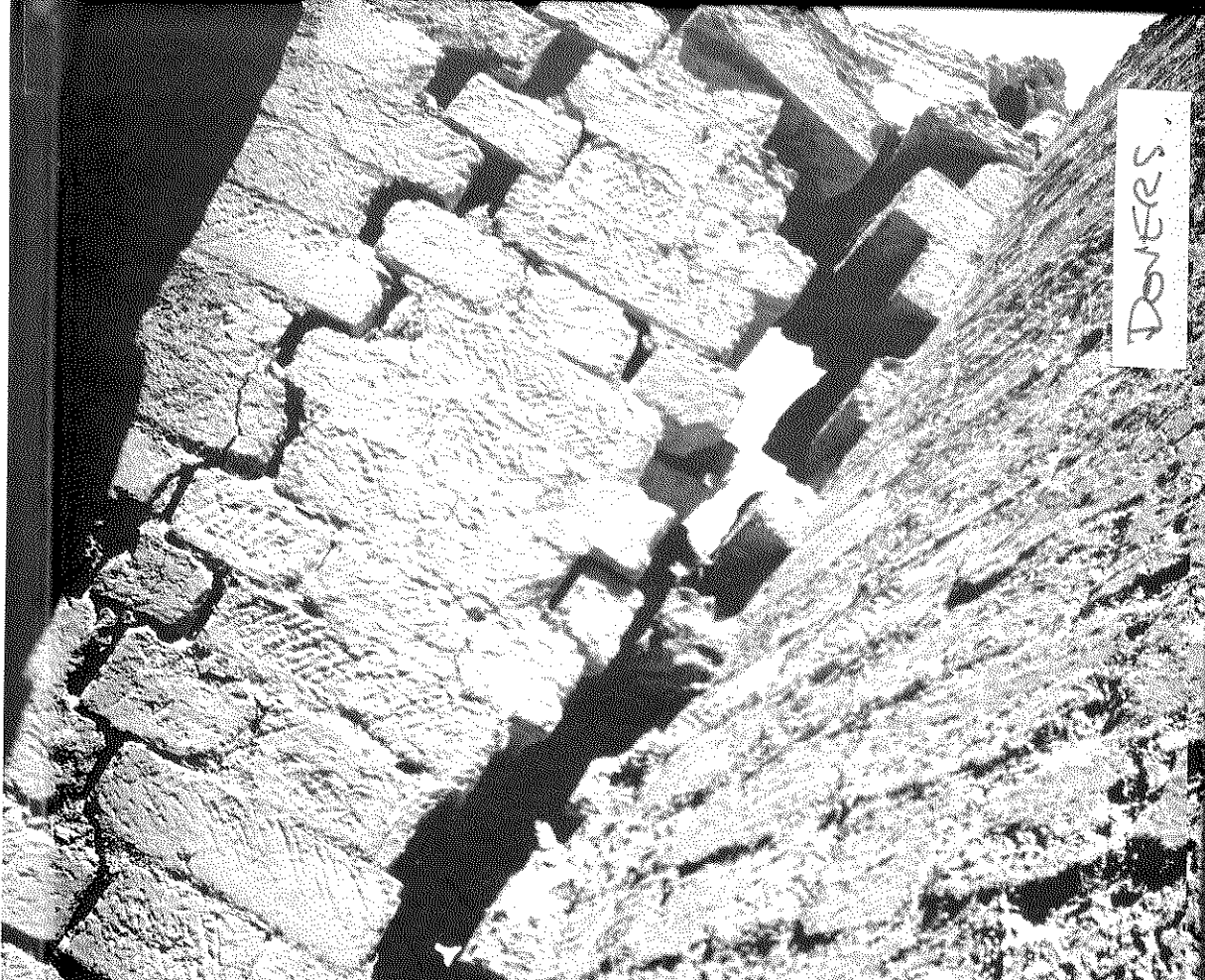




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Uncertainty and Risk

Multidisciplinary Perspectives

Edited by
Gabriele Bammer and Michael Smithson

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Uncertainty and Risk

Multidisciplinary Perspectives

'This is a major, and deeply thoughtful, contribution to understanding uncertainty and risk. Our world and its unprecedented challenges need such ways of thinking! Much more than a set of contributions from different disciplines, this book leads you to explore your own way of perceiving your own area of work. An outstanding contribution that will stay on my shelves for many years.'

Dr Neil T. M. Hamilton, Director, WWF International Arctic Programme

'This collection of essays provides a unique and fascinating overview of perspectives on uncertainty and risk across a wide variety of disciplines. It is a valuable and accessible sourcebook for specialists and laypeople alike.'

Professor Renate Schubert, Head of the Institute for Environmental Decisions and Chair of Economics at the Swiss Federal Institute of Technology

'This comprehensive collection of disciplinary perspectives on uncertainty is a definitive guide to contemporary insights into this Achilles' heel of modernity and the endemic hubris of institutional science in its role as public authority. It gives firm foundations to the fundamental historic shift now underway in the world, towards normalizing acceptance of the immanent condition of ignorance and of its practical corollaries: contingency, uncontrol, and respect for difference.'

Brian Wynne, Professor of Science Studies, Lancaster University

'Bammer and Smithson have assembled a fascinating, important collection of papers on uncertainty and its management. The integrative nature of *Uncertainty and Risk* makes it a landmark in the intellectual history of this vital cross-disciplinary concept.'

George Cvetkovich, Director, Center for Cross-Cultural Research, Western Washington University

Uncertainty governs our lives. From the unknowns of living with the risks of terrorism to developing policies on genetically modified foods, or disaster planning for catastrophic climate change, how we conceptualize, evaluate and cope with uncertainty drives our actions and deployment of resources, decisions and priorities.

In this thorough and wide-ranging volume, theoretical perspectives are drawn from art history, complexity science, economics, futures, history, law, philosophy, physics, psychology, statistics and theology. On a practical level, uncertainty is examined in emergency management, intelligence, law enforcement, music, policy and politics. Key problems that are a subject of focus are environmental management, communicable diseases and illicit drugs. Opening and closing sections of the book provide major conceptual strands in uncertainty thinking and develop an integrated view of the nature of uncertainty, uncertainty as a motivating or de-motivating force, and strategies for coping and managing under uncertainty.

Gabriele Bammer is a Professor at the National Centre for Epidemiology and Population Health at The Australian National University and a Research Fellow at the Hauser Center for Nonprofit Organizations at Harvard University.

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Uncertainty, Complexity and the Environment

*Stephen Dovers, Michael Hutchinson, David Lindenmayer, Adrian Manning,
Franklin Mills, Paul Perkins, Jason Sharples and Ian White*

COMPLEXITY AND UNCERTAINTY IN RESOURCE AND ENVIRONMENTAL POLICY AND MANAGEMENT

This chapter characterizes uncertainty in the resource and environmental policy domain, and research, policy and management responses. It moves from a general orientation to a practical and empirical one to illustrate contemporary challenges. The first section offers a general perspective on the domain and the forms of and responses to uncertainty. Summary tables are used to convey major features of the domain as space does not permit full description (for further detail see WCED, 1987; Berkhout et al, 2003; Page and Proops, 2004; Steffen et al, 2004; Dovers, 2005). Later sections examine a contemporary water supply, catchment management and disaster recovery case study to extend these general themes.

The parameters of the domain

Resource and environmental policy and management cover multiple resource stocks, environments, and policy and management sectors. They aim to understand and manage interventions in interdependent human and natural systems. The original managerial focus of the field was on preserving a sample of high-profile species and selected natural areas, and managing pollution and scarce resources. Today, a wider array of environmental resources is included and 'managing the environment' holds equal place with the need to manage people and societies and their interactions with natural systems. Moreover, the salient time-span has been stretched into the future, and the simple trade-off of

Table 21.1 *The constituent issues of sustainability*

1. Issues of resource depletion and degradation	2. Issues of pollution and wastes	3. Issues of fundamental ecological life-support services	4. Issues of society and the human condition
• biological diversity (wild species/ecosystems, domesticated species) • land and soil resources • water resources • forests and timber resources • fisheries and other marine resources • energy resources, especially non-renewable • mineral resources • scenic and cultural amenity	• atmospheric pollution • marine and estuarine pollution • pollution of surface and ground waters • soil contamination	• ecosystem integrity and evolutionary potential • hydrological cycle • nutrient cycles • climate change	• population growth • economic development, poverty • food security • resource security and equity • health and disease • rapid urbanization • human rights and environmental justice • skills, education and empowerment • debt and trade inequities

Source: Dovers (2005)

environment versus development replaced by the harder challenge of integrating the two.

This chapter covers only selected aspects of this domain, although resources and environment are now embedded in the larger, more problematic arena of sustainability. Sustainability (or sustainable development) entails the integration of environmental, social and economic considerations in policy over the long term, with commitments stated in international and national policy and law. Table 21.1 identifies the constituent issues of sustainability, with subsets (1) and (2) representing traditional resource and environmental issues, subset (3) extending and deepening those, and subset (4) covering social and economic issues and imperatives. Multiple uncertainties confront those attempting to integrate these subsets.

Most governments and many non-government sectors have made policy commitments to sustainability. Sustainability is best understood as a higher-order social goal akin to other such goals like democracy, justice or the rule of law – a complex, contestable challenge spanning generations (Connor and Dovers, 2004). Three major elements are common to policy and legal codifications of sustainability (including the foundational 1992 UN Rio Declaration). The first element is a pattern of economic and human development that protects opportunities for future generations to use natural resources and enjoy a healthy environment, while allowing for human development goals, especially

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Source: Dovers

for the world's poor, to be met in the near term. The second is the recognition of major social and policy goals, including:

- recognizing the importance of biodiversity and ecological life-support systems; and
- treating environment and development in an integrated rather than a separate way.

The third element is principles for policy- and decision-making, including:

- factoring in short- and long-term considerations;
- integrating environmental, social and economic concerns in policymaking;
- taking precautionary measures in the face of uncertain but possibly serious environmental degradation (the 'precautionary principle');
- considering global implications of domestic policy directions;
- using innovative policy approaches (for example participation, institutional change and market mechanisms); and
- involving communities in decisions that affect them.

Uncertainty and environment

Specific issues (see Table 21.1 for examples) are the usual focus of attention, but the nature of sustainability problems can be best appreciated through the identification of common underlying attributes of subsidiary policy problems. Table 21.2 presents attributes encountered more often, and more often in combination, in sustainability than in many other policy domains. Other domains (service

Table 21.2 *Attributes of policy problems in sustainability*

1	Broadened, deepened and highly variable spatial and temporal scales.
2	Possible ecological limits to human activities; threshold effects in system behaviour.
3	Often cumulative rather than separate environmental impacts of human activities.
4	Irreversible impacts, policy urgency and high stakes.
5	Complexity within and connectivity between problems.
6	Pervasive risk and uncertainty; lack of or poor quality information.
7	New moral dimensions (e.g. non-human species, future generations); multiple interests/values.
8	Systemic causes in patterns of production, consumption, settlement and governance.
9	Paucity of uncontested or well-developed research methods, policy instruments and management approaches.
10	Key assets/values not traded in formal markets, thus not assigned economic value.
11	Poorly defined policy, management and property rights, roles and responsibilities.
12	Mixture of public and private costs and benefits.
13	Demands and justification for community participation in policy and management.
14	A need for integrative/interdisciplinary research and policy approaches.
15	Novelty, articulated on policy agendas only in recent times (i.e. since the Rio Declaration – UN, 1992).

Source: Dovers (1997)

delivery, economic policy and so on) may not themselves be simple, but significant sustainability problems demand forms of knowledge and policy responses different from those readily available in traditional policy-oriented disciplines and professions.

Attribute 6, uncertainty, is a prime characteristic in part determined by other attributes (for example scale, limits, poorly defined rights and ethical issues). Three attributes (5, 8, 11) closely related to uncertainty warrant recognition. Attribute 5 (complexity and connectivity) refers to multiple interactions in natural and human systems. Rarely can one problem be attended to in isolation in either research or policy (for example estuarine fisheries' productivity is determined by upstream land use, tightly coupled fire regimes and water yield in forests). Complexity and connectivity shape uncertainty through multiple cause-and-effect linkages.

Integration across policy and management sectors, to capture multiple environmental issues as well as connections to social and economic factors, is a primary imperative in sustainability, inviting integrative or 'whole-of-government' strategies (addressing attribute 11). Systemic causes (attribute 8) is another critical attribute, requiring attention to underlying (indirect) causes of problems as well as the traditional policy target of proximate (direct) causes. For example, high per capita energy use, and thus urban pollution and greenhouse gas emissions may be directly caused by private vehicle use and household energy consumption, but these stem from a form and structure of urban settlements that necessitates reliance on private vehicles, price structures and user knowledge.

Uncertainty is a major research and policy challenge, both for specific issues and the larger agenda. The following lists identify sources and forms of uncertainty and the range of actual or proposed scientific and policy responses. The proposed chief sources of uncertainty are:

- the nature of human and natural systems (for example frequency and abundance of biota, climate variability, streamflow patterns, nutrient and energy fluxes in ecosystems, and non-marketed resource consumption);
- the nature and importance of interactions within and among elements of these systems (for example species interdependence, critical limiting nutrients or material cycles, community reliance on resources and environmental assets, and resilience to climate shifts);
- the nature and importance of human impacts on natural systems;
- future changes in human and natural systems, and whether 'natural' or human-induced drivers of change are more significant;
- changing political agendas and societal values, and the range of stakeholders in future policy debates;
- the efficacy of approaches to informing decisions in the absence of sufficient knowledge, such as predictive modelling and inference from limited data; and

- the implications.

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- risk, with outcomes research (river);
- uncertainty, precise beliefs (scientific scale);
- ignorance where impact precipitates

These definitions

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Resilient levels of general into impact operations

- the impact of past, current and proposed policy and management interventions.

The impact of multiple sources of uncertainty is typically compounded by fragmentation of responsibilities across portfolios and agencies. The scope of risks under consideration has increased from quantitative risk, towards including residual uncertainty, qualitative approaches to risk assessment and a wider array of forms of uncertainty. Drawing on Wynne (1992) and Dovers and Handmer (1995), this shift moves through the following definitions:

- risk, where believable probability distributions can be assigned to possible outcomes; that is, we know the odds (for example the likely impacts on well-researched aquatic species of the release of a known chemical residue into a river);
- uncertainty, where the direction of change is believed to be known, but precision in predicting the scale or probability of impacts is not possible and believable probability distributions cannot be assigned (for example current scientific consensus regarding human-induced climate change on the global scale); and
- ignorance, where not even the broad directions of change are known, and where thresholds and surprise are understood as likely (for example local impacts of climate change, which may involve increased or decreased precipitation and unforeseeable changes in extreme events).

These definitions convey both the *degree* and *kind* of uncertainty.

A proposition relevant to policy interventions in poorly understood human–natural system interactions is Wynne's (1992) claim that uncertainty will change and probably increase following policy or technological *commitments* based on imperfect knowledge. This does not imply an aversion to change but acknowledges the dynamic nature of systems we intervene in and of our knowledge base. Uncertainty does not simply exist 'out there in the environment', but is constructed and negotiated in human society. To include this in deepening understanding and framing policy, some have drawn on a wider body of knowledge outside the dominant natural sciences to incorporate 'non-scientific' forms of uncertainty – Dovers and Handmer (1995), for example, emphasize elements of Smithson's (1989) typology of ignorance, such as taboo, distortion and irrelevance, common features of sustainability debates.

Responses to uncertainty have changed over time. Table 21.3 identifies three levels of response to uncertainty in addressing the social goal of sustainability: general principles informing the policy style adopted; frameworks to extend this into implementation and within which specific strategies can be chosen; and operational tools and techniques to inform policy- and decision-making.

Table 21.3 *Hierarchy of responses to uncertainty in the resource and environment domain*

Level	Components (selected)
1. <i>Principles</i> (general instructions codified in policies and laws)	The 'precautionary principle' (widely codified, some specification) 'Adaptive management' (rarely codified or specified) Monitoring
2. <i>Frameworks</i> (through which principles are applied and techniques chosen)	Risk Management standards (e.g. Australian Standard 4360) Assessment procedures (e.g. environmental impact assessment, strategic environmental assessment, sustainability assessment) Others (e.g. ISO 14000 Environmental Management, TQM)
3. <i>Tools and techniques</i> (selected examples)	a) <i>Proximate or direct causes and impacts:</i> • research and monitoring • modelling and inference • policy monitoring and evaluation • environmental impact assessment • risk assessment • expert judgement – cooperative learning • extended cost–benefit analysis • non-market valuation • regret matrices (minimax, maximax) • performance assurance bonds • multi-criteria analysis (deterministic) • mediation, negotiation, conflict resolution • small-scale deliberative techniques (e.g. citizens' juries, focus groups, charettes, multi-criteria mapping) • population viability analysis • regulatory safe minimum standards • court proceedings b) <i>Underlying or indirect causes and impacts:</i> • long-term research and monitoring • policy monitoring and evaluation • strategic environmental assessment • sustainability assessment, integrated assessment • strategic risk assessment • expert judgement • mediation, negotiation • multi-criteria analysis (heuristic) • large-scale deliberative techniques (deliberative polls, consensus conferences); institutionalized small-scale techniques • commissions of enquiry • court proceedings • institutional reform to enable the above c) <i>Integration through institutional reform</i> • interdepartmental committees, interagency processes • commissioners for environment/sustainability • sustainability policy units within central agencies • mega-departments • regional-scale integration of environmental, social and economic policy • integrated catchment management

Source: Dovers (2005).

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Here, we can only touch on principles (level 1 in Table 21.3) and frameworks (level 2). The 'precautionary principle' is widely codified in national and international policy and law, although implementation has only begun (see, for example, Harding and Fisher, 1999; Fisher et al, 2006). A standard definition is:

Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation. (UN, 1992, Principle 15)

'Adaptive management' proposes that, in the face of complexity and uncertainty, management interventions be framed as hypotheses to allow action while also informing structured learning over time. First applied in bounded ecosystem management contexts, the idea has been extended to policy and institutional settings (Gunderson et al, 1995; Dovers and Mobbs, 1997). However, some systems, such as estuaries or species populations, may be hysteretic, where small changes result in catastrophic collapses not easily reversed. For these, adaptive management involves risk.

From level 2 in Table 21.3, standards and decision-support frameworks can be illustrated by two examples. The Australian/New Zealand Standard 4360 Risk Management (Standards Australia, 2004) is being applied in many policy sectors, including the environment, providing a framework for handling risk and uncertainty and suggesting specific methods (Standards Australia, 2000). Strategic environmental assessment extends the long-standing practice of project-oriented environmental impact assessment to identify and ameliorate less understood (in other words more uncertain) indirect environmental implications of policies, plans and programmes, and is mandated in some jurisdictions (Marsden and Dovers, 2002).

The imperatives of inclusion and integration

Two recent imperatives are relevant for conceptualizing and responding to uncertainty. The integration of environmental, social and economic factors demanded by sustainability requires bringing together previously unconnected intellectual and policy traditions and forms of data and analysis. The universal endorsement of community participation as a policy principle brings previously unconnected values and interests together, to be integrated or at least traded off in a comprehensible manner. The implications of expanded participation in policymaking for confronting uncertainty can be illustrated by burdens of proof and the way in which responses to uncertainty are justified (Cranor, 1999; Dovers, 2006). Reliance on mathematical probability in the sciences might be incomprehensible to someone from the humanities working in narrative or philosophical argument, and vice versa. Very different burdens of proof are applied in an environmental debate by scientists (95–98 per cent confidence), the courts (for civil law, the balance of probabilities), neoclassical economic models

(dependent on assumptions), local residents (strong precaution) or the media (variable, largely unburdened?). All are relevant politically in a democratic system, if not equally valid intellectually. Even within disciplines, significant variation occurs. Empirical ecologists and ecosystem theorists can disagree substantially when predicting anthropocentric impacts on the basis of incomplete data and poorly understood system processes.

Integration is the aim of many level 3a and b (Table 21.3) options such as deliberative techniques and multi-criteria analyses. Creating institutional settings and policy processes conducive to applying such techniques is the point of levels 1–2 and 3c. Currently, many methods are still being developed and no cross-disciplinary consensus exists on the efficacy of specific tools or how to choose from the toolkit.

We have provided an overview of uncertainty in the resource and environmental domain. To ground this perspective, we turn now to aspects of uncertainty in an illustrative case study: the Cotter River catchment in south-eastern Australia, a conservation and water catchment area devastated by fire and drought in 2003. This case study evidences the multiple forms of uncertainty that typify the domain, multiple disciplinary and other perspectives, and the importance of non-linear change and short- versus long-term factors driving policy and management decisions. Recalling Table 21.1, this case typifies the situation where uncertainties are confronted in a suite of interacting issues, involving traditional resource management and conservation challenges, economic development, fundamental ecosystem resilience, and human health and wellbeing.

AN ILLUSTRATIVE CASE: THE COTTER CATCHMENT¹

Australia's capital city, Canberra, obtains much of its water from dams in the 484-square-kilometre Cotter River catchment within the Australian Capital Territory (ACT). The catchment comprises Namadgi National Park and adjacent protected catchment reserves under native (upper catchment) and plantation (lower catchment) forests. Supplementary supply is accessed from the Googong Dam in the Queanbeyan catchment in nearby New South Wales, which is under a variety of land uses necessitating higher levels of water treatment. While intermittent water supply shortages have been experienced in the past, an adequate quantity and quality of water has been enjoyed since 1967, with increasing commitments to the environmental flow requirements of rivers.

Past management of the catchment has been passive, catering for water supply and nature conservation, along with subsidiary uses including plantation forest production and recreation, but in a fragmented fashion typical of resource management. An integrative mechanism, the Cotter Catchment Management Committee, was discontinued in 1987, and soon afterwards primary statutory authority for water passed to the multi-utility ACTEW Corporation. Land and

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environmental management are the responsibility of ACT Urban Services, a federation of customer-focused businesses and regulatory units. Environment ACT is one of those, with responsibilities for over-viewing water policy, and within it ACT Parks and Conservation manages Namadgi National Park. The Lower Cotter is largely outside the Park and ACT Forests manages the Lower Cotter plantations and monitors water quality throughout them, reporting results to the Environment Protection Authority.

The ACT Water Resources Act 1998 appointed Environment ACT as co-regulator for water with the ACT Prices Commissioner. Water in dams and pipes in the Cotter comes under a different management regime. Before 2000, the electricity and water utility ACTEW Corporation had sole responsibility, a model typical of previous Australian water management. After 2000, ACTEW Corporation became a government-owned holding company with interests in providing water and wastewater services. The ACT Government, through ACTEW Corporation, owns the water and wastewater network and infrastructure. The public-private joint venture company ActewAGL is an electricity, natural gas, water and sewerage services utility that contracts its services to ACTEW Corporation. ACTEW Corporation buys bulk water from the ACT Government and contracts ActewAGL to treat water and reticulate it to communities and industry in the ACT, who also pay for sewerage and wastewater treatment by ActewAGL. ActewAGL returns almost half of the water abstracted to the Murrumbidgee River as high-quality treated water, as part of environmental flow obligations negotiated by Environment ACT. Because of the fixed-fee contract, the major incentive for ActewAGL is cost minimization. Monitoring of rainfall, quantity and quality of water in dams and catchments is contracted to ECOWISE Environmental, a subsidiary of ActewAGL.

Enter drought and fire

This administratively complex but largely unproblematic situation was shaken by two events embodying significant uncertainty and extreme impacts. A prolonged drought across much of Australia from 2002 forced attention on sustainable supply and use of water, including in the ACT, and drove major policy reform via a National Water Initiative (COAG, 2004). Following dry conditions, extreme weather caused wildfires in January 2003 that burnt 98 per cent of the Cotter Catchment, including the bulk of the ACT forest plantation estate, and destroyed 500 houses. Four people died in one of the most extreme fire events in the settled history of one of the world's most fire-prone countries (for general information, see Bradstock et al, 2002; Cary et al, 2003).

The fires removed much of the ground cover and riparian vegetation, and in some areas consumed soil organic matter, greatly increasing the potential for erosion. Large amounts of charred organic matter were also produced (Wasson et al, 2003). Intense rains in March 2003 shifted fire debris and sediment into the Corin and Bendora Reservoirs. Bendora is the off-take storage for Canberra's

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water supply system, and an estimated 19,300 tons of inorganic sediment and 1900 tons of organic matter were deposited there in the aftermath of the fires (Wasson et al, 2004). Salvage logging operations in the lower catchment added to soil disturbance. Sediment inflows caused major water quality problems, making the water unfit for reticulation for extended periods. Runoff following the fires caused unprecedented increases in principal water quality parameters – turbidity, iron, manganese, phosphorus and nitrogen – by up to two orders of magnitude over previous events (White et al, 2005). These water quality problems severely disrupted domestic water supplies, requiring water restrictions and construction of an AU\$40m water-treatment plant. The back-up capacity of Googong Reservoir proved crucial in maintaining supply.

As well as impacts on life, property, water and plantation forests, extensive conservation reserve areas were moderately or severely burnt, along with various built assets within Namadgi Park. The short- and long-term implications for biodiversity are unclear – the intensity and extent of the burning had no recorded precedent (although previous, less-documented fires may have had comparable impacts), on top of existing uncertainties about the viability of wildlife populations in the absence of disturbance.

The combined impact of the fires, post-disaster recovery, drought, and water supply and quality problems continue to dominate ACT policy and community debates. Earlier fragmented and passive catchment management arrangements have been found wanting. A number of official enquiries have ensued, and ongoing conflict and legal dispute have created an environment of uncertainty, complexity and blame, and demands for near- and long-term policy and management responses that can account for multiple values and uses. Chief among these are human safety, water supply, the future of land use in the Cotter and biodiversity conservation. In addition, future human-induced climate change confounds predictions of land-use viability, local ecological processes, water availability and the likelihood of extreme weather events (see IPCC, 2001).

Fragmented approaches to understanding environmental processes and framing responses have failed to cater to multiple social demands. Integrated approaches are widely viewed as necessary and are prescribed in contemporary policies. Integration includes multi- or inter-disciplinary research, as well as policy and management arrangements that coordinate previously unconnected, specialized responsibilities and functions (for example water, forests, biodiversity and emergency management).

Furthermore, the integration of 'expert' knowledge with other knowledge systems through participatory research and management is increasingly accepted as necessary. In situations such as the Cotter, things deeply valued by the community are contested and at risk – their own physical safety, the amenity of their landscape, adequate water supply, wildlife. For better or worse, policy will be informed not only by science and other expert knowledge systems, but by cultural, community and political knowledge and imperatives. Uncertainty is

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constructed in human systems, not in natural systems, and various interests in society have very different constructions and burdens of proof (or of disbelief). When life, property and valued environments are at risk, that observation becomes not merely theoretically interesting, but compelling on practical grounds.

The summary menu of options for integration presented in Table 21.3 offers some ways forward, but debate surrounds all these research approaches, decision-support techniques and institutional options, both singly and in terms of choice across situations.

The post-fire response

We now briefly explore how the ACT policy community handled the aftermath of the 2003 fires, and what this suggests about scientific and policy capacities to handle uncertainty and complexity. Although compressed in time and politically charged, the issues in the Cotter are typical of, and the responses, on balance, no better or worse than in, other complex environmental management contexts.

The sheer magnitude of post-fire emergency response and rehabilitation produced delays, frustration and politicization. While public health, community amenity and initial disaster recovery operations have been largely successful, coordination of longer-term policy remains unsettled. In the case of water supply, while ACTEW commissioned immediate response and restoration studies, the operations of a Non-Urban Taskforce overtook their efforts. Thereafter ACTEW concentrated on fast-tracking infrastructure and planning for future water-supply security. The Taskforce concentrated on broader aspects of land management, with more detailed work left to existing agencies or recommended to new non-statutory committees.

Complex relationships between key policies such as the Namadgi National Park Management Plan, the Molonglo Catchment Action Plan, the ACT Natural Resource Management Plan and the Think Water, Act Water Strategy (ACT Government, 2004) remain problematic. Responsibilities for initiating (or reviving lapsed) long-term monitoring of key landscape functions are scattered, although poor performance in previous monitoring has also left a legacy of insufficient time series data. The location of responsibility for integration is being contested among agencies and units. The placement of more water responsibilities in the Chief Minister's Department (including in a central sustainability unit), the merging of ACT Forests and ACT Environment, and the creation of an advisory catchment committee are partial responses, but they contrast with more integrated catchment management arrangements existing elsewhere in Australia (see, for example, Ewing, 2003). When considered against the demands of the new, pervasive National Water Initiative (COAG, 2004, Connell et al, 2005) and cross-border supply and new storage options, a highly uncertain policy environment emerges, with great scope for disharmony.

Further, some long-term policy questions have been pre-empted by emergency response strategies, particularly in cases where change instruments (action or management plans and so on) are developed to tight timetables, but within previous policy frameworks, by threatened organizational units. In the case of integrated management of the catchment, tension exists between the previous preservationist culture across specialized agencies, the decimated plantation sector and emerging ideas of a managed landscape producing multiple outcomes (for example water yield, minimizing wildfire risk, and nature conservation).

The institutional and organizational arrangements for policy, regulation and management are becoming more rather than less complex, uncertainty has increased, and the ability to extract and apply best practice knowledge is weakened. In contrast, the US Burnt Areas Emergency Response model (US DoI, 2001) offers a model for achieving completed restoration plans supported by scientific assessment within weeks of an event. Broad community acceptance and reduced politicization result, as does more rapid implementation of restoration projects.

Finally, the complexity of natural resource systems and human values pose difficulties for community engagement and challenge public confidence in government leadership and agencies' ability to deliver timely and equitable outcomes. The gap between short-term demands by prominent players in policy debates is inconsistent with the need for long-term investment in research and adaptive management through transitional investment steps. Single issue foci are inconsistent with the integrated logic of sustainability. In these circumstances, excessive reform poses risks for hard-pressed officials on the one hand, and a risk that the public will revert to selfish demands for 'more' water, rather than agreeing to an optimal portfolio of water supply and conservation measures, on the other. Suitable policy and institutional settings for handling such complexity and uncertainty (level 3, Table 21.3) remain to be developed.

DISCUSSION: UNCERTAINTY AND POLICY WINDOWS

The Cotter situation exemplifies generic challenges raised by uncertainty in resource and environmental management. Understanding and managing multiple factors, processes and values in an integrated fashion on the landscape scale is an accepted social goal, but supremely difficult. The challenges are synthesized in the following summary, which highlights key uncertainties and reflects a number of other attributes of sustainability problems identified in Table 21.2.

- Considerable uncertainty attaches to important, *single variables*, a function of the nature of the phenomena and/or poor monitoring. The abundance, life histories and vulnerabilities of most species are insufficiently understood for confidence in management interventions. The parameters of climate and

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hence streamflow variability are not well understood, a result of relatively short (less than 100 years) meteorological records, and the local and regional impacts of climate change are highly uncertain. Consequently, the frequencies of extreme weather events and associated large-scale fires are unpredictable.

- Key interests, and the values associated with these, as manifested in land uses, economic activities and environmental and other land management goals, are affected by multiple processes and variables. For example, wildlife populations will be influenced by fire regimes and climate change, just as water supply will be. Fire regimes are determined by a range of natural and human factors. The uncertainties in each of these is compounded by interaction with other, also uncertain factors.
- Situations such as the Cotter demand long-term research, monitoring and policy responses. Key variables and processes, such as forest regrowth, population dynamics of wildlife populations, climate change and sediment movements in catchments, operate over decadal or longer spans, making believable predictions of future conditions extremely difficult. These long-term contingencies are difficult to address under the constraints of short-term administrative and political timescales and similarly short planning and research funding cycles.
- The efficacy and possible indirect impacts of specific policy interventions designed to achieve desired outcomes are also uncertain. The uptake and impact of water-saving behaviours and technologies, currently actively promoted, are not clear. Likewise, the effectiveness of revegetation strategies for wildlife conservation and the dynamics of water yield from fire-affected catchments are poorly understood, as is the effectiveness of strategies to reduce fire risk at the urban-rural interface.
- If these sectors, land uses, values and natural processes are to be coordinated through integrated policy responses, further uncertainties arise as to requisite institutional designs and organizational structures. There are no 'blueprints' for organizational reform for integration, and integration opposes the tradition of specialization and vertical hierarchy that underpins traditional systems of public administration. Thus institutional and policy reform to create more resilient, robust and adaptable capacities is in itself something to be approached in an explicitly experimental fashion.

An underlying issue is the ability of research to inform decision-making in a timely fashion. In cases such as the Canberra fires, that timeline may be very short. Even in more 'relaxed' contexts, time demands on decision-makers are invariably stricter than those researchers would consider necessary to produce quality data. In the natural sciences, long-term monitoring and enhanced understanding of issues such as hydrological systems, weather and climate, biodiversity, and vegetation responses, and especially of the interactions among

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them, is one answer to framing responses to uncertainty. In many areas, however, long-term research and monitoring have been weak. Whatever the timescales, there is the challenge of reconciling different constructions of uncertainty – epistemological, theoretical, methodological – so that stakeholders share an understanding of the interactions among interdependent phenomena.

However, even with much better understanding of natural processes and human variables, sound responses to uncertainty are unlikely in the absence of appropriate management regimes, policy processes and institutional systems capable of utilizing such information. The fragmentation and lack of coordination across policy sectors exacerbate uncertainty, and proven ways of ensuring integration across the traditional silos of research organizations are still scarce. Institutional fragmentation invites the social sciences to contribute, including via the various decision- and policy-support methods referred to in Table 21.3, yet sufficient time to choose and utilize appropriate data and techniques may not be available. Nevertheless, time should be available to enact immediate responses while concurrently constructing the institutional capacities and establishing information streams to enable longer-term adaptation.

Natural systems are rarely stable, and sudden changes may produce opportunities for positive change, or for rushed and poor decisions. Policy systems also are unstable, and the idea of ‘policy windows’ captures those occasions when the sensitivity of policy and management agencies to the need for reform will be heightened (Dovers, 2005; see also Howlett, 1998):

- More predictable policy windows result from situations such as the lead-in period to a government’s annual budget; review of a policy programme; publication and consideration of a major review such as a state of environment report; finalization of an intergovernmental agreement requiring implementation; or an election, whether that returns the old government or a new administration.
- More unpredictable policy windows result from events such as scientific discoveries; unforeseen environmental changes (drought, wildfires, pollution episodes); sudden realization of policy failure; or an unexpected rise in the influence of an interest group.

Constructive use of policy windows requires maintaining long-term information capacities (for example weather and climate data, biodiversity monitoring, and analyses of the impacts of current management interventions), and connecting these to processes determining future policy and management. Maintaining such links has proved difficult in most places and defines the challenges of adaptive management: seeking the best possible information; including different knowledge systems; and deciding and acting, but in a way that enables learning and the recognition that uncertainty, complexity and sudden change are inevitable.

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NOTE

- 1 The organization detail in this case is accurate for 2003–2006, and thus during the fire-related issues discussed.

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Richie Cole, Kenny Werner, Jim McNeely, Lew Tabackin, Toshiko Akiyoshi and James Moody and national greats including Dale Barlow, James Morrison, Vince Jones and Don Burrows. He lectures in advanced improvisation techniques and the psychology behind effective practice techniques, and conducts improvisation workshops throughout the world. His interests in research are varied, including a desire to have the brain mapped while improvising, to ascertain which parts of the brain are being utilized during this process. He has appeared on over 10 albums and his solo album *Pantano Drive* was released July 2005 on Enigma Records.

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