'SIMDELTA GLOBAL'- TOWARDS A STANDARDISED INTERACTIVE MODEL FOR WATER INFRASTRUCTURE DEVELOPMENT

Ties RIJCKEN

Delft University of Technology, Department of Hydraulic Engineering, Postbus 5 , 2600 AA Delft, The Netherlands
http://home.tudelft.nl/index.php?id=5820&L=0, t.rijcken@tudelft.nl

David K. CHRISTOPHER

Indiana University, School of Public and Environmental Affairs, 107 S. Indiana Ave. 47405-7000 Bloomington, USA
http://www.indiana.edu/~spea/, christdk@indiana.edu

Abstract

The research project 'SimDelta' builds on novel internet technology to support the development of the Rhine-Meuse delta water infrastructure. It has three goals: education, organisation of research and design studies, and stakeholder polling. A current question is how the SimDelta technology could be made transferable to systems outside Europe, such as in California, Shanghai, Thailand and Indonesia. Fundamentally, all water systems are similar. Technically they differ in scale, geometry, resolution and functional emphasis, but system boundaries can be standardised. It is essential that SimDelta graphically acknowledges different data quality levels, to allow for standardisation and piecemeal development. Political coordination of infrastructure improvements appears to be difficult everywhere. Since SimDelta aims to clarify connections between high and low scale levels, it is expected to benefit the development of any water system. However, strategically it is recommended to start with the California system, for reasons of scientific maturity and political openness.

Keywords: *Water infrastructure planning, interactive modeling, crowdsourcing, water management, hydraulic engineering, adaptive management.*

1. INTRODUCTION

The use of the internet worldwide is expanding and technology keeps improving, perhaps most in the domain of on-line social communities. Complexity of spatial planning and public infrastructure is also increasing, because of growing pressure on space, increasing levels of education, environmental awareness, democratization and decentralization. Numerous interactive internet-based tools have been developed to support planning and public policy-making, and they will continue to be improved. Preliminary analysis suggests that most of these interactive models are either complex models filling large databases with interfaces accessible only to a few experts, or relatively simple 'serious games', with an attractive

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interface over a simple model (Van Schijndel 2005; Rijkswaterstaat 2007; van den Roovaart en Meijers 2011; Mayer 2009; Bekebrede 2010). Long-term projects that use attractive interfaces, complex modeling, and the internet to probe a large group of stakeholders seem to be in stages of infancy. Water infrastructure development might be a good field to experiment with this combination of complex modeling and fine web-based interface design. Infrastructure has a large number of stakeholders and is knowledge-intensive. The costs of maintaining an interactive model are small in comparison to investments in national flood safety, fresh water supply, shipping, and healthy aquatic ecosystems, which can run into the billions a year.

At Delft University of Technology, the 'SimDelta' project aims to build such an interactive model for the Dutch Rhine-Meuse delta system (Figure 1). The model has three goals. First: education. Interactive features educate and engage the user on the status of the current system and explain the interaction between future scenarios, problems and solutions in an intuitive way (Figure 2). Second: organisation of research and design activities. SimDelta's standardized graphical language streamlines expertise into a common venue. It becomes easier for users to relate different studies to each other, to find related documents and to identify data or design gaps. Third: stakeholder polling. Online model users fill in a user profile and convey their preferences and criticism in sessions and on discussion forums. If enough stakeholders do this seriously, and SimDelta registers their input statistically, this will provide information to decision-makers comparable to market-research (Rijcken, T, Stijnen, J, en Slootjes, N 2011).
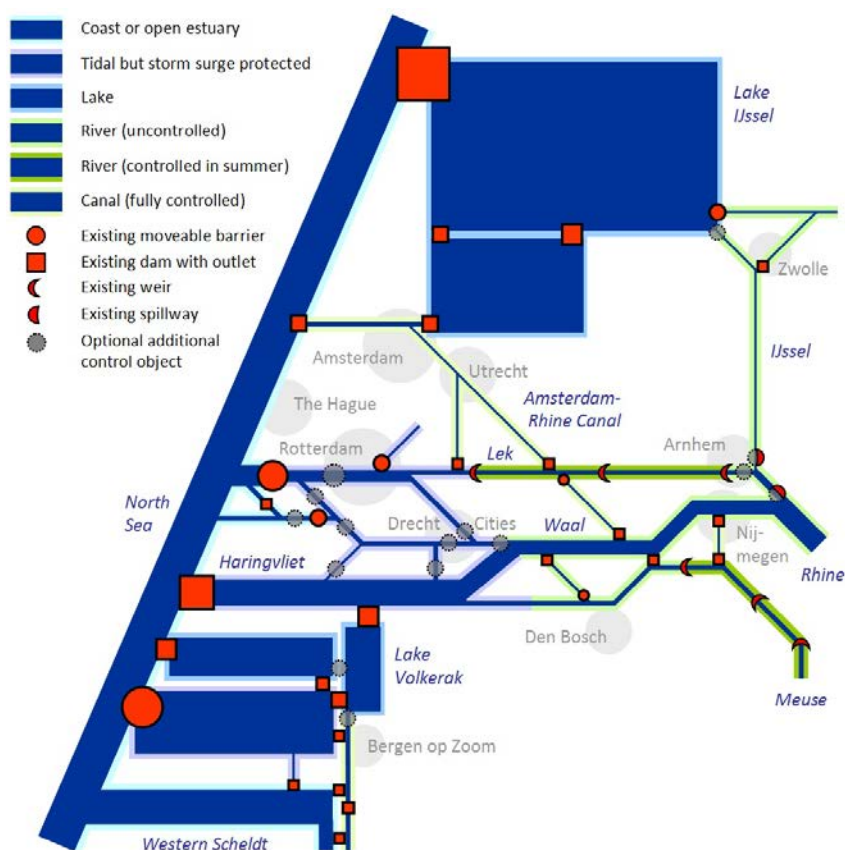

Figure 1. Schematization of Rhine-Meuse Delta system in the Netherlands. Rivers and channels are scaled according to their maximum flow capacity. Reservoirs have been approximately scaled according to their storage capacity.

At this moment, SimDelta is working with limited functionality (see www.simdelta.nl). Current activities focus on technical and conceptual foundations. Demos are made to study usability and improve the interface. The vision is to develop a sufficiently general graphical language that allows the model to be applied to water systems elsewhere on the planet. This paper will investigate how the SimDelta technology could be made transferable, and whether this would be valuable. To what extent do water system objectives differ around the world? Do differences in data availability limit a universal applicability of SimDelta? How important is scale? Are governments interested in democratization by internet communities? Studying these questions, precisely in a stage where the foundations are being laid, will probably result in technical modifications and strategic reconsiderations to the concept initially developed for the Netherlands.
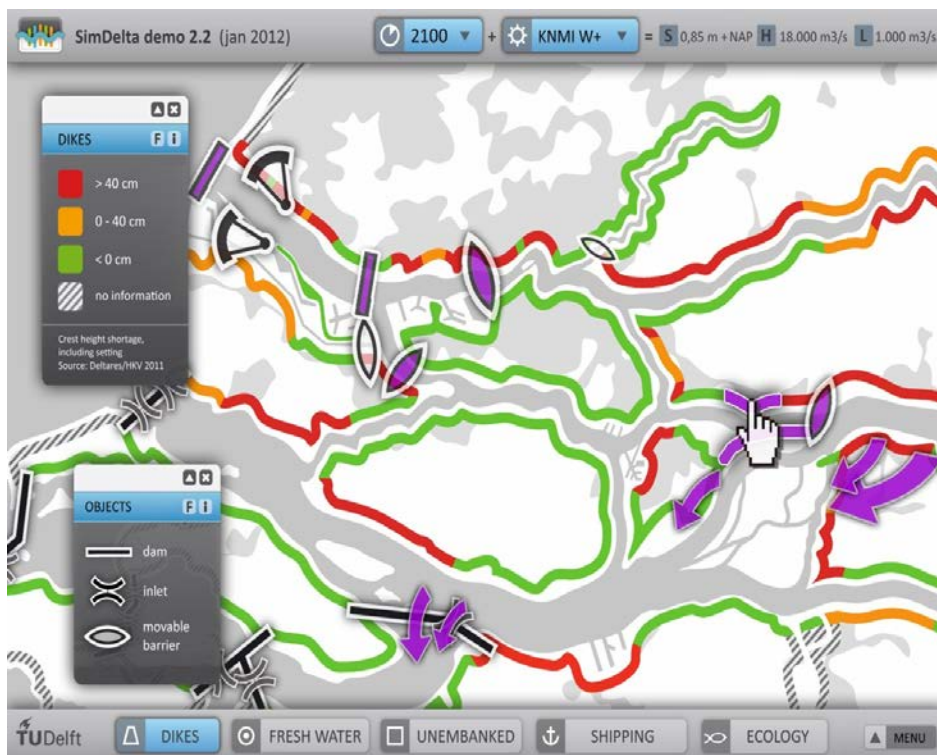

Figure 2a. Screen shot of the SimDelta interface in the Rhine-Meuse delta. Dike rings are coloured to show the risk of failure based on user-determined specifications (sea level rise, year, and design standards or return period). Possible new infrastructure projects ('solutions') to prevent failure along the highlighted dike segment (a 'problem') are shown in purple.

2b-1: Selecting the return period under which to see the system performance.

2b-2: Clicking on the fresh water button and on a red 'problem' shows available solutions in purple (similar to figure 2a for flooding).

2b-3: Clicking on a 'solution' gives a project sheet by a designer.

2b-4: Behind each problem-window, solution-window and legend are discussion forums.

Figure 2b. Some functionalities of the SimDelta demo 2.2.

2.   METHODOLOGY

The applicability of SimDelta to different water systems is evaluated studying four water systems outside Europe, two of which will constitute the core of this paper: the California Central Valley water system (US) and the Greater Shanghai water system (China). These systems have been selected based on their scale, level of complexity, and integration of functions: fresh water supply, flood protection, navigation, and provision of ecological services.

Applicability means whether expanding the SimDelta concept to the other systems would be *possible* and *valuable*. Four criteria are used: scientific maturity, political feasibility, technological maturity, and problem urgency. Scientific maturity examines the availability of information about hydrology, existing infrastructure, future scenarios, and possible projects. Political feasibility assesses the capacity of governing institutions to implement changes (new projects and new operations), and the adaptability of interactive modeling and online polls into the current process of decision-making. Technological maturity examines the use of the internet in current governance and the ability of the government to mobilize stakeholders using E-communication, indicated by the 2008 United Nations E-Governance index. Problem urgency indicates the level of traction that an interactive model may generate. It evaluates whether the water system problems are on the top of politicians' lists, or if water

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infrastructure development takes a backseat to other political, economic, and environmental matters.

We see two distinct ways to implement the SimDelta concept. First, it could be adopted by the highest governing body (the Department of Water Resources in California and the Water Affairs Bureau in Shanghai) as the primary way to organize business and plan for the future (internal use). Second, SimDelta could be coordinated by an independent entity, such as a foundation or a university, and maintained by research subsidies, student projects, and local stakeholder inputs (external use). The internal usage would provide access to a limited number of users; external use explicitly aims at mobilising a large crowd of experts and stakeholders, with a larger number of users and conceptual links to 'crowdsourcing' (Surowiecki 2005; Brabham 2010). These avenues of implementation will be informed by our examination of the four applicability criteria at the end of the paper.

3. SIMDELTA APPLIED TO CALIFORNIA, SHANGHAI, THAILAND AND INDONESIA

3.1. Central Valley Water System

California's Central Valley spans more than 700 km parallel to the Pacific Coast of the United States (Figure 3). The valley is abutted by the Sierra Nevada mountain range to the east, which drains into two major arteries: the Sacramento River in the north and the San Joaquin River in the south. These rivers join in the California 'inland Delta'. The Central Valley produces nearly 25% of the United States food supply (Struglia, Winter, and Meyer 2003). The agricultural productivity and high rate of population growth in Southern California are fuelled by an extensive man-made network that redistributes water resources from the wetter north to the drier south (Lund, J a.o. 2007). The largest structures, the California Aqueduct and the Delta-Mendota Canal, flow south from pumping stations in the Delta. Other water infrastructure including bypasses, weirs, and levees, have been constructed to prevent flooding in the Delta and along rivers in the northern part of the valley. Hundreds of reservoirs, lakes, forebays, and retention basins throughout the state store water for fresh water supply, recreation, flood prevention, and hydropower. Additionally, the sea ports of Sacramento and Stockton, the main rivers and a number of canals in the Central Valley form a 460 km long inland waterway network used for shipping (USDOT 2002). Maintaining or restoring healthy aquatic ecosystems is a major concern throughout California (Hanak a.o. 2011).

Scientific Maturity: There is an abundance of information on hydrology and infrastructure for the Central Valley system available for public use. The United States Geological Survey, the California Department of Water Resources, the Federal Bureau of Reclamation and many smaller organisations maintain historical logs of construction activity and monitor more than 1400 dams (Goslin 2005) and thousands of kilometres of waterways and levees. This information has been used to develop elaborate models of California's water resources, for example on predicting changes in water availability as a result of climate change and changing land-use scenarios. Some have integrated economic analyses of water supply and the implications of extreme drought in California (Harou, J a.o. 2010). Most models focus on one function of the system. SimDelta is most valuable in revealing relationships between different functions. Not all components of the Central Valley system are interconnected, but for example fresh water storage and flood protection can be linked through dam height and reservoir operations. Fresh water supply and ecology in the Delta are connected through pumping station design and operations, etcetera.
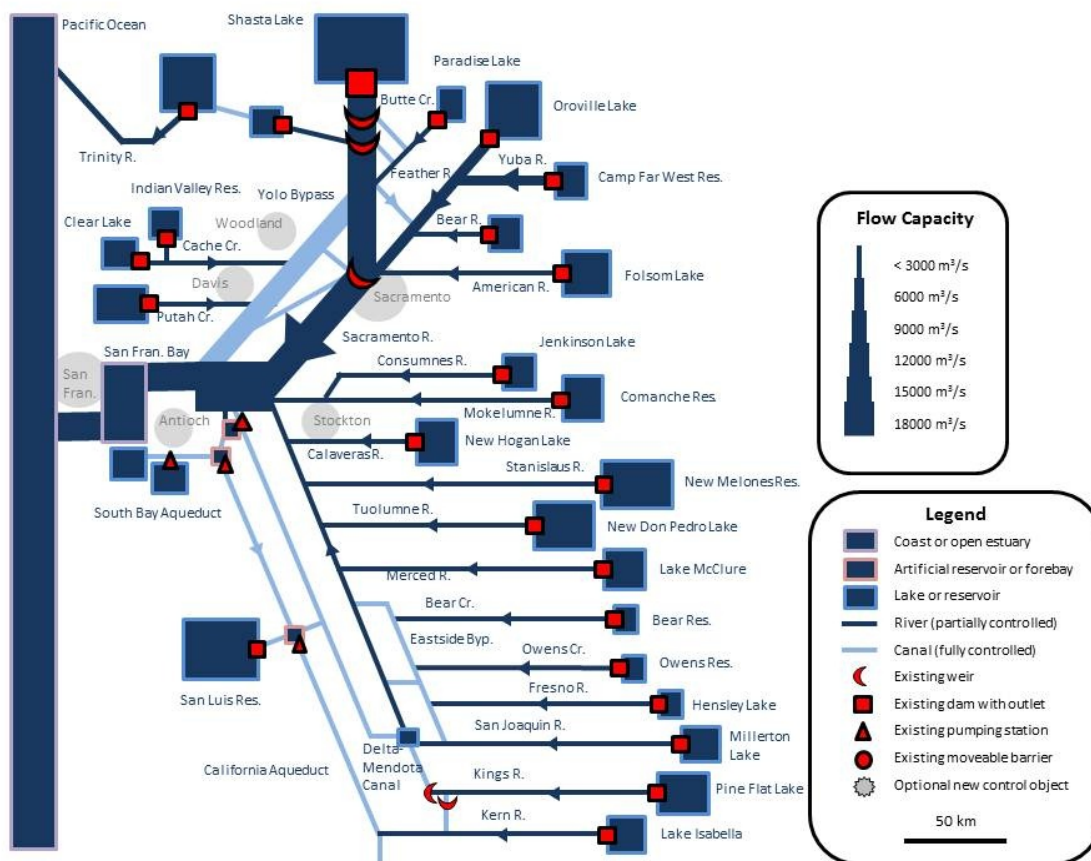
Figure 3. Schematic representation of California's Central Valley water system. Rivers and channels are scaled according to their maximum flow capacity. Reservoirs have been approximately scaled according to their storage capacity.

Political Feasibility: Operation of the Central Valley water system is conducted by federal, state, regional and local agencies (Little Hoover Commission 2010). The State Department of Water Resources (DWR) is responsible for state-wide management of water resources including operating the California Aqueduct and maintaining many levees and dams across the state. The federal Bureau of Reclamation owns and operates the Central Valley Project, which carries water from the northern part of the valley south through the Delta-Mendota Canal. Federal presence is mostly contracted out to regional water authorities (Little Hoover Commission 2010). These authorities distribute water resources among various water districts. There are many local entities for particular tasks, for example the Sacramento Flood Control Agency (SAFCA).

In 1994, in response to substantial conflict and litigation surrounding management of water resources in California, the state established the CALFED Bay-Delta program. CALFED's goal was to protect the ecological viability and fresh water supply in the California Delta, improve coordination of the state and federal water projects, and conduct long term planning for the state's water resources (Kallis, G, Kiparsky, M, and Norgaard, R 2009). Drought and financial shortfalls in the early part of the millennium dissolved much of the cooperative spirit that CALFED started to create, and litigation surrounding the management of water re-emerged as a driving force of day-to-day operations. Recent discussions have called for the reorganization of water management in California to establish a centralized agency to coordinate operation between the various stakeholders. Changes in

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water management "call not only for new science, but also for new agreements among various stakeholders" (Lund, J a.o. 2007) p. 89). The SimDelta graphic framework could support this call for more integration while supporting a local focus (Rijcken, T, Stijnen, J, and Slootjes, N 2011).

Technological Maturity: The vitality of national communication technology infrastructure is quantified by the United Nations 2008 E-Governance survey. It evaluates technological capacity by measuring web integration, internet infrastructure, and human capital (United Nations 2008). The United States received an overall score of 0.8644 (out of 1), which ranks 4th globally. Consequently, the state of California is in an excellent technological position to implement an internet-based interactive model. This model could be developed and disseminated within the existing physical and organizational information networks.

Problem Urgency: The most prominent problems in the Central Valley system are fresh water shortage risks due to climate variation, climate change and changing land uses, impaired ecological health of the Delta and many rivers, increasing flood risks due to increased urbanisation, maintenance backlogs and land subsidence (Mount, J en Twiss, R 2005) and the increasing probability of an earthquake to hit the Delta levees, flooding islands with salt water, disconnecting the south from fresh water supply for months on end. Changes in the operations and use of existing infrastructure, water conservation and water markets offer some solutions (Zetland 2011; Hanak a.o. 2011). The heydays of new infrastructure might be over, but additional or modified infrastructure such as canals, bypasses and levee upgrades, will always play a role in the future development of the system (CA DWR 2011; Lund, J a.o. 2007). This is perhaps best illustrated by the re-emergence of support for the 'peripheral canal', which would transport water from the Sacramento River to the southern half of the Valley, bypassing the California Delta.

The state of California has historically managed large floods and augmented fresh water supplies effectively (Lund, J 2012). Similar to the Netherlands, California has a developed water system with low probabilities for disasters, but where remaining risks could still be lowered cost-effectively. Most citizens, however, have a short memory and may be less inclined to take interest in water management without provocation by extreme events (Correia, F a.o. 1998). SimDelta precisely aims at explaining how infrastructure modifications reduce risks, rather than directly respond to a disaster, and should thus help to gain political support for rational risk-reducing investments.

3.2. Greater Shanghai System

The major river flowing through Shanghai, China, is the Huangpu River, which originates in the Taihu Lake basin, 100 km to the west of the city. It flows east and then north where it ends in the Yangtze River near the confluence with the East China Sea (Figure 4). Shanghai's 23 million residents generally extract their drinking water from the Huangpu south of the city and from the Yangtze river north of Lake Taihu. Multiple drainage canals and control objects have been constructed to protect the city from flood threats due to tidal influences, storm surges, and excess precipitation, which can top 28 cm in a 24-hour period (Zong, Y en Chen, X 1999). Future investments in water infrastructure have been planned mostly to improve the treatment and disposal of sewage, and to protect against various kinds of flooding. These projects will have to be implemented carefully to avoid disrupting Shanghai's inland and sea shipping industry, which includes the third busiest port in the world (Capineri, C en Randelli, F 2007).
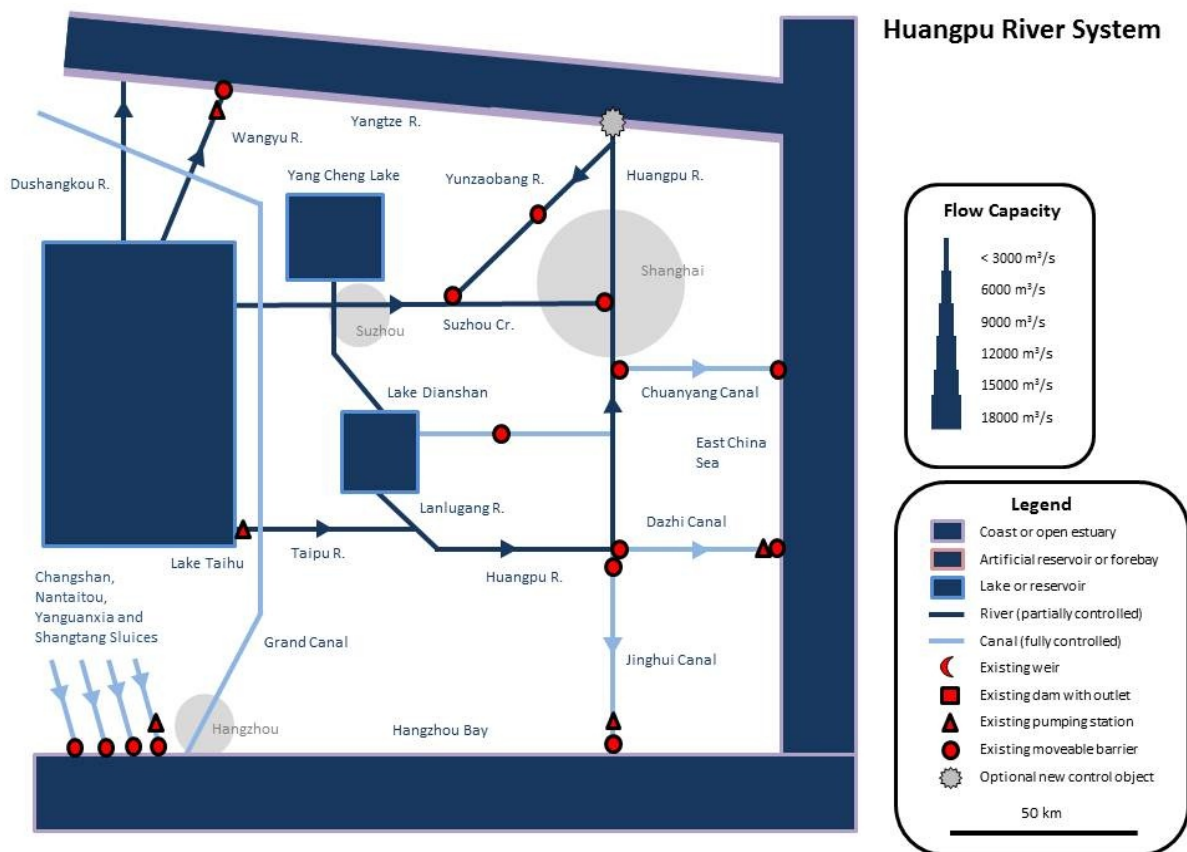
Figure 4. Schematic representation of the Huangpu water system. Rivers and channels are scaled according to their maximum flow capacity. Reservoirs have been approximately scaled according to their storage capacity.

Scientific Maturity: There is a substantial amount of information about the hydrology, water quality, and infrastructure on the Huangpu River System. The Chinese government monitors precipitation, discharge, and water quality at three primary hydrological stations along the main river. Additional data collection has been conducted by a variety of local and national organizations, as well as academic researchers. However, information is tightly controlled by Chinese officials (Gleick, P 2008). The concept of SimDelta is largely based on the free-flow of information. The 'suppliers' of concepts for water infrastructure projects (mostly engineers, architects and local stakeholders) utilize SimDelta to integrate their designs within the greater water system. A lack of accessibility may limit the input of project proposals and stymie the collaborative process. Recent legal and institutional developments have laid the groundwork for a more open system of information exchange, but have yet to realize their full potential (Gleick, P 2008). For example, the Environmental Impact Assessment Law was passed in 2003, largely in response to public anger about pollution in China's waterways. The law "encourages relevant units, experts and the public to participate in the EIA process in appropriate ways" (Eng, M en Ma, J 2006). Broader involvement in the decision-making process is likely to expand as channels of communication are established between the Chinese government and water infrastructure stakeholders. Still, the Shanghai system could be called mature in a sense of data availability, but the global data accessibility required for SimDelta is an issue.

Political Feasibility: Management of water resources in China is conducted by a variety of national, provincial, and municipal agencies (Gleick, P 2008). National directives generally place control of water supply at the municipal level and limit the influence of national environmental agencies. In Shanghai, water resources are managed by the Water Affairs Bureau, whose various departments oversee water supply, drainage and wastewater treatment, groundwater use, water conservation, and flood prevention (Cosier, M en Shen, D 2009). The Bureau shares flood protection responsibility with the Taihu Basin Authority, which is an national agency, and the provincial government. Some responsibilities are jointly administered with outside organizations, such as France's Veolia Group, which owns half of Shanghai's water utility. Other non-governmental entities generally do not play a major role in management of the city's water resources. Gleick (2008) suggests that the network of agencies that govern infrastructure, water management, and transportation lack clear jurisdictional boundaries, leading to a confusing set of policies with weak enforcement mechanisms. This has impaired communication between agencies and reduced management efficiency (Cosier, M en Shen, D 2009). Additionally, laws and policies developed by the Chinese government have limited the participation of private organizations in water infrastructure development (Bellier, M en Zhou, Y 2002). These coordination difficulties look somewhat similar to the political problems in California, where historically grown local operations seem to impair the advantages of coordination and planning on a higher level, and to which SimDelta may provide answers.

Technological Maturity: According to the United Nations, China's e-Governance ranked 65th in 2008, ranking lower on the web measure index and infrastructure index than the Netherlands and the United States. This score however measures performance at the national level and is likely not reflective of the technological capacity in and around Shanghai. Still, the Chinese government does not utilize telecommunication technology as much as other comparable countries. This may reflect the tendency of Chinese officials to limit the distribution of information and exert stronger controls on internet use and content.

Problem Urgency: Shanghai's current biggest problems are flood risk, shipping capacity, and poor water quality. Shanghai has always disposed waste in and received fresh water from the same Huangpu river and its tributaries, resulting in extensive environmental pollution and health issues. This problem peaked in the 1980's and 1990's and has since been mitigated by expanding the treatment infrastructure network (Zhang, C 1997). The growth of the Shanghai sea port and hinterland industry is expected to ask for increase of channel depths, lock capacities and to remove obstacles and bottlenecks. The risk of flooding comes from the sky and the sea. Rainstorms can overflow the urban water system network during the plum rain season (when it can rain for weeks on end, in June and July), and the typhoon season (with extreme torrential rainstorms, between May and September). When a storm surge coincides with astronomic tide, weak segments in the flood defences of the Huangpu river embankments (with design standards of 1/100 and 1/200) could be breached (Ren, W a.o. 2003; Wu, C a.o. 1999). This never happened between 1984 and 2009, when other floods caused 28 deaths but little economic damage (less than 100 million $) (Shi en Cui 2011). Future sea level rise, growing peak precipitation, land subsidence and urbanization will further increase flood probabilities and consequences (Han, M, Hou, J, en Wu, L 1995). These threats have generated support for the construction of a movable storm surge barrier at the mouth of the Huangpu River (Wang, J a.o. 2011). This barrier would require careful design and operations not to disturb shipping too much. Similar to California and the Netherlands, the urgency to improve the Shanghai system is not as much provided by frequent disasters, but by rational risk management. It seems there is sufficient complexity and urgency for an interactive decision support tool to be of use.

3.3. Water Infrastructure Systems in Developing Countries

The question if and how the SimDelta concept could be expandable towards a globally applicable tool, was also informed by a brief investigation of the Lower Chao Phraya River system in Thailand and the Citarum River basin in Java, Indonesia (Table 1). These systems face higher climatic variability and bigger threats from flooding, interruptions in fresh water supply and water pollution than the Netherlands, California or Shanghai. The general scientific maturity of these systems is limited, but investments are made on the basis of some information, however limited by western standards. This suggests that SimDelta would need to be able to also provide information with lower quality levels than the most detailed modeling results, if it would want to be universally applicable.

Political capacity to coordinate water infrastructure improvements at a national level appears to be difficult with all water systems around the world; in California and the Netherlands because of gridlocks and stalemates by local disadvantaged stakeholders, in Shanghai because of jurisdictional confusion, in Thailand and Indonesia because of limited government authority in general. Perhaps an independent interactive tool would be useful in most complex systems, even extremely authoritarian or anarchist ones, because issues with communication and coordination between different scale levels is intrinsic for large complex water systems.

On the United Nations 2008 e-Governance survey, Thailand ranks 64th and Indonesia 166th. After the 2011 flooding in Thailand, with over 800 fatalities and US$ 45 billion (Jonkman a.o. 2012), problem urgency is now so high that investments will probably be decided on before SimDelta is well developed. Even so, in both the Chao Phraya and the Citarum systems, many conceivable infrastructure improvements are expected to be cost-effective because of their early stage of development.

In Indonesia few people can read English, and Thailand and China do not even use the Latin script. This would put even more emphasis on the SimDelta attempt to create a language that is so graphic, that it is understandable if one would only see the images and understand most of the numbers, allowing users to communicate in the local language on the many forums throughout SimDelta. Water infrastructure projects in Thailand and Indonesia largely rely on outside funding from the Asian Development Bank and other organizations who use English as the working language. SimDelta, with its fundamentals in English, could be a communication bridge between international funding organisations and local stakeholders.

4. IMPLICATIONS

The survey of the four water systems around the world has been conducted in order to change some of the technical fundamentals of SimDelta and to contribute to determining the strategy for further development. In general, it seems that all water systems serve four primary goals: fresh water distribution during dry times, prevent flooding at wet times, facilitate shipping and protect aquatic ecosystems at all times. Additional functions are for example recreation, raw materials extraction and hydropower generation. In SimDelta, there is a 'remainder category' to address all possible secondary objectives. From this paper it may appear that a primary function is missing, but this is not the case. Hydropower, for example, looks at first like a primary water function in California, but from the perspective of the water system it is additional to fresh water distribution and flood prevention and can be put in the remainder category (in an interactive model on energy distribution, hydropower would be a primary element). On a fundamental level, all water systems are the same around the world, but

technically they differ in scale, geometry, density and resolution, functional emphasis and data quality.

Table 1. Main attributes to the five studied systems.

System	Service area (km2)	Popu-lation served (millions)	Average annual precipi-tation (m)	Discharge capacity largest river (m3/s)	Storage capacity largest reservoir (km3)	Lowest point (m)	Max. land subsidence (cm/ y)
Rhine-Meuse, Netherlands	40.000	15	0,8	16.000 (Rhine)	3,0 (IJssel Lake)	-6,7	3,0
Central Valley, United States	100.000	30	0,5	17.000 (Sacra-mento)	5,5 (Shasta Lake)	-8	2,3
Huangpu (Shanghai), China	35.000	20	1,1	10.000 (Huang-pu)	6,3 (Taihu Lake)	1	2,4
Citarum Basin, Indonesia	15.000	25	1,8	-	3,0 (Jatiluhur Reservoir)	-	-
Chao Phraya, Thailand	20.000	10	1,5	3.000 (Chao Phraya)	0,78 (Pasak Reservoir)	-	-

4.1. Technical Implications

The SimDelta interface consists of layers representing the condition of the four main water system functions. Users select one or more future scenarios pertaining to projected sea level rise, water infrastructure demands, design standards, etcetera. This triggers the model to present to what extent preferred water system functions are met, with graphic coding. Lines, planes and nodes show existing and conceptual system components. It is often difficult to find information, and available information has different quality levels. Studying water systems around the world, we found that acknowledging levels of data quality is intrinsic to understanding a system. Poor data is not necessarily a reason not to make investments, nor would it necessarily lead to bad investments (as shown for example by the historical development of the Dutch system). We invented a couple of ways to represent this phenomenon graphically. For example, a thin line means there is information about the presence of a levee, an irrigation channel or a shipping route, but not about the 3D-geometry (line thickness) nor about whether it meets any preferences (line colour). When this information is available, a clear colour means the data is of high quality (an official government study or high academic source), a grey dotted pattern shows the result of a student report, grey strokes represent an expert guess. With such graphic coding, we can start representing any system by browsing existing maps and satellite images, and slowly add research data. SimDelta users will be guided in directions with the best data, but can also indicate (in the forums) where they would like better data to be added.

When the same graphic language describes multiple systems, it should cover the smallest and the largest elements throughout all systems, and will thus differ from the original Dutch model. Furthermore, system boundary rules have to be standardised. For example, the approach in all systems is that a 'solution' solves a 'problem' relative to a 'reference point'

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caused by a 'scenario'. In a standardised model, we want to treat a major change in operations of a control object on the same level as adding new infrastructure (both 'solutions'), even when in some countries new building projects are perceived as much more significant than a change in operations. In the interface however, a user can build a storm surge barrier to prevent flooding, with similar clicks as he can 'build' more frequent gate openings for fish migration. In California, local water conservation is a major strategy. SimDelta focuses on the national infrastructure. Conservation is represented as a change in operations at a fresh water inlet, and not by physical projects, such as water conserving toilets. Similar system boundaries are set for the other functions: if a user supports shallower ships in Shanghai, he can reduce the maximum shipping channel depths. If he wants floating housing to mitigate flood consequences in Bangkok, he can lower the levee design standards and express his support for floating housing in the forum. In a universal model, the border between maintenance and new projects should also be standardised, but could in policy-making reality be seen differently throughout the world.

4.2. Future Research and Design Strategy

When the data availability and system boundary recommendations are implemented, it should be possible to design a globally-applicable and standardised interactive model for learning, organisation and engagement for national water infrastructure development. The next questions are who would use it, which water systems to focus on, and how to proceed.

In the methodology section we distinguished two ways for SimDelta to be used: the internal way, where a national government would adopt it, and the external way, where it would be developed by an independent entity such as a university. A likely strategy would be to start with external adoption and see whether a government would catch on when a critical mass of interest and information is reached. In the Netherlands and California, it is possible to use freely available government data (officially-approved and therefore the highest quality level, but always slightly old), add data and designs by for example universities or conceptual engineers (novel ideas, but a quality level more likely to be disputed), and slowly create advantages over the existing policy development support models. In Shanghai, however, even though the SimDelta 'internal use' model seems an opportunity to assist in solving the internal communication problems, it would likely meet resistance from Chinese officials. The government is reluctant to release data and seems less interested in crowdsourcing, open communication and democratization, so a 'SimShanghai' will probably not easily gain enthusiasm by the Shanghai authorities.

For an overview of scientific maturity, political feasibility and problem urgency of the five studied systems, see table 2. Following from our analysis, California is the preferred system to expand towards first. The Netherlands have a primarily flood- and shipping-based water system, situated in a delta. California is a semi-desert, with a water system primarily for fresh water distribution. If a graphic language would work for both, it will most probably work elsewhere. Openness to political debate is an important prerequisite for success of the SimDelta concept. After California, the next step could be to work on a system in a developing country with a high score on the 'democratic quality of the political system', where, on a scale of 1-100, the Netherlands score 92, the United States 87, Indonesia 56, Thailand 45 and China 26 (Campbell a.o. 2011).

Table 2. Evaluation of criteria for the expansion of the SimDelta interactive model in four candidate water systems additional to the Netherlands. We conclude to first expand to California, and then to a system in a developing country with a high problem urgency and the highest democratic quality.

System	Scientific maturity	Political feasibility	Technologi-cal maturity (E-ranking)	Problem urgency	Democratic quality	Likely implemen-tation mechanism
Rhine-Meuse, Netherlands	High	High	High	Moderate	High	External
Central Valley, United States	High	High	High	Moderate	High	External
Citarum Basin, Indonesia	Low	Low	Low	High	Moderate	External
Chao Phraya, Thailand	Low	Low	Moderate	High	Low	External
Huangpu, China	Moderate	Moderate	Moderate	Moderate	Low	Internal

Studying the water systems in developing countries lead to the new ideas of representing data quality levels with graphic coding. This provides a perspective on the piecemeal development of SimDelta that suits the second 'external way' for further development. The lowest graphic level are thin grey lines and dots that only show the topography of the system (similar to the diagrams in figures 3 and 4). With this basis, the new SimDelta concept will allow local agencies with jurisdiction over a specific portion of the system to invest in expanding the model to the area that concerns them, without creating an imbalance (some parts are more deeply elaborated on than others, but the model is still 'complete'). SimDelta can be filled gradually and expanded endlessly once other organizations perceive the benefits of an interactive model that uses the internet to connect modelers and designers with stakeholders.

4.3. Discussion

This paper was written for the European Journal of Geography but studied water system outside Europe. California was selected for its size and arid circumstances, Shanghai and the developing countries for their different political systems and scientific maturity levels. If the SimDelta framework would be used within Europe, preferred countries would be Germany, Belgium and France, to cover the whole Rhine-Meuse system, and not just its delta. Other European systems where SimDelta could be of value (meaning sufficient technical complexity on a national scale level) could be the Rhine-Danube corridor, perhaps Spain, with a climate similar to California, the Danube delta, or other parts of central and eastern Europe. We think the water systems of France, England, Italy and Scandinavia have less intertwined functions (on the national level), but perhaps we are wrong.

The analysis in this paper mainly dealt with flooding, fresh water and shipping. It might seem that water quality and ecological health were missing. Parts of water quality however are either embedded in the fresh water functionality, or do not interact with the other functions too much. Ecology interacts a lot with all other functions. In the development of

SimDelta, ecology is kept in sight, but most current endeavour goes towards the functions that in policy-making reality seem to have priority: flooding, fresh water and navigation.

Of course, SimDelta is a concept under development and it is therefore not sure whether it will catch on and gain the large audience we hope it will. For a discussion on the pros and cons of the idea and the chances for success, we refer to earlier work (Rijcken, T, Stijnen, J, en Slootjes, N 2011).

Finally, the name 'SimDelta' will not cover large systems like California, the whole Rhine or for example Egypt. When the time comes, a better name will have to be found.

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