Chapter 13

Comparative Approaches in Managing Wetland Environments and Land Uses: Rainbow Lake in Michigan, Guangzhou City in China, and Chinese Sponge Concept Case Studies

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Additional information is available at the end of the chapter

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Abstract

Environmental scientists, natural resources agencies, planners, landscape architects, engineers, and concerned citizens are interested in the impacts that land uses within watersheds have upon lake water quality and water runoff volume. For the past 40 years, much has been discovered and many North American water bodies from small to large can be reliably modeled and studied, employing phosphorus as the identifier of water quality. We present an overview of the key features in this multi-disciplinary effort and illustrate how to apply the general method to Rainbow Lake, in Gratiot County, Michigan, the USA. In addition, we illustrate how these fundamental ideas are being employed at the Haizhu wetland park, a large wetland setting in Guangzhou, the People's Republic of China, and present Chinese planning and design efforts termed "sponge city" to address new ideas to reduce runoff and improve water quality.

Keywords: environmental design, landscape architecture, site hydrology, watershed studies, landscape research

1. Introduction

In the USA, watershed and site hydrology water quality modeling and runoff volume predictions made rapid advances in the 1960s and 1970s. By the 1980s, investigators could reliably predict both the volume and the quality of water runoff. However, this ability and technology has only slowly been adapted in other parts of the world. Nevertheless, such concerns have been of interest by humans for many millennia. Luo et al. describes concerns in managing the Yellow River in China, 5000 years ago, and more recent concerns in Japan [1]. The natural landscape was reconfigured with massive hill removals and topographic changes thought to reduce the impacts of flooding.

In Western Anatolia (Western Turkey), American environmental interest was invigorated by George Perkins Marsh (1805–1882). He wrote *Man and Nature: of Physical Geography as Modified by Human Action* [2]. He was stationed as an Ambassador to the Ottoman Empire. During his travels, he learned about the Meander River, a winding river in Western Turkey. Especially during the Greek and Roman eras, he learned about the deforestation of the surrounding hills and the ensuing erosion that expanded the Meander River's delta into the Mediterranean Sea (**Figure 1**) [3]. Along with his other observations in Europe, he developed his ideas about landscape stewardship. There was great concern that such adverse environmental impacts should not occur in North America. Individuals such as Gifford Pinchot developed a land management ethic and worked with Frederick Law Olmsted at Biltmore where Olmsted established the bass ponds to control soil erosion from the large construction site [3]. Today erosions control and detention ponds are commonplace.

French, English, German, Russian, and American engineers were engaged in developing methods and mathematical models to predict water flow in pipes, culverts, sewers, swales, creeks, and rivers culminating in such books as *Design Data Book for Civil Engineers* [4]. In

Figure 1. An image of the Meander River valley between the ancient Greek cities of Priene and Melitus. Both cities were Mediterranean ports during Greek Ionian times. Today the Mediterranean Sea in the figure is many miles to the right of the image (copyright 2006 Jon Bryan Burley, all rights reserved, used by Permission).

many respects by the end of World War II, the fundamentals of site hydrology and erosion control had been established for American landscapes. The effort was made possible because of the national rainfall data collected by the US Department of Agriculture across the country and various investigators had studied runoff percentages for numerous soils and cover types. Civil engineers now could predict estimated water flow for various types of storm events.

The understanding concerning the impacts to changes in watersheds was investigated. In the American West, the Mono Lake Basin illustrated the impacts of water removal to southern California [5]. Watershed hydrology was considered at the ecosystem level. The Colorado River was a case study in watershed ecosystems, as most of the water is harvested and very little flows out of the delta through Mexico [6]. Other investigators discovered large cataclysmic events, such as the massive great floods across western Washington during the end of the last ice age [7]. Ice dams blocked rivers, releasing water at an estimated 9.46 cubic miles per hour traveling at 58 miles per hour. The flow of water was over 10 times the flow of water in the world and 60 times great than the flow of water in the Amazon. It is estimated that this event may have occurred at least 40 times. Knowledge built concerning low- and high-water events and activities.

Refinements and modifications in planning and design continued. Albe Munson, a Professor at Michigan State University, both a landscape architect and a civil engineer, wrote the first noted American landscape construction book integrating site hydrology and landscape development [8]. Yet the book contained only simple estimates for yearly runoff. However, others later presented more usable equations to estimate pond sizing, pipe sizing, and swale sizing [9, 10]. Eventually extensive and quite comprehensive publications featured a wide array of knowledge in planning and design concerning water for landscape architects and engineers [11–13].

Soil scientists and hydrologists continued refinements in hydrological calculations. They considered models that were more reflective of field conditions such as saturated soil and frozen soil. Today, site hydrology calculations are more complicated than in the past with several methods and choices [14].

The integration of land use, human activities, and the forces of nature are being examined in a more integrated manner. The recent publication of a book titled *Third Coast Atlas: Prelude to a Plan*, illustrates this integration [15] The third coast is the coastline of the Great Lakes system and St. Lawrence seaway. It is longer than either the Atlantic Coast or Pacific Coast. Humans are attempting to integrate both large-scale issues and small-site detailed features in a more comprehensive manner.

One topic that has taken some time to develop was the prediction of water quality. By the late 1970s and early 1980s progress was made as investigators understood that the nutrients of phosphorus and nitrogen at excessive levels in the water reduced water quality. Wang (et al.) recently published an overview of this prediction approach where investigators are now attempting to develop treatments to intercede upon water quality [16]. The essential feature concerning improving water quality is to have the water come in contact with the substrate that removes the nutrient (phosphorus or nitrogen) from the liquid. Large volumes of standing water not in contact with the substrate will only be marginally treated. In addition, measures to limit the nutrients from entering free-flowing water in the hydrological system are also very effective and reduce the need for water treatment basins.

Two important seminal developments occurred in search to predict non-toxic water quality. Much of this work was conducted in Minnesota and Wisconsin, the USA, where there are thousands of lakes to study and manage. The first development was the recognition that nitrogen ions and suspended phosphorus in the water were key limiting nutrients influencing water quality. Investigators could approximate the amount of these nutrients in the water by simply placing a Secchi disk in the water and determining the depth at which the disk disappeared. The quicker it disappeared under the water, the more nutrient rich was the water and the poorer was the water quality [17]. The second development was the ability to assign phosphorus contributions to free-moving water by the land area and land cover type. By combining these contributions from the land to the hydrological calculations of water flowing through a watershed, the concentration of phosphorus in the water on a yearly basis could be estimated [18]. It was a long series of equations to estimate water quality, with each variable having a fair amount of variance. The reliability of such a series of equations to predict water quality was at first suspect because it was believed that the accuracy of each section of the equations could lead to a highly inaccurate prediction. However, as we introduce in the methodology and results sections, the set of equations produced a relatively accurate estimation of water quality for a water body.

Our intent in this investigation is to illustrate how this environmental prediction methodology is applied to management watershed in the states of Michigan (Rainbow Lake and Minnesota (Sauk River Watershed), the USA. In addition, the chapter discusses how the quest to manage water in rural and urban environments continues in parts of the world, employing two examples from the People's Republic of China (PRC). The chapter also includes statements and comments from an interview (May 2017) of Dr. Jon Bryan Burley, FASLA, a landscape architect who has been engaged in teaching and writing academic papers concerning landscape for over 40 years. He has witnessed the evolving changes in this technology over this time period.

"When I was a young professor at age 27 in 1982, modeling watershed quality in Minnesota was just becoming possible," recalls Dr. Burley. "I used to have students in my landscape planning classes model land-use development within watersheds for selected lakes and prepare land-use plans to prevent a change in the perceived water quality of that lake. The Minnesota Department of Natural Resources provided publically available information concerning land cover and water quality in the state. Combined with information about rainfall and evapotranspiration, it was possible to estimate potential water quality changes due to changes in the landscape," describes Dr. Burley. "In 1990, when I went to the University of Michigan to work on my PhD this type of watershed modeling was considered as a possible topic for my dissertation. But in discussions with faculty at the School of Natural Resources, such a topic seemed far too ecologically complex to produce a meaningful dissertation. They seemed to be weary of such a long series of equations to predict water quality. I certainly understand their caution. Their concern was that if a series of 10 equations each could only explain 80% of the variance, then by the 10th equation (80% of 80% repeated ten times), the results maybe explaining less than 10% of the variance," expressed Dr. Burley. "So I pursued another topic, addressing surface mine reclamation and in the meantime, I attempted to communicate the findings of various studies undertaken by my students and myself over the past decade. The one that was published is a little known article published by the American Society of Landscape Architects, describing a study concerning how much development could occur within the Lake Itasca watershed (the headwaters of the Mississippi River) to protect the lake's water quality," added Dr. Burley [19]. The article presents a graph of water quality based upon various land cover environments: 100% forested watershed, a catastrophic fire event, unchecked development and, limited development. The development was limited to keep the lake a meso-trophic lake. "Students could develop land-use plans containing various levels of forested land, agricultural land, low density rural housing, and urban land. I thought this was an excellent landscape planning exercise for students to relate development, land management, and natural resource protection," reflected Dr. Burley.

"During this time, I submitted a research article to a journal about the Sauk River watershed in Minnesota, where I had conducted a 1983 study statistically validating the prediction modeling process (originally using hand drawn overlays and a planimeter, but updated in the mid-1980s and replicated with a micro-computer geographical information systems (GIS) application), illustrating the concordance of actual water quality measures with predicted estimates by dividing the watershed into sub-watersheds and comparing measured and predicted scores. And while the results were publishable (no reviewer disputed the findings) and no investigator had ever done this before, by the time I had submitted the manuscript, the GIS technology had radically changed (from mostly hand drawn overlay maps measured with a planimeter, to crude computer maps with over-printing of alpha- numeric characters, to digital colored GIS maps—and the GIS world had changed). The manuscript was rejected for its dated technology, with the reviewers stating that there were better and newer landscape planning tools. They were correct, but I had not interest in updating the research with newer technology that did not change the fundamental results," recalled Dr. Burley. "Reviewers can find numerous reasons to reject an abundance of submitted articles. Journals have reputations to maintain and that may mean not presenting dated technology. Still the fundamentals of that study remain true," confided Dr. Burley. This study of the Sauk River Watershed illustrates the methodology for this investigation. "I am pleased that the Sauk River watershed study conducted in 1983 still has some value and portions of the study can be employed in some useful fashion," added Dr. Burley. "I also want people to recognize the great value and contributions that people like Carlson, Garn, and Parrott made; otherwise it would have been impossible to model the watershed and make any prediction," suggested Dr. Burley [17, 18].

2. Methodology

2.1. Sauk River Watershed, Minnesota

An overview of fundamental methodology is illustrated by a study on the Sauk River, Minnesota, conducted in the 1980s. The Sauk River is in central Minnesota on the border between the Western prairie lands and the Eastern woodlands. Before emptying into the Mississippi River, the water passes through Cedar Island Lake. This lake has experienced algae blooms and diminished water quality. Recreational housing along the lake was blamed for poor water quality. Employing the GIS technology of the time, maps of the watershed's land cover types and soils were generated (**Figures 2** and **3**) [20]. Predicted phosphorus concentrations for each sub-watershed in the study area were statistically compared to measure levels, employing Kendall's Coefficient of Concordance, a nonparametric statistical method to search for significant agreement (note that most statistical tests examine significant difference) [21]. It was discovered that the scores significantly agreed. Therefore, the modeling approach had some degree of validation. This can be surprising, as one might expect the error and increasing amount of variance to be passed from one equation to the next. Yet, at the end of the computations, the process approximates reality. Being able to estimate real conditions, the next step in the process was to examine pre-settlement conditions of the lake with current conditions. The results of the study indicated that the predicted water quality from pre-settlement times should be no different than existing land uses with agriculture and housing in the watershed. Yet, the measured phosphorus levels were higher in the lake than the model predicted. Upstream along the main course of the river, a point source of phosphorus was discovered. The water was not toxic and the effluent met discharge requirements, but the level of suspended phosphorus in the discharged water was enough to influence the water quality downstream. Removing the point-source discharge of phosphorus improved the water quality of the lake and matched predictions. "I believe the interesting part of this study was that farmers (many dairy farms) and recreational home owners were blamed for the problems. But they were not at fault and were unfairly blamed," states Dr. Burley. "A very simple fix at the food processing plant upstream would solve much of the problem. I thought this study was a very practical example concerning how ecological modeling and landscape planning could work together. But sometimes investigators believe their discoveries are much more important than the rest of the academic and professional communities believe. I am afraid I too was susceptible to that disease of over estimating the importance of my study," recalled Dr. Burley.

Back in 1983, BASIC programming was a mathematical tool to make calculations, especially repeated calculations. "In 1974, I had taken a Fortran IV programming class and found Basic programming quite easy [22]. In an afternoon, I could put together the foundation of a computer program to calculate phosphorus concentration for a lake. In a 90 minute lecture in 1985, I gave a detailed explanation of the program to a graduate level landscape architecture class. I thought I was going to be brilliant; instead I was preposterously boring. Unless one wanted to use the model, what I had to say was of little interest," reflected Dr. Burley. "My lecture did not match the interests of the audience."

Today, all this calculation work can be accomplished on a spreadsheet. "Spreadsheets were just being invented and applied back then in the early 1980s," recalled Dr. Burley. "In addition, land cover data, graphic presentation, and area tabulation are much more convenient in this era. Back then it took hundreds of hours just to code and typing to make one map," observed Dr. Burley. The handbooks and machines that could engage the old BASIC computer programming have been discarded for 25 years. "Towards the end of these studies with my students, I was using EPPL 7, a GIS program that could be facilitated with map digitization and color map, making the process must faster to obtain results," notes Dr. Burley [23].

"At Michigan State University, in the early 1990s I imagined that I might pursue such water quality studies for nearby lakes or even for lakes such as Lake Erie. ARC-GIS and other

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Figure 2. A map of the Sauk River, Minnesota pre-settlement vegetation. Back in the mid-1980s, black and white alpha-numeric GIS maps were often the standard. The technology had been transferred down from mainframe computers to the recently developed micro-computers (copyright 1983 Jon Bryan Burley, all rights reserved, used by Permission).

more-friendly GIS software was available to be incorporated into the study. But when I inquired about conducting such studies, the university's hydrology research institute was interested in other kinds of investigations and I met the same kind of skepticism at my school as I had encountered at the University of Michigan. So I did not pursue the topic. Yet I am pleased that somebody persevered, and have applied such activities to pursue what I had also envisioned," exclaimed Dr. Burley.

Figure 3. A map of the Sauk River, Minnesota study area comprised of land-uses with soil type. Based upon this information the amount of water runoff and phosphorus contribution can be estimated (copyright 1983 Jon Bryan Burley, all rights reserved, used by Permission).

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"It takes a special kind of landscape student to be interested in landscape planning studies. At Michigan State University, I found most landscape students were interested in site design," observed Dr. Burley. "Most students expect to make their professional careers from site development. In the landscape planning classes, students who are interested in landscape planning are interested in the shapes and patterns of land cover types (traditional landscape ecology applications) for greenways, plant preservation, wildlife habitat, and to find land that is optimal for development. No one seemed interested in lake and hydrological modeling," proposed Dr. Burley. "But in the past decade something changed. Nations such as P.R. of China, have a renewed interest in managing water, greenways, and water quality. This is a nation with a long history concerning the management of water. International landscape graduate students envision opportunities to model the environment and prepare regional land use plans. They come to study with me at Michigan State University and to learn about how to model site hydrology and water quality. However, I will retire soon. This article is an opportunity to 'pass-along' the present state of knowledge concerning predicting non-toxic water quality to an interested international readership from around the world," replied Dr. Burley.

2.2. Rainbow Lake, Michigan

Rainbow Lake is a small private artificial lake (a lake created by placing a dam across a creek) for housing development in Gratiot County, Michigan (**Figure 4**). The valley that was formed by Pine Creek was produced when the nearby Maple River was the outlet for Glacial Lake Saginaw, sending massive amounts of glacial melt-water down the Maple River, into the Grand River, into post-glacial Lake Michigan (Lake Chicago), eventually reaching the Mississippi River. The valley that was cut by glacial melt-waters also meant that the nearby Pine Creek would also cut a small valley into the landscape to meet the Maple River. This valley was suitable for the creation of a dam and a lake. The surrounding landscape is mostly agricultural as Gratiot County has the largest percentage of agricultural land for any of Michigan's county

Figure 4. An image of Rainbow Lake in Gratiot Country, Michigan looking from east to west. The lake is a long winding water body through a post-glacial valley (copyright 2017 Jon Bryan Burley, all rights reserved, used by Permission).

growing corn, soybeans, winter wheat, dairy herds, beef cattle, horse farms, apple orchards, and hardwood lumber. Surrounding the lake is a residential development, enclosed by the rural environmental agricultural matrix. The lake is used for recreational boating, summer fishing, and winter ice fishing.

Ultra-oligotrophic	<5
Oligo-mesotrophic	5–10
Meso-eutrophic	10–30
Eu-polytrophic	30–100
Polytrophic	>100

Table 1. Trophic state lake classification and the associated Carlson Index Score.

C1 = terrestrial and other water body phosphorus supply in kg/ yr.
C2 = Carlson Index score
E1 = evaporation in meters
F = flushing rate
L2 = maximum lake depth in meters
L4 = nutrient supply
M2 = mean lake depth in meters
P1 = prescription in meters
P2 = present phosphorus level in mg/l
P3 = predicted phosphorus level in mg/l
O1 = areal water load in meters/year
R = retention coefficient
R1 = volume of watershed runoff to lake in cubic meters
S1 = surface area of lake in square meters
T1 = point source phosphorus pollution input
V1 = lake volume in cubic meters
W6, W7, W8 = woodland in square meters
P6, P7, P8 = grassland area in square meters
U6, U7, U8 = urban savanna in square meters
I6, I7, I8 = industrial in square meters
B6, B7, B8 = agriculture in square meters
6 = clayey soils, 7 = loamy soils, 8 = sandy soils.

Table 2. The list of variables employed to calculate non-toxic water quality.

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To predict the water quality of the lake, one must know the soil types for the watershed, the land cover types, the amount of yearly rainfall, the evapotranspiration rate, the volume of water in the lake, and the existing phosphorus concentration in the lake. The yearly expected phosphorus concentration can be calculated by the series of equations presented in the results section of this chapter. **Table 1** illustrates the relationship of the final calculated Carlson Index Score with lake quality. The Carlson Index Score can be calculated from either phosphorus concentrations, nitrogen concentrations, or Secchi disk readings. Phosphorus estimations can be used for landscape modeling applications. **Table 2** presents the series of variables employed in calculating the Carlson Index Number.

The trophic state of the lake is associated with the life forms and levels of nutrients found in the water body. Ultra-oligotrophic lakes are very nutrient poor and contain relatively little aquatic life in them. Oligo-mesotrophic lakes are suitable for cold-water fish species such as trout and salmon (*Salmonidae G. Cuvier*). Meso-eutrophic lake contains fish species like walleye (*Sander vitreus*; Michill, 1818). Eu-polytrophic lakes often are suitable for large-mouth bass (*Micropterus salmoides* Lacepede) and bluegill (*Lepomis macrochirus* Rafinesque). Polytrophic lakes often contain no fish.

3. Results

Figure 5 illustrates the land cover types within the study area; while **Figure 6** presents the soil types for the study area. A series of 11 equations (Eq. (1)–(11)) resulted in the final calculated Carlson Index Score, which was 92.52, placing the lake at the high end of a eu-polytrophic lake. The predicted results match the classification results for the lake.

Lake volume in meter cube

$$V1 = ((1.047) * S1/3.14) * (L2) \tag{1}$$

$$V1 = 1760827.261 \text{ m}^3$$

where S1 = 1,320,200 m^2 (derived from CAD and public maps); L2 = 4 m.

Mean lake depth in meters

$$M2 = V1/S1 \tag{2}$$

$$M2 = 1.33 \text{ m (calculate).}$$

where V1 = 1760827.261 m^3; S1 = 1320200.00 m^2.

Runoff calculations

$$R1 = ((U6 * 0.8) + (U7 * 0.6) + (U8 * 0.7) + (B6 * 0.5) + (B7 * 0.1) + (B8 * 0.3) + (P6 * 0.4) + (P7 * 0.2) + (P8 * 0.225) + (W6 * 0.2) + (W7 * 0.3) + (W8 * 0.125) + (I6 * 0.9) + (I7 * 0.85) + (I8 * 0.8) + O1)) * P1 \tag{3}$$

$$R1 = 38229613.000.$$

where Yearly P1 = 33.22 inches = 0.844 m and **Table 3**.

Phosphorus contribution in calculations

$$C1 = (((U6 + U7 + U8) * 4) + ((B6 + B7 + B8) * 0.35) + ((P6 + P7 + P8) * 0.25) + ((W6 + W7 + W8) * 0.1) + ((I6 + I7 + I8) * 4) + (O1 ^{*} 0.46))/10^4 \quad (4)$$

$$C1 = 10753.8.$$

Further calculations

$$O2 = R1 + (S\,1^{*}(P1 - E1)) \quad (5)$$

$$O2 = 6144742.000 + (1{,}320{,}200^{*}(0.844–0.635)).$$

$$O2 = 6{,}420{,}664.$$

where R1 = 6144742.000; S1 = 1,320,200 m^2 (CAD and map); P1 = 0.844 m/year; E1 = 25 inches = 0.635 m/year.

$$Q1 = O2/S1 \quad (6)$$

$$Q1 = 6, 420, 664/1320200.$$

$$Q1 = 4.86.$$

$$R = 13/(13 + Q1) \quad (7)$$

$$R = 13/(13 + 4.86).$$

$$R = 0.73.$$

$$F = O2/V1 \quad (8)$$

$$F = 6, 420, 664/1760827.261.$$

$$F = 3.65.$$

Total present nutrient supply

$$L4 = (((S1 * 0.46 * (10^{-4})) + C1) * 10^{6}) + (P2 * V1 * (10^{-3}))/S1 \quad (9)$$

$$L4 = 8244.93 \text{ mg/m}^2\text{.year.}$$

where S1 = 1,320,200 m^2 (CAD and map); C1 = 10753.8; P2 = 40 mg/m^3; V1 = 1760827.261 m^3.

Predicted phosphorus level

$$P3 = L4 * (1 - R)/(M2 * F) \quad (10)$$

$$P3 = L4 * 0.6/1.33 * 14.54.$$

$$P3 = 458.57 \text{ mg/m}^3.$$

where L4 = 8244.93; R = 0.73; M2 = 1.33 m; F = 3.65.

$$\text{Carlson index} = 14.42 * \text{Ln}(P3) + 4.15 = 92.52 \quad (11)$$

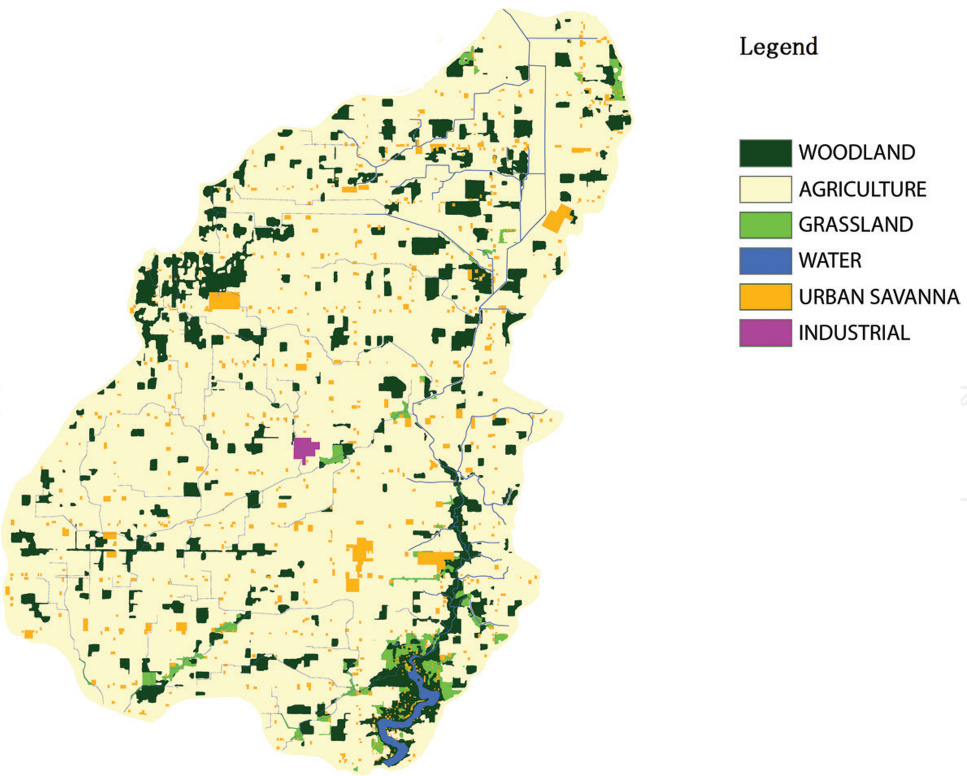

Figure 5. This map presents the land cover types in the study area, with Rainbow Lake in the lower right. Beneath the lake is the Maple River and the Maple River Game Management area. This convergence was the general location of outlet of Glacial Lake Saginaw with flowage from right to left (copyright 2017 Zhen Wu, all rights reserved, used by Permission).

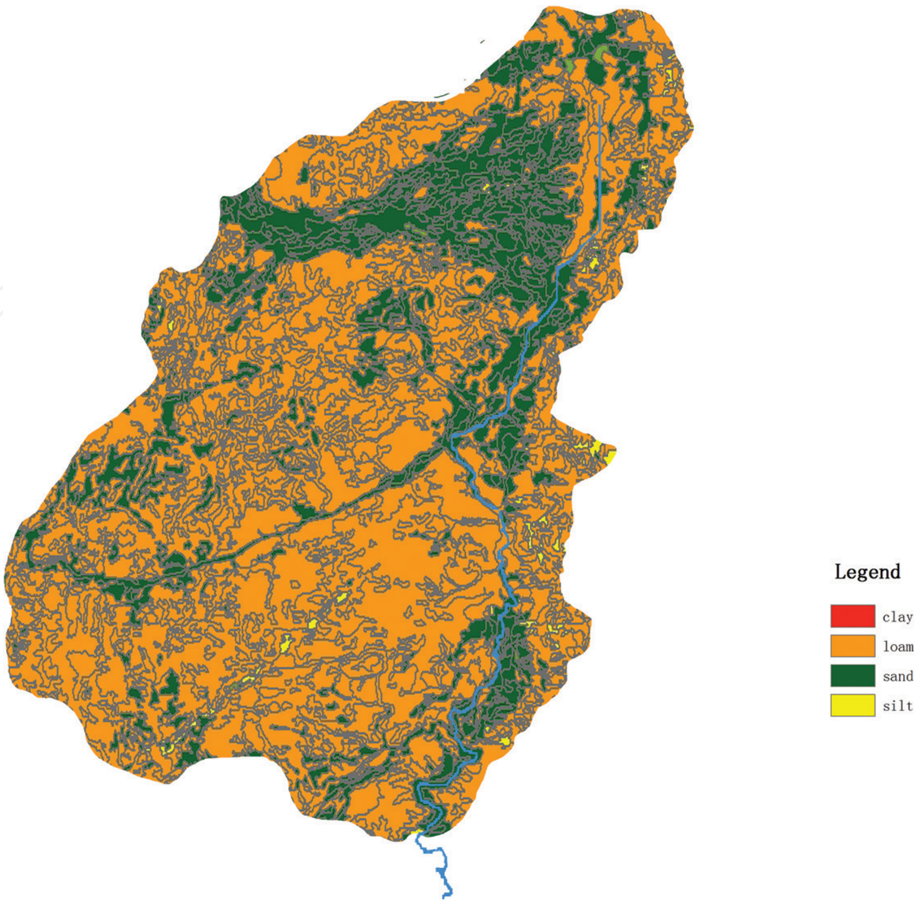

Figure 6. A map of the soil types in the study area (copyright 2017 Zhen Wu, all rights reserved, used by Permission).

Classification	Soil	Area (km²)	Percentage in each land use	Percentage in total research area
Woodland		29.48	1.00	0.12
	Sand (W8)	11.20	0.38	0.046
	Loam (W7)	18.28	0.62	0.074
	Clay (W6)	0.00	0.00	0.000
Grassland		8.52	1.00	0.03
	Sand (P8)	1.11	0.13	0.004
	Loam (P7)	7.50	0.88	0.026
	Clay (P6)	0.00	0.00	0.000
Urban savanna		4	1.00	0.02
	Sand (U8)	1.64	0.41	0.008
	Loam (U7)	2.36	0.59	0.012
	Clay (U6)	0	0.00	0.000

Classification	Soil	Area (km^2)	Percentage in each land use	Percentage in total research area
Industrial		3.52	1.00	0.01
	Sand (I8)	1.48	0.42	0.004
	Loam (I7)	2.04	0.58	0.006
	Clay (I6)	0.00	0.00	0.000
Agriculture		203.12	1.00	0.81
	Sand (B8)	40.62	0.20	0.162
	Loam (B7)	162.50	0.80	0.648
	Clay (B6)	0.00	0.00	0
Water	(O1)	2.80	1.00	0.01
	Sand	1.37	0.49	0.005
	Loam	1.43	0.51	0.005
	Clay	0.00	0.00	0.000

Table 3. The area of land in square meters for various land-cover types by soil types.

4. Discussion and conclusion

4.1. Rainbow Lake, Michigan

"The student who conducted the study of Rainbow Lake was surprised how available information was to make the prediction and conduct the modeling," stated Dr. Burley. "He stated that such information is not as freely available in other parts of the world," commented Dr. Burley. "It is true that information can equate to power. But in the United States and Canada, such information is supported by the public and the public has the right to access such information. Farmers, citizens, and researchers are free to access the information to make calculations to refute or support the findings of others. It is expected if not demanded," said Dr. Burley. "In many respects it is comforting that there are checks and balances in the use and application of information. If there are disputes, they can be openly addressed in public forums," mentioned Dr. Burley. "Especially at the township, county and state level, public employees responsible for natural resource management work together with citizens and comparatively, there is a fair amount of respect and trust amongst everyone.," reports Dr. Burley.

"The largest disputes that I have witnessed have been amongst hydrological experts who may debate methods of sampling or the accuracy of equations to predict hydrological variables. These academics often have varying opinions. But any equation is simply an approximation and estimation of physical phenomena. In the engineering field, if the approximation generally works, then it is accepted with no theoretical explanation or search for a better equation. This was true of the Manning formula of confined water flow in swales and pipes. This equation is over 140 years old and is unquestioned by many, but it is simply a mathematical approximation of water flow," observes Dr. Burley. "I am sure that today investigators could develop improved equations and even supply a set of theories to explain the improved equation. For example, the equation assumes laminar flow, however, it has been observed the flow may be at times helical/spiral with undercurrents. Nevertheless, researchers are often not interested in discovering a new finding to something that by society's measure is considered 'not broken,'" adds Dr. Burley.

"The greatest difficulty by the student was actually determining the watershed boundary by topographical maps," noted Dr. Burley. "If one has had surveying in college or physical geography, reading topographical maps and determining ridge lines can be easily accomplished. I know I could do this by the time I was 12 or thirteen years of age and I am not necessarily the smartest person, even in a very small group," assessed Dr. Burley. "But I understand this is not always easy for some to accomplish and learning how to read topographic maps is an important skill in landscape planning and hydrological studies" added Dr. Burley. "The PhD student was very capable in creating map overlays with the appropriate data to estimate cover types on various soil types. This was very reassuring. I suspect that landscape students around the world could conduct such a study providing the information is available," confirmed Dr. Burley. "It took him about 2 months working full time (40 hours a week) to complete the study. There is much to read, intellectually digest, and apply," Dr. Burley reported.

"Rainbow Lake is near the upper boundary for being a eu-polytrophic lake," advises Dr. Burley. "That means additional inputs of phosphorus into the lake could temperately change the perceived water quality. During large rare storm events, of which I have only witnessed a couple in a 25 year period, massive amounts of suspended soil particles enter the lake. You can see the lake change to temporarily a polytrophic lake. A Secchi disk disappears immediately when placed in the water. The lake may even rise six of more feet above the normal lake level. Before I lived in Michigan, the dam was even 'washed-out' and had to be re-built. For many years the water quality in the lake is quite stable. But in these large storm events, enormous soil erosion takes place at key places along Pine Creek. After the storm, these key spots are radically altered with new gullies and small valleys where many cubic meters of soil had completely disappeared and been removed. Natural resource managers and soil erosion specialists are focusing upon preparing for these large rainfall events by working with land owners to create detention areas to control the outfall during these substantial but rare storms," adds Dr. Burley.

"In addition, over the last two decades, one has witnessed the development of rain gardens and more thoughtful management of shorelines," describes Dr. Burley. "Land owners actually think globally and act locally. There is great pride in many land owners for managing their land independently and thoughtfully, by eliminating the need for mowing their landscape to the water's edge, developing naturalized areas, being respectful for the needs of amphibians, turtles, shorebirds, and wildflowers. Rain gardens convey water through naturalized swales and ravines to the lake. There is a very different attitude by many towards the treatment of the landscape when compared to behavior 40 years ago," observed Dr. Burley.

4.2. Guangzhou wetland parks

In the P.R. of China, it is recognized that wetland open-space/greenway systems are essential to properly manage water. For a time, spaces to hold and retain water were occasionally

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developed for housing, reducing the ability of the land to hold water and avoid flooding conditions. Initial open-space land-use plans were revised to convert green space to development. Eventually the green space disappeared. However, it was recognized that such conversion could not always continue. In Guangzhou, the P.R. of China, wetland parks were created to store water and improve water quality (**Figures 7–9**). During low water periods the green space can be used as a stroll park. The park is part of a connected system to accommodate high water, being linked to Shiliugang He (Pomegranate Hillock River) and Da Wei Yong (Big Surrounded Water-surge), Da Tang Yong (Big Pond Water-surge), Shang Chong Yong (Out to Rush Water-surge), Yang Wan Yong (Poplar Cove Water-surge), and Xi Lu Yong (West Busy Water-surge). The water in the lake can also supply fresh-water requirements for the city. The Haizhu (sea bead) district contains an exterior ring drainage system and an embankment system circling an internal lake for water storage that is controlled by flood gates. There is an island in the center of the lake, designated as a bird habitat. By the lake, a structure with a night-light beam (like a lighthouse) provides identity and gives meaning to the term "Haizhu." Such symbolism and affiliated meaning can be important in Chinese culture. Numerous floating-leaved aquatic plants and emergent plants are employed in the design to aid in improving water quality.

The design is very park like There are many trails, bridges, leisure boating, buildings, open spaces for group gatherings, cultural exhibits, and concessions. The number of people who can visit the park is limited each day to 3000 people. There are parking facilities, police, and

Figure 7. An image of a wetland park in the Haizhu District of Guangzhou. The lake is 53 hectares in size and the embankment land in the wetland is 41.8 hectares, with additional 55 parkland hectares. Notice the large towers in the distance and the proximity of urban development to the park. (copyright 2015 Jon Bryan Burley, all rights reserved, used by Permission).

Figure 8. A view of the same park in Guangzhou from one of the large towers. Guangzhou experiences torrential rains and typhoons. The proportion of land dedicated with hydrological management network, while substantial, may still be minimal for catastrophic storms. Other parks and improvements are planned and may be implemented (copyright 2015 Jon Bryan Burley, all rights reserved, used by Permission).

Figure 9. A view of the large gate in a Guangzhou Haizhu wetland park. "Other than the many lighthouses in numerous Michigan state parks, I am not familiar with any such substantial features in Michigan natural areas. Nevertheless, the Chinese gates provide a strong sense of entry and identity." stated Dr. Burley. People learn about the value of wetlands, exercise in the park, and socialize (copyright 2015 Jon Bryan Burley, all rights reserved, used by Permission).

medical assistance. The main entrance is connected to the city highway system. Portions of the facility educate visitors about recycling water and reuse.

"An interesting feature of these parks is how much intervention (paths, ornamental plantings, seating, and small structures) occur in the parks," observed Dr. Burley. "The Chinese enjoy water-side stroll parks [3]. Guangzhou has a population greater than the entirety of the state of Michigan. So it is not surprising that these parks would be more developed than many Michigan naturalized settings," commented Dr. Burley. "In Michigan it would be considered a waste of money to expend funds for walkways and ornamental plantings in areas such as the Maple River Game Management area which is adjacent to Rainbow Lake in Michigan. But in China with such a large population, it makes good sense to allow the public access to enjoy these wetland areas," advised Dr. Burley. "I greatly appreciate the approaches of both cultures in the management of use of their wetlands. In Michigan, the goal is to management hydrological resources, provide recreation, facilitate wildlife, and provide green space. In China the role is also to manage hydrological resources, provide stroll gardens, and educate people about the importance of wetlands. I could imagine in just one wetland park, the expenditures for planting is greater than the yearly budget for the state of Michigan in planting vegetation," compared Dr. Burley.

4.3. Sponge city concept

While environments such as Michigan may have a remaining substantial space to accommodate hydrological functions, large urban expanses such as in the P.R. of China may not have the luxury of designating the required amount of space to accommodate hydrological needs. The Chinese have embarked on the "sponge city" concept, where hydrological water storage and water cleansing are accomplished as much as possible at the site level before ever getting to a greenway or water basin.

Recently the Chinese held a competition to explore ideas to accomplish the sponge-city concept. A team at the Michigan State University entered the competition (**Figures 10–12**). In many respects the design incorporates and blends water storage and water-cleansing functions with the aesthetic functions of a soft-scape pocket garden. The figures illustrate the process the team employed to create the design. "What I like about the documentation of this project, is that it demonstrates how a design evolves and is created," notes Dr. Burley. "Experienced professionals understand this process, but novices sometimes believe that a design is just drawn, rendered, and finished. The figures show how hand drawing is often important in initiating a design and as the design emerges, computing technology may be employed to envision the project. The project is drawn, redrawn, and redrawn. During each version, the design is critiqued and assessed," observes Dr. Burley.

"When I teach design to beginning students, it is difficult to get them to evolve the design," describes Dr. Burley. "For the beginning student, being able to create just one version of a design is a milestone. But in truth, this is just the beginning of the process," suggests Dr. Burley. "It takes time for students to be objective about their design and be open to improvements and refinements. In design, there is not 'the answer' there are only 'answers.' Design is not a math problem with a discrete answer. And even in mathematics there are systems and examples where a discrete answer is not possible to discern, such as with irrational numbers

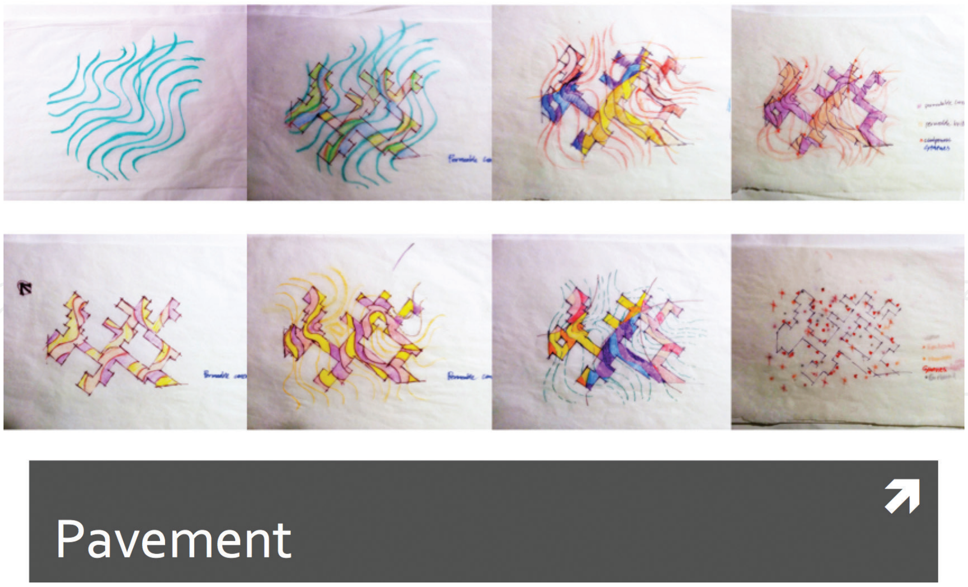

Figure 10. A series of drawings exploring ground plane patterns for the sponge city design. (copyright 2016 Na Li and Yiwen Xu).

Figure 11. A series of 3-D models exploring the three dimensional properties and possibilities in the sponge city design (copyright 2016 Na Li and Yiwen Xu).

or mathematical universes that fade in, fade out, and change in volume across time," advises Dr. Burley. "Creating the design can be a process whereby the dots to be connected may not be apparent and the sequence to connect the dots is not apparent either. Some people are not comfortable with such puzzles and others enjoy the challenge," states Dr. Burley. "The sponge city competition typifies such a challenge. It is creating a new set of relationships and standards previously unexplored and untested," reveals Dr. Burley.

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Figure 12. Two perspectives of the sponge city design under different climatological events (copyright 2016 Na Li and Yiwen Xu).

“The sponge city competition illustrates what is occurring and evolving in the use and application of hydrological issues in the management and development of the environment. Needs change, opportunities emerge, and ideas evolve,” states Dr. Burley. For example, members of this same sponge city team, name, and date conducted and reported a case study in Grand Rapids, Michigan, where equations and methods were employed to measure and predict water use by vegetation for a developed site [24]. “This is new and evolving knowledge with direct applications to landscape planning and design,” concludes Dr. Burley.

“It has been that way for a long time. I remember as a young professor in the 1980s studying shoreline treatments for landscape stabilization for a small lake in eastern North Dakota or developing shoreline treatments along the shores of Lake Superior, or designing for wildlife habitat in reclaimed surface mine lakes near St. Paul, Minnesota or the gallery forest Red River of the North, and advising citizens how to design with plants along the riverine landscape [25–29]. Most projects involve water in some form or manner. There is still much to be learned and discovered,” concluded Dr. Burley.

5. Conclusion

Knowledge about water, its management, and use continues to grow and evolve. An analytical approach developed and employed in one part of the world may eventually become important in other parts of the world. This has been the case in the development of non-toxic water-quality estimation methods developed in the USA and being considered elsewhere. In addition, the special needs of selected societies and cultures may necessitate the evolution of new functions and design standards in planning and design. Applications of these standards will continue to evolve and be applied in different manners across the world. In future, some of these relatively newer equations and applications may be included in textbooks and studied by most landscape and civil engineering students.

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