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Anthropocene**

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Watershed systems science – a new paradigm to understand and govern the impact of human activities on the earth’s surface in the Anthropocene

Ray Ison^{1*} & Yongping Wei²

¹ Professor of Systems, Applied Systems Thinking in Practice Group, School of Engineering & Innovation, The Open University, UK. ² ARC Future Fellow (River Basin Management), Associate Professor, School of Earth and Environmental Sciences, Faculty of Science, University of Queensland, St Lucia, Queensland, Australia; *Corresponding author ray.ison@open.ac.uk

Recent scholars’ work in Vol 58 Issue 1 (2015) and Cheng & Li’s paper in Vol 58 Issue 7 (2015) in *Science China Earth Sciences* propose development of “Watershed science” by “Bridging new advances in hydrological science with good management of river basins”. An analysis of the language and key concepts used in the abstracts, titles and keywords of this set of 8 papers and an editorial reveals that ‘Watershed’, ‘River’, ‘Science’ and ‘System’ are the main terms employed by authors (Figure 1). It is not surprising that ‘Watershed’, ‘River’, and ‘Science’ are used most frequently, given the nature of this special issue in a science-driven journal. That the concept ‘system’ features highly is somewhat surprising but understandable as this journal is devoted to the concept ‘earth system’. So, our first interest is how employing the concept *system* in particular ways can assist in developing watershed systems science.

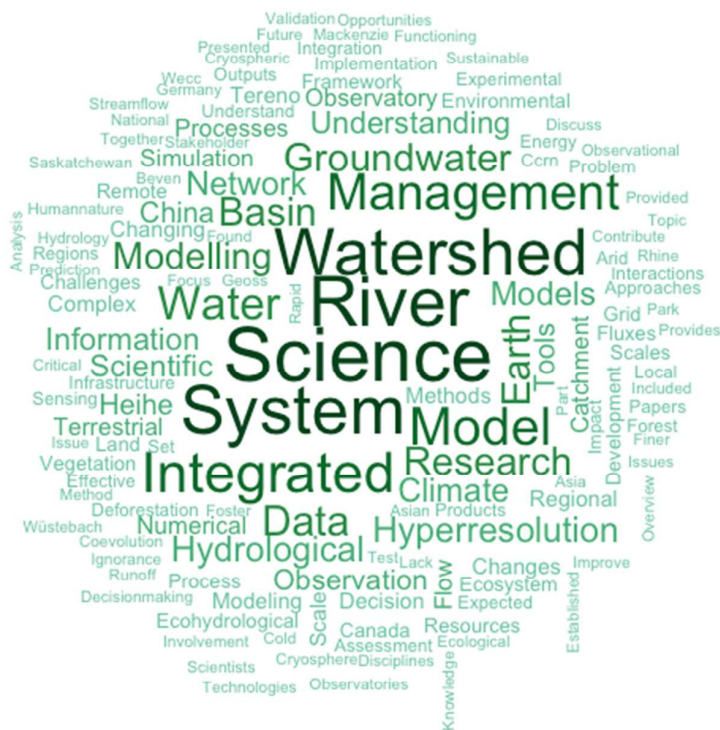


Figure 1. Words clouds included in titles, key words and abstracts of 7 papers in China *Science* Vol 58 Issue 1 (2015) and Cheng & Li’s paper in Vol 58 Issue 7 (2015)

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27 biophysical world whether to understand or transform it (Ison 2017).

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44 platforms: (i) systems science; (ii) complex systems; (iii) scale problems and (iv) Newtonism
45 vs. Darwinism (v) hydro and eco-economics and (vi) meta-synthesis. Consistent with their
46 claim that watershed science 'should be integrated with philosophical conceptualization,
47 theorization, methodological exploration, infrastructure construction and field
48 experimentation' (p. 1167) it is necessary to explore how the concept 'system' is employed
49 by authors and how their conceptions relate to, or shape, research practice in a new field of
50 watershed science. We believe that philosophical clarification of the concept 'system' could
51 facilitate the systemic integration of all six intellectual platforms of Cheng & Li (2015) and
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19 social sciences for governing the impact of human activities on the earth’s surface in the
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25 Cheng & Li (2015) argue that watershed systems are highly co-evolved, complex human-
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28 culture and nature. The negotiation is a result of human decision-making, which is the
29 primary driver of earth system change. We argue that any human decision is determined by
30 the interactions between social values (willingness to change), technology progress
31 (capacity to change) and institutional arrangements (change regulated formally by
32 government or through self-organising informal institutions) at different system levels (Wei
33 and Zhang, 2017 and Wei et al. 2017). Therefore, while we agree with Cheng & Li (2015)
34 that hydro-economics is important for understanding interdependence between economic
35 activities and natural systems, three sub-disciplinary fields from hydrology: socio-hydrology,
36 techno-hydrology and institutional-hydrology are needed for the development of watershed
37 systems science. Developments in these sub-disciplines can provide understanding of the
38 mechanisms for governing the impact of human activities on the earth’s surface in the
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44 Unfortunately, very limited research on a single watershed has been conducted from the
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50 catchment processes in an arid and semi-arid region; it sits within an important part of the
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3 River Basin and the resources committed to understand and manage it constitute an ideal
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8 economy system for sustainable river basin management. Since then over 500 papers have
9 been published covering traditional hydrology, remote-sensing hydrology, eco-hydrology,
10 hydro-economics and socio-hydrology. The challenge remains that identified by Cheng & Li
11 (2015) when they ask: how can the innovations in Earth system science and technology be
12 used to support a sustainable future Earth?" (p. 1159).
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16 The arguments made by Cheng & Li (2015) for the 'atomic' nature of a watershed, and thus
17 its utility as a locus of study and of governance are conceptually sound. They also allow
18 consideration of co-evolutionary dynamics between a social and a biophysical system but
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20 water transfers are made, or human wellbeing is linked to economic activity that spans
21 watersheds then the question of system boundary choice, aligned to human purpose must
22 be addressed. A holistic science that begins with systemic sensibilities and does not
23 privilege linear or systematic causality is needed in all situations, including an earth system,
24 characterized by interdependency, uncertainty, complexity, and controversy. These are the
25 features of an Anthropocene world in which human action is effecting whole earth
26 dynamics and in which traditional understandings and practices such as commitments to
27 stationarity in hydrological modelling are no longer adequate. Achievements from the
28 'Heihe Plan' constitute a unique opportunity and significant investment to further build on
29 multi-disciplinary achievements. To transform further towards a mature watershed systems
30 science we urge the systemic use of the concept 'system' and bringing in new social-
31 oriented subdisciplines of hydrology. The HRB could be developed as an iconic watershed
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For Review Only

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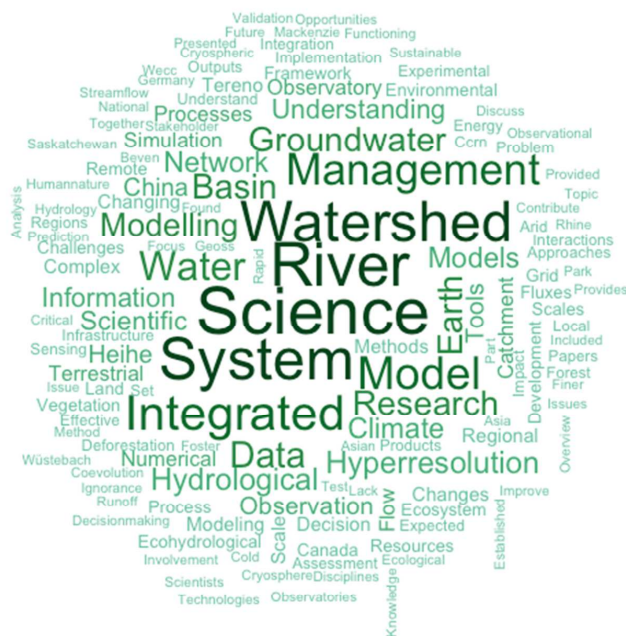


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3 As outlined by Ison (2016) the use of the concept 'system' is widespread but all too often is
4 employed without adequate theoretical insight. As Lakoff (2010) would say it has become a
5 common framing choice: "And since frames come in systems, a single word typically
6 activates not only its defining frame, but also much of the system its defining frame is in"
7 (Lakoff 2010 pp. 71-72).¹ The issue of boundary choice is critical to the deployment of the
8 concept 'system' (Midgeley 2003). Understood metaphorically the concept *Earth System*
9 implies a boundary associated with the whole Earth. For example, IGBP say that 'the term
10 "Earth system" refers to Earth's interacting physical, chemical, and biological processes. The
11 system consists of the land, oceans, atmosphere and poles. It includes the planet's natural
12 cycles — the carbon, water, nitrogen, phosphorus, sulphur and other cycles — and deep
13 Earth processes
14 ([http://www.igbp.net/globalchange/earthsystemdefinitions.4.d8b4c3c12bf3be638a800010](http://www.igbp.net/globalchange/earthsystemdefinitions.4.d8b4c3c12bf3be638a80001040.html)
15 [40.html](http://www.igbp.net/globalchange/earthsystemdefinitions.4.d8b4c3c12bf3be638a80001040.html)). In this use of the concept people and human action do not feature or only
16 implicitly. In contrast the Wikipedia description of Earth system science claims it 'is the
17 application of [systems science](#) to the [Earth sciences](#). In particular, it considers interactions
18 between the Earth's "spheres"—[atmosphere](#), [hydrosphere](#), [cryosphere](#), [geosphere](#),
19 [pedosphere](#), [biosphere](#), and, even, the [magnetosphere](#)—as well as the impact of human
20 societies on these components. At its broadest scale, Earth systems science brings together
21 researchers across both the [natural](#) and [social](#) sciences
22 (https://en.wikipedia.org/wiki/Earth_system_science). The *system* concept is of utility
23 when one is concerned with elements and their relations e.g., within the Earth System at
24 system, sub-system or sub-sub-system levels e.g. watershed system, social system, farming
25 system etc. At every systemic level the question of boundary judgment applies – it is we
26 humans who must take responsibility for boundary choices as means to engage with the
27 biophysical world whether to understand or transform it (Ison 2017).

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34 However, there is a systemic trap in the use of the concept *system*, a noun in the English
35 language (Ison 2016). Whilst the concept draws attention to the elements and relationships
36 that might exist and operate in a system of interest, what is concealed by the use of the
37 term are (i) the act of making a boundary judgment by an observer or observers; (ii) an
38 appreciation that making a boundary judgement realises another relational dynamic – the
39 act of making a distinction between a system and its environment and (iii) awareness that
40 using the term system is always a shorthand for a system-environment relationship
41 mediated by a boundary judgement. Cheng & Li (2015) frame the watershed as a basic unit
42 of the Earth system. They argue that watershed science shares the characteristics of
43 fundamental research in Earth system science and ground their arguments in six intellectual
44 platforms: (i) systems science; (ii) complex systems; (iii) scale problems and (iv) Newtonism
45 vs. Darwinism (v) hydro and eco-economics and (vi) meta-synthesis. Consistent with their
46 claim that watershed science 'should be integrated with philosophical conceptualization,
47 theorization, methodological exploration, infrastructure construction and field
48 experimentation' (p. 1167) it is necessary to explore how the concept 'system' is employed
49 by authors and how their conceptions relate to, or shape, research practice in a new field of
50 watershed science. We believe that philosophical clarification of the concept 'system' could
51 facilitate the systemic integration of all six intellectual platforms of Cheng & Li (2015) and
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57 ¹ It should not escape notice that Lakoff employs the concept system to make his points; whether this is an
58 adequate use of the concept system is a question worth asking.
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3 the overall aspiration for a new 'watershed science'.
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5 The aim of this special issue was to develop watershed science by bridging new advances in
6 hydrological science with good management of river basins. Six papers from leading
7 scientists on watershed science in China, the USA, Japan, the United Kingdom and Germany
8 make significant contributions to understanding the impact of human activities on the
9 earth's surface in the Anthropocene through modelling work (e.g., Beven et al. 2015) and
10 improvements in observational technologies and infrastructure (e.g. Koike et al. 2015).
11 Unfortunately, this issue fails to link *hydrological science* with *good management of river*
12 *basins* challenges as only Cai et al. (2015) call for drawing together disparate disciplines into
13 an integrated scientific framework for a new generation of Decision Support System (DSS)
14 for river basin management. Notably few key words relevant to river basin management or
15 governance dominate (Figure 1). In a later issue, Cheng & Li (2015) ask: "*How can we better*
16 *integrate the achievements of social sciences so that the large role of humans in Earth*
17 *systems is fully understood?* arguing this is one of most significant challenges for developing
18 watershed systems science. Therefore, our second interest is how to employ social sciences
19 for governing the impact of human activities on the earth's surface in the Anthropocene.
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24 Cheng & Li (2015) argue that watershed systems are highly co-evolved, complex human-
25 nature systems. They thus set the groundwork for how co-evolutionary processes function.
26 However, this co-evolution is based on long term and complex 'negotiations' between
27 culture and nature. The negotiation is a result of human decision-making, which is the
28 primary driver of earth system change. We argue that any human decision is determined by
29 the interactions between social values (willingness to change), technology progress
30 (capacity to change) and institutional arrangements (change regulated formally by
31 government or through self-organising informal institutions) at different system levels (Wei
32 and Zhang, 2017 and Wei et al. 2017). Therefore, while we agree with Cheng & Li (2015)
33 that hydro-economics is important for understanding interdependence between economic
34 activities and natural systems, three sub-disciplinary fields from hydrology: socio-hydrology,
35 techno-hydrology and institutional-hydrology are needed for the development of watershed
36 systems science. Developments in these sub-disciplines can provide understanding of the
37 mechanisms for governing the impact of human activities on the earth's surface in the
38 Anthropocene.
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43 Unfortunately, very limited research on a single watershed has been conducted from the
44 perspective of different sub-disciplines of watershed systems science. Such studies could
45 cross-fertilise the development of individual sub-disciplines and generate systemic
46 knowledge for watershed managing and governing. The Heihe River basin (HRB) in China is
47 perhaps the one exception; it is the second longest inland river in China, with a length of
48 948 km and an area of approximately 143, 000 km². HRB covers typical ecosystems and
49 catchment processes in an arid and semi-arid region; it sits within an important part of the
50 ancient Silk Road established in the Han Dynasty (206 BC–AD 220) and thus within the new
51 Belt and Road initiative being undertaken by China. The HRB 'story' is of a typical watershed
52 involving many catchment processes related to hydrology and experiencing several
53 management phases in early civilization, rapid economic development, serious
54 environmental degradation and rebalance between humans and environment. The Heihe
55 River Basin and the resources committed to understand and manage it constitute an ideal
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3 watershed 'laboratory' for inter-disciplinary research on watershed co-evolutionary
4 dynamics. In 2010, the National Natural Science Foundation of China launched a major
5 research plan titled "Integrated Study of the Eco-hydrological Processes of the Heihe River
6 Basin" (referred to as the "Heihe Plan") which aimed to understand the water-ecosystem-
7 economy system for sustainable river basin management. Since then over 500 papers have
8 been published covering traditional hydrology, remote-sensing hydrology, eco-hydrology,
9 hydro-economics and socio-hydrology. The challenge remains that identified by Cheng & Li
10 (2015) when they ask: how can the innovations in Earth system science and technology be
11 used to support a sustainable future Earth?".
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15 The arguments made by Cheng & Li (2015) for the 'atomic' nature of a watershed, and thus
16 its utility as a locus of study and of governance are conceptually sound. They also allow
17 consideration of co-evolutionary dynamics between a social and a biophysical system but
18 unfortunately many watersheds are no longer purely 'natural systems'; when inter-basin
19 water transfers are made, or human wellbeing is linked to economic activity that spans
20 watersheds then the question of system boundary choice, aligned to human purpose must
21 be addressed. A holistic science that begins with systemic sensibilities and does not
22 privilege linear or systematic causality is needed in all situations, including an earth system,
23 characterized by interdependency, uncertainty, complexity, and controversy. These are the
24 features of an Anthropocene world in which human action is effecting whole earth
25 dynamics and in which traditional understandings and practices such as commitments to
26 stationarity in hydrological modelling are no longer adequate. Achievements from the
27 'Heihe Plan' constitute a unique opportunity and significant investment to further build on
28 multi-disciplinary achievements. To transform further towards a mature watershed systems
29 science we urge the systemic use of the concept 'system' and bringing in new social-
30 oriented sub-disciplines of hydrology. The HRB could be developed as an iconic watershed
31 for watershed systems science – a new paradigm to understand and govern the impact of
32 human activities on the earth's surface in the Anthropocene.
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