PROBLEMS, PERCEPTIONS AND SOLUTIONS TO INCREASED FLOODING THREATS IN URBAN AREAS OF THE PACIFIC NORTHWEST, USA

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ABSTRACT

Rapid urbanization in high rainfall areas of western Washington, western Oregon and northern Idaho has increased the potential for flooding. As a result, the area of permeable surfaces to dispose of excess water from precipitation has decreased. This lack of permeable surfaces places pressure on storm sewers and surface waters to move the excess precipitation water off-site. The purpose of this article is twofold: (1) to document public perceptions of the likelihood of increased flooding events in urban areas and (2) to evaluate a potential solution that could mitigate the flooding problem in developing urban areas. Public attitudes, aptitudes and understanding of the potential flood threat in urban areas were determined using seven specific questions in a mail-based survey instrument conducted in 2017. Population projection data were used to forecast future changes in the permeability of landscapes. Rain gardens to increase water infiltration into the ground and reduce excessive precipitation runoff were evaluated from feasibility and public acceptance standpoints. Study results showed that the public is increasingly concerned about future flooding events, understands the linkage between reduced permeability of soils to flooding and is willing to consider using rain gardens as a flood mitigation strategy. As a consequence of effective outreach programs and local subsidies, 3,980 rain gardens have been established in the Puget Sound region since 2012.
Key words: public concerns, public opinion, rain gardens, urban flooding.

1 INTRODUCTION

Populations in watersheds receiving more that 80 cm of annual precipitation are rapidly growing in the states of Washington, Oregon and Idaho. In fact, the regions' population is expected to grow from 11,500,000 in 2018 to upwards of 18,000,000 by 2050. This ongoing rapid development has resulted in an increase in impervious surfaces which in turn increases the risk of urban flooding in the future.

2 BACKGROUND

Impervious surfaces negatively impact lakes and streams by (1) increasing the velocity of water runoff resulting in sediment delivery, (2) increasing surface water pollution and (3) reducing groundwater recharge [1]. In many human-affected watersheds, the quantity of impervious surfaces has become a key issue in determining habitat health. It has been documented that runoff from impervious surfaces is 5 to 40 times greater than runoff from an equivalent area of grass [1]. In partially forested watersheds in Washington state, increase in impervious land cover has increased the incidence of flooding [2]. When forests are replaced with impervious surfaces, changes in the hydrologic balance between surface and subsurface water has been observed. Within watersheds, the directly connected impervious area (DCIA) to a storm water system is a key indicator of urbanization impact on storm water quality and quantity [3]. Interpretation of satellite data is currently the most used and accurate way to

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determine the extent of impervious surface cover in developing areas [3–6]. More recently, additional urban data parameters including number of households, employment, population density and distance from the central business district have been used to develop impervious numbers [4].

In 2004, it was estimated that impervious surfaces covered more than 111,400 km^2 in the USA [1]. In addition, 1,011 km^2 are either paved or repaved each year. If one assumes that 25% of this amount is newly paved surfaces, impervious surface coverage in the USA exceeded 115,000 km^2 in 2018. As much as 65% of the impervious cover in the USA consists of the support system for the automobile – streets, parking lots and driveways. Approximately, 1.05% of the USA's land area is impervious surface [7]. Conversely, 0.49% of the world's land area is considered impervious surface as of 2018. China has the greatest amount of impervious surface translating into 67 m^2 per person. Impervious surface per capita in the USA is 297 m^2. The watersheds most damaged by impervious surfaces are found in the USA, Europe, Japan, China and India.

A recent idea to help mitigate the impact of impervious surfaces in urban and rapidly urbanizing watersheds is the installation of rain gardens [8–10]. Technically, a rain garden is a planted depression that allows rainwater runoff from impervious urban areas, like streets, driveways, parking lots, parking lots, sidewalks and compacted areas, the opportunity to be absorbed by the soil and recharge groundwater. Studies have shown that rain gardens can reduce water runoff by up to 45% and also reduce pollution of surface waters and increase groundwater recharge [9, 10]. The installation of a rain garden is an action that can be employed by an individual homeowner. However, when many homeowners install and maintain this practice, substantial benefits are afforded the entire local watershed.

3 METHODOLOGY

A survey instrument containing 60+ questions was developed to access public attitudes, priorities and concerns about water resource issues in the Pacific Northwest, USA. This survey was distributed to the public in 2017. The seven survey questions covered in this article are as follows:

1. Do you live in a rapidly growing area (increasing population)? *Answer choices: yes, no, I don't know*
2. Do you think that the potential for flooding is increasing in your neighbourhood? *Answer choices: yes, no, I don't know*
3. If you indicated above that the potential for flooding is increasing, what do you consider the primary reason for this increase risk? *Answer choices: climate change, failure of local sever systems, less permeable surfaces (more paved surfaces with development)*
4. Does flooding adversely affect surface water quality? *Answer choices: yes, no, I don't know*
5. Does flooding adversely affect groundwater quality? *Answer choices: yes, no, I don't know*
6. Do you know what a rain garden is? *Answer choices: yes, no, I don't know*
7. Have you, or do you know someone that has installed a rain garden on their property? *Answer choices: yes, no, I don't know*

The survey target audience was a representative sample of the 9,000,000 adult residents of Idaho, Oregon and Washington that live within the four Pacific Northwest states (Alaska, Idaho, Oregon and Washington). In addition, demographic information, including state of residence, community size, length of time residing in the region, gender, age and educational level, were also collected from survey respondents.

In this survey, a target of 1,000 completed questionnaires was chosen as the survey goal to result in a sampling error of 4–6% [11]. The survey process was designed to receive a completed survey return rate more than 50%. Addresses were obtained from a professional social sciences survey company (SSI, Norwich, CT). Four mailings were planned to achieve the 50% return rate [11–13].

It took four mailing to achieve the 50% return rate in 2017. The first mailing included the water issues survey form, a business reply envelope and a cover letter that (1) identified the survey's authors; (2) explained the purpose of the survey; (3) assured the respondent of anonymity and (4) asked the respondents to fill out and return the survey via the business reply envelope. The second mailing (4 weeks later) consisted of a postcard that stressed the importance of the survey and reminded the respondent to fill out and return the survey sent out in the first mailing. Five weeks later, the third mailing was sent to residents who did not respond to the first or second mailing. This mailing included a reminder letter, another copy of the water issues survey and a business reply envelope. The fourth mailing, used in 2017, consisted of a reminder postcard 6 weeks after the third mailing.

Survey answers were coded and entered into Microsoft Excel. Missing data were excluded from the analysis. The data were analysed at two levels using SAS [13]. The first level of analysis generated frequencies, while the second level evaluated the impacts of demographic factors.

4 RESULTS AND DISCUSSION

The 2017 survey study achieved a return rate of 53.7%. This high response rate coupled with the survey design assured that the survey results achieved values that were within a sampling error of less than 5% [13]. A snapshot of people taking this survey included the following: (1) 51.4% of the survey respondents were male, (2) over 41% of survey respondents lived in communities of more than 100,000 people, (3) 16.2% of respondents lived in towns with less than 7,000 people and (4) almost half of the survey respondents attended at least 1.5 years of college. The demographics of the survey respondents mirrored the 2010 USA census data for the region. Thus, the survey respondents were representative of the actual population living in the Pacific Northwest. Consequently, when coupled with the low sampling error of the survey, respondents can be equated to residents in the following discussion.

Because the questions covered in this report were based on flooding potential and consequent mitigation, responses from residents living in drier areas of the region were eliminated from the data. The goal was to evaluate survey data from citizens living in the wettest areas of the region. Consequently, in this report, answers were evaluated from residents of counties in Washington, Oregon and Idaho with annual precipitation exceeding 80 cm. This resulted in evaluating data from all Washington and Oregon counties west of the Cascade crest and five northern counties in Idaho – Boundary, Bonner, Kootenai, Shoshone and Benewah.

4.1 The potential for flooding

Most residents taking part in this survey believed that they were living in a rapidly growing community (Table 1). Over 70% of residents living in communities of more than 25,000 considered their communities rapidly growing. Conversely, a slight majority of residents in

Table 1: Public response to the following question: do you live in a rapidly growing area (increasing population)? The answers were based on the 2017 Pacific Northwest water issues survey.

Answer	Community size	
	More than 25,000 (%)	Less than 25,000 (%)
Yes	70.3	52.4
No	15.8	20.7
I don't know	13.9	26.9

communities with less that 25,000 residents identified their communities as rapidly growing. The views of residents are in line with population growth projections for the region. Most of the projected population growth in Washington and Oregon will be west of the Cascade mountain range in the higher precipitation areas. Based on growth projections, the population of Washington state should grow from 7,300,000 in 2018 to 11,250,000 in 2050. Likewise, Oregon is projected to grow from 3,900,000 now to 6,800,000 in 2050. The northern five counties in Idaho will double in population by 2050.

Residents of the wetter counties in Washington, Oregon and Idaho believed that the potential for flooding is increasing in their neighbourhoods (Table 2). Over 70% of respondents from large communities (>25,000) thought that the potential for flooding was increasing. Although lower, still a majority of residents of smaller communities (<25,000) considered flooding potential more likely in the future.

The survey respondents thought that future flooding is more likely and were asked to identify reasons for this increased risk. Almost three-quarters of respondents identified one of three given reasons. These results were interesting because in the larger communities (>25,000) almost half of the residents identified less permeable surfaces (increased pavement) as the most likely cause of increased flooding risk (Table 3). On the other hand, residents of the smaller communities were more likely to identify climate change as the causal factor for increased future flooding. Despite differences in community size, a majority of residents identified less permeable surfaces or climate change as the likely reason for increased flooding in the future. Residents of smaller communities were more likely to not identify a reason for increased flooding.

Table 2: Public response to the following question: do you think that the potential for flooding is increasing in your neighbourhood? The answers are based on the 2017 Pacific Northwest water issues survey.

Answer	Community size	
	More than 25,000 (%)	Less than 25,000 (%)
Yes	71.3	59.3
No	19.3	26.2
I don't know	9.4	14.5

Table 3: Public response to the following question: if you answered that the potential for flooding is increasing in your neighbourhood what do you consider the primary reason for the increased threat of flooding?

Answer	Community size	
	More than 25,000 (%)	Less than 25,000 (%)
Climate change	29.2	36.8
Failure of local sewer Systems	5.4	9.2
Less permeable surfaces (more pavement with development)	46.3	18.7
I don't know	19.1	35.3

4.2 The link between flooding and reduced water quality

Over 70% of survey respondents recognized the link between flooding and reduced surface water quality (Table 4). Respondents from larger communities (>25,000) were more likely to associate flooding with reduced surface water quality than residents of smaller communities.

The demographic factors of gender, age and education level affected how respondents linked flooding to surface water quality. First, females were more likely than males (78.4% vs 66.7%) to say that flooding reduced surface water quality. Second, respondents younger than 50 years old were more likely to believe that flooding reduces surface water quality compared to residents older than 50 years old (Table 5). Third, residents with college degrees were more likely to link flooding with reduced surface water quality than respondents with some college education (Table 6). Residents with some college education were more likely to link flooding with reduced surface water quality that respondent who had not attended college.

Survey respondents also linked flooding to reduced groundwater quality (Table 4). However, this linkage with reduced water quality was less strong than the flooding – reduced surface water quality relationship. Between 39 and 44% of survey respondents linked flooding with reduced groundwater quality.

Table 4: Public response to questions about the impact of flooding on surface and groundwater quality based on the 2017 Pacific Northwest water issues survey.

Question	Answer	Community size	
		More than 25,000 (%)	Less than 25,000 (%)
Does flooding adversely affect surface water quality?	Yes	74.2	70.7
	No	12.6	18.3
	I don't know	13.2	11.0
Does flooding adversely affect groundwater quality?	Yes	43.9	39.2
	No	32.2	29.6
	I don't know	24.1	38.2

Table 5: The influence of the demographic factors of age on public views of the effect of flooding on surface and groundwater quality surface based on the 2017 Pacific Northwest water resources survey.

Water	Age	Yes (%)	No (%)	Don't know (%)
Surface water	<30 years	80.4	10.6	9.0
	30–39	80.6	11.4	8.0
	40–49	77.6	14.2	8.2
	50–59	65.7	13.4	20.9
	60–69	66.2	16.6	17.2
	70+	72.4	17.4	10.2
Groundwater	<30 years	56.2	28.4	15.4
	30–39	49.7	26.2	24.1
	40–49	42.6	22.8	32.6
	50–59	37.9	31.4	30.7
	60–69	24.3	34.5	31.2
	70+	36.2	35.1	28.7

The demographic factors of gender, age and education level impacted how survey respondents linked flooding with groundwater quality. Females were much more likely than males (60.3% vs 26.1%). In addition, younger people (<40 years old) were more likely to say that there was a negative relationship between flooding and groundwater quality (Table 5).

Survey respondents with an advanced college degree were most likely to say that flooding results in decreased groundwater quality (Table 6). In fact, residents with at least some

Table 6: The influence of the demographic factors of education level on public views of the effect of flooding on surface and groundwater quality surface based on the 2017 Pacific Northwest water resources survey.

Water	Education level	Yes (%)	No (%)	Don't know (%)
Surface water	<HS diploma	60.1	15.5	24.4
	HS diploma	64.4	20.1	15.5
	Some college	71.4	16.4	12.2
	College degree	78.2	10.4	11.4
	Advanced college degree	83.6	12.6	3.8
Groundwater	<HS diploma	29.4	39.2	31.4
	HS diploma	31.5	36.5	32.0
	Some college	40.6	33.4	26.0
	College degree	49.2	23.6	27.2
	Advanced college degree	53.5	24.2	25.3

exposure to college were more likely to say that flooding reduces groundwater quality than respondents without exposure to college.

4.3 Knowledge about rain gardens

Over two-thirds of survey respondents were not aware of the definition of rain garden (Table 7). Only 34.2 and 26.2% of residents of towns with more than 25,000 and towns with less than 25,000 indicated a knowledge about rain gardens, respectively. When asked about the actual locations of rain gardens, less than 20% of survey respondents had actually installed one or knew the location of an existing installation (Table 7).

The answers to the above questions indicate that local knowledge of rain gardens is limited at present. Various demographic factors did impact the rain garden knowledge levels of Pacific Northwest residents, however (Table 8). First, females were more likely than males (36.1 vs. 24.4%) to know the definition of a rain garden. People with more formal education were more likely to say they knew what a rain garden was than those less formally educated. People living in communities of between 25,000 and 100,000 were more knowledgeable about rain gardens than those living in smaller or larger communities. The demographic factor of age did not impact rain garden knowledge.

Females and survey respondents with some exposure to college education were more likely to have installed a rain garden or to have known about a local installation. Again, respondents from communities ranging in size between 25,000 and 100,000 were most likely to have installed or be knowledgeable about a local rain garden.

4.4 Education, use and rain garden installation

In the high precipitation areas of the Oregon, Washington and Idaho, there have been efforts to educate the public on green storm water infrastructure strategies, such as rain gardens, to reduce flooding and the amount of contaminants reaching local waterways. Rain gardens infiltrate storm water runoff and thus alleviate flooding problems, as well as reduce the amount of contaminants reaching waterways [14].

All three land grant universities in the Pacific Northwest – the University of Idaho (UI), Oregon State University (OSU) and Washington State University (WSU) – have outreach programs targeted at storm water management. The most notable efforts have been led by

Table 7: Public response to questions about rain gardens based on the 2017 Pacific Northwest water issues survey.

Question	Answer	Community size	
		More than 25,000 (%)	Less than 25,000 (%)
Do you know what a rain garden is?	Yes	34.2	26.2
	No	65.7	73.8
Have you or do you know someone that has installed a rain garden on their property	Yes	16.3	8.9
	No	83.7	91.1

Table 8: The influence of the demographic factors of gender, age, education level and community size on (1) the definition of a raingarden and (2) knowing someone who has installed a raingarden based on the 2017 water resources survey.

Demographic factor	Parameter	Know raingarden definition (%)	Know raingarden user (%)
Gender	Female	36.1**	16.9***
	Male	24.4	8.1
Age	<30 years	30.2ns	12.9ns
	30–50 years	33.1	11.6
	50–70 years	29.6	12.4
	>70 years	28.0	13.6
Education	<HS diploma	21.6**	5.8**
	HS diploma	20.1	8.6
	Some college	39.2	17.9
	College degree	37.8	17.2
Community size	<25,000	26.2***	8.9**
	25–100,000	39.1	20.5
	>100,000	29.7	12.1

ns = not significant; *, ** and *** = significant at 0.05, 0.01 and 0.001 levels.

WSU in the Puget Sound region of Washington state. Hence, this discussion focusses on programs developed by WSU. Twelve of the Puget Sound jurisdictions offer rebate programs for homeowner rain garden installation that range from $400 to $5000. In the region, WSU, along with a number of local jurisdictions, non-profits and soil conservation districts, has provided a significant amount of outreach related to green storm water infrastructure, especially rain gardens. The '12,000 Rain Gardens Campaign' initiated by Washington State University Extension in collaboration with Stewardship Partners developed an outreach campaign and a set of outreach materials to promote rain garden installation (http://www.12000raingardens.org/). This program has accounted for the installation of 3,980 rain gardens since the inception of the program in 2012 through February 2018. The partners with WSU believe that many more rain gardens could have been installed in this time period if the following were done: (1) additional extension time devoted to the outreach program, (2) additional resources developed including lists of local plant suppliers and landscape contractors and (3) more detailed rain garden planting plans. The major limitation to this effort was the lack of funding necessary to have staff for the outreach, promotion and material development.

The outreach efforts, even with limited financial resources, were considered by WSU's partners and the 2017 survey described earlier in the article to be very successful. Here, residents of the Puget Sound geographic area were 27% more likely to know about rain gardens and their benefits than other residents of Idaho, Oregon and Washington.

In many jurisdictions in the region, WSU has developed locally rooted outreach and education programs in collaboration with a range of community partners to implement rain gardens. This has included providing over 300 workshops and field experiences that have directly reached over 8,000 residents in the region. Through its partnership with Stewardship Partners, WSU has provided specialized training to the Master Gardener programs in the region, which resulted in the construction of demonstration rain gardens around the region, as well as the development of the WSU Rain Garden Mentor program in some counties. The Rain Garden Mentor Program utilizes trained Master Gardener program volunteers to provide on-site planning and design assistance to individuals interested in installing rain gardens. WSU has also provided over 15, two-day training programs on rain garden design, installation and maintenance specifically targeted to landscape professionals throughout the region.

To build the availability of expertise available to developers, residents and business, WSU initiated the 'Low Impact Development' certificate program that reaches over 300 landscape architects, public works officials, civil engineers, local planners and landscape contractors annually. In an effort to extend educational outreach efforts, WSU has also provided over 20-day long workshops that have reached over 600 real estate professionals. These courses have provided clock hours that real estate professionals in Washington state need to keep their real estate licenses current. This audience was chosen since some are developers and most have a high degree of interaction with people at the time of land use transition and potential change which is an opportune time to consider utilizing green storm water infrastructure strategies such as rain gardens to reduce runoff.

All of these efforts have been effective in reaching people in industries related to development and landscaping. Rain gardens have been shown to be very effective in solving isolated problems; however, with a total population of over 5,000,000 people in the Puget Sound basin alone, more widespread incentive and education programs need to be implemented if significant change is to occur. These programs should build and expand upon the resources and strategies that have already been developed.

5 CONCLUSIONS AND RECOMMENDATIONS

Residents of the high precipitation areas (>80 cm annual precipitation) of Idaho, Oregon and Washington recognize that flooding in urban areas will be an increasing problem as both rapid population growth and rapid urbanization occur over the next 30 years in the region. Key findings of this study include the following:

- Residents of the high precipitation areas of the Pacific Northwest believe that the potential for urban flooding is increasing.
- Residents of larger communities (>25,000) were most likely to identify a reduction in permeable surfaces as the most likely reason for increased future flooding risk.
- Residents of smaller communities (<25,000) were most likely to identify climate change as the causal factor for future flooding.
- Over 70% of respondents recognized the link between flooding and reduced surface water quality. Conversely, the linkage between flooding and reduced groundwater quality was recognized by less than a majority of the public.
- University extension has been successful at providing relevant information about rain gardens and ultimately getting 3,980 of them installed in the Puget Sound region since 2012.
- Additional financial resources for outreach programs, printed materials and rain garden planting plans would result in the establishment of significantly more rain garden installations over the next decade.

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