1 Potential of Palaeohydrology in Relation to Global Change

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> *The past is not dead. It is not even past*. William Faulkner (Cited in Peter Carey *True History of the Kelly Gang*. Faber and Faber, London, 2001)

William Faulkner's sentiment is very apposite to the study of the earth's physical environment: "the present is the key to the past" has been an acclaimed dictum since the nineteenth century, but it is only very recently that the importance of past environmental change for understanding the present and the future has become more widely acknowledged. Greater attention to environmental processes (Gregory, 2000) focusing on techniques, process mechanics and modelling meant that research was developed independently from that on Quaternary environmental change. Once analysis of environmental processes was firmly established and short-term variations recognised, paralleled by questions raised by interpretations of Quaternary environmental change, the potential of a fruitful interaction was appreciated. Such interaction has become even more prescient with the advent of global change research in the last two decades of the twentieth century. Concern for future global change requires understanding of past as well as present environmental conditions so that the title for this volume "Palaeohydrology – Understanding Global Change" was chosen in order to expound one particular perspective. No single discipline is able to do justice to all aspects of global change, many new hybrid research fields having been generated at research frontiers where disciplinary boundaries intersect. Palaeohydrology is one such multidisciplinary field: its development, and the methods of approach employed, may be seen in relation to global change and scenarios developed, as a basis for potential links between palaeohydrology and global change, prior to showing how this volume is structured to address the potential research opportunities.

1 DEVELOPMENT OF PALAEOHYDROLOGY

Palaeohydrology is an excellent example of a research field that arose at the interface of several disciplines and is multidisciplinary in nature. Its development since 1954, when it was first formally defined (Leopold and Miller, 1954), has been chronicled (Gregory, 1983). Alluvial chronology was fundamental to the approach employed by Leopold and Miller (1954), and the global hydrologic cycle (Schumm, 1965), involving comparison of present and past water balance situations, was basic to the approach of Quaternary palaeohydrology specified by Schumm (1965). It was later supplemented by water

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quality and composition (Schumm, 1977), with important contributions developed from the investigation of underfit streams (Dury, 1964a; 1964b; 1965; 1977). Palaeohydrology could therefore appropriately be defined as "the science of the waters of the earth, their composition, distribution and movement on ancient landscapes from the beginning of the first rainfall to the beginning of continuous hydrological records" (Gregory, 1983). Subsequent research developments increased interdisciplinary effort (Baker, 1983; 1998), involved a broadening scope (Baker, 1995) encompassing ancient lake sediments and past groundwater levels. It visualised palaeohydrology as a new branch of the earth sciences (Starkel, 1995) with branches that included fluvial palaeohydrology (Branson *et al.*, 1996) all focusing upon interpreting indices of past hydrological processes (Baker, 1996). One way in which this new branch of geoscience could be manifested was by applying models of hydrological cycles and water balance to the scenarios of the past (Grosswald, 1998) and speculations relating to the geological past had been presented (Schumm, 1968).

Palaeohydrological research is therefore less than 50 years old; it began with a global thrust, evolved and advanced by focus on particular areas such as the Temperate Zone (Starkel *et al.*, 1991) and has now returned to a global focus supported by particular research themes (Gregory *et al.*, 1995; Branson *et al.*, 1996). Throughout this time, emphasis shifted from a conviction that predictions can be achieved to a more realistic view that acknowledges the difficulties of the past as well as that of the future "reconstructions". Contributions from international researchers were significant during the progress of International Geological Correlation Programme 158 A and B (Starkel *et al.*, 1991) and from 1991 to 2003 by the Global Continental Palaeohydrology Commission of INQUA (GLOCOPH). Both these international research programmes culminated in collections of research papers, most recently concerned with environmental change (Benito *et al.*, 1998), and with particular areas (Brown and Kadomura, 2001) in addition to the many productive international research meetings. The Commission on Global Continental Palaeohydrology was established by INQUA in Beijing in 1991 (see Chapter 2) in order *to undertake research on the global process of water for the continental areas of the Earth using evidence of past changes and emphasizing issues relevant to the human habitability of the planet*. The primary aim specified in 1994 was *to analyze the nature of global and zonal hydrological changes, fluxes and stores using the timescale 100–1,000 years with emphasis on those areas which hold the greatest human population and are most sensitive in terms of water resources and global changes*. Professor Leszek Starkel was President of the Commission from 1991 to 1995, Professor Vic Baker from 1995 to 1999, and Professor Ken Gregory from 1999 to 2003. Global palaeohydrological change was considered by the previous President (Baker, 1995), and a recent GLOCOPH volume emphasised palaeohydrology and environmental change (Benito *et al.*, 1998), so that this book, at the end of the GLOCOPH period, is overtly constructed to focus attention upon the contributions that palaeohydrology can make.

External changes have necessarily affected the development of palaeohydrological research, but not perhaps always as rapidly as they might have done. They have included, first, the way in which philosophy has been more prominent in the scientific agenda (Baker, 1996), the techniques revolution increasingly reflected in research reported in palaeohydrological publications (Gregory, 1983; Wohl and Enzel, 1995), particularly the impact of information and database technology (Branson *et al.*, 1995), culminating in admirable palaeohydrological reconstructions (Starkel, 1987; 1990; Starkel *et al.*, 1991). Secondly, external changes have encouraged greater concern for relevance including research on global change, on the collation of world data, on the linkages from global circulation models to hydrological models, and on management of the present system from basin and river channel perspectives. Underpinning these emerging perspectives has been greater recognition of the benefits of knowledge of temporal change (see Chapter 21, Table 21.3).

2 APPROACHES EMPLOYED

Palaeohydrology when first defined was associated with retrodictive analyses based upon quantitative relationships between precipitation, runoff and sediment yield. The earliest approaches in palaeohydrology were founded on the relationships proposed by Langbein and Schumm (1958) and by Schumm (1965), subsequently developed by river metamorphosis equations (Schumm, 1969) from proposals by Lane (1955). As indicated in Chapter 17, a numerical approach was also involved in the analysis of underfit streams pioneered by Dury (1977), so that there emerged a major group of approaches based particularly upon studies of palaeochannels. A somewhat separate group of research investigations was founded using pollen analysis and other techniques for the reconstruction of environmental history and was able to develop interpretations of water balances in the past. Subsequently, a series of significant contributions came to be made from the study of palaeofloods. In the 1980s, under the aegis of IGCP 158, palaeohydrological research investigations were organized into those associated with lakes and mires (the *pollen* emphasis in subproject 158B) and those under the fluvial subproject (158A) in which investigations based upon *palaeochannels* were especially notable. By the end of the 1980s, these two subprojects saw the polarisation of approaches: one dedicated to environmental history and the water balance, and the other more concerned with river and channel behaviour. From this foundation, it was appreciated that analysis of the spatial pattern was necessary as a context for understanding the sequence of hydrological development. In theory, palaeohydrology is concerned with all components of the hydrological cycle, but in practice most research focuses on river channels and discharge, on lake level fluctuations, on fluctuations in groundwater levels and isotope chemistry and on proxy indicators of past precipitation characteristics such as tree rings, ice cores, pollen, or soils (Anthony and Wohl, 1998).

Significant developments have been achieved in the integrated global context since 1991 when GLOCOPH was established as a Commission of INQUA. At the four international conferences in Southampton in 1994, Toledo in 1996, Tokyo in 1998 and Moscow in 2000, 221 papers were presented and their subjects give clues to the approaches prevailing on those dates. It is not easy to categorise all the approaches adopted and the techniques employed because some of the intriguing technique developments included forest colonisation of river beds, lake ice phenology and the use of literary records; research included contributions from all continents except the Polar areas and the size of areas studied ranged from the Amazon and the Yenesei to small headwater basins in Crete, Japan and Poland. However, throughout all these GLOCOPH research investigations, it is notable that many were based upon analysis of data from sedimentary sequences, especially alluvial sediments and alluvial chronology. Of the papers presented at the four international conferences (Table 1.1), 29% were explicitly concerned with sediment-based investigations; if the papers that implicitly involved sediment analysis are included, then this accounts for 55% of all the papers presented. The rank order of the major research themes (from Table 1.1) is:

Table 1.1 Subjects of papers presented at GLOCOPH meetings

Dominant theme	Southampton and London 1994	Toledo, Spain 1996	Kumagaya, Japan 1998	Moscow 2000	Total
Glacial	0	5	6	2	13 (5.9%)
Techniques-based including palaeoecology, historical records	4	12	17	15	48 (21.8%)
Modelling	4	0	1	10	15 (6.9%)
Processes	3	6	15	9	33 (15.0%)
Sediment-based	15	19	23	7	64 (29.0%)
Basin components including palaeochannel, lakes, planform	11	17	4	4	36 (16.3%)
Drainage basin	2	5	3	2	12 (5.4%)

- *sediment-based* including slackwater deposits, sedimentary sequences and terrace deposits,
- *techniques-based* including palaeoecology and historical records,
- *basin components* including palaeochannels, lakes and planform,
- *processes* including volcanic eruptions, tectonics, groundwater, palaeofloods and water balance.

Therefore palaeohydrology is no longer founded upon the water balance and pollen, or upon the river and palaeochannels because other themes have become prominent.

The trend towards greater emphasis upon results from analysis of sedimentary data is very necessary because an increasingly diverse range of analytical techniques has been available to enable palaeohydrological reconstructions to be undertaken at a level that could not be anticipated in 1954 when palaeohydrology was first formally specified. However, relatively few research investigations, just 5% (Table 1.1), explicitly focused upon basin-wide changes or referred analysis to a basin framework, although major shifts of river channel pattern and glacial drainage changes have been investigated. This is perhaps inevitable in view of the way in which GLOCOPH has been able to advance palaeohydrology because it was necessary for emphasis to be placed upon use of a range of techniques, upon constructing different climatic scenarios and upon formulating palaeohydrological sequences for particular areas. However, as it is now appropriate to see how the results from GLOCOPH, together with those from the previous basin-based IGCP 158 research programme can be integrated and applied, reference to a basin context becomes essential to facilitate a link to hydrological modelling.

3 GLOBAL CHANGE SCENARIOS

The greenhouse effect has probably been recognised since 1827 (Jones and Henderson-Sellers, 1990), but it is only the last two decades of the twentieth century that saw substantial interest in global change; and only towards the end of that century has there been worldwide consensus on the direction of that change, namely, an increase of temperature resulting from an equilibrium doubling in greenhouse gases over pre-industrial levels (Henderson-Sellers, 1994). From the 1972 United Nations Stockholm conference up to the 1992 Rio Earth Summit, which focused on issues of climate change, biodiversity protection and sustainable development, debate about global change accelerated. The Agenda 21 Report produced for the 1992 meeting laid out an agenda for research and action over the next century. Subsequent world meetings in Kyoto (1997) and Buenos Aires (1998) were equally significant for furthering international discussion. The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 to assess scientific information in relation to global warming and to suggest response strategies (Drake, 2000), three reports having already been published, engendering considerable international discussion and debate. Global environmental change was sometimes used in the sense of global aspects of natural environmental change, but this is no longer tenable (Mathews, 2001) because of the interaction of natural and anthropogenic processes. Global environmental change, often used synonymously with global change, can be thought of in two ways (Goudie, 2000): firstly, systemic global change including those global changes in climate brought about by atmospheric pollution; and secondly, change which is the consequence of areal or localized transformation processes so ubiquitous and pervasive that they cumulatively result in global change. In addition to the IPCC reports concerned primarily with climate change, there have been a number of international initiatives concerned with global change (see Chapter 3) including the International Geosphere–Biosphere Programme (IGBP) of the International Council of the Scientific Unions (ICSU). The six key questions posed in their Global Change report in 1990 notably did not include a specific hydrological question. Growing interest in global change research has been reflected in the creation of new journals such as *Global Environmental Change* (Pergamon, 1990), *Global Outlook Environment* (NY UNEP distributed by OUP, 1997) and *Global Ecology and Biogeography* (Blackwell, 1992); and also in the publication of encyclopaedic volumes such as *The Encyclopaedic Dictionary of Environmental Change* (Mathews, 2001) and the *Encyclopedia of Global Environmental Change* (Munn, 2001).

Despite greatly increased attention being given to global change, it has not been easy to raise general public awareness of the problems involved although a report *Global Environmental Outlook 2000* (United Nations, 1999) was widely reported as indicating that global warming will trigger a series of disasters with serious world implications. A major focus has been the contribution made by research on global climate models with knowledge and understanding of the mechanics of the world climate system being enhanced as a result of the building of sophisticated climate computer models, the vast amounts of remotely sensed data available and the establishment of a reliable calendar of geological events (Huggett, 1991). Some research has focused upon the ways in which climate change, as indicated by the outputs from Global Circulation Models (GCMs), might impact on the environmental system, exemplified by changes of surface air temperatures, precipitation rates and soil–water world patterns produced for different seasons (Henderson-Sellers, 1994).

Research undertaken on the hydrological consequences of global change has included exploration of aspects of greenhouse hydrology (Wilby, 1995), but GCMs are not well suited to answering questions concerning regional hydrologic variability (Xu, 1999), which are of primary interest to hydrologists. GCMs were originally designed to predict average synoptic scale general circulation patterns of the atmosphere, so their outputs cannot easily be harnessed by downscaling to provide inputs to hydrologic models at regional or local scales. Estimation of hydrology and water resource changes continues to pose problems for hydrologists (Nemec, 1995). Analyses of scenarios have been considered for river flow extremes and fluvial erosion in particular areas such as England and Wales (Newson and Lewin, 1991) and implications have also been explored for water resources in the United Kingdom (Arnell, 1996) and in Europe (Arnell, 1999). Against a background of methodologies for climate change impact assessments, techniques for developing climate change scenarios and hydrological models, Arnell (1996) utilised a case study of 21 catchments in the United Kingdom to explore changes in river flows and groundwater recharge in Britain that might occur by the 2050s, and analysed the possible impacts of the changes on water uses and the management of water resources. However, it is not simply an issue of documenting climate change and proposing appropriate mitigation measures; it is also important to consider how to adapt to climate change (Parry *et al.*, 1998).

Whereas results from GCMs suggest that rising concentrations of greenhouse gases may have significance for global climate, it is less clear as to what extent local (subgrid) scale processes will be affected (Wilby and Wigley, 1997). Downscaling techniques emerged to bridge the gap between what climate modellers are able to provide and what impact assessors require. However, it is not only a question of downscaling spatially but also of recognising that the data analysed also has to be downscaled temporally – it is these problems of spatial and temporal scale that need to be addressed. A major limitation in undertaking downscaling and in using hydrological model approaches is the lack of sufficient data sets in a variety of climatic and physiographic regions related to a range of spatial and temporal scales (Xu, 1999) and it is towards such a paucity of data that palaeohydrological results may contribute.

4 POTENTIAL LINKS BETWEEN PALAEOHYDROLOGY AND GLOBAL CHANGE

Advances in the investigation of climate change and associated global change have not been accompanied by equivalent attention devoted to impacts on the hydrological system, despite the fact that in facets of hydrology major impacts of global change are really sustained. This disparity has arisen because attention had to be focused initially upon climate change and only once sufficient research had been achieved was it possible to consider detailed impacts such as hydrological ones. Additionally, the downscaling necessary to establish hydrological impacts cannot be completely achieved by reference to continuous hydrological records and contemporary timescales, so that it may be necessary to search longer timescales for analogous behaviour. Climate reconstructions of the past were achieved from the COHMAP (Cooperative Holocene Mapping Project) project (Wright *et al.*, 1993) in which water balance changes were included, although it did not extend to include hydrology or palaeohydrology. In scrutinising aspects of climate change in the last 2,000 years, GCMs are insufficiently detailed so that a better understanding of not only what has happened over the past 2,000 years but also the history of forcing factors is vital to distinguish between natural variability and that resulting from anthropogenic influence on the climate system (Jones *et al.*, 1994). Prior to the end of the twentieth century, the citation pattern, as demonstrated by content analysis, reflects the emphasis on palaeoclimate showing that palaeohydrological research has not been extensively quoted, so that Physical Geography Abstracts show Palaeoclimate, Palaeoenvironment, Palaeooceanography, and Palaeolimnology all cited more frequently than palaeohydrology (Table 1.2); and in books dealing with Quaternary environmental change, or with global change in general, palaeohydrology is seldom mentioned. This may be because development of palaeohydrology is recent although it has been argued that one of the major applications of research from GLOCOPH is to inform interpretations

Table 1.2 References in Physical Geography Abstracts

Term	1994	1995	1996	1997	Total
Palaeoclimate	38	43	43	51	175
Palaeoenvironment	55	40	59	72	226
Palaeooceanography	19	12	20	45	96
Palaeolimnology	35	25	15	15	90
Palaeohydrology	23	12	15	16	66
Palaeogeography	10	5	24	10	49
Palaeoclimatology	10	9	10	4	33
Palaeobotany	4	3	5	3	15
Palaeopedology	1	1	0	1	3
Palaeohydrology: database	101	85	57	22	265

of global climate change (Gregory, 1998). In specific terms, it has been shown how palaeoflood hydrology can assist in the design of hydraulic structures and in water resources management (Jarrett, 1996); and it has been noted that attention needs to be given to human adaptation to the changing global environment (Baker, 1998). The situation is changing so that books (e.g. Arnell, 2002) and dictionary entries (Anthony and Wohl, 1998; Mathews, 2001) now refer to the potential that palaeohydrology offers in the range of palaeosciences, defined as those branches of the natural environmental sciences that focus on the reconstruction and modelling of past events rather than direct observation and experiment (Mathews, 2001). It is presumptuous to assume that any one multidisciplinary discipline can, on its own, contribute to knowledge of global change because throughout many disciplines it is now appreciated (e.g. Cotton and Pielke, 1995) that scientists are grossly underestimating the complexity of interactions between the earth's atmosphere, ocean, geosphere and biosphere so that earth system science (Chapter 21) is being promulgated. Furthermore, when considering global change it has to be recognised that adjustments in water resources will be regional (with floods and droughts both projected to increase in intensity) or local (riparian zones) but, despite the sure knowledge that global change will occur (Perry, 1999), the exact nature of the consequential changes cannot be predicted with current limitations in our knowledge and computing power (Gleick, 1993). Indeed, Baker (1995) regretted how the international global change science initiative has made little appropriate use of the treasure of experience gained from past environmental changes.

Climate change analysed using GCMs (Henderson-Sellers, 1994) has been considered in relation to palaeohydrology (Arnell, 1996), but the question arises as to how far outputs from GCMs can be effectively coupled to hydrological models of an appropriate scale. It is generally agreed that regional climate prediction is not an insoluble problem, although it is characterized by inherent uncertainty that is derived from two sources: the unpredictability of the climatic system as a result of deterministic chaos and of the global system that renders climate predictions uncertain through unpredictability of external forcings superimposed on the climate system (Mitchell and Hume, 1999). It has been contended (e.g. Airey and Hulme, 1995) that model simulations of future changes to magnitude, timing and spatial pattern of global precipitation should be viewed as scenarios, not predictions. There remain, therefore, significant gaps relating to hydrological forecasts and to water resource estimation, including requirements for reliable techniques for downscaling climate model simulations to the catchment scale and for more integrated models (Arnell, 1996). To achieve relationships between global climate change investigations and impacts, it is necessary to complement inductive and deductive global change science approaches with retroductive global change science. Retroduction is a characteristic reasoning mode in Earth Sciences that involves synthetic reasoning often using analogies, applying the classical doctrines of commonsensism, fallibilism and realism (Baker, 1995) and because it emphasises deriving hypotheses from nature, it is very appropriate for palaeohydrology.

In considering potential links between palaeohydrology and global change, it is possible to identify several categories, to show how the subsequent chapters relate to these issues (Section 5) and demonstrate their pertinence in relation to river channel management (Chapter 21, Table 21.3), and then finally (Chapter 22) to suggest how conclusions from the chapters relate to the issues identified. Major issues relate to the following:

- Derivation of *data* to complement periods of continuous hydrological records relating to water balance, hydrological extremes, water quality, especially sediment involving historical sequences of change more clearly elucidated from the neolithic to the twentieth century.
- *Mechanics* of temporal change, including the significance of thresholds, sensitivity/hypersensitivity/undersensitivity, control by vegetation, human activity in this regard, debris stores and slugs, links with ecology including woody debris and planform.
- *Spatial contrasts* – differences between world zones, within zones and within basins, and their synchroneity.
- *Coupling* of Global Climate Change Models to hydrological models and the necessary forcing mechanisms.
- Construction of *new models* of a retroductive kind that may be non-linear, aided by techniques such as ^{137}Cs.

Examples of palaeohydrological contributions already made to these five categories (Table 1.3) are necessarily sequential with examples of the later ones depending upon further research. There will be the need to develop a conceptual basis as a framework of reference within which research results are presented in order to facilitate their application. Although research contributions focused upon the component elements of the palaeohydrological water balance, upon the balance itself, upon alluvial chronology and upon contributions in accord with the PAGES (see Chapter 3) framework are essential, it is also necessary to place research results in the context of a drainage-basin-based qualitative model of river channel structure. It is argued here that this is one necessary next step for palaeohydrology in order to facilitate further applications of research results; some progress has been made in this direction as indicated in Chapter 17. The need for a basin framework has been anticipated in some studies presented to GLOCOPH and it has been argued that, in the humid tropics, although considerable attention has been paid to studies of lake levels worldwide and to the palynology of mires, there has been a reluctance to translate these findings into interpretations or models of landscape response to climate change (Thomas, 1994), so that alternative models of stream response to climatic change are still necessary (Thomas, 1998). Some uncertainty remains an element in any forward estimation of future scenarios because of complex interactions of systems with large numbers of variables that may be non-linear and difficult to model, as well as the paucity of long-term data

Table 1.3 Examples of use of palaeohydrology results in relation to global change

Category of application	Example	Source
Derivation of *data* to complement periods of continuous hydrological records relating to water balance, hydrological extremes, water quality, especially sediment. Involving historical sequences of change more clearly elucidated particularly from the Neolithic to the twentieth century	Balance between precipitation and evaporation derived from past lake levels in closed basins by dating sedimentary deposits.	(Fontes and Gasse, 1991)
	Holocene flood chronology for the Upper Mississippi Valley from palaeochannel evidence.	(Knox, 1993)
	Dendrochronologic evidence for the frequency and magnitude of floods.	(Yanosky and Jarrett, 2002)
	Thousand-year record of channel change reconstructed for middle Trent and may be valuable for both model validation and planning purposes.	(Brown *et al*., 2001)
Mechanics of temporal change, including control by vegetation, woody debris, human activity, debris stores and slugs, the significance of thresholds, sensitivity/ hypersensitivity/ undersensitivity	Climatic and human controls on runoff and qualitative descriptions on torrential floods since the Bronze Age.	(Provansal, 1995)
	Impact of land use changes since the Neolithic on soil erosion and hydrology, with quantification of average rates of sediment yields at different periods.	(Jorda *et al*., 1991)
Spatial contrasts – differences in palaeohydrology and palaeoforms between world zones, within zones and within basins and their synchroneity	*Between zones*: Intracontinental runoff systems of North Asia and the influence of ice-dammed lakes.	(Rudoy, 1998)
	Within zones: Regional chronology of flood magnitude and frequency in small basins in western Arizona.	(House and Baker, 2001)
	Within basins: Palaeoflood hydrology of the Tagus river, Spain. Modelling fluvial dynamics along Allier/Loire, France.	(Benito *et al*., 1998; Veldkamp and Van Dijke, 1998)
Palaeohydrologic data used in *coupling* of Global Climate Change Models to hydrological models and the necessary forcing mechanisms	Lake and pollen observations of past climates are compared with climates simulated by numerical climate models.	(COHMAP Members, 1988)
	A simplified GCM is used to investigate the climate and hydrological regime sensitivity to the changes in insolation flux at the top of atmosphere, CO_2 variations, and topographic changes during the last 20 ka.	(Kislov and Surkova, 1998)
Construction of *new models*, possibly non-linear, of a retroductive kind, aided by techniques such as ^{137}Cs	Regional palaeoflood databases applied to flood hazards and palaeoclimate analysis.	(Diez-Herrero *et al*., 1998.)

and the fact that there may be factors previously ignored, with nature possibly having surprises up its sleeve in the form of catastrophic or extreme events (Goudie, 1993).

5 STRUCTURE

The chapters in this book are designed, in the light of the culmination of GLOCOPH Research (1991–2003), to demonstrate how palaeohydrology can be of value in the understanding of global change. A brief section of perspectives, therefore, provides some indication of the INQUA context (Chapter 2) and of the relationship to global change programmes (Chapter 3). The major sections of the volume are concerned with 10 major world areas, with explanation of the regional division that is adopted in Chapter 4. A second major section is devoted to recent progress interpreting evidence of environmental change and, like the regional section, cannot be comprehensive; topics are selected to focus upon issues subject to current research and capable of considerable application. In the final two chapters of the section, attention is directed to the significance of short-term changes (Chapter 20), a topic appearing as one of increasing recognition from many strands of palaeohydrological research; and to river channel management (Chapter 21), which is a major area for application.

Referring back to William Faulkner's sentiment: the past is certainly not dead, for scientists directly interested in palaeohydrological research and also for many others who might benefit from the results obtained.

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