MAUKA TO MAKAI: FROM THE MOUNTAINS TO THE SEA

Reducing Stormwater Runoff Pollution in Maunalua Bay, O'ahu, Hawai'i

Natalie Dornan | Eléonore Durand | Erica Johnson | Tara Jagadeesh

ABOUT OUR PROJECT

Urbanization has severely altered the natural hydrology of many watersheds globally. A topic of contemporary interest in watershed management is reducing the amount of polluted stormwater runoff that enters streams and oceans. This phenomenon is worsened in watersheds with short and steep drainage basins and flashy precipitation, such as those in the Hawaiian Islands. Stressors including stormwater pollution have negatively impacted the physical environment and biological community structure in Maunalua Bay [1] (Figure 1). Fine sediments are particularly damaging to reefs [1, 2], as they are carried with high peak flows of stormwater [3, 4] and transported over impervious surfaces. To better understand how to reduce stormwater pollution in the Maunalua Bay region, we prepared the Environmental Protection Agency’s Storm Water Management Model (SWMM) 5.1 [5] for a representative watershed: Wailupe watershed.

PROJECT OBJECTIVE

Develop a model using the Environmental Protection Agency’s Storm Water Management Model 5.1 to facilitate identification of "hotspot" areas that contribute higher stormwater pollution relative to surrounding areas in the Maunalua Bay Region.

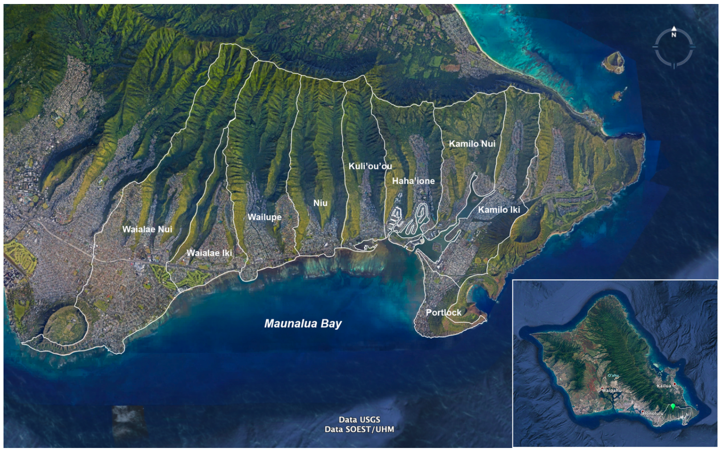
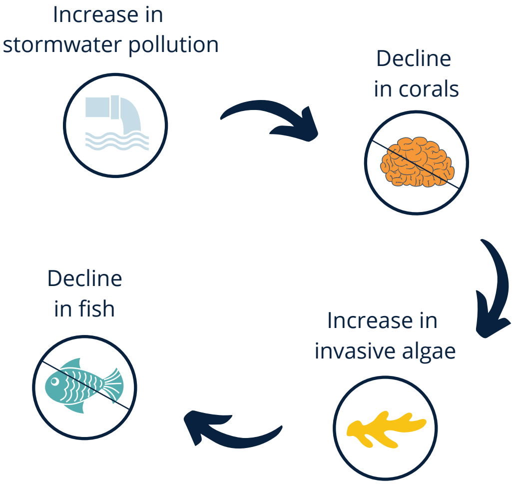


Figure 1. The Maunalua Bay Region, Oʻahu, Hawaiian Islands, U.S.A. Data provided by the U.S. Geological Survey and the University of Hawaiʻi at Mānoa School of Ocean, Earth, Science, and Technology (SOEST).



Increase in stormwater pollution

Decline in corals

Increase in invasive algae

Decline in fish

Figure 2. Diagram of ecological impact of stormwater pollutants

APPROACH

1. Characterize data availability and limitations for each of the 10 watersheds in the region

2. Delineate a representative watershed into subcatchments using the heterogeneity of the natural and built environment

3. Use a hydrologic model, SWMM 5.1 to obtain a baseline estimate of runoff pollutant loading in the chosen watershed

4. Identify hotspot subcatchments that contribute higher total flow volume or peak flow relative to other subcatchments.

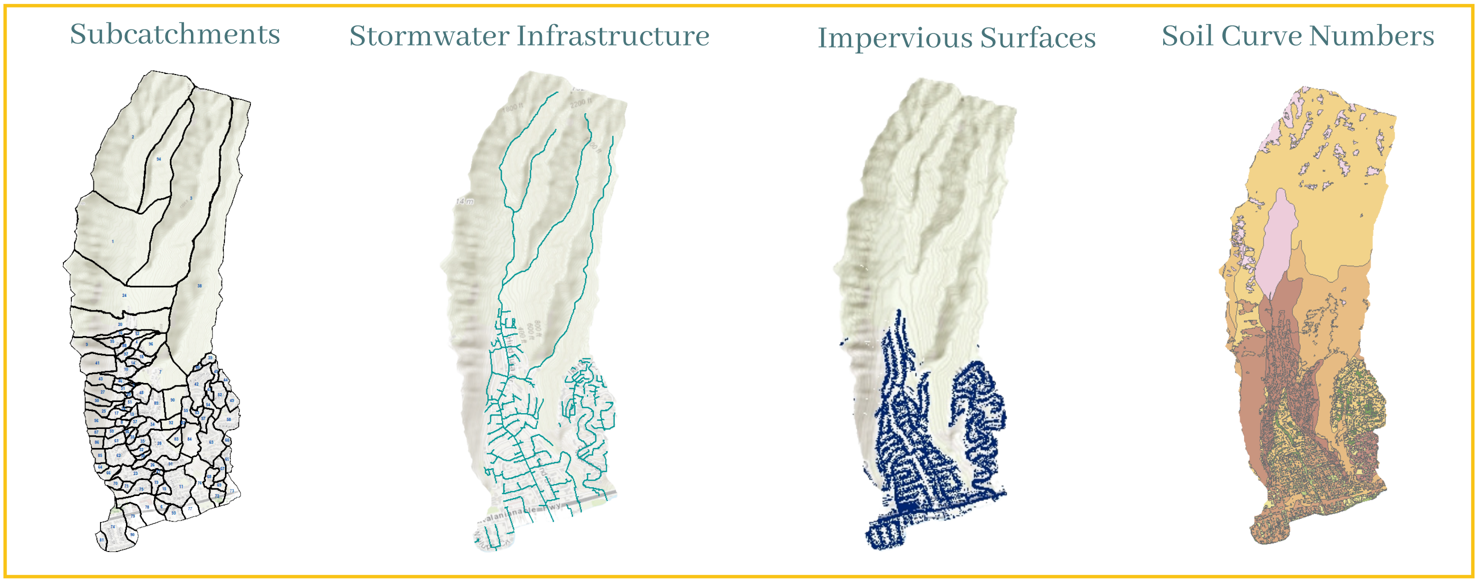


Figure 3. Primary data layers for Wailupe watershed for input in the SWMM 5.1 model.

To estimate runoff and identify hotspots, we delineated the representative Wailupe watershed into subcatchments and compiled stormwater infrastructure, impervious surface, and soil curve numbers data (Figure 3).

MODEL ACCURACY

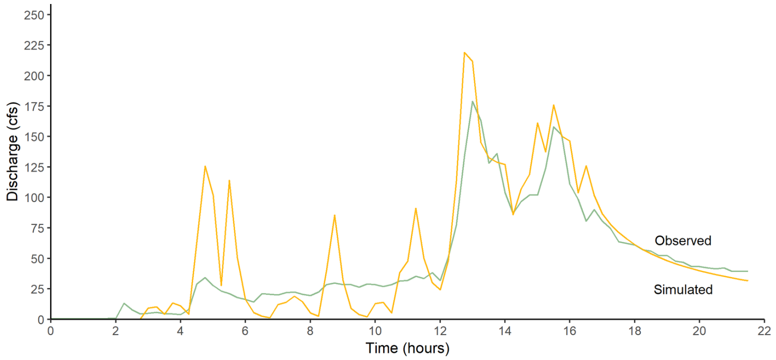


Figure 4 .Simulated vs. observed discharge (cfs) for December 2010 storm

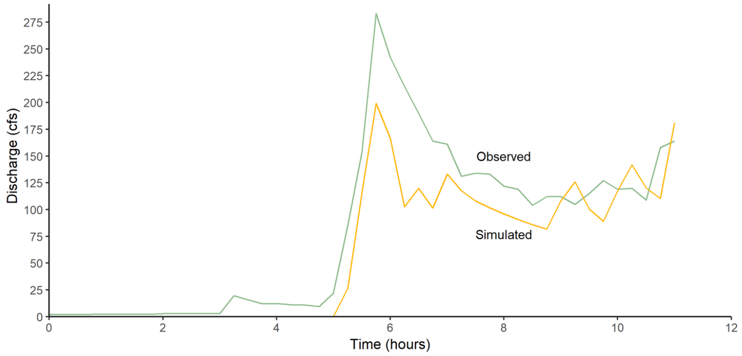


Figure 5 .Simulated vs. observed discharge (cfs) for March 2009 storm

We chose two storm events for simulations in SWMM 5.1: one was a 21-hour storm which took place on December 19th, 2010 and the other was an 11-hour storm which took place on March 14, 2009 [6]. The model was assessed using the coefficient of determination (R2) and the Nash-Sutcliffe model efficiency coefficient (NSE). An NSE between 0.5 and 1 indicates a valid hydrologic model [7]. December 19, 2010 Simulation Performance: 0.80 R2 ; 0.65 NSE; -24% Peak simulated discharge (Figure 5). March 14, 2009 Simulation Performance: 0.89 R2; 0.80 NSE; -24% Peak simulated discharge. Simulated runoff displays more pronounced peaks due to limited rainfall data in the upper watershed and limited groundwater data to generate baseflow.

MAIN FINDINGS

1 Positive Linear Relationship Between Urbanization and Runoff

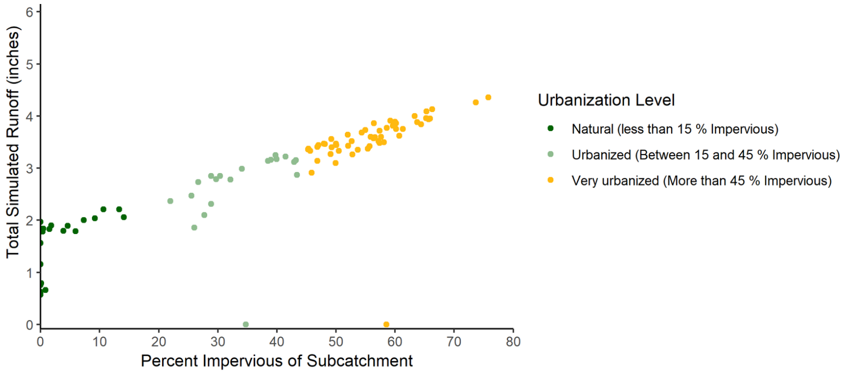


Figure 6. Total runoff (inches) by percent impervious cover for Dec 2010 storm

Our model shows a clear positive linear relationship between the increasing urbanized (impervious) land cover in a subcatchment and simulated runoff. The more urbanized an area, the more runoff it contributes. As such, our model is useful to identify spatial distributions of runoff and the associated hotspot locations.

2 Stormwater Volume Hotspots

Top 20 hotspot subcatchments were determined by overlaying subcatchments with relatively high runoff rations (0.64-0.80) from the two storm events. All hotspots are located in the urban watershed within predominantly residential areas with impervious surface cover greater than 50%.

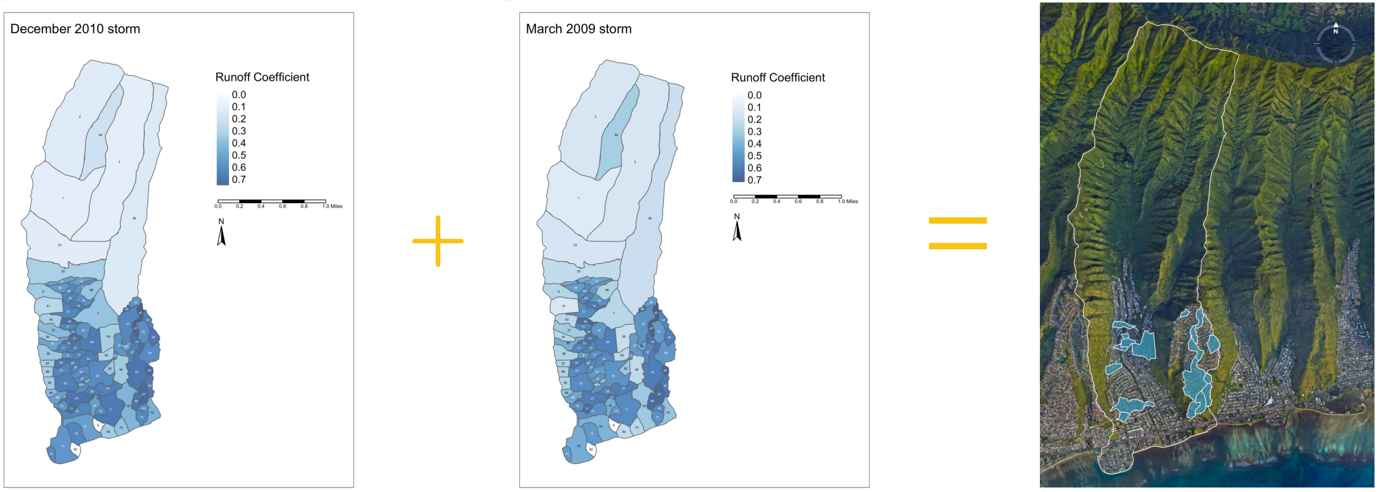


Figure 7. Diagram representing determination of top 20 subcatchments for total stormwater volume runoff. The runoff coefficient is a ratio of how much precipitation becomes runoff. The top 20 contributing subcatchments for both storm were overlayed to produce the final hotspot map.

3 Peak Flow (Sediment) Hotspots

Top 20 hotspot subcatchments for peak flow were determined by overlaying subcatchments with relatively high peak flows (13 - 92 cfs) for the two storm events. Hotspots occur in the upper watershed due to steep slope (~25% or more), and in the urban watershed due to high impervious cover (~45% or more).

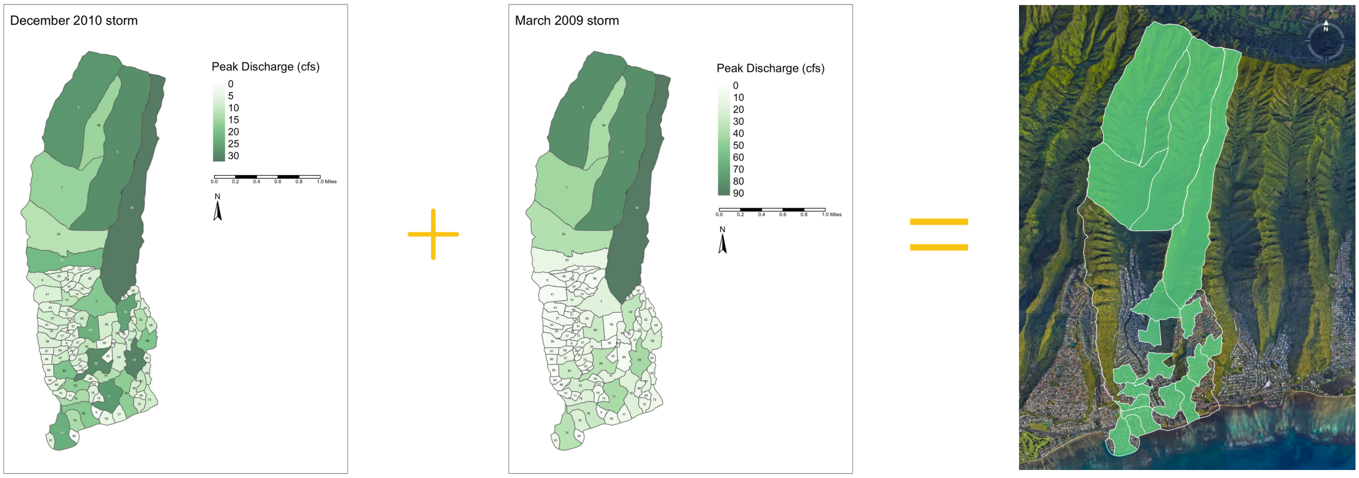
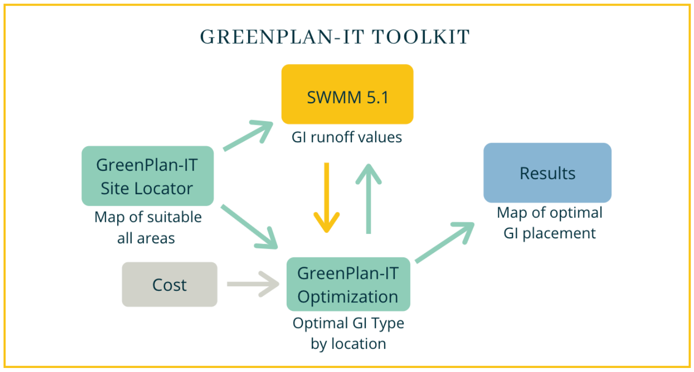


Figure 8. Diagram representing determination of the top 20 subcatchments for peak flow. The top 20 contributing subcatchments for both storm were overlayed to produce the final hotspot map.

RECOMMENDATIONS

1 Stormwater Volume

Explore the viability of strategically-placed green infrastructure that will increase infiltration of stormwater and sediments into natural soils. To do this, pair the model with a tool such as the San Francisco Estuary Institute's GreenPlan-IT Toolkit to evaluate viable green infrastructure placement by location and cost [8]. The SWMM model will then quantify reductions in stormwater runoff and sediment loading from hotspots.



GREENPLAN-IT TOOLKIT

SWMM 5.1

GI runoff values

GreenPlan-IT Site Locator

Map of suitable all areas

Cost

GreenPlan-IT Optimization

Optimal GI Type by location

Results

Map of optimal GI placement

Figure 9. Diagram of how to pair GREENPLAN-IT with SWMM results

2 Peak Flow (Sediments)

Decrease overall sediment at the source by implementing erosion control measures for mass wasting areas in the upper watershed. If not reduced at the source, sediments can also be captured en-route to the ocean. Prioritize green infrastructure that provides sediment control, such as bioretention cells or permeable pavement, and pair them with other infrastructure such as sediment detention basins.

Figure 10. Photo of heavy sediment erosion, called mass wasting area

3 Regional Strategy

Use the model as part of a regional strategy to prioritize hotspot subcatchments for the remaining watersheds with viable data in the bay. Involve the community and other stakeholders in an informed decision making process based on results from the model, tools, and ground truthing.

ACKNOWLEDGEMENTS

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