sustainability

MDPI

Article

Sustainable Stormwater Management: Examining the Role of Local Planning Capacity in Mitigating Peak Surface Runoff

Hyun Woo Kim * **and Ming-Han Li**

Department of Landscape Architecture and Urban Planning, Texas A&M University, 3137 TAMU, College Station, TX 77843-3137, USA; minghan@tamu.edu

* Correspondence: kim7230@email.tamu.edu; Tel.: +1-979-571-0530

Academic Editor: Davide Geneletti

Received: 24 April 2016; Accepted: 25 July 2016; Published: 31 August 2016

Abstract: The Chesapeake Bay, the largest estuary in the United States, is rich in natural resources. Its watershed has been impacted by excessive and degraded stormwater runoff from rapid urbanization. We used an empirical approach to investigate how local planning capacity in the Chesapeake Bay watershed affected stream flow. A multiple regression analysis was employed to examine to what extent that the planning factors and other contextual variables were associated with peak runoff. Counterintuitively, we found that sub-basins included in the sample jurisdictions with a relatively high plan quality score tend to generate higher volumes of peak runoff. Results further indicate that specific geographical, basin characteristic, and biophysical factors affected mean annual peak runoff significantly. Overall, our findings highlight the importance of local planning capacity and sustainable stormwater management concepts in mitigating excessive runoff.

Keywords: sustainability; plan quality; planning capacity; runoff; stormwater; flooding; Chesapeake Bay

1. Introduction

The occurrence of excessive runoff and flooding events is increasing in the United States due to rapid urbanization and aging stormwater infrastructure. According to the most recent U.S. Census, from 1950 to 2010, urbanized areas expanded by almost 210 percent, and population in urban areas increased by more than 130 percent. Land consumption rate is outpacing the population shift from urban areas to suburban areas [1]. The ability of nature to respond to change has decreased due to rapid urbanization and urban sprawl. Conventional low-density development patterns, which caused environmental degradation, has significantly enlarged the area taken up by impervious surfaces, and thus facilitated landscape fragmentation, habitat displacement, and flood risks [2,3]. The influences of land use changes, such as urbanization and deforestation, led to the rising increment of stormwater runoff volume and pollution [4,5]. Previous studies [6–8] have discovered that increased impervious surfaces caused by urbanization generate negative hydrologic consequences, including excessive overflow, lack of infiltration, and insufficient aquifer recharge.

Downstream water pollution and flooding have been exacerbated because of the early stormwater runoff system design and aging pipeline infrastructure. Specifically, conventional stormwater management approaches have focused on removing stormwater as promptly as possible in order to mitigate impacts from flooding in a particular subdivision [9]. Hence, old pipeline drainage systems have increased the volume and velocity of runoff as well as peak flows, which incur greater danger to downstream water bodies in the form of flooding [9]. Maintenance and replacement costs for these pipelines are relatively expensive compared to other on-site management systems such as Best

Management Practices (BMPs) and Low Impact Development (LID) techniques [10,11]. Unfortunately, the majority of local jurisdictions have historically paid little attention to stormwater management related infrastructure, and funding has been limited by regional and state governments compared to other governmental infrastructure activities such as road and land construction, which are classified as mainstream works [12,13].

In sum, these two problems are significant issues resulting in excessive runoff and will become more problematic as they continue to disturb the hydrological cycle and increase flood damage. Effective control and regulation in the early phases of development can help forestall or resolve these issues. Planning includes diverse planning processes, incorporating the active participation of various stakeholders. The decision-making processes before development provides local governments an opportunity to more effectively and comprehensively address runoff issues by embracing a wide range of goals toward sustainable stormwater management. In addition, planning is a process directed by a plan document that must be a long-range blueprint for a community's future development [14]. Thus, incorporating stormwater management policies while adopting a plan may play a critical role in establishing stormwater management strategies for implementation in the initial stage and help effectively minimize adverse impacts from flooding and overflow. Most importantly, since many factors relating to stormwater runoff—such as rapid urbanization, urban sprawl, and inadequate drainage systems—are at the local level, the role of local land use decision making is becoming more crucial in managing stormwater and reducing excessive runoff [9,15].

Local governments are responsible for land use planning; they guide and regulate various urban environments and developments that may directly affect the stormwater system. Therefore, stormwater management should be addressed in the local comprehensive plan to proactively prepare for future flood risks and manage stormwater in a manner incorporated into larger concepts such as hazard, environmental, and ecosystem planning.

For almost two decades, local planning instruments have been evaluated in relation to the aspects of resilience, natural hazards, climate change, sustainability, smart growth, urban sprawl, citizen participation, green infrastructure, ecosystem management, and environmental planning [1,15–32]. However, no studies have examined whether the concepts, policies, and strategies of sustainable stormwater management are incorporated into planning documents. In addition, although the relationships among various factors and surface runoff have been examined in the past [2,7,33–36], few studies [6] have thoroughly explored the effects of planning capacity on flood mitigation. Given these gaps in the previous research, this study is intended to assess the impact of local planning capacity on mean annual peak runoff. Seventy-five sub-basins within the Chesapeake Bay watershed were selected for investigation. The results will provide valuable information to nearby local decision-makers and watershed planners on how to improve their stormwater management planning and plan documents that may effectively minimize the volume of runoff and enhance the overall health of the bay area in the long term.

2. Planning Capacity and Its Impact on Runoff

Internal planning capacity refers to features that can be controlled by local governments, such as the planning resource and process as well as the institutional capacity. It has been known to be a key criteria in examining whether the function of local governments work well or not [37]. Local jurisdictions with high commitment to local planning will likely to have stronger awareness and ability to mitigate stormwater runoff even though limitations still exist to verifying the degree to which planning factors affect the implementation of plan parameters in practice. Planning capacity investigated in this study included plan quality score, plan adopted year, number of planning staff, and involvement of consultant because they are considered most related to creating planning documents.

Plans that incorporate stormwater management mechanisms, such as non-structural tools (e.g., regulations on land use, taxes, site design, building codes, and public participation and education programs) and structural tools (e.g., LID practices, BMPs, and green infrastructures), tend to have local governments with higher commitment to controlling runoff. Brody and Highfield [24] used 18 plan quality indicators to assess whether wetland permit clusters in Florida conform to the original designs of comprehensive plans. They identified that plan quality scores of specific environmental and implementation policies had significant correlations with the degree of plan implementation (e.g., wetland development). Nelson and French [38] discovered that seismic safety elements within local comprehensive plans may have a positive effect in minimizing earthquake damage. Kang [39] found that plan quality scores of flood mitigation policies were positively associated with insured flood losses, even though the coefficient was statistically insignificant.

When localities have more resources and expertise, higher-quality plans can be generated, and thus specific policies have better chances to be implemented [21,39,40]. Several previous studies [40–42] underscored planning staffs because of their crucial role in mitigating hazards, especially regarding flood damage. Brody et al. [1] found that jurisdictions with more planning agency staff had stringent sprawl-mitigation measures in their local comprehensive plans. Tang and Brody [32] discovered that more planners in the staff would contribute to higher-quality local environmental plans. Furthermore, more recently updated plans are likely to include up-to-date information, natural- and built-environmental conditions, and techniques, and thus they may enable local governments to develop better plans and encourage their implementation. Hiring private consultants may also bring more technical and human resources to the table with which to improve plan quality and facilitate implementation. Some studies further examined the impacts of internal planning factors such as budget, collaborative effort, planners' commitment, participation, and leadership on plan outcome [24,38,39]. While this study did not include surveys with planning staff or community leaders, acquiring this information may better represent the entire local planning efforts and capacities; and thus, help explain the variations of surface runoff generation.

In this study, we tested the following hypotheses: (1) Sub-basins with plans of higher quality have lower peak runoff; (2) sub-basins that are included in jurisdictions that have recently adopted the plan, are less likely to generate excessive runoff; (3) sub-basins that are included in jurisdictions with more planners while drafting a local plan, will generate less peak runoff; and (4) sub-basins that are included in jurisdictions that engage private consultants for drafting a local plan will generate less peak runoff.

3. Research Methods

3.1. Conceptual Model

In this study, a conceptual model was developed with two phases to examine the effects of four specific factors (planning capacity, geographical, basin characteristics, and biophysical variables) on mean annual peak runoff (Figure 1). In Phase 1, plan quality score was derived by evaluating whether local jurisdictions in the sample sufficiently integrate the key principles of sustainable stormwater management into local comprehensive plans. A coding protocol for the plan evaluation was developed through the review of the literature associated with stormwater management. In Phase 2, the variance of mean annual peak runoff was analyzed by conducting multivariate regression analysis with four specific variables.

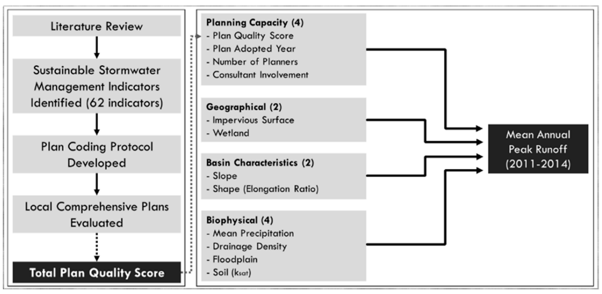

Figure 1. Conceptual model.

3.2. Study Sample

The target population of this study is sub-basins within the Chesapeake Bay watershed. The Chesapeake Bay is the largest and most biologically diverse estuary in North America located in the Mid-Atlantic region [43]. The watershed covers approximately 166,000 km^2 and a total of 203 counties and independent cities lie within or adjoining the bay watershed (see Figure 2). The study area has historically been polluted by human developments and impervious surfaces accompanied by rapid population growth. The population in the watershed has doubled between 1950 and 2000 (from 8 to 16 million). This growth has contributed to an impaired bay ecosystem, including habitat loss and water quantity/quality degradation [44]. Approximately 15 percent of the total nitrogen entering the bay originates from urban and suburban polluted runoff, which has been recently recognized as the greatest threat to bay water quality [45].

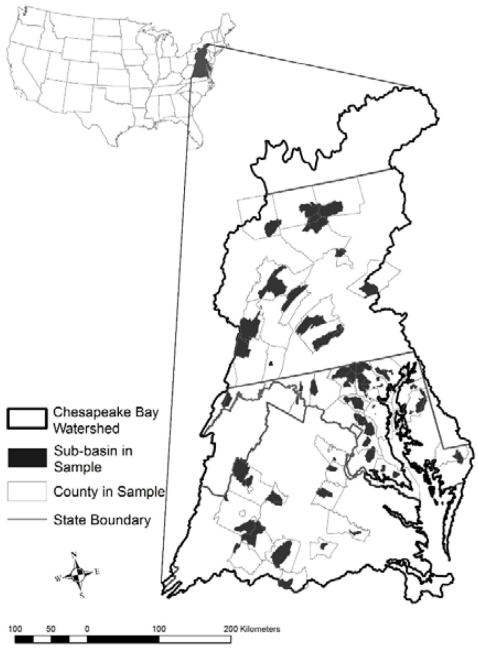

Figure 2. Selected sub-basins in the Chesapeake Bay watershed.

The study area for this research was chosen based on the following steps. First, local jurisdictions that overlap with the Chesapeake Bay watershed boundary by more than 50 percent were selected to avoid the jurisdictions that may not directly influence the entire watershed ecosystem; Second, the sample was limited to jurisdictions with populations greater than 10,000 to prevent skew toward small jurisdictions, where areas exert little influence on the bay and often lack the resources to initiate a sufficient planning effort [19]. Third, jurisdictions that adopted comprehensive plans between 2000 and 2010 were selected to determine the implementation effect of planning capacity factors on mean annual peak runoff from 2011 to 2014. The interpretation of results, however, should be made carefully because the lag time between plan implementation and hydrologic change can be large and we cannot guarantee whether the plan has been implemented; Finally, sub-basins that overlap with the boundary of a specific jurisdiction by more than 80 percent were chosen for the final sample, in order to represent the planning factors where the unit of analysis is at the county level. Through the above selection process, a total of 42 local jurisdictions and 75 sub-basins were contained in the sample.

3.3. Unit of Analysis

The unit of analysis for this study is sub-basin. The sample sub-basins have been delineated based on stream gauge data from the United States Geological Survey (USGS) [46] by following three sampling processes. First, a gauge that has its outlet located within a reservoir or has a dam on the upstream was excluded from the sample since the data can be impacted by storage capacity. Second, only gauges that have streamflow records between 2011 and 2014 were chosen for the final study, in order to examine the implementation effects of local plans that were adopted from 2000 to 2010. Third, for data efficiency and accuracy only gauges that have at least 90 percent of streamflow records per year were selected [34].

By using StreamStats, a Web-based GIS application that was developed by the USGS and Environmental Systems Research Institute (ESRI) for water resources planning and management, a distinct sub-basin boundary from each gauge station was delineated.

3.4. Concept Measurement

3.4.1. Dependent Variable

Mean annual peak runoff of 75 sub-basins from water years of 2011 to 2014 were obtained from the USGS gauge stations. Because stations provided the annual peak discharge rates for each sub-basin with the unit of cubic meter per second (m^3/s), this study converted the flows into total annual runoff depth (in millimeters). Specifically, the converting method that the USGS applied for its estimation was employed. First, 86,400 s per day was multiplied to convert the value into a total annual flow volume (m^3). Second, runoff volume expressed in depth was computed by dividing the total annual flow volume by the contributing drainage area measured by ArcGIS. Third, meter measurement has been converted into the millimeter measurement by multiplying 1000. The mean annual peak runoff from each gauge station was obtained by averaging four-year (2011–2014) annual peak runoff. To better approximate a normal distribution, mean annual peak runoff was log-transformed (see Table 1).

3.4.2. Independent Variables

For examining the plan implementation process, several studies have adopted plan quality score as a causal variable. Through employing the content analysis methodology that is widely used as an evaluation protocol in plan assessments [19,23,47], this study conceptualized local plan quality on sustainable stormwater management, based on five key plan components: (1) Factual basis; (2) goals and objectives; (3) inter-organizational coordination; (4) policies, tools, and strategies; and (5) implementation. Sixty-two indicators were developed in evaluating local comprehensive plan by referring the concepts of sustainable stormwater management that were established in previous research [48–57] and various federal, state, and local water resources and stormwater management and planning guidelines [58–65]. Table 2 shows the detailed indicators, measurements, and descriptive statistics for each plan component. Total plan quality scores for each jurisdiction was measured using Equations (1) and (2) (see Brody [47] for more details of the calculation process) and they are shown in the Appendix A (Table A1).

$$\mathrm{PCQ_j} = \frac{10}{2\mathrm{m_j}} \sum_{\mathrm{i}=1}^{\mathrm{m_j}} \mathrm{I_i} \tag{1}$$

where PCQ_j refers to the quality of the j-th plan component; m_j refers to the total number of indicators within the j-th plan component (scale: 0–10); and I_i refers to the i-th indicator's scores (scale: 0–2; scale for the "goals and objectives" component: 0–1).

$$\mathrm{TPQ} = \sum_{\mathrm{j}=1}^{5} \mathrm{PCQ_j} \tag{2}$$

where TPQ refers to the total plan quality scores (scale: 0–50).

Table 1. Concept measurement.

Variable	Description	Data Source	Mean	S.D.	Range
Dependent variable					
Mean annual peak runoff (log)	Mean annual peak streamflow at each USGS gauge station divided by basin area (mm)	USGS (2011–2014)	7.79	1.08	4.24–9.91
Planning capacity variables					
Plan quality score	Five plan components' score (point)	Plan coding protocol (2000–2010)	23.58	5.81	7.56–33.14
Plan year	Plan adopted year minus 2010	Each jurisdiction's plan (2000–2010)	−3.07	3.09	−10–0
Planning staff	Number of planning staff during creating plan	Each jurisdiction's plan (2000–2010)	5.75	3.93	1–19
Consultant	Participation of consultants during adopting/creating plan (1 = yes, 0 = no)	Each jurisdiction's plan (2000–2010)	0.47	0.50	0–1
Geographical variables					
Impervious surface	Percent impervious land cover; NLCD Class 22, 23, 24	USGS (2011)	21.59	25.83	0.9–95.21
Wetland	Percent wetland land cover; NLCD Class 90, 95	USGS (2011)	3.54	7.25	0–51.49
Basin characteristics variables					
Slope	Average percent slope of sub-basin	USEPA—NHDPlusV2 (2012)	10.09	7.36	0.76–32.47
Shape	Circumference of a circle with the same area; *Elongation ratio*	ArcGIS	0.58	0.13	0.33–0.98
Biophysical variables					
Precipitation	Average monthly rainfall (mm)	Parameter-elevation Regressions on Independent Slopes Model (PRISM) Climate Group (2011–2014)	1143.97	83.29	942.21–1357.79
Floodplain	Percent overlapping a FEMA-defined 100-year floodplain (DFIRM; Q3)	FEMA Map Service Center (2014)	5.50	3.46	0–17.27
Natural drainage density	Total length of basin streams divided by basin area	USDA (2003)	1.28	0.32	0.35–2.02
Soil	Saturated hydraulic conductivity (K_{sat}) by SSURGO	USDA (2003)	3.07	1.89	0.87–10.67

Notes: Number of observations is 75 for all variables.

Table 2. Indicators in sustainable stormwater management plan coding protocol.

Components	Indicators	Measurements	Mean [1]	Min. [1]	Max. [1]
Factual basis	Classification/description of vegetation and forests Map or inventory of watersheds, wetlands and water resources Classification/description of soils Inventory of local climate Map or inventory of current and/or future land use Current population and population growth projection Present and/or future needs of stormwater infrastructure and services Map or inventory of main water pollution types and sources Impervious surface area density and/or road density	(Scale: 0–2) 0 = not mentioned 1 = mentioned, but not detailed 2 = mentioned and detailed	5.43	2.78	7.78
Goals and objectives	Goals are clearly specified Presence of measurable objectives Protect natural processes/functions Encourage open spaces/recreation actions Improve water quality Maintenance of stormwater management facilities Control/reduce stormwater runoff and/or flood Encourage public participation Minimize impervious surfaces from development Promote low impact development Establish adequate funding for stormwater management	(Scale: 0–1) 0 = not mentioned 1 = mentioned	4.70	0.91	8.18
Inter-organi-zational coordination and capabilities	Other jurisdictions/organizations/stakeholders identified Coordination with other jurisdictions/organizations/ stakeholders identified Coordination with higher levels of governments (state/federal) Integration with other environmental plans/programs in the region Coordination with private sectors Commitment of financial resources Coordination within jurisdiction specified	(Scale: 0–2) 0 = not mentioned 1 = mentioned, but not detailed 2 = mentioned and detailed	5.22	2.14	7.86

Table 2. *Cont.*

Components	Indicators	Measurements	Mean [1]	Min. [1]	Max. [1]
Policies, tools, and strategies	Innovative stormwater management practices (BMPs/LID techniques/Green Infrastructure) Certified green building (LEED) Constructed wetlands Consistency with other ordinances and regulations Setbacks and buffer zones Restrictions on local vegetation and forest removal Erosion and sediment control Development away from floodplains Land use restriction near sensitive water bodies Innovative design for new/re-developments Urban service/growth boundaries Water quantity and quality monitoring Pest control regulations Building codes to require water-efficient facilities Total Maximum Daily Load (TMDL) Water-efficient landscaping Minimum pipe size Clustering development Transfer of development rights Density bonuses Stormwater fee discounts Stormwater impact fees Openspace preservation Conservation easements Other land acquisition techniques Fee simple purchase Education/outreach program Training/technical assistance Maps of areas subject to flood hazards or stormwater runoff	(Scale: 0–2) 0 = not mentioned 1 = recommended 2 = required	2.81	1.03	5.34
Implementation	Regular plan updates and assessments Designation of responsibilities for actions Identification of financial and technical support Clear timeline for implementation Highlighting stormwater sustainability Monitoring of stormwater runoff impacts	(Scale: 0–2) 0 = not mentioned 1 = mentioned, but not detailed 2 = mentioned and detailed	5.22	2.14	7.86

[1] Scale of each plan component: 0–10.

The measurement of total plan quality score followed the procedure of previous plan evaluation studies and they are computed by four steps.

- Step 1: Score each indicator (scale: 0–2) within a plan component and add them all to gain total plan component score. Indicators were coded on a 0–2 ordinal scale. Indicators for the "goals and objectives" component, however, have been scored on a 0–1 scale. Specifically, an indicator scored two points when it was fully identified and demonstrated within a plan. If an indicator was explained or identified without a detailed description, it received 1. Zero points were given to an indicator when it was never mentioned within a plan. For "policies, tools, and strategies" component, an indicator scored 2 when it was clearly mentioned with a firm commitment words, such as "require," "must," "shall," and "will." Score of 1 was received when an indicator was portrayed with vague commitment words (e.g., "encourage," "should," "may," and "consider"). When an indicator was specified but was not described with detailed information (e.g., "what," "where," how," and "when"), it received one point.
- Step 2: Each plan component was standardized by dividing the total indicator scores within a component by the total available scores of a component.
- Step 3: Multiply each plan component score by ten in order to make a 0–10 scale.
- Step 4: Sum the scores of all five plan components (scale: 0–50).

To maintain an inter-coder reliability and reduce personal bias in judgment, two trained scorers have evaluated all 42 local comprehensive plans. The plan indicators were pre-tested by the first scorer and re-tested by the second scorer using the same plan coding protocol. The percent agreement score, which is a generally accepted technique to measure inter-coder reliability in past plan evaluation studies, was computed through "ReCal", a Web-based tool [66]. The overall average percent agreement score calculated from the double-coded data was about 84 percent. Generally, past plan quality evaluation studies considered a score higher than 80 percent as acceptable [67,68].

To examine the level of inter-item consistency and reliability, Cronbach's Alpha test, which assesses the degree to which a set of indicators are correlated as a group, was conducted in this study. The Cronbach's alpha exceeded 70 percent for all five plan components. An α value in the range of 70 percent or above is typically considered as an adequate reliability by many researchers [69,70].

The plan adoption year data were computed by subtracting the year that a plan was adopted from the year 2010. Data on the number of planners and the participation of consultants while drafting a plan were obtained from each local jurisdiction's comprehensive plan. Individual contacts have been made with local planning department officials where sufficient information was not provided within a plan.

Land use/land cover dataset (2011) was obtained from the USGS National Land Cover Database (NLCD) [71] at a 30 m resolution. Developed areas were represented by grouping three land use/land cover classes (LULC Class: 22–24): Low-intensity, medium-intensity, and high-intensity developed areas. These intensities were classified based on the percentage of impervious cover, and each comprises 21–49 percent, 50–79 percent, and 80–100 percent of impervious surfaces, respectively. Land uses for low- and medium-intensity developed areas are typically single-family housing, whereas high-intensity developed areas generally contain apartment complexes and commercial/industrial facilities [72]. Wetland areas were represented by two LULC classes (woody wetland and emergent herbaceous wetland; LULC Class: 90–95). The percentages of LULC distribution were calculated by ArcGIS [73] with the Geospatial Modelling Environment (GME) extension [74].

Both mean slope and basin shape were measured by using ArcGIS. Specifically, mean slope was calculated based on the 30 m resolution DEMs obtained from the National Hydrography Dataset (NHD) Plus Version 2 [75]. From the several basin shape measurements, such as circularity ratio, length to width ratio, and elongation ratio, this study employed the elongation ratio approach, which is frequently used in recent hydrological research. The value of elongation ratio was attained through calculating Equation (3).

$$\text{Elongation Ratio} = \frac{\sqrt{4 \times \frac{A}{\pi}}}{L} \tag{3}$$

where A refers to the basin area; and L refers to the basin length from the gauge station to the farthest point within a basin boundary.

Four biophysical factors that may directly/indirectly influence the quantity of stormwater runoff are included in this variable: average monthly precipitation, natural drainage density, percentage of 100-year floodplain, and soil characteristics. Average monthly precipitation data were acquired from the PRISM Climate Group for the period from 2011 to 2014. The PRISM Climate Group produced a continuous record of surface precipitation by using the Climatologically-Aided Interpolation (CAI) approach. Each basin's average monthly precipitation was summed over the water year (1 October to 30 September) and was measured for the study period using ArcGIS to calculate average weighted mean of raster data. Natural drainage density was measured using ArcGIS with the national hydrography dataset obtained from the USDA's GeoSpatial Data Gateway [76]. The ratio of total stream length to basin area was calculated. The digital flood insurance rate map (DFIRM) and Q3 data were obtained from the FEMA Map Service Center [77] to calculate the percentage overlapping a FEMA-defined 100-year floodplain with the basin area. To obtain the saturated hydraulic conductivity (K_{sat}) value, which is often used in soil interpretation, the Soil Survey Geographic Database (SSURGO) was obtained from the USDA's Web Soil Survey [78] and run using the Soil Data Viewer 6.1. Average K_{sat} value of each sub-basin was then created using ArcGIS GME extension to weight the value according to the proportional areas.

3.5. Data Analysis

An ordinary least squares (OLS) technique was used to test how the independent variables (planning capacity, geographical, basin characteristics, and biophysical factors) explain the variance of dependent variable. Due to the relatively small sample size (n = 75) compared to the number of independent variables, variables were analyzed by four block groups. This approach was frequently adopted by several studies that had small number of sample sizes in order to alleviate the impact of each variable on the validity of statistical conclusion [30,32,39,79,80]. Five models have been analyzed in this analysis. Specifically, Model 1 (baseline model) included only the block group of planning capacity variables. Geographical, basin characteristics, and biophysical variables were then added one by one to create the next models (Models 2–4). Only statistically significant variables in each of four models were then chosen for the final fully specified model (Model 5). By following Equation (4), multiple regression analyses were conducted.

$$\text{MAPR} = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon \tag{4}$$

where MAPR refers to mean annual peak runoff; α refers to regression intercept; β_x refers to partial regression coefficients; X_1 refers to planning capacity factors; X_2 refers to geographical factors; X_3 refers to basin characteristics factors; and X_4 refers to biophysical factors.

To ensure that OLS regression assumptions were not violated and to check whether the OLS would yield best, linear, and unbiased estimates, this study tested model specification, outliers, multicollinearity, heteroskedasticity, and spatial autocorrelation. No major violations were detected through the diagnostics.

4. Results

We examined the influence of planning capacity, geographical, basin characteristics, and biophysical variables employing multiple regression analysis. Table 3 reports both multivariate regression coefficients and standardized coefficients for mean annual peak runoff. The variance of the dependent variable was explained the most by Model 5 (65 percent), followed by Model 2 (46 percent), Model 4 (42 percent), Model 3 (35 percent) and Model 1 (25 percent).

With respect to the association between planning capacity variables and peak runoff, plan quality score was constantly positive and significant in all models except Model 2. Its degree of coefficients, however, was relatively weak to explain the variance of the dependent variable, and directions were opposite to our initial expectation that sub-basins of higher plan quality would generate less peak runoff. Involvement of consultants was negative and statistically significant only in Models 1 and 3. Both plan adopted year and number of planners were statistically insignificant in all models.

For geographical variables, impervious surface had a positive and statistically significant relationship with mean annual peak runoff in Models 2 and 5. For 1 percent increase in impervious surface, peak runoff can be increased by approximately 1.7 percent. Specifically, impervious surface was the most powerful predictor in explaining the variance of mean annual peak runoff (Beta = 0.4634). Wetland was negatively associated with mean annual peak runoff in Model 2, but did not show a significant result in the fully-specified model. Although no serious multicollinearity was detected in Model 5, relatively high correlation ($r = 0.53$) between wetland and soil might be a possible reason for a reduced statistical effect on mean annual peak runoff.

Among the two basin characteristics variables, only basin shape (elongation ratio) was positively and significantly associated with mean annual peak runoff in Models 3 and 5. One unit increase in elongation ratio increase more than double, in the peak runoff. Average basin slope, however, was not statistically significant while the direction followed the expected signs.

Biophysical factors were highly related to runoff generation. Average monthly precipitation, the percentage of floodplain, and saturated hydraulic conductivity (soil) had statistically significant effects on mean annual peak runoff in Models 4 and 5. Specifically, sub-basins with a high percentage of floodplain were more likely to generate less peak runoff. Saturated hydraulic conductivity (soil) displayed a negative relationship with peak runoff. This result supports that sub-basins containing a higher percentage of permeable soils are likely to generate less mean annual peak runoff. Natural drainage density had a positive but statistically insignificant relationship with the dependent variable.

Table 3. Factors influencing mean annual peak runoff.

	Model 1		**Model 2**		**Model 3**		**Model 4**		**Model 5**	
	β	**Beta**	**β**	**Beta**	**β**	**Beta**	**β**	**Beta**	**β**	**Beta**
Planning capacity variables (Baseline)										
Plan quality score	0.0765 ** (0.0240)	0.4518 **	0.0353 (0.0219)	0.2083	0.0728 ** (0.0225)	0.4294 **	0.0477 * (0.0225)	0.2748*	0.0261 † (0.0135)	0.1543 †
Plan year	−0.0146 (0.0438)	−0.0470	0.0320 (0.0391)	0.1032	−0.0182 (0.0430)	−0.0586	−0.0045 (0.0391)	0.1495		
Number of planners	0.0304 (0.0272)	0.1259	0.0146 (0.0257)	0.0605	−0.0264 (0.0283)	0.1094	0.0345 (0.0247)	−0.0145		
Consultant	−0.4098 * (0.2013)	−0.2145 *	−0.1934 (0.1751)	−0.1012	−0.3498 † (0.1870)	−0.1831 †	−0.1566 (0.1997)	−0.0845	−0.0085 (0.1545)	0.0045
Geographical variables										
Impervious surface			0.0172 ** (0.0040)	0.4643 **					0.0172 ** (0.0031)	0.4634 **
Wetland			−0.0275 * (0.0126)	−0.2078 *					−0.0100 (0.0120)	−0.0750
Basin characteristics variables										
Average slope					0.0035 (0.0144)	−0.0271				
Shape					2.5813 ** (0.7112)	0.3460 **			1.6231 ** (0.5408)	0.2176 **
Biophysical variables										
Precipitation							0.0029 * (0.0013)	0.2518 *	0.0020 * (0.0010)	0.1776 *
Natural drainage density							0.4410 (0.2927)	0.1475		
Floodplain							−0.0863 ** (0.0262)	−0.3121 **	−0.0834 ** (0.0207)	−0.3009 **
Soil							−0.0735 ** (0.0266)	−0.2597 **	−0.0425 ** (0.0264)	−0.1497 **
Constant	2.3389 ** (0.6361)		3.1744 ** (0.5616)		0.9499 (0.7175)		0.3207 (1.5546)		0.5056 (1.2249)	
R^2	0.2858		0.5054		0.4067		0.4795		0.6894	
Adj. R^2	0.2450		0.4618		0.3544		0.4164		0.6517	
Root MSE	0.8337		0.7039		0.7709		0.7329		0.5662	

Notes: $n = 75$; D.V.: Mean annual peak runoff; † $p < 0.1$; * $p < 0.05$; ** $p < 0.01$.

5. Discussion and Policy Implications

The explanatory results of this study have revealed several facets that are worth further consideration in minimizing surface runoff. First, local plan quality score was positively associated with mean annual peak runoff. This result suggests that possessing a high-quality plan does not always result in minimizing surface runoff. Perhaps this relationship may stem from several reasons. Although a jurisdiction develops a thorough comprehensive plan incorporating various policies and action strategies associated with stormwater management, those policies may not be implemented in practice. Several indicators used for the plan evaluation in this study may also be difficult for local planners and administrators to measure whether the implementation has occurred. Thus, we recommend that state and local agencies develop a plan implementation evaluation system that assesses whether plan outcomes conform to the initial intent of a plan. For example, they might adopt the methodology that Laurian et al. [81,82] used to identify whether land development permitting processes followed a plan's development policies. Such plan implementation evaluation systems may also play an important role in regular plan updates by discerning how certain policies have been actually implemented.

In addition, jurisdictions that have frequently experienced damages due to flooding or excessive runoff may have already recognized their vulnerability to stormwater runoff, and thus have integrated diverse stormwater management policies and tools into their comprehensive plans beforehand. If this is the case, plan quality score will be a reactive measure to the previous flooding experiences. As a result, even though a sub-basin is included in a jurisdiction that has a high-quality plan, the sub-basin may generate more runoff compared to sub-basins that generate less stormwater runoff historically.

The scores obtained from the plan evaluation process might also be a reason for the unexpected result. Although we have used the five plan components approach that is most commonly employed in the previous plan evaluation research, considering other components, such as "monitoring", "public participation," and "organization and presentation" may allow more number of practical indicators to be utilized for the assessment and alter the overall scores [83]. Moreover, while indicators here were developed based on concerning several literature, guidelines, and opinions from experts, weighting schemes were not applied. Assigning unequal weights and values to different indicators based on multiple practitioners and planning researchers' judgment may lead to the different result.

Lastly, the volume of peak runoff may be significantly influenced by upstream human disturbances. Although the sampled sub-basins were delineated based on the topography and flow direction and accumulation, upstream development pressures may considerably impact the quantity and quality of interconnected downstream flow. Therefore, degraded upstream sub-basins will impact downstream ones on peak runoff and flooding. For this reason, local planners should actively cooperate with the upstream and nearby jurisdictions in regulating peak runoff even though they have developed a thorough comprehensive plan towards mitigating floods.

Because of the above interpretations, further research in the relationship between plan quality and surface runoff generation is needed. Comprehensive plan is a long-range policy document that guides a community's future development. It takes efforts to implement a plan and time to observe the outcomes. Communities that consider only immediate and short-term concerns of mitigating stormwater runoff without long-term visions, goals, objectives, and action strategies will fail to manage stormwater sustainably. Thus, local planners and decision-makers should continuously monitor whether specific policies have been successfully implemented and then determine if those implemented policies were effective.

Second, despite the unexpected result, the directions of plan updated year versus peak runoff and the participation of consultants versus peak runoff support the findings of previous studies: (1) The latest information and circumstances should be regularly included in updated plans and, thus, encouraging local planners to apply up-to-date techniques within the action strategies; (2) For small jurisdictions, assistance from outside consultants may also have positive influence in controlling runoff by adding more planning resources, analyses, and GIS resources into a plan.

Third, the percentage of floodplain had a negative association with peak runoff. This may be because land developments within the 100-year floodplain were well regulated by local governments, and thus the amount of excessive runoff might be minimized.

Fourth, impervious surfaces, which accounted for an average of 21.6 percent of land cover in the study area, were highly associated with peak runoff: a one percent increase in the impervious surface resulted in approximately 1.7 percent increase in mean annual peak runoff, holding other variables constant. That is, sound land regulations and strategies should be made to reduce the impervious surfaces during the development process. Local/state planners and agencies are strongly recommended to manage and monitor the spatial distributions and configurations of impervious land cover in order to effectively control the excessive runoff that might be caused by indiscriminate land development [84]. In addition, BMPs and LID practices should be installed in places where the percentage of impervious surface is too high to efficiently manage runoff and prevent flooding events. These proactive planning approaches may also lead local governments to save initial construction and maintenance costs because on-site source control practices are more cost-effective than conventional drainage systems [85].

6. Conclusions

Although the relationship between land use and stormwater quantity has been researched for a while, this study is unique by utilizing planning capacity linked with hydrologic measures. In contrast to large-scale flooding caused by hurricanes and extreme rainfalls, stormwater runoff and/or flooding can be more effectively controlled at the local level. This study found that local planning and other contextual factors may significantly influence mean annual peak runoff in the Chesapeake Bay watershed. By far, a point increase in plan quality score would increase the peak runoff, inferring that the majority of local governments may already recognize the significance of stormwater runoff and flood occurrence, and thus substantially incorporate concepts of sustainable stormwater management in their plans. The link between comprehensive planning and successful stormwater management, however, is still tenuous and can be influenced by other factors that are not well represented in this study. Thus, interpretation of plan implementation results should be made carefully. Findings also support the pattern of previous plan evaluation studies that continuous and regular plan updates as well as more human resources may contribute significantly on minimizing the occurrence of flooding. Although the results of our study supported efforts to better understand the relationship of local planning capacity and the generation of peak runoff, some methodological limitations exist that need further investigation.

First, due to our stringent selection criteria and processes of the study area, a relatively small number of samples, 75 sub-basins, were chosen for this study. This is a threat to sound statistical conclusions. Further studies should increase the sample size by employing an alternative way of representing jurisdictions by watersheds, such as the weighting approach that Brody et al. [15] applied in their study. Because of the weak statistical power, the findings should be generalized to other areas with care, especially where natural and built environments have dissimilar patterns.

Second, this study equally weighted the indicators while evaluating the plan quality in order to reduce personal bias. Although typical plan evaluation studies have avoided prioritizing specific indicators for the purpose of minimizing vague judgments, future studies should assign differential weighting schemes by considering more opinions from planning practitioners, which may enable this evaluation protocol to be more useful in the practice [32,83].

Third, temporal limitations exist for runoff and precipitation data. The data in this study were examined on an annual basis. However, the amount of runoff and precipitation vary significantly by each month or season. For example, this study ruled out hydrological fluctuations that may be caused by snowmelt. Further studies should address temporal impacts of surface runoff, precipitation, and other natural environmental attributes.

Finally, to account for these temporal dimension issues and explain the causal relationship between independent and dependent variables, longitudinal analysis or panel analysis should be performed in future research rather than cross-sectional analysis if data are available. Particularly, panel analysis may better explain whether planning capacities have implementation effects in surface runoff by looking at the percent change of two distinct periods.

Acknowledgments: The publishing fee of research work was covered by the Texas A&M University Online Access to Knowledge (OAK) Fund, supported from the University Libraries and the Vice President for Research.

Author Contributions: Both authors significantly contributed to the scientific study and writing. Hyun Woo Kim designed the study, analyzed and interpreted the data, and wrote the manuscript. Ming-Han Li supervised the analysis, participated in the development of this study, and edited the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Total plan quality scores for 42 local jurisdictions.

States	Local Jurisdictions	Factual Basis	Goals and Objectives	Inter-Organizational Coordination	Policies, Tools, and Strategies	Implementation	Total Plan Score
MD	Allegany	3.61	4.55	5.00	3.28	1.67	18.10
	Anne Arundel	6.67	5.45	7.86	4.83	8.33	33.14
	Baltimore	6.11	8.18	5.71	4.31	5.83	30.15
	Carroll	7.22	4.55	7.86	3.45	5.00	28.07
	Charles	4.17	6.36	5.71	2.24	5.00	23.49
	Frederick	6.67	4.55	7.86	3.45	2.50	25.02
	Harford	2.78	4.55	6.43	1.55	5.83	21.14
	Howard	5.83	3.64	7.14	3.45	5.00	25.06
	Kent	6.39	3.64	5.00	2.24	1.67	18.93
	Prince George's	4.72	4.55	5.71	1.90	2.50	19.38
	Queen Anne's	6.11	4.55	3.57	3.97	5.00	23.19
	St. Mary's	5.56	6.36	5.71	5.34	5.00	27.98
	Washington	6.39	3.64	3.57	1.55	0.83	15.98
	Wicomico	5.83	8.18	5.71	4.31	2.50	26.54
PA	Bedford	6.67	4.55	5.00	3.45	5.83	25.49
	Blair	6.11	4.55	7.14	2.76	7.50	28.06
	Bradford	4.44	0.91	4.29	1.90	1.67	13.20
	Centre	5.83	2.73	4.29	2.24	1.67	16.75
	Cumberland	6.39	2.73	3.57	1.55	3.33	17.57
	Fulton	5.00	1.82	3.57	1.03	2.50	13.92
	Huntingdon	6.39	2.73	5.00	2.76	0.83	17.71
	Lycoming	6.11	4.55	5.71	2.07	3.33	21.77
	Mifflin	5.83	3.64	5.71	1.72	5.83	22.74
	Montour	3.33	5.45	4.29	2.59	5.83	21.49
	Perry	6.67	3.64	7.14	3.28	3.33	24.06
	Potter	6.11	5.45	5.71	2.41	5.83	25.53
	Schuylkill	5.83	3.64	5.00	1.90	5.83	22.20
	Tioga	6.39	6.36	5.00	2.07	3.33	23.15
VA	Amherst	3.61	5.45	5.00	2.76	3.33	20.16
	Augusta	7.78	6.36	7.14	4.31	7.50	33.09
	Buckingham	6.39	4.55	4.29	2.59	1.67	19.47
	Greene	4.72	6.36	3.57	2.24	2.50	19.40
	Hanover	4.17	4.55	4.29	1.55	2.50	17.05
	Nelson	5.56	3.64	2.14	1.21	0.83	13.38
	Powhatan	3.89	5.45	4.29	3.28	7.50	24.41
	Prince Edward	5.28	3.64	5.00	2.41	2.50	18.83
	Prince William	3.61	8.18	3.57	3.79	4.17	23.32
	Rockingham	5.00	4.55	4.29	2.07	6.67	22.57
	Spotsylvania	5.56	5.45	5.00	5.17	6.67	27.85
	Stafford	6.67	4.55	5.71	4.48	6.67	28.08
WV	Jefferson	2.22	0.91	2.74	0.86	0.83	7.56
DC	Washington DC	4.17	6.36	7.86	3.45	8.33	30.17

References

1. Brody, S.D.; Carrasco, V.; Highfield, W.E. Measuring the adoption of local sprawl: Reduction planning policies in florida. *J. Plan. Educ. Res.* **2006**, *25*, 294–310. [CrossRef]
2. Arnold, C.L.; Gibbons, C.J. Impervious surface coverage: The emergence of a key environmental indicator. *J. Am. Plan. Assoc.* **1996**, *62*, 243–258. [CrossRef]

3. Weber, T.; Sloan, A.; Wolf, J. Maryland's green infrastructure assessment: Development of a comprehensive approach to land conservation. *Landsc. Urban Plan.* **2006**, *77*, 94–110. [CrossRef]
4. Chang, H.; Franczyk, J. Climate change, land-use change, and floods: Toward an integrated assessment. *Geogr. Compass* **2008**, *2*, 1549–1579. [CrossRef]
5. Lehner, P.H.; Aponte Clarke, G.P.; Cameron, D.M.; Frank, A.G. *Stormwater Strategies: Community Responses to Runoff Pollution*; Natural Resources Defense Council: New York, NY, USA, 1999.
6. Brabec, E. Imperviousness and land-use policy: Toward an effective approach to watershed planning. *J. Hydrol. Eng.* **2009**, *14*, 425–433. [CrossRef]
7. Paul, M.J.; Meyer, J.L. Streams in the urban landscape. *Annu. Rev. Ecol. Syst.* **2001**, *32*, 333–365. [CrossRef]
8. Schueler, T. The importance of imperviousness. *Watershed Prot. Tech.* **1994**, *1*, 100–111.
9. Kaiser, E.J.; Burby, R.J. Emerging state roles in urban stormwater management. *Am. Water Resour. Bull.* **1987**, *23*, 443–453. [CrossRef]
10. Gaffney, M. Containment policies for urban sprawl. In *Approaches to the Sutdy of Urbanization*; Stabuber, R.L., Ed.; University of Kansas: Lawrence, KS, USA, 1964.
11. U.S. Environmental Protection Agency (USEPA). Combined Sewer Overflows: Overview. 2010. Available online: http://cfpub.epa.gov/npdes/home.cfm?program_id=5 (accessed on 5 March 2015).
12. Dollery, B.; Marshall, N. *Australian Local Government: Reform and Renewal*; Macmillan Education Australia Pty Ltd.: South Melbourne, Australia, 1997.
13. Pyzoha, D. *Implementing a Stormwater Management Program*; CRC Press: Boca Raton, FL, USA, 1993.
14. Kaiser, E.J.; Godschalk, D.; Chapin, F.S. *Urban Land Use Planning*, 4th ed.; University of Illinois Press: Champaign, IL, USA, 1995.
15. Brody, S.D.; Highfield, W.; Carrasco, V. Measuring the collective planning capabilities of local jurisdictions to manage ecological systems in southern florida. *Landsc. Urban Plan.* **2004**, *69*, 33–50. [CrossRef]
16. Berke, P.R. Evaluating environmental plan quality: The case of planning for sustainable development in new zealand. *J. Environ. Plan. Manag.* **1994**, *37*, 155–169. [CrossRef]
17. Berke, P.R. Enhancing plan quality: Evaluating the role of state planning mandates for natural hazard mitigation. *J. Environ. Plan. Manag.* **1996**, *39*, 79–96. [CrossRef]
18. Berke, P.R.; Dixon, J.; Ericksen, N. Coercive and cooperative intergovernmental mandates: A comparative analysis of florida and new zealand environmental plans. *Environ. Plan. B Plan. Des.* **1997**, *24*, 451–468. [CrossRef]
19. Berke, P.R.; Conroy, M.M. Are we planning for sustainable development? *J. Am. Plan. Assoc.* **2000**, *66*, 21–33. [CrossRef]
20. Berke, P.R. Does sustainable development offer a new direction for planning? Challenges for the twenty-first century. *J. Plan. Lit.* **2002**, *17*, 21–36. [CrossRef]
21. Brody, S.D. Are we learning to make better plans? A longitudinal analysis of plan quality associated with natural hazards. *J. Plan. Educ. Res.* **2003**, *23*, 191–201. [CrossRef]
22. Brody, S.D. Examining the role of resource-based industries in ecosystem approaches to management: An evaluation of comprehensive plans in florida. *Soc. Natl. Resour.* **2003**, *16*, 625–641. [CrossRef]
23. Brody, S. Implementing the principles of ecosystem management through local land use planning. *Popul. Environ.* **2003**, *24*, 511–540. [CrossRef]
24. Brody, S.D.; Highfield, W.E. Does planning work: Testing the implementation of local environmental planning in florida. *J. Am. Plan. Assoc.* **2005**, *71*, 159–175. [CrossRef]
25. Burby, R. Have state comprehensive planning mandates reduced insured losses from natural disasters? *Natl. Hazards Rev.* **2005**, *6*, 67–81. [CrossRef]
26. Fu, X.; Tang, Z. Planning for drought-resilient communities: An evaluation of local comprehensive plans in the fastest growing counties in the us. *Cities* **2013**, *32*, 60–69. [CrossRef]
27. McDonald, L.; Allen, W.; Benedict, M.; O'connor, K. Green infrastructure plan evaluation frameworks. *J. Conserv. Plan.* **2005**, *1*, 12–43.
28. Norton, R.K. More and better local planning: State-mandated local planning in coastal north carolina. *J. Am. Plan. Assoc.* **2005**, *71*, 55–71. [CrossRef]
29. Talen, E.; Knaap, G. Legalizing smart growth an empirical study of land use regulation in illinois. *J. Plan. Educ. Res.* **2003**, *22*, 345–359. [CrossRef]

30. Tang, Z. Evaluating local coastal zone land use planning capacities in california. *Ocean Coast. Manag.* **2008**, *51*, 544–555. [CrossRef]
31. Tang, Z.; Lindell, M.K.; Prater, C.S.; Brody, S.D. Measuring tsunami planning capacity on us pacific coast. *Natl. Hazards Rev.* **2008**, *9*, 91–100. [CrossRef]
32. Tang, Z.; Brody, S.D. Linking planning theories with factors influencing local environmental-plan quality. *Environ. Plan. B Plan. Des.* **2009**, *36*, 522–537. [CrossRef]
33. Carlson, T.N. Analysis and prediction of surface runoff in an urbanizing watershed using satellite imagery. *J. Am. Water Resour. Assoc.* **2004**, *40*, 1087–1097. [CrossRef]
34. Highfield, W.E. Section 404 permitting in coastal texas: A longitudinal analysis of the relationship between peak streamflow and wetland alteration. *Environ. Manag.* **2012**, *49*, 892–901. [CrossRef] [PubMed]
35. Todeschini, S. Hydrologic and environmental impacts of imperviousness in an industrial catchment of northern italy. *J. Hydrol. Eng.* **2016**, *21*, 05016013. [CrossRef]
36. Du, J.; Qian, L.; Rui, H.; Zuo, T.; Zheng, D.; Xu, Y.; Xu, C.-Y. Assessing the effects of urbanization on annual runoff and flood events using an integrated hydrological modeling system for qinhuai river basin, China. *J. Hydrol.* **2012**, *464*, 127–139. [CrossRef]
37. Loh, C.G. Conceptualizing and operationalizing planning capacity. *State Local Gov. Rev.* **2015**, *47*, 134–145. [CrossRef]
38. Nelson, A.C.; French, S.P. Plan quality and mitigating damage from natural disasters: A case study of the northridge earthquake with planning policy considerations. *J. Am. Plan. Assoc.* **2002**, *68*, 194–207. [CrossRef]
39. Kang, J.E. *Mitigating Flood Loss through Local Comprehensive Planning in Florida*; Texas A&M University: College Station, TX, USA, 2009.
40. Dalton, L.C.; Burby, R.J. Mandates, plans, and planners: Building local commitment to development management. *J. Am. Plan. Assoc.* **1994**, *60*, 444–461. [CrossRef]
41. Burby, R.J.; May, P.J. *Making Governments Plan: State Experiments in Managing Land Use*; Johns Hopkins University Press: Baltimore, MD, USA, 1997.
42. Godschalk, D.R.; Brower, D.J.; Beatley, T. *Catastrophic Coastal Storms: Hazard Mitigation and Development Management*; Duke University Press: Durham, NC, USA, 1989.
43. Chesapeake Bay Program. Chesapeake 2000. Available online: http://www.chesapeakebay.net/content/publications/cbp_12081.pdf (accessed on 23 April 2015).
44. Phillips, S.W. *US Geological Survey Chesapeake Bay Studies: Scientific Solutions for a Healthy Bay and Watershed*; US Department of the Interior, US Geological Survey: Reston, VA, USA, 2006.
45. U.S. Environmental Protection Agency (USEPA). *Chesapeake Bay Health and Restoration Assessment—A Report to the Citizens of the Bay Region*; U.S. Environmental Protection Agency: Annapolis, MD, USA, 2008; Available online: http://www.chesapeakebay.net/documents/cbp_26038.pdf (accessed on 3 August 2015).
46. U.S. Geological Survey (USGS). StreamStats. Available online: http://streamstatsags.cr.usgs.gov/streamstats (accessed on 5 May 2014).
47. Brody, S.D. *Ecosystem Planning in Florida: Solving Regional Problems through Local Decision-Making*; Ashgate Publishing Company: Burlington, VT, USA, 2008.
48. Barbosa, A.E.; Fernandes, J.N.; David, L.M. Key issues for sustainable urban stormwater management. *Water Res.* **2012**, *46*, 6787–6798. [CrossRef] [PubMed]
49. Benedict, M.; McMahon, E. *Green Infrastructure: Linking Landscapes and Communities*; Island Press: Washington, DC, USA, 2006.
50. Brown, R.R. Impediments to integrated urban stormwater management: The need for institutional reform. *Environ. Manag.* **2005**, *36*, 455–468. [CrossRef] [PubMed]
51. Brown, R.R.; Keath, N.; Wong, T.H.F. Urban water management in cities: Historical, current and future regimes. *Water Sci. Technol. J. Int. Assoc. Water Pollut. Res.* **2009**, *59*, 847–855. [CrossRef] [PubMed]
52. Cettner, A.; Ashley, R.; Hedström, A.; Viklander, M. Sustainable development and urban stormwater practice. *Urban Water J.* **2013**, *11*, 185–197. [CrossRef]
53. Cheng, C.; Brabec, E.; Yang, Y.; Ryan, R. Rethinking stormwater management in a changing world: Effects of detention for flooding hazard mitigation under climate change scenarios in the charles river watershed. In Proceedings of the 2013 CELA Conference, Austin, TX, USA, 27–30 March 2013.
54. Debo, T.N.; Reese, A. *Municipal Stormwater Management*; CRC Press: Boca Raton, FL, USA, 2002.

55. McManus, R.; Brown, R. The increasing organisational uptake of source control approaches for sustainable stormwater management. In Proceedings of the 9th International Conference on Urban Storm Drainage—CD ROM, Portland, OR, USA, 30 August–3 September 2002.
56. Morison, P.J. *Management of Urban Stormwater: Advancing Program Design and Evaluation*; Monash University: Melbourne, Australia, 2009.
57. Wong, T.H. A changing paradigm in australian urban stormwater management. In Proceedings of the 2nd South Pacific Stormwater Conference, Auckland, New Zealand, 27–29 June 2001; pp. 1–18.
58. American Planning Association (APA). Policy Guide on Planning for Sustainability. Avaiable online: https://www.planning.org/policy/guides/adopted/sustainability.htm (accessed on 10 December 2014).
59. American Planning Association (APA). Policy Guide on Smart Growth. Avaiable online: https://www.planning.org/policy/guides/adopted/smartgrowth.htm (accessed on 10 December 2014).
60. American Planning Association (APA). Policy Guide on Water Resources Management. Avaiable online: https://www.planning.org/policy/guides/adopted/waterresources.htm (accessed on 10 December 2014).
61. American Planning Association (APA). Policy Guide on Wetlands. Avaiable online: https://www.planning.org/policy/guides/adopted/wetlands.htm (accessed on 10 December 2014).
62. Atlanta Regional Commission. *Georgia Stormwater Management Manual*, 1st ed.; Atlanta Regional Commission: Atlanta, GA, USA, 2001.
63. Department of Environment and Heritage Protection. *Urban Stormwater Quality Planning Guidelines*; Queensland, T.S.O., Ed.; Department of Environment and Heritage Protection: Brisbane, Australia, 2010.
64. U.S. Environmental Protection Agency (USEPA). A Handbook for Water and Wastewater Utilities. 2012. Available online: http://water.epa.gov/infrastructure/sustain/upload/EPA-s-Planning-for-Sustainability-Handbook.pdf (accessed on 2 December 2014).
65. Water Environment Research Foundation. Commonly Used Policies and Programs. Available online: http://www.werf.org/liveablecommunities/toolbox/policies.htm (accessed on 6 January 2015).
66. Freelon, D.G. Recal: Intercoder reliability calculation as a web service. *Int. J. Internet Sci.* **2010**, *5*, 20–33.
67. Berke, P.; Godschalk, D. Searching for the good plan: A meta-analysis of plan quality studies. *J. Plan. Lit.* **2009**, *23*, 227–240. [CrossRef]
68. Miles, M.B.; Huberman, A.M. *Qualitative Data Analysis: An Expanded Sourcebook*; Sage: Thousand Oaks, CA, USA, 1994.
69. Acock, A.C. *A Gentle Introduction to Stata*, 3rd ed.; Stata Press: College Station, TX, USA, 2010.
70. Nunnally, J.C. *Psychometric Theory*, 2nd ed.; McGraw-Hill: New York, NY, USA, 1978; Volume 226.
71. U.S. Geoglogical Survey (USGS). National Land Cover Database. 2011. Available online: http://www.mrlc.gov/nlcd11_leg.php (accessed on 11 January 2015).
72. Homer, C.; Huang, C.; Yang, L.; Wylie, B.; Coan, M. Development of a 2001 national land-cover database for the united states. *Photogramm. Eng. Remote Sens.* **2004**, *70*, 829–840. [CrossRef]
73. Environmental Systems Research Institute (ESRI). *ArcGIS*; version 10.3; GIS Software; Environmental Systems Research Institute (ESRI): Redlands, CA, USA, 2014.
74. Beyer, H.L. Geospatial Modelling Environment, Version 0.5.2 (Software). 2010. Available online: http://www.spatialecology.com/gme (accessed on 11 March 2014).
75. National Hydrography Dataset (NHD) Plus. Dataset. U.S. Environmental Protection Agency. Available online: http://www.horizon-systems.com/NHDPlus/index.php (accessed on 4 April 2014).
76. U.S. Department of Agriculture (USDA). GeoSpatial Data Gateway Dataset. Available online: https://gdg.sc.egov.usda.gov (accessed on 10 June 2014).
77. Federal Emergency Management Agency (FEMA). Flood Map Service Center Dataset. Available online: https://msc.fema.gov/portal (accessed on 18 May 2014).
78. U.S. Department of Agriculture (USDA). Web Soil Survey. Available online: http://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx (accessed on 20 June 2014).
79. Brody, S.D.; Zahran, S.; Highfield, W.; Grover, H.; Vedlitz, A. Identifying the impact of the built environment on flood damage in texas. *Disasters* **2008**, *32*, 1–18. [CrossRef] [PubMed]
80. Zahran, S.; Brody, S.D.; Peacock, W.G.; Vedlitz, A.; Grover, H. Social vulnerability and the natural and built environment: A model of flood casualties in texas. *Disasters* **2008**, *32*, 537–560. [CrossRef] [PubMed]

81. Laurian, L.; Crawford, J.; Day, M.; Kouwenhoven, P.; Mason, G.; Ericksen, N.; Beattie, L. Evaluating the outcomes of plans: Theory, practice, and methodology. *Environ. Plan. B Plan. Des.* **2010**, *37*, 740–757. [CrossRef]
82. Laurian, L.; Day, M.; Berke, P.; Ericksen, N.; Backhurst, M.; Crawford, J.; Dixon, J. Evaluating plan implementation: A conformance-based methodology. *J. Am. Plan. Assoc.* **2004**, *70*, 471–480. [CrossRef]
83. Stevens, M.R.; Lyles, W.; Berke, P.R. Measuring and reporting intercoder reliability in plan quality evaluation research. *J. Plan. Educ. Res.* **2014**, *34*, 77–93. [CrossRef]
84. Brody, S.D.; Zahran, S.; Maghelal, P.; Grover, H.; Highfield, W.E. The rising costs of floods: Examining the impact of planning and development decisions on property damage in florida. *J. Am. Plan. Assoc.* **2007**, *73*, 330–345. [CrossRef]
85. U.S. Environmental Protection Agency (USEPA). Reducing Stormwater Costs through Low Impact Development Strategies and Practices. 2007. Available online: http://water.epa.gov/polwaste/green/upload/2008_01_02_NPS_lid_costs07uments_reducingstormwatercosts-2.pdf (accessed on 19 March 2015).