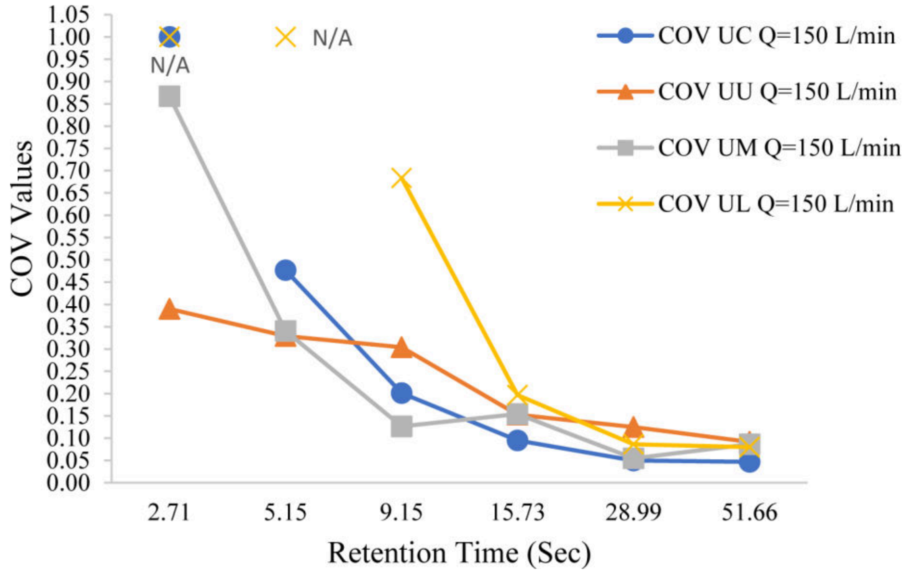

Fig 4.COV values for injection at upper-wall, Q=150 L/min, v=1.0 fps

By comparing the results in figure 4, it can also be seen that producing a homogeneous mixture requires more retention time if the injection and sampling are at the upper-wall, than the situation where injection is at upper-wall and samples are collected from the bottom of the pipe. The results in figure 4 shows that in all conditions but one condition (UC), all stations have COVs higher than 0.05 except for stations 5 and 6.

The procedure for 2.0 fps was the same as lower velocity. The flow range of the main stream changed between 297.5-306.0 L/min in all steps. The salt water was being injected with the flow rate of 6.98 mL/min to the centerline of the pipe and the target concentration of the mixed flow rate was expected to be 12.11 mg/L of TDS higher than the background value. The results are presented in figures 5 for COV values.

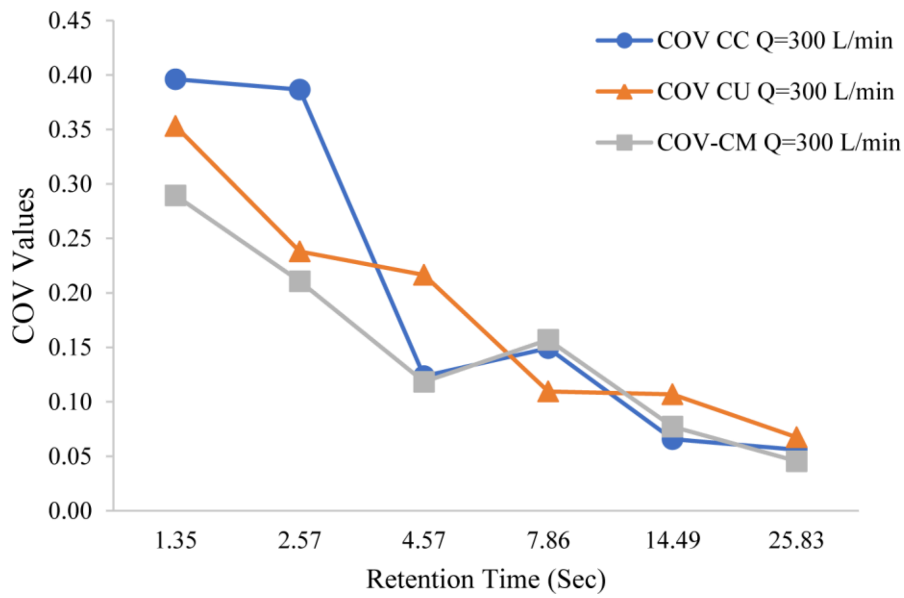

Fig 5.COV values for centerline injection, Q=300 L/min, v=2.0 fps

By comparing the results from figures 3 and 5 it can be seen that the effect of higher

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turbulence, lowers the retention time to its half in order to get almost the same COV values.

The results for injection at upper-wall of the pipe for flow rate equal to 300 mL/min are shown in figure 6.

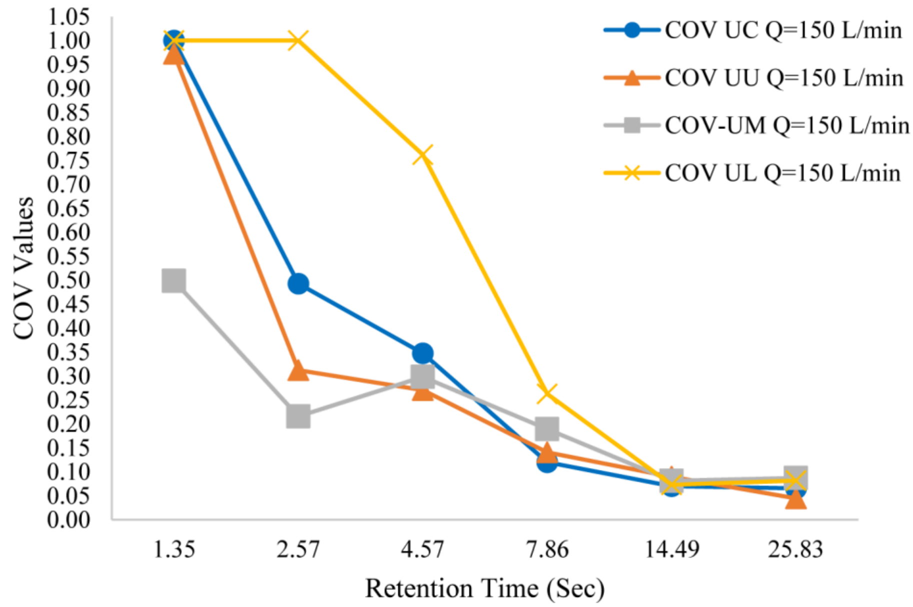

Fig 6.COV values for injection at upper-wall, Q=300 L/min, v=2.0 fps

It can be seen in figure 6 that only for UU condition at 2.0 fps, COV value is less than 0.05 for the 6th station, which is the indication of a proper mixing.

It was figured out that at lower flow rates, less traces of salt was being observed for upper-wall injection and with higher flow rates, more traces of salt was observed. Therefore, for cases that lower velocities did not lead to proper mixing, the experiment was done with higher velocities. A comparative result is presented in figure 7 for UL and UC condition, at first and second stations with different velocities of 1,2, 4 and 8 fps.

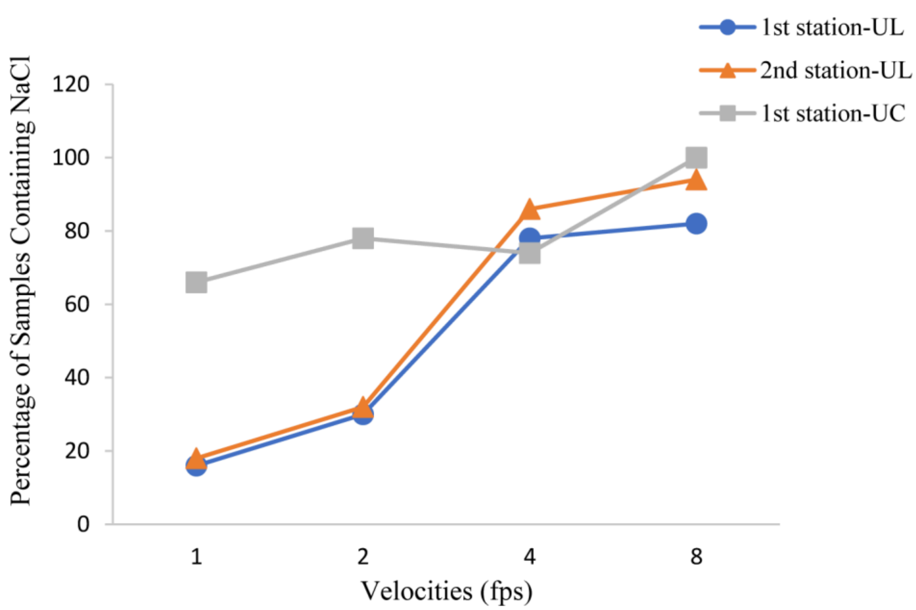

Fig 7. Percentage of salt observed for different velocities

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CONCLUSION

Water treatment plants that use chloramines as their secondary disinfectant, add certain amount of chlorine and ammonia under various conditions. The added chemicals go through a reaction to form chloramines. Enough contact time and distance between the chemicals is required to improve chloramine formation. The target product of the reaction between chlorine and ammonia is monochloramine. Among all the conditions that affect a better formation of monochloramines mixing was investigated in this study. For this purpose, a stream of salt water was injected to a 4.0 inch pipeline at different flow rates. The injection flow rates were the same as what is commonly used in treatment plants and NaCl was used as the tracer salt and its conductivity was measured throughout the pipe. The velocity of the water in the 4.0 inch pipeline was increased through the experiment to investigate effect of turbulent on chemical mixing in the pipeline. The injections were done at the centerline and upper-wall of the pipeline. Six points at different distances from injection point were chosen as sampling stations. Samples were collected at centerline, upper-wall and half the distance between upper-wall and centerline. Coefficient of variation and intensity of segregation were calculated to measure complete mixing in the pipeline. It was concluded that a 60 ft of straight pipe is enough to achieve mixing even with the lowest flow rate. Most of the mixing was done at station 5 which was 30 ft from injection point. It was observed for all conditions COV values decreases with distance from the injection point. Overall, according to the data it is recommended for the plants to focus more on the centerline injection. However, it was observed that increase in the flowrate guides the salt flow to further directions in the cross section of the pipe. In the upper-wall injection condition, the number of samples containing NaCl were low, but as the flow rate increased, more traces of NaCl were seen in the collected samples in the first two stations. The percent of samples with traces of salt increased by 34% for centerline sampling and it increased from 16% to 82% for lower wall sampling in the first station and from 18% to 94% in the second station. This increase shows that the strength of turbulent field is a greater factor than the retention time in the pipeline.

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A New Perspective on BMPs' Application for Coastal Flood Preparedness

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ABSTRACT

Increasing vulnerability of societies in coastal areas, particularly in the east coast of the United States, has increased the attention to flood management issues by many investigations. In this study, the ideas generated for the aftermath of Superstorm Sandy in a national competition entitled Rebuild by Design have been evaluated utilizing best management practices (BMPs). Task one in this regard is to analysis flood data. The impact of storm surges on coastal infrastructures is a major threat for functioning of coastal cities. So it is necessary to provide a systems' approach to set strategies to improve the performance of the elements of a system such as waste water treatment facilities. Then the reliability index is used to determine systems' functioning by load and resistance methods utilizing a multiple criteria decision making (MCDM) techniques. After that, adaptive strategies are suggested to reduce the load. Performance index for these categories is defined considering related criteria and sub-criteria. The efficiency of a selected BMP as a multilayer levee is also evaluated. Finally, a conceptual design has been introduced to make the proposed structures more reliable for flood risk management. The methodology outlined in this paper can be utilized for other urban coastal settings to plan for flood preparedness.

Keywords: Flood Adaption, Surge Modeling, MCDM, Reliability Analysis, Conceptual Design

INTRODUCTION

To implement a framework for upgrading waste water treatment plants' (WWTP) system performance, reliability index is utilized to measure the state of preparedness of these facilities. To aim this, four aspects have been studied in this paper including flood hazard identification, system performance index, flood adaptive strategies such as BMPs and their conceptual design.

Natural hazard and climate risk mapping are important parts of management strategies for populated urban area. In order to develop cities, enhancement of current situation, increasing people awareness of probable risks, and evacuation zone identification, flood inundation maps are crucial. In this study, flood inundation map has been implemented by Gridded Surface-Subsurface Hydrological Analysis (GSSHA). GSSHA is a physical distributed model which aims to simulate the hydrological processes of watershed (Downer and Ogden, 2004). Flood mapping analysis has been utilized for vulnerability analysis of study area by Karamouz et, al. (2017,a) to

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consider simultaneous impacts of inland and coastal flooding for different flood scenarios. Stefanidis and Stathis (2013) have used the Analytical Hierarchy Process (AHP) and Geographical Information Systems (GIS) jointly in order to assess flood hazard by defining flood hazard indexes based on either on natural or anthropogenic factors.

Karamouz, et. al. (2017,b) have assessed the state of WWTPs and evaluated WWTPs' performance by reliability index. Niku et. al. (1979) have tried to analyze uncertainties and their effects utilizing probabilistic methods and proposed reliability model to calculate a WWTP performance.

Kenyon (2007) has defined criteria for the evaluation of flood risk management strategies. These criteria are flood, economic features including tourism, maintenance, jobs and industry, environmental features such as nature, social aspects as looks, practicality, safety, social, and cultural. Vis et al. (2003) have made a comparison between the current flood risk management policy in the Netherlands including a resistance strategy to prevent flooding by raising the dikes, and resilience strategies to minimize the consequences of these floods, allowing some flooding. David A. Jaffe et al. (2007) have considered an engineered levee breach as a measure to mitigate flood and examine the design attribute of the optimal levee breach. Flood control command system, flood hazard mapping and flood-reduction in urban underground space have been stablished as non-engineering systems by Liu et al. (2014). Rebuild by design (RBD, 2014) is a competition which had been started in 2013 after superstorm Sandy consisting 10 teams of engineers, landscape architects and experts in different fields. Their purpose was to find solutions that are applicable not only to the flood control infrastructures during the extreme events but also during the normal weather conditions.

What today is often called a natural disaster is mainly the result of massive engineering failures. By all expert accounts, the failures of levees and floodwalls during Katrina are considered to be the worst engineering disaster in the history of the United States. In other words, the surge gained its entrance permission to the developed areas by overtopping the levees designed to resist it. Professional independent reviews and the U.S. Army Corps of Engineers itself have attributed the flooding of New Orleans to mistakes in levee design and construction, stretching back over decades and under the supervision and control of the federal government (Verchick, 2010).

This study would attempt to present a new perspective in the design of levees so that they could be accredited as reliable structures for flood protection. To do this, the physical exposure to geographic hazards should be minimized by preserving natural buffers against them and integrating those buffers into artificial systems like levees.

CASE STUDY

Coastal zones are one of the most flood susceptible areas due to their exposure to coastal flooding. With a population of 8'537'673, large number of underground systems and infrastructures, and many vital facilities located on the edge of it, New York City is one of the most vulnerable places in the world. Manhattan, Brooklyn, Queens, Bronx and Staten Island are the five precincts of New York city which have each periodically faced flood-related catastrophes. Due to its local topography, dense urban development patterns and aging sewer system, Bronx city with a land area of 109 km^2 and a population of 1'455'720 is the focus of this study. Bronx city is located at The Bronx River watershed in the northernmost part of NYC. The River starts from West Chester and ends up in Long Island after flowing through southeast in a path approximately 39 km long. Map of Bronx city and location of Hunts point WWTP is

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represented in Figure 1. The hydrological storm surge data has been obtained by historical data indicated in Table 1. For identification of the spatial and physical characteristics of the basin, digital elevation model (DEM) with 10*10 resolution, land use map and soil map (USDA, 2017) of the region have been obtained respectively.

Table 1- Historical data of study region

Station name	Data	Longitude (W)	Latitude (N)	Record period (Year)	Source
Kings point (1998-2017)	Water level	73°45.8′	40° 48.6′	19	NOAA (2017a)
Willets point (1946-2000)	Water level	73°46.9′	40°47.6′	54	NOAA (2017b)

(a) (b)

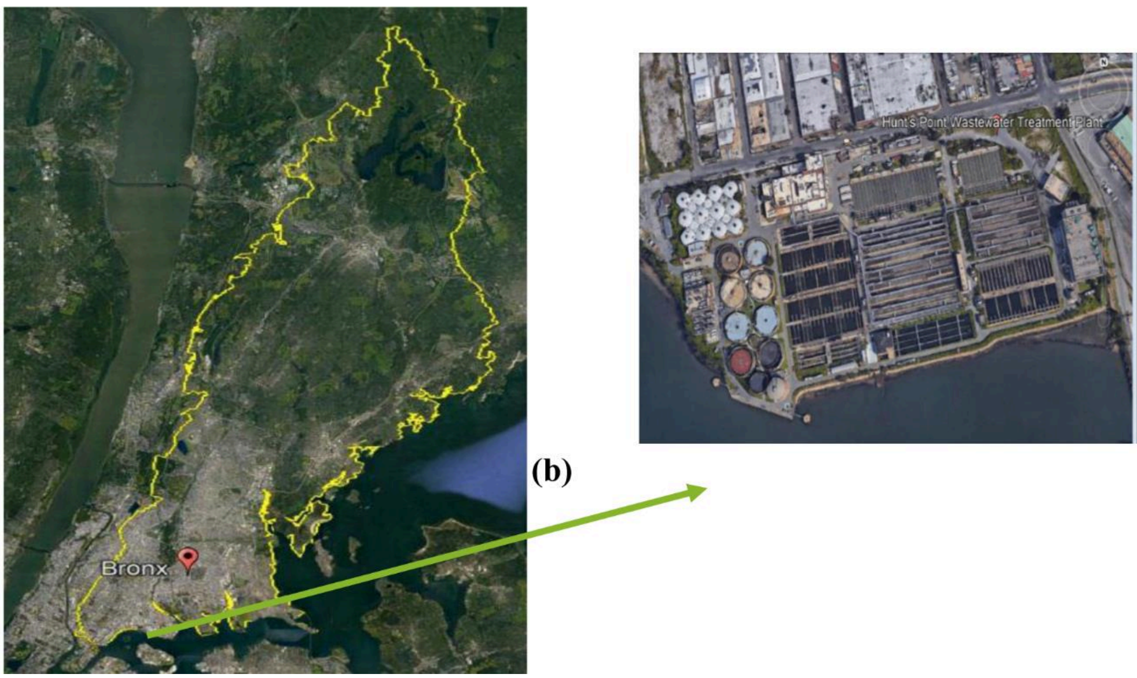

Figure 1- Map of Bronx city (a) and Hunts Point's WWTP(b)

METHODOLOGY

In order to implement a framework to upgrade system performance, reliability index is utilized to measure the state of preparedness of WWTPs. The first step is understanding the flood hazard by application of flood inundation maps. The principle objective of this paper is the development of a framework of combined structural and nonstructural/operational approaches (BMPs) to enhance system performance. To achieve this, effective factors on reliability of WWTPs are recognized and quantified before and after BMPs' application Figure 2 shows a flowchart for the steps taken to reach the overall objective.

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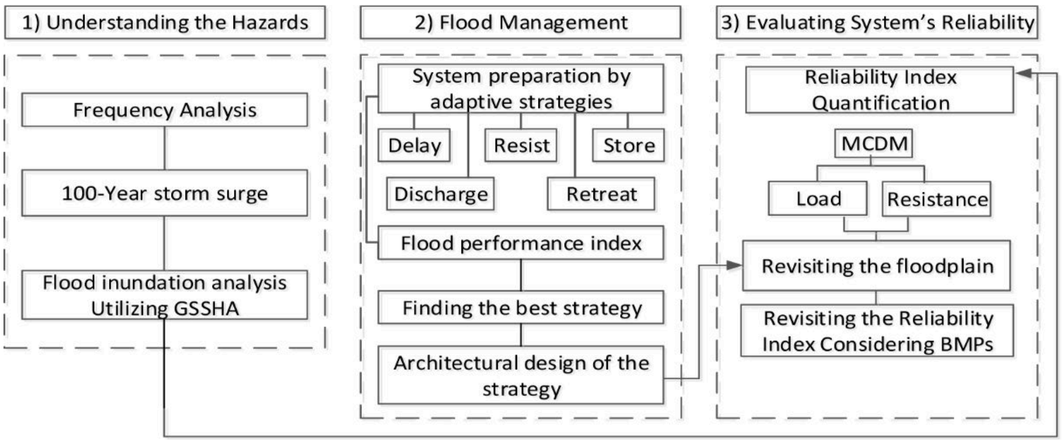

Figure 2- The framework of BMPs' Application for Infrastructures Preparedness

Flood inundation map modeling by GSSHA

The GSSHA model employs the diffusive wave approximation of saint-venant equation to calculate the overland flow from each grid cell into two orthogonal directions. One of the numerical methods in GSSHA model is Alternative Direction Explicit (ADE) which has been used in this study. To simulate the infiltration the Green-Ampt model has been applied in the model considering relevant soil type parameters based on soil map. In this study evaporation has been assumed to be negligible.

Quantification of system's performance

The load and resistance concept is based on reliability analysis. In this study, system performance is analyzed by calculating the reliability in different situations. To do this, load and resistant index has been obtained by MCDM approaches. For load index coastline exposure, accessibility, water level of most Historical Flood, maximum inundation depth, additional load during flood, population served, and initial quality of runoff are sub-criteria. For resistance index function of screen, grit chamber, primary and final sedimentation pump, aeration tank, chlorine tank, bypass channel, main swage pump are sub-criteria which are demonstrated in Table 2 and 3. They are weighted using Analytic Hierarchy Process (AHP) and an MCDM approach called Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) has been utilized. (For more information about PROMETHEE refer to Karamouz et al, 2016).

Table 2- Criteria and sub criteria for Load index

Load index											
Force										Demand load	
Hydrological		Water Quality					Exposure				
Maximum Inundation Depth	Water Level of Most Historical Flood	Concentration of Entrance BOD	Concentration of Entrance COD	Concentration of Entrance TSS	Concentration of Entrance TN	Concentration of Entrance TP	Direct Exposure to Sea	Flooded road		Population served	Additional load During flood

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Table 3- Criteria and sub criteria for resistance index

Resistance Index	Structural								
	Main Equipment							Auxiliary Equipment	
	Initial Treatment			Secondary Treatment		Final Treatment			
	Screen	Secondary Screen	Primary Sedimentation Pond	Aeration Tank	Chlorine Contact Tanks	Secondary Sedimentation Pond		Main Swage Pump	Bypass Channel
	Non-structural								
	Natural				Management			Human Based	Redundancy
	Vegetation	Elevation Above The Sea Water Level	Distance from the Sea	Natural Topography of The Treatment Plant Site	Ability to Protecting Vital Structures Against Flood	Percent of Not at Risk Vital Structure	Additional Storage Capacity	Number of Staff	Distance to The Nearest WWTP

Flood management strategies

Flood management strategies have been divided in 5 main categories, namely resist, delay, discharge, store and retreat. In order to find the PROMETHEE index for each practices of resist, delay, discharge, store and retreat, certain factors have been identified including hazard mitigation, structural reliability, adaptability, aesthetic-tourism-recreation, recovery and maintenance, capital cost, degree of enhancement, ecological and water quality impact and ease of execution. First, weight of each factor has been obtained by AHP. After that value of each factor has been gathered by expert judgment and filling questionnaires. Then values and weights are giving to PROMETHEE to find the final index. Finally, the resist strategy has the bigger value than other strategies. For this strategy a multi- layered levee as an effective BMP is chosen.

Conceptual design

Conceptual design is basically the first phase of any design process in which a final outline of the out coming effects and their pros and cons, is articulated. In this study, a set of integrated ideas and concepts about what the objective is, what the proposed design should do, how it should behave and look like in a way that brings adaptability, applicability, and effectiveness at the same time, is considered based on the selected strategy.

Among the resist category, Multi Layered Levee (MLL) has been chosen to identify its effects on flood plain and WWTP's reliability. According to spatial limitations that the area has, a vertically multi-layered levee is proposed which would improve typical levee designs, limit

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