Study for the Proper Management of Rainwater Withing the Mexican Water Technology Institute

Rodrigo Santos-Tellez(✉), Oscar Llaguno Guilberto, Manuel Rodriguez Varela, and Manuel Figueroa Mendiola

Urban Hydraulics Department, Mexican Institute of Water Technology, Jiutepec, Morelos, Mexico
rodrigo_santos@tlaloc.imta.mx

Abstract. The Mexican Water Technology Institute (IMTA) is located at the meeting point of two streams that tend to saturate and overflow during the rainy season. Several flooding incidents have taken place throughout past decades resulting in complications for the IMTA and surrounding zones. This article presents the results of the analysis of basins-of-contribution drainage, the behavior of the streams and the flood zones for different return periods. A proposal to modify the pluvial-drainage network was developed with the results of the analysis in order to mitigate flood impacts. The efficiency of the proposed infrastructure was evaluated under the same conditions of the original scenario. All of this was carried out with the aid of a digital elevation model (DEM), of the basins of contribution, a hydrological study performed with the help of software developed at the IMTA. Several drainage coefficients were taken into account for the distinct uses of land in the zone, primarily urban, and mathematical simulation models were created in two dimensions that included current pluvial infrastructure, the digital elevation model, and the sub-basins with their particular characteristics.

Keywords: Digital elevation model · Hydraulic model's · Flood risks

1 Introduction

Every year during the rainy season, the IMTA facilities are affected by a great volume of water running off onto its grounds, this happens when it rains for several consecutive days, causing the ground in the basin to saturate. When it rains heavily, there is water runoff which surpasses the capacity of the pluvial drainage network of the institute. Some of the heaviest floods on record took place on the 12th of June 2001 with flow of 86 mm, on the 13th of October, 1997 with 39 mm, and on the 21st of August, 1992, with only 33 mm. These inundations impede the pedestrian and vehicular circulation at the Institute as can be seen in Fig. 1, resulting in economic losses and loss of time.

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Fig. 1. Flood problems at the IMTA in 2001

1.1 Application Site

The IMTA is found within the urban zone of the city of Cuernavaca, Morelos. Its subbasin is located in the northern part of the institute (Fig. 2) and has an area that is relatively small, around the order of 0.67 km^2.

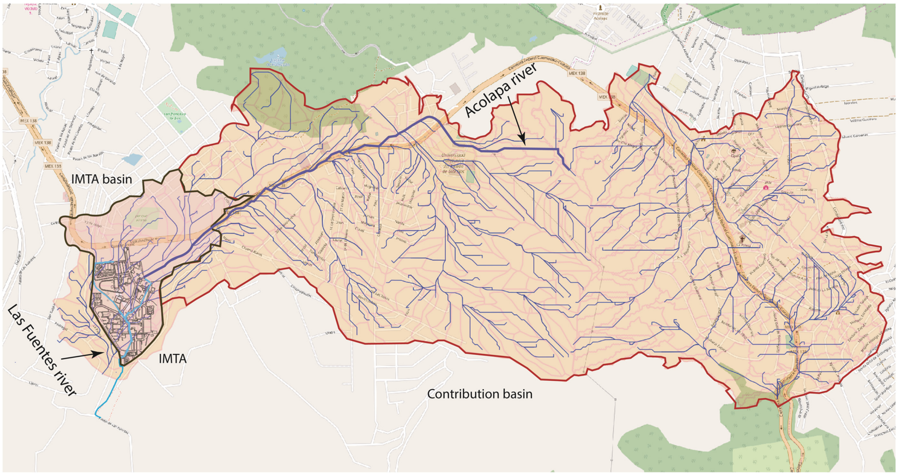

Fig. 2. Basins of contribution to IMTA

Nevertheless, the Acolapa river easily flows over due to its low capacity, causing almost all runoff to go into the basin that corresponds to the IMTA and afterwards, towards the drainage channels of the institute. This increases the contribution area of the basin to 6,848 km^2.

1.2 Study Objective

The objective of the study lies in determining the flows for different return periods generated by contributing basins and redesigning the pluvial drainage network of the institute since its current capacity is not enough to transport the flows caused by the rains.

2 Materials and Methods

2.1 Hydrological Study

The calculation of rains for different return periods was done using a distribution of frequency analysis with nine functions that were processed and evaluated in the program AFA v.1.1, developed by the IMTA. When deciding on the type of rainfall to use, the precipitation that took place in 2001 was chosen, which had a duration of 14.5 h and a precipitation of 111.16 mm.

2.2 Creation of a Digital Elevation Model

A digital elevation model (DEM) was created with a topographical rendering which then served to make a triangulated irregular network (TIN), observe in Fig. 3.

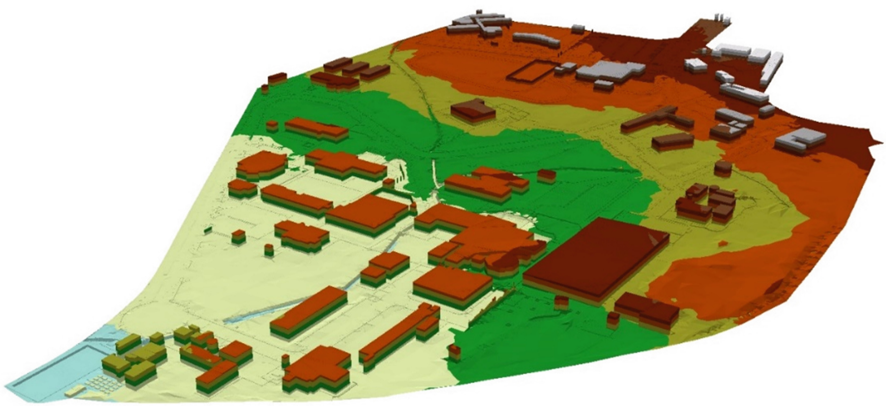

Fig. 3. Digital elevation model of IMTA

2.3 Land Use

To properly model basin runoff, a database was created logging the different types of land uses for the zone. Each land use type was assigned a corresponding runoff factor: for streets it was 0.95, sidewalks were 0.85, the planimetry or constructed zones 0.95, level-ground areas 0.85, the jogging trail 0.17, the green areas as well as the perimeter fence were 0.70, the natural canal was 0.35, the concrete canal was 0.95 and finally the green areas were 0.25.

2.4 Rainfall Drainage Within the Institute

Additionally, rainfall drainage data for the IMTA infrastructure was included with the purpose of evaluating current capacity to drain rainfall. There are pipes with diameters that range from 0.15 m up to 0.76 m, overall, the current network covers 3.07 km.

2.5 Hydraulic Model

A hydraulic model was created that included the plotted lines and sections of canal pipes, the piping of the pluvial infrastructure, the digital elevation model and the micro-watersheds with their particular characterizations. The mesh proposed for the modeling is rectangular with a varying size that makes up the 5×5 m zone of the institute, the first main contribution zone is 10×10 m and the secondary contribution zone is 20×20 m. Six hydraulic simulations were done for different return periods (2, 5, 10, 35, 50 and 100 years), this storm design along with the 505 contributing micro-watersheds, the pluvial infrastructure, the retention deposits and the projected collectors were brought together in a hydraulic simulation model in which maximum flows were calculated.

The cost of surveying in Mexico is very costly, the budgetary confines of the project obligated a specific plotting practice to know the elevations, flat areas were allotted more space and less space was used in more pronounced ones. The 5×5 resolution in the DEM explicitly represents the topographical possibilities of the terrain, given that sidewalks, streets and buildings were surveyed independently for the TIN.

A Geographic Information System (QGIS) was used to process data, which created a rendering of the morphometric characteristics of the basin and then geopositioned the urban infrastructure of the institute. For the modeling, the PCSWMM 2d program was used, which creates a 1d-2d interaction so as to generate the rainfall-runoff process in the basins and in the pluvial system in order to identify piping capacities and overflow.

3 Results and Discussion

3.1 Hydraulic Model Results

The hydraulic model's results are arrived at using the computational scenarios proposed for different return periods, each linked to a storm design. Figure 4 presents the maximum flows that resulted from the simulation, and makes evident that the most affected zone is in the southern part of the institute.

3.2 Proposed Solution

The hydraulic model was used in the effort to tackle the inundation and puddling problems using diverse proposals like works. The optimal solution requires installing

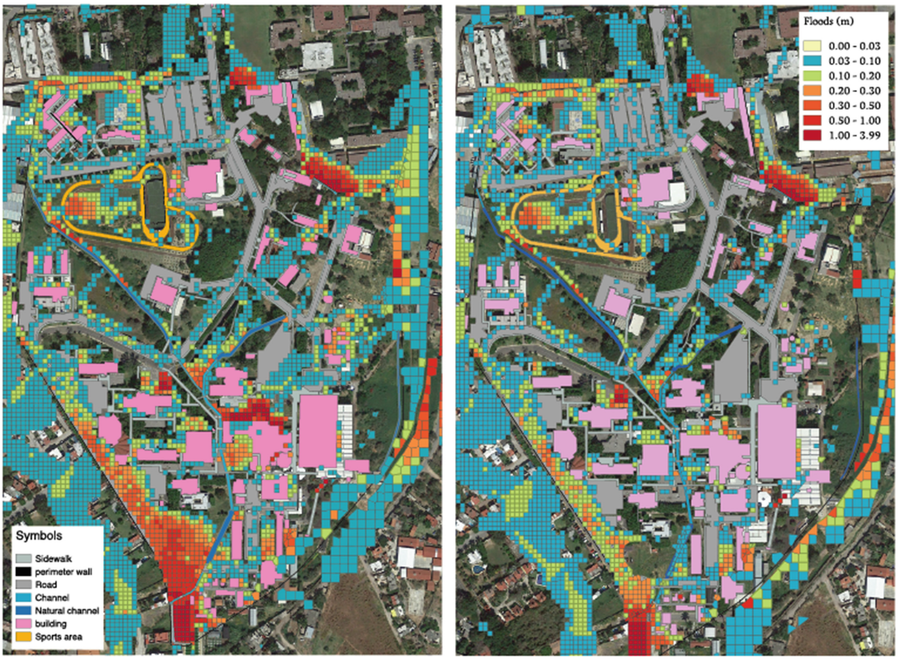

Fig. 4. Comparison of maximum flows for the current situation and the proposed solution for a return period of 25 years

five infiltration and retention systems along with collectors that would permit rainfall to be drained in less time. Figure 4 presents a side-by-side comparison of the current conditions with the proposed solution for a return period of 25 years.

3.3 Solución Óptima

The optimal solution was identified via the employment of available knowledge of the areas and the maximum flows that are presented, afterwards, the proper dimensioning of retention ponds was worked out and finally a pluvial system was established that will improve the transport of water to avoid flooding. The IMTA, being an institute that receives students of different hydrological degrees throughout the year, allows them to get to know the retention and detention infrastructure as a means to avoid flooding.

The Institute has a channel system the permits the evacuation of water coming from the higher elevations and from the basin, this system is very useful for return periods of less than ten years, for anything beyond that though, there are losses in the form of intangible and tangible costs. The problem is complex because the annual average precipitation in Morelos is 900 mm, which indicates that storms here are of a short duration. The use of low-impact works was considered but they would only help with return periods under 10 years.

4 Conclusions

The development of an optimal solution for reducing flood risks is an interdisciplinary task. The new pluvial system that the IMTA requires was developed using more adequate mathematical tools but more importantly, was richly supplied with data from rainfall measurements and drainage flows in the field under strict collection standards. The precision of the mathematical model permitted the significant prediction of flood areas caused by rainfall with a return period of 20 years, these results were presented in June 2017. This flood allowed model results to be calibrated and corroborated, thus assuring that the projected infrastructure meet its objective. Moreover, an economic evaluation was carried out for the project considering distinct, existing technologies like prefabricated retention systems, and diverse materials for collectors among them reinforced concrete, polyethylene, galvanized piping and PVC.

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