

FLOOD MODELLING AND MANAGEMENT OF URBAN STORMWATER DRAINAGE SYSTEMS

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FLOOD MODELLING AND MANAGEMENT OF URBAN STORMWATER DRAINAGE SYSTEMS

by

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Submitted

in fulfillment of the requirements for the degree of Doctor of Philosophy

to the



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Dedicated to

My father

Late Shri. Chandrika Prasad

CERTIFICATE

This is to certify that the thesis entitled “**Flood Modelling and Management of Urban Stormwater Drainage Systems**”, being submitted by **Mr. Satish Kumar** to the Indian Institute of Technology, Delhi (India) for the award of the degree of **Doctor of Philosophy** in Civil Engineering, is a bonafide research work carried out by him under our joint supervision. The thesis work, in our opinion has reached the standard, fulfilling the requirements for the said degree. Further, we certify that this submission is Mr. Satish’s own work and that, to the best of our knowledge and belief, it contains no material previously published or written by another person which to a substantial extent has been accepted for the award of any other degree or diploma of any University or Institute, except where due acknowledgement has been made in the text.

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ABSTRACT

Urban flooding has turned into an increasingly imperative issue in many parts of the world and will inspire the ways in which cities develop in the future. Over the past few decades, urban areas around the world have extended rapidly. Floods can be a major menace to these towns and can produce catastrophic losses with substantial influence on national economies. Nevertheless, it is worth mentioning that flood damages are the consequences of a complex system of factors that inspire the overall dynamics and effects.

Flood risk managers and decision-makers are often confronted with the challenging responsibilities of planning efficient adaptation and mitigation policies. When we talk about low-frequency and sudden urban flooding taking place because of extreme storm events the combination of surface runoff and storm surcharge are the two foremost contributors of inundation.

The urban stormwater drainage system has picked up importance lately in light of pluvial flooding. The flooding is mostly due to urban expansion, reduction in infiltration rates and environmental changes. In order to minimize flooding, hydrologists are using conceptual rainfall-runoff models as a tool for predicting surface runoff and flood forecasting. Manual calibration is often a tedious process because of the involved subjectivity, which makes the automatic approach more preferable. Thus, in the present thesis, three evolutionary algorithms (EA) namely Shuffled Frog Leaping Algorithm (SFLA), Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) were used to calibrate SWMM parameters for the two study areas of the highly urbanized catchments (Delhi, India). The work incorporates, auto-tuning of a widely used SWMM, via internal coupling of SWMM with all three EAs in MATLAB environment separately. It was found that GA performs better, SFLA's performance was similar to GA whereas PSO results were satisfactorily.

The SWMM model is a one dimensional (1D) model which provides only bulk information like the flow rate of the drains as an output and does not provide the extent of flood inundation. For generating the flood extent information, two dimensional (2D) models are available but their computational time is very high. Therefore, to overcome the disadvantages of the 2D model, the coupling of 1D (SWMM) model with 2D (iRIC) model also known as hybrid model has been developed. It can be used to assess the feasibility of the iRIC model as a flood simulator in the urban catchments which experiences frequent flooding. The developed hybrid model could be deployed to manage floods in urban areas and options can also be created to effectively manage the flooding in the other areas. Further, constructed wetland with orifice setting controller (to maintain desire water depth) was proposed for the area which was getting inundated by the excess water overflowing from the drain. Thus the problem of backflow and flooding got reduced substantially.

Accordingly, these types of measures such as non-structural approach will assist managers in keeping the urban areas safe from the dangers of different pluvial flood risks. In the present time, the concept of smart cities has evolved various types of flood mitigation measures and a lot of work has been done in this direction. In the present work, for mitigating the urban floods the concept of Best Management Practices (BMPs) / Low Impact Development (LIDs) is proposed where the application of BMPs/LIDs were linked with the existing stormwater drainage system on the basis of present climatic conditions i.e. rainfall. A cost-effective urban runoff control LID-BMPs plan has been used to extenuate the undesirable influences of urbanization. It found out that by implementing Green Roofs and Infiltration Trenches in 75% and 25% of the study area can reduce flooding to half.

Lastly, the climate change also plays an important role in urban flooding where heavy rainfall occurs at shorter intervals and is increasing year after year. In such rainfall events whether the existing drainage will be sufficient to accommodate the surface runoff surface in the next 5,

10, 20 years is discussed. Thus, to study the change in rainfall events and its intensity, three different climate models were considered to find the possibility of urban flooding in the study area. The results indicate that with respect to present climatic conditions, surface runoff will increase by 3 to 7 times in near future.

Hence, it can be concluded from the above discussion that the present doctoral thesis explores the potential uses and combinations of single objective optimization algorithms and hydrodynamic models along with the BMPs/LIDs application for assessing the risk of flooding in urban stormwater drainage systems, providing valuable information to decision-makers.

सार

शहरी बाढ़ दुनिया के कई हिस्सों में एक तेजी से अनिवार्य मुद्दा बन गया है और भविष्य में शहरों के विकास के तरीकों को प्रेरित करेगा। पिछले कुछ दशकों में, दुनिया भर के शहरी क्षेत्रों में तेजी से विस्तार हुआ है। इन शहरों में बाढ़ एक प्रमुख खतरा हो सकता है और राष्ट्रीय अर्थव्यवस्थाओं पर पर्याप्त प्रभाव के साथ भयावह नुकसान पैदा कर सकता है। फिर भी, यह ध्यान देने योग्य है कि बाढ़ नुकसान कारकों की एक जटिल प्रणाली के परिणाम हैं जो समग्र गतिशीलता और प्रभावों को प्रेरित करते हैं।

बाढ़ जोखिम प्रबंधकों और निर्णय निर्माताओं को अक्सर कुशल अनुकूलन और शमन नीतियों की योजना बनाने की चुनौतीपूर्ण जिम्मेदारियों का सामना करना पड़ता है। जब हम कम-आवृत्ति और अचानक शहरी बाढ़ के बारे में बात करते हैं क्योंकि अत्यधिक तूफान की घटनाओं के कारण सतह अपवाह और तूफान अधिभार का संयोजन दो सबसे महत्वपूर्ण योगदान हैं।

शहरी तूफानी जल निकासी प्रणाली ने हाल ही में बहुवचन बाढ़ के प्रकाश में महत्व को उठाया है। बाढ़ ज्यादातर शहरी विस्तार, घुसपैठ की दर में कमी और पर्यावरणीय परिवर्तनों के कारण है। बाढ़ को कम करने के लिए, जलविज्ञानी सतह के अपवाह और बाढ़ के पूर्वानुमान की भविष्यवाणी के लिए एक उपकरण के रूप में वैचारिक वर्षा-अपवाह मॉडल का उपयोग कर रहे हैं। मैनुअल कैलिब्रेशन अक्सर शामिल विषयवस्तु के कारण एक थकाऊ प्रक्रिया है, जो स्वचालित दृष्टिकोण को अधिक बेहतर बनाता है। इस प्रकार, वर्तमान थीसिस में, तीन विकासवादी एल्गोरिदम (ईए) अर्थात् Shuffled Frog Leaping Algorithm (SFLA), जेनेटिक एल्गोरिदम (GA) और पार्टिकल स्वॉर्म ऑप्टिमाइज़ेशन (PSO) का उपयोग उच्च शहरीकृत कैचमेंट के दो अध्ययन क्षेत्रों के लिए SWMM मापदंडों को कैलिब्रेट करने के लिए किया गया था। (दिल्ली, भारत)। इस कार्य में एक व्यापक रूप से प्रयुक्त SWMM की ऑटो-ट्यूनिंग शामिल है, अलग-अलग MATLAB वातावरण में सभी तीन EAs के साथ SWMM के आंतरिक युग्मन के माध्यम से। यह पाया गया कि GA बेहतर प्रदर्शन करता है, SFLA का प्रदर्शन GA के समान था जबकि PSO के परिणाम संतोषजनक थे।

SWMM मॉडल एक आयामी (1D) मॉडल है, जो एक आउटपुट के रूप में नालियों के प्रवाह की दर की तरह केवल थोक जानकारी प्रदान करता है और बाढ़ की बाढ़ की सीमा प्रदान नहीं करता है। बाढ़ सीमा की जानकारी उत्पन्न करने के लिए, दो आयामी (2D) मॉडल उपलब्ध हैं, लेकिन उनका कम्प्यूटेशनल समय बहुत अधिक है। इसलिए, 2D मॉडल के नुकसान को दूर करने के लिए, 2D (iRIC) मॉडल के साथ 1D (SWMM) मॉडल के युग्मन को हाइब्रिड मॉडल के रूप में भी जाना जाता है। इसका उपयोग शहरी कैचमेंट में बाढ़ सिमुलेटर के रूप में iRIC मॉडल की व्यवहार्यता का आकलन करने के लिए किया जा सकता है जो लगातार बाढ़ का अनुभव करता है। विकसित हाइब्रिड मॉडल को शहरी क्षेत्रों में बाढ़ के प्रबंधन के लिए तैनात किया जा सकता है और अन्य क्षेत्रों में बाढ़ को प्रभावी ढंग से प्रबंधित करने के लिए विकल्प भी बनाए जा सकते हैं। इसके अलावा, छिद्र सेटिंग नियंत्रक (इच्छा पानी की गहराई को बनाए रखने के लिए) के साथ निर्मित वेटलैंड उस क्षेत्र के लिए प्रस्तावित किया गया था जो नाली से अधिक पानी के बहाव से जलमग्न हो रहा था। इस प्रकार बैकफ्लो और बाढ़ की समस्या काफी हद तक कम हो गई।

तदनुसार, इस प्रकार के उपाय जैसे गैर-संरचनात्मक दृष्टिकोण शहरी क्षेत्रों को विभिन्न प्लवकालीन बाढ़ जोखिमों के खतरों से सुरक्षित रखने में प्रबंधकों की सहायता करेंगे। वर्तमान समय में, स्मार्ट शहरों की अवधारणा ने विभिन्न प्रकार के बाढ़ शमन उपायों को विकसित किया है और इस दिशा में बहुत सारे काम किए गए हैं। वर्तमान कार्य में, शहरी बाढ़ को कम करने के लिए बेस्ट मैनेजमेंट प्रैक्टिसेज (बीएमपी) / लो इम्पैक्ट डेवलपमेंट (एलआईडी) की अवधारणा प्रस्तावित है, जहां बीएमपी / एलआईडी के आवेदन को वर्तमान जलवायु परिस्थितियों के आधार पर मौजूदा तूफानी जल निकासी प्रणाली से जोड़ा गया था। यानी बारिश। शहरीकरण के अवांछनीय प्रभावों को दूर करने के लिए एक लागत प्रभावी शहरी अपवाह नियंत्रण एलआईडी-बीएमपी योजना का उपयोग किया गया है। यह पता चला कि 75% में ग्रीन रूफ और घुसपैठ खाइयों को लागू करने और अध्ययन क्षेत्र के 25% तक बाढ़ को आधा कर सकते हैं।

अंत में, जलवायु परिवर्तन भी शहरी बाढ़ में एक महत्वपूर्ण भूमिका निभाता है जहां कम अंतराल पर भारी वर्षा होती है और साल दर साल बढ़ रही है। ऐसी वर्षा की घटनाओं में, क्या अगले 5, 10, 20 वर्षों में सतह अपवाह सतह को समायोजित करने के लिए मौजूदा जल निकासी पर्याप्त होगी। इस प्रकार, वर्षा की घटनाओं में परिवर्तन और इसकी तीव्रता का अध्ययन करने के लिए, अध्ययन क्षेत्र में शहरी बाढ़ की संभावना को खोजने के लिए तीन अलग-अलग जलवायु मॉडल पर विचार किया गया था। परिणाम बताते हैं कि वर्तमान जलवायु परिस्थितियों के संबंध में, निकट भविष्य में सतह अपवाह 3 से 7 गुना बढ़ जाएगा।

इसलिए, उपरोक्त चर्चा से यह निष्कर्ष निकाला जा सकता है कि वर्तमान डॉक्टरेट थीसिस शहरी तूफानी जल निकासी प्रणालियों में बाढ़ के जोखिम का आकलन करने के लिए बीएमपी / एलआईडी आवेदन के साथ एकल उद्देश्य अनुकूलन एल्गोरिदम और हाइड्रोडायनामिक मॉडल के संभावित उपयोग और संयोजनों की पड़ताल करता है, बहुमूल्य प्रदान करता है। निर्णय लेने वालों को जानकारी।

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