Modeling Flooding Regime and Temporal Dynamics for Riparian Forest Wetland Restoration in an Urban Landscape

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ABSTRACT

Landscape changes in urbanizing watersheds can substantially alter stream hydrology, which have significant implications for flooding regimes of riparian systems. We examined the historical steam flow (1969-1979 and 1989-1999) in Rowlett Creek based on data from a nearby USGS gauging station and associated flooding regimes in a proposed riparian forest wetland restoration site. Flooding frequency has increased significantly over the three decades. A simulation model was developed to assess the hydrology of the restoration site for developing and evaluating alternative designs. In anticipation of the uncertainty in the flooding regime, the design of the restoration incorporated topographic variations at multiple scales with ridges, bottomland with mound-and-pool structures, sloughs, and an oxbow lake. Simulation studies were conducted with alternative inflow/outflow controls. Frequency distributions of areas on bottomland and ridges under different flooding regimes (frequency and duration) were generated and used to evaluate alternative strategies for planting combinations of tree species with different flood tolerance levels.

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INTRODUCTION

Bottomland hardwood forests provide essential functions that are vital to the health of ecosystems. Successful restoration and creation of these wetlands is imperative as 63% of bottomlands have been lost in the Lower Mississippi Alluvial Valley since European colonization. However, many restoration attempts fail because of a lack of understanding of the most important component of wetlands—the hydrologic regime.

Hydrologic characteristics of bottomlands include a relatively dry growing season and wet non-growing season. Bottomlands are located within river floodplains (Fig. 1) and receive the majority of their water inputs as floodwaters rise during winter and spring storms. The implications of the timing and duration of flooding events are key as prolonged flooding during the growing season may increase the mortality of tree species less tolerant of flooding.

As urbanization increases, hydrology of the area invariably changes. This changing hydrology may alter the functions and structure of wetlands located within the urban environment over time. Understanding of the changing hydrology and quantification of its effects on riparian systems are essential to successful restoration of long-lived forested wetlands.

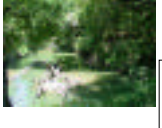

Fig. 1. Bottomland hardwood forest (L) and Rowlett Creek (R) located north of Dallas, TX.

OBJECTIVES

The purposes of the study were to quantify, through simulation modeling, the hydrologic regimes at a riparian forest wetland restoration site with respect to flooding frequency and duration, and to evaluate the impact of urbanization on the hydrologic regime based on stream hydrologic records of 1970's and 1990's.

STUDY SITE

The study site is located in Garland, Texas, Dallas County, on a 31 ha borrow pit adjacent to the Castle Drive Landfill (Fig. 2). The landfill has reached capacity, and the city is in the process of restoring/reclaiming the land impacted by the landfill. Rowlett Creek, which flows along the eastern border of the borrow pit, will supply the flooding water needed to restore the wetland. Dominant vegetation along Rowlett Creek and in bottomlands in the region include pecan (*Carya illinoensis*), elms (*Ulmus* spp.), and sugarberry (*Celtis laevigata*). Average annual precipitation is 89 cm with a mean annual temperature of 18ºC.

Fig. 2. Location of Castle Drive Landfill (L) and the borrow pit (R).

METHODS

1) A conceptual design and digital model of the wetland was created using ArcInfo.
   - Contour lines of the wetland were delineated based on the design of the oxbow, sloughs and ridges (Fig. 3).
   - The ArcInfo command TOPOGRID was used for spatial interpolation to create a digital elevation model (DEM, Fig. 3) for the site.
   - The DEM was analyzed to determine flooding area and volumetric relationships.
2) A simulation model was developed in Stella® (Fig. 3) to quantify the flooding regimes of the proposed wetland and evaluate the effects of control structure and changing stream hydrology for developing restoration strategies.
   - Simulations based on gauging station data from the 1970's (10/1/69 to 9/30/79) and 1990's (10/1/89 to 9/30/99) were conducted using the Stella® model to evaluate the effect of changing stream hydrology on wetland flooding regime.
   - Two heights (2.1 m and 2.7 m from the creek bottom) of the inlet and outlet structures were use in simulations to examine their effects on flooding regime in response to the changing stream hydrology.

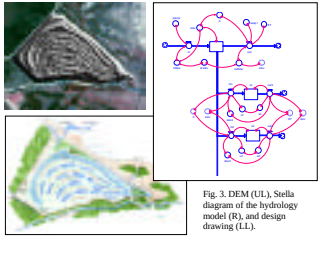

Fig. 3. DEM (UL), Stella diagram of the hydrology model (R), and design drawing (LL).

RESULTS

Figs. 4, 5

1. Both flood frequency and duration for the simulated wetland were higher during the 1990s than 1970s regardless of weir height.
2. Frequency of low (water) level flooding decreased and that of high (water) level flooding increased in the wetlands from the 1970's to 1990's; this change was more consistent during the growing season than non-growing season.
3. Flooding frequency decreased and duration increased with increasing weir level (from 2.1 m to 2.7 m) in both the 1970's and 1990's. The decrease was more pronounced in the flat bottom and ridge top than in the slough and ridge slope portions of the wetland.
4. Average water level in the wetlands was significantly higher when using a higher weir in both the 1970's and 1990's. For the 1990's, the average water level in the wetland was 20cm higher (P<0.001) when the higher weir was used.

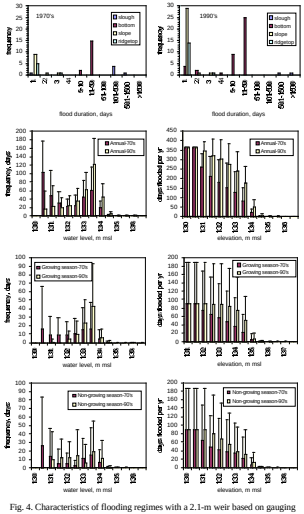

Fig. 4. Characteristics of flooding regimes with a 2.1-m weir based on gauging station data from the 1970's and 1990's.

CONCLUSIONS

1. As a consequence of urbanization in the watershed, significant changes have occurred from the 1970's to 1990's in stream hydrology, which has important implications in the flooding regimes of riparian wetlands.
2. High weir structure will result in fewer floods and less floodwater entering the wetland, compared to a low wire structure; it will, however, increase the flood duration and water level by retaining more water in the wetlands after flood events.
3. The effects of changing stream hydrology and that of different weir structures on wetland flooding regimes were complex with considerable spatial and temporal variations. Simulation modeling is an effective approach for quantifying the spatial and temporal dynamics of the flooding regimes and provide a basis for formulating restoration strategies such as species composition and spatial patterns of planting regimes.
4. Simulation models provide an effective method for evaluating the flooding dynamics of a wetland restoration site. Decisions regarding placement of inlet and outlet structures, as well as planting regimes based on known species water tolerance levels, can be based on results of model simulations coupled with field data.
5. Urbanization may continue to change the hydrologic regime of the system. Information on anticipated changes in stream hydrology would be helpful in the design of riparian wetland restoration. Sufficient extent and spatial variation in elevation within restored wetlands, as well as the ability to adjust the weir structure, can help improve the long-term success of the restored riparian-forested wetlands.

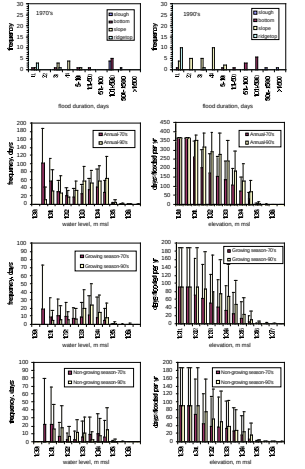

Fig. 5. Characteristics of flooding regimes with a 2.7-m weir based on gauging station data from the 1970's and 1990's.