAIERI Trust (2nd Stage).** Continued existing programs including monthly Newsletters on Trust Activities (www.taieri.net.nz/docs/newsletters.html).

2004 International multi-stakeholder symposium "Taieri Waterways: Sustaining Our Lifestyles, Livelihoods and Living Systems," Dunedin, New Zealand. TAIERI Trust Coordinator (Gretchen Robinson) becomes the youngest elected councillor on the Otago Region Council.

2006 (May) Final newsletter, marks end of Ministry for Environment funding for Coordinator position. Water quantity (scarcity) and quality issues in the Upper Taieri identified as critical issues for the future.

PHASE IV 2007–2009 **Upper Taieri Water Management Steering Group** receives New Zealand Ministry of Agriculture and Fisheries Sustainable Farming Fund award for "Effective Community Water Resource Management." Project overview states: "This project builds on the existing concept of *community-led* decentralised irrigation schemes/companies and brings in a new component—*multi-stakeholder involvement*. The project couples a farmer-led scheme with the formalised involvement of a multi-stakeholder '*Catchment Management Group*.' The group will implement project deliverables which will develop better relationships, improved monitoring, smoother Resource Management Act processes, *fairer* whole-of-community outcomes, improved environmental outcomes, and more efficient use of water." (SFF, 2008)

The initial motivation for community engagement in the Taieri project was community knowledge and awareness of the overlapping social, environmental and health benefits of the Taieri River (Phase I). In this phase, community members attended meetings motivated by the opportunity to discuss the "Taieri River and your community health." The level of interest in these issues was identified in a community survey (Parkes, 2003b) and reinforced by the formation of voluntary community reference groups of catchment residents whose meetings identified the need for learning and exchange between upstream and downstream communities—and subsequently led to these groups choosing to convene a cross-catchment meeting (Box 7, Phase I).

The evolution of community reference group *participation*, cross-catchment *collaboration*, community-university *partnership* and formalization of a community-based catchment "trust" demonstrates a range of features that characterize collective learning and decision-making (Brown, 2007a, 2007b) and the benefits of collaboration that combines horizontal and vertical integration across and between different types of stakeholders (Parkes and Panelli 2001; Parkes et al., 2005). These interactions also demonstrate some of the "bridging" and "bonding" dynamics seen to characterise participation and social capital formation in other natural resource management contexts (Pretty & Smith, 2004).

A personal account of the benefits of the multi-stakeholder processes and interactions outlined in Box 7 is provided by the Chair of the TAIERI Trust (Taieri Alliance for Information Exchange and River Improvement) as the 2nd stage of funding (Phase II) came to a close in 2004:

> "*From the source to the sea, our use of the river affects others downstream for better or worse. The Trust has shown everyone can help to improve the health of the river; school children, fishermen, farmers, university academics, local bodies, government departments, power companies, and recreational users can all play a part in making the river a better place*" (TAIERI Trust, 2006,p.3).

While the development of activities in the Taieri was not always focused explicitly on health and well-being, the notion of integrated watershed (catchment) management as an investment to improve the determinants health continued to feature explicitly and implicitly throughout the project. This is especially indicated by the ongoing emphasis on "Sustaining Our Lifestyles, Livelihoods and Living Systems" during a multi-stakeholder symposium held in the 4th year of the TAIERI Trust (TAIERI Trust, 2004). The adaptive and iterative process summarised in Box 7, also exemplifies the potential for watershed processes to focus on different scales of the social-ecological system at different times. This is evident in the mutually negotiated and pragmatic decisions to shift attention from individual place-based communities (Phase I), to whole-of-catchment activities (Phase II and III), followed by a return to priority issues of water quantity and quality in the dry-highlands of the upper catchment or sub-catchment (Phase IV).

In another example of "nested" interactions, the perspectives and contributions of Māori—the indigenous people of New Zealand (also known as Tangata Whenua, or people of the land)—were an important and particular feature of this unfolding project (Parkes & Panelli, 2001). Even before the process outlined in Box 7 was initiated, members of the local iwi (or tribe), were deeply engaged in integrated processes of research, decision-making and actions in relation to the "co-management of freshwater resources" in the Taieri and surrounding regions (Tipa & Teirney, 2003; Tipa, 2003; Townsend *et al.*, 2004; Panelli & Tipa, 2007). In this case "co-management" designates a treaty- and legislation-bound relationship between Māori tribes (iwi) and the designated authorities of the Crown or government of New Zealand, with obvious implications for any emerging catchment forum. The extent of work already underway by Māori colleagues and organizations created a parallel but complementary process—as well as a fertile tension—that informed, led, and provoked the process underway with other catchment stakeholders, and participation by local iwi in the TAIERI Trust.

Finally, other boundary crossing also took place in relation to sectoral mandates and "ownership" of the unfolding catchment process, particularly with regard to sources of funding. Throughout its course the project received funding from the "Education/Research" sector (Phase I, during initial community-univer-

sity partnership), the "Environment" Sector (Phase II, Ministry for Environment Sustainable Management Fund), and the Agriculture sector (Phase III Ministry of Agriculture and Fisheries, Sustainable Farming Fund). While the "Health" sector may not have been actively engaged to date, the relevance to the determinants of health continue to be evident in Phase IV, and the reference to "fairer whole-of-community outcomes" speaks to the issues of inequity and justice that are at the heart of social determinants of health and reducing health inequities.

4.2.4 Addressing Social-ecological Inequities and Promoting Health in Watersheds

Prior to presenting overall suggestions and recommendations, this section of the paper draws together themes from earlier in the report to highlight three priority areas for understanding the health benefits of watershed management in relation to overcoming poverty and inequalities; promoting resilience; and as a context to apply existing environmental health tools. Each of the priority areas are based on a view of watershed-based management as "double dividend" strategy—improving health by addressing both its environmental and social determinants (Figure 10).

(i) Watershed management as an asset to address poverty and reduce inequities

> *"Addressing the intersection between social determinants of environmental change and the effect of environmental change on health inequities will benefit sustainable ecological and population health alike"* (Marmot, 2007, p.1156).

The most well-established evidence in the social determinants of health literature focuses on inequities as a social hazard that increases morbidity and mortality (Wilkinson & Marmot, 2003; Stansfeld, 2006; Marmot & Wilkinson, 2006). Our proposal is simply that watershed management—if done well—has the potential to decrease poverty and related drivers of health inequities, and provide an ecosystem-based context within which to improve the social determinants of health. Conversely, watershed management that results in degradation of ecosystem goods and services and/or that exacerbates social inequities can have concerning consequences in terms of worsening poverty and negative downstream implications for health and well-being.

Just as studies of health tend to focus on disease and illness (or a "loss" of health), inter-relationships between water resources management, poverty and the social determinants of health are most dramatically presented through a focus on the deficits associated with a change or "loss" of access to, or availability of water. The links between water resources, poverty and inequities are especially notable in the contexts of dams and drought, both exacerbated by climate change.

By acknowledging that "the issue of equity—in terms of pre-existing nutritional and health conditions of the population and the capacity to resist new health problems—is at the root of the adverse health impacts of dams," the World Commission on Dams makes important links between the "sustainable development" perspective and the "social determinants of health" perspective of the Prism Framework (Figure 10). The Commission's reference to "health conditions" includes recognition of the links between the socio-economic impacts of dam development and health disparities- drawing attention to the inequitable impacts in relation to displacement of people, implications for indigenous peoples, downstream livelihoods, gender, cultural heritage, human health and equity (World Commission on Dams, 2000). The inequitable impacts of dams in terms of ecosystem change and social impact underscore the influence of water resources management on the "causes of the causes" of health inequalities, well beyond the direct impacts of hazardous exposures and water-related disease arising from ecosystem disruption.

The short- and long-term impacts of drought also offers valuable insights into the influence of water resources management on health disparities. In their review of the health consequences of drought in the

Canadian Prairies, Smoyer-Tovic and colleagues (2004) make a useful elaboration of the macro and micro factors that cause drought, and identify direct and indirect effects on health ranging from waterborne disease, respiratory effects from fire and dust, and mental health issues. Smoyer-Tovic *et al.* also highlight the important—but largely overlooked—impacts of drought on mental health in rural and agricultural communities, and the fact that family and small-scale landholders are especially vulnerable.

Yet what is missing from this analysis are the longer-term, indirect effects of drought as an contribution to health disparities, some of which are beginning to gain attention in relation to climate change—particularly in the context of rural and remote communities (Campbell *et al.*, 2008; Jones *et al.*, 2008). A more comprehensive perspective on drought and the determinants of health needs to consider the concerning domino effect that can result from a lack of water resources, including loss of yield (crops, livestock or virtually any agricultural product), loss of food production, loss of jobs, loss of lifestyles and cultural values, as well as complex challenges to local, regional and global economies. In this light Drought can be seen to have far-reaching and long-term implications on the determinants of health through impact on income; employment and working conditions; food security; and environment and housing. The socio-economic impact of drought on communities and services (especially small, remote and rural communities) also has the potential to exacerbate health inequalities related to disruptions to education and literacy services; early childhood development; social support; health behaviours; and access to health care.

The examples of dams and drought exemplify the range of "downstream" implications for the determinants of health when access to or availability of water is disrupted and compromised. Yet an alternative view is possible by shifting attention from preventing deficits to promoting assets. Prioritizing sustainable watershed management as a strategic asset to improve the determinants of health, strengthens the case for maintenance (or restoration) of ecosystem integrity, as well fostering sustainable livelihoods, equity and social engagement. In this light watershed management can be seen as a strategy to promote both health and social-ecological resilience.

(ii) Promoting health and resilience in watersheds: A re-integration of approaches

> "*In the catchment context, promotion of health and resilience converge toward a common goal: to cultivate enduring capacity to respond positively to change and challenges*" (Parkes & Horwitz, in press).

While the convergence between promoting health and resilience has been suggested in other literature (for example Hegney *et al.*, 2007, Rapport *et al.* 1998; Waltner-Toews & Wall, 1997) the idea has often lacked a "place" or setting for practical application and implementation. This report has identified watersheds as an ecosystem-based and socially relevant context within which to consider the conceptual and operational overlaps between resilience and health.

In proposing that "enduring capacity to respond positively to changes and challenges" can become a common goal for promoting health and resilience in catchments, Parkes and Horwitz also acknowledge overlaps with indigenous and place-based understandings of the relationship among health, ecosystems and communities, that have developed over millennia (2008). The re-integration of approaches proposed in this report recognizes that indigenous communities—and their traditional relationships and perspectives on nature and health—bear particular relevance to any emerging focus on ecohealth and watersheds. This is consistent with the important contributions of indigenous knowledge to the fields of adaptive management (Berkes *et al.*, 2000), ecohealth (Wernham, 2007; Panelli & Tipa, 2007; Stephens *et al.*, 2007), and as integral to multi-stakeholder watershed processes in particular (Lebel *et al.*, 2008; Turton, 2000). A notable example is the resurgence of interest in the approaches to land and water management in mountains-to-sea ecosystems across Polynesian cultures that are being revisited in both Hawaii and New Zealand (Tipa & Teirney, 2003; Kaneshiro *et al.*, 2005).

Engaging with the precedent and contemporary relevance of indigenous knowledge can be seen as part of a broader process of engaging with multiple different types of knowledge to inform collective understanding of health and sustainability in the watershed setting—including "local" and "place-based" knowledge of individuals or communities that have built up a relationship with land or specific ecosystems over time (Brown, 2007a, 2007b; Hegney *et al.*, 2007; Horwitz *et al.*, 2001). Brown (2007a) is explicit about the range of different knowledge to be recognized and valued as part of collective learning and decision-making for health and sustainability including individual, local community, specialized, organizational and holistic knowledge (Brown, 2007a). The themes of this report suggest that multi-stakeholder watershed management provides a particularly relevant ecosystem-based contexts in which to apply this kind of thinking—not least to highlight opportunities for convergence and synergies among public health, sustainability governance and environmental management (Brown, 2007c).

(iii) Watersheds as a context for intersectoral management tools and policy integration

> *"Addressing the underlying determinants of health through intersectoral efforts is key to ensuring sustained health improvements and ecologically sustainable development"* (von Schirnding, 2006).

Building on ideas development throughout the report another priority is the opportunity of integrated watershed management as a context to enable intersectoral policies and apply management tools that can have multiple benefits—for public health, ecosystem sustainability, development and governance. As an ecosystem context for intersectoral policy integration, watersheds could be the setting to implement a range of innovative and integrative management approaches:

a) the converging fields of *impact assessment*, including environmental impact assessment (EIA) , environmental health impact assessment (EHIA), and health impact assessment (HIA) (Banken, 1999; Hegney *et al.*, 2007; Wernham, 2007) including explicit consideration of watersheds as the context for land-use planning decisions and their health implications (Dannenberg *et al.*, 2003; Bhatia, 2007; Malizia, 2006)

b) integrated approaches to *security*, including water-, environmental-, food- and human-security (Falkenmark and Folke, 2002; O'Brien, 2006a), especially in the context of climate change (Catford, 2008; Jones *et al.*, 2008); and

c) promoting health and reducing inequities through attention to *environmental (in)justice and inequities* (Cifuentes and Frumkin, 2007; Gee & Grimpayne-Sturgesalt, 2004; Howze *et al.*, 2004; Lee 2002; Parizeau, 2006).

In the final section we focus on the opportunities, challenges and gaps in responding to these ideas—proposing watersheds as globally relevant settings to integrate health, environment, development and poverty alleviation (World Bank, 2007; UNEP, 2007).

5.0 Challenges, Gaps and Opportunities

In seeking to bring a holistic and interdisciplinary view of the potential relationships between the emerging field of ecohealth and the setting of the watershed, this paper integrates a wide range of current literature. The challenge remains, however, of synthesizing the material and the message into a framework that speaks not only to public health professionals, but also to ecologists, water managers and the development community. To this end, in this final section of the report, we pull together a range of challenges, gaps and opportunities for discussion, and look forward to creating new fora for discussions that will allow us to further develop these ideas. The potential for watershed systems to act as settings for research, implementation and action that explicitly address the "causes of the causes" of health inequalities is an exciting new area of research.

5.1 Challenges and Opportunities

Despite the value that we see in explicitly addressing concerns about human health and well-being on a watershed basis, it is apparent (even in this paper) that a myriad of challenges exist—many of which are not borne of the combination, but are embedded in each of its parts. These include the challenges of jurisdiction, of integrating both academic disciplines and multiple worldviews, of spatial-temporal scale and the relationship between systems defined at different scales, and of the complexity of the issues pertaining to each aspect of these social-ecological systems (including climate and atmospheric processes, land uses, ecological processes, social networks, livelihoods and lifestyles). Our research has highlighted the irreducible uncertainty inherent in many of these systems, and the relevance of resilience as a cross-cutting theme related to many aspects of this research approach.

Notwithstanding the challenges inherent to our chosen research paradigm, we find ourselves in the position of asking whether the watershed context may in fact be the right environment to examine some of these long-standing dilemmas. The following paragraphs highlight the challenges, gaps and opportunities related to the integration of watershed-based management and ecohealth.

a) Governance Challenges and Opportunities

Effective watershed governance links health and sustainability with the concept of watersheds as ecosystems. There are few precedents in the literature that explicitly make this link. Indeed, compared to traditional approaches to resource management we do not yet have much experience in applying ecosystem approaches (such as watershed-based IWRM) or to recognizing the often common goals of health and sustainability where natural resource management is concerned. The experience we do have has been constrained by institutional environments oriented historically to top-down management, more narrow jurisdictional and sectoral mandates than required by the ecosystem approach, and existing laws, policies and regulations that support historical orientations based in reductionism and management of ecological systems for maximization of the production of (usually) a single resource. The challenge of watershed governance is in finding a compromise position between a plethora of viewpoints based on potentially conflicting worldviews—and doing so at a multitude of different scales. An additional challenge is the implications of recognizing the extent of health outcomes that may result from governance choices outside the health sector—a concept recently framed as the idea of "Health in All Policies." (Kickbusch *et al.*, 2008). The call for multi-level, intersectoral and multi-stakeholder governance structures is not new, but the question of whether or not the watershed can act as a specific place-based context in which to bridge health and sustainability (including an emphasis on the social and ecological determinants of health) remains to be

answered. We have proposed four different perspectives on governance for ecohealth and watersheds as a starting point for integration (Figure 10).

b) Spatio-temporal Scale

The nested hierarchy (or holarchy as per Kay *et al.* [1999] or panarchy as per Gunderson and Holling [2002]) of the watershed is both a strength and a weakness. Systems theory tells us that systems defined at different scales are different systems, and this means that interventions that may be successful at one spatial (or temporal) scale may not be successful at another. This is linked to the challenge of "scaling-up" in international development studies. Wrestling with the concept of scale in watershed settings and its implications (research, policy, outreach) for water managers, public health officials and development workers has the potential to lead to some very useful information "in the field." While both watershed management and public health are well-suited to multi-scalar interventions and governance processes, it is notable that watersheds provide a "meso-scale" for health analysis that tend to be larger that urban conglomerates that are often the unit of analysis in health studies (neighbourhoods, cities) but smaller than large scale jurisdictions such as provinces, states, countries, or even global level analysis. Challenges and opportunities of this meso-scale analysis are highlighted by Parkes and Horwitz (in press) as an important area for consideration in ecosystem-based settings for health.

The links between individual and collective (community/social-ecological) resilience is an important research theme (Lebel, 2008; Masten and Obradovi, 2008; Hegney *et al.*, 2007). Given the importance of scale to discussions about watersheds, it is reasonable to suggest that watershed-based studies and interventions can provide a suitable context for examining this important issue in more detail. The question of whether or not this can be done proactively (building resilience), or only in retrospect (analyzing how resilience may be linked with improved health outcomes) is another challenging research question.

c) The Public Health Paradox

Throughout this paper, we have argued that there are potential benefits for human health and well-being that can be gained through inclusive and dynamic social processes operating in watersheds defined at different spatial scales. Yet how to measure and attribute interventions for positive health gains (i.e., health promotion or prevention of diseases), including "wellness," is an area fraught with difficulty. Traditional environmental health interventions seek to measure hazards, morbidity and/or mortality and to work to reduce them. Interventions that aim to promote health gains (including increasing resilience and health promotion) are methodologically and epistemologically much more difficult. This is an argument that is sometimes linked with what is known as the public health paradox, whereby success (producing health) can be considered a non-event (Rose, 1985). This results in the common tendency for 'health' policy and research to be oriented almost entirely to "disease." with the promotion of health in a broader sense—including the determinants of health—often linked with "well-being." The distinction between health and well-being is particularly notable in the Millennium Ecosystem Assessment which makes distinctions, for example between "consequences and options for health" (mostly referring to disease) and "consequences of responses on human well-being and poverty reduction" (MA Series, 2005, Policy Responses, Chapter 16 and 17). While this report has sought to overcome this dichotomy—with a more integrated focus on social and environmental determinants of health, an important consequence of the public health paradox remains—that is that attribution of improved health and well-being beyond traditional measures of health (or disease) to watershed management processes will be a significant challenge.

d) Ecological Goods and Services on a Watershed Basis

The Millennium Ecosystem Assessment (2005) raised the profiles of ecological goods and services and their link to human health. This theme also resonates with researchers who are interested in the resilience of social-ecological systems and in particular in the issue of phase shifts (or regime shifts) that find "places" changing rela-

tively quickly from one stable ecosystem type (e.g., a coral reef) to another (e.g., an algal-dominated marine ecosystem). These different ecosystems provide human beings with a different suite of ecological goods and services—some of which are better suited to the promotion of human health and well-being than others. In this paper, this shift is linked to the idea of the "hydrological imperative" driving watershed ecosystems and the link between green and blue water in the upstream and downstream reaches of a catchment area. Clear and persuasive arguments concerning ecological goods and services may be an effective mechanism to communicate integrated concerns about human health and well-being and ecological system protection/management/governance. Such arguments may have the advantage of being readily understood by the general public, given its admittedly anthropocentric focus. Among the many research and policy challenges associated with operationalizing this concept is the difficulty of placing value on the various ecological goods and services, as well as the difficulty of separating out those goods and services (and their relative importance/value at different scales) that are unique to watersheds (as opposed to other ecological constructs like biomes).

e) Poverty and Watersheds

Access to ecological goods and services provided by watersheds is one of many strategies available to articulate the links between poverty and watersheds, and can be linked with the notion of sustainable livelihoods—especially in agricultural and resource-dependent communities (see especially Nichol, 2000). We see a focus on ecohealth and watersheds as a specific context in which to operationalize the growing interest in adopting ecosystem approaches to health, natural resource management and poverty reduction. A related question raised in this paper is whether or not the link between disasters, poverty, health and sustainability are better highlighted at the watershed level? For example, an ecohealth-oriented watershed approach to disaster preparedness may enable new ways to understand and respond to issues such as marginal land use, the over-exploitation of resources (lack of property rights), the need for collective action as part of disaster preparedness and reduction, and social networking opportunities. Many features of watershed management, for example multi-barrier approaches to drinking water safety, link watershed management processes to development policies and programs as well as to human health. The possibility to couple proactive watershed-based investments with reduction of poverty-driven health inequities and improvement of social equity is an important opportunity revealed by the integration of ecohealth and watershed management. A related research question has to do with the efficacy of such an approach.

f) "New-generation" Policy Instruments

In keeping with the challenges of creating effective governance structures and processes for ecohealth on a watershed basis, there is a need to develop and test a "new generation" of policy instruments that encourage behavioural change on the part of both individuals and institutions. It may be that the watersheds can provide a new context for creating, refining and adapting a suite of policy instruments that build on the convergent "win-win" areas where health, well-being and ecological processes complement each other. A number of existing initiatives, developed since the Rio Earth Summit in 1992, may be further strengthened by an explicit focus on links between ecosystems, health and well-being. These include environmental health indicators, environmental health surveillance programs (Morris and Cole, 2002; Pong *et al*., 2002; von Schirnding, 2002) and the link between public health and environmental impact assessments (see for example: Bhatia, 2007). Policy instruments linked to promoting a "preferred" suite of ecological goods and services through proactive environmental management (such as the Alternative Land Use Services program in Manitoba) is another example of watershed-based policy innovations that should be explored for their potential to contribute to human health and well-being. It is likely that demand for new-generation policy tools will be become increasingly urgent in the face of the inherently cross-sectoral challenge of climate change.

g) Building Capacity for a Paradigm Shift

Despite the growing recognition of the usefulness of conceptualizing social and ecological phenomena together as complex adaptive systems, environmental and ecosystem management on the basis of such con-

ceptualization is difficult, and more traditional practice is still the norm. In part this has to do with the governance challenges noted above. Our institutions, laws, policies and regulations are not designed to approach problems in such a way. If this is difficult in environment and resource management arenas, it is even more so in the core health disciplines.

There is a need address this issue at multiple scales, so that thinking and acting with respect to interconnected social and ecological factors is commonplace, and examples of managing interconnected (complex, adaptive) contexts for human health and well-being are known, available and accessible to policy-makers, managers and stakeholders. In our post-secondary institutions there is a need to make training in complexity science and systems thinking common across disciplines and programs and to introduce it not only at the (post-) graduate level in sciences and environmental disciplines, but at undergraduate levels in a broad range of subject areas, particularly the health disciplines. Similarly, outreach to governmental actors and other stakeholders is necessary. Related to this, there is a need to develop and disseminate case studies on watershed-based management for human health and well-being, and to foster both research and practice in this area.

Innovations in training and research within post-secondary institutions are starting to emerge in response to this need. One mechanism that may contribute in this area in Canada is the newly initiated "Community of Practice for Ecosystem Approaches to Health" (see www.copeh-canada.org) which will foster learning and exchange between those interested in the emerging field of ecohealth, as well as organize and fund training in ecohealth for emerging researchers and practitioners. This development echoes training programs associated with IDRC-funded Communities of Practice in Ecosystem Approaches to Health elsewhere (www.insp.mx/copeh-tlac/eng/inf/index.php), and integrated graduate programs emerging in the U.S., including "Integrating Ecology, Conservation, and Pathogen Biology" (www2.jabsom.hawaii.edu/ igert/) and a graduate certificate in Humans and the Global Environment (CHANGE, http://www.sage.wisc.edu/ igert/index.html). In addition to generic programs linking health, ecosystems and society, we also see potential for training programs with a specific focus on watersheds and public health—which could include a balance of capacity building in technical skills (e.g., GIS, hydrology, contaminant detection, epidemiology), as well as short courses and experience in integrated policy development, watershed management techniques, and multi-stakeholder community-based planning.

5.2 Research Questions

By identifying opportunities, challenges and research gaps, we have also identified a number of areas where research is needed to address not only governance and policy concerns, but also fundamental gaps in our understanding of how public health, wellness and watershed-based management fit together. For example, as we move between different viewpoints and different models conceptualizing health and sustainability, new questions related to research, practice and policy become apparent. A selection of key research questions are outlined below.

- What are the linkages between watershed management and public health?
- Can poverty alleviation, rural development and human well-being outcomes be measurably improved by linking watershed-based ecosystem management and public health?
- How can barriers to integrating watershed management with human health be overcome and opportunities enhanced?
- Is there added value of bringing the social and ecological determinants of health into the discussion of sustainability in the watershed setting?

- If yes, what would water management look like if it engaged with the social and environmental determinants of health at a variety of interconnected temporal and spatial scales?
- What are the characteristics of good practices and policy tools linking watershed management and the determinants of health?
- How can public health and watershed management strategies be aligned to improve community resilience and adaptive capacity to respond to climate change?
- What are the theoretical, epistemic, institutional, and practical barriers to integration?
- What are the implications for development policy?

These questions form the basis for the next steps of a research program that will continue to be explored through the collaboration that lead to this report.

5.3 Recommendations and Next Steps

The challenges and opportunities identified in this paper are summarized in Table 3 with respect to their implications for research, policy and public outreach. The main recommendation of this paper is that further research and discussion are needed to examine all of these themes more fully and to provide an integrated platform for ongoing work in the field.

A variety of next steps are envisioned to provide a structure for a wide variety of research, capacity building and knowledge exchange activities related to the themes of watersheds and ecohealth. Among these are building an international community of practice interested in discussing and developing these ideas. To that end, this paper will initially be circulated to potential members of an international community of practice in ecohealth and watersheds, which will be based out of IISD's offices in Winnipeg. Their feedback and ideas will contribute to a more robust description of the issues discussed in this paper, as well as the key research questions that require urgent attention. We intend to extend on this work through the identification of additional case studies and policies that bridge between watershed management and ecohealth. This is planned to occur during a series of meetings and events during 2008 and 2009, as well as through the development of research proposals for submission to relevant funding agencies. Our intention is that this paper will provide a useful springboard and preliminary guide for future research and policy "action" at the interface of watershed management and ecohealth.

Table 3. Key challenges and opportunities associated with the integration of watersheds and ecohealth

	Research	Policy	Outreach
Governance Challenges and Opportunities	Evaluating the role of watersheds as a placebased context in which to govern for both health and sustainability.	Call for health in all policies, poses new opportunities to link IWRM and public health.	Communities could benefit from increased integration of services to achieve multiple objectives.
Spatial-Temporal Scale	Watersheds offer a meso-scale unit of analysis that reflects ecosystem processes.	Watersheds as a new meso-scale setting for action to improve social and environmental determinants of health.	Watersheds as a scale to which communities can relate, and enable a re-integration of social-ecological issues
The Paradox of Promoting Health	"Attribution" of specific health improvements to watershed changes is challenging.	Success in health promotion can be considered "invisible" or a "non-event" and is harder to measure than strategies focused on diseases.	Health gains as a result of watershed actions may be difficult for the public to identify and recognize.
Ecological Goods and Services (EGS) on a Watershed Basis	Potential to link the research agendas relating to EGS, livelihoods and social determinants of health.	Valuing ecological goods and services within a watershed context may help drive more integrated intersectoral approaches.	EGS could assist with communication about health impacts of watersheds.
Poverty and Watersheds	Linking research agendas across health, ecosystems and society (especially in relation to reducing inequities).	Potential to link services and policies across health, sustainability and disaster reduction objectives.	Initiatives to sustain ecosystems and livelihoods, and increase social equity could have profound health benefits.
"New-generation" Policy Instruments	A focus on watersheds as a setting to link and integrate tools—including impact assessments, indicators, risk and surveillance.	Policy leadership will be necessary to encourage proactive instruments and integration between approaches at the watershed scale.	Public demand for accessible and community-relevant policy instruments might drive policy innovation and integration at the watershed scale.
Building Capacity for a Paradigm Shift	Conceptualizing and managing complex adaptive social ecological systems for human health.	Policy may need to drive and demand new approaches to training and knowledge translation. Mechanisms for crossing jurisdictional barriers need to be implemented.	Watershed-based ecohealth case studies can support extension of the approach to governmental actors and other stakeholders. Communities of practice and funded training in ecohealth are required.

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Ecohealth and Watersheds

Ecosystem Approaches to Re-integrate Water Resources Management with Health and Well-being

Our health and well-being are linked to the watersheds in which we live, but our experience with managing watersheds for health is limited. This publication presents a new field of research, policy and practice that is addressing this need by focusing on watersheds as settings to integrate ecosystem management and public health. The reader is introduced to a range of international innovations—including two complementary approaches to health and the environment: **ecohealth**, which argues that human health and well-being are not only dependent on ecosystems but are also important outcomes of effective ecosystem management; and watershed-based **integrated water resources management** (IWRM), which is based on the premise that watersheds are appropriate units for managing social-ecological systems.

The benefits of IWRM for health, social equity and social-ecological resilience are examined, emphasizing the potential role of well-managed watershed systems as buffers against environmental hazards and disasters, as well as new-generation settings for governance, social learning and human well-being. The paper highlights the need for integrated frameworks and governance—especially those that can speak to the converging agendas of public health, development and water resources management communities. Key issues are described, laying the foundations for future research, policy and outreach.