GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH

Industry Sector Risk Profile: The Case of KEPZ and Kalurghat Industrial Area in Chattogram

Final Report

Submitted to

National Resilience Programme (NRP)

Programming Division, Bangladesh Planning Commission

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Prepared by

Institute of Water Modelling (IWM)

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To
S M Morshed PhD
Project Manager
National Resilience Programme (NRP)
Programming Division, Planning Commission,
Sher-e-Bangla Nagar, Dhaka-1207

Subject: **Submission of Final Report**

Reference: Contract Agreement for Consultancy Services for "**Developing Disaster and Climate Change Risk Profile of Industry Sector in Bangladesh**". [RFP Identification No.: RFP-BD-2019-053]

Dear Sir,

We are pleased to submit herewith the Final Report on "Developing Disaster and Climate Change Risk Profile of Industry Sector in Bangladesh."

The Final Dissemination Workshop to be done as per the contract. However, due to COVID-19 pandemic situation and lockdown in Bangladesh, the workshop could not be conducted. We commit to conduct the workshop whenever the COVID-19 situation comes back to normal and shall fix the date, venue in consultation with the project authority.

We hope it would be fulfilling the contract requirements as specified therein.

Yours sincerely

Dr. Mollah Md Awlad Hossain
Director, ICT-GIS Division
Institute of Water Modelling (IWM)

Copy:

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FOREWORD

Bangladesh being a country in the Brahmaputra-Ganges deltaic plain suffers in many ways from different kinds of disasters and all her development sectors including Industry get recurrently affected. Dealing with hazards has become a common phenomenon in this country; but the hazard risk profiles of many sectors are seldom available as yet. Among all, the hazard risk profiles of the Industry sector in view of the climate change effects are very much important to the national policy makers, investors, and relevant interest groups in the country. The present study for "Developing Disaster and Climate Change Risk Profile of Industry Sector in Bangladesh" is the first of this kind in Bangladesh to formulate a novel methodology on risk profiling. The main objective of the profile would be to provide risk information to the current as well as aspirant investors for the risk informed development. Programming Division is therefore, happy to publish this risk profile as a part of its initiatives to promote resilience in business sector acknowledging linkage of economic development with disaster resilience.

This study considered flood, cyclone, water logging, salinity, earthquake, fire incidents and the recent Covid-19 pandemic for a case study in Karnaphuli EPZ and partially in the Kalurghat industrial area in Chattogram, Bangladesh. The selection of these two areas covers both the EPZ and non-EPZ industrial areas of the country. Chattogram as the study area obtained the scope of highlighting her exposure to cyclone, tidal surges and salinity hazards while these are not the cases for investigation in the inland areas of Bangladesh. On the other hand, it has missed the effects of flush flood, drought, and ground water scarcity.

The hazard maps and risk profiles produced during the study could be a guideline for further similar investigations. The Institute of Water Modelling (IWM) has prepared GIS maps using digital surveys and other modes of investigations with most modern equipment (Terrestrial Laser Scanner, Drone etc.) in conjunction with reliable mathematical simulation models harnessing the resources of most recent information and precise data from within the study areas. Eventually, they established a very sound database with all relevant information and data on functioning of industries which would become a valuable asset for the related organizations.

Given the contractual bindings and several other hurdles including inadequacy of times and resources, especially limited access to data due to the Covid-19 situation, the study team had to interact with experts, industrialists, and higher officials of relevant organizations through virtual meetings and online workshops to make the analyses and recommendations effective as far as possible.

The study prepared a policy brief and also recommended certain issues allowing for inclusion of the risk profiles for industries appropriately in the overall policy statements. It is expected that these documents will contribute in the risk screening for future investment initiatives.

The risk profiles for industries are quite location specific. It is suggested that care should be taken to use this study as a prototype for future investigations and preparing risk profiles of interest.

ACKNOWLEDGEMENT

It was a pleasant experience for IWM in preparing the Industry Sector Risk Profile for Chattogram areas with due focus in both the EPZ and Non-EPZ complexes. The aim was to make the risk information available as a ready reference document for the investors. From the very beginning of the study design to accomplishing filed works, the study team obtained due support to enrich their database with the information provided by the local Govt. and Non Govt. agencies, research organizations, planners and civil society think thanks.

We would like to express our gratitude to Karnaphuli EPZ authority, Chattagram Chamber of Commerce and Industry and also some other investors in EPZ and Non EPZ areas for their cordial cooperation.

It will remain much of the things untold if we do not acknowledge the whole hearted support and guidance received from Khandker Ahsan Hossain, Chief of Programming Division, Dr. Nurun Nahar, Joint Chief and Project Director, NRP in conducting the study successfully.

Likewise, the absolute help and cooperation extended from UNDP, Bangladesh and NRP-Programming Division Part team, was not only encouraging for us but also added much values to this work.

We are also thankful to the officials of GED, BEZA, BEPZA and other Government departments and Non-Government agencies, who actively contributed in draft sharing presentation on 8th April 2021 with important feedback. It was very much helpful in updating the report with required information.

Lastly, the cordial cooperation and assistance obtained from the senior management of IWM inspired us very much for successful completion of this assignment.

EXECUTIVE SUMMARY

From the view point of global positioning, Bangladesh lies on such a location on the earth's crust that is well known since time immemorial as one of the natural hazard prone areas in the world. Flood and Cyclone are the most frequently occurring catastrophes in Bangladesh. It also suffers from the problems arising out of drainage congestion, salinity intrusion, earthquake etc. The natural calamities of different kinds and magnitudes affect our lives, livelihoods and properties eventually retarding the pace of our national development. Of late, the Government has been trying utmost to curb the effects of devastations and spoils of natural hazards taking place in human habitats through adopting adequate safety measures to protect the lives and properties of the people.

UNDP took an initiative to develop Hazard Risk Profile for the industries sector of Bangladesh facing certain common and frequent phenomenon of disasters like Flood, Cyclone and Tidal Surges, Drainage/Water Logging, Salinity, Earthquake and Fire incidences. On 18 February 2020, the Bangladesh Chapter of UNDP engaged the Institute of Water Modelling (IWM) to conduct this study under a consultancy contract. The COVID-19 Pandemic situation spreading all around in the world including Bangladesh also adversely affected the study. At a later stage, the impacts of the epidemic diseases like Novel Corona and others occurring as the Force Majeure and risk factor were additionally included within the scope of the study. The host organization of this study is the National Resilience Program (NRP), Planning Commission, Bangladesh.

One of the key aspects of the study was to select the study areas from the view point of two different perspectives; (i) an organized industrial area such as the Export Processing Zone (EPZ) or an Economic Zone (EZ), and (ii) a less organized industrial area. It was decided that adopting this area specific study approach would prove worth of reflecting the risk profiles as representative of most of the industrial areas in Bangladesh. Accordingly, at the beginning of the study, (i) Karnaphuli EPZ, and (ii) Part of Kalurghat industrial areas in Chattogram were selected as the Study Areas.

In this study, the spatial data included the industrial structure footprints, land use, topography, roads, rivers, canals, cyclone tracks, satellite images, fire stations etc.; and the non-spatial data included hydro-meteorological data of historical time series like water level, water discharge, salinity intrusion in the Karnaphuli river system, rainfall data, and related hazards such as water logging, Fire Incidences, COVID-19 etc.

The study conducted a digital land survey using Terrestrial Laser Scanner (TLS), and Drone to prepare detail and high-resolution Digital Elevation Models (DEM) to represent study area surface topographies. To collect the industrial information relevant to the hazards, a questionnaire survey was conducted across 57 industries. For assessing the earthquake hazard, Rapid Visual Screening (RVS) survey was conducted in 71 numbers of industrial buildings/structures in KEPZ area and another 91 numbers of structures/buildings in Kalurghat area.

Hydro-meteorological data for water and hazard simulation modelling were collected from BWDB, CPA, SoB, BMD, DDM, CDA, IWM, CCC and many other organizations. For fire incidence and damages, necessary data were collected using questionnaire and newspaper information. COVID-19 information was also gathered as a part of the Industrial questionnaire survey.

Several mathematical models were developed and used in assessing the impacts of the hazards (flood, storm surge, water logging, and salinity) for average year conditions along with 25 and 50-year return periods considering the Climate Changes of year 2050. The used models are: (i) hydrological model for rainfall-runoff model (NAM), (ii) river flood model for 1D hydrodynamic model (MIKE 11), (iii) drainage model for 1D hydrodynamic model (MIKE 11), (iii) storm surge model MIKE-21 FM model plus Wind pressure & direction, and (iv) salinity model for 1D hydrodynamic model plus AD model. The model considered projections according to the climate change scenario in accordance with the directives of IPCC Assessment Report-5 (IPCC, AR5). The relative mean sea level rise of 50 cm by 2050 was also considered.

The disaster risk model was used to couple exposure data of industries with vulnerability and hazard for ultimate generation of deterministic and probabilistic risk estimates.

It was observed that, in Kalurghat, the flood risks are Low in 93% areas under 25-year return period condition and 40% areas will be at Medium Risk level while 52% areas will be subjected to High Risk level with climate change impacts. In case of KEPZ, the Flood Risks will be Very Low for 99% areas in 25-year return period; but in case of 50-year event, 70% areas will be in a Very Low risk level and 30% areas will experience Low Risk conditions.

Risks of Water logging hazard in Kalurghat will be Very Low in 100% areas in average year condition; but 80% areas will be at Low risk level, 19% areas will be at Medium risk and remaining 1% area will fall under High risk situation in 25-year return period. In 50-year return period, 22.58% areas will come under Medium risk, 53.56% will be at High risk and 23.68% will be at Very High Risk zone.

In KEPZ, the Waterlogging hazard risk is Very Low in 100% areas in average year condition; 99.70% areas will register Very Low in 25-year return period. Likewise, 73% areas will be at Very Low level risk and 27% area will be at Low Risk level in 50-year return period.

The cases of Cyclone hazards in KEPZ indicates that the risk is Very Low in 100% areas under average year condition. Only 8.6% areas will be at Medium risk level while 89.2% areas will fall under High risk and 2.2% area will come under Very High risk condition in 25-year return period. The hazard levels will show Medium for 5.8% areas, it will be High for 58.6% areas while Very High risk condition will prevail in 35.6% areas in 50-year return period. In Kalurghat Industrial areas, 100% areas will register Very Low risk in average year condition while in 25-year return period, 96.3% areas will be at Low risk and 3.5% areas will be subjected to High risk condition. In 50-year return period, only 4.3% areas will be at High risk and 95.7% areas will fall under Very High risk level.

Model test results carried out under this study showed that the salinity level is about 1 ppt near Kalurghat area in average year condition, whereas at near the KEPZ area the salinity concentration is more than 1 ppt at

200 m3/s release. The salinity of 1 ppt propagates upward by 5.8 km and 6.4 km respectively in 25-yr and 50-yr return periods with climate change.

In case of earthquake, it is evident that in all the cases Kalurghat buildings are at greater risk than those at KEPZ. However, for moderately rare events which correspond to the Building Code prescribed loading, only 22% buildings at KEPZ and 7% buildings at Kalurghat are less likely to be damaged.

Fire hazard was assessed for Kalurghat Industrial Area based on travel distances of the industries from the fire service stations and primary product types. It is found that chemical and consumer product type of industries are most vulnerable to fire hazard, about 6% of industries were found in the Very High hazard category as per this study.

Covid-19 risk zone was developed based on the facilities available and steps taken by KEPZ to face the Novel Corona virus infection. It was observed that 46 numbers of people were infected by Covid-19 out of 67,713 people in KEPZ until August 2020. Estimates show that in KEPZ industries, 62% of employees are in Low risk and 38% are in High risk of being affected by Covid-19. More precautionary measures to be taken to reduce the risks of Covid-19. For Kalurghat Area, Covid-19 Risk map has not been developed due to inadequate data.

Risk Profiles:

Based on model simulation results, the exposure, vulnerability and finally the "risk profiles" have been developed for the mentioned hazards in the industries of the two study areas in the form of GIS maps and tables.

The hazard risk profiles will give an idea of probable risks from Flood, Cyclone and Tidal Surges, Water logging/ Drainage, Salinity, Earthquake, Fire and COVID-19 incidences.

Considering the combined risks, following table shows the situation of risks in the industries in Kalurghat and KEPZ areas.

Risks Levels	Kalurghat Study area			KEPZ Study area		
	Avg. Yr	25-Yr	50-Yr	Avg. Yr	25-Yr	50-Yr
Very High			38%			
High			62%			11%
Medium		100%			11%	32%
Low	40%			16%	35%	57%
Very Low	60%			84%	54%	

The information in the table above shows that the percent of industries in Kalurghat and KEPZ are moving towards the higher risk zones with higher return period (25- and 50-yr) hazards. In Kalurghat, the situation would be more risk for the industries than that of KEPZ. More than 62% industries will be in High-Risk Zone in Kalurghat, whereas in KEPZ it will be only 11% for 50-year multi hazard risk zone.

The existing and future industrial investors could use the risk profiles to take measures in the adjustment as well as in planning efforts to minimize the probable losses in their investments.

Also, the risk profiles may also be used in the public sector to obtain essential information in policy decisions, development planning and industrial sector investments to allow for more resilience. This study portrays a methodology for developing risk profiling for the industrial sector which could be replicated to other industrial zones and areas in Bangladesh.

Policy Guidelines:

The present study identified several policy issues which need to be addressed to reduce risks in the industrial sector of the country. The identified policy issues in brief are mentioned below:

a) Land Zoning for future Industrial establishments - the government should delineate industrial zones considering natural hazards and risks thereof;
b) Inclusion of clause(s) concerning Natural Hazards and Risks - necessary clauses should be inserted in the Industrial Acts of Bangladesh to allow for managing the risks and natural hazards;
c) Disaster Impact Assessment (DIA) - there should have provisions in investment port folios to conduct DIA before establishing any industry;
d) Emergency Response policy and guidelines – these are essential to address natural hazards/risks thereof in individual industries in line with the National Disaster and Emergency Response policy;
e) Insurance Policy - some of the natural hazards cannot be avoided such as cyclones, storms, earthquakes and pandemic effects arising out of Force Majeure conditions. So, the Insurance Policy can be introduced to compensate for the financial losses;
f) Business Continuation Plan - to keep the business running and unaffected due to natural disasters vis-à-vis while facing the effects of natural hazards, it should be made mandatory for the industries to have their own framework for Business Continuation Plan as a part of obtaining clearance / license from the Government; and
g) Availing industrial loans (facilities) from financing institutions /agencies – as a pre-requisite of granting such facilities, concerned institutes/agencies may ask for incorporation / consideration of natural hazard/risk management Profile in their criteria.

Limitations:

Like many other projects, this study has got some limitations. Alongside the efforts undertaken to collect handful of primary data as much as possible, the study also had to bank on secondary sources information / data on hazards (e.g flood, cyclone, drainage, salinity etc.) to a large extent. Unavailability of recent data on salinity and basin topography might bias the results of hazard assessment and influence the Risk Profiles. The study considered only "Physical Vulnerabilities" due to limited time and funds. We had to limit our efforts to explore the accessibility to industries and field inspections, data collection and stakeholder consultations due to COVID-19 pandemic situation.

Recommendations:

This is a pioneering study which may be followed up to augment further Risk Reduction efforts in the industrial sector of the country. Risk Profiles, as produced in the present study can be utilized by the investors, industrial planners, policy makers, development planners and other stakeholders. Keeping an eye on how to materialize the objectives of the project, several recommendations are made as under:

(a) Some more micro level studies similar to the present one would be necessary to offset the weaknesses and limitations encountered so far;

(b) One macro level study should be conducted on priority basis to fix up industrial areas for further micro level investigations;

(c) Develop an online GIS based interactive Risk Profiling System;

(d) Mainstreaming the use of Risk Profiles for industrial investments and issuing clearances by incorporating it in Industrial Acts;

(e) To mitigate the Earthquake Risk: (i) Site Specific Design Spectrum should be developed; (ii) liquefaction potential of sites must be considered; (iii) Seismic Vulnerability of existing structures should be assessed; and (iv) structural retrofitting should be implemented for existing vulnerable structures;

(f) To reduce the Epidemic Hazard Risks, there should have the provisions of Health Insurance for the industry workers (*each of the industries shall prepare its own contingency plans to face the epidemic situations and all the industries of EPZ can make group epidemic insurance funds*);

(g) To reduce the water logging risks/hazards in KEPZ: (i) the drainage network of KEPZ should be completely segregated from the other outside drainage network (*until this segregation is done, a periodic removal of the sludge is proposed as a temporary solution*);

(h) To keep the Chattogram City safe enough from cyclones and tidal effects (*i.e preventing influx of water due to diurnal upheaval during tides and cyclonic surges at times*) Dykes / Embankments around the city (*Sea Dyke on the seaside and high embankment along the bank of the river Karnaphuli*) should be maintained to the level of “no-failure at all”;

(i) Earthquake Hazard Reduction measures within the framework of a nationwide Earthquake Hazard Reduction Program should be taken (i.e to prepare earthquake risk profiles in the industrial areas on a priority basis, extensive sub-soil investigations and other seismic measures may be hunted for); and

(j) The study outcome could be shared with BDP 2100 as it qualifies to fulfill the specific goal number one of BDP 2100.

ABBREVIATIONS

AD	Advection-Dispersion
ADB	Asian Development Bank
AR5	Assessment Report 5
BARC	Bangladesh Agricultural Research Council
BCCSAP	Bangladesh Climate Change Strategy and Action Plan
BD	Bangladesh
BEPZA	Bangladesh Export Processing Zones Authority
BEZA	Bangladesh Economic Zones Authority
BGMEA	Bangladesh Garments Manufacturers and Exporters Associations
BMD	Bangladesh Meteorological Department
BNBC	Bangladesh National Building Code
BoI	Board of Investment
BSCIC	Bangladesh Small and Cottage Industries Corporation
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
CC	Climate Change
CCC	Chattogram City Corporation
CDA	Chattogram Development Authority
CDMP	Comprehensive Disaster Management Programme
CIMA	Chartered Institute of Management Accountants
COVID-19	Corona Virus Infectious Diseases 2019
CPA	Chattogram Port Authority
CWASA	Chattogram Water Supply and Sewerage Authority
CWSISP	Chattogram Water Supply Improvement & Sanitation Project
DDM	Department of Disaster Management
DEM	Digital Elevation Model
DFR	Draft Final Report
DGPS	Differential Global Positioning System
DHI	Danish Hydraulic Institute
DIA	Disaster Impact Assessment
DoE	Department of Environment
DSM	Digital Surface Model
DTM	Digital Terrain Model
EICC	East Indian Coastal Current
EPZ	Export Processing Zone
FEMA	Federal Emergency Management Agency
FRF	Fire Risk Factor
GCP	Ground Control Points
GDP	Grand Domestic Product
GFDRR	Global Facility for Disaster Reduction and Recovery
GIS	Geographic Information System
GSB	Geological Survey of Bangladesh
HEPP	Hydroelectric power plants
IDW	Inverse Distance Weighted
IFC	International Fire Code
IPCC	Intergovernmental Panel on Climate Change
IWM	Institute of Water Modelling
JICA	Japan International Cooperation Agency
KEPZ	Karnaphuli Export Processing Zone
LGED	Local Government Engineering Department

MCE	Maximum Considered Earthquake
MoEF	Ministry of Environment and Forest
MW	Mega Watt
ODK	Open Data Kit
PSHA	Probabilistic Seismic Hazard Assessment
RTK	Real time kinematic
RVS	Rapid Visual Screening
SDG	Sustainable Development Goal
SLR	Sea Level Rise
SoB	Survey of Bangladesh
SPT	standard penetration test
TEPSCO	Tokyo Electric Power Services co. Ltd
TLS	Terrestrial Laser Scanner
TOR	Terms of Reference
UAV	Unmanned Aerial Vehicle
UN	United Nations
UNDCCC	United Nations Framework Convention on Climate Change
UNDP	United Nations Development Programme
UNDRR	United Nations office for Disaster Risk Reduction
UNISDR	UN Office for Disaster Risk Reduction (former UNDRR)
UN-SPIDER	United Nations Platform for Space-based Information for Disaster Management and Emergency Response
WTP	Water Treatment Plant

GLOSSARY

Hazards	*A hazard can be defined as a dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage. Example: Flood, Cyclone, Earthquake, Water logging, Salinity, Tidal surges, Drainage congestion, Fire events etc.*
Exposure	*Exposure refers to people, property, systems, or other elements present in hazard zones that are thereby subject to potential losses. Also, the situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas* (UN-SPIDER, n.d.).
Vulnerability	*Vulnerability refers to the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard.*
Risk	*"The potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, and capacity"* (UN-SPIDER, n.d.). *In the technical sense, it is defined through the combination of three terms: hazard, exposure and vulnerability.*
Resilience	*Resilience can be defined as the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions.*
Risk Profile	*Risk Profiles provide a comprehensive view of hazard, risk and uncertainties for different kinds of disaster, in this case in a changing climate, with projections at 2050. The risk assessment considers a number of possible scenarios, their likelihood, and associated impacts. Risk Profile is usually presented in a form of matrix.*

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Chapter 1: INTRODUCTION

This submission presents the study background on which the study was initiated, the overall and specific objectives of the study, and the detail scopes of the works. At the beginning, a chapter is dedicated to describe the understanding of the Risk Profile and different types of natural hazards discussed in the study and finally it describes the organization and the contents in each chapter helping the readers to look through at ease.

1.1 BACKGROUND

Bangladesh is one of the world's most climate vulnerable countries facing geo-physical hazards of different types and magnitudes. The impacts of most of these natural disasters are well understood in Bangladesh in the context of agricultural production and rural livelihoods. The devastating catastrophes and climate change effects also disrupt normal functioning as well as overall growth in the industries sector in Bangladesh and will continue to do so in the future also. Hot summer days, irregular and heavy monsoons, heavy rainfalls in a short spell of time, tropical cyclones etc. are causing severe stress in built urban environments, infrastructure and services. Cyclones cause heavy disruption in port activities and thus affect the export-import of the country badly. Over the last 20 years, Bangladesh experienced more than 13 earthquakes with magnitudes of 4.5 and above in the Richter scale. At present the economic cost of disaster is 10 times higher in Bangladesh compared to those happened in the seventies and the devastations range from 0.8 to 1.1% of the country's GDP. According to the Department of Disaster Management (DDM), heavy floods of 1987, 1988, 1998, 2004 and 2007 caused Bangladesh to encounter an economic loss of $8.4 billion; and cyclone Sidre (2007) and Aila (2009) caused a loss of $3.2 billion - the total losses and damages thus rose to $11.6 billion during those periods. Not in Bangladesh alone, climate change effect perceived all over the world is visibly disrupting business and industries. It is true that in Bangladesh and more specifically in the Industries Sector, not enough has been done either in the public sector or at the private domains to protect Bangladesh's economic growth from these natural disasters.

As with any form of disruption, climate change and other natural hazards are creating and will continue to create risks and opportunities for industries in a diverse number of ways. Resilience360 - a supply chain risk management company managed by DHL, in their first annual risk report of 2018 found natural disasters as one of the main disruptive events affecting the global supply chain. According to the World Economic Forum Global Risk Report 2019, investors, regulators and other stakeholders are now challenging companies to shoulder responsibilities by adopting an integrated, strategic approach to addressing climate change and natural disaster impacts to their businesses. According to the report, environmental risks, water shortages, and natural disasters are becoming recognized more and more by global businesses as threats to their operations.

The IPCC reports that climate change will increase the probability of occurrence of extreme weather events. A recent study published in the science journal Nature (Steckler et al., 2016) revealed new evidence of a hidden fault buried under miles of river sediment, which could generate an earthquake of magnitude 8.2 to 9.0 in Bangladesh. These may have significant repercussions on assets and operations related to industries:

disruptions of transport, shipping delays, halt of operations and production, etc. Catastrophes of this kind impose risks on business facilities as warehouse and storage buildings can be negatively affected by extreme weather, resulting in damage or loss in goods. This will affect the livelihoods of thousands of workers and RMG companies and their suppliers may lose international competitiveness in an already tightly pressurized supply chain. However, in real life situation the impacts of natural disasters and climate change on the production process, raw materials supply, accessories supplies, shipment logistics, etc. will vary from company to company. Yet in general, it has therefore become imperative to have a proper understanding about identification of risks together with the quantification of possible direct and indirect impacts, to achieve economic resilience of the industry sector and the society as a whole. To this end, the Institute of Water Modelling (IWM) on being assigned to develop a sample risk profile for the industry sector, prepared risk maps and put forward some policy recommendations for risk-informed business practices in Bangladesh.

1.2 RATIONALE OF THE STUDY

Bangladesh has the 3rd highest growth attained in economy in the world and highest in Asia in 2020 according to the International Monetary Fund (Source: June 19, 2020 Daily Star). Moreover, the country with an impressive track record for growth and development, aspiring to be a middle-income country by its 50th Birthday (source: WB 30th March 2021). According to WB 2020, the GDP was 8.15% in the last financial year and will be increased to 3.8% in 2021 (source: January 01, 2021, Daily Star). The contribution of Industrial sector alone to the annual GDP was 35.15% in 2018-19 and expected to reach 40% by 2021 (Source: The Daily Star, July 2019). So, the lion shares of Country's economic growth come from the contribution of Industrial Sector. Even though, the Industrial sector is passing through the hurdles of Covid-19 pandemic and facing the challenges of climate change impacts, which leads to happen natural disasters frequently over the country. The country has been suffering from more and more natural disasters in recent years. It is estimated that Bangladesh incurred a financial impact of about $3.12 billion per year on an average due to cyclones and floods, or about 2.2% of gross domestic product (Source: 30th September 2018 ADB).

So, the time has come now to protect the Industries Sector and make her own preparedness against the frequently occurring natural disasters. The industrial sectors, related authorities, decision makers, new investors and the industry owners should be aware of the hazards and disaster risks and their consequences on industries sector. A multi hazards disaster Risk profile can provide information about different levels of risks that result from different disaster events such as Flood, Storm Surge and Cyclone, Water Logging, Salinity, Earthquake, Fire and Infectious disease. The new investors may be informed of the natural disaster risks for the proposed locations, the existing industrialist can make themselves prepared to protect and/or to reduce hazards from disasters and the decision makers, planners can formulate and execute new projects to combat the impacts of disaster events.

With these views in end, NRP initiated this study under the financial assistances of UNDP and IWM was engaged as the consulting firm to carry out the assigned responsibilities of consultancy services.

1.3 OBJECTIVES OF THE PROJECT

The aim of this study is to develop a risk profile of the industry sector in order to provide industrialists, decision-makers and authorities an effective planning approach for minimizing losses and damages caused due to climate change and natural disasters. The risk profile will provide a comprehensive view of hazard, risk and uncertainties for selected natural disasters in a changing climate with projections for the period 2030-2050. The objectives are:

(a) Review of the existing study plan and road map to identify disaster and climate change related risks in the industry sector with special reference to some selected industries located in the Chattogram City Corporation (CCC) area;

(b) Develop a novel methodology for assessment of risks in industry sector vis-à-vis selected industries on representative basis in Chattogram;

(c) Assess the vulnerability of the industries on representative basis and estimate potential damages due to climate change and natural disasters; and

(d) Produce a ***Risk Profile*** of the industry sector in terms of hazards due to natural calamities and disasters faced by industries with a view to use the same for developing strategies towards addressing the identified disaster and climate related risks as well as investment opportunities.

1.4 SCOPE OF WORKS

The Risk Profile will consider different possible scenarios, their likelihood of occurring and associated impacts of climate change and natural disasters on the industries located in the study area. It will provide the visual information (now prevalent); essential data and information on hazards that actually happened; condition of exposure and risks associated; and estimated impact of disasters on the industry sector. The Risk Profile will be used in policy decisions, development planning and infrastructural investment to ensure a more resilient business in Bangladesh. The risk modelling/scenario has undertaken focuses on flood, cyclone, tidal surge, earthquake, salinity, waterlogging and fire incidents. The scope of work included the following activities:

(a) Comprehensive analysis of existing risks and vulnerability studies for the selected industries in the study area;

(b) Develop a structured approach/method to identify and evaluate disaster and climate change related risks of the industry sector;

(c) Develop GIS maps of industries showing types/categories located in the study area and prepare GIS maps of the existing land use along with relevant features and information;

(d) Prepare a high-resolution Digital Elevation Model (DEM) and produce comprehensive scenario-based hazard (flood, cyclone, tidal surge, earthquake, salinity, waterlogging and fire incident) maps of the industry sector (*hazard maps will be produced for different return periods considering the aspects and factors of climate change*);

(e) Inventory of multi-sectoral exposure for the following elements at risk:

- Buildings in terms of their structure type (wood-framed, concrete-framed, steel-framed, etc.);
- Critical facilities, i.e. healthcare (hospitals, clinics, basic health unit, etc.), warehouses, stockpiles, banks, police stations, fire stations, etc.; and
- Infrastructures, i.e. roads, bridges, airports, seaports, railways, dams, telecommunication network, power supply, etc.

(f) Create a comprehensive categorization and GIS map of the targeted elements (critical facilities, buildings and infrastructure) at risk in terms of selected hazard types;

(g) Identify the state of elements at risk by overlapping hazard maps with exposure maps;

(h) Develop Risk Profiles of industries considering the above-mentioned hazards and exposure with different return periods (*and also identify high risk areas by mapping geospatial distribution of risks to the industry sector*); and

(i) Provide detailed guidance on how climate change and disasters data projections and information should be interpreted and applied in policy and investment decision making.

The scope of works further included the risk issues of epidemic due to diseases as the industries had been facing the on-going Covid-19 pandemic situation.

1.5 Understanding The Risk Profile

1.5.1 General

Bangladesh has targeted the 17 Sustainable Development Goals (SDG), which were globally set by the United Nations General Assembly in 2015. The study objectives will support the achievement of four SDGs directly (Figure 1-1) such as SDG 8,9,12 and 13.

Figure 1-1: The Study aligns with SDG 8, 9, 12 and 13

SDG 8 - Decent Work and Economic Growth. SDG 9 – Industry, Innovation and Infrastructure. SDG 12 – Responsible Consumption and Production. SDG 13 – Climate Action.

All these four SDGs mentioned above, are dependent on reduced risk of investments in the industry sector. Hence, development of the Risk Profiles for the Industries in Bangladesh has a direct bearing upon the achievement of 4 SDGs.

1.5.2 HAZARD

Hazard is a process, phenomenon, or human activity that may cause loss of lives, injury, or other health impacts, property damage, social and economic disruption, or environmental degradation. (UNISDR 2017).

Within the purview of this study, the natural hazards considered in profiling the risks generally occurring in industry sector are: Flood, Cyclone, Tidal surge, Earthquake, Salinity, Waterlogging and Fire incident. Also, at later stages of the study, pandemic situation arising all around the globe due to COVID-19 and the likely outbreak of other such infectious diseases were added in the consideration of risk profiles of industry sector.

The hazards (flood, cyclone, tidal surge, earthquake, salinity, waterlogging, fire incidents and COVID-19) with consequences thereof are estimated for different events and magnitudes for the Chattogram area.

1.5.3 EXPOSURE

Exposure is the degree to which a system is exposed to significant climatic variations. Exposure changes in response to the decisions and policies of individuals, communities, agencies and governments about where to locate growing populations, industries and resource-use activities. Exposure will change as the intensity, frequency and distribution of hazards change and as new hazards emerge (Australian Government, 2019).

Industries are treated as the main exposure or **Elements-at-Risk** under this study. The exposure is also defined as the situation of **elements-at-risk** located in hazard prone areas.

1.5.4 VULNERABILITY

The conditions determined by physical, social, economic, and environmental factors or processes which increase the susceptibility of an individual, a community, assets, or systems to the impacts of hazards (UNISDR 2017).

Physical vulnerability —refers to the potential for physical impact on the built environment. It can be relatively quantified because it is directly dependent on the physical impact of a hazard event; and it relates to the magnitude and intensity of the hazard, and the characteristics of the elements-at-risk (Van Westen, 2011).

1.5.5 RISK

Exposure and vulnerability turn a hazard into a disaster. Since 1980, nearly 1.6 billion people have been killed in disasters (UNISDR, 2015a). Extreme hazards are translated into risk through exposure and vulnerability (UNDRR, n.d.).

Risk is defined as the probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions (UN-ISDR, 2009, EC, 2011). According to the terminology of UNDRR, disaster risk is defined as “the potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, and capacity”.

Understanding of the Risk is number one of four priorities of “Sendai Framework for Disaster Risk Reduction 2015 – 2030” (UNDRR, n.d.). Policies and practices for disaster risk management should be based on an understanding of disaster risk in all its dimensions of vulnerability, capacity, exposure of persons and assets, hazard characteristics and the environment. Such knowledge can be leveraged for the purpose of pre-disaster risk assessment, for prevention and mitigation and for the development and implementation of appropriate preparedness and effective response to disasters” (UN, 2015).

Disaster Risk Reduction "is aimed at preventing new and reducing existing disaster risk and managing residual risk, all of which contribute to strengthening resilience and therefore to the achievement of sustainable development". The UNDRR definition further annotates that “disaster risk reduction is the policy objective of disaster risk management, and its goals and objectives are defined in disaster risk reduction strategies and plans" (UN-SPIDER, n.d).

Risk can be expressed as the function of Hazard, Vulnerability and Exposure.

$$\text{Risk= Probability of Loss} = f(Hazard, Vulnerability, Exposure)$$

Risk can be presented conceptually with the following basic equation indicated in Figure 1-2 (Westen, n.d.).

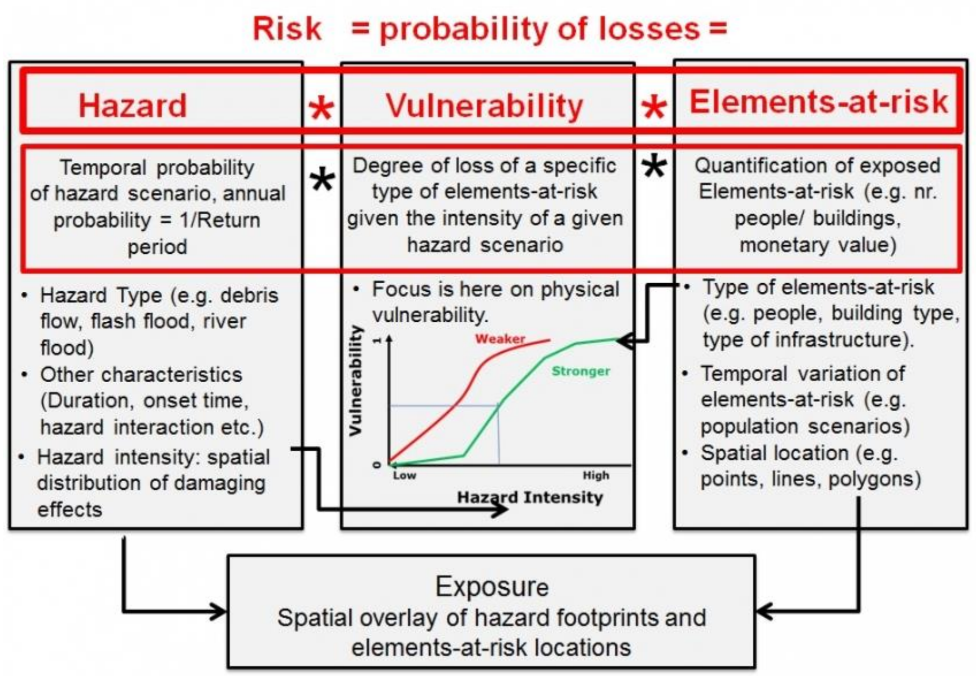


Figure 1-2: Schematic representation of risk as the multiplication of hazard, vulnerability and quantification of the exposed elements-at-risk. The various aspects of hazards, vulnerability and elements-at-risk and their interactions are also indicated.

1.5.6 Risk Assessment Frameworks

In January 2005, 168 Governments adopted a 10-year plan to make the world safer from natural hazards at the World Conference on Disaster Risk Reduction, held in Kobe, Hyogo, Japan. The Hyogo Framework was the global blueprint for disaster risk reduction efforts between 2005 and 2015. Its goal was to substantially reduce disaster losses by 2015 - in lives, and in the social, economic, and environmental assets of communities and countries (PreventionWeb, n.d.).

On 18 March 2015, UN Member States adopted the Sendai Framework for Disaster Risk Reduction 2015-2030, the successor instrument to the Hyogo Framework for Action. The Sendai Framework outlines seven global targets to be achieved between 2015 and 2030 (PreventionWeb, 2020). The Figure 1-3 shows the Sendai Framework at a glance. It has 4 priorities and 38 indicators to assess the hazard risks.

Figure 1-3: Sendai Framework at a glance

Source: https://www.preventionweb.net/sendai-framework/sendai-framework-for-drr/at-a-glance

Bangladesh government is also committed to comply with the Sendai Framework. This study has been done in line with the Sendai Framework.

The Assets, primarily the industries along with population, communication system and other relevant critical facilities of the study area and surroundings are assessed for exposure to the estimated hazards. The exposures are estimated (quantitative/qualitative) and mapped in GIS following the applied procedures in studied under GFDRR.

1.5.7 Risk Profile

Risk Profile is a snapshot of all the risks that a target community, in this case industries, is subject to within a given timeframe. A simple Risk Profile includes a set of hazard scenarios, potential losses, and the probability of occurrence. A more comprehensive Risk Profile may include impacts of risk, relative priority of the risk, acceptable level of risk, linkage between different levels of risks, ways of measuring the risk (qualitative/quantitative), key risk areas/hotspots, risk reduction measures, capacity of risk treatment learning needs and tools etc. (Yan, Dr. Jianping, 2010).

Risk Profile is presented usually in four ways:

(i) Risk Matrix
(ii) Risk Curve
(iii) Fact Table
(iv) Risk Maps

Colored risk-matrix shows the hazard, likelihood of occurrence, estimated risks against vulnerable entities. A probable Risk Matrix for a hazard is presented in Figure 1-4 below.

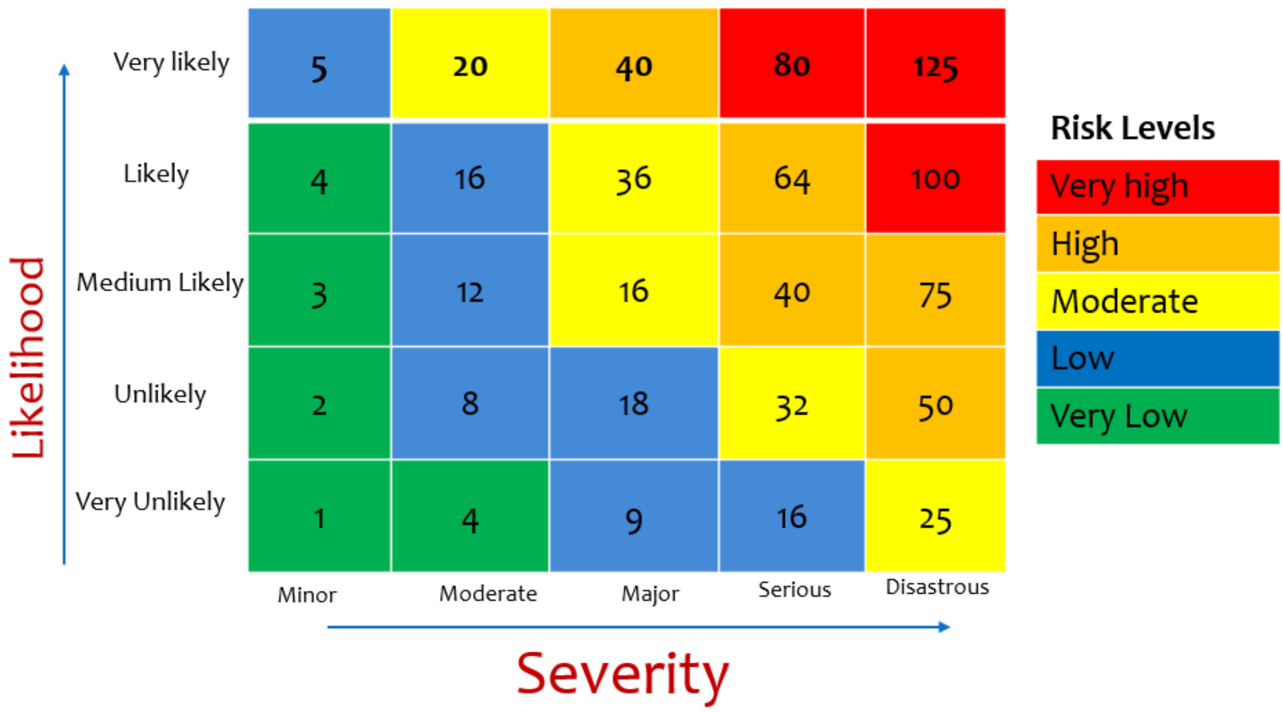


Figure 1-4: A probable Risk Matrix for particular hazard

As per GRIP (Yan, 2010) a Composite Disaster Risk Profile, shown below nearly followed as a guidance under this study.

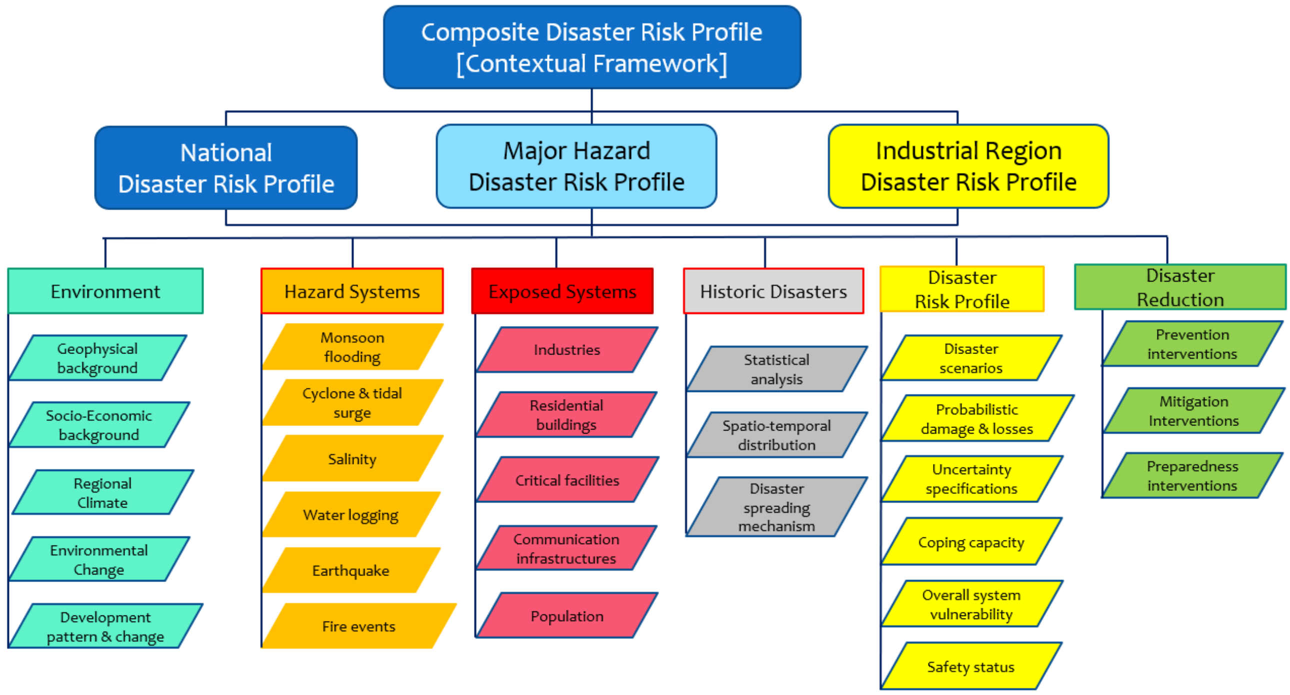


Figure 1-5: Composite Disaster Risk Profile. Reference (Yan, 2010)

An example of Flood Risk Profile developed for Afghanistan in a World Bank project is presented in Figure 1-6.

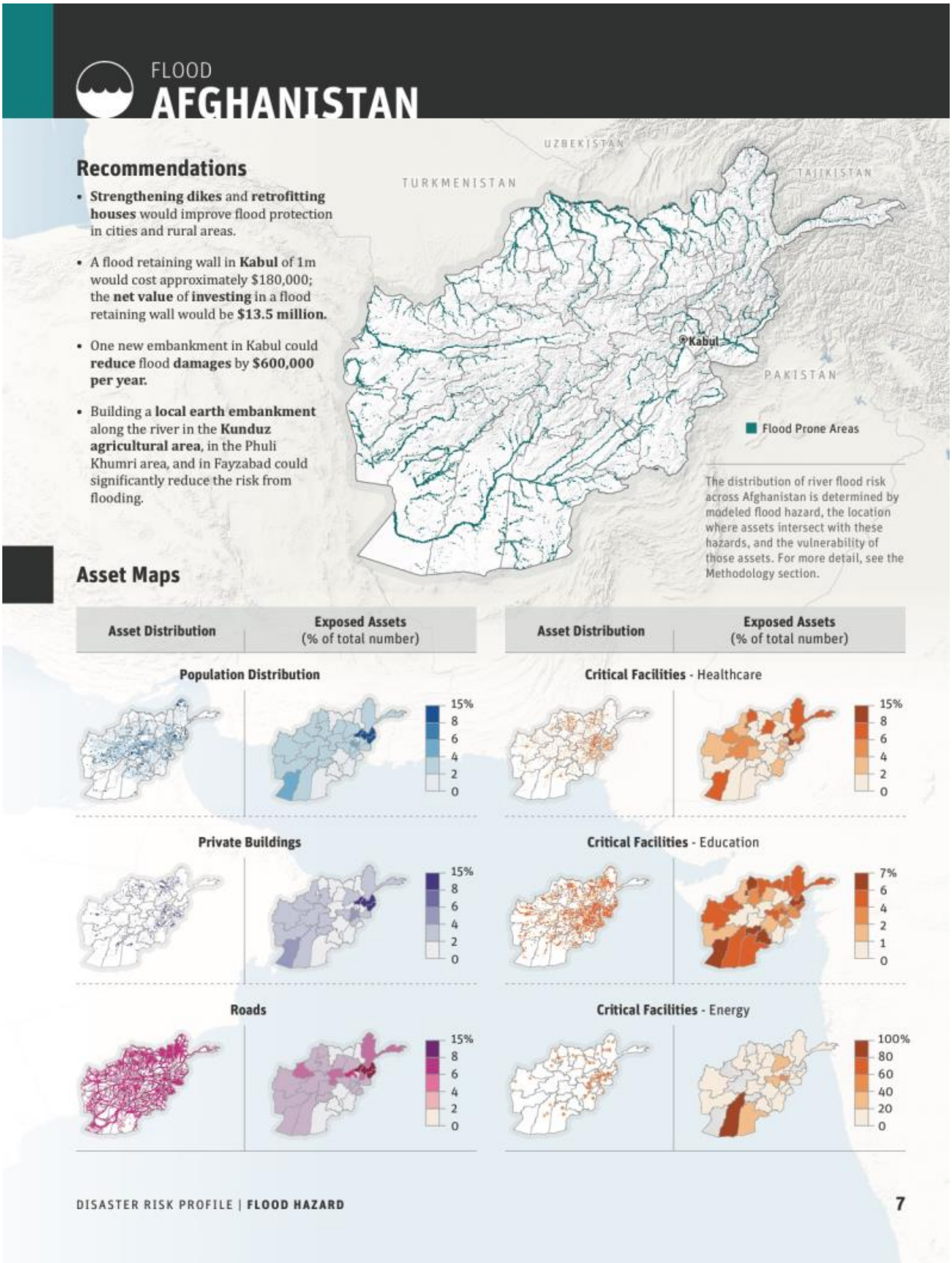


Figure 1-6: Disaster Flood Risk Profile (Source: The World Bank and GFDRR, 2017)

1.6 Structure of The Report

This report presents the risk profiles of the industry sector specifically in the Chattogram industrial areas Karnaphuli EPZ and Kalurghat Industrial Area. The report describes data collection, processing, modelling of selected hazards (Flood, Cyclone & Tidal Surges, Water Logging, Salinity, Earthquake, Fire and COVID-19 as epidemic disease) under different event and climate scenarios, and finally presents the Risk Profiles.

During the tenure of the project, IWM submitted (i) Inception report where the Literature Reviews, Methodology and Work Plan were described, (ii) Field Operation Plan, and (iii) Mid Term Report along with questionnaire form(s) for Industry Survey of KEPZ and Kalurghat Industrial Areas in Chattogram.

Several meetings were conducted to review the process of developing risk profiles and the work progress. Recently, on 8-April, 2021 an online presentation was delivered on the study and the DFR before the experts and stakeholders. The online session was presided over by the Secretary, Planning Division, Ministry of Planning. Dozens of high officials participated in that session and some of them put forward suggestions and comments on the study and the presentation. The participants were mainly from the Planning Commission, UNDP, BEPZA, BEZA, BUET and some other relevant organizations.

The Risk profiles are prepared targeting the investors in the industrial sector. Feedback on the report was collected through a stakeholder consultation meeting and transmittals Stakeholders to NRP through emails and accordingly these Feedback were compiled in this final submission.

The report starts with an Executive summary which describes the study background, objectives, activities, outputs, policy guidelines, recommendations, and conclusions in brief. The report consists of Seven Chapters Which are:

Chapter-1 describes the background, objectives, scope of works, study area information and understanding of risk profile elements.

Chapter-2 describes the study framework and methodology of the study in graphical representation. It also described the concept of development of the risk profile under this study in brief.

Chapter-3 described data collection for both Primary and Secondary data sources under this study with required elaborations.

Chapter-4 describes the hazard analysis (flood, drainage, cyclone & storm surge, and salinity) for average, 25 and 50-year return periods including the Climate Change impacts as described in IPCC Report (AR5). Also, it describes the analysis of earthquake, fire incidents and Covid-19 pandemic hazards in the context of industrial risks.

Chapter-5 describes the development of Risk Profiles in the form of GIS maps and tables.

Chapter-6 describes the policy recommendations to be adopted in relevant industrial policies in Bangladesh. This chapter also provides a brief description of the Business Continuity Plan (BCP) for industries in the events of the hazards. And finally,

Chapter-7 describes the recommendations for implementing the risk informed investment in industrial sector of Bangladesh.

1.7 LIMITATIONS OF THE STUDY

Generally, every study and investigation remain associated with some limitations. This study also has several limitations which could not be overcome. These are as under:

- The study was largely depended on secondary data for hazards assessment (flood, cyclone, drainage, salinity etc.). Unavailability of recent data on salinity and basin topography might bias the results on hazard assessment, and hence there is some probability of influence also on the Risk Profiles;
- The study considered only “Physical Vulnerabilities” due to limited scopes in terms of time and funds, it would be better if it could be done including the Socio-Economic, Environmental and gender issues;
- The project started with the COVID-19 pandemic situation which hampered data collection and stakeholder consultations. The scope of access to industries were limited, mobility of field staffs was impeded which ultimately hampered information gathering;
- The study areas are located in Chattogram City area of Bangladesh, which are dominated by cyclones, tidal surges and salinity hazards and not subjected to Flush Flood. So, the flush flood risk could not be assessed;
- There are no hills in and around the two study sites (KEPZ and Kalurghat). Hence the Landslide hazard could not be studied in this context;
- In the seismic vulnerability assessment, vulnerabilities of only the structural components of the buildings were considered. Vulnerabilities of the non-structural components of the buildings were not considered; and
- Due to the limited scope of the study, simplified methods of assessments were followed in the seismic risk assessment.

Chapter 2: STUDY FRAMEWORK

This chapter presents the Research Framework describing the flow of activities vis-à-vis the literature review, identification of data requirement, data collection, data processing and analysis including production of the outputs results. It also describes the step-by-step workflow of Risk Profile development.

2.1 RESEARCH FRAMEWORK

A comprehensive planning of the works is the first and foremost part to execute the project towards its success. Putting forward this idea to develop better planning, understanding of the data requirements and overall goal of the study is the pre-requisite, which can be achieved through development of a study framework.

Keeping an eye on the Terms of Reference (ToR) and understanding the objectives of the assignment, an overall study framework was designed to carry out works on a modular basis which is presented in Figure 2-1. It was meticulously followed during the course of this study.

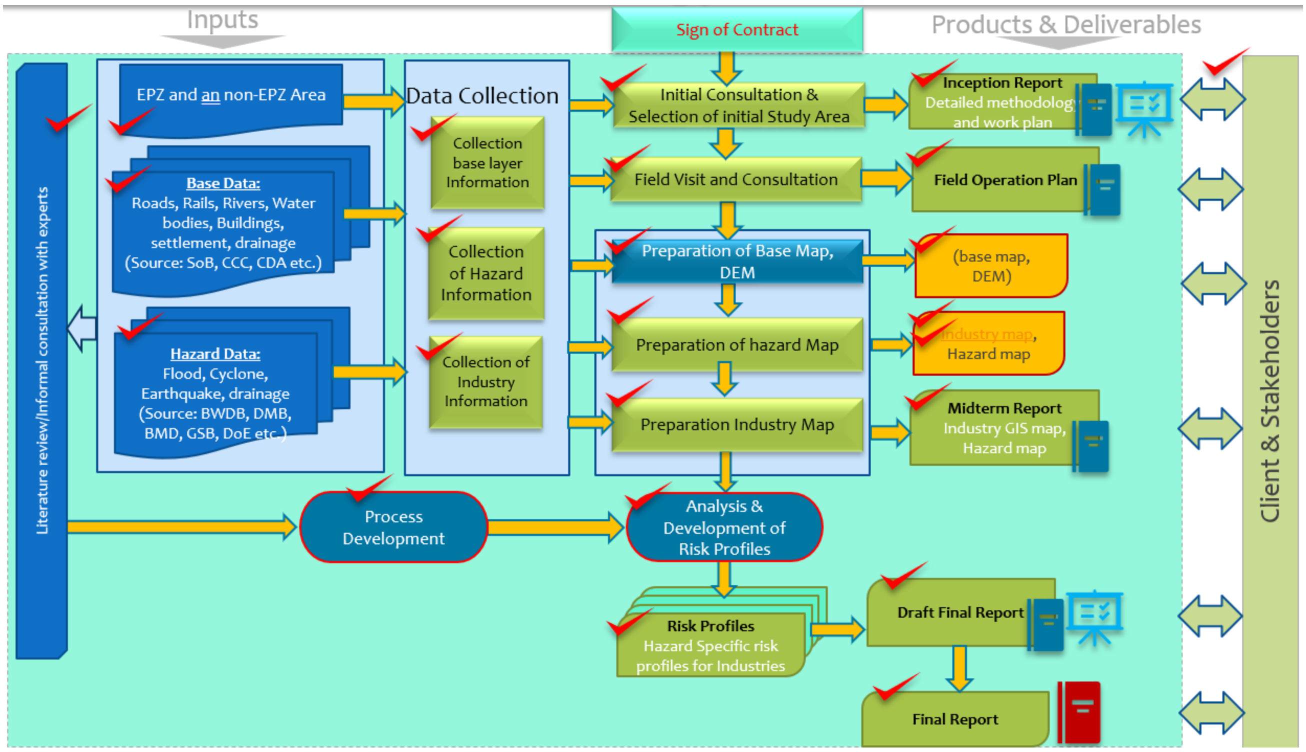


Figure 2-1: Research Framework of the Study

The figure explains the sequence of activities in a flow diagram shown above. All steps of the study viz. literature review, identification of data requirements, data collection, data processing and analysis and production of the outputs in reports were fully passed through. The client and a number of relevant stakeholders were also consulted in every step of the study activities.

2.2 CONCEPT OF DEVELOPMENT OF RISK PROFILE

The Hazard Risk Profile provides an opportunity to look at the targeted exposures and identify the hazards that could impact the exposed assets with severity. Literature review and informal consultation with relevant experts were carried out to find a suitable method for hazard analysis and risk estimation with available data.

Vulnerabilities to each category of existing industries were estimated. Also, the potential risks considering climate change were considered for the probable future projected occurrence in return periods (1 in 25 and 1 in 50-year recurrence).

The workflow of risk analysis is presented in Figure 2-2.

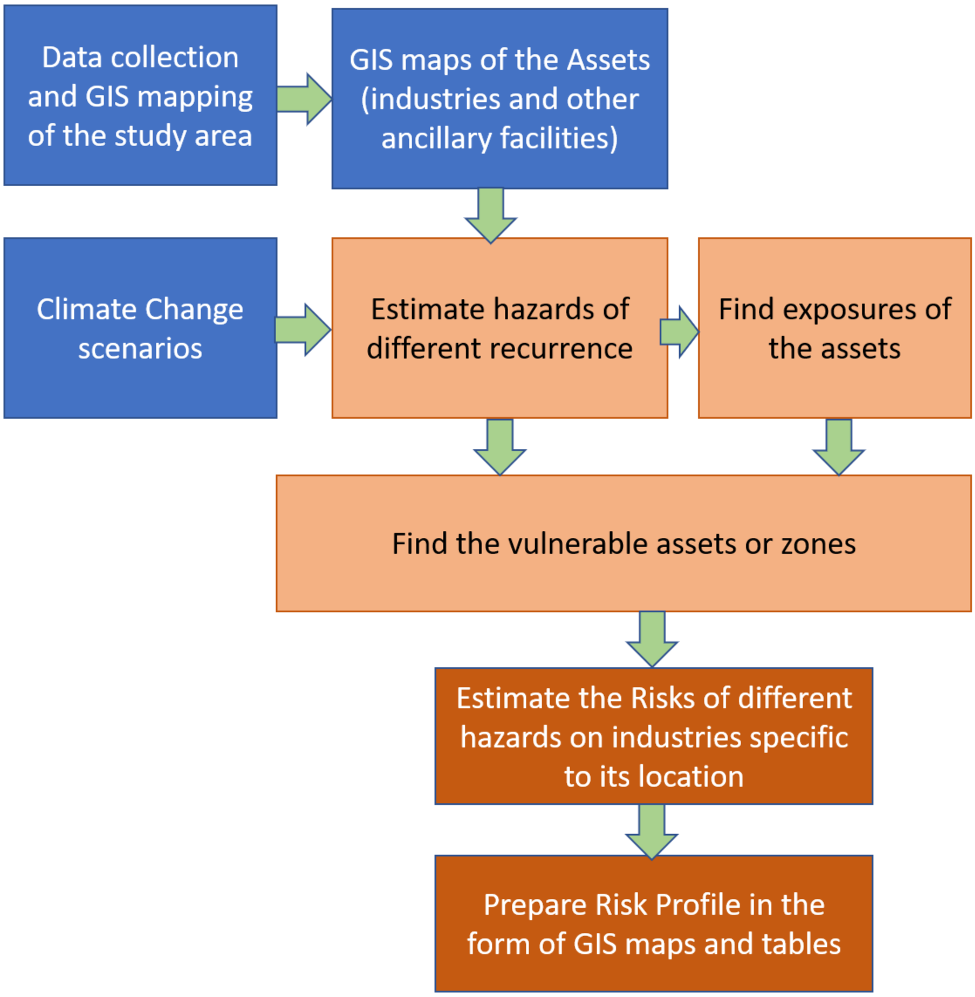


Figure 2-2: Workflow of Risk Profile preparation

Step 1. This step included the collection of relevant data and GIS mapping of the study areas. Secondary and Primary both types of data were collected for this study. Collection of secondary data included land use, road network, river, khals and existing drainage networks, existing industries, historical water level data and other ancillary facilities relevant to the selected hazards. Collection of primary data included Topographic survey, Industry survey. Topographic survey was conducted through combination of wide range of modern techniques such as Total station, Terrestrial Laser Scanner (TLS) and Drone survey. This industry survey was aimed at collecting baseline information of the industries. Another type of primary survey was also conducted named Rapid Visual Screening Survey (RVS) for seismic risk assessment.

Step 2. The hazards for different return periods are estimated using mathematical models and other tools and techniques. Average year represent the current situation having no climate change consideration. Another two are 25- and 50-year return period with climate change consideration.

Step 3. The exposure has been calculated from the inundations from flood, drainage, cyclone and tidal surges using the hydrodynamic model. In case of salinity the values were estimated along the Karnaphuli river under different scenarios. RVS used for assessing the seismic hazard exposure. Actual exposure data were normalized for subsequent risk calculation.

Step 4. Identify the vulnerable assets and estimate its magnitude based on geographic locations and other parameters. Only physical vulnerabilities were considered for this study. Seven vulnerability indicators have been used such as Plinth Height, Drainage Condition, Number of floors, State of maintenance, No of Basements, Structural typology, Construction Year/age etc. to assess the vulnerability of an industry. Weightage on the indicators have been assigned based on the nature of hazard. The vulnerability of industry data then has been converted to raster data using Inverse distance weighting (IDW) method.

Step 5. In this stage, the risks of different hazards on the industries were computed. The risk has been calculated by multiplying the hazard, vulnerability, and exposure in GIS environment. For multi hazard risk, the individual risk grids were overlapped, and combined using arithmetic average method.

Step 6. **Risk Profile Preparation**: The output risk raster conveys information in 5-meter by 5-meter grids. The risk grid/raster data were returned for each of the scenarios: average year risk, 25-year risk and 50-year risk and they were categorized into 5 groups- very low, low, medium, high and very high. This categorization has been conducted following a similar project funded by UNDP entitled as "Multi Hazard Risk Assessment in the Rakhine State of Myanmar". Subsequently, statistics of were generated that how many industries, and what percent of area fall in different risk categories. The output risk map along with statistics has been denoted as risk profile for this study.

Chapter 3: Description of Study Area

This chapter presents the detailed information of two study area KEPZ and Kalurghat Industrial Area in Chattogram City. The chapter also includes the climatic conditions, hydrology, existing situation of Rivers and Khals, physiographical units, Ocean currents in Bay of Bengal and finally historical cyclone tracks.

3.1 Study Area Information

This section describes physical location and the environmental information of the study area related to the hazards considered under this study.

3.1.1 Selection of the Study Area

The Chattogram City was selected by UNDP with reason that it is exposed to the Cyclone & Tidal surges, Sea Level Rise and Salinity in addition to other common hazards.

This study opted to consider two kinds of areas: one is a well-planned exclusive industrial area and another of mixed nature. The EPZs in Bangladesh are exclusive industrial areas, but there are many other industrial areas which are not exclusive and lack required facilities and hazard protections for industries unlike the EPZs.

Investigations were made in the Chattogram EPZ, Karnaphuli EPZ, Kalurghat Industrial Area, Sholoshor Industrial Area and Fouzdarhat Industrial Area. From those, (a) Karnaphuli EPZ and (b) Non-EPZ area – Kalurghat Industrial Area in CCC covering parts of Wards 4 and 5 are selected as the study areas in consultation with the client and some of the stakeholders.

The selection of the study area was based on two criteria as mentioned: (a) Physical Location and (b) well-planned Industrial Area. In the context of physical locations, Kalurghat Area is located in the North side of Chattogram City and its area extends to the riverbank of Karnaphuli whereas KEPZ is located in the Southern part of Chattogram City Area located a few Kilometers inside from the bank of Karnaphuli River. The river side of Kalurghat area is not protected well by Embankment whereas KEPZ is protected by city Roads along Karnaphuli river bank. KEPZ is a planned and organized Industrial Zone, where international and national industries are in operation. KEPZ authority is providing services for safety and security of industries, making good relation among stakeholders, establishing labor rights and maintaining other operations. In Kalurgat Area no such authority is available for providing similar services. Most of the industries are local, few industries are International in this Area. So, there are significant differences between these two areas observed. These two scenarios of Industrial establishment might be the representative to other industrial zones/areas in Bangladesh. Considering the above situations, KEPZ and Kalurghat Industrial Area were selected for the study.

Features of the study areas are presented below:

Karnaphuli EPZ	Area: 82.61 ha. Number of industries: 57, Surveyed on 37 nos of active Industries

	KEPZ is located within the Chattogram City Corporation Ward No. 40. KEPZ is connected with the Karnaphuli river on its east side by road with a distance of about 300 meters. At this location it is also connected to the Airport Road. On the west, it is on the side of the highway - M. A. Aziz Road. KEPZ is a well-planned and protected area within the BWDB Polder 62 which has strong embankment with concrete protection to protect the area from surges of the Bay of Bengal. Drainage congestion or water logging is a frequent hazard for the KEPZ.
Kalurghat Industrial area	A part of Kalurghat industrial area of about 500 hectares was taken into consideration for this study. Number of industries within the area is about 134 and out of it 20 were surveyed as samples for the analysis of this study. This area is located within the Chattogram City Corporation and it is parts of Ward No. 4 and Ward no. 5. It is on the Bank of the Karnaphuli river on the east side. A channel named Noa Khal passes through this area which drains to the Karnaphuli. This area is not as well planned as the KEPZ. Without the non-functional protection and measures the area is subject to suffer from flood, cyclone, drainage and salinity hazards.

Following Figure 3-1 shows the study areas.

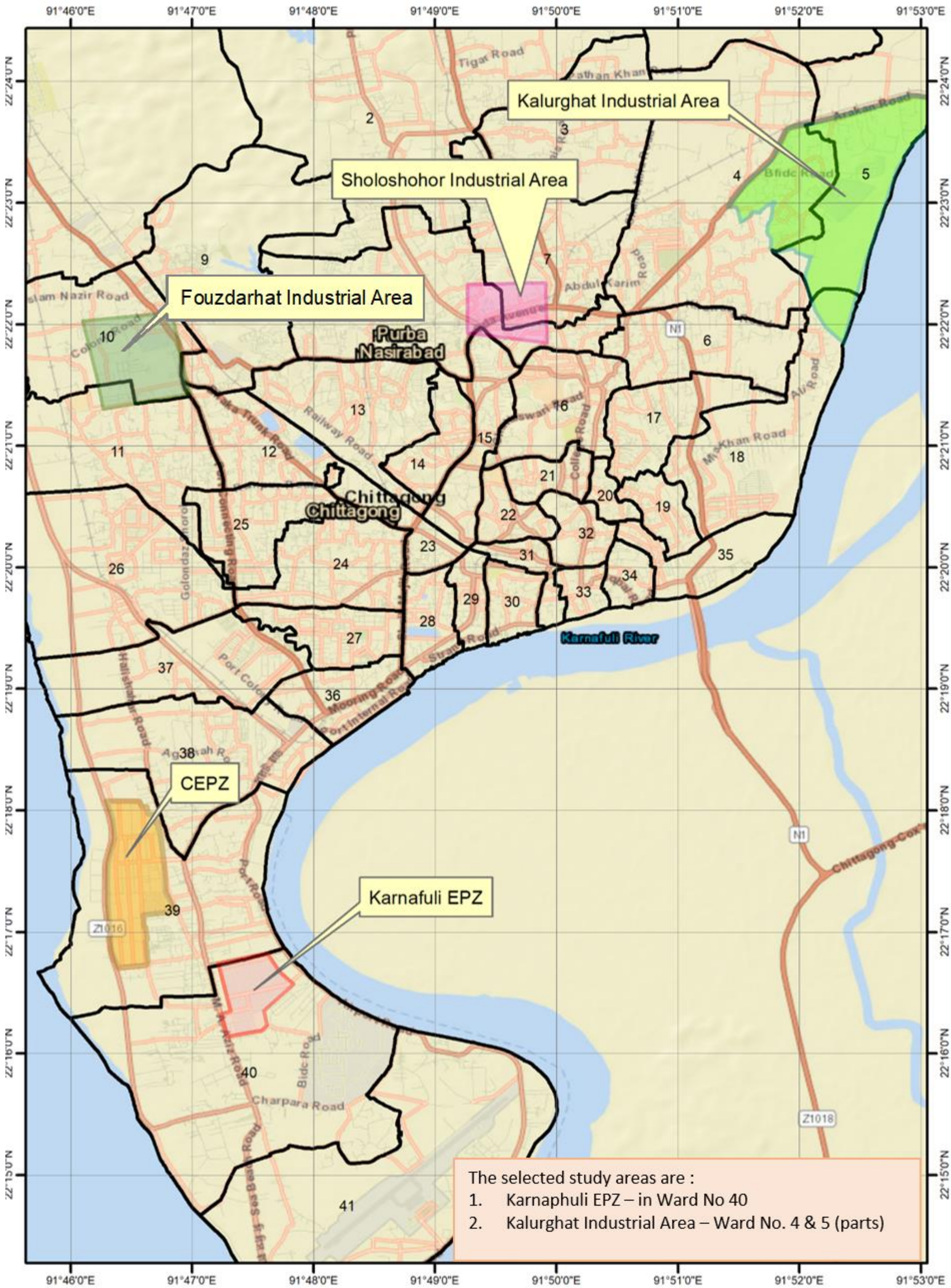


Figure 3-1: Study areas at (a) Karnaphuli EPZ and (b) Kalurghat Industrial Area

3.1.2 Climate and Hydrology

A typical tropical monsoon climate exists in the study areas. The dry and cool season is from November to March; pre-monsoon season is from April to May which is very hot. The sunny and the monsoon season are from June to October, which is warm, cloudy and wet. The mean temperature in the region varies from 13°C to 37°C. Annual rainfalls are estimated to about 2600mm. About 64% of the rainfall occurs in the months of June, July and August. In the dry months of November, December, January, February and March the amount of rainfall is very little. Humidity varies from around 37% to 95%. During the dry season, the winds are predominantly from the north-northeast whereas during monsoon they are from the south-southeast. Data on the climatic conditions of the Chattogram city collected from the nearest climate station of Bangladesh Meteorological Department (BMD) which is summarized in Table 3-1.

Table 3-1: Climate parameters at the Chattogram Station of BMD

Month	Max. temp. (ºC)	Min. temp. (ºC)	Rainfall (mm)	Rainy day (nos.)	Mean humidity (%)	Mean wind speed (m/s)
Jan	26	13.9	5.6	1	73	2.54
Feb	28	16.2	24.4	2	70	3.27
Mar	30.6	20.3	54.7	4	74	5.03
Apr	31.8	23.4	147.4	8	77	7.54
May	32.3	24.7	298.6	13	79	7.44
Jun	31.5	25.2	607.3	16	83	8.77
Jul	30.9	15.1	727	19	85	8.87
Aug	31.1	25.1	530.6	17	85	7.92
Sep	31.6	25.1	259.3	13	83	5.56
Oct	31.5	24	184.8	7	81	3.06
Nov	29.8	20.3	67.5	3	78	2.14
Dec	27	15.6	11.9	1	75	2.11
Average	30.2	20.7	243.3	8.7	78.6	5.4

3.1.3 River and Khal system

Entire Chattogram City was taken into consideration in modelling the flood, cyclone, water logging, and salinity hazards. The Bay of Bengal is on the west side of the study areas. The Karnaphuli flows by the eastern side. The Halda river flows from the north to the south and meets the Karnaphuli river near Kalurghat. Moreover, there are many major and minor khals which fall into the Karnaphuli and Halda Rivers Figure 3-2 shows the locations of the Karnaphuli-Halda River System.

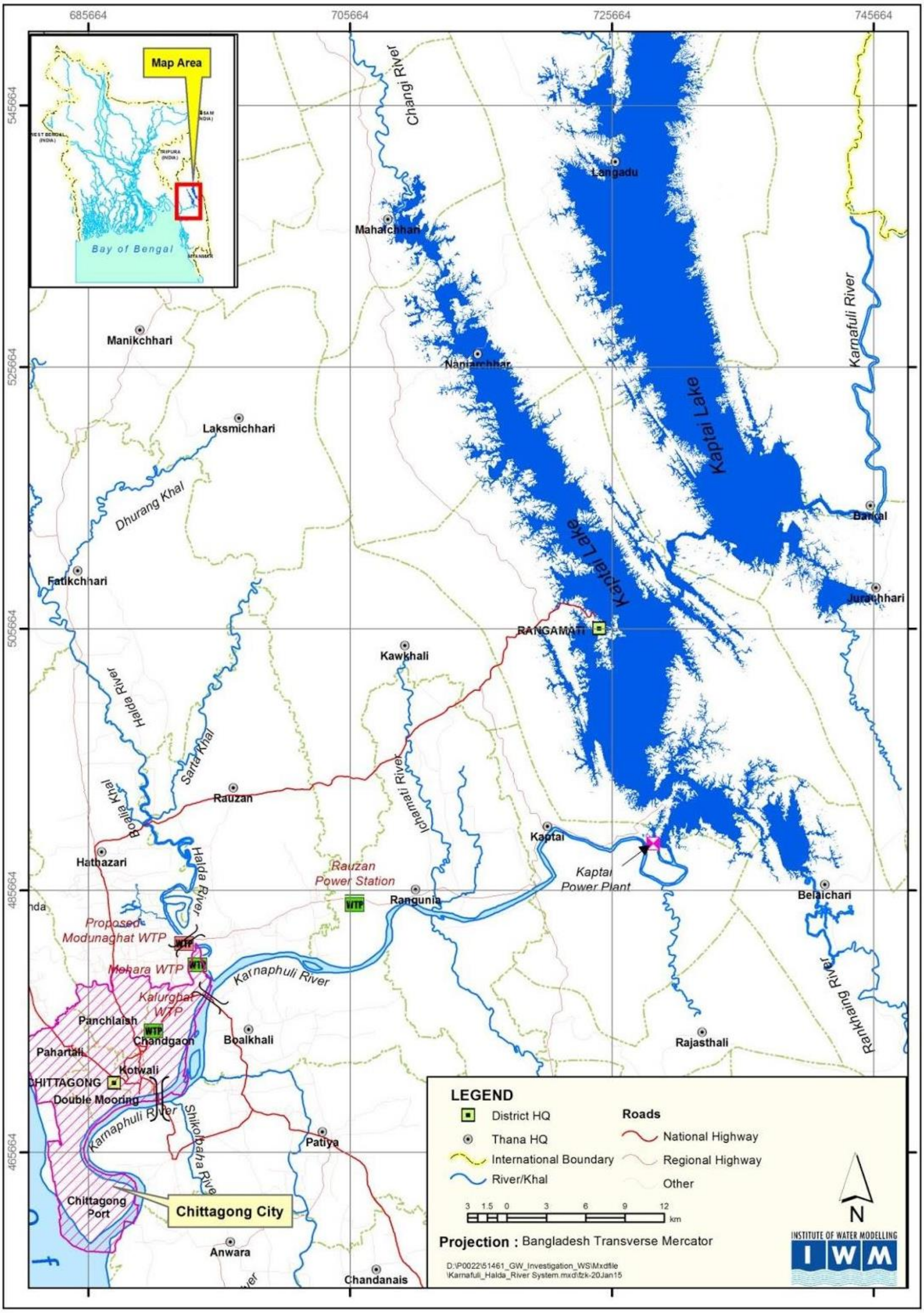


Figure 3-2: Locations of the Karnaphuli-Halda River System

3.1.3.1 THE KARNAPHULI RIVER

The Karnaphuli River originates in the Lushai Hills of Mizoram in the Indian Territory. It joins with its several tributaries inside India and then enters into Bangladesh in Bhushan Chara Union of Barkal Upazila of Rangamati Hill District and follows a tortuous but generally south-westerly course before it falls in to Kaptai Lake in Bali Khali Union of Rangamati Sadar Upazila. The largest Hydro Power Plant of Bangladesh was constructed over the Karnaphuli in 1960. This dam stores water to produce hydro-electricity and checks flash floods towards the Chattogram Metropolitan City. In the downstream of Kaptai Dam, the Karnaphuli flows through Rangunia, Boalkhali, Patiya, Chandgaon, Bakalia, Anwara and Patenga and falls into the Bay of Bengal at Patenga, some 16 km below the Chattogram main city.

The Karnaphuli River has a total length of about 320 km from its offtake in India to its outfall in the Bay of Bengal. Its length within Bangladesh is about 161 km. The river is tidal for about 80 km from its outfall at Patenga. The maximum tidal fluctuation is at the outfall and it varies from 4.13 to 5.73 meter.

The river is connected with many hilly tributaries, like Chengi, Rainking River from Rangamati District, Maini and Kasalong River from Khagrachari District. Besides, many streamlets are also connected with the River Karnaphuli. The flow of the river is dependent mostly on the rainfall in the upper large hilly catchment area. The catchment of the Karnaphuli and its allied streams covers about 13,120 sq. km.

Dam over the Karnaphuli at Kaptai, Rangamati

The Karnaphuli Dam Reservoir is situated at Kaptai of Rangamati Hill District, about 70 km upstream of the Chattogram port. The Dam was constructed over the Karnaphuli River at Kaptai in December, 1961 to produce hydro-electricity. This is the only hydroelectric project in Bangladesh.

After construction of the Dam over the Karnaphuli River at Kaptai, a large water body has been formed at the upstream of the project, popularly known as 'Kaptai Lake'. The size of the reservoir is about 777 km^2 at a maximum water level of 33.23 m MSL. A policy guideline is followed by using "Rule Curve" to operate and manage the reservoir. Under the existing rule curve, the highest water level is 33.23 m MSL in November. The annual average rainfall varies between 2200-3600 mm. At Present five power generating units are producing a total of 230 MW electricity. There is a feasibility study report in the name of 'Karnaphuli Hydroelectric Power Extension (no. 6 & 7) Project carried out in October, 1998 by TEPSCO (Tokyo Electric Power Services co. Ltd). The study recommended the extension of unit 6 and 7 for generation of additional 100MW electricity, but this has not been yet brought under operation.

3.1.3.2 THE HALDA RIVER

The Halda River is one of the major rivers in the South-East region of Bangladesh. It originates from Halda chhora (হালদা ছড়া) at 2 no. Patachara union in Ramgarh Upazila under Khagrachari District. It flows through Fatikchhari Upazila, Hathazari Upazila, Raozan Upazila and Chattogram Chandgaon Thana before falling into the Karnaphuli River near Kalurghat area. The 98 km long river has a very turbulent tributary, the Dhurung River, which joins at Sundarpur about 48.25 km downstream.

Dhurung River (Khal) and Sarta Khal are the two main tributaries of the Halda River. The drainage basin consists of 12 catchments or sub-basins**.**

3.1.3.3 KHAL SYSTEM IN THE CHATTOGRAM CITY AREA

There are about 43 nos. of open khals of length about 107km which flow through the Chattogram City Area. Khankakia, Krishna, Noa, Domkhali, Chaktai, Rajakhali and Maheshkhali khal are the major khal systems. Most of the khals fall into the Karnaphuli River.

3.1.4 PHYSIOGRAPHY

The area considered in water related hazard modelling (using Mike 11) falls under two different types of physiographic units which are the North-Eastern hills and Chattogram Coastal Plain Land. Some portions in the northern and middle part fall under the low hill ranges of the North-Eastern Hills where the remaining portion falls under the Chattogram Coastal Plain. The physiographic map of Bangladesh is shown in Figure 3-3 (Source: SRDI, 1995).

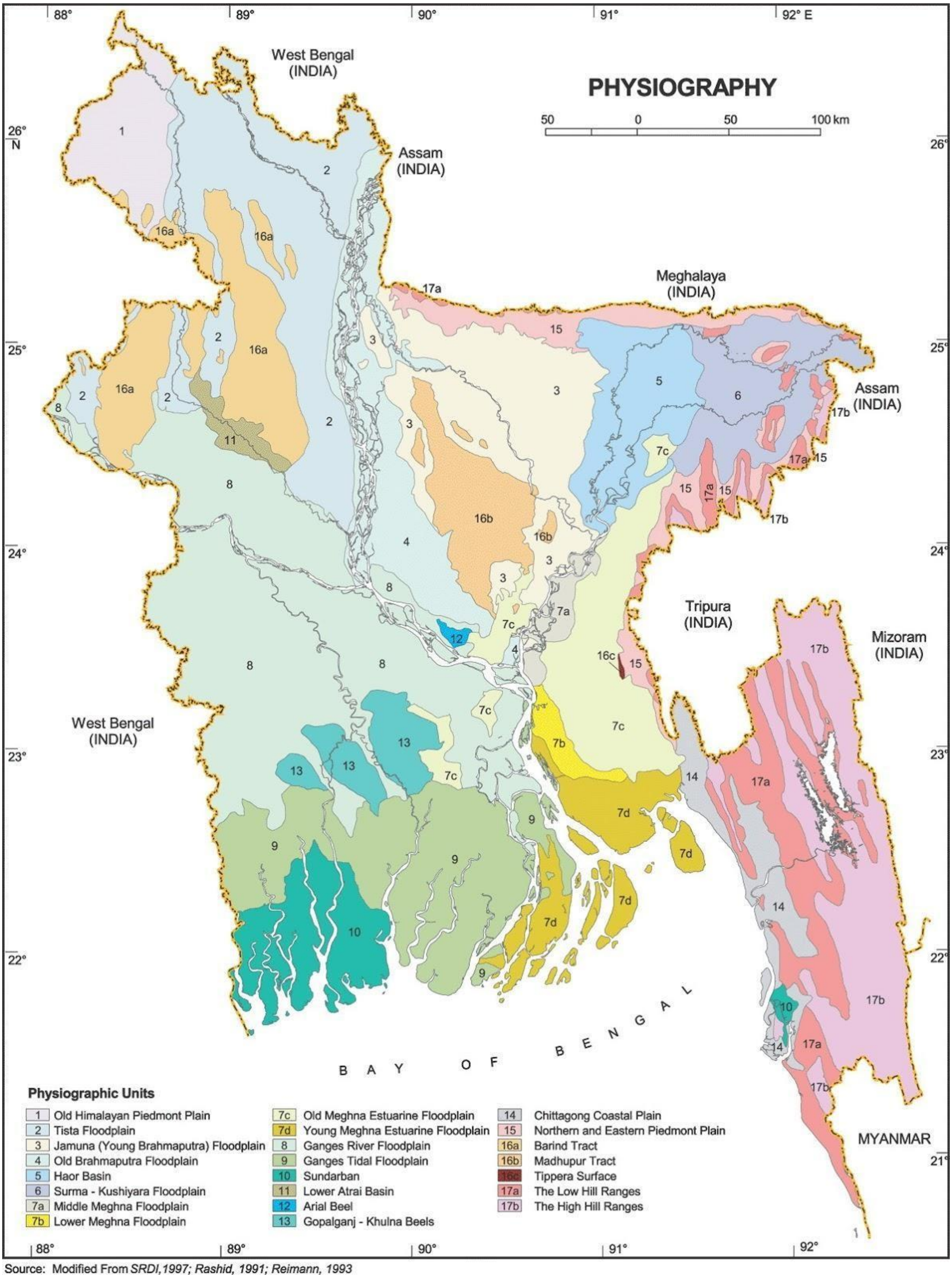


Figure 3-3: Physiographic map of Bangladesh (Source: SRDI, 1995)

3.1.5 OCEAN CURRENT CIRCULATION PATTERN IN THE BAY OF BENGAL

The upper layer circulation of the Bay of Bengal is subject to strong seasonal variability as shown in Figure 3-4. During the early northeast monsoon in November the large-scale flow pattern in the bay is cyclonic (clockwise circulation), and the western boundary current, the East Indian Coastal Current (EICC) flows southward from the Bengal. In February the EICC reverses and flows northward along the Indian coast, reaching its maximum strength during the early southwest monsoon in April/May (Shetye et al., 1993). In the interior of the Bay of Bengal the large-scale flow is anti-cyclonic (clockwise circulation) during this time. This variability is associated with the Indian monsoon: dry northeasterly winds coupled with cooling and evaporation in winter and southwesterly winds coupled with heating, precipitation, and an increased freshwater runoff into the northern bay in summer.

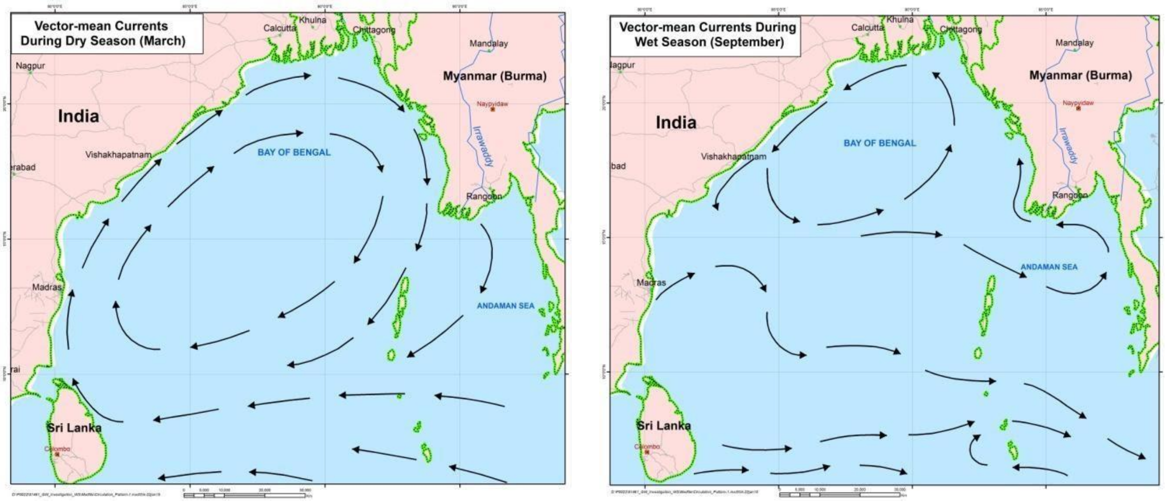


Figure 3-4: Typical large-scale ocean current circulation pattern in the Bay of Bengal in dry and wet season- Deutsches hydrographic Institute (1960)

Saline water from the Bay of Bengal enters Karnaphuli and transmits to further upstream. The salinity in the river varies over the year, which depends on the wind circulation in the Bay of Bengal, salinity concentration in the sea, tidal influence, rainfall in the upper catchments, discharge release from Kaptai reservoir, fresh water flow through the Halda and Ichamati Rivers. It is expected to reach a maximum salinity at the end of the dry season and a minimum during or immediately after the rainy season. Because of the higher density of salinity in the sea, it tends to enter the river along the bed during flood tide, while on the other hand the fresh water from the river tends to advance along the surface during the ebb tide. In the dry season the salinity propagation mostly depends on the fresh water flow release from the Kaptai dam. When the release is very low, the salinity front goes further upstream in the Karnaphuli and Halda Rivers.

3.1.6 HISTORICAL CYCLONE STORM

During the period of 1960-2009, about twenty-five (25) numbers of severe cyclones hit the coast of Bangladesh. After 2009, at least four tropical cyclones (MAHASEN-2013, ROANU-2016, MORA-2017, AMPHAN-2020) hit the Bangladesh coast which formed into severe cyclones. The most devastating cyclones that have passed near the project area are the 1960, 1970 and 1991 cyclones. The information of the cyclones includes cyclone period, position of cyclone, cyclone intensity, pressure drop (ΔP), maximum wind speed (Wm) and radius to maximum wind (Rm). Tracks of major cyclones that crossed Bangladeshi coast are shown in Figure 3-5.

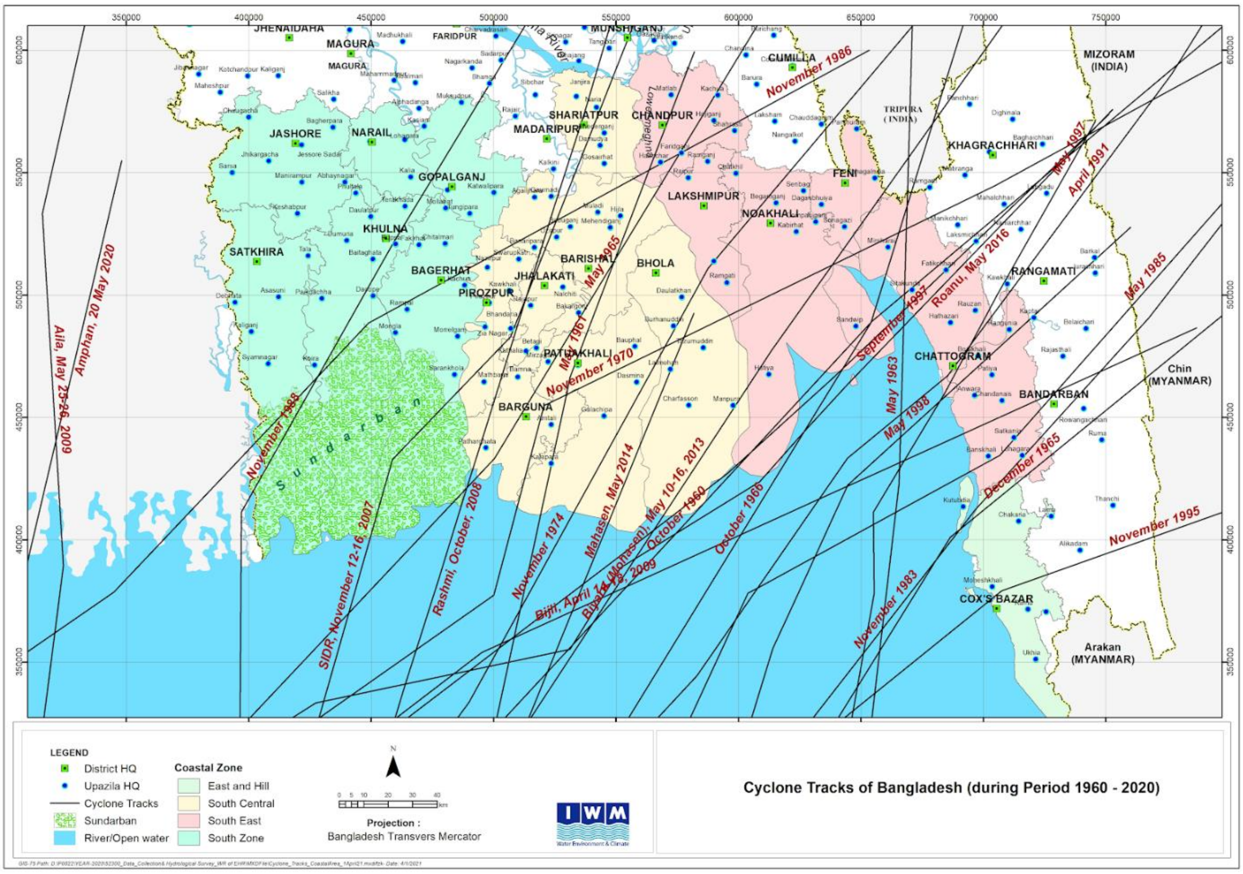


Figure 3-5: Cyclone Tracks during the period of 1960- 2020.

Chapter 4: DATA COLLECTION AND PROCESSING

The primary and secondary data collection activities including data collection methods, equipment used etc. are described in detail in this chapter. The primary data collection includes the topographic data from the two sites, Industrial questionnaire surveys, rapid visual screening (RVS) for earthquake vulnerability assessment. Data processing is also included in this chapter. This chapter further includes different types of mapping such as topographic mapping, base maps, and industrial maps for two sites. The secondary data collection includes long historical time series data of Rainfall of Chattogram City Area, River water level of Karnaphuli River, water discharge data from Kaptai Hydro-Electric Power Plant, Water abstraction, climate change data of the region and Geophysical data of two sites.

Data collection and processing is an important aspect of this study. Inaccurate data can impact the study results adversely. Hence, in the initial stage of the project, IWM team has identified the required data, their availability, sources, and their access.

According to the sources and availability data are categorized as:

(a) Primary data - captured or newly collected data under this study.
(b) Secondary data – existing data from different organization and studies.

A gap analysis was done to identify the primary data collection.

4.1 PRIMARY DATA COLLECTION

The primary data have been collected using different means and methods such as

- Questionnaire survey - for industry information
- Topographic height surveys using Terrestrial Laser Scanner (TLS) - in KEPZ area
- Topographic height surveys by Drone - in Kalurghat Industrial area
- High resolution satellite images - to capture the structure footprints, and other infrastructure such as roads, bridges, khals/canals
- Rapid Visual Screening (RVS) survey – in industrial areas for earthquake analysis

4.1.1 INDUSTRIAL DATA COLLECTION BY QUESTIONNAIRE SURVEY

The industry level data have been collected through a questionnaire survey. A questionnaire was prepared in consultation with the NRP and UNDP project related officials. An Android mobile App has been developed and used to collect data through interviewing the relevant officials of each industry. The geographical locations in terms of Latitude and Longitude and photographs of each industrial site were also collected through the mobile app. Alongside the app the data were in the hardcopy questionnaire form. The collected data was immediately stored in the database server located at the IWM office in Dhaka. The Questionnaire Form and the collected data are presented in Appendix-I.

The industry level survey in the KEPZ was conducted during the August 2020. There are 57 numbers of industries of types A, B & C (A=International, B=International & National and C=National) producing different categories of products. Among them 37 numbers of industries were surveyed, and the remaining industries were either closed or under construction. The list of the surveyed industries is given in Table 4-1 below.

Table 4-1: List of surveyed industries in KEPZ study area

Sl No	Name of Industry	Products	Industry Type
1	Bangladesh Pou Hung Industrial Limited	Footwear & Leather goods	Others
2	BD Designs Private Limited	Garments	Garments & Related
3	Bestec BD Limited	Garments	Garments & Related
4	Campvalley Global Ltd.Unit-1	Tent	Others
5	Campvalley Global Ltd.Unit-2	Tent	Others
6	CBC Optical Industries BD Co. Ltd.	Electronics & Electrical goods	Electric Item
7	Corvo Cycles Limited	Miscellaneous	Others
8	Eusebio Sporting (Bangladesh) Co. Ltd.	Tent	Others
9	Geebee (Bangladesh) Ltd.	Garments	Garments & Related
10	HKD Outdoor Innovations Limited	Tent	Others
11	Intimate Apparels Ltd.	Garments	Garments & Related
12	Kenpark Bangladesh Apparel (Pvt.) Ltd.	Garments	Garments & Related
13	Lhotse (BD) Limited	Tent	Others
14	Naturub Accessories Bangladesh (Pvt.) Ltd.	Garment Accessories	Garments & Related
15	OFMA Camp. Ltd.	Tent	Others
16	Paolo Footwear (BD) Ltd	Footwear & Leather goods	Others
17	Park (Bangladesh) Company Limited	Garments	Garments & Related
18	Shah Amanat Accessories Ltd.	Tent	Others
19	Sheng Tseng Enterprise Co., Ltd.	Footwear & Leather goods	Others
20	Strong Footwear Ltd.	Footwear & Leather goods	Others
21	Trendex Furniture Industry Co. Limited.	Furniture	Others
22	Trident Cycles Company Limited	Miscellaneous	Others
23	Whitex Garments(Bangladesh) Pvt. Ltd.	Garments	Garments & Related
24	World Ye Apparels (BD) Limited	Garments	Garments & Related
25	Xin Chang Shoes (BD) Limited	Footwear & Leather goods	Others
26	Young Zhen Metal Industries Ltd.	Garment Accessories	Garments & Related

Sl No	Name of Industry	Products	Industry Type
27	Denim Expert Ltd.	Garments	Garments & Related
28	Arrow Fabrics (Pvt.) Ltd.	Garments	Garments & Related
29	Finesse Apparels Limited	Garments	Garments & Related
30	Hela Clothing Bangladesh Limited	Garments	Garments & Related
31	Liberty Poly Zone (BD) Ltd.	Garment Accessories	Garments & Related
32	Mars Sportswear Ltd.	Sports goods	Others
33	Resource Foam & Accessories	Garment Accessories	Garments & Related
34	Vancot Limited	Garments	Garments & Related
35	Ventura (Bangladesh) Limited	Garments	Garments & Related
36	ZANT Accessories Limited	Garment Accessories	Garments & Related
37	Karnaphuii RO Water Limited (Water Treatment Plat)	Others	Others

During the data collection, the authority of the KEPZ assisted the IWM team through their Social and Environmental counsellors to access the industries for data collection. Some photographs of data collection in the KEPZ are presented following Figure 4-1.

Figure 4-1: Meeting with General Manager, KEPZ

A part of Kalurghat industrial area of about 500 hectares was taken into consideration for this study. Number of industries within the area is about 135 and out of it 20 were surveyed as samples for the analysis of this study during August 2020.

The samples were selected to represent 8 unique types of industries as follows:

- Chemical,
- Electric Item,
- Food,
- Garments & Related,
- Metal,
- Packaging,
- Paper,
- Plastic

The list of surveyed industries in Kalurghat is presented below in Table 4-2 .

Table 4-2: List of surveyed sample industries in Kalurghat Study area

Sl No.	Name of Industry	Product	Industry Type
1	Al Ittefaq Textiles LTD.	Textiles	Garments & Related
2	Aramit cement limited	Cement	Others
3	Base Textiles Limited	Textiles	Garments & Related
4	Bengal Sack Corporation LTD.	Packaging	Packaging Industry
5	Berger Paints Bangladesh Ltd.	Paints	Chemical
6	Chattogram Jute Manufacturing Company Ltd	Jute	Others
7	Fabian Thread LTD.	Garments & Accessories	Garments & Related
8	Gazi wires Limited	Cables	Electric Item
9	Maf Shoes Limited	Shoes	Others
10	Meridian Foods Limited	Food	Food
11	Mir plup and paper industry	Pulp and Paper	Paper
12	Moon star paints & chemical industry	Paint & Chemicals	Chemical
13	National Iron and Steel Industry Ltd.	Iron & Steel	Metal
14	Olympic Milk Food Packaging Industries (pvt.) LT	Milk Food	Packaging Industry
15	Reliance Box Industries Ltd.	Packaging	Packaging Industry
16	Reliance Can Industries (Pvt) Ltd.	Plastic	Plastic
17	Resimix Industries Ltd	Chemicals	Chemical

18	Transcom Beverage Limited	Beverage	Food
19	United Chemical and Pharmaceutical Limited	Pharmaceuticals	Chemical
20	Usmania Glass Sheet Factory	Glass	Others

Chattogram Chamber of Commerce facilitated the access to the industries by providing a staff with the IWM survey team. Sample photographs of data collection in Kalurghat Industrial Area are shown in the following Figure 4-2 .

Figure 4-2: Data Collection of Clifton Group in Kalurghat Area

4.1.2 Topographical Data Collection and Processing

Recent topographic data is the primary need for hazard, exposure, vulnerability and risk assessment of the study areas. Hence, the topographic surveys were conducted for two study areas in KEPZ and Kalurghat industrial area using advance digital survey technologies.

4.1.2.1 Topographic Survey

The topographical land height data have been collected using the Terrestrial Laser Scanner (TLS) for the KEPZ Area to acquire high precision data. Terrestrial laser scanners are contact-free measuring devices which can collect dense point-clouds of objects with x, y, z coordinates, color, and reflectance values. The relative precision is 0.1mm at 10m and 0.240mm at 24m distance. It can collect data around 360° (azimuth) x 120° (zenith) of field of view.

The TLS was placed on 34 four numbers of locations as shown in Figure 4-3 covering the whole area of land surface and building tops inside the KEPZ area. These locations were established by the RTK DGPS method.

A GPS-base station was established on the rooftop of the KEPZ Service office using the reference Benchmark (BM) of Survey of Bangladesh (SoB) in Chattogram.

The list of the benchmarks is presented in Table 4-3 below.

Table 4-3: List of Benchmarks with other parameters

Sl No.	Items	Latitude	Longitude	Altitude (m) MSL
1	Benchmark (BM)- 5992, established by SOB. The BM Pillar is situated in cultivated land, about 50 feet west from Daulatpur Highschool west wall. Village: Daulatpur, Upazila: Patia, District: Chattogram	22°15’54”N	91°52’7.99”E	3.27606
2	Temporary Benchmark (TBM) established by IWM at the South-East corner on the Rooftop of Golden Inn Hotel, 336 Station Road Chattogram.	22°20'9.97"N	91°49'30.69"E	33.829
3	Temporary Benchmark (TBM) established by IWM at the South-East corner on the Rooftop of Karnaphuli EPZ Authority Office, Patenga Thana, Chattogram.	22°16'19.50"N	91°47'25.20"E	32.261
4	Benchmark (BM)- 6912, established by SOB.	022°17’31.58”N	91°52’11.04”E	3.5215
5	Benchmark (BM)- 504, established by SOB.	022°22’34.63”N	91°49’51.68”E	7.4947

Figure 4-3: RTK GPS locations in KEPZ area

Figure 4-4: Establishment of GPS Base Station on the rooftop of KEPZ Service office

An Unmanned Aerial Vehicle (UAV) or Drone Survey was conducted in October 2020 for capturing of ground surface images with high spatial resolution for producing point cloud data, Digital elevation Model (DEM), Digital Terrain Model (DTM) and Digital Surface Model (DSM) of the selected area in the Kalurghat Industrial Area. The specifications of the Drone and Camera is given in Table 4-4 below.

Table 4-4: Drone and Camera Specifications

Items	Description
Sensor	1’’ CMOS, Effective pixels: 20M
Lens	FOV 84° 8.8 mm/24 mm (35 mm format equivalent) f/2.8 - f/11 auto focus at 1 m - ∞
ISO Range	Video: 100 - 3200 (Auto) 100 - 6400 (Manual) Photo: 100 - 3200 (Auto) 100- 12800 (Manual)
Mechanical Shutter Speed	8 - 1/2000 s
Electronic Shutter Speed	8 - 1/8000 s
Image Size	3:2 Aspect Ratio: 5472 × 3648 4:3 Aspect Ratio: 4864 × 3648 16:9 Aspect Ratio: 5472 × 3078
PIV Image Size	1280×720(1280×720 24/25/30/48/50/60/120p)
Still Photography Modes	Single Shot Burst Shooting: 3/5/7/10/14 frames Auto Exposure Bracketing (AEB): 3/5 bracketed frames at 0.7 EV Bias Interval: 2/3/5/7/10/15/20/30/60 s
Video Recording Modes	H.265 4K:3840×2160 24/25/30p @100Mbps

Items	Description
Max Video Bitrate	100 Mbps
Supported File Systems	FAT32 (≤32 GB); exFAT (>32 GB)
Photo	JPEG, DNG (RAW), JPEG + DNG
Video	MP4/MOV (AVC/H.264; HEVC/H.265)
Supported SD Cards	Micro SD Max Capacity: 128GB Write speed ≥15MB/s, Class 10 or UHS-1 rating required
Operating Temperature Range	32° to 104°F (0° to 40°C)

The required flight plan was configured with an altitude of 250m to achieve the expected spatial resolution of the surface images. The collected images were georeferenced using Ground Control Points (GCPs). The locations of GCPs are shown in Figure 4-5, which were established by RTK DGPS utilizing the Benchmark locations of SOB as the base station.

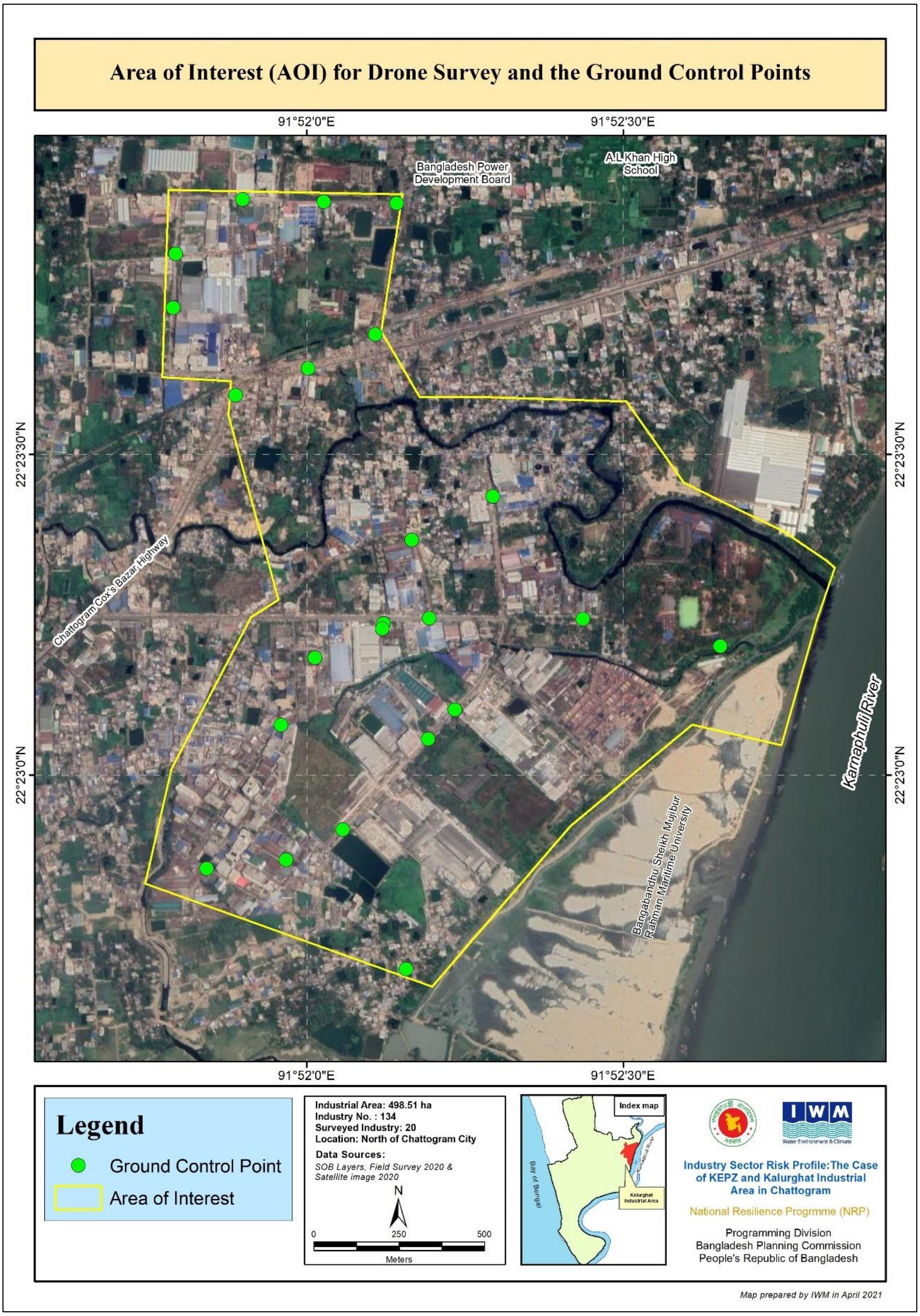


Figure 4-5: Area of Interest (AOI) for Drone Survey and the Ground Control Points

Some of the sample photos of UAV flight preparation, GCP reference station of SoB and establishment of GCPs for Drone Survey are shown following Figure 4-6.

Figure 4-6: UAV flight preparation activities in the site

4.1.2.2 DIGITAL ELEVATION MODEl

The TLS surveyed data has been geo-referenced, which was downloaded and processed for separating the ground and buildings. The ground elevations were further processed in Spatial Analyst of ArcGIS software to produce 2m grid Digital Elevation Model (DEM). This DEM represents the topographic model representing heights above the SoB datum. The DEM having the contour map in KEPZ study area is presented in Figure 4-7 below.

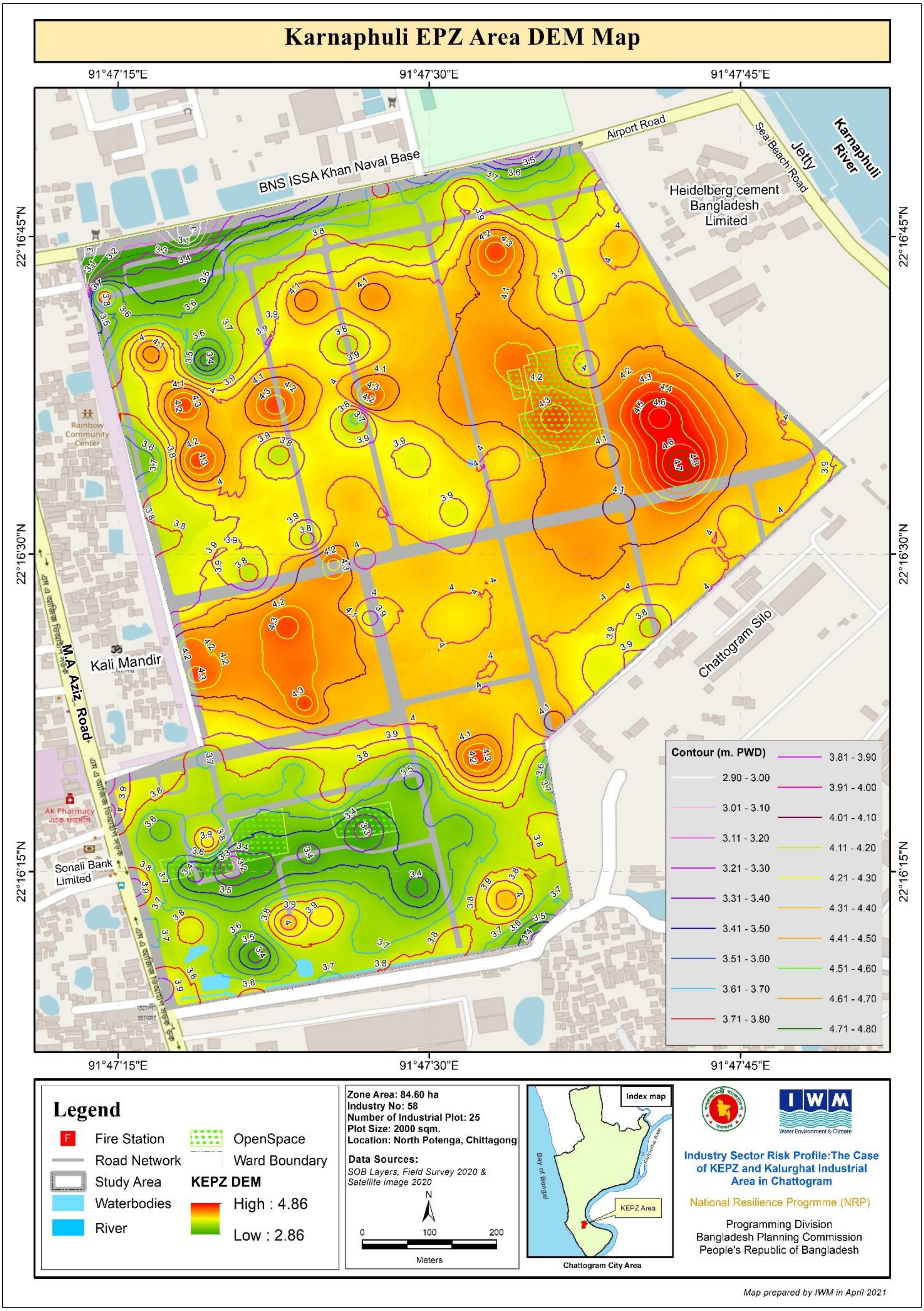


Figure 4-7: Digital Elevation Model of KEPZ area

The Drone collected photographs were geo-corrected and processed using advance photogrammetric software and point clouds were generated. After processing the data, Digital Surface Model (DSM) and Digital Elevation Model (DEM) were prepared. The DEM along with the contour of Kalurghat study area is presented in Figure 4-8 below.

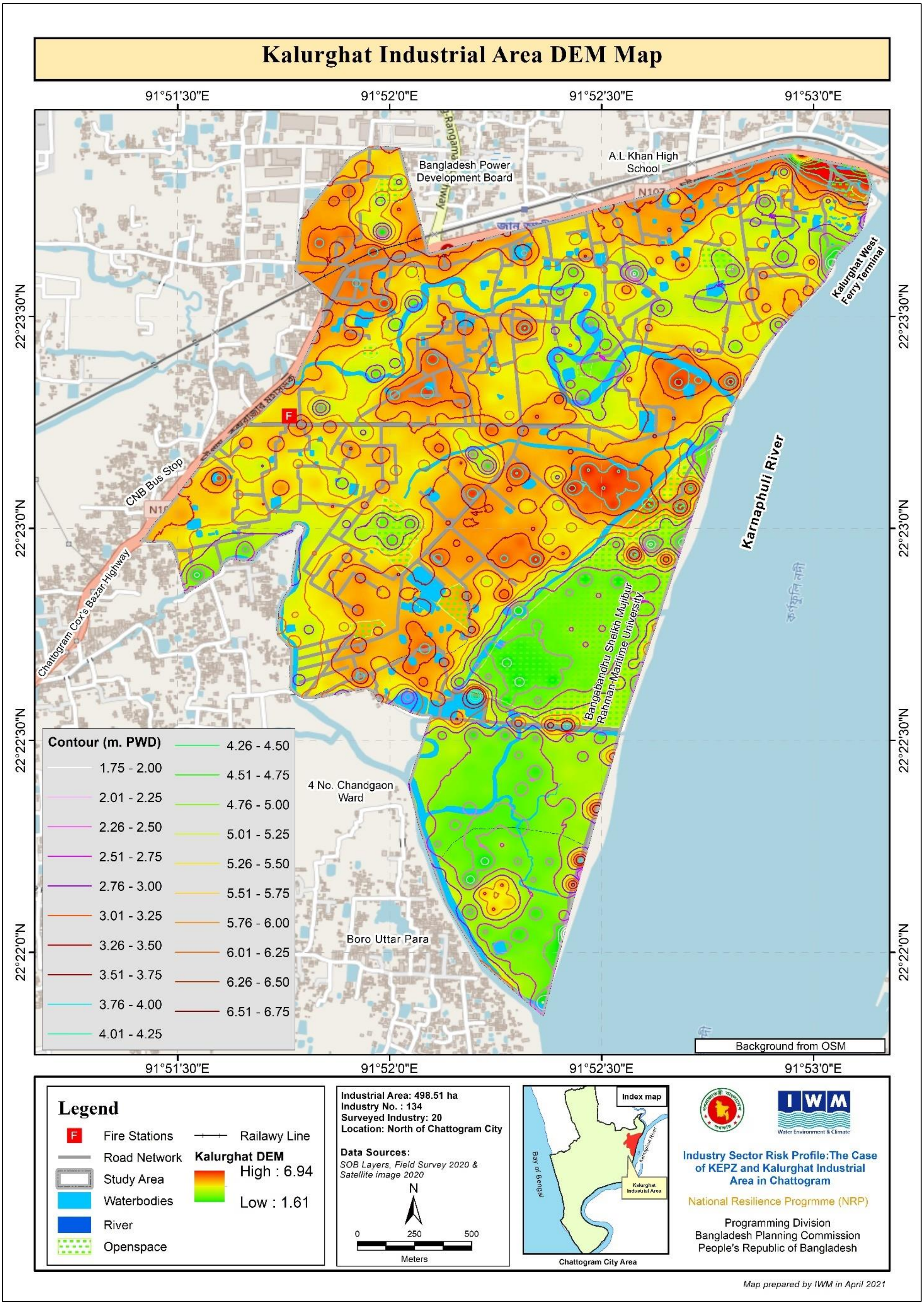


Figure 4-8: Digital Elevation Model of Kalurghat area

4.1.2.3 LAND LEVEL FOR MODEL BASIN

The hydrodynamic model covers a basin area where the two study areas are only small parts of it (Figure 4-9 below). For the model basin topography, 0.3m contour lines shape file has been collected from CDA through the S8 component of CWSISP project of CWASA. A land level DEM of cell size of 5mx5m has been developed using the contour lines and later—the portions of KEPZ and Kalurghat industrial areas on the DEM have been updated as shown in the Figure 4-9 by the collected spot elevation points data through TLS and Drone survey under this project. Ultimately this DEM was used in hydrodynamic modelling activities.

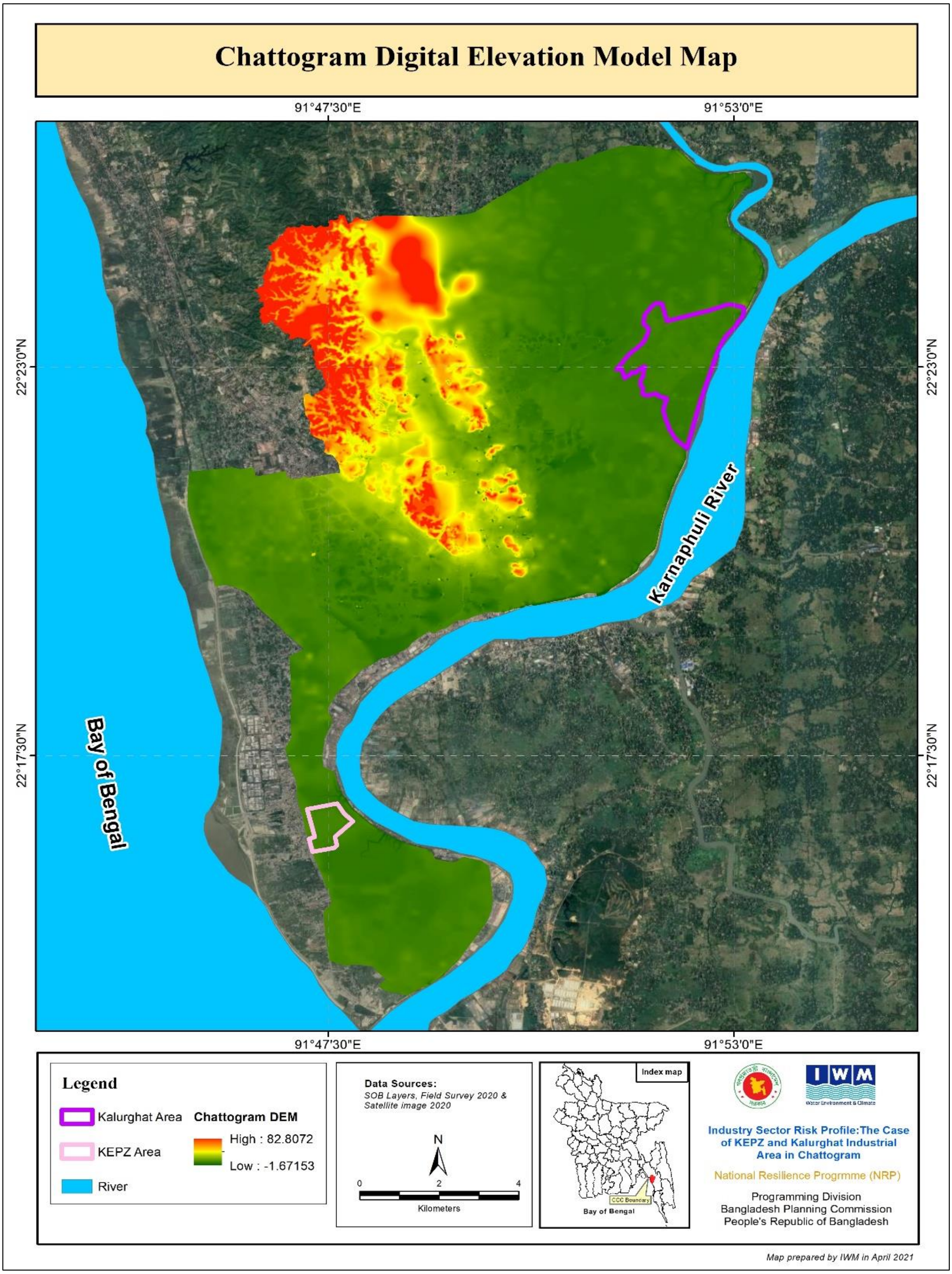


Figure 4-9: DEM Chattogram City Area

The DEMs are used in Hydrodynamic models to generate the inundation maps due to flood, cyclone and tidal surges under normal and different scenarios as described in the analysis chapter.

4.1.2.4 TOPOGRAPHIC FEATURE MAP OR BASE MAPS

One of the tasks within the scope of works of this project is to develop GIS maps of industries showing types/categories located in the study area and prepare GIS maps with existing land use along with relevant features and information. The function of the base map is to provide visual details and background of the industrial locations on the map.

The content features of the base map were prepared from GIS data and satellite images that make up the layers such as structure footprints, open spaces, roads & bridges, bus stops/terminals, railways, fire stations, cell phone towers, ferry terminal, water bodies, rivers, canals etc. for the two study areas. The source data from which the map contents have been prepared is shown in Table 4-5 below.

Table 4-5: List of data layer used in Base Map

Sl No	Items	Data Source
1	Structure Footprint	TLS Survey Data for KEPZ Drone Survey data for Kalurghat Satellite Image of World View-III, Stereo Image, ground resolution 30cm and the image capture date was 2nd March 2020.
2	Open Spaces	-do-
3	Roads	-do-
4	Waterbodies	-do-
5	Bridges	SoB digital layer (1:25000) extracted from Photogrammetry in 2012
6	Railways	-do-
7	Bus Stoppage/Terminals	-do-
8	River Terminal Jetty	-do-
9	Cell Phone Tower	-do-
10	Fire Stations	-do-
11	Rivers & Canals	SoB Layers and Satellite Image
12	Ward Boundary	Chattogram Development Authority (CDA)

The base maps of two areas are shown in Figure 4-10 and Figure 4-11. The feature map of Kalurghat Industrial Area has been prepared from the features captured from the drone survey as shown in Figure 4-12.

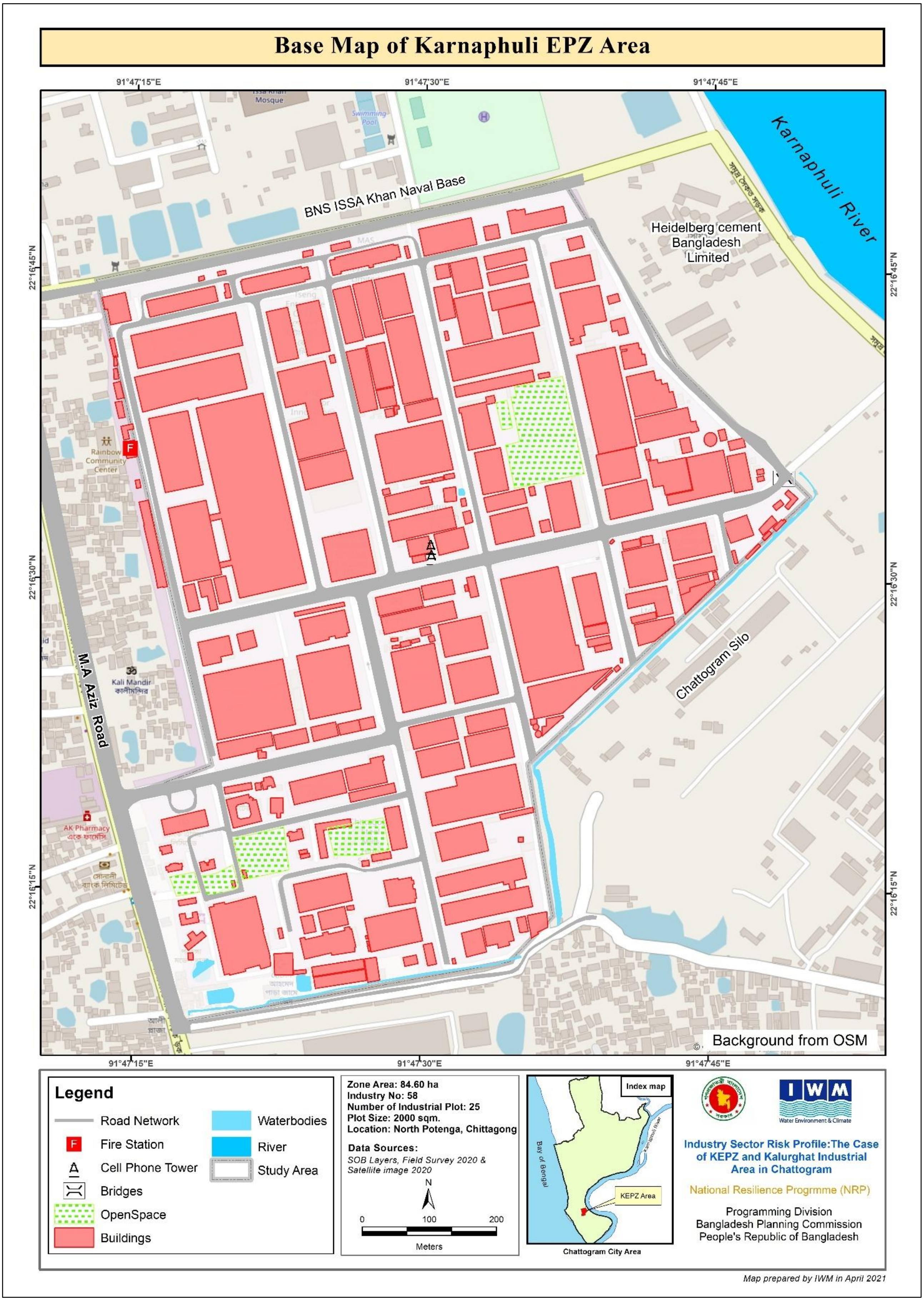


Figure 4-10: Base Map of Karnaphuli EPZ Area

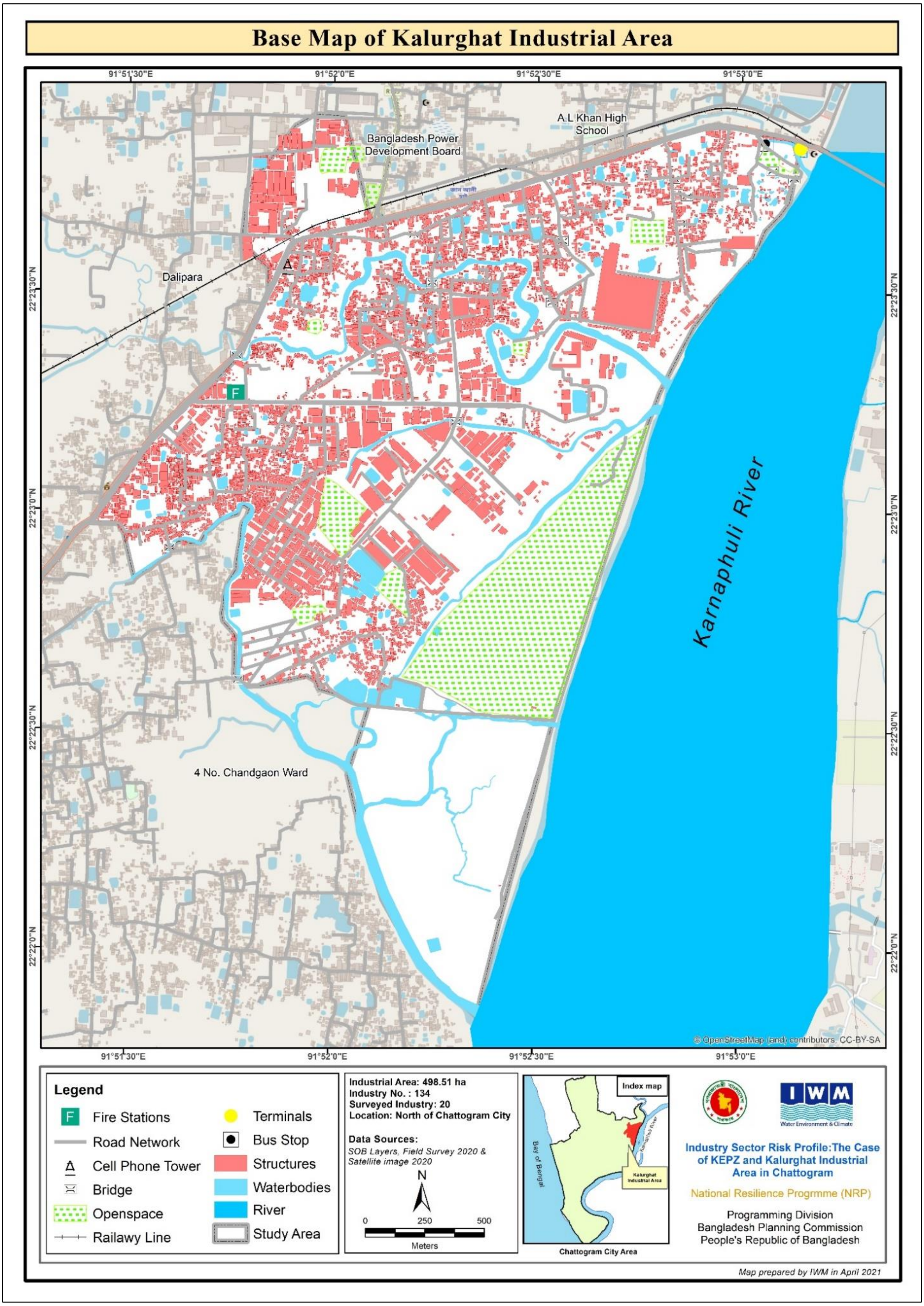


Figure 4-11: Base Map of Kalurghat Industrial Area

Figure 4-12: Digitized features from drone survey in Kalurghat Industrial Area

The content features of the Industrial map were prepared from GIS data layers of Industrial locations and footprint of industrial structures identified by the label numbers, and associated data layers such as road network, river, canals, water bodies and other features for two study areas. The industrial locations were identified by the IWM team through detailed field surveys. The prepared industrial maps are shown in Figure 4-13 and Figure 4-14 for the two areas.

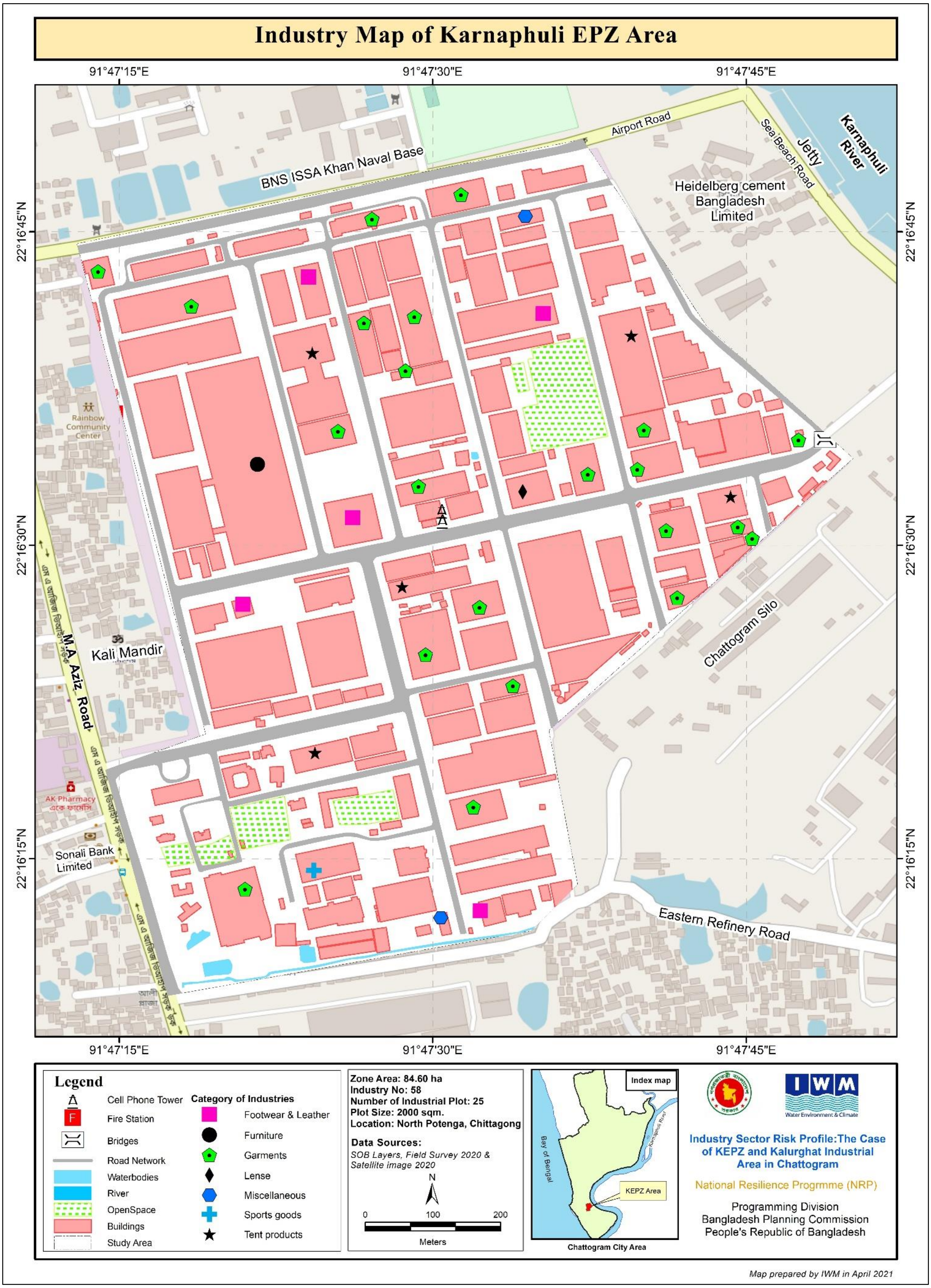


Figure 4-13: Industrial Map of KEPZ Area

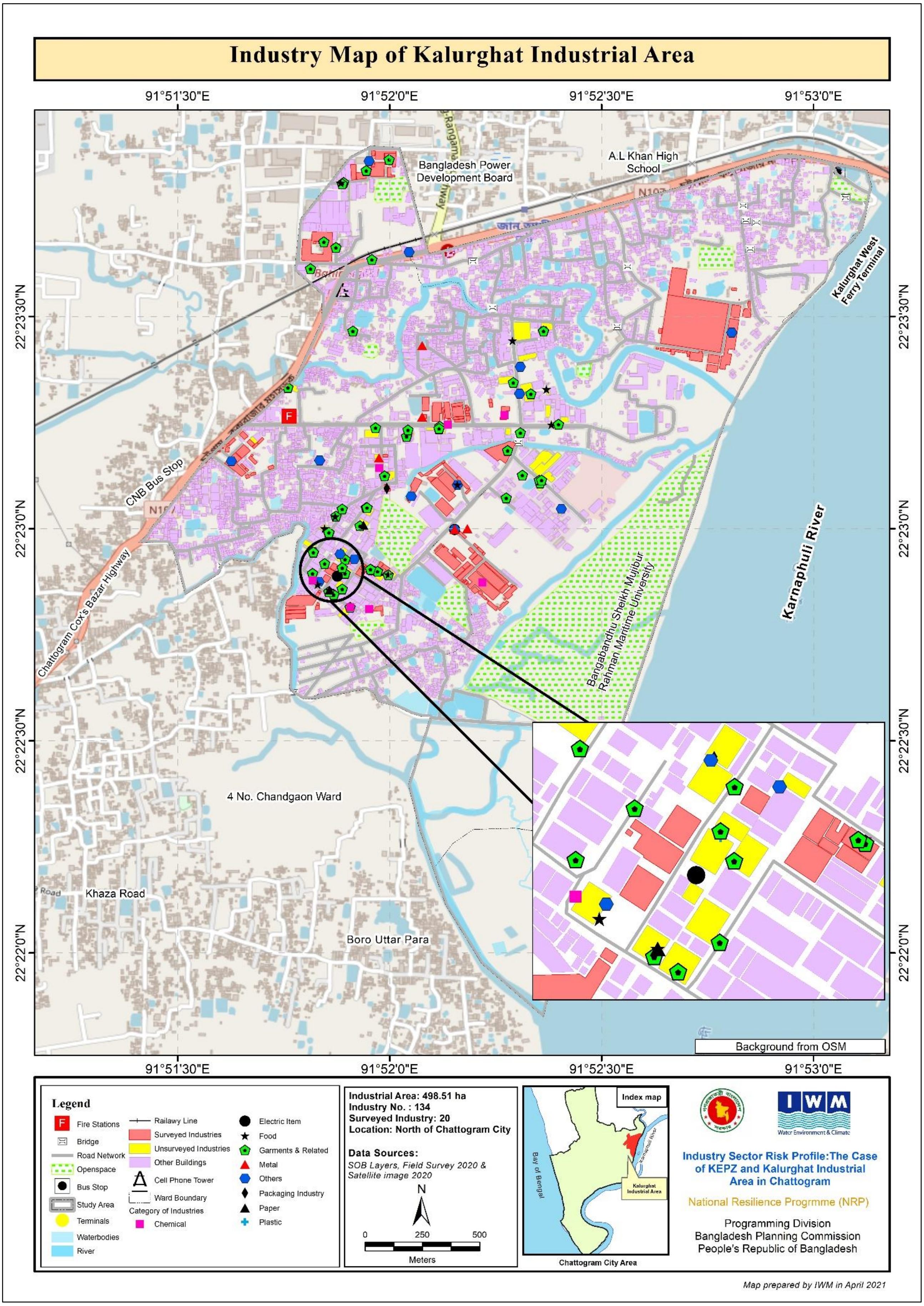


Figure 4-14: Industrial Map of Kalurghat Industrial Area

4.1.3 Fire Hazard Data

Information of four cases of fire incidents in industries were collected during the study which are described below. Available information for these cases were collected.

4.1.3.1 Fire Incident in Resource Foam & Accessories Ltd

Fire incident occurred in Resource Foam & Accessories Ltd. in the KEPZ area located at Plot 25/8 as shown in Figure 4-15 in the year 2016. The principal products of this company were Foams and Accessories. Till the fire event the industry is fully closed. The nearest fire station is located at Karnaphuli EPZ at a distance of about 200 meters.

It was suspected that the fire had originated from an electric short circuit. The fire quickly spread to the factory buildings and warehouse at Resource Foam. Huge oil and foams gutted by the fire very soon.   Fire fighting vehicles rushed to the area at around 6:30am in the morning. By that time, the maximum raw materials in the factory were burnt out. There was no report of casualty by the fire. The fire fighters brought the incident under control after two hours.

Figure 4-15: Resource Foam & Accessories Ltd.

4.1.3.2 Fire Incident in Kader Trading Company:

A fire incident occurred in Kader Trading Company located in Kalurghat industrial Area on 31st December 2021. Primary product of the industry is Felt, made of waste garment cloth, fiber, thread etc. Major use of felt is to produce Mattress, Cushion etc. All these raw materials and finished goods are highly flammable and susceptive to fire.

The fire started at 10: 30 pm, nearest fire service station of Kalurghat responded first after fire was first ignited. Total 8 (eight) units of Fire Service Units from Kalurghat and Agrabad worked together to put the fire out and they finally were able to extinguish the fire at 3:30 am. The IWM team visited the industry to investigate the site on 13th January 2021 and collected following information:

Name of the proprietor: Mr. Fazlul Kader

Location: The industry is in Badamtali Mor (BFIDC Road) of Kalurghat Heavy Industrial Area, just outside the jurisdiction area of Bangladesh Small and Cottage Industries Corporation (BSCIC) Chattogram. The geographical location of this industry is 22.387° N, 91.872°E. The industry was established in 2018.

Reason of Fire: The fire was ignited through an electric short circuit and went on through the air tunnel to the intermediate product chamber.

Loss estimation: All the raw materials, machineries etc. were burnt out by the fire. The industry bought 3 new machines from China to enhance the production, but before any production was made, all were burnt out. The industry does not have any other production unit at present. The losses in monetary terms are presented in Table 4-6 below.

Table 4-6: Status of Losses due to Fire incidence of Kader Trading Company

SI	Item	Loss (crore BDT)
1	Felt machine	8
2	Cotton machine	2
3	Other goods	5
4	Infrastructure	1.5
	Total	**16.5**

The key information has been provided by Mr. Pipul Chowdhury, Manager (Admin & HR), Kader Trading Company, Kalurghat, Chattogram. Some photos of the burnt entities is presented in Figure 4-16.

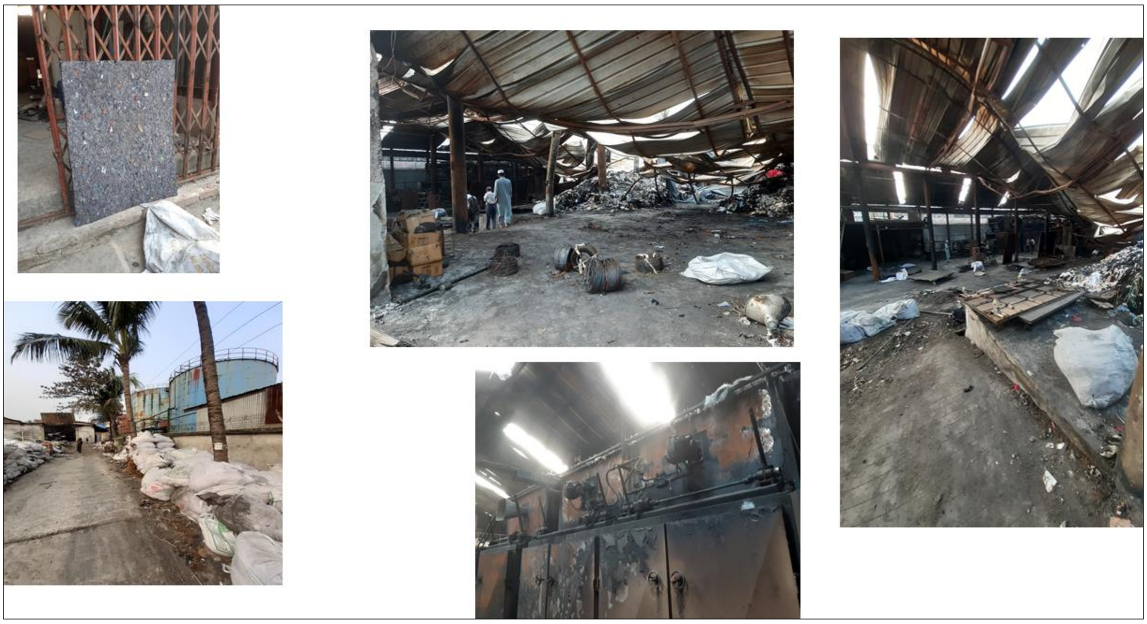


Figure 4-16: Sample Photographs of burnt machineries of Kader Trading Company

4.1.3.3 Fire Incident in SKD Innovation Factory

SKD Innovation is a garment factory located in the KEPZ area in Chattogram city. A fire incident occurred in the Factory around 6:15 am on Wednesday 27th November 2019. The fire originated in Sector-1 of the factory. It took around 3 hours to bring the fire under control. The damage from the fire had not been determined initially. However, no casualties were reported in the incident.

4.1.3.4 Fire Incident in Meridian Chips Factory

Meridian chips, a product of Meridian Foods Ltd., is well-known and one of the oldest chips industries in Bangladesh. In the early morning on 27th July 2021, a fire broke out at this factory located in Kalurghat, Chattogram. The fire damaged various raw materials, machineries, ground floor and two-story labs of the Meridian Chips factory. However, no casualties had been reported in the incident. Earlier, a fire broke out in the factory on December 21, 2011 causing a loss of about Taka 6 lakhs.

4.1.4 Earthquake - Rapid Visual Screening (RVS) Survey

The RVS is a method to estimate the seismic vulnerability of a large number of structures based on the Federal Emergency Management Agency (FEMA) guideline. FEMA guideline was to develop Next-Generation Performance-Based Seismic Design Procedures for New and Existing Buildings by the US Federal Government.

The RVS is based on correlations between the buildings' predicted seismic performance and structural typology (frame, shear wall, monolith, in-fill), material (steel, reinforced concrete, reinforced/unreinforced masonry, wood, composite), design methods used, and other details. Additional inputs to the evaluation include the level of earthquake hazard. The estimates are based on expert opinions, pushover analyses, dynamic response studies and performance of similar buildings in past seismic events. A scoring system is used to quantify the vulnerability of a structure.

An IWM team under supervision of Professor Dr. Raquib Ahsan (BUET) visited Chattogram in January, 2021 to carry out an Earthquake Risk Assessment survey in Kalurghat Industrial Area and KEPZ area. The team conducted a Rapid Visual Screening (RVS) questionnaire survey to identify seismic vulnerability of the industrial structures by inspecting each structure of the industries in these two industrial areas. During the survey, the team covered 71 numbers of structures in KEPZ, and 91 numbers of structures in Kalurghat Industrial Area. A filled up questionnaire is presented below in Figure 4-17 and Figure 4-18.

Checklist for Rapid Visual Screening (RVS)

Abu Zaffar (owner)

1. **Name of the Interviewer** Md. Iqbal (01819644103) Clark
2. **Industry Name** National Metal
3. **Structure ID** 49
4. **Geographical Coordinate (DD in WGS84):** Lat 22°23'10", Long 91°51'58"
5. **Occupancy**
   - Assembly
   - Commercial
   - Residential
   - ✓ Industrial
   - Office
   - School
   - Utility
   - Warehouse
   - Emergency Service
6. **Ownership of the building**
   - Public
   - ✓ Private
7. **No. of Story** *(Above Grade) :* 0
8. **No. of Story** *(Below Grade) (if not type 0):* 0
9. **Floor Area** *(Approximate in square ft) (Write in sequence, i.e. GF+1st Floor+2nd Flood so so)*

   GF: 90 ft x 70 ft 1st Floor: 2nd Floor: 3rd Floor: 4th Floor: 5th floor :
10. **Building Type** *(Please look for the question at supporting document)*
    - C2 - Concrete Shear Wall Building
    - C3 - Concrete Frame With Masonry Infill Walls
    - URM - Unreinforced Masonry Building
    - SI - Steel Moment Resistant Frame
    - S2 - Braced Steel Frame
    - ✓ S3 - Light Metal Building
    - S5 - Steel Frame With Unreinforced Masonry Infill Wall
    - W1 - Wood Light Frame
    - W1A - Multi-Storey Multi-Unit Residential (Plan Area > 3000 sq. ft)
    - W2- Wood Frame Commercial & Industrial (Plan Area > 5000 sq. ft)
11. **Severe Vertical Irregularity** *(Please look for the question at supporting document)*
    - Short Column
    - ✓ Soft Storey / Weak Storey
    - Out of Plane Setback (if the cantilever portion is greater than 2 feet)
    - None
12. **Moderate Vertical Irregularity** *(Please look for the question at supporting document)*

Page **1** of **2**

Figure 4-17: Sample RVS questionnaire (page-1/2)

- In Plane Setback
- Split Level
- Sloping Site
- None

13. **Plan Irregularity** *(Please look for the question at supporting document)*
    - Torsional Irregularity
    - Reentrant Corner
    - Out of Plane Offset (only exterior)
    - Non-Parallel System
    - Diaphragm Opening
    - None

14. **Pounding Potential** *(Please look for the question at supporting document)*
    - Floors are not aligning vertically
    - Minimum gap doesn't meet
    - None
    - The building is at the end of a row of three or more buildings
    - One building is two or more stories taller than the adjacent building

15. **Falling Hazard** *(Please look for the question at supporting document)*
    - Unsupported Water Tank
    - Heavy Cladding
    - Flower Pot at Roof
    - Unsupported Parapet
    - Masonry Tower
    - None
    - Cornices
    - Chimney

16. **Geological Hazard** *(Please look for the question at supporting document)*
    - Loose Fill
    - Organic Soil
    - Landslide
    - None

17. **Significant Damage**
    - Visibly Sagging Beam/ Floor/ Slab
    - Large Exterior Cracks
    - Visible Foundation Elements with Large Cracks
    - Visibly Broken Beam/ Column
    - Visible Distress From Previous Earthquake
    - Foundation Elements Exposed Due to Significant Erosion of Adjacent Soil
    - Sloping Floor
    - Visible Fire Damage
    - None

18. **Is Mortar Eroding Away?**
    - Yes
    - No

19. **Is There Any Exposed Rebar?**
    - Yes
    - No

20. **Is There Any Member Corroded?**
    - Yes
    - No

21. **Extent of Review**
    - Partial
    - All side

22. **Interior Inspection**
    - Visible
    - Entered
    - None

23. **Take photo** Yes

Page 2 of 2

Figure 4-18: Sample RVS questionnaire (page-2/2)

Some samples of structure observations during the RVS survey are presented in Table 4-7 below.

Table 4-7: Samples of Structure observations during RVS Survey

Structure	Observations
 **Corvo Cycles Ltd. in KEPZ**	**Ownership Type:** Private **Use:** Industrial Warehouse **Building Type:** Steel Frame with unreinforced Masonry Infill wall **Severe Vertical Irregularity:** Soft Storey Weak Storey **Plan Irregularity:** Torsional Irregularity
 **Zant Lobby Industry Zant plant room**	**Ownership Type:** Private **Use**: Industry **Building Type:** Steel Moment Resisting Frame **Pounding Potential:** Minimum gap doesnt_meet **Significant Damage:** Visibly Sagging Beam Floor Slab

Denim Expert Ltd, KEPZ

Ownership Type: Private

Use: Industry

Building Type: Concrete Shear Wall Building

Sever Vertical Irregularity: Soft Storey Weak Storey

Transcom Beverages Ltd., Kalurghat

Ownership Type: Private

Use: Industrial

Building Type: Steel Frame with Unreinforced Masonry Infill Wall

Sever Vertical Irregularity: Short Column

Plan Irregularity: Non Parallel System Reentrant Corner

Pounding Potential: Minimum gap does not meet

Significant Damage: No Damage

National Metal, Kalurghat Industrial Area

Ownership Type: Private

Use: Industrial

Building Type: Light Metal Building

Sever Vertical Irregularity: Soft Storey Weak Storey

Plan Irregularity: Non Parallel System Diaphragm Opening

Falling Hazard: Unsupported Parapet

Significant Damage: Visibly Broken Beam Column Visibly Sagging Beam Floor Slab

Mortar Eroded: Yes

Exposed Rebar: Yes

Member Corroded: Yes

4.2 SECONDARY DATA

Several types of secondary data such as spatial and non-spatial including Hydrological, Meteorological and relevant data have been collected from secondary sources. Following Table 4-8 presents the list of secondary data which have been used in the study.

Table 4-8: List of Secondary data used in this study

Sl No	Items/Description	Source	Data Types
1	Water Level	Chattogram Port Authority (CPA) and BWDB	Spatial & Tabular (Timeseries)
2	Groundwater Table	BWDB	Spatial & Tabular (Timeseries)
3	Daily Rainfall	BWDB	Spatial & Tabular (Timeseries)
4	Temperature Daily Max-Min/Average, Humidity daily Average	BMD	Spatial & Tabular (Timeseries)
5	Water Logging	KEPZ – No water logging	
6	Salinity	BWDB, IWM, CWASA and CPA	Spatial & Tabular (Timeseries)
7	Historical Cyclone Track	DDM	Spatial & Tabular (Timeseries)
8	Earthquake (micro level)	DDM	Spatial & Tabular (Timeseries)
9	Satellite Image (30 cm resolution), Band 8	World View-III	Raster Image

Sl No	Items/Description	Source	Data Types
10	Topographic Height (entire Chattogram)	CDA for CWSISP Project	Spatial
11	Kaptai Dam Release data	Karnaphuli Hydro-Power Station, BWDB	

4.2.1 Rainfall Data

Historical Rainfall data has been collected from BWDB for the stations influencing Chattogram city drainage catchments. There are two rainfall stations located in Chattogram City (Station ID: CL306 of BWDB) and Hazrat Shah Amanat Airport (Station ID: 1192 of BMD). Historical time series rainfall data is available for the City station. IWM has collected and analyzed historical rainfall data from 1970 to 2019 of Chattogram City station. Year wise daily and 2-day maximum rainfall data are shown in Figure 4-19 and Figure 4-20.

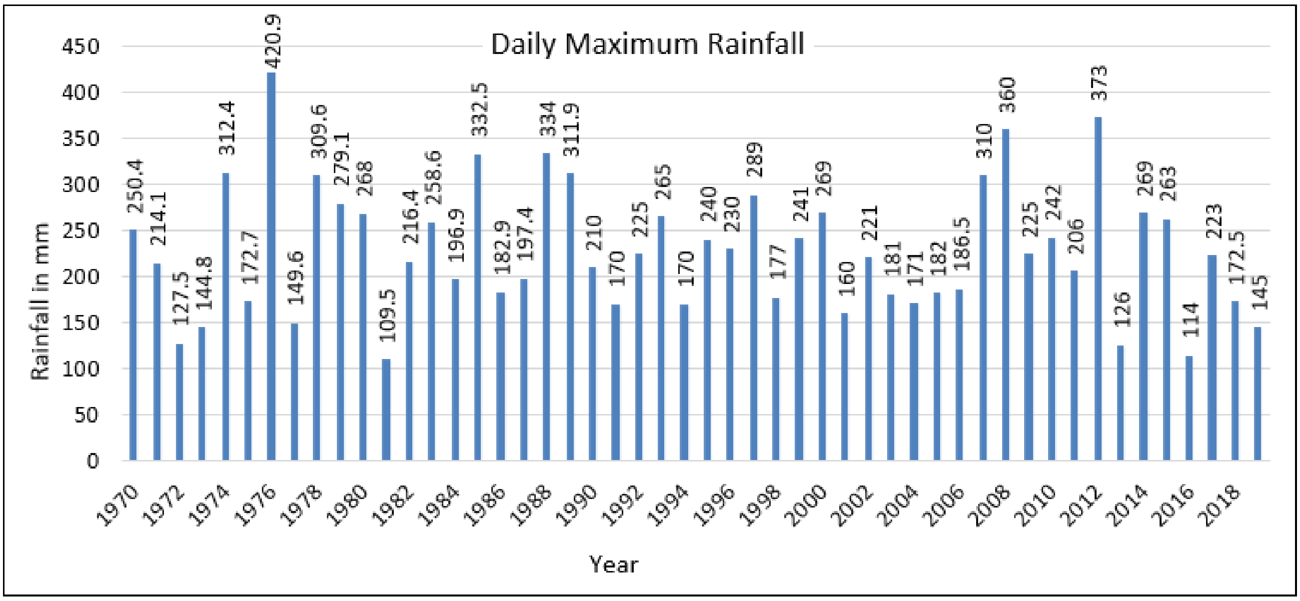


Figure 4-19: Yearly maximum daily rainfall in Chattogram City Area

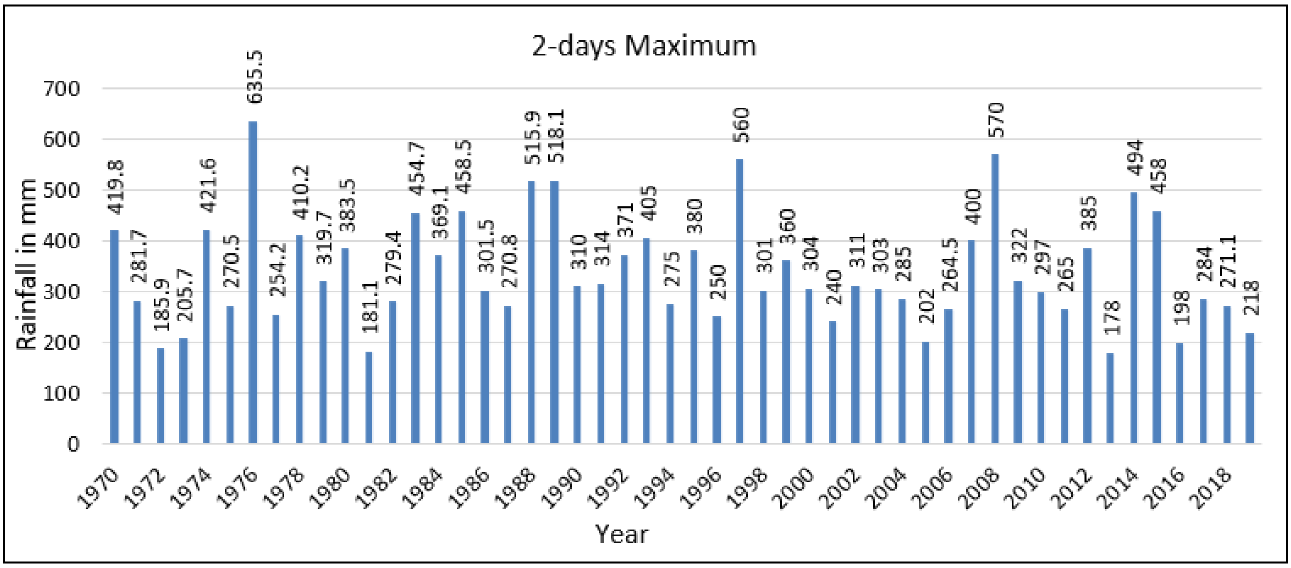


Figure 4-20: Yearly 2-day maximum daily rainfall in Chattogram City Area

Yearly total rainfall of Chattogram city is about 3100 mm. The monthly rainfall distribution as shown in Figure 4-21. It is found that 80% of the total rainfall occurs in the months from May to September. The highest rainfall is observed in July and lowest rainfall in December.

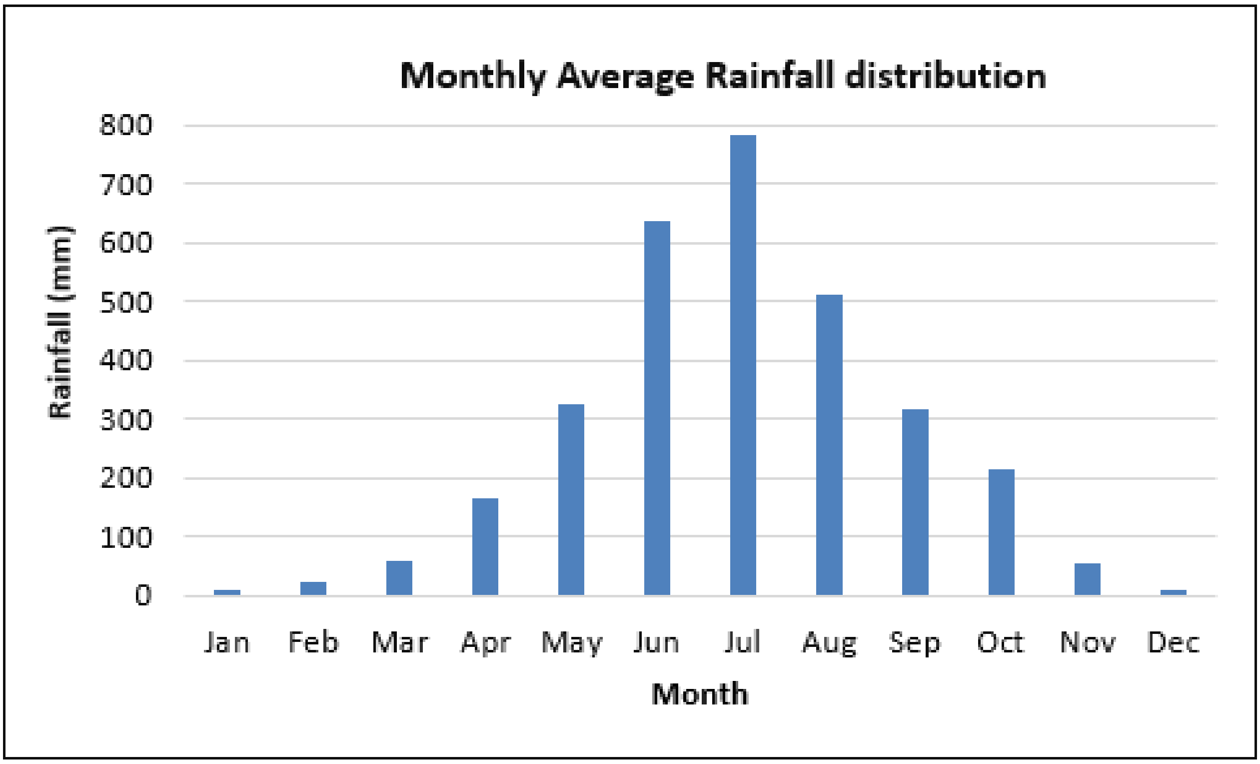


Figure 4-21: Monthly rainfall in Chattogram City Area

For runoff estimates of the Chattogram city drainage catchments, rainfall data from BWDB stations have been used. For the current study 2-day cumulative rainfall event has been selected for different drainage scenario analysis. Table 4-9 shows the calculated rainfall amounts based on linear interpolation from different return period events.

Table 4-9: Rainfall data frequency analysis in Chattogram City Area

Return Period Year	Log-normal Distribution		Gumbel Distribution	
	Daily RF (mm)	2-day RF (mm)	Daily RF (mm)	2-day RF (mm)
2	218	322	217	320
2.33	230	341	228	338
5	283	420	279	416
10	325	482	320	480
20	364	540	360	541
25	372	552	368	554
50	414	614	411	619
100	450	669	449	678

The design storm consists of 78% rainfall in the 1st day and 22% rainfall in the 2nd day (JICA 1991). The pattern indicates in Figure 4-22 in which the peak intensity occurs at the 3rd hour after the rain starts, where 44% of the total rainfall falls.

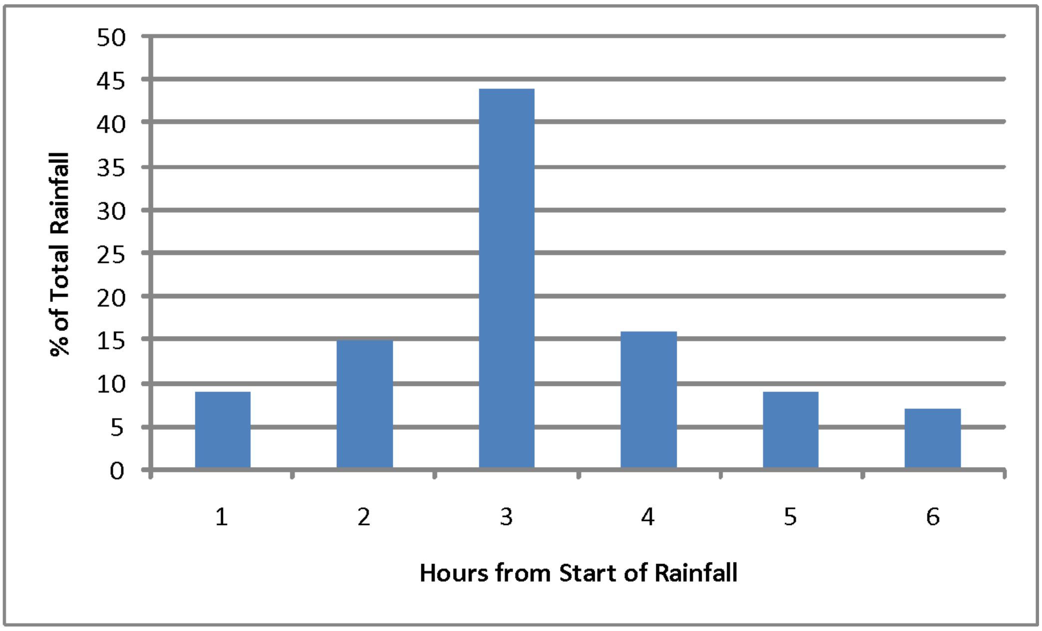


Figure 4-22: Hourly Fractions of 6-hour Design Storm Event

4.2.2 Water Level Data

Historical water level data has been collected for Khal-10, Sadarghat and Kalurghat stations from Chattogram Port Authority (CPA) and BWDB for the time period shown in Table 4-10.

Table 4-10: Inventory of collected water level data for the current study

Sl	Location	River	Data source	Period of Collection
1	Khal 10	Karnaphuli	CPA	January 1993 to April 2015
2	Sadarghat	Karnaphuli	CPA	January 1993 to April 2014
3	Sadarghat	Karnaphuli	BWDB	January 2012 to August 2019
4	Kalurghat	Karnaphuli	BWDB	January 2012 to October 2019

The CPA collected hourly water level data through automatic gauge, so the data is continuous. BWDB also collected hourly water level data but only for high tide and low tide periods. For analysis, water level data of CPA at Sadarghat station for the available period is combined with BWDB data for the remaining period. The yearly highest water level data of Sadarghat is shown in Figure 4-23

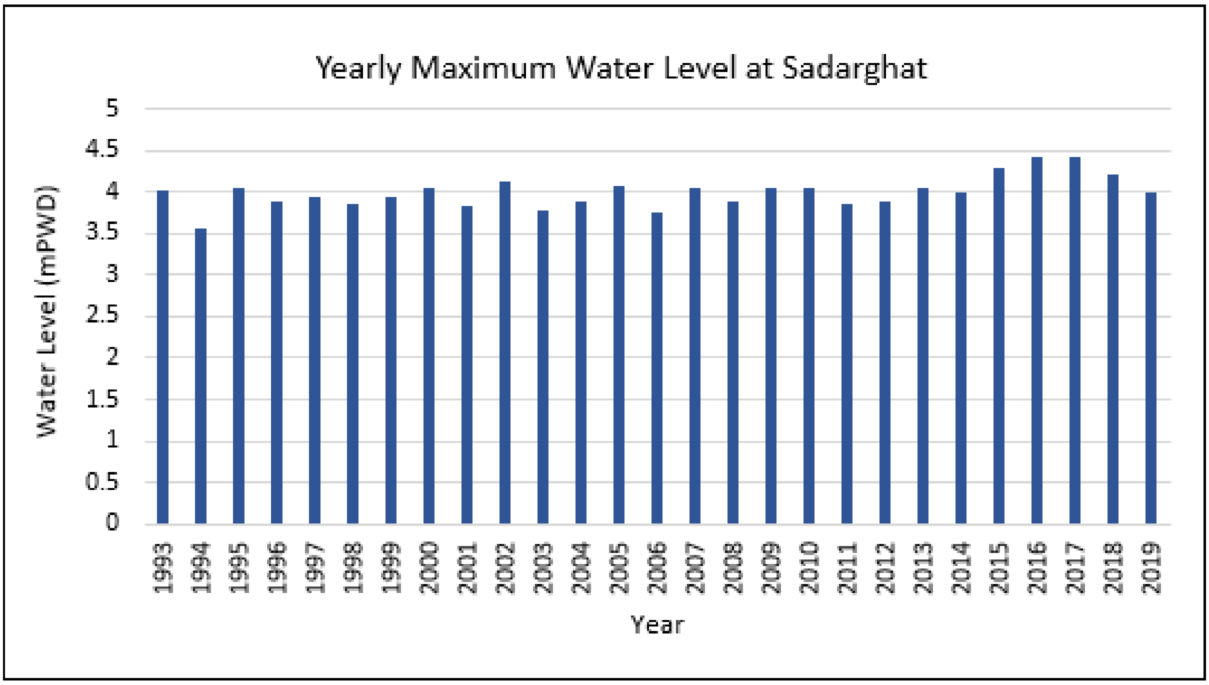


Figure 4-23: Yearly maximum water level near Sadarghat

Table 4-11 shows the water level frequency analysis which represents the flood level for Sadarghat station.

Table 4-11: Water level data frequency analysis at Sadarghat

Return Period	Log-normal Distribution (m PWD)	Gumbel Distribution (m PWD)
2	4.01	3.98
2.33	4.04	4.01
5	4.18	4.16
10	4.27	4.27

Return Period	Log-normal Distribution (m PWD)	Gumbel Distribution (m PWD)
20	4.35	4.39
25	4.37	4.41
50	4.45	4.53
100	4.51	4.64

4.2.3 Discharge Data -Kaptai Dam Release

Daily total water release data from Kaptai dam through the hydropower plant has been collected from 1997 to 2018 from Karnaphuli Hydro-Power Station, BWDB.

Karnaphuli Reservoir Operation and Rule Curve

The reservoir is operated by a set of two rule curves as shown in Figure 4-24.

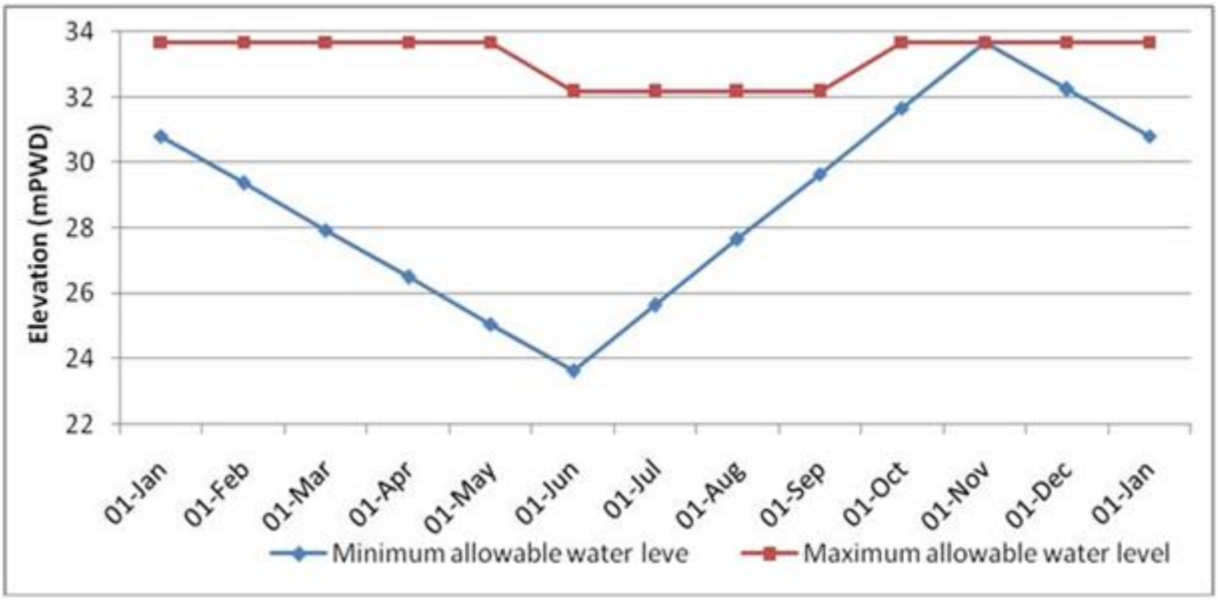


Figure 4-24: Rule curve of Kaptai reservoir

According to the rule curve, the maximum storage in the reservoir is 6097 Million m^3 and the dead storage is 1212 Million m^3. Thus, the balance 4885 Million m^3 storage can be utilized in the dry period. This may be considered as the active storage of the reservoir. This amount of water release passes through the turbine and flows through the downstream of Karnaphuli River. According to the rule curve the minimum flow release from the Kaptai reservoir to the Karnaphuli River is shown in Table 4-12

Table 4-12: Flow release from the Kaptai reservoir to the Karnaphuli River

Date	Min allowable WL in reservoir (m PWD)	Stored Volume (Mm^3)	Minimum Discharge release (m^3/s)
01-Nov	33.68	6097	
01-Dec	32.24	5071	396
01-Jan	30.81	4166	338
01-Feb	29.37	3377	295
01-Mar	27.93	2694	282
01-Apr	26.49	2111	218
01-May	25.06	1619	190
01-Jun	23.62	1212	152

The Salinity in Karnaphuli is pushed down by the water release from the Kaptai lake. Hence this data is collected to run the salinity model.

4.2.4 Salinity Data

Salinity data has been collected by IWM for the 2010-11 and 2013-14 dry period along Karnaphuli and Halda River at Potenga, 11 no. Ghat, Sodor Ghat, CUFL point, Kalurghat, Rangunia, Shikolbaha and Modunaghat [data source: IWM, BWDB, CPA]. Based on these data the salinity profile along the Karnaphuli River for 2013-14 dry period is shown in Figure 4-25.

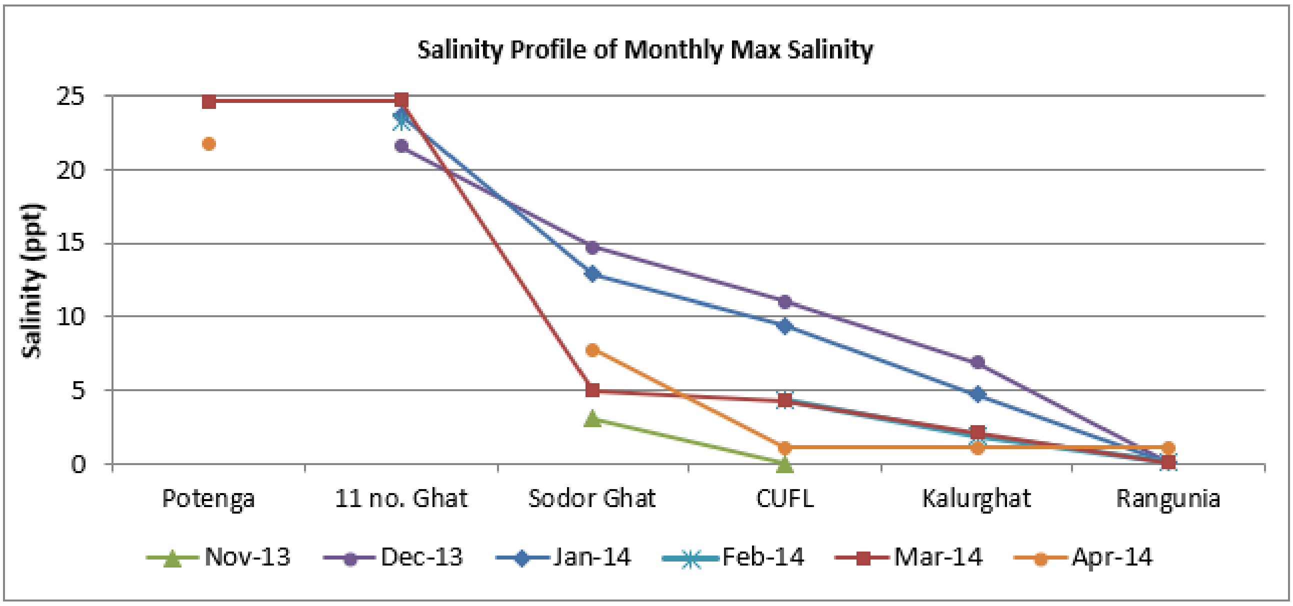


Figure 4-25: Salinity profile along the Karnaphuli River

Moreover, salinity data has been collected from CWASA and CPA. These data are plotted in the following Figure 4-26, Figure 4-27, Figure 4-28, Figure 4-29, Figure 4-30 and Figure 4-31. It is observed that at Patenga the salinity varies up to about 26 ppt in dry season. In the upstream the salinity decreases due to the upstream freshwater flows.

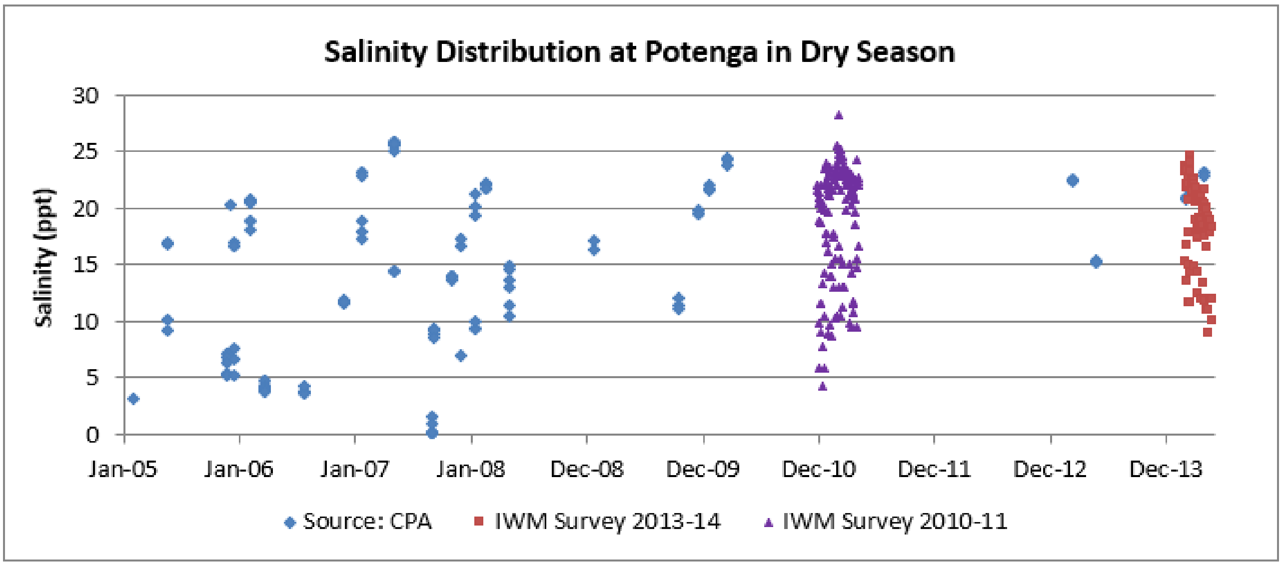


Figure 4-26: Dry season salinity at Patenga in the Karnaphuli River

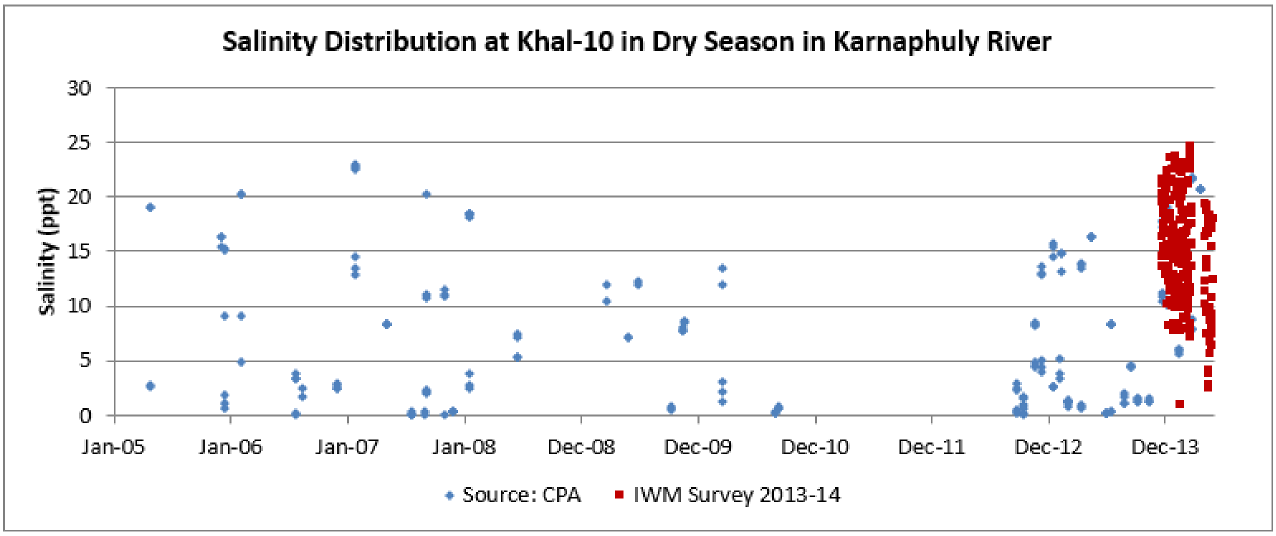


Figure 4-27: Dry season salinity at Khal-10 in the Karnaphuli River

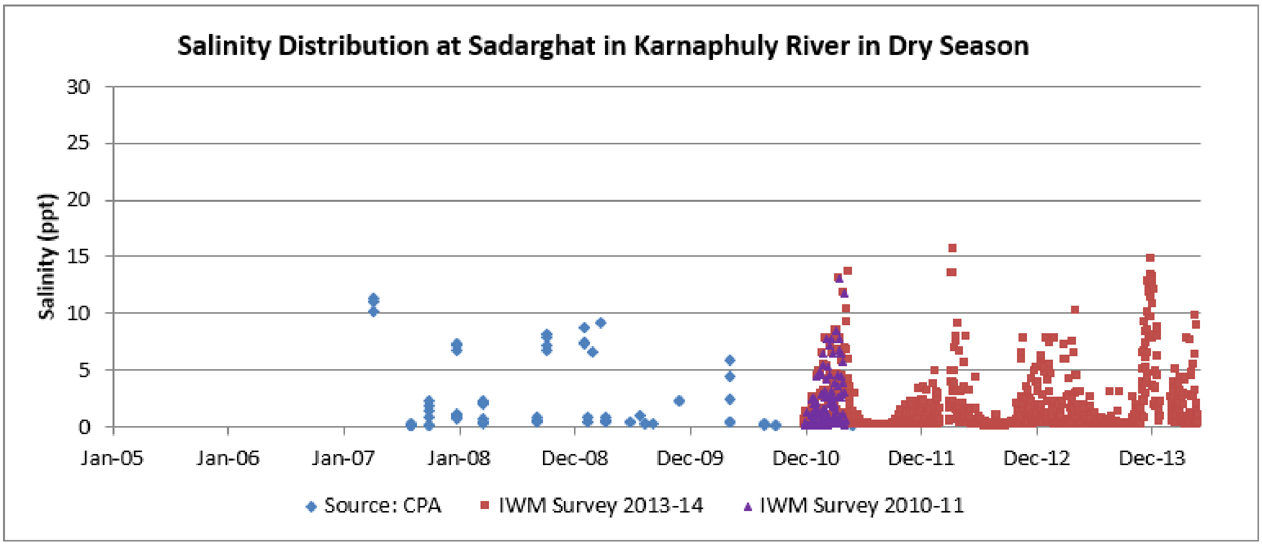


Figure 4-28: Dry season salinity at Sadarghat in the Karnaphuli River

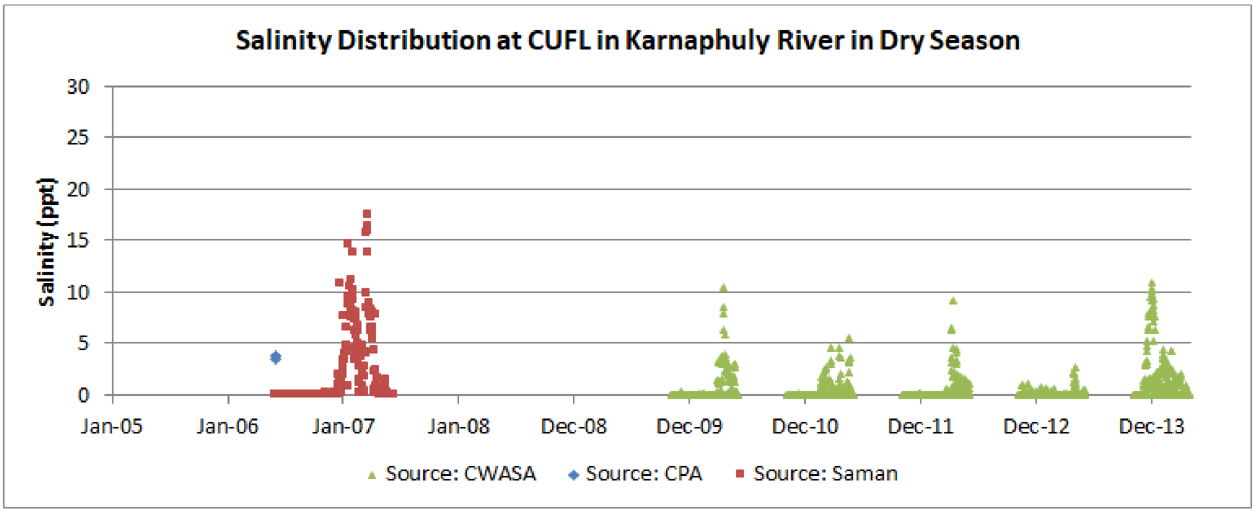


Figure 4-29: Dry season salinity at Chattogram CUFL in the Karnaphuli River

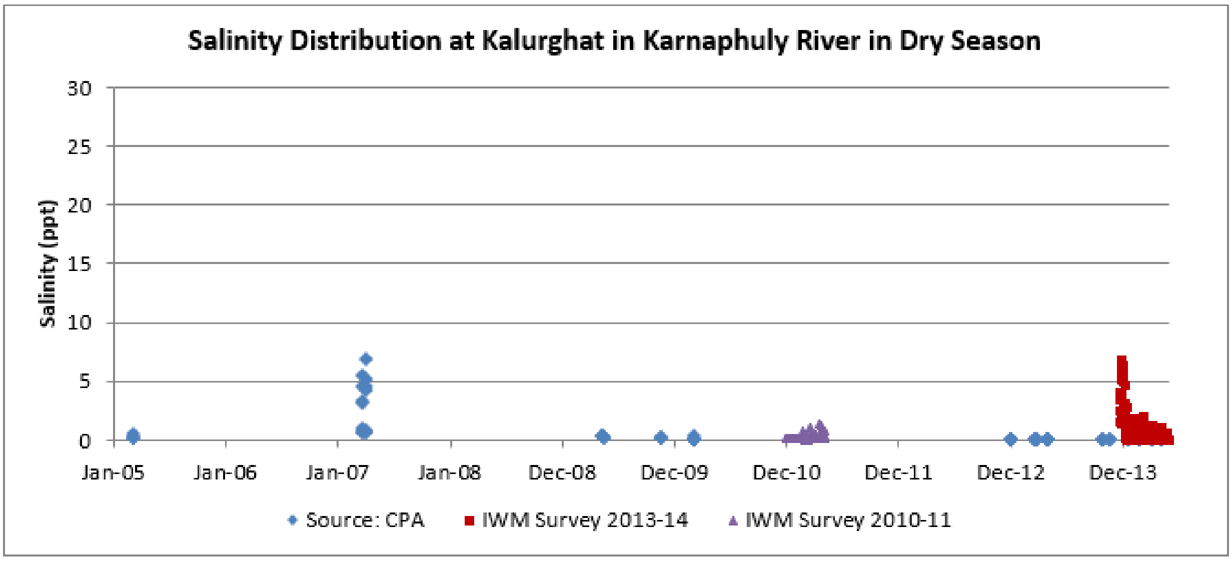


Figure 4-30: Dry season salinity at Kalurghat in the Karnaphuli River

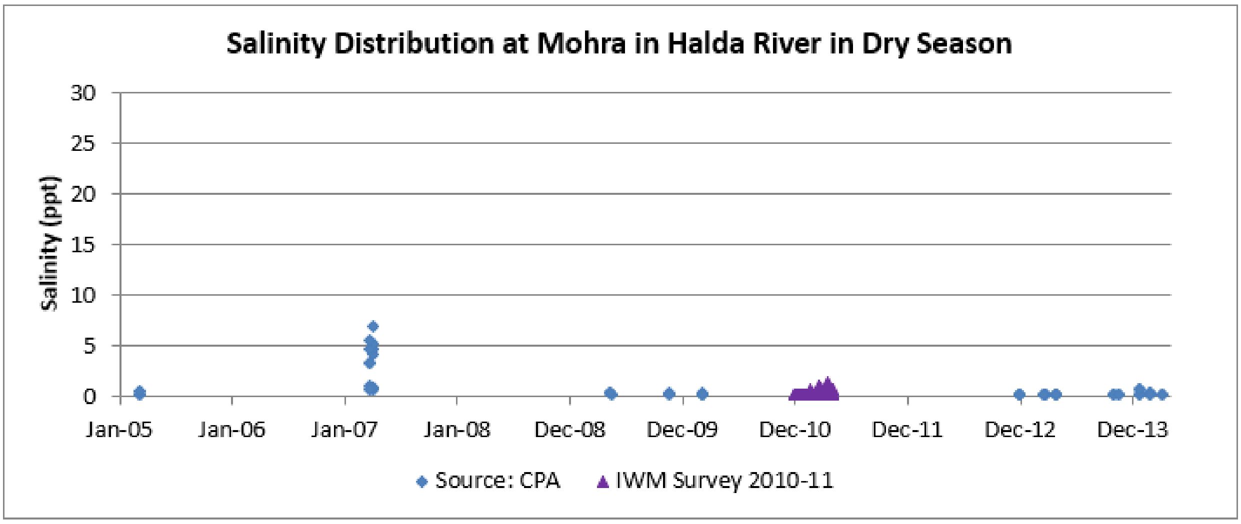


Figure 4-31: Dry season salinity at Mohra in the Halda River

4.2.5 WATER ABSTRACTION DATA WITH FUTURE PROJECTION

Water abstraction from the rivers have impacts on the flow in downstream having consequences in salinity and water levels.

Data on existing as well as planned abstractions from the rivers were initially obtained from KOICA master plan. The data has been updated based on the current situation as shown in Table 4-13.

Table 4-13: Existing and Planned Abstractions from the Karnaphuli and Halda River

Water Abstraction Plan					
Type of Water Use	**River**	**Intake**	**Existing Abstraction (m^3/day)**	**Additional Planned Abstraction (m^3/day)**	**Projected Total Abstraction (m^3/day)**
City Water	Halda	Mohra WTP	91,000	140,000	231,000
	Halda	Moduna Ghat WTP	90,000		90,000
	Karnaphuli	Karnaphuli WTP	143,000	143,000	286,000
	Karnaphuli	Bhandal Jhuri		60,000	60,000
Irrigation	Karnaphuli -Halda	Karnaphuli	153,000		153,000
	Halda	Halda Extension	9,000	293,757	302,757
	Halda	Nischintapur FCDI		77,348	77,348
	Karnaphuli	Boalkhali	579,000		579,000

	Halda	Other Irrigation	129,600	86,400	216,000
	Karnaphuli	Other Irrigation	188,924	209,916	398,840
Industrial	Karnaphuli	Paper Mill	74,000		74,000
	Karnaphuli	Thermal Power Plant	32,000		32,000
	Karnaphuli	Fertilizer Plant	20,000		20,000
	Karnaphuli	Other Plants	17,000		17,000

4.2.6 Geotechnical Data

Secondary soil test data was collected for both KEPZ and Kalurghat industrial area. Soil test data from four industrial complexes of KEPZ and two complexes of Kalurghat area were collected. At KEPZ soil test data of three garment factories and one shoe factory and at Kalurghat soil test data of one printing factory and one denim factory have been collected. The locations of the test sites are shown in Figure 4-32 and Figure 4-33. Representative borehole data of each of the test locations are shown in Figure 4-34 to Figure 4-39. A summary of the average SPT value (N) in top 30 m in all the sites along with BNBC 2020 site classification for these sites is shown in Table 4-14. From the table it is found that one site at Kalurghat consists of very soft clay to a significant depth. One site in the KEPZ contains loose to medium silty soil. Other sites contain dense sand or stiff clay.

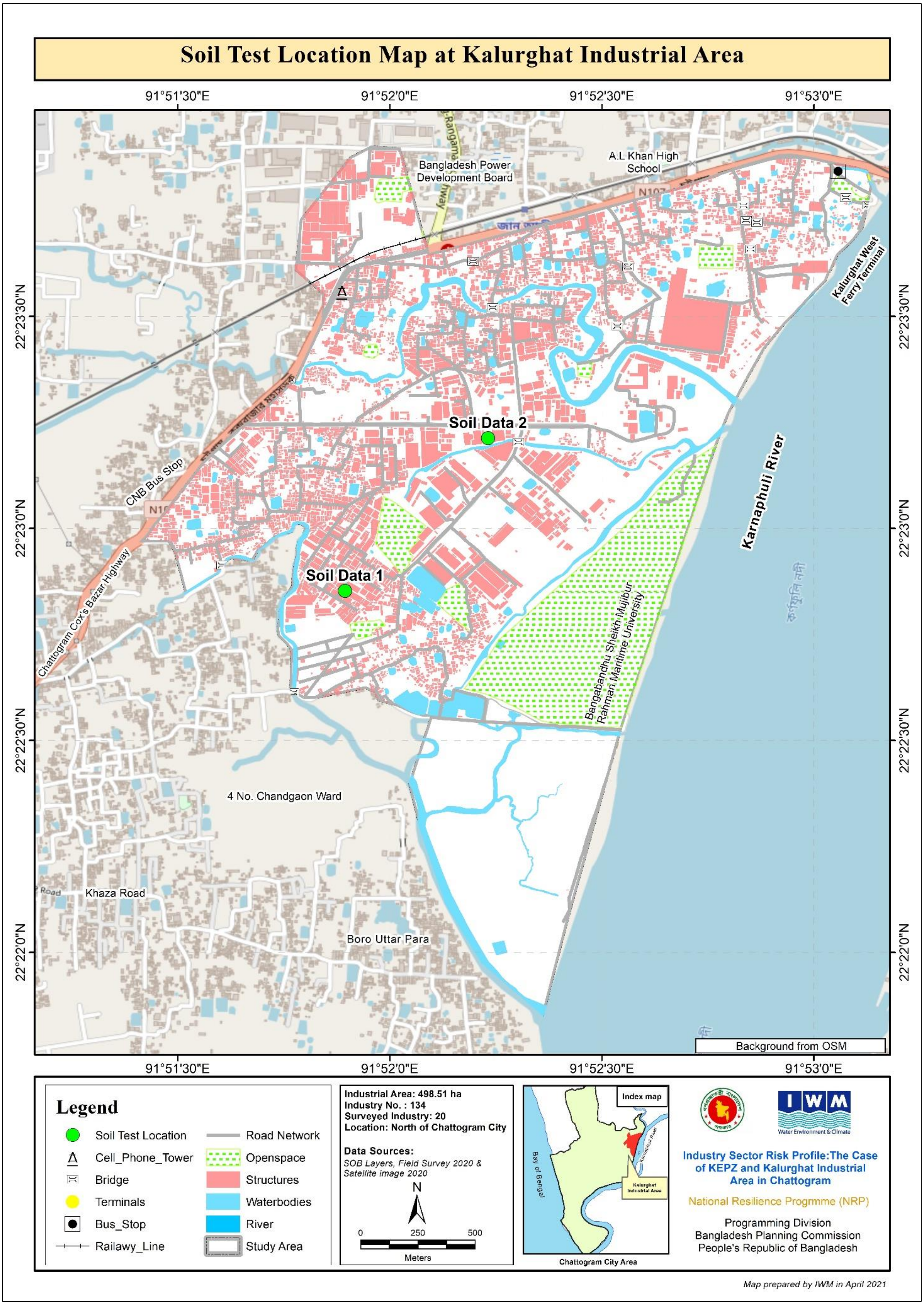


Figure 4-32: Soil test locations in Kalurghat Area

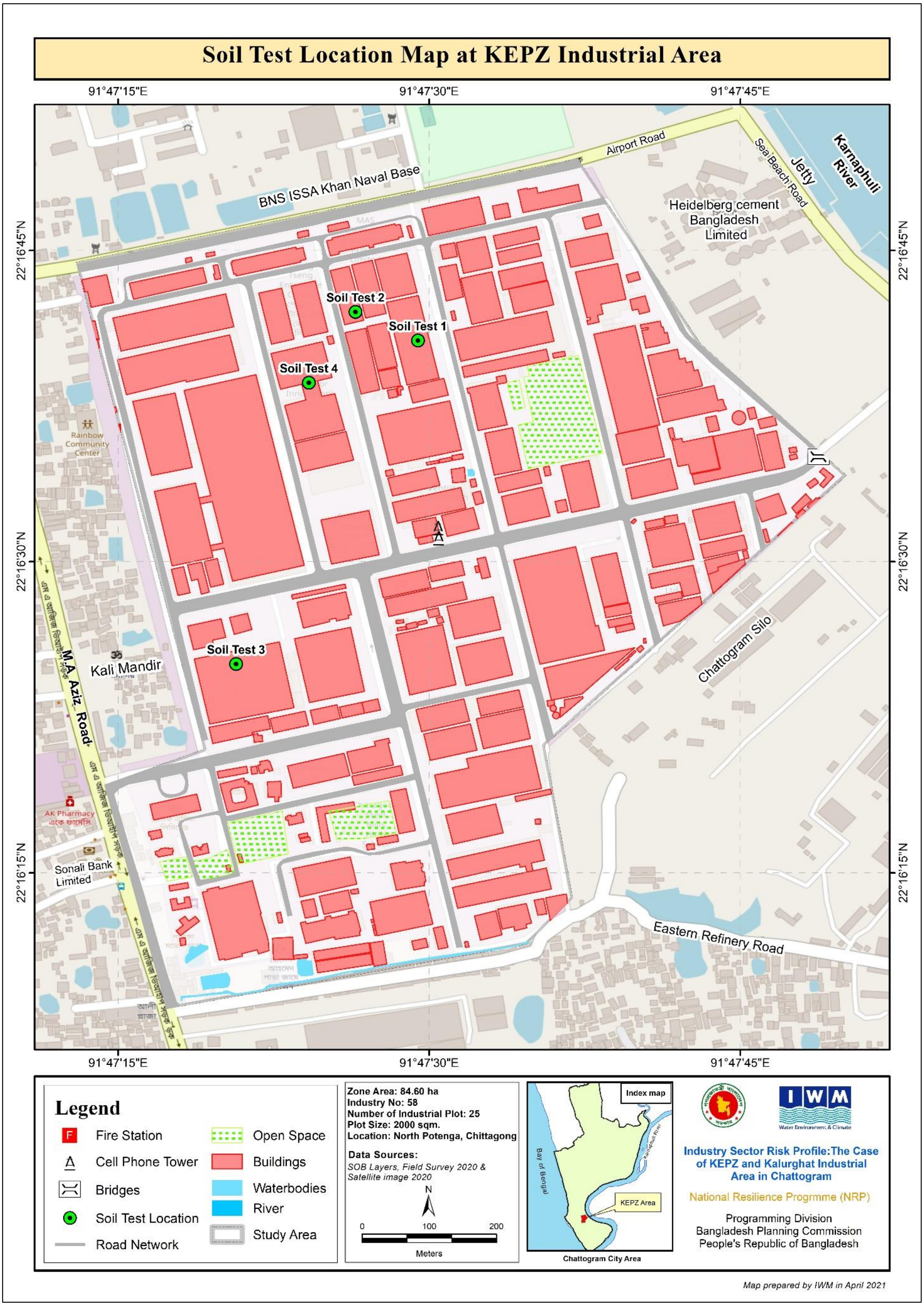


Figure 4-33: Soil Test Location Map in KEPZ Area

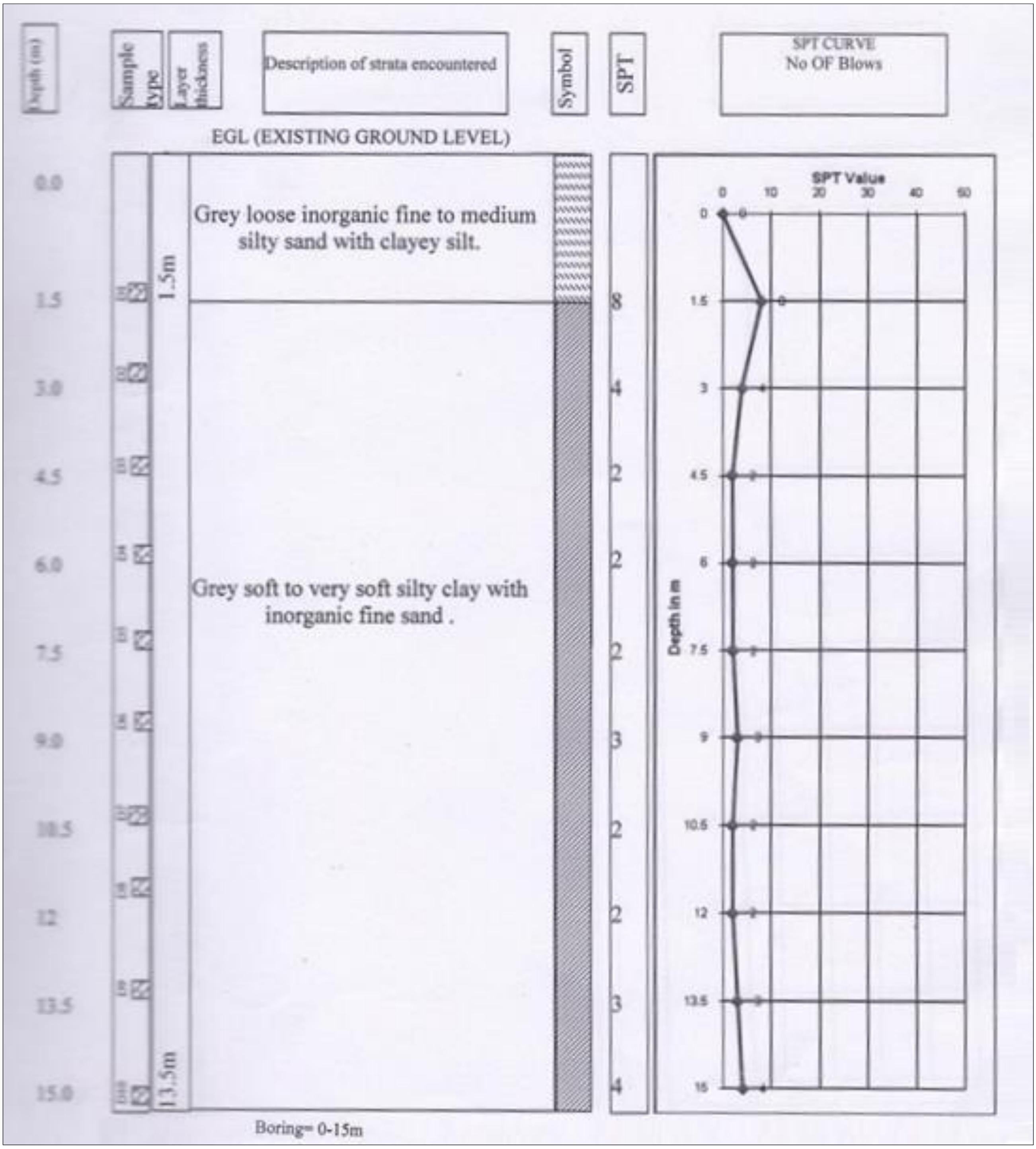
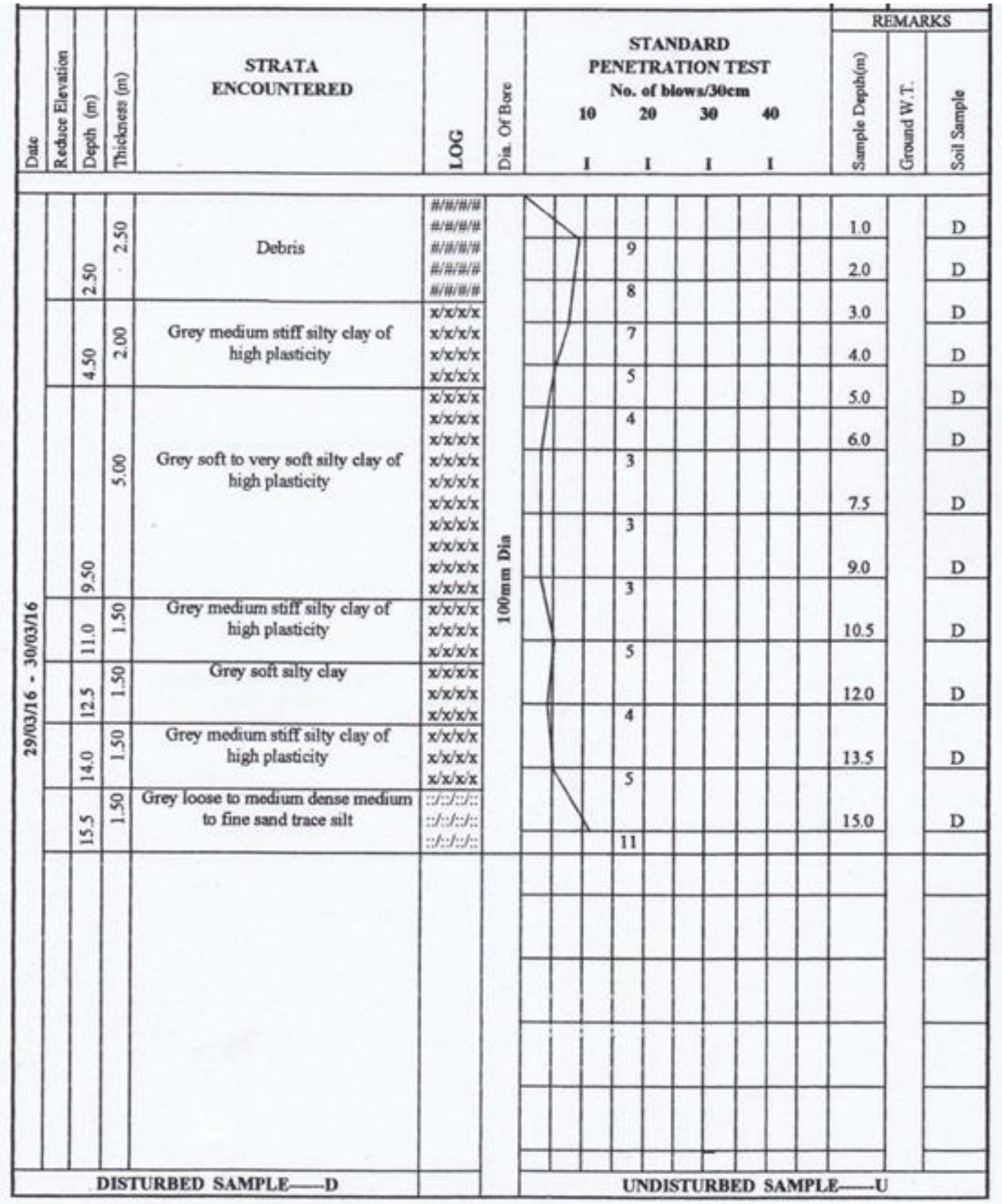


Figure 4-34: Representative borehole data of test location - 1 in Kalurghat Area



Date	Reduce Elevation	Depth (m)	Thickness (m)	STRATA ENCOUNTERED	LOG	Dia. Of Bore
29/03/16 - 30/03/16		2.50	2.50	Debris	#/#/#/#	100mm Dia
		4.50	2.00	Grey medium stiff silty clay of high plasticity	x/x/x/x	
		9.50	5.00	Grey soft to very soft silty clay of high plasticity	x/x/x/x	
		11.0	1.50	Grey medium stiff silty clay of high plasticity	x/x/x/x	
		12.5	1.50	Grey soft silty clay	x/x/x/x	
		14.0	1.50	Grey medium stiff silty clay of high plasticity	x/x/x/x	
		15.5	1.50	Grey loose to medium dense medium to fine sand trace silt	::/::/::/::	

STANDARD PENETRATION TEST No. of blows/30cm	REMARKS: Sample Depth(m)	Ground W.T.	Soil Sample
9	1.0		D
8	2.0		D
7	3.0		D
5	4.0		D
4	5.0		D
3	6.0		D
3	7.5		D
3	9.0		D
5	10.5		D
4	12.0		D
5	13.5		D
11	15.0		D

DISTURBED SAMPLE——D UNDISTURBED SAMPLE——U

Figure 4-35: Representative borehole data of test location - 2 in Kalurghat Area

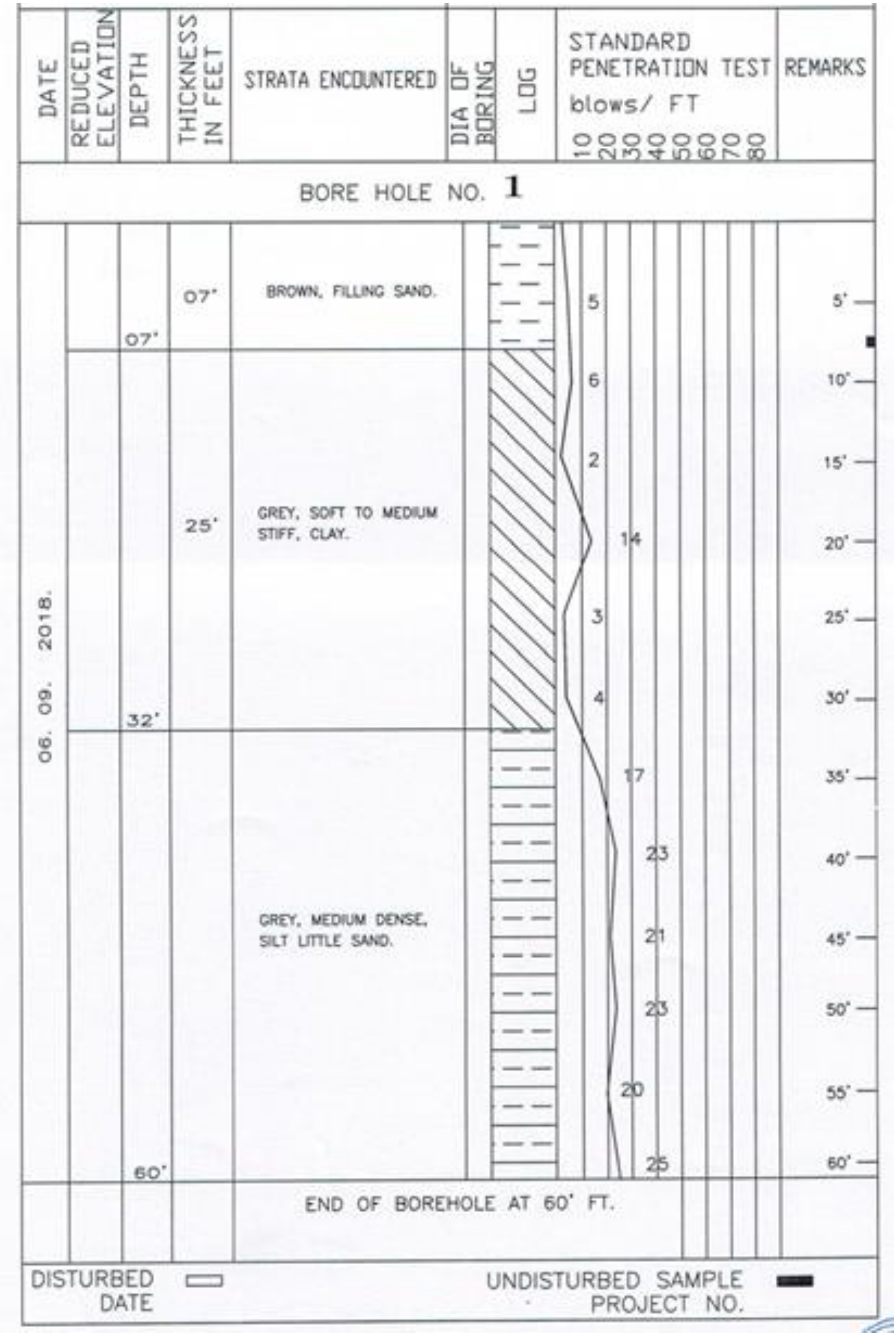


Figure 4-36: Representative borehole data of test location - 1 in KEPZ Area

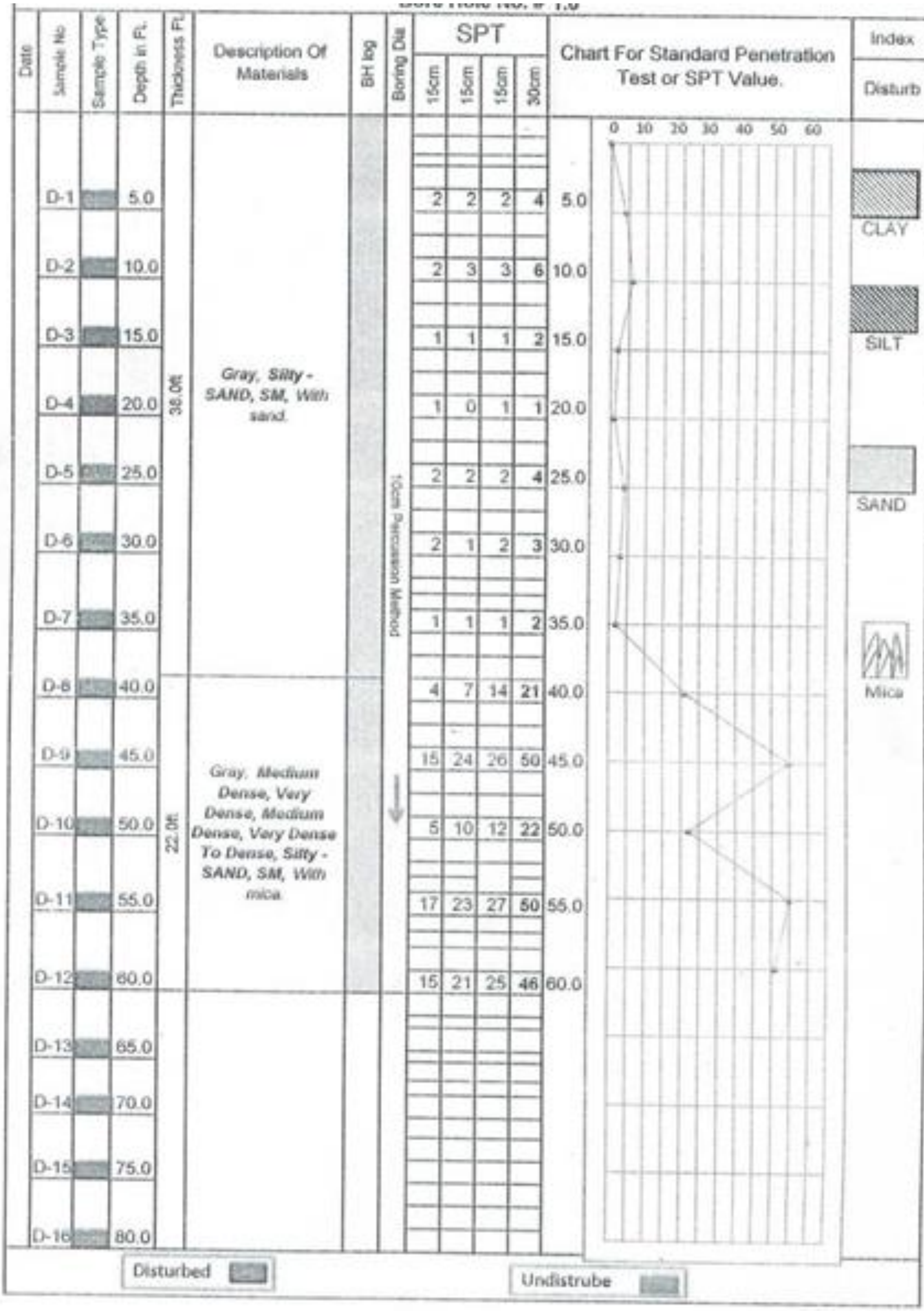


Figure 4-37: Representative borehole data of test location - 2 in KEPZ Area

DEPTH (m)	SAMPLE NO.	LAYER THICKNESS	STRATA COMPOSITION	USCS	PLASTICITY	CONSISTENCY OR COMPACTNESS	S.P.T VALUE
1.5	D-01	1.5 m	Mostly **Sand** with Little Silt and Few Clay	**SM**, Silty Sand	Non-Plastic	Medium Dense	12
3	D-02	1.5 m	Mostly **Clay** with Some Silt	**CL**, Lean Clay	Plastic	Soft	3
4.5	U-01, D-03	1.5 m	Mostly **Clay** with Some Silt	**CL**, Lean Clay	Plastic	Medium Stiff	6
6	D-04	1.5 m	Mostly **Clay** with Some Silt	**CL**, Lean Clay	Plastic	Soft	3
7.5	D-05	1.5 m	Mostly **Sand** with Some Silt and Little Clay	**SM**, Silty Sand	Non-Plastic	Very Loose/Loose	4
9	D-06	1.5 m	Mostly **Sand** with Little Silt and Few Clay	**SM**, Silty Sand	Non-Plastic	Loose	9
10.5	D-07	3 m	Mostly **Sand** with Few Silt	**SP-SM**, Poorly graded Sand with Silt	Non-Plastic	Medium Dense	29
12	D-08						13
13.5	D-09	1.5 m	Mostly **Silt** with Some Clay	**CL**, Lean Clay	Plastic	Soft/Medium Stiff	4
15	D-10	1.5 m	Mostly **Sand** with Few Silt	**SP-SM**, Poorly graded Sand with Silt	Non-Plastic	Medium Dense	13
16.5	D-11	3 m	Mostly **Sand** with Few Silt	**SP-SM**, Poorly graded Sand with Silt	Non-Plastic	Dense	36
18	D-12						36
19.5	D-13	1.5 m	Mostly **Sand** with Few Silt	**SP-SM**, Poorly graded Sand with Silt	Non-Plastic	Medium Dense	29
21	D-14	3 m	Mostly **Sand** with Few Silt	**SP-SM**, Poorly graded Sand with Silt	Non-Plastic	Loose	9
22.5	D-15						8
24	D-16	1.5 m	Mostly **Sand** with Little Silt and Few Clay	**SM**, Silty Sand	Non-Plastic	Medium Dense	24
25.5	D-17	1.5 m	Mostly **Sand** with Little Silt and Few Clay	**SM**, Silty Sand	Non-Plastic	Loose/Medium Dense	10

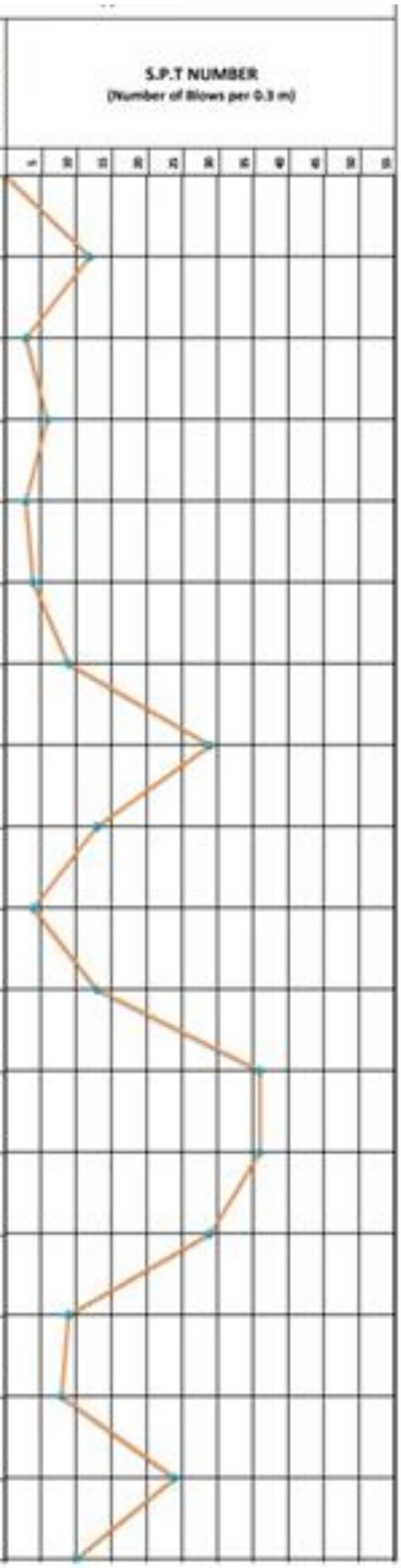


Figure 4-38: Representative borehole data of test location - 3 in KEPZ Area

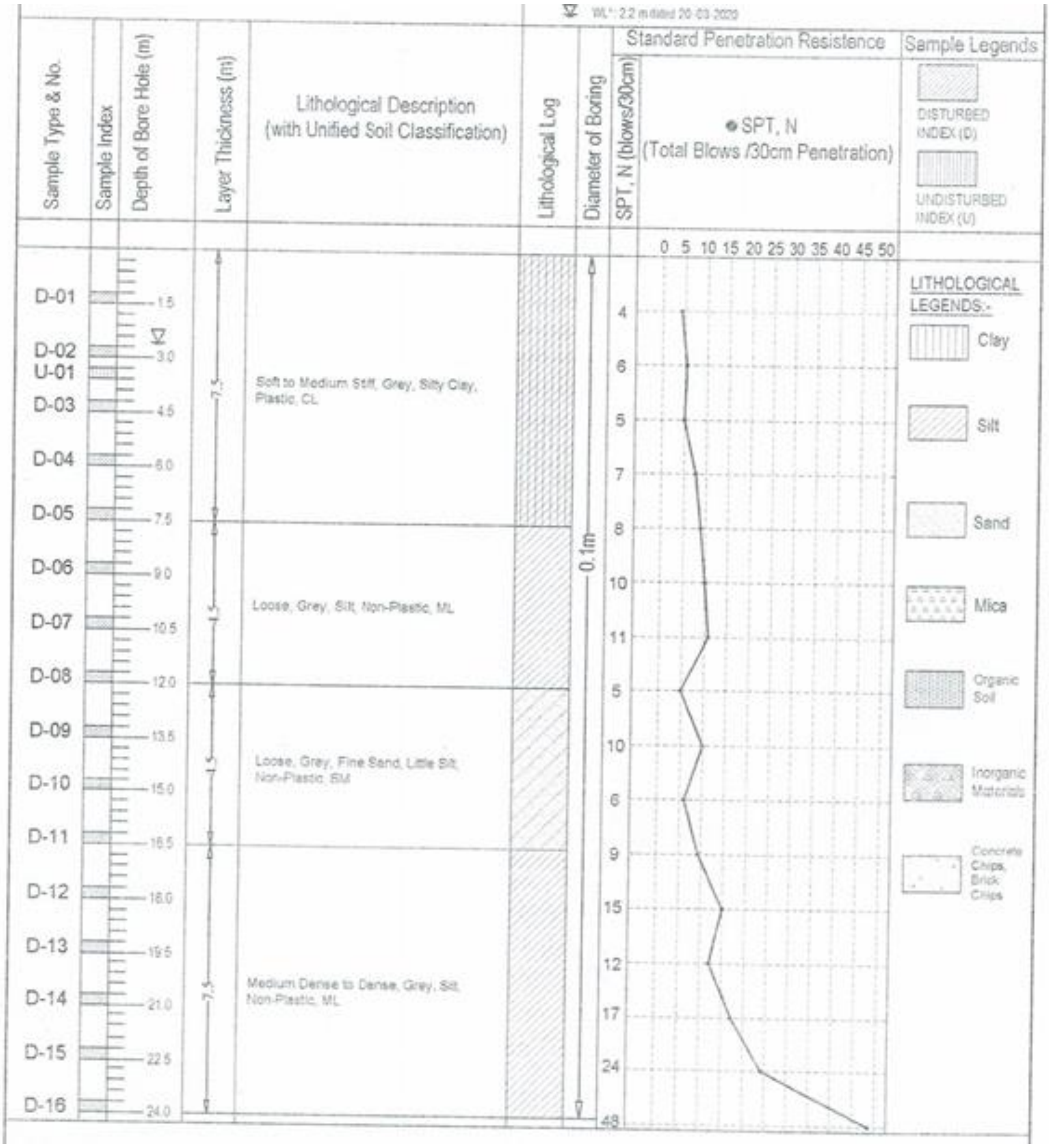


Figure 4-39: Representative borehole data of test location - 4 in KEPZ Area

Table 4-14: Average SPT Value and BNBC 2020 Site Class

Site	Average N value	Site Class
Kalurghat – 1	6	S1
Kalurghat – 2	23	SC
KEPZ – 1	28	SC
KEPZ – 2	28	SC
KEPZ – 3	17	SC
KEPZ – 4	15	SC

Chapter 5: HAZARD ANALYSIS

This chapter presents different types of analyses and methods which have been applied for assessing the hazards (flood, tide & storm surge, water logging, salinity, earthquake and infectious disease like Covid-19) adequately attaching the results in GIS maps, tables and statistical charts. Assessment of hazard is a key element to estimate the risk of exposed industries. The disaster risk modelling allows to couple exposure data with vulnerability and hazard to eventually generate deterministic and probabilistic risk estimates. Several mathematical models have been used in assessing the hazards (flood, tide & storm surge, water logging, and salinity) for different events under this study. Fire incidents, earthquake and Covid-19 risks are analyzed separately in different ways.

5.1 MATHEMATICAL MODELS

Hydro dynamic mathematical models are simplification of a real-world system in hydrology that aids in understanding, predicting, and managing water resources and assessing hazards due to the natural and manmade events. A set of mathematical models, tools and software systems for the water sector developed by Danish Hydraulic Institute (DHI) are available in IWM, and it is under continuous up-gradation and maintenance by DHI.

Five types of models have been prepared under this study for analyzing flood, cyclone and tidal surge, water logging and salinity. These are as under:

(i) Hydrological Model -Rainfall-runoff model (NAM)
(ii) River Flood Model -1D hydrodynamic model (MIKE 11)
(iii) Drainage Model -1D hydrodynamic model (MIKE 11)
(iv) Storm Surge Model -21 MIKE FM model plus Wind pressure & direction
(v) Salinity Model -1D hydrodynamic model plus AD model

The output of the rainfall-runoff model has been used as input to the hydrodynamic model of River Flood Model, Drainage Model and Salinity Model. The workflow diagram of the modelling under this study is given in Figure 5-1

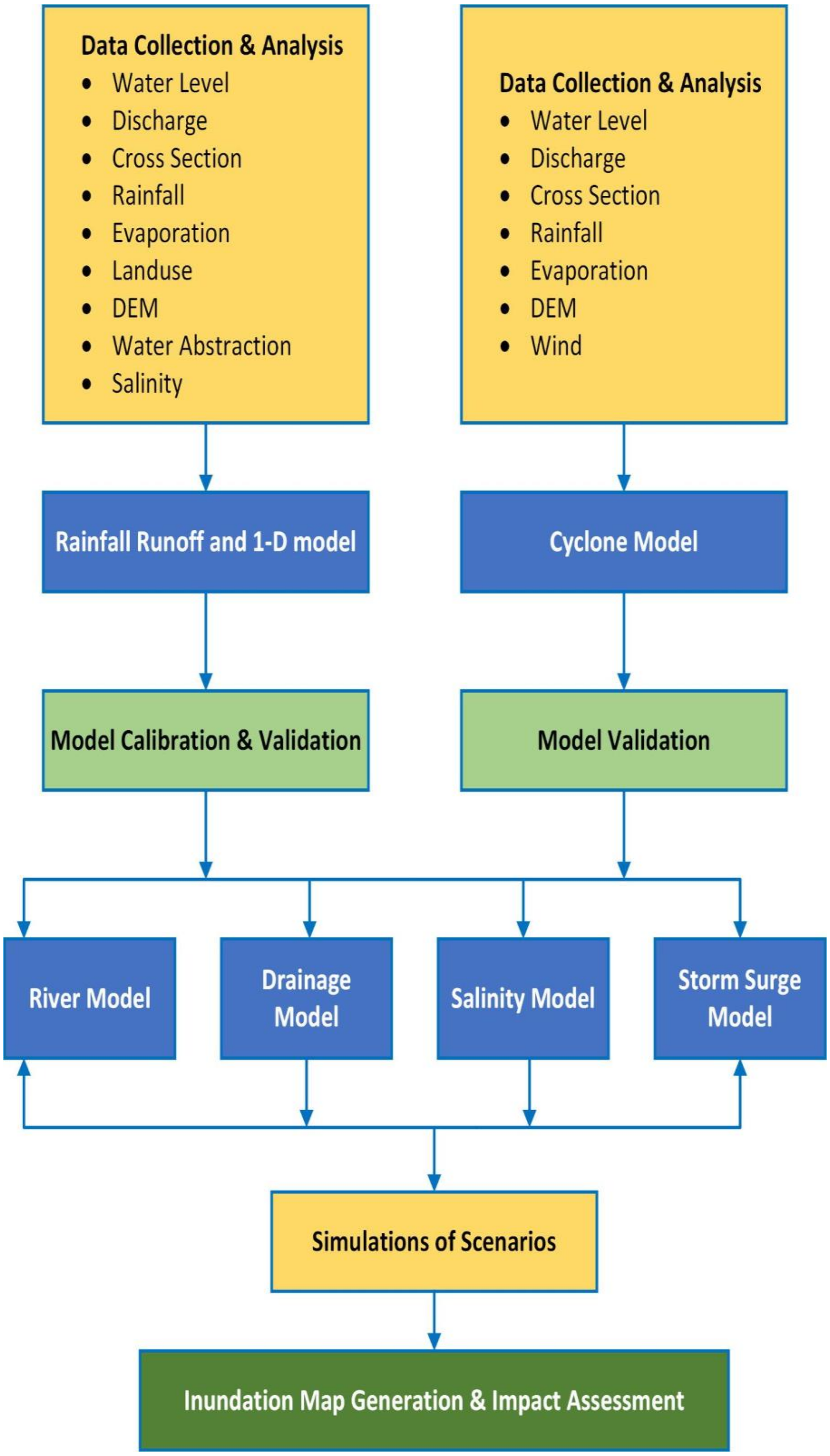


Figure 5-1: Workflow diagram of modelling activities

5.2 HYDROLOGICAL MODEL

Based on the NAM rainfall-runoff modelling tool, the existing regional hydrological model has been developed, which used rainfall and evaporation data collected from BWDB. The urban catchments of Chattogram City were delineated under CWSISP project and the hydrological model was developed using Mike Urban (a modelling tool). These are presented in Figure 5-2 below.

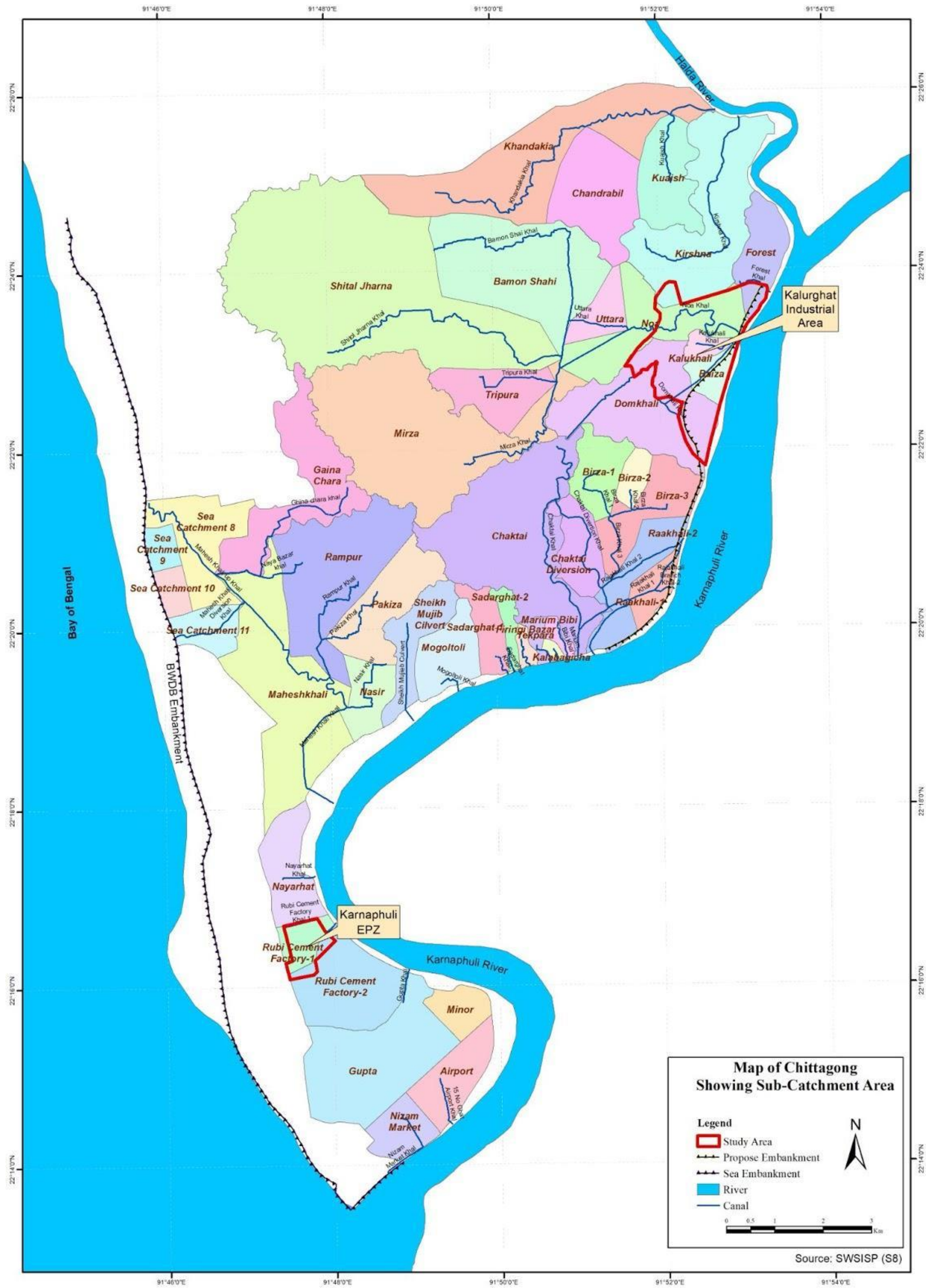


Figure 5-2: Urban Catchment of Chattogram City Area

The imperviousness has been calculated based on the land use data available with IWM (Figure 5-3) and collected from CDA as shown in Figure 5-4. According to the land-use type, the percentage of imperviousness on runoff and infiltration for Chattogram city has been tabulated based on the recent topographic features. A comparative statement of present and future land use type for different drainage catchments are shown in Table 5-1.

Table 5-1: Comparative statement of present and future percentage of imperviousness

Catchment Name	Catchment Area (km^2)	% of Impervious Area	
		Existing condition	Proposed 2030 condition
Airport	1.89	11.10%	28.87%
Baiza	1.11	22%	54.72%
Chaktai	8.11	52.22%	51.40%
Domkhali	5.28	11.68%	46.90%
Firingi Bazar	0.26	55.20%	76.99%
Forest	1.75	12.90%	22.44%
Gupta	5.40	40.37%	25.84%
Kalabagicha	0.12	55.20%	30.80%
Khandakia	13.37	11.66%	33.79%
Kirshna	6.14	12.80%	38.40%
Maheshkhali	20.97	51.65%	42.79%
Marium Bibi	0.25	55.20%	48.26%
Minor	1.00	30.71%	19.84%
Mirza	8.96	41.88%	46.57%
Mogoltoli	1.81	54.46%	41.43%
Nayarhat	2.07	69.84%	25.75%
Nizam Market	1.26	30.60%	6.66%
Noa	31.09	37.79%	43.22%
Rajakhali	8.90	32.70%	51.87%
Rubi Cement Factory	4.19	79.32%	81.56%
Sadarghat-1	1.08	51.30%	37.31%
Sadarghat-2	0.51	55.17%	60.62%
Sheikh Mujib Culvert	1.84	54.22%	39.13%
Tekpara	0.30	55.20%	56.11%

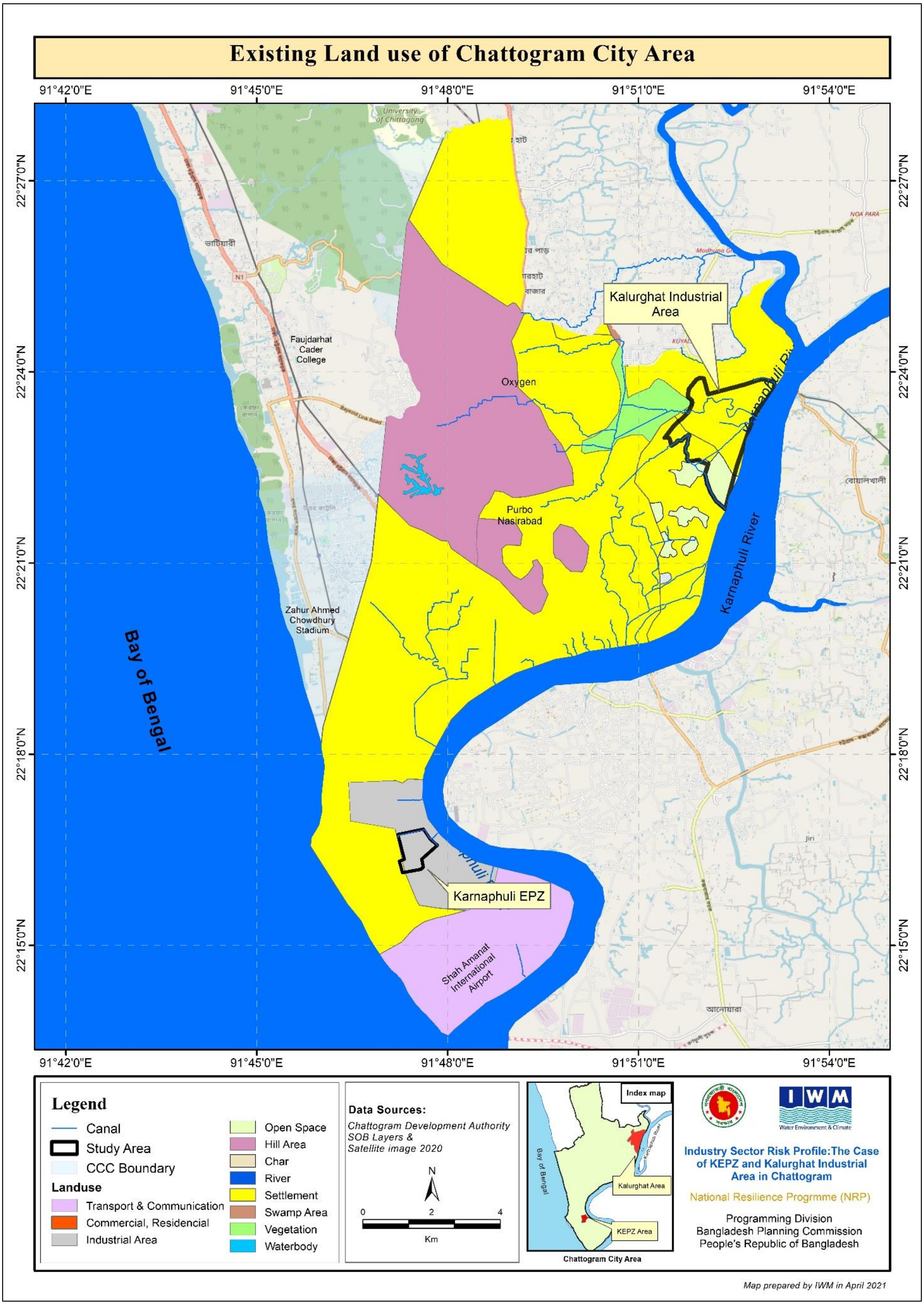


Figure 5-3: Existing Land use of Chattogram City Area

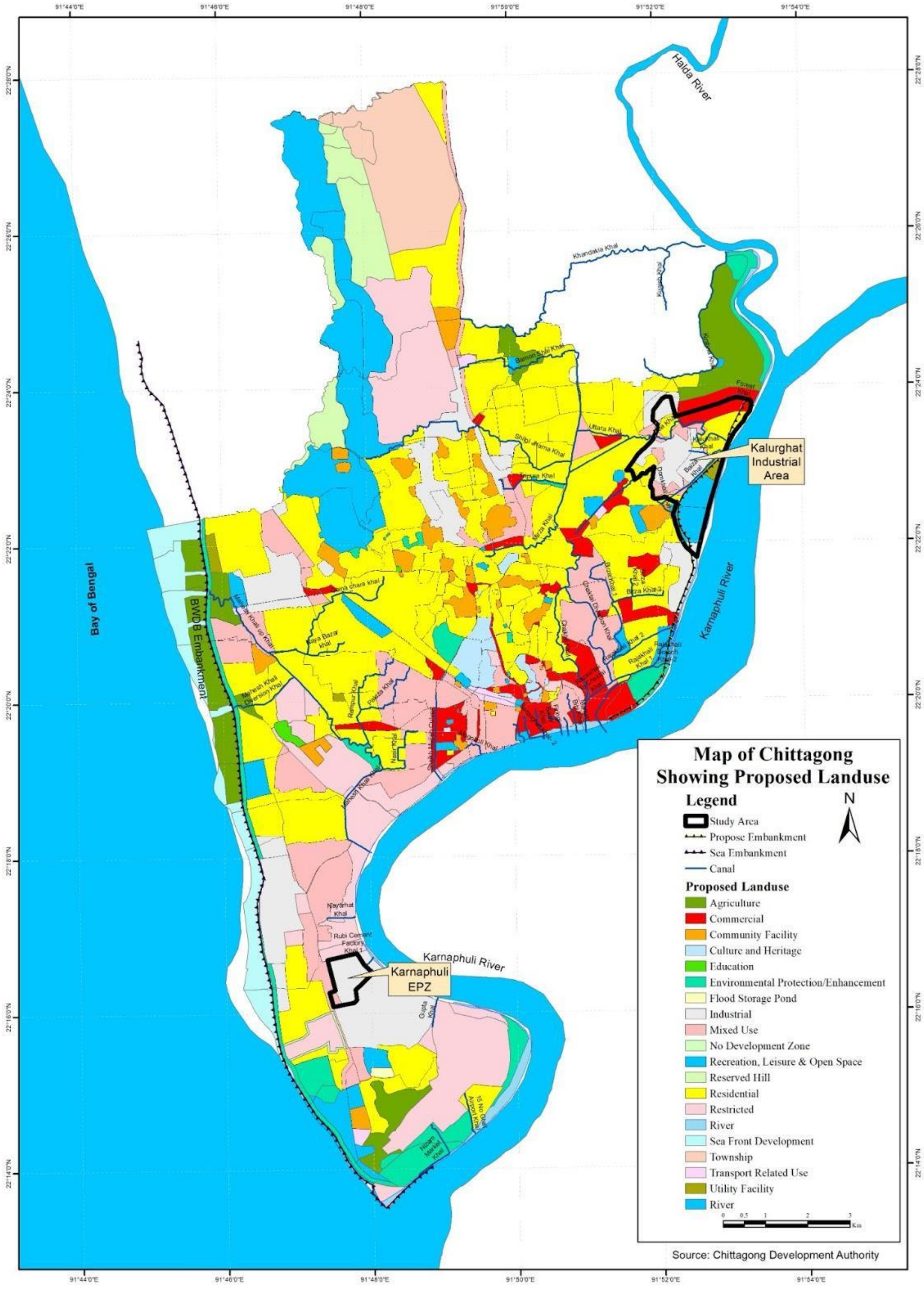


Figure 5-4: CDA Proposed Land use for 2030 for Chattogram City Area

5.3 Hydrodynamic Models

5.3.1 Model Setup

The river network of the Hydrodynamic model includes Karnaphuli , Halda and Ichamati River and the existing khal system of Chattogram city as shown in Figure 5-5. The cross-section data of MaheshKhali khal system was collected by IWM in 2008. The cross-section data of the remaining khals were collected under CWSISP project in 2016.

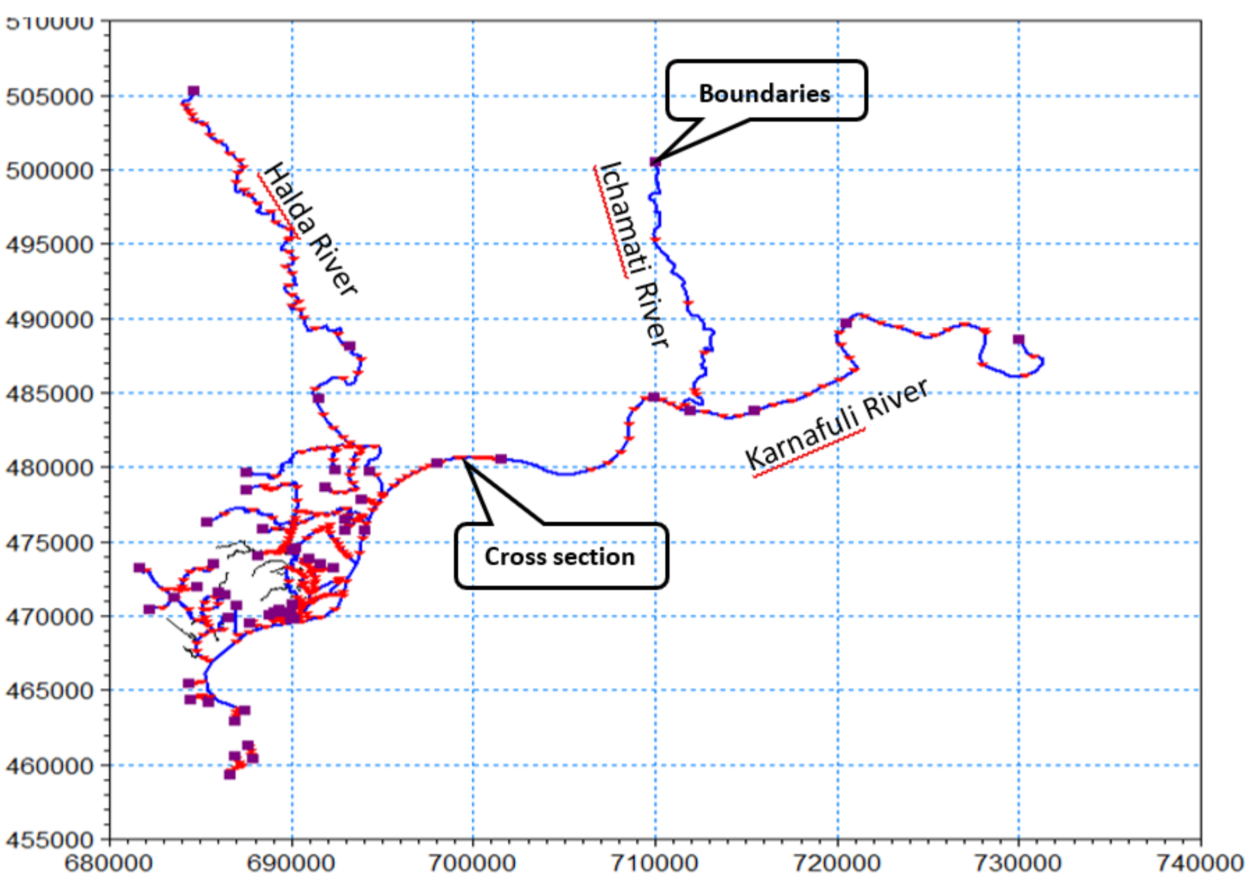


Figure 5-5: River/Khal system of Hydrodynamic Model

The khal network geometry was included and the boundaries were configured in the set-up of Hydrodynamic Model as below:

a) Inflow at the upstream end of river/khals; and
b) Water level as a time series at downstream end of Karnaphuli River.

The Water-release data of Kaptai Dam at the upstream of river Karnaphuli was used as the boundary. Rated discharge data based on observed water level and other discharge data were used as boundary at the upstream of Halda and Ichamati River. As the base flow in the khal network was negligible in terms of overbank flooding, zero flow boundary was considered.

5.3.2 MODEL CALIBRATION

Long historical time series data has been collected from CPA which was used for calibration of the Hydrodynamic model. The calibrations are shown in Figure 5-6 and Figure 5-7.

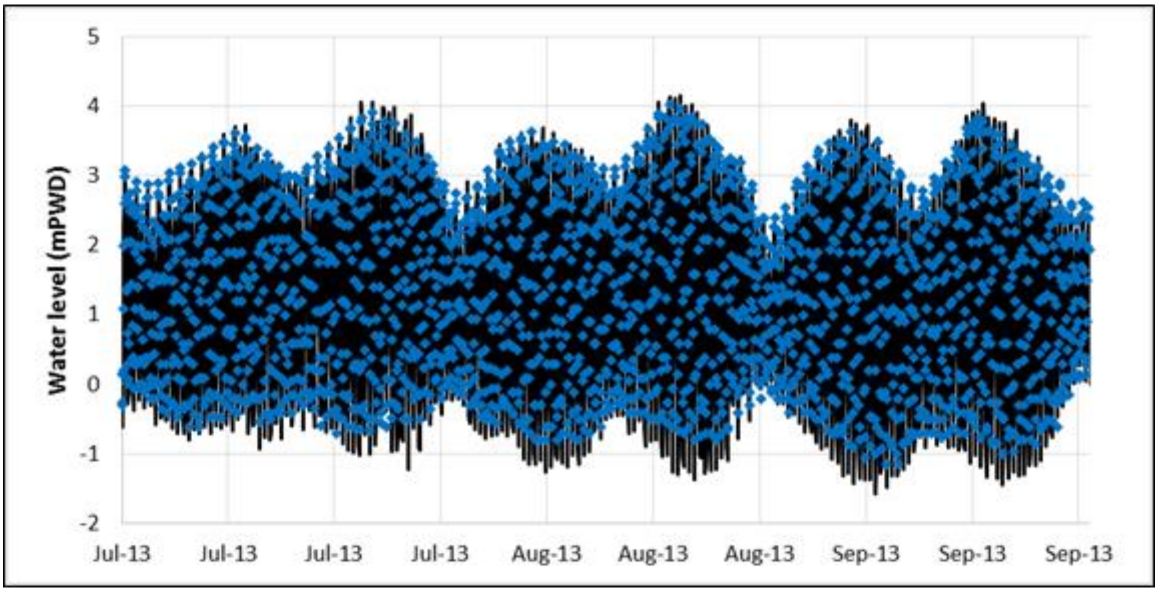


Figure 5-6: Water level calibration plot at Sadarghat

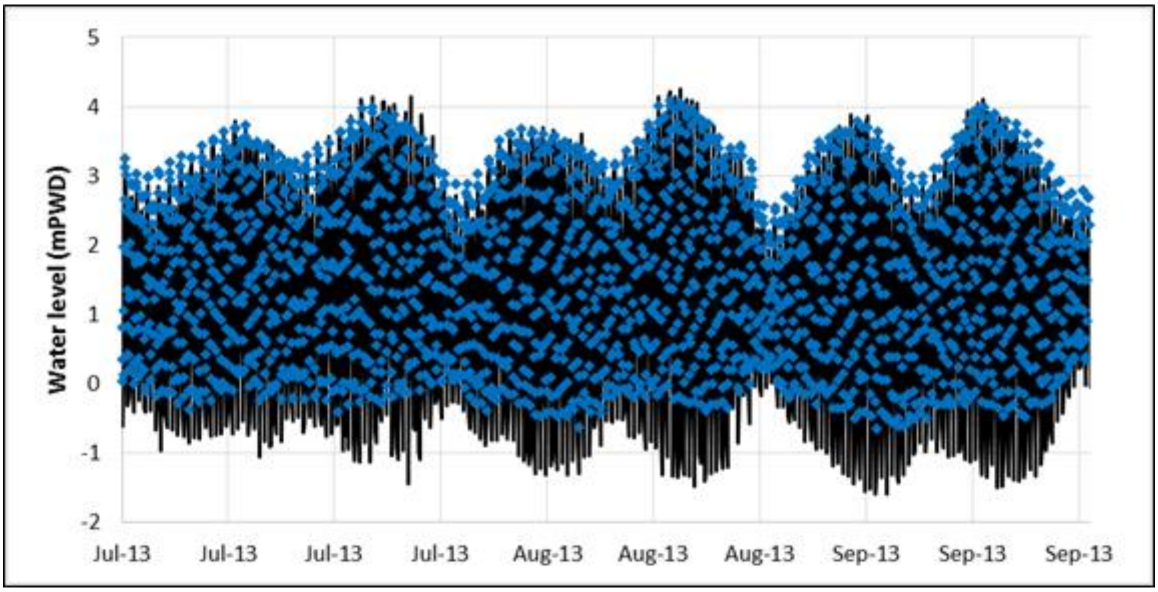


Figure 5-7: Water level calibration plot at Kalurghat

5.4 PROJECTION OF CLIMATE CHANGE (CC) AND SEA LEVEL RISE (SLR)

The projection of specific meteorological variables at the coastal zone of Bangladesh are required in accordance with the IPCC Assessment Report-5 (IPCC, AR5). Projections on the following meteorological and hydrological conditions are required and have been established based on IPCC reports and recent literature review.

I. Temperature Change
II. Precipitation Change
III. Sea level rise
IV. Wind Speed change

5.4.1 Sea Level Rise (SLR)

One of the most important impacts of climate change for low lying countries like Bangladesh is the sea level rise. Sea level rise is caused by global warming which affects two main processes, which are higher ocean water temperature caused by thermal expansion and atmospheric warming results in the melting of ice. Projected change in global mean sea level rise for the mid- and late 21st century relative to the reference period of 1986–2005 (IPCC, AR5 2014) is presented in Table 5-2.

Table 5-2 : Project Change in global mean sea level rise (in meter)

Scenario	2046-2065		2081-2100	
	Mean	**Likely range**	**Mean**	**Likely range**
RCP 2.6	0.24	0.17 to 0.32	0.4	0.26 to 0.55
RCP 4.5	0.26	0.19 to 0.33	0.47	0.32 to 0.63
RCP 6.0	0.25	0.18 to 0.32	0.48	0.33 to 0.63
RCP 8.5	0.3	0.22 to 0.38	0.63	0.45 to 0.82

The relative mean sea level rise for Bangladesh can be calculated considering local effect and land subsidence. Based on the global scenarios by Hinkel et al. 2014, the sea level rise in Bangladesh is slightly higher than the global average means i.e. by 2050 sea level rise could be up to 4 cm higher than global mean and by the end of the century up to 10 cm. No detailed and fully reliable study on land subsidence is available for Bangladesh. Considering uncertainties on this issue, the relative mean sea level rise is approximated **to be 50 cm** by 2050 for this study.

In order to incorporate the climate change parameters to ascertain the storm surge level the increase in cyclonic wind speed increase in the North Indian Ocean is **considered 8%** based on AR5, IPCC, 2014.

5.4.2 Change in Rainfall

Due to climate change, many climate models show the volume of rainfall increasing during the summer monsoon (May-October) and reducing during the dry period (December–March). Moreover, the frequency of short duration, high-intensity rainfall is expected to increase during the monsoon. According to IPCC's scenario A1FI the rainfall will be increased by **16%** in monsoon in Bangladesh. This assumption has been used in this study. IPCC's scenario A1 describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. A1 with technological emphasis: fossil intensive is known as A1FI.

5.5 Flood Hazard Assessment

To assess the flood hazard, a river flood model has been developed generating different scenarios of different return periods.

5.5.1 Scenarios of River Flood Model

The calibrated hydrodynamic model has been simulated for the monsoon period under different scenarios to access river flood impacts for two study areas. The different scenarios for assessing the river flooding are shown in Table 5-3.

Table 5-3: Scenarios to assess river flooding by river flood model

Sl. No.	Scenario	Description
1	F_Sc-1	Simulated for 1 in 2.33-year maximum Water Level Existing land use
2	F_Sc-2	Simulated for 1 in 10-year maximum Water Level Climate change >>>> Sea level rise & rainfall change for 2050 Proposed land use
3	F_Sc-3	Simulated for 1 in 25-year maximum Water Level Climate change >>>> Sea level rise & rainfall change for 2050 Proposed land use
4	F_Sc-4	Simulated for 1 in 50-year maximum Water Level Climate change >>>> Sea level rise & rainfall change for 2050 Proposed land use
	Outputs: Inundation map	

The water level for different scenarios have been selected based on the frequency distribution of water level at Sadarghat station mentioned earlier.

For scenarios of F_Sc-2, F_Sc-3 & F_Sc-4, rainfall and sea level rise due to climate change scenario A1FI has been incorporated. Besides, imperviousness based on future land use plans for Chattogram City has been used to generate run-off for different urban catchments.

5.5.2 Result Analysis of River Flood Model

It is observed that the total inundation area in Chattagram city for average year flood is about 29.9%, whereas in Kalurghat industrial area and KEPZ area the inundation is about 36.8% and 1% respectively in average year flood condition with protection.

The inundation of Kalurghat industrial area and KEPZ area has increased to nearly about 100% for 25 year and 50-year flood conditions respectively without protection of embankment. In these scenarios, the runoff increases not only for higher flood events but also due to change in land use pattern and climate change impacts. The flood maps of different scenarios for river flooding are presented in Figure 5-8, Figure 5-9, Figure 5-10, Figure 5-11 and Figure 5-12.

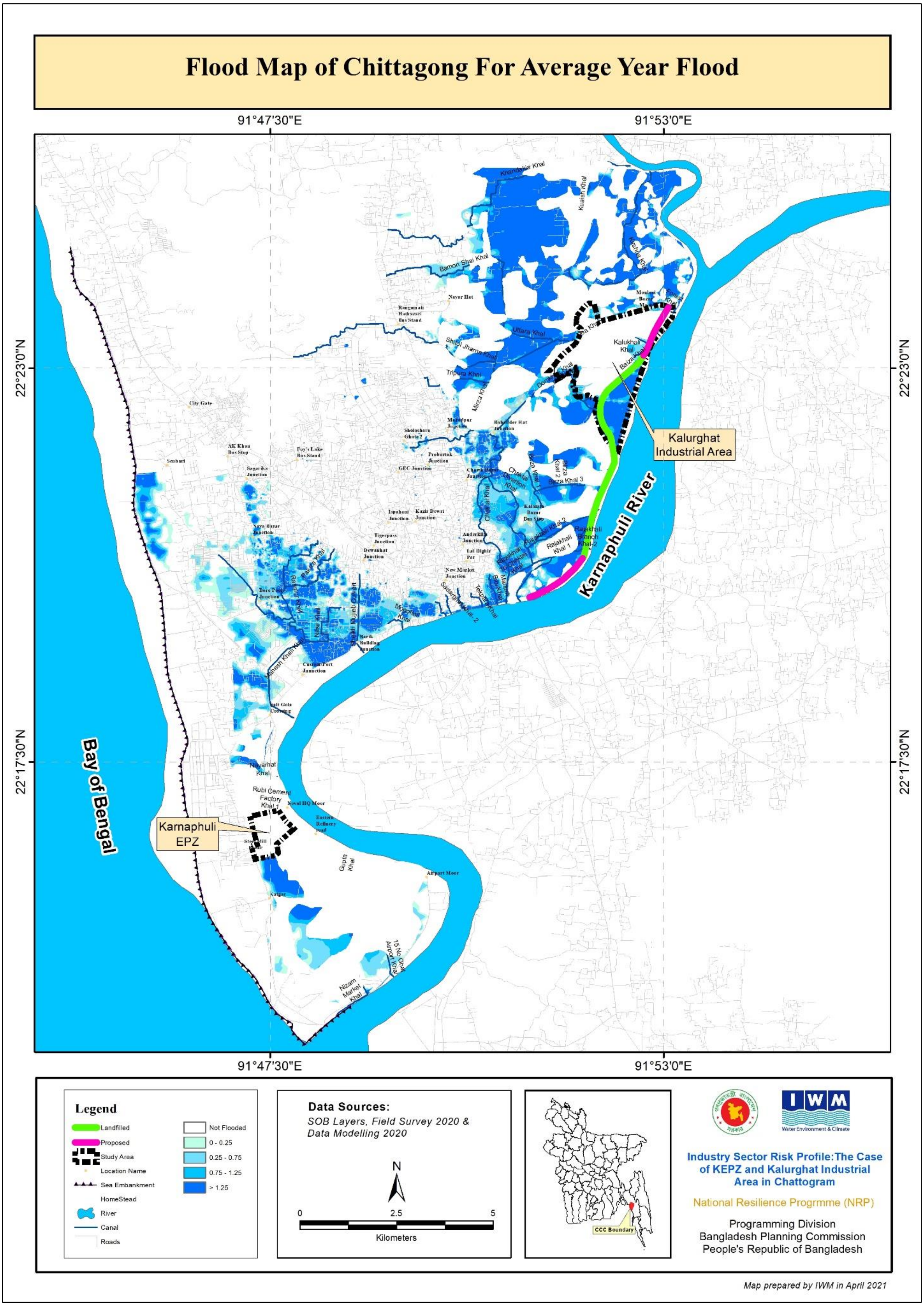


Figure 5-8: Inundated area in average year condition with Protection

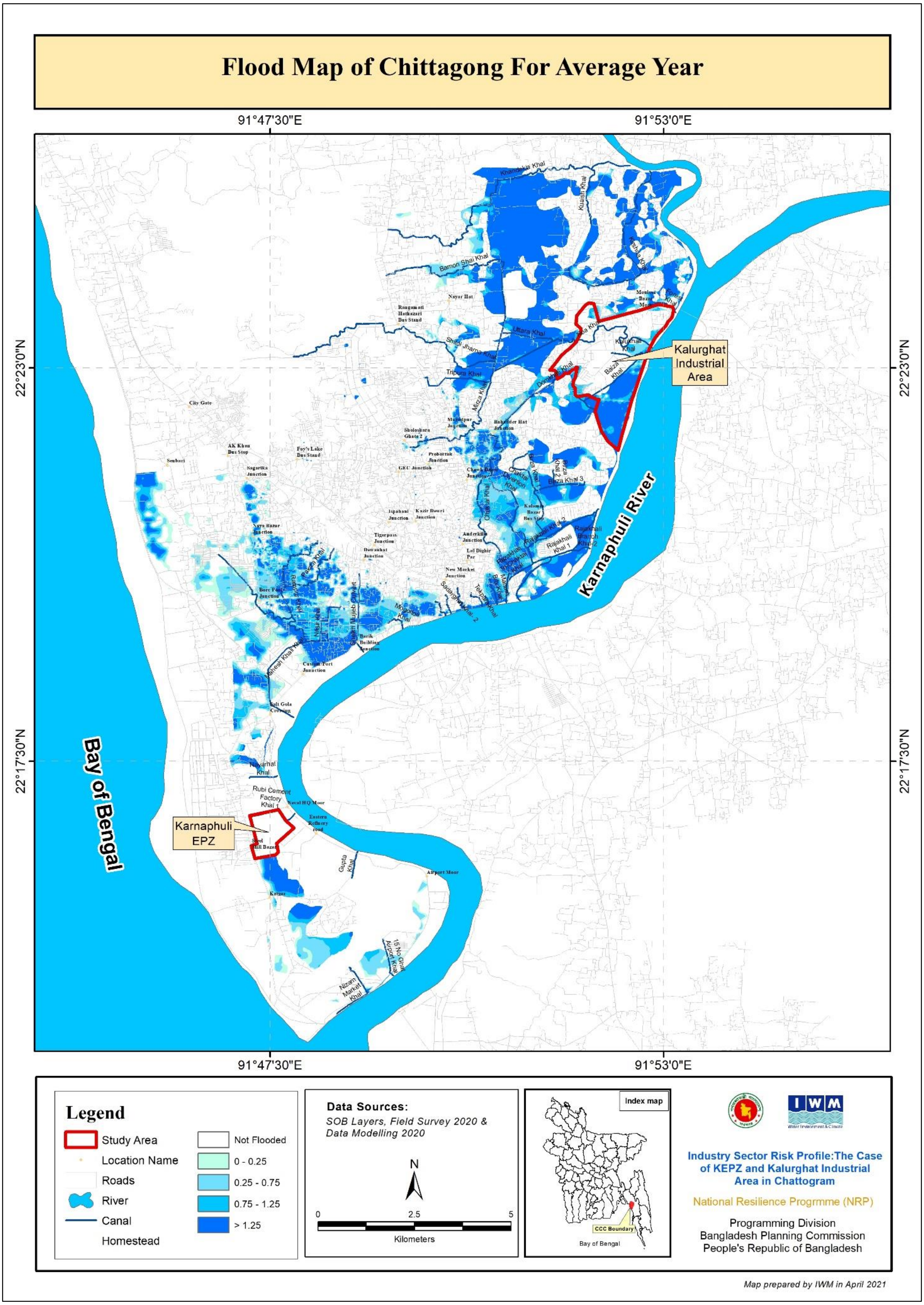


Figure 5-9: Flood inundation map under scenario F_Sc-1

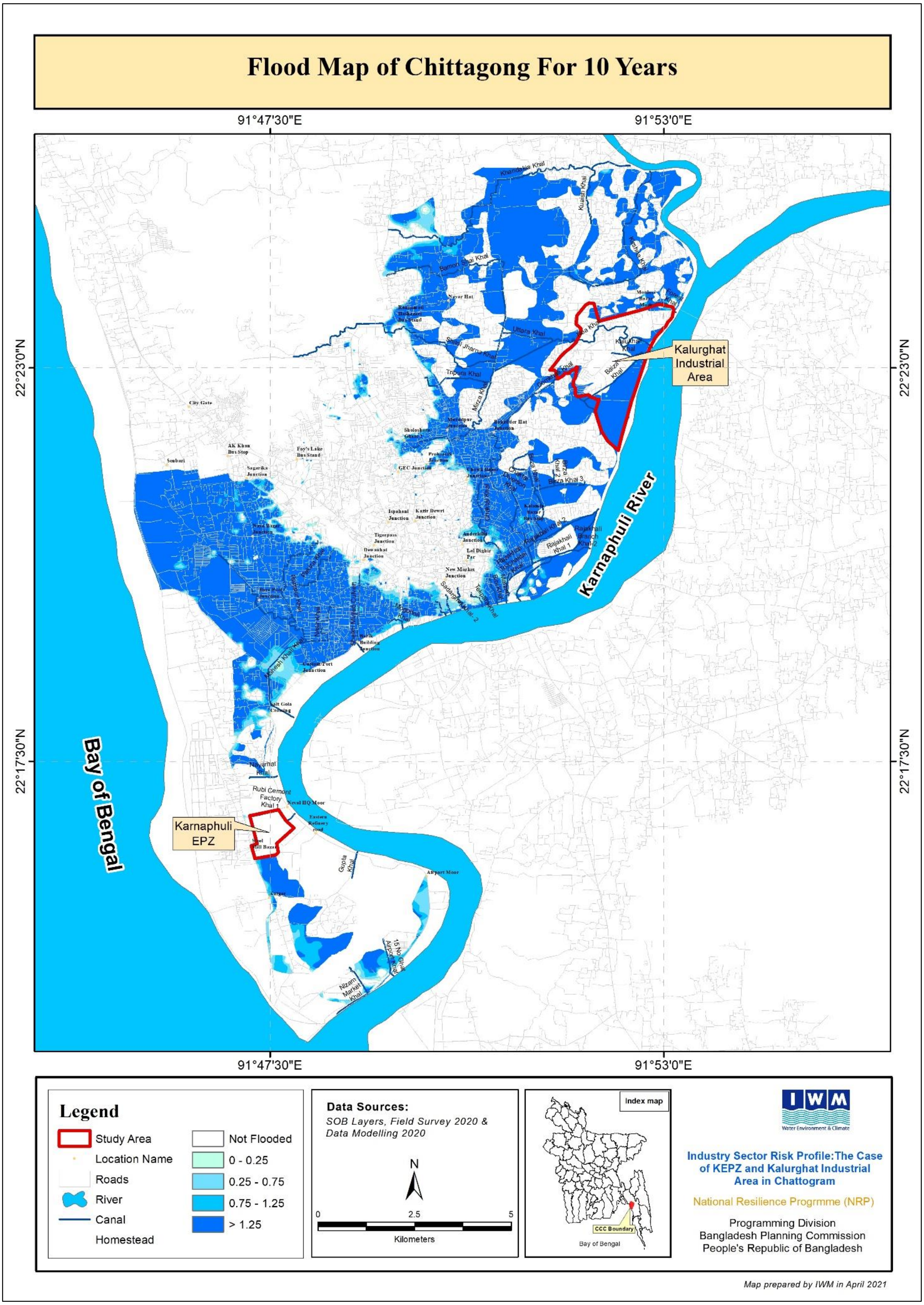


Figure 5-10: Flood inundation map under scenario F_Sc-2

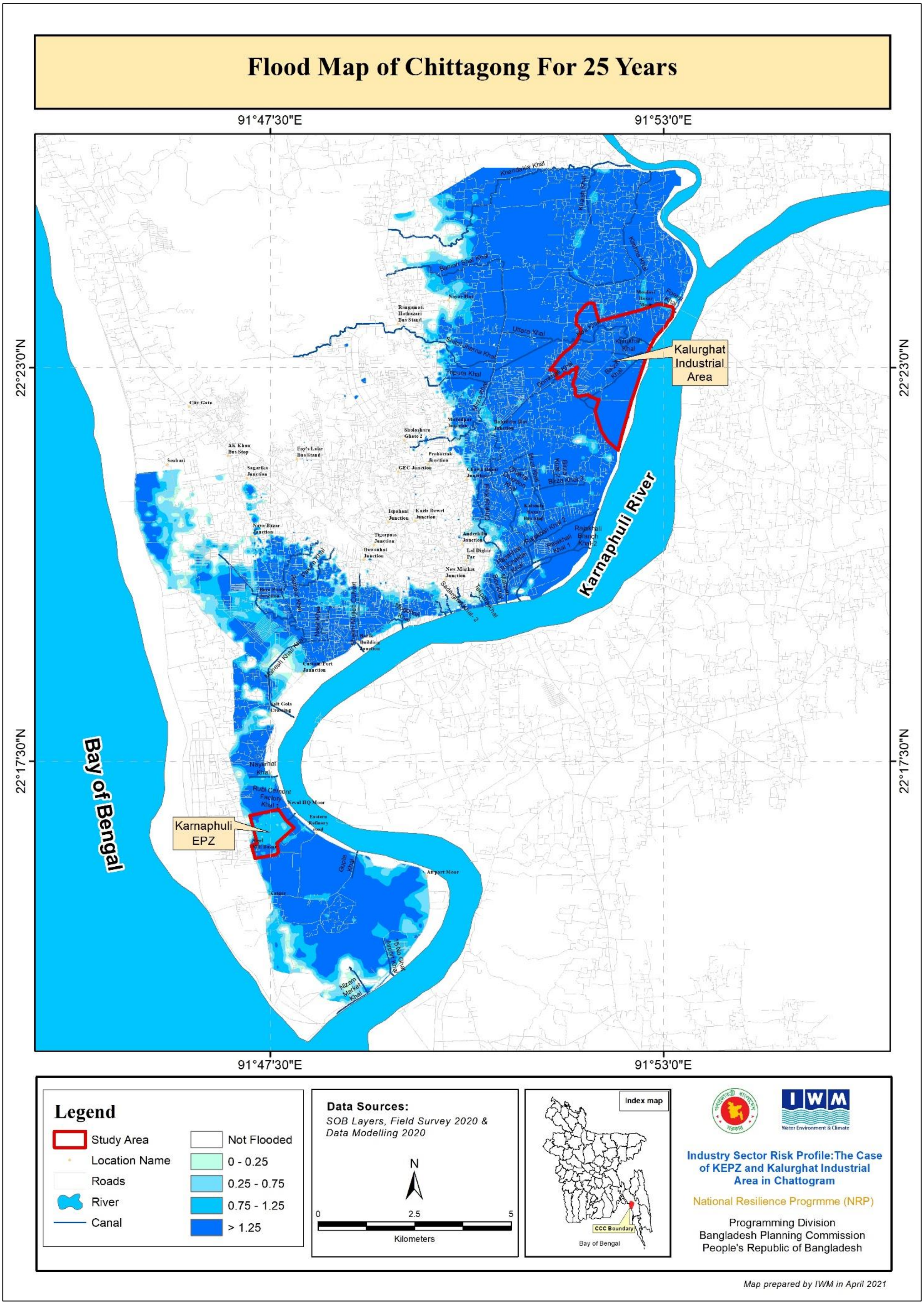


Figure 5-11: Flood inundation map under scenario F_Sc-3

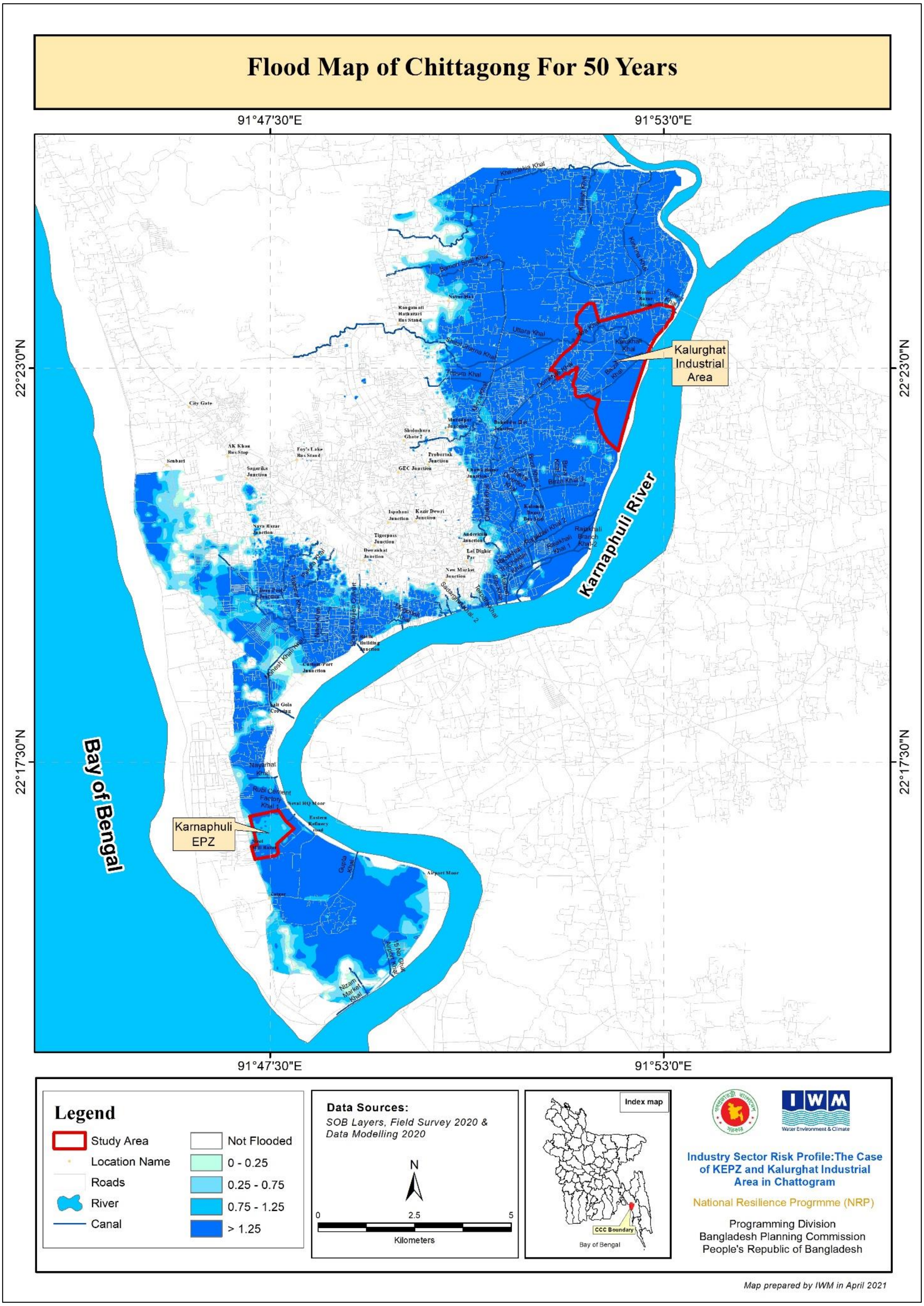


Figure 5-12: Flood inundation map under scenario F_Sc-4

5.6 Water Logging Hazard Assessment

With the global climate change and acceleration of urbanization process, waterlogging has become a frequent occurrence of the major natural disasters in many cities in the world and as well as in Bangladesh. Especially in Chattogram (which is in the coastal area), rapid urbanization and encroachments of city's natural canals by land grabbers exacerbate the risk of waterlogging in the city area. The study locations are not out of this water logging disaster risk. Drainage model has been used to assess the water logging hazards in the study areas.

5.6.1 Drainage Model

5.6.1.1 Scenarios of Drainage Model

The calibrated Hydrodynamic model has been used as a drainage model incorporating design rainfall to generate run-off for urban catchments. The drainage model has been simulated under different scenarios to access water logging on the study areas. The scenarios so developed to assess water logging are shown in Table 5-4 below.

Table 5-4: Scenarios to assess water logging by drainage model

Sl. No.	Scenario ID	Description
1	D_Sc-1:	Simulated for 1 in 2.33-year design rainfall 1 in 2.33-year maximum Water Level Existing land use
2	D_Sc-2	Simulated for 1 in 10-year design rainfall 1 in 10-year maximum Water Level Climate change > Sea level rise & rainfall change for 2050 Proposed land use
3	D_Sc-3	Simulated for 1 in 25-year design rainfall 1 in 25-year maximum Water Level Climate change > Sea level rise & rainfall change for 2050 Proposed land use
4	D_Sc-4	Simulated for 1 in 50-year design rainfall 1 in 50-year maximum Water Level Climate change > Sea level rise & rainfall change for 2050 Proposed land use
	Outputs: 2-day rainfall inundation-duration hydrograph at each grid point	

5.6.1.2 Design Rainfall

A critical rainfall event that is used for assessing the flood hydrograph of a certain return period is called "design rainfall". The design storm consists of 78% rainfall in the 1st day and 22% rainfall in the 2nd day (JICA 1991) and the rainfall occurs in the first 6 hours only. The pattern (Figure 5-13) consists of a peak intensity - 3 hours after the rain starts, where 34% of the 2-day rainfall occurs in an hour. This design rainfall has been used for analyzing water logging in the study area under different scenarios.

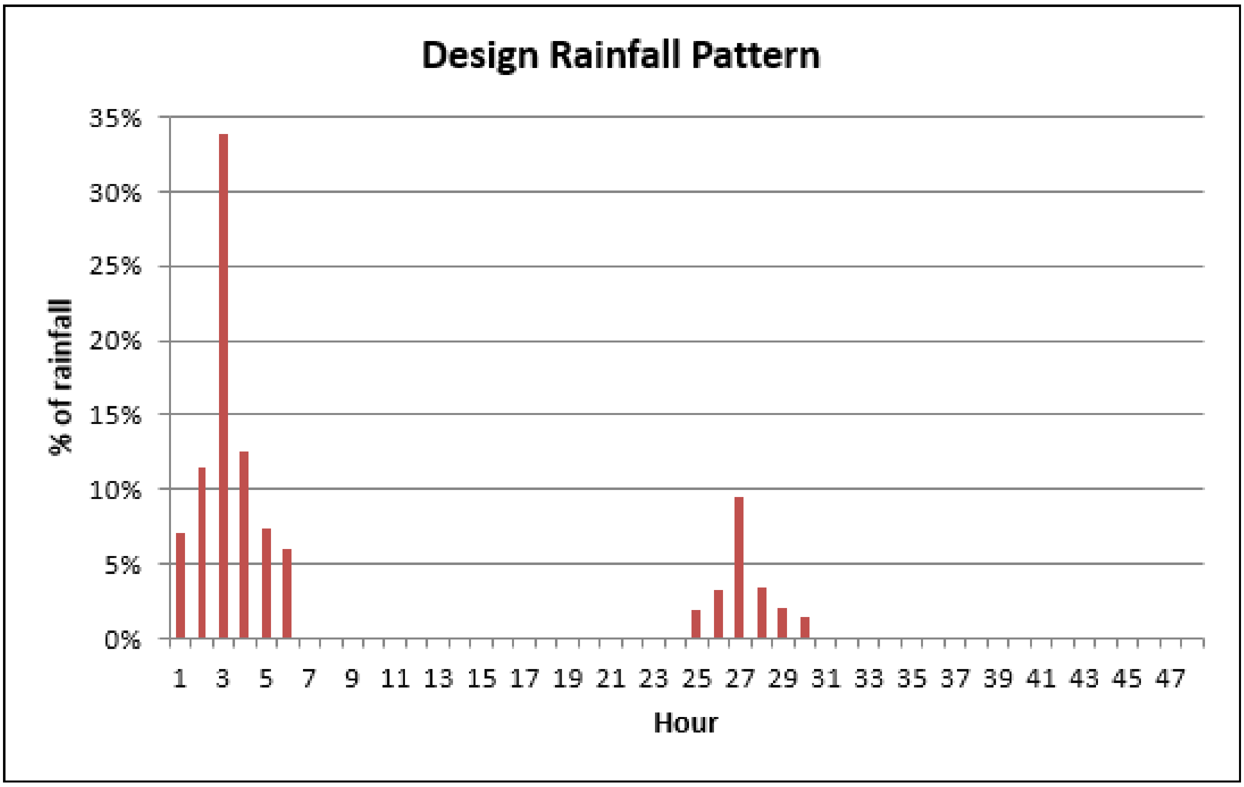


Figure 5-13: Design rainfall with hourly distribution

5.6.1.3 Result Analysis of Design Rainfall

It is observed that the total inundation area in Chattogram city for average year flooding is about 39.1% whereas in Kalurghat industrial area and KEPZ area the inundation area is about 36.9% and 1% respectively in average year flooding condition. The inundation area for Chattogram city will be increased for 25 year and 50-year return period. In these scenarios the rainfall runoff will be increased not only for higher rainfall events but also due to changes in land use pattern and climate change impacts. The inundation map of different scenarios for drainage congestion is presented in Figure 5-14 to Figure 5-17. The water levels that cause drainage congestion at different locations in the river/khals is also given in Figure 5-18 to Figure 5-21.

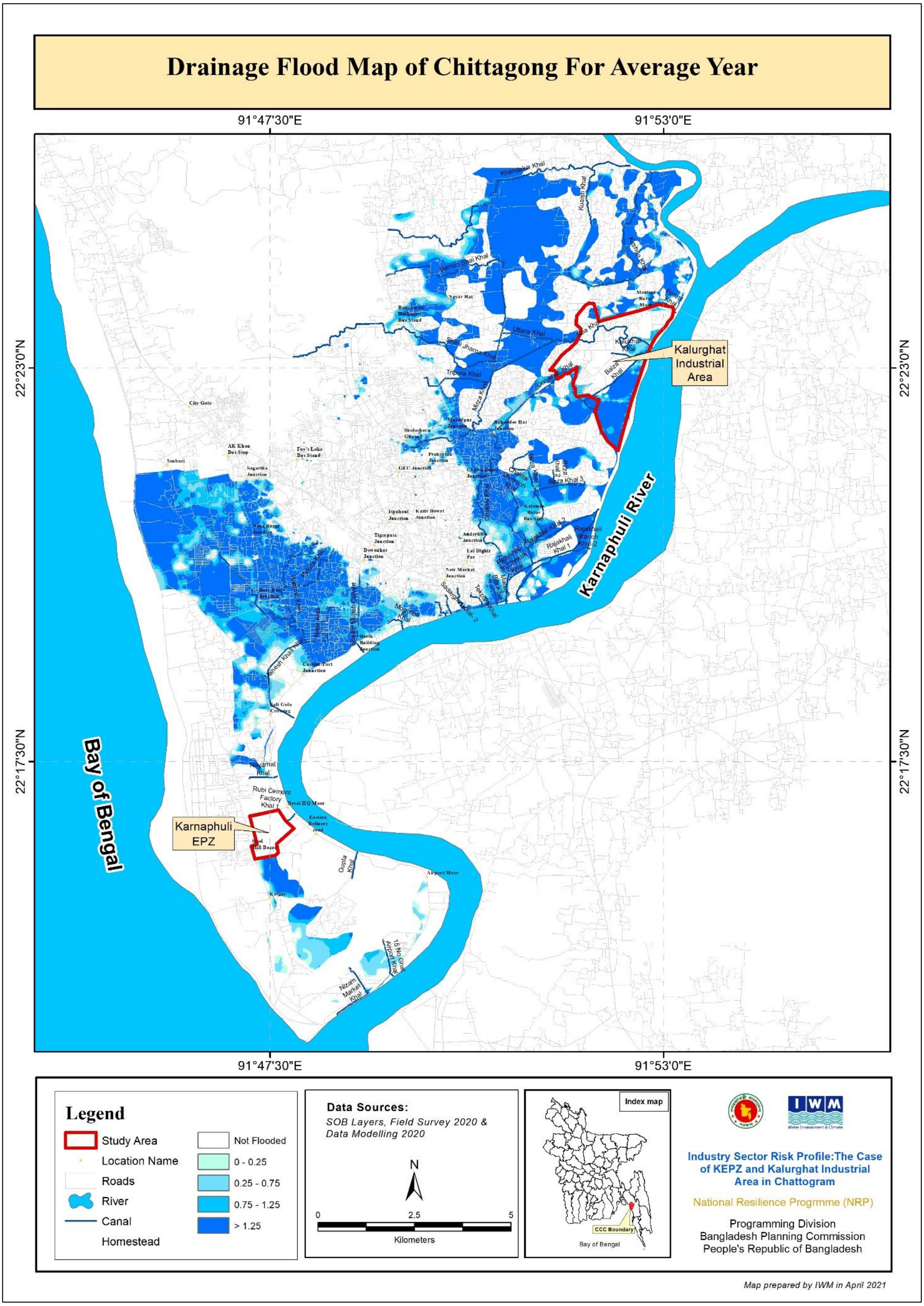


Figure 5-14: Water Logging inundation map under scenario D_Sc-1

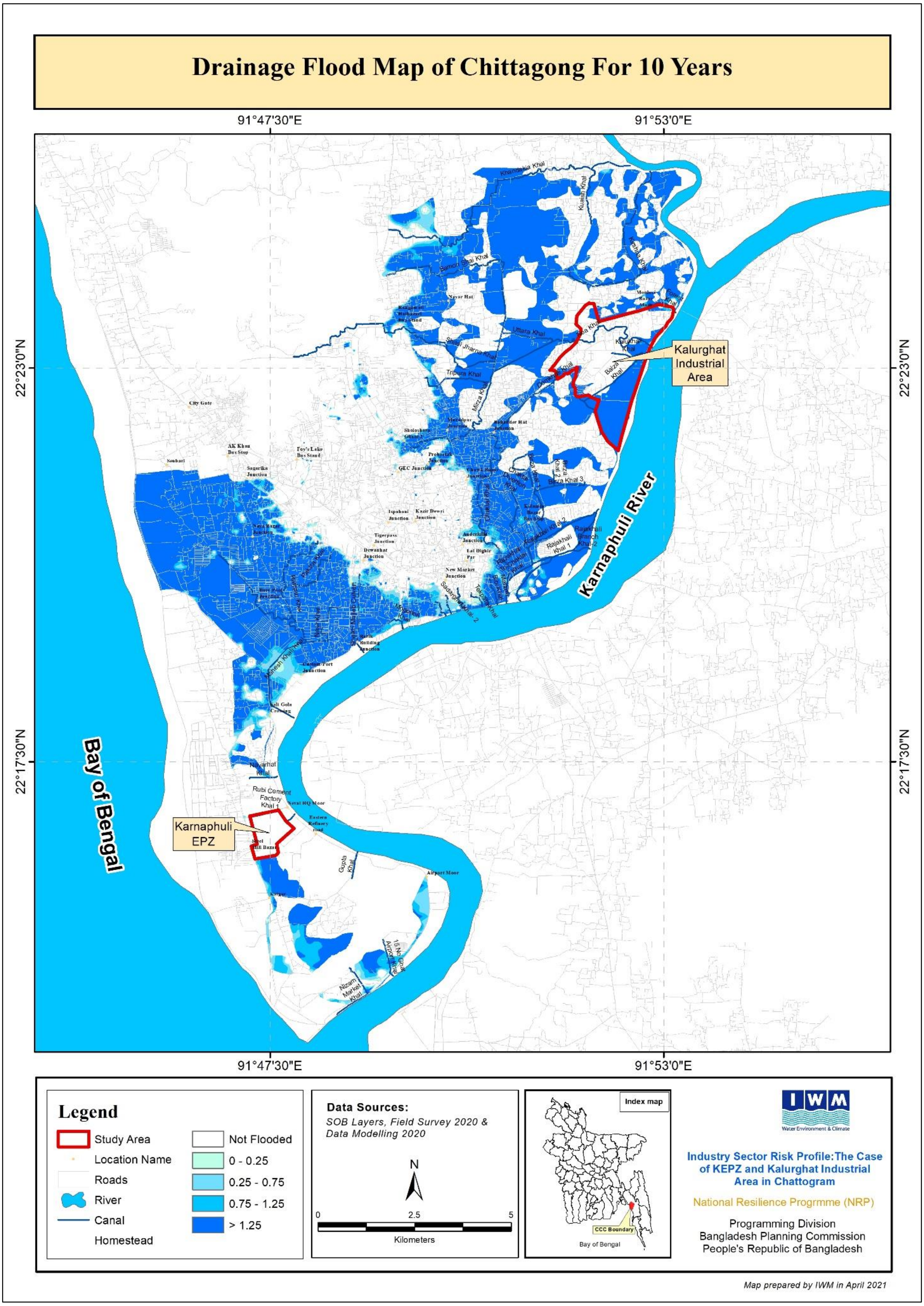


Figure 5-15: Water Logging inundation map under scenario D_Sc-2

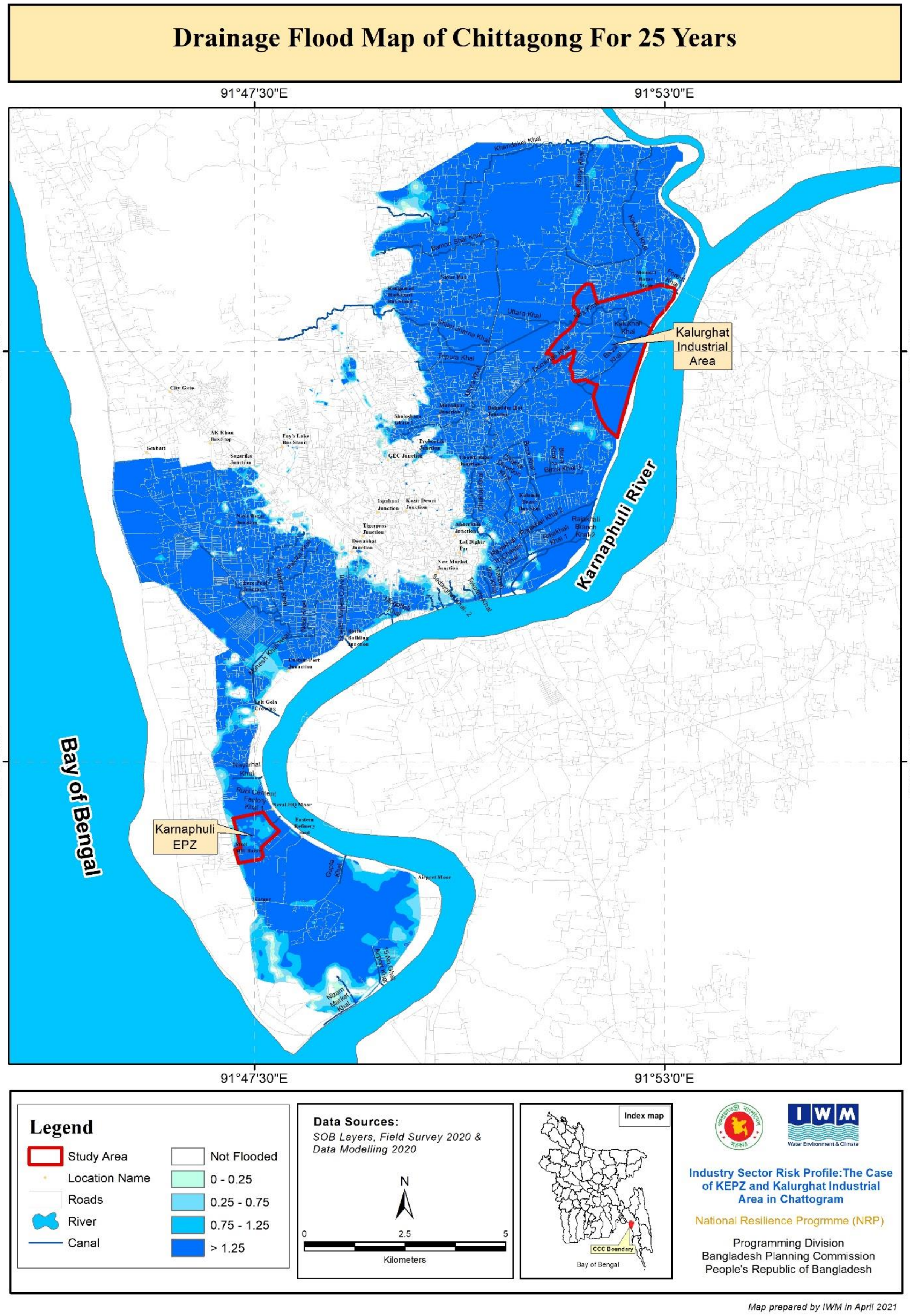


Figure 5-16: Water Logging inundation map under scenario D_Sc-3

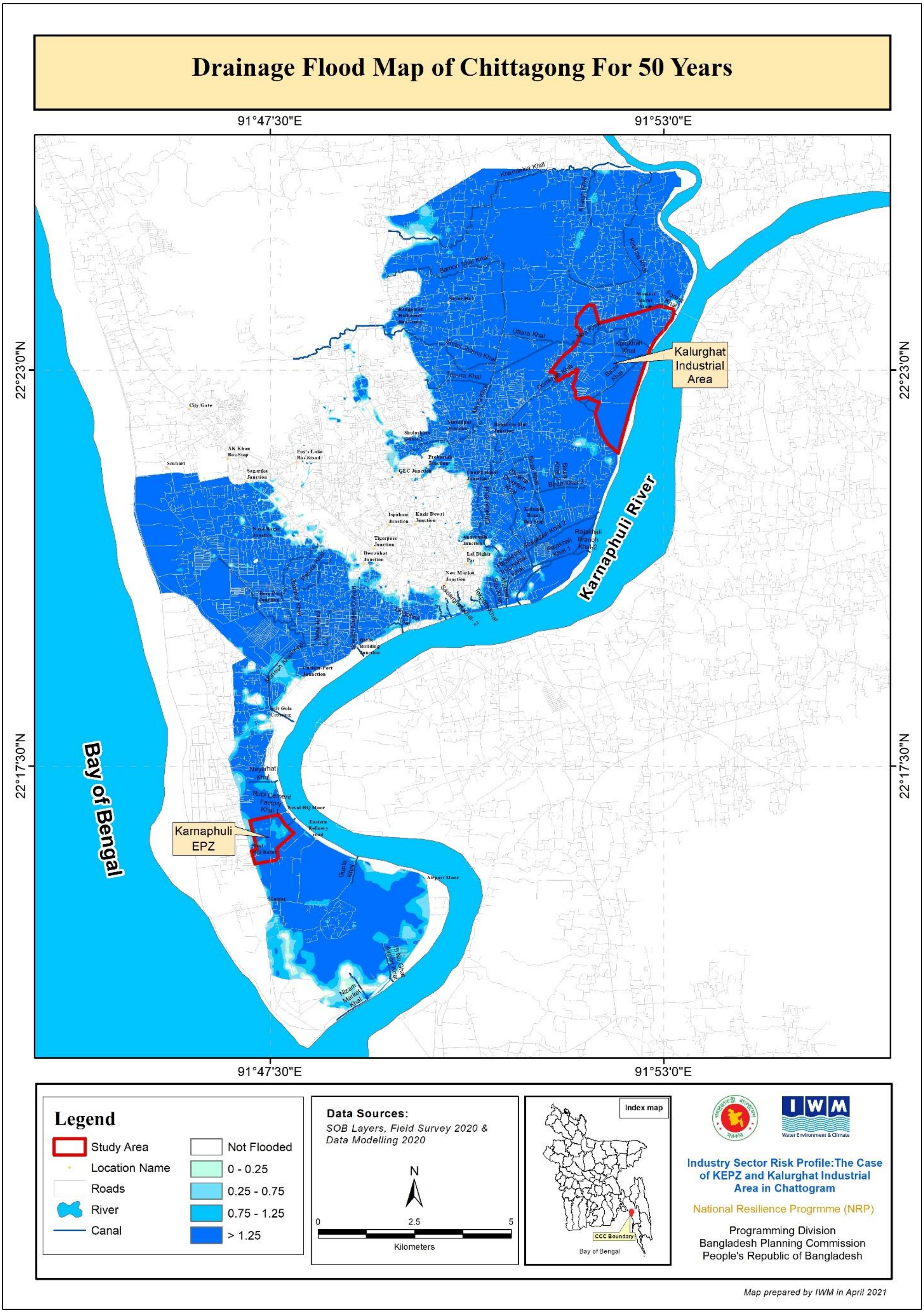


Figure 5-17: Water Logging inundation map under scenario D_Sc-4

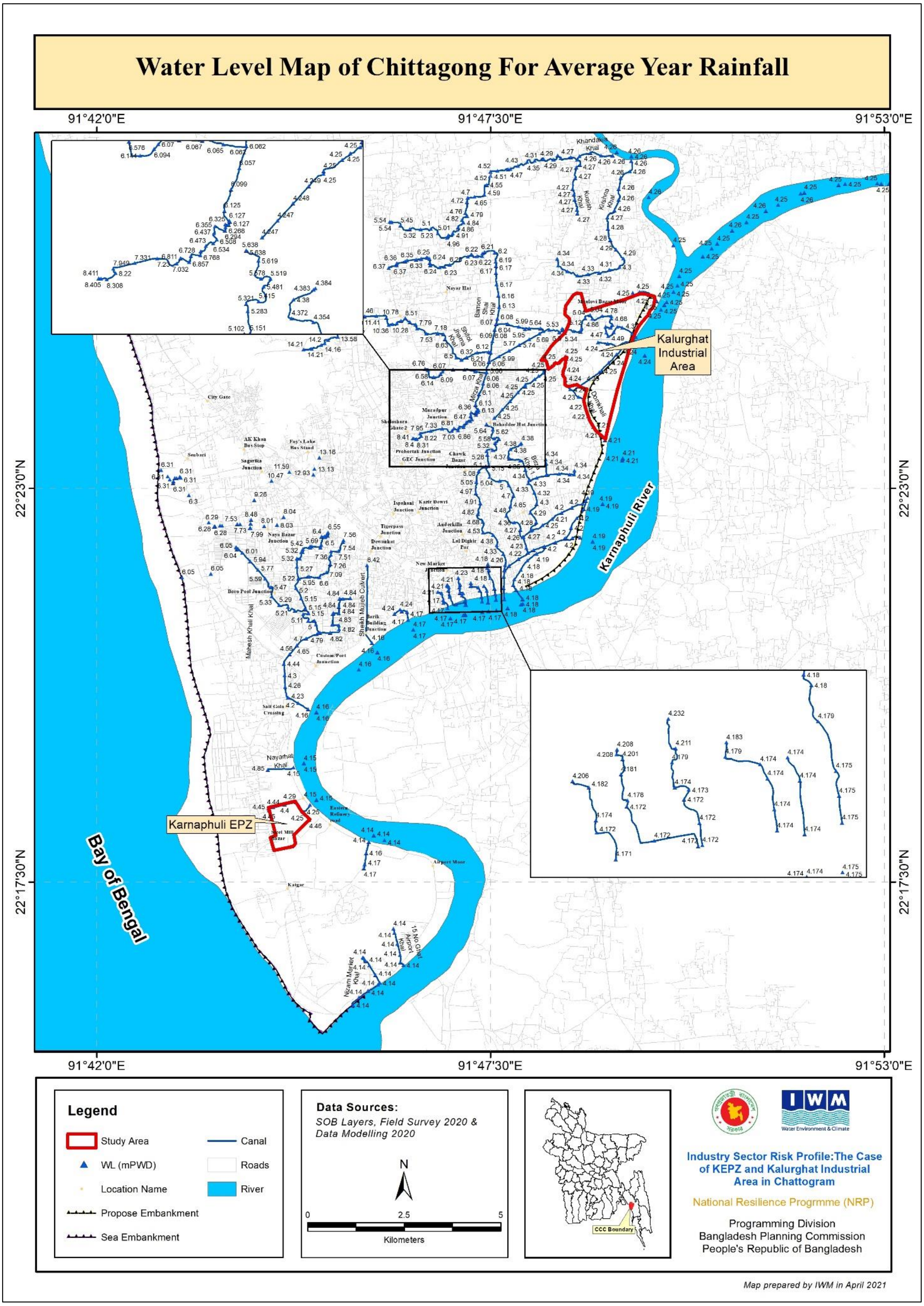


Figure 5-18: Water level at different locations under scenario D_Sc-1

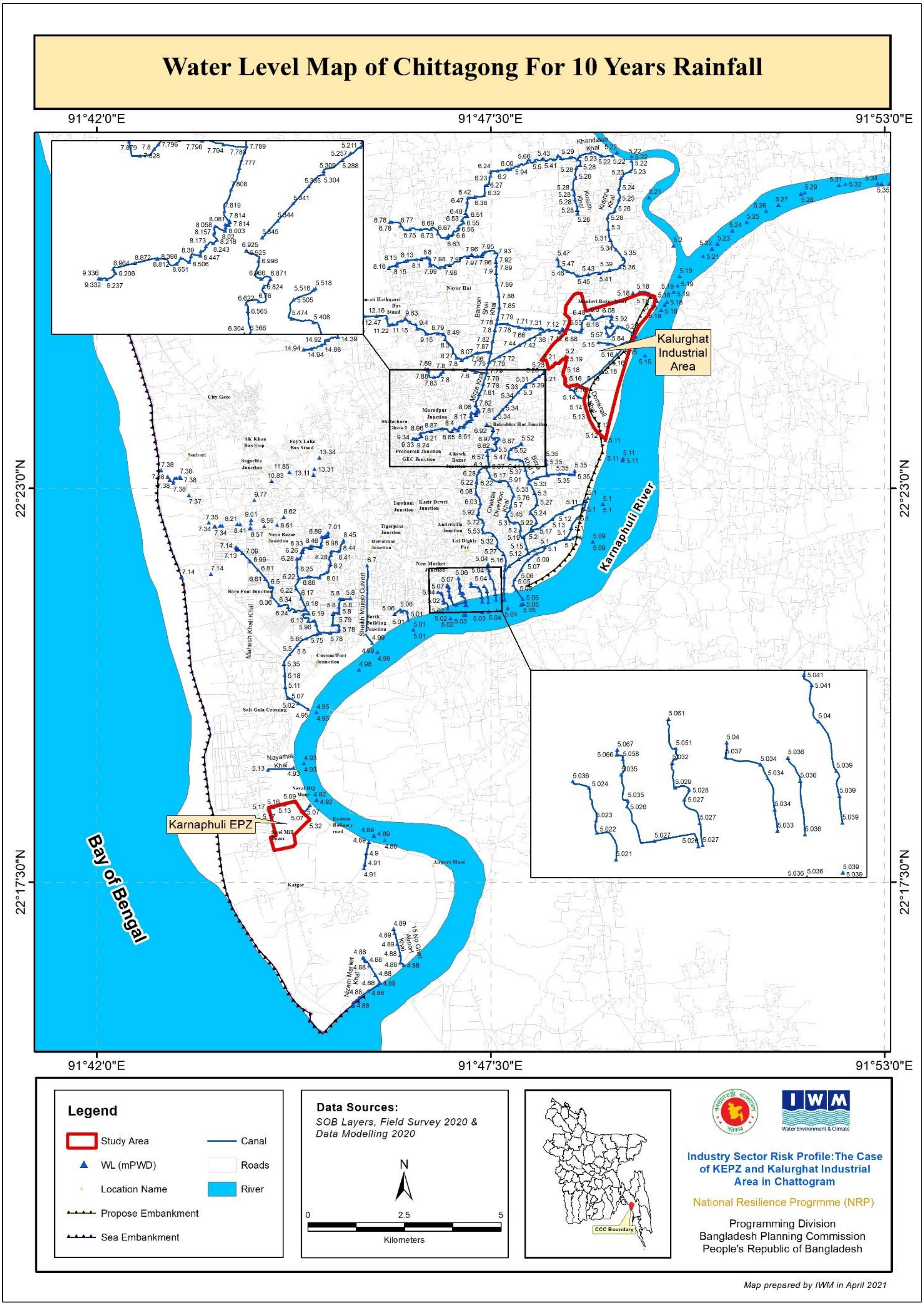


Figure 5-19: Water level at different locations under scenario D_Sc-2

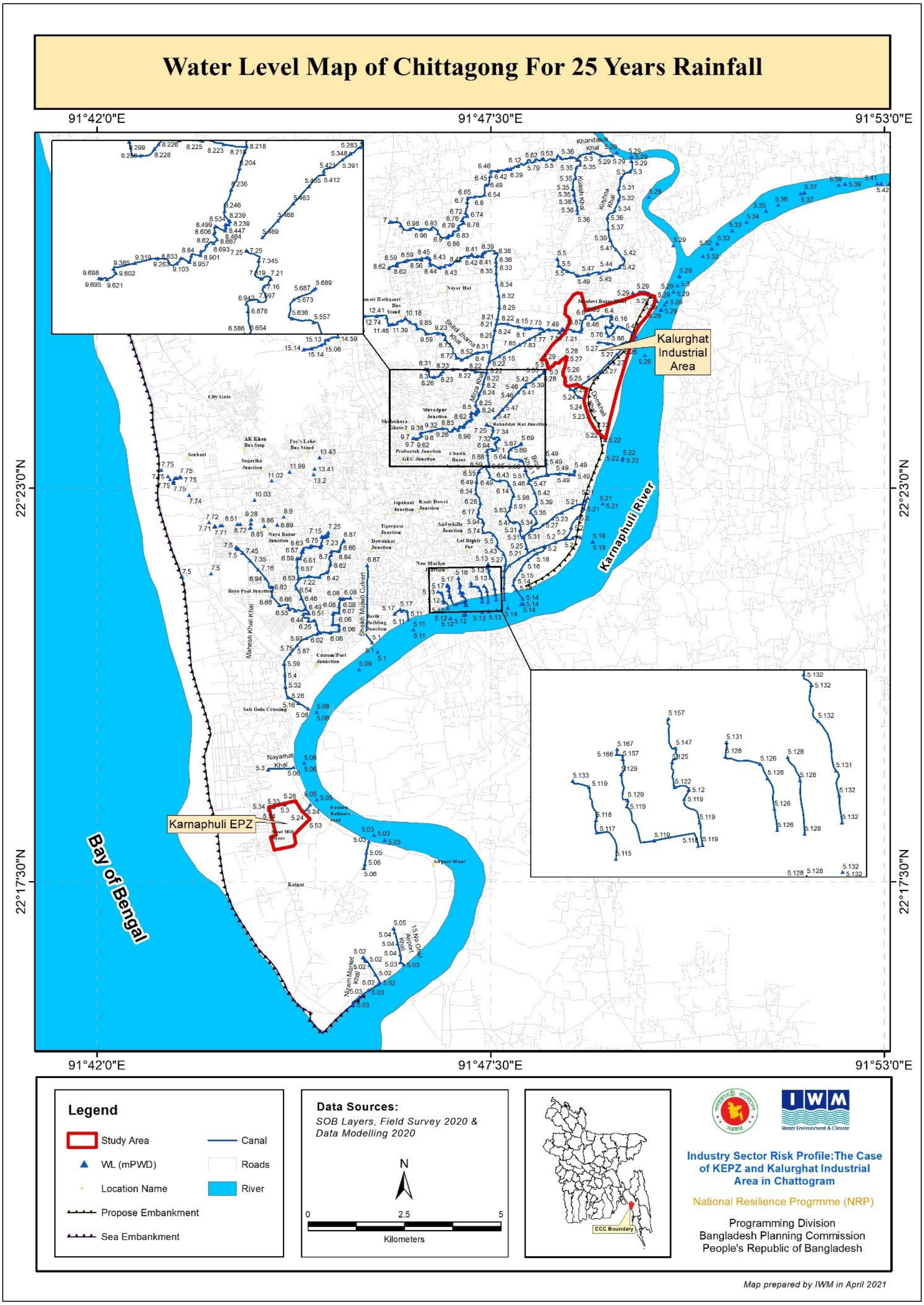


Figure 5-20: Water level at different locations under scenario D_Sc-3

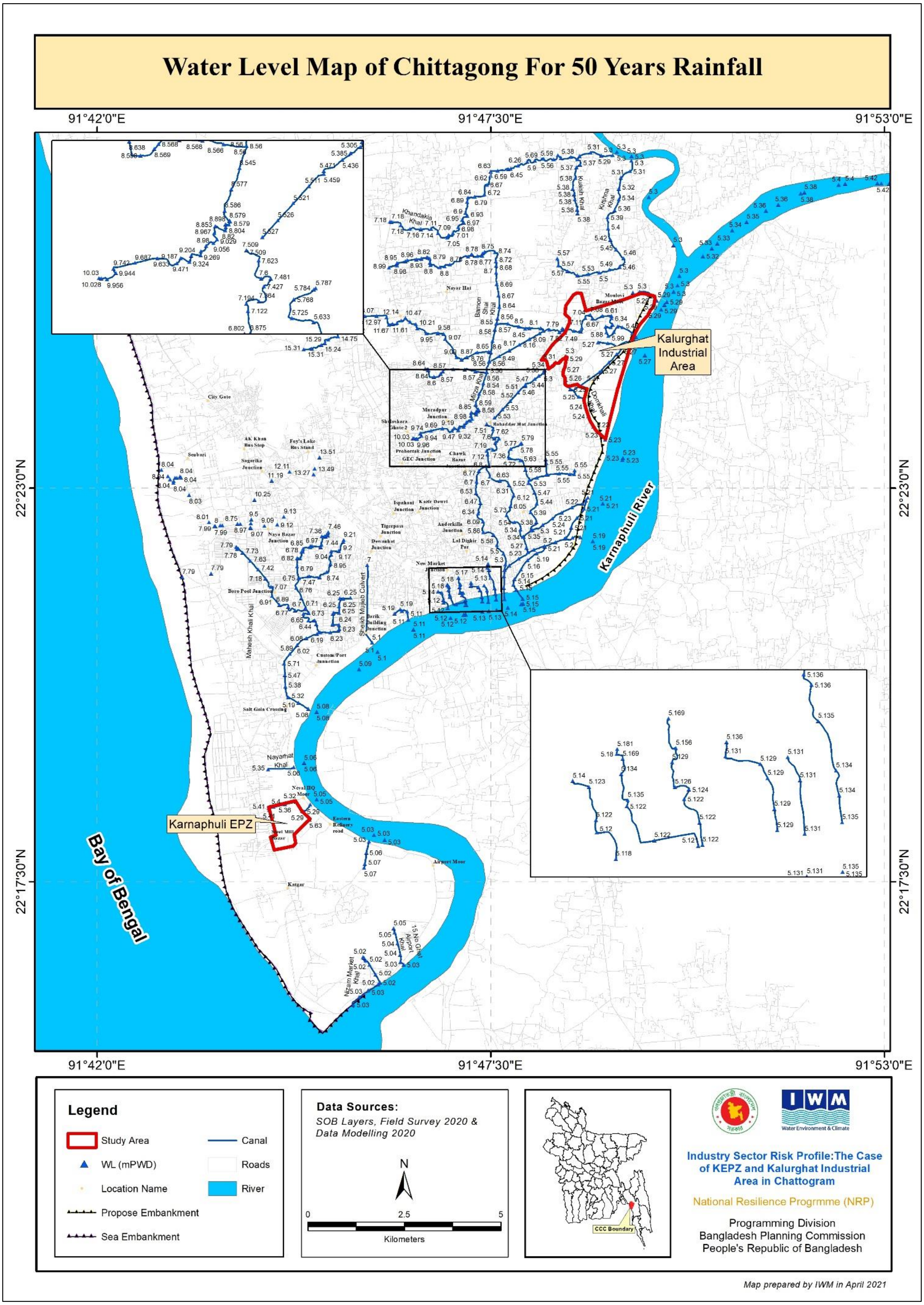


Figure 5-21: Water level at different locations under scenario D_Sc-4

5.7 Cyclone & Storm Surge Hazard

Chattogram, the biggest seaport and the second largest city of Bangladesh lies in a Cyclone prone region that also induces Storm Surge flooding. There were more than 20% chances of potentially damaging wind speeds in the last 10 years (source: GFDRR; https://thinkhazard.org/en/report/576-bangladesh-chittagong/CY). The Hazards of Cyclones should be considered with importance while designing the establishment of industrial structures. For assessing the Cyclone and Storm Surge Hazard, results of Cyclone and Storm Surge model have been used for two industrial areas for the study.

5.7.1 Cyclone & Storm Surge Model

A Storm surge model of the Coastal region is available with IWM, which is used to determine the storm surge level and wave height due to cyclonic effect in the Bay of Bengal. Storm surge model is the combination of hydrodynamic and cyclone models. For simulating the storm surge and associated flooding, an updated and calibrated Bay of Bengal model based on MIKE21 hydrodynamic modelling system has been used in this study.

In the hydrodynamic model simulations, meteorological forcing due to the cyclone has been added by applying wind and pressure fields derived from the analytical cyclone model. The MIKE 21 modelling system includes dynamic simulation of flooding and drying processes, which was used for a realistic simulation of flooding in the coastal area and inundation.

5.7.2 Hydrodynamic Model

This model is two way nested and includes four different resolution levels (grid size) in different areas. The coastal region of Bangladesh and Meghna estuary are resolved on a 200m grid.

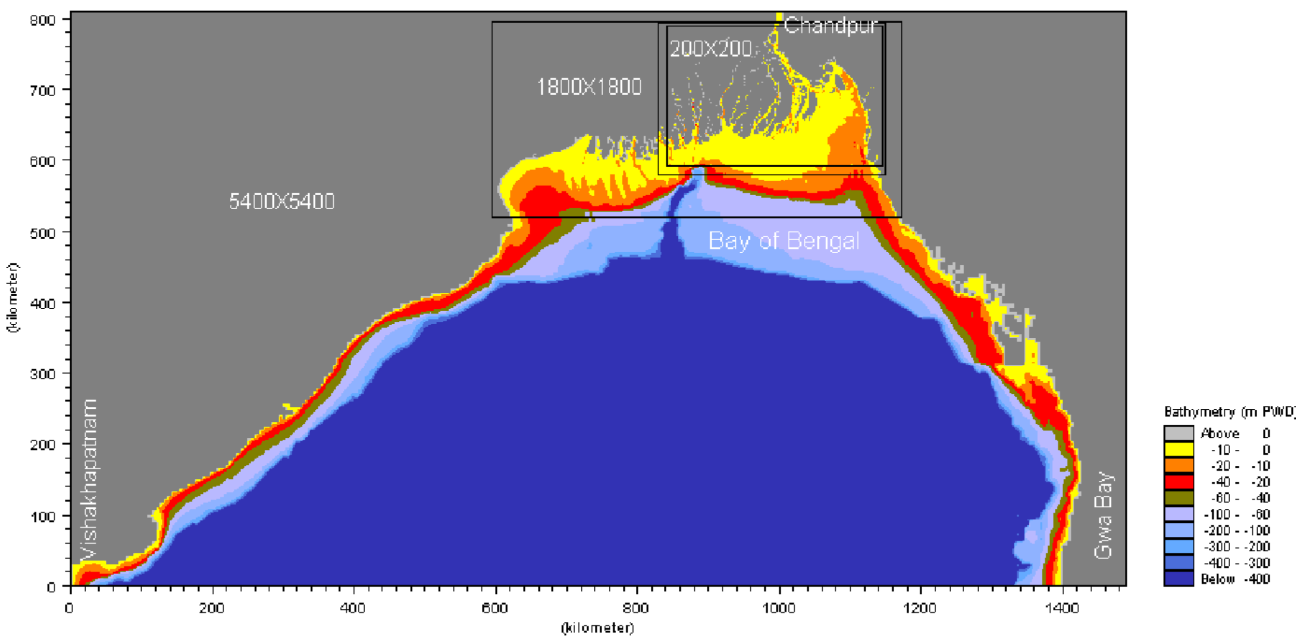


Figure 5-22: Nested bathymetry of Bay of Bengal Model

Bathymetry of the model has been generated based on data collected from different sources. In shallow areas bed friction is important and effectively used to adjust the amplitude of tides. Bed friction in the model is defined by the Manning number, M ($m^{1/3}/s$). Manning number distribution used for calibration is presented in Table 5-5.

Table 5-5: Manning number distribution

Areas with depths	Manning number ($m^{1/3}/s$)
Less than -20 m	32
-20 to -15 m	60
-15 to -10 m	65
-10 to -5 m	90
-5 to 0.46 m	100
Mangrove Forest	15
Settlement & Rice field	25

The model has two open boundaries; one is in the Lower Meghna River near Chandpur and another one is in the open sea located along the line extending from Vishakhapatnam of India to Gwa Bay of Myanmar. In the river boundary, measured water level has been prescribed and the sea boundary has been generated from the Global Tide Model. Another open boundary is located in the north in the Meghna River, which is narrow and shallow.

5.7.3 Cyclone Model

The description of a cyclone is based on a few parameters related to the pressure field, which is imposed on the water surface and a wind field acting as a drag force on the water body through a wind shear stress description. The pressure field creates a local level set-up close to the eye up to one meter only. The wind shear contributes more to the surge giving a level set-up on the right side of the eye and a level set down on the left side.

To generate the wind field, Holland Single Vortex theory (introduced by Marchioro and Pulvirenti (Mechanics, analysis and geometry: 200 years after Lagrange, North-Holland Delta Ser., Amsterdam, North-Holland, pp. 79–95, 1991) has been applied. The cyclone model used following data for the description of wind field and pressure field:

- Radius of maximum winds, R_m,
- Maximum wind speed, V_m and
- Cyclones track forward speed V_f and direction.
- Central pressure, P_c
- Neutral pressure, P_n

- Holland Parameter, B= 2.0-(Pc-90)/160

In order to obtain surface winds, a boundary layer wind speed correction has been applied to the gradient wind. The near-surface wind$_{10}$, is usually obtained by the following relation (Harper et al., 2001):

$$V_{10\,r} = K_m .\, V_{g(r)}$$

- where Vg is the rotational wind gradient speed at a distance r from the center of the cyclone.
- K_m is geostrophic correction factor

A speed-dependent formulation for Km is also proposed by Harper et al. (2001) and seems widely used in Australia. This has been implemented in the Cyclone Wind Generation Tool as the "Harper et al."

K_m =	0.81	$for\ Vg < 6\ m/s$
	$0.81 - 2.96\ 10^{-3}(Vg - 6)$	$for\ 6 \le Vg < 19.5$
	$0.77 - 4.31\ 10^{-3}\ Vg - 19.5)$	$for\ 19.5 \le Vg < 45$
	0.66	$for\ Vg > 45\ m/s$

For this study **0.75** is used as a geostrophic correction factor.

Cyclone models can generate wind speed and pressure fields over the domain. As an example, the propagation of cyclonic eyes generated by the model during cyclone 1991 is shown in Figure 5-23 .

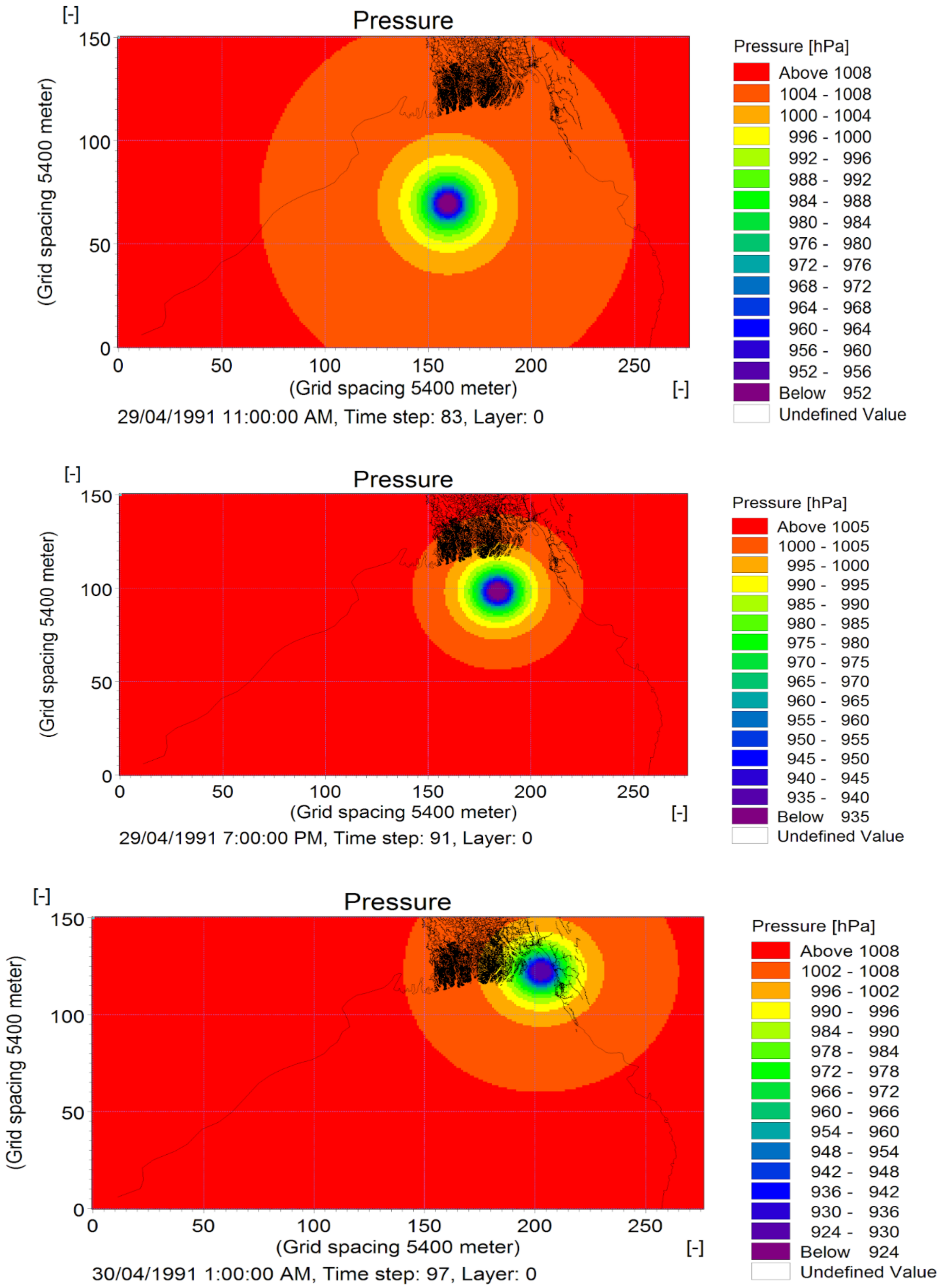


Figure 5-23: Propagation of Cyclonic eye during 1991

5.7.4 Cyclone & Storm Surge Model Scenarios

The calibrated Hydrodynamic model has been used to assess hazards and the impacts of flooding situations due to cyclone & tidal surge in Chattogram City area. Different model scenarios have been used as shown in Figure 5-23.

Table 5-6: Scenarios of flooding impacts due to cyclone & tidal surge

Sl. No.	Scenario ID	Description
1	C_Sc-1:	Simulated for 1 in 4-year tide due to cyclone Existing land use
2	C_Sc-2	Simulated for 1 in 10-year tide due to cyclone Climate change >>>> Sea level rise Proposed land use
3	C_Sc-3	Simulated for 1 in 25-year tide due to cyclone Climate change >>>> Sea level rise Proposed land use
4	C_Sc-4	Simulated for 1 in 50-year tide due to cyclone Climate change >>>> Sea level rise Proposed land use
	Outputs: Inundation map	

5.7.5 Assessment of Storm Surge Level

There were about 25 severe cyclones that have hit the coastal area from 1960 to 2020. These cyclones made landfall at different tidal phases i.e., either at low tidal or at high tidal phases. All these cyclones were simulated for high and low tidal phases with and without climate change. The climate change condition was considered based on the 5th IPCC report. Frequency distribution analysis has been done considering 38 storm surge levels. The cyclones that have been chosen for different return periods are given in Table 5-7.

Table 5-7: Cyclonic events for different scenarios

Scenario ID	Cyclonic event
C_Sc-1	1965_LT_MAY_BASE
C_Sc-2	1966_HT_CC
C_Sc-3	1970_LT_CC
C_Sc-4	1991_HT_CC

5.7.6 Result Analysis of Cyclone & Storm Surge Model

The inundated area of Chattogram city and the study area due to cyclone and storm surge under different return periods are estimated. It is observed that the total inundation area in Chattogram city for an average year storm surge event is about **39.1%,** whereas in Kalurghat industrial area the inundation is about **27.7%** and no flooding is observed in KEPZ area. The inundation area of Chattogram city will increase for 25-year and

50-year rainfall conditions. Similarly, the increase of inundated area in Kalurghat industrial area and KEPZ area are also significant for 25-year and 50-year cyclone induced flood conditions. In these scenarios the runoff increases, and inundation changes due to higher storm surge level events. The inundation maps of different scenarios for cyclone and storm surge conditions are presented in figures below (Figure 5-24 to Figure 5-27).

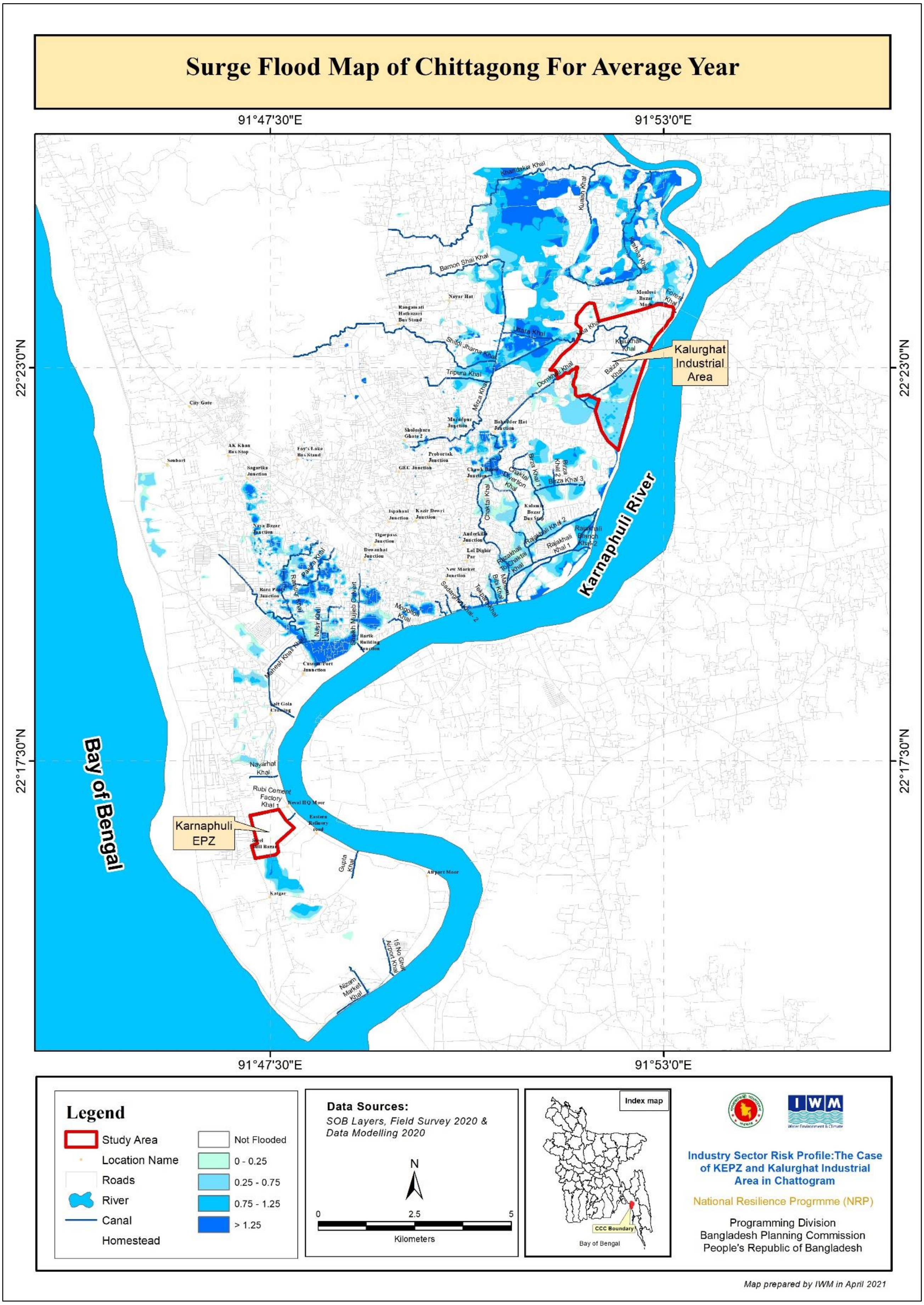


Figure 5-24: Cyclone inundation map under scenario C_Sc-1

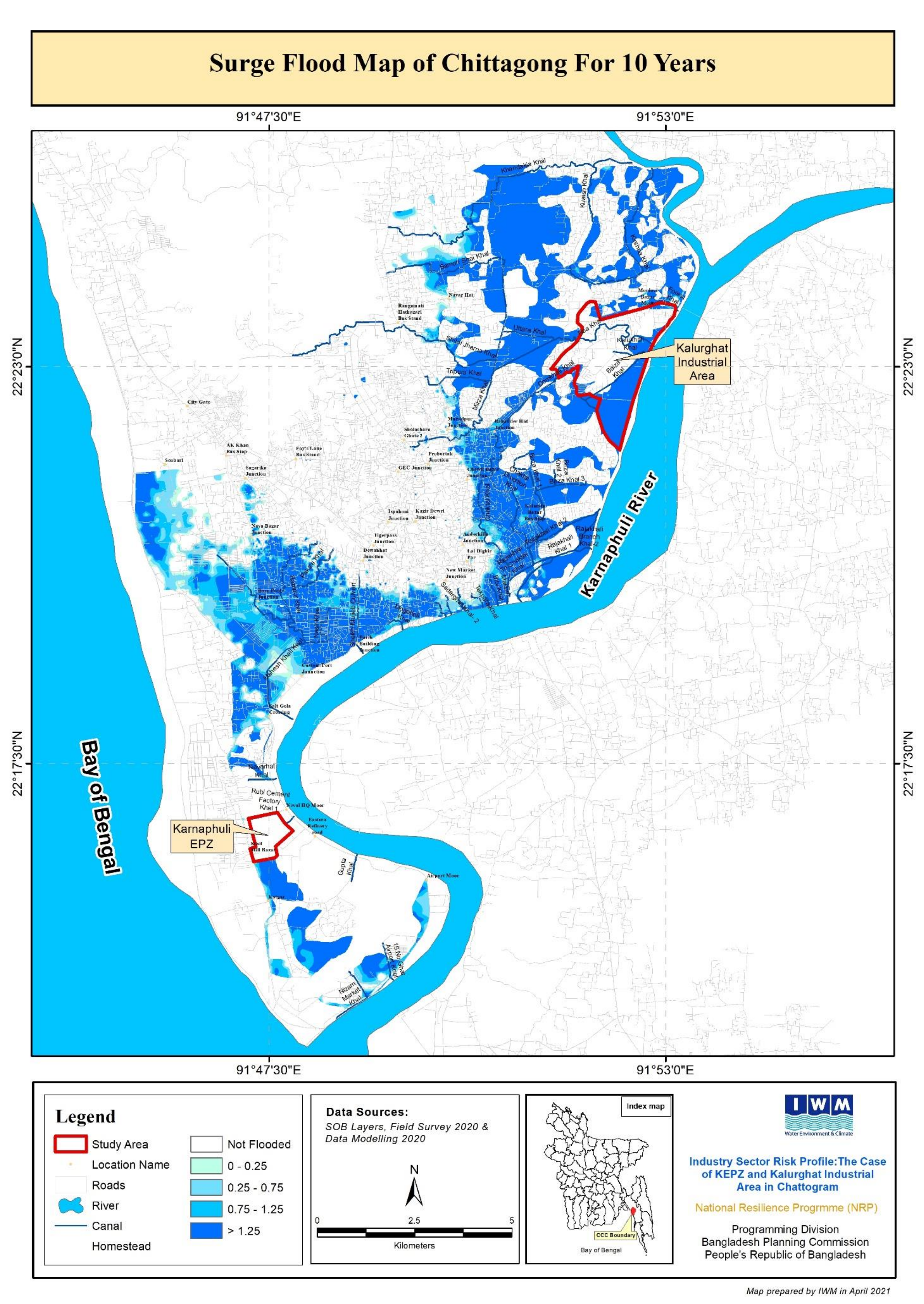


Figure 5-25: Cyclone inundation map under scenario C_Sc-2

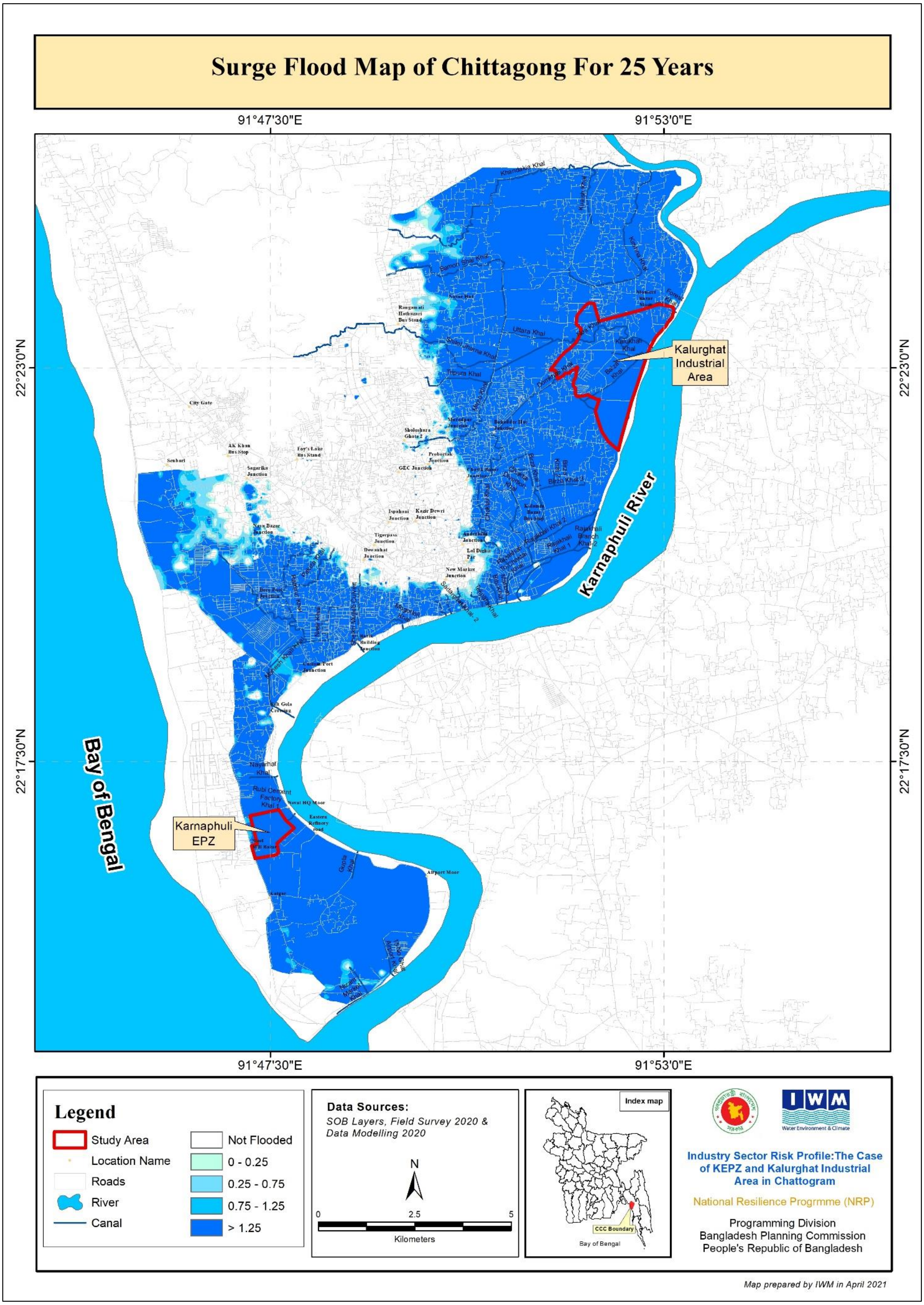


Figure 5-26: Cyclone inundation map under scenario C_Sc-3

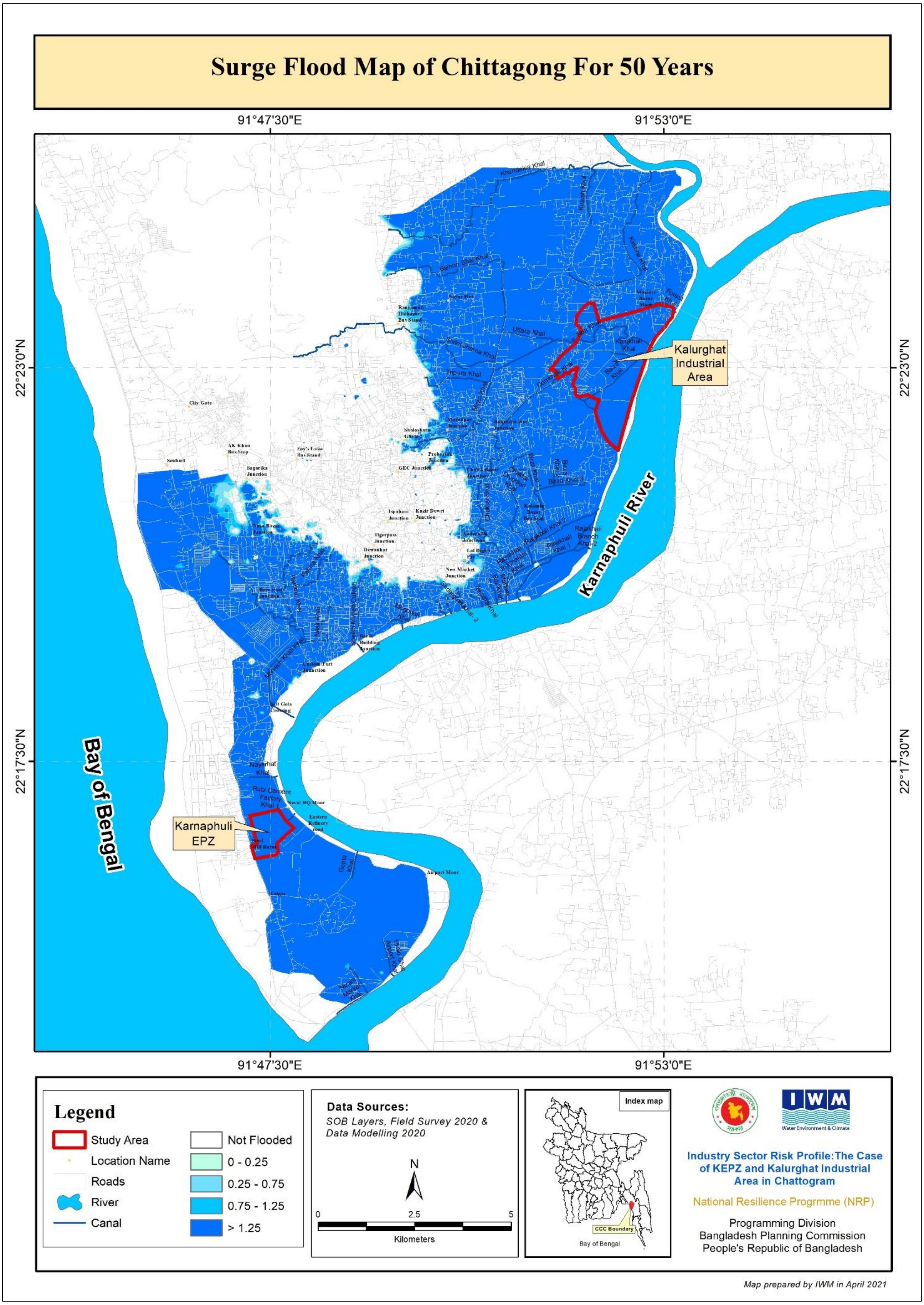


Figure 5-27: Cyclone inundation map under scenario C_Sc-4

There were some limitations in analyzing the inundation situation due to cyclones and storm surges, such as: (i) *the flood map is generated based on 1D hydrodynamic model*, (ii) *the wind impacts inside the study area could not be addressed*, and (iii) *the actual rainfall value during the cyclone is not available*.

5.8 Salinity Hazard

5.8.1 Salinity Model

The calibrated Hydro Dynamic Model has been used to develop salinity models for the Karnaphuli River system. Salinity boundary data were mainly collected from CPA. The salinity model for the rivers system has been developed using the Advection-Dispersion (AD) module of MIKE 11.

Owing to the practical shortcoming of unavailability of time-series salinity data at Khal-10 on Karnaphuli River, the salinity at the boundary has been developed based on the available data. An equation has been developed as shown in Figure 5-28, which reflects salinity variation for the whole year. The equation shows that salinity begins to rise in September and the maximum salinity occurs in February. It is observed that since the annual variation of salinity levels at the boundary is not so significant, the same pattern has been used for computing the total simulation period.

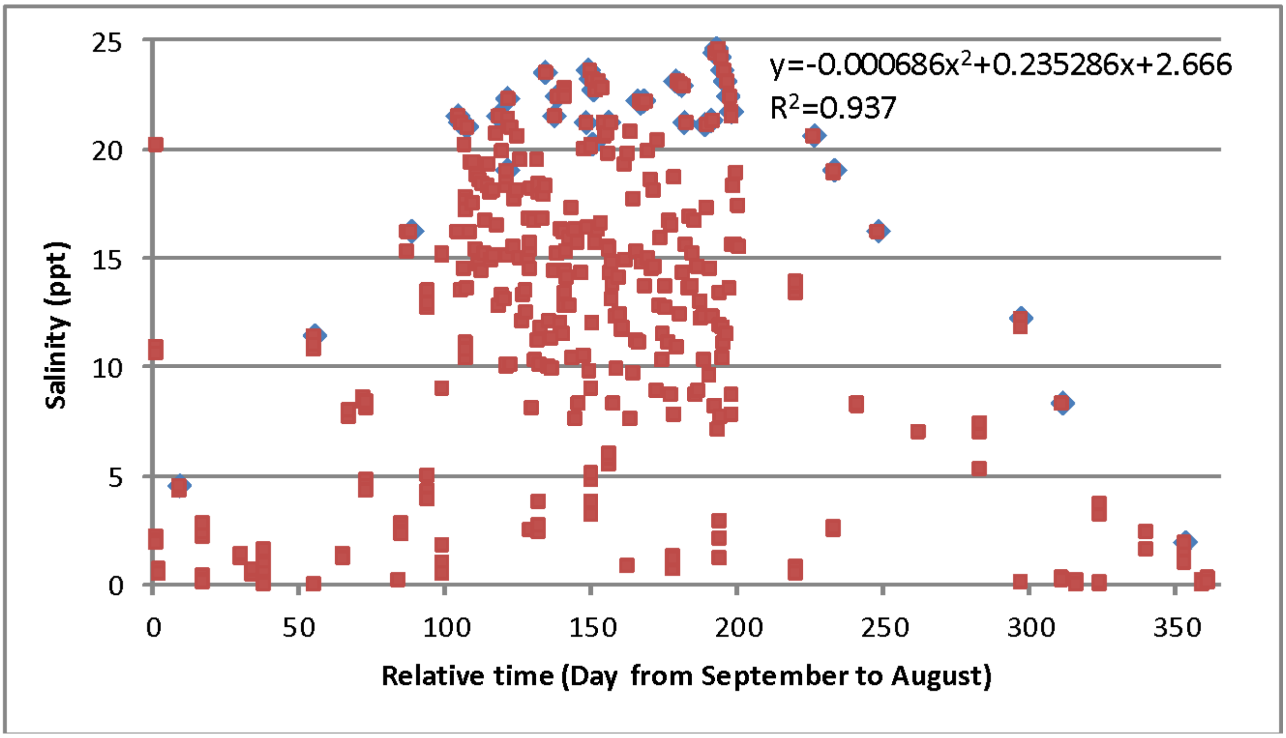


Figure 5-28: Generation of salinity curve at Khal-10

5.8.2 Salinity model calibration

Recent data from the short-term measurement of tidal salinity along the Karnaphuli and Halda rivers have been used to calibrate the model. Calibrations of the salinity model are shown in figures below (Figure 5-29 to Figure 5-32).

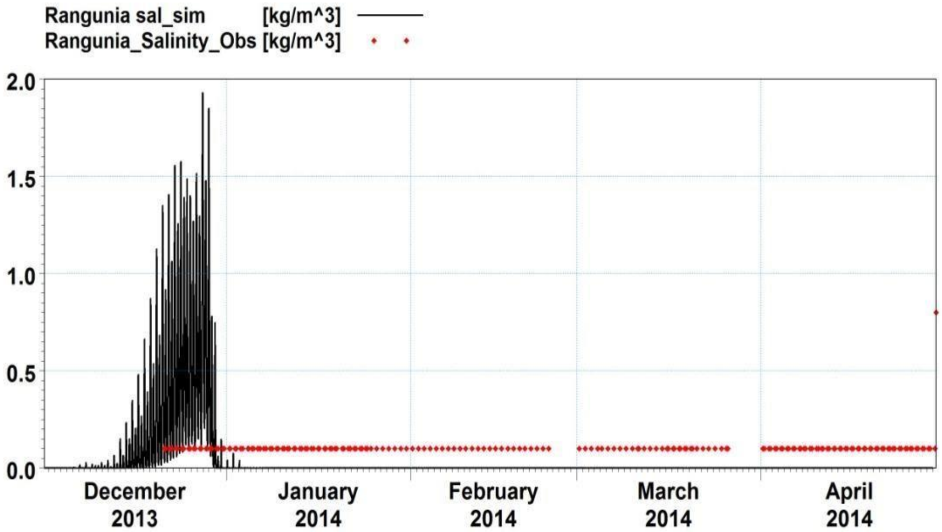


Figure 5-29: Calibration plots of salinity at Rangunia

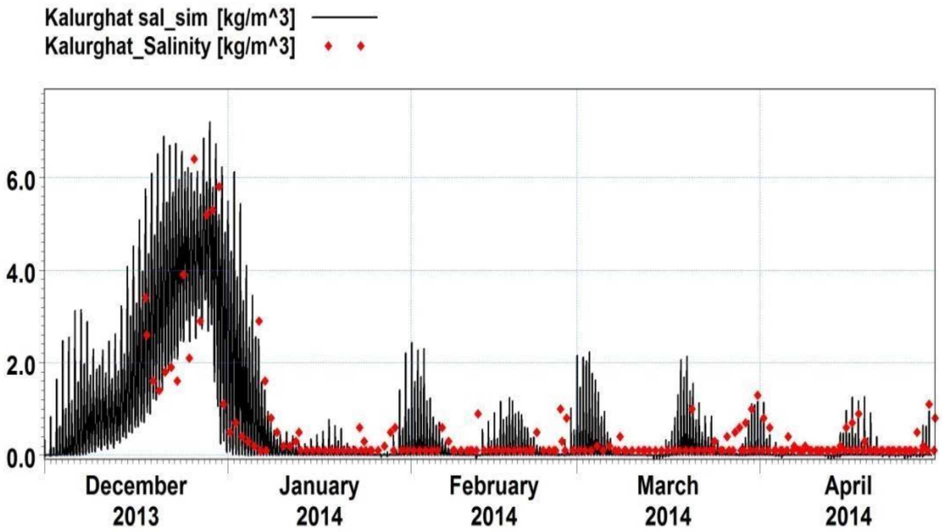


Figure 5-30: Calibration plots of salinity at Kalurghat

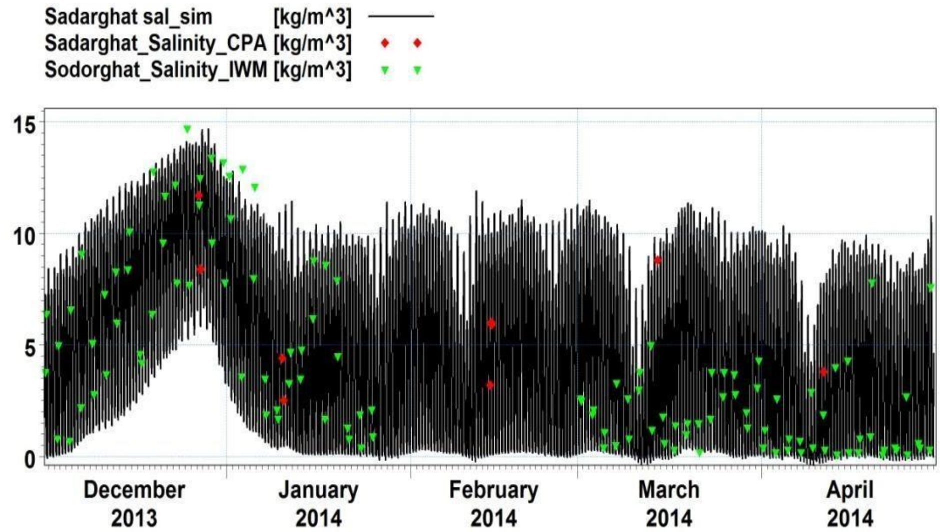


Figure 5-31: Calibration plots of salinity at Sadarghat

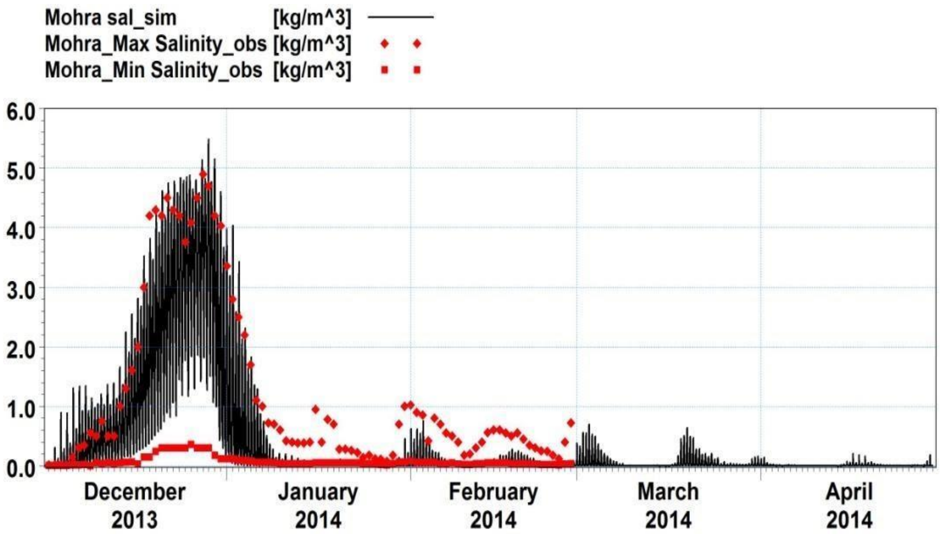


Figure 5-32: Calibration plots of salinity at Mohra

1.1.1 4.8.3 Salinity Model Scenarios

The calibrated salinity model is used to simulate various scenarios to assess salinity conditions along the rivers as shown in Table 5-8.

Table 5-8: Scenarios to assess salinity along the rivers using salinity model

Sl. No.	Scenario ID	Description
1	S_Sc-1:	Simulated for ● 1 in 2.33-year low flow in dry period ● Existing water abstractions from rivers ● Kaptai dam release as below:
1.1	S_Sc-1_1	● Kaptai dam no release
1.2	S_Sc-1_2	● Kaptai dam release with minimum 100m^3/s
1.3	S_Sc-1_3	● Kaptai dam release with minimum 200m^3/s
1.4	S_Sc-1_4	● Kaptai dam release with minimum 500m^3/s
1.5	S_Sc-1_5	● Kaptai dam release according to rule curve
2	S_Sc-2	Simulated for ● 1 in 10-year low flow in dry period ● Proposed water abstractions from rivers ● Climate change >>>> Sea level rise ● Kaptai dam release as below:
2.1	S_Sc-2_1	● Kaptai dam no release
2.2	S_Sc-2_2	● Kaptai dam release with minimum 100m^3/s
2.3	S_Sc-2_3	● Kaptai dam release with minimum 200m^3/s
2.4	S_Sc-2_4	● Kaptai dam release with minimum 500m^3/s
2.5	S_Sc-2_5	● Kaptai dam release according to rule curve
3	S_Sc-3	Simulated for ● 1 in 25-year low flow in dry period ● Proposed water abstractions from rivers ● Climate change >>>> Sea level rise ● Kaptai dam release as below:
3.1	S_Sc-3_1	● Kaptai dam no release
3.2	S_Sc-3_2	● Kaptai dam release with minimum 100m^3/s
3.3	S_Sc-3_3	● Kaptai dam release with minimum 200m^3/s
3.4	S_Sc-3_4	● Kaptai dam release with minimum 500m^3/s

Sl. No.	Scenario ID	Description
3.5	S_Sc-3_5	● Kaptai dam release according to rule curve
4	S_Sc-4	Simulated for ● 1 in 50-year low flow in dry period ● Proposed water abstractions from rivers ● Climate change >>>> Sea level rise ● Kaptai dam release as below:
4.1	S_Sc-4_1	● Kaptai dam no release
4.2	S_Sc-4_2	● Kaptai dam release with minimum 100m^3/s
4.3	S_Sc-4_3	● Kaptai dam release with minimum 200m^3/s
4.4	S_Sc-4_4	● Kaptai dam release with minimum 500m^3/s
4.5	S_Sc-4_5	● Kaptai dam release according to rule curve
	Outputs: Salinity map along the River	

5.8.3 Low Flow Condition Analysis

Actual low flow data is not available because measuring the discharges in tidal rivers is very costly. Low flow occurs in tidal rivers during the highest tide condition. To represent low flow, the highest tide level of Sadarghat station in the dry period has been analyzed. Frequency analysis for the highest tide level to represent low flow situations for Sadarghat station has been done presented in Table 5-9.

Table 5-9: Frequency analysis for highest tide level at Sadarghat

Return Period	Log-normal Distribution (m PWD)	Gumbel Distribution (m PWD)
2	-1.49	-1.47
2.33	-1.51	-1.49
5	-1.58	-1.56
10	-1.63	-1.62
20	-1.67	-1.68
25	-1.68	-1.69
50	-1.72	-1.76
100	-1.75	-1.81

5.8.4 Result Analysis of Salinity Model

Salinity models have been simulated for different volumes of water release from Kaptai HEPP with different low flow conditions. Among these scenarios, 200 m^3/s discharge has been used for risk analysis as this discharge retrieves an acceptable level of (1 ppt) salinity level in around Kalurghat Area in the average year (2.33-year return period) condition. In the 25-year and 50-year return period, the 1 ppt salinity line will be propagated upward (upstream of river) as shown in the following maps in Figure 5-33, Figure 5-34 and Figure 5-35.

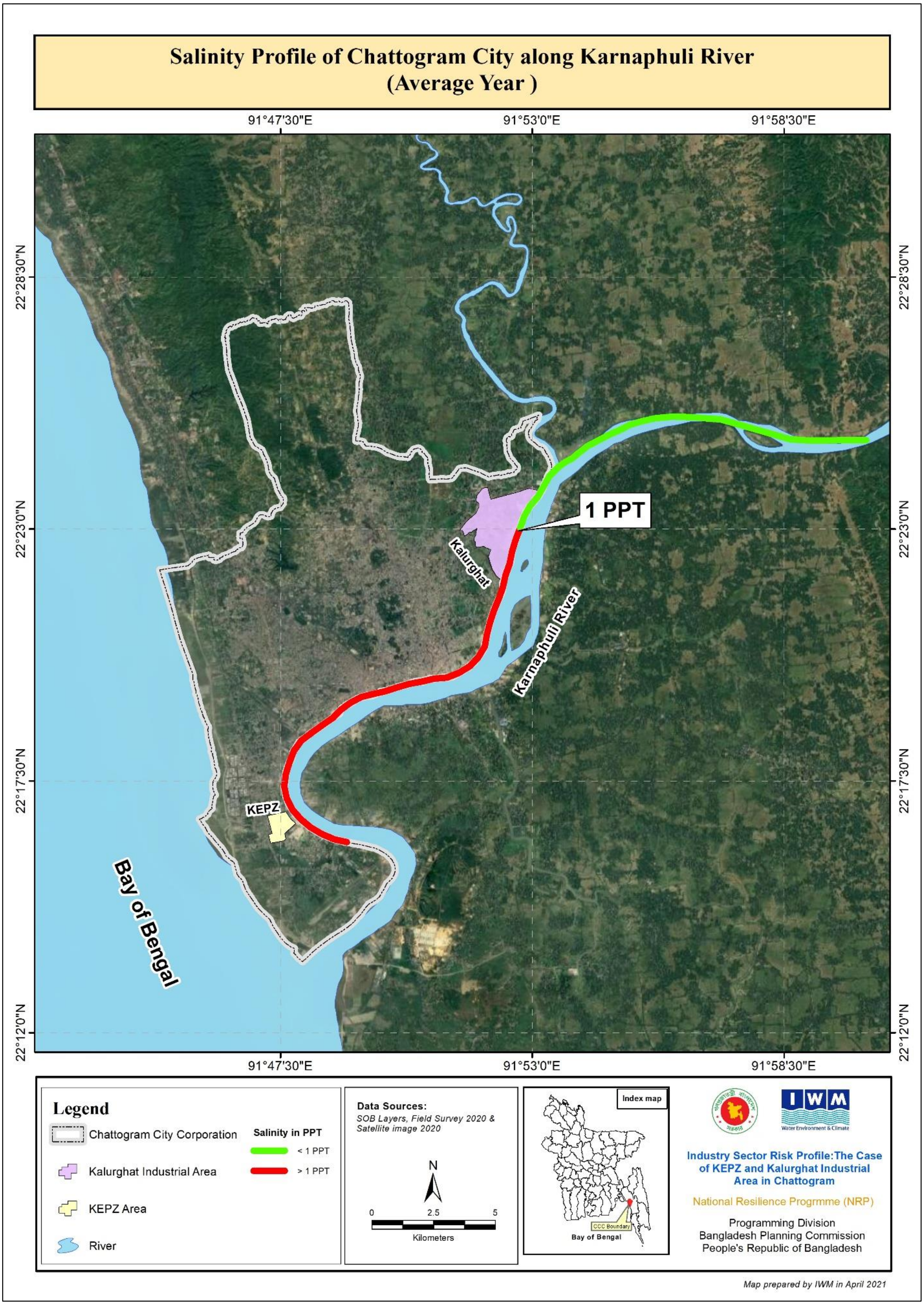


Figure 5-33: Salinity Profile of Chattogram City along Karnaphuli River (Average Year) at release 200 m^3/s

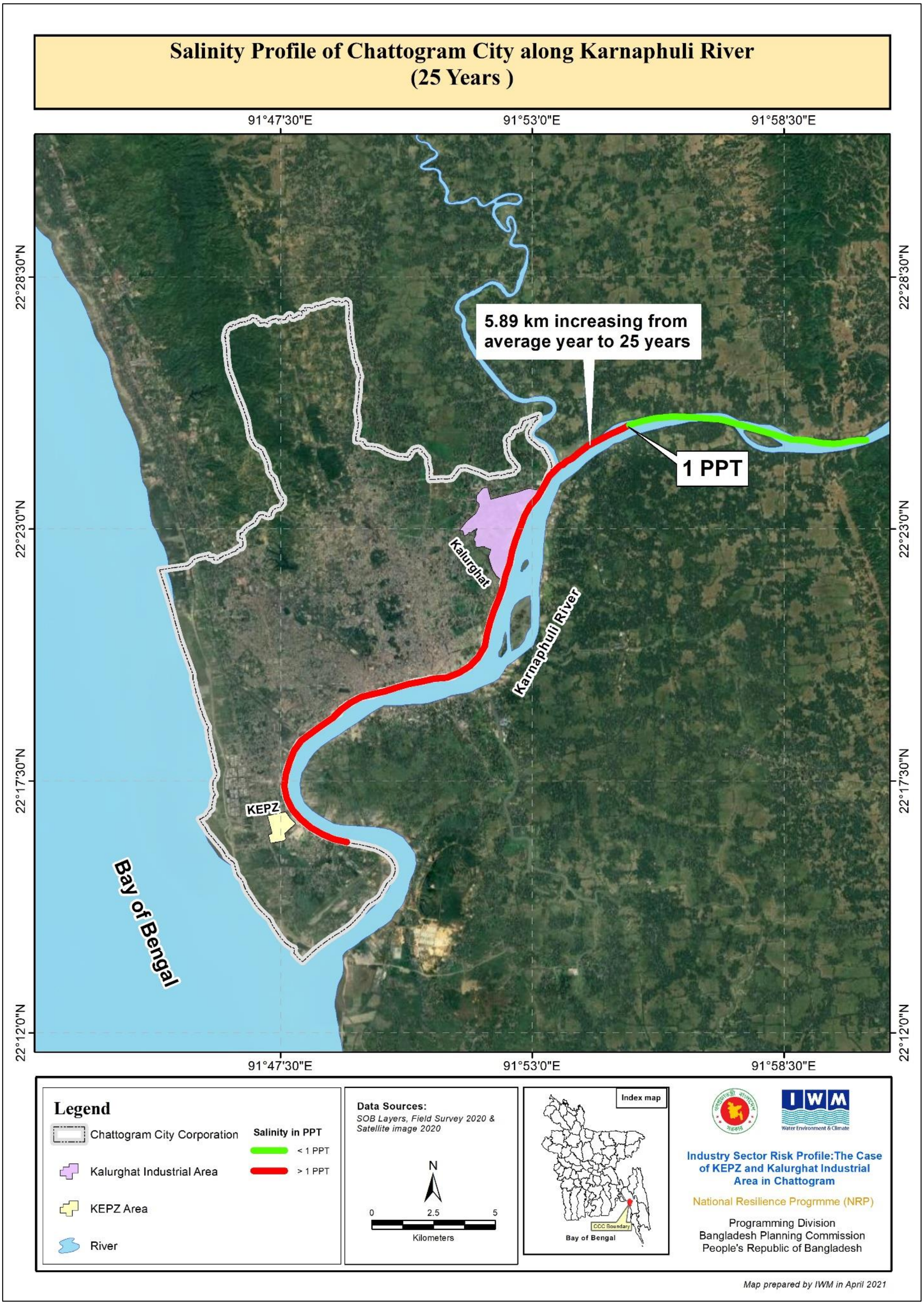


Figure 5-34: Salinity Profile of Chattogram City along Karnaphuli River (25 Year) at release 200m^3/S

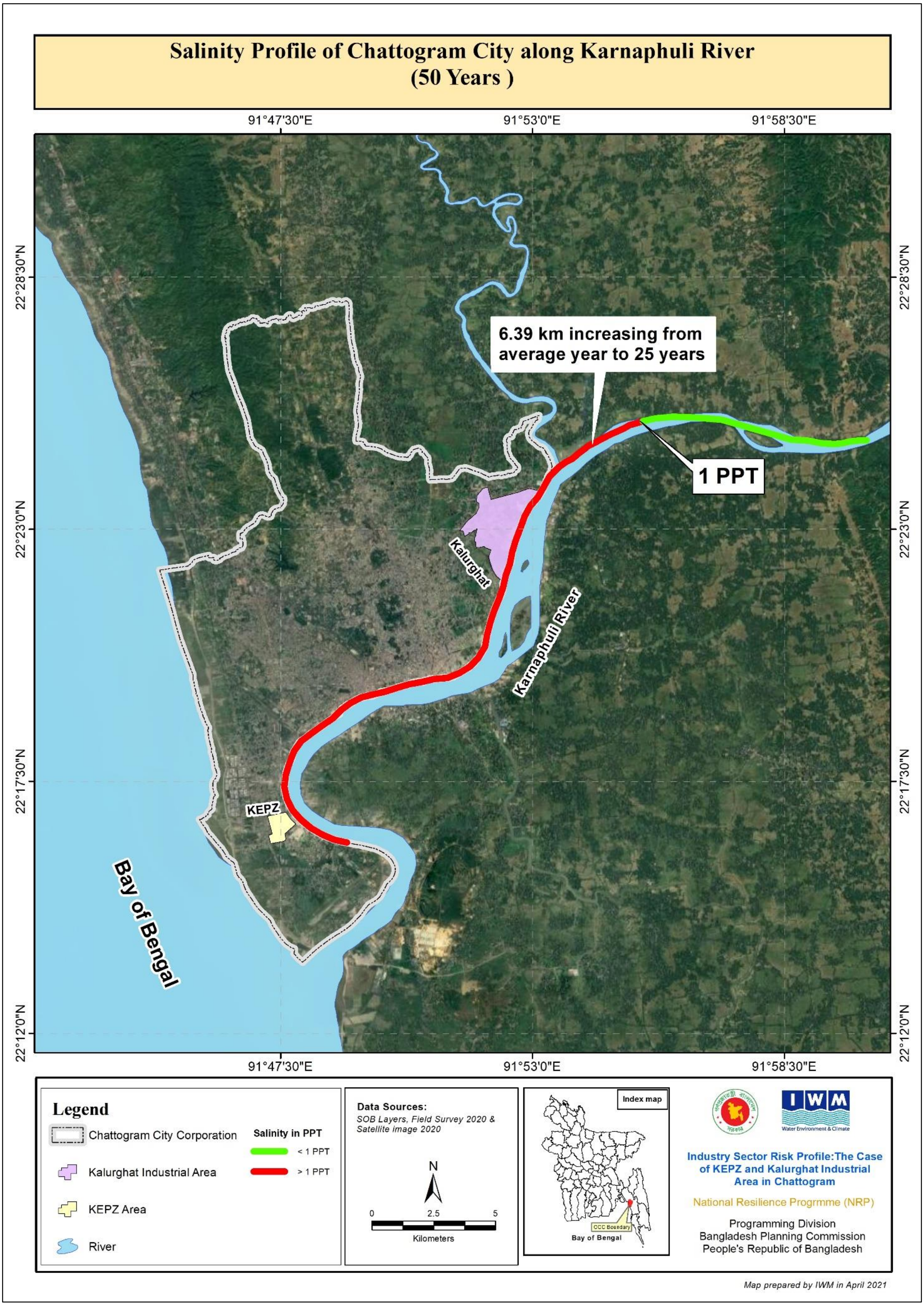


Figure 5-35: Salinity Profile of Chattogram City along Karnaphuli River (50 Years) at 200m^3/s release

5.9 Earthquake Hazard

Earthquake hazard assessment involves two steps. First, assessment of probable base rock motion in the region. Secondly, assessment of the local site characteristics. There are two approaches in assessing base rock motion of the region, i.e., Probabilistic Seismic Hazard Assessment (PSHA) and Deterministic Seismic Hazard Assessment. In PSHA, historic earthquakes and their probability of occurrence are taken into consideration. On the other hand, the Deterministic approach is scenario based where a particular fault is characterized, and the effect of earthquake generated by that fault is simulated. The seismic zonation map in the Bangladesh National Building Code (BNBC) 2020 was produced with a probabilistic analysis. In the CDMA (2009) study, the deterministic approach was employed and PGA values for different parts of Chattogram city were mapped. Local site effects were also investigated in the CDMA (2009) study. In the present study, Base rock motion reported in the CDMA (2009) study is compared with the zonation map of the BNBC 2020 and appropriate values are considered. The local site effects determined in the CDMA (2009) study are compared using the soil profiles collected in the present study.

5.9.1 Base Rock Motion

A fault model for Bangladesh was developed in the CDMP (2009) study (Figure 5-36). The fault model was developed on the basis of available seismic data, literature, and paleo-seismic trench investigation. The necessary parameters that are required to determine base rock motion are shown in Table 5-10. The time of events, recurrence period, elapsed time since the latest event and the 50 years probability of future earthquake occurrence for each active fault are shown in Table 5-11.

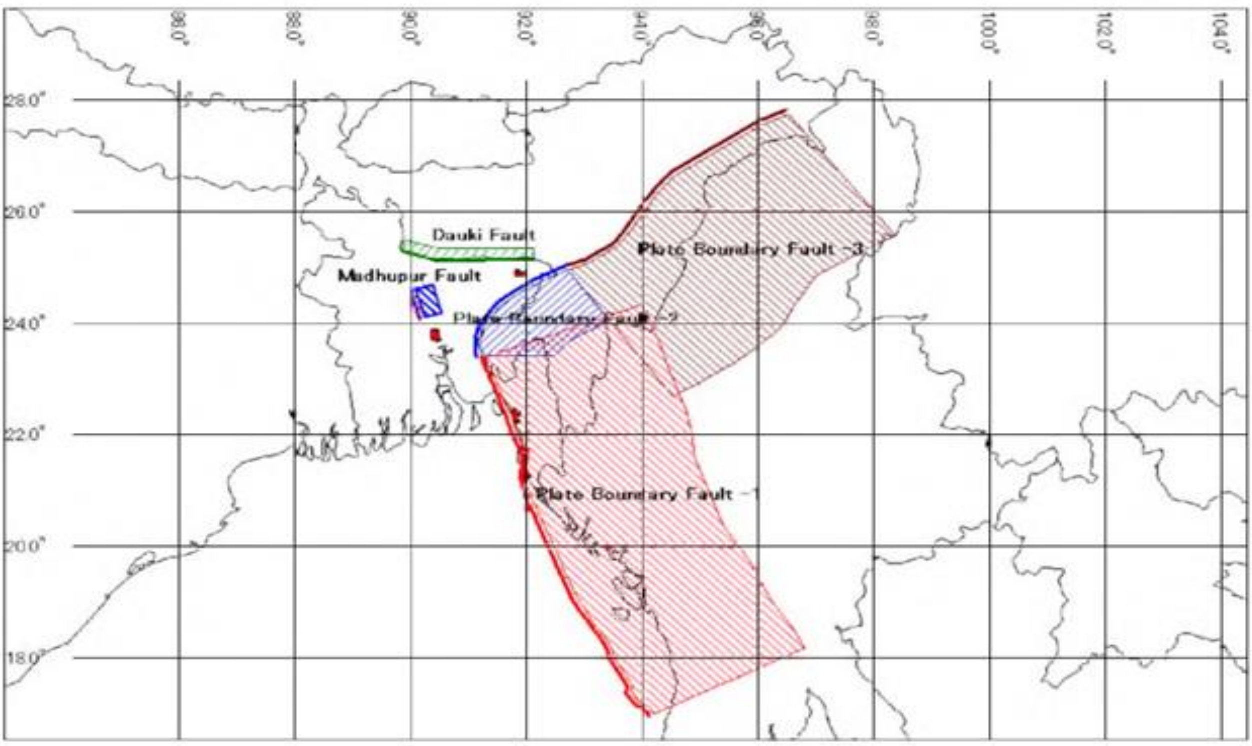


Figure 5-36: Scenario earthquake fault model (CDMP, 2009)

Table 5-10: Fault Parameters (CDMP, 2009)

Fault	Mw	Depth to top of fault (km)	Dip (degree)	Down-dip rupture width (km)	Fault Type
Madhupur Fault (MF)	7.5	10	45	42	Reverse
Dauki Fault (DF)	8.0	3	60	43	Reverse
Plate Boundary Fault -1 (PBF-1)	8.5	3	20/30	337	Reverse
Plate Boundary Fault -2 (PBF-2)	8.0	3	20	137	Reverse
Plate Boundary Fault -3 (PBF-3)	8.3	3	20/30	337	Reverse

Table 5-11: Elapsed time since the latest event and the 50 years probability

Segment		Events	Observed Recurrence Period (years)	Elapsed Time since Last Event (years)	50 year Prob. Time-Dependent (%)	Estimated Magnitude (Mw)	Length (km)
Plate Boundary Fault (PBF)	PBF-1	**AD 1762**[1)] AD 680 to 980[1)] BC 150 to AD 60[1), 2)] BC 1395 to 740[1)]	900	246	1.1	8.5	795
	PBF-2	before 16th century	> 900	> 508	> 6.7	8.0	270
	PBF-3	before 16th century	> 900	> 508	> 6.7	8.3	504
Dauki Fault (DF)		**AD 1897**[3)] AD 1500 to 1630[3)] (AD 1548 ?)	349	111	7.0	8.0	233
Madhupur Blind Fault (MF)		**AD 1885**	350	123	8.7	7.5[4)]	60
Non-characteristic but relating to fault [5)] (PBF-2, PBF-3, DF)		AD 1918 (PBF-2) AD1869, 1943, 1954, 1988 (PBF-3) AD 1664, 1923, 1930 (DF)	20	-	-	7.0 – 7.4	-

The PGA values, the short period spectral acceleration, S_s and the 1-s spectral acceleration, S_1 for Chattogram city for different scenarios are shown in figures (Figure 5-37 to Figure 5-39). From these figures it is evident that the most dominant fault for the Chattogram city is PBF-1. The PGA, S_1 and S_2 for the sites under present study for PBF-1 would be 0.7 g, 1.5 g and 0.5 g respectively. However, it should be noted that PBF-1 is an exceedingly rare event with only 1.1% probability of exceedance in 50 years. Maximum Considered Earthquake (MCE) is defined as the earthquake with probability of exceedance of 2% in 50 years. For MCE BNBC 2020 prescribes S_s and S_1 values of 0.7 g and 0.28 g at the engineering base rock. When compared with the values estimated in the CDMP study, BNBC 2020 prescribed values seem reasonable. In the present study S_s and S_1 are assumed as 0.7 g and 0.28 g at the engineering base rock for an MCE level earthquake.

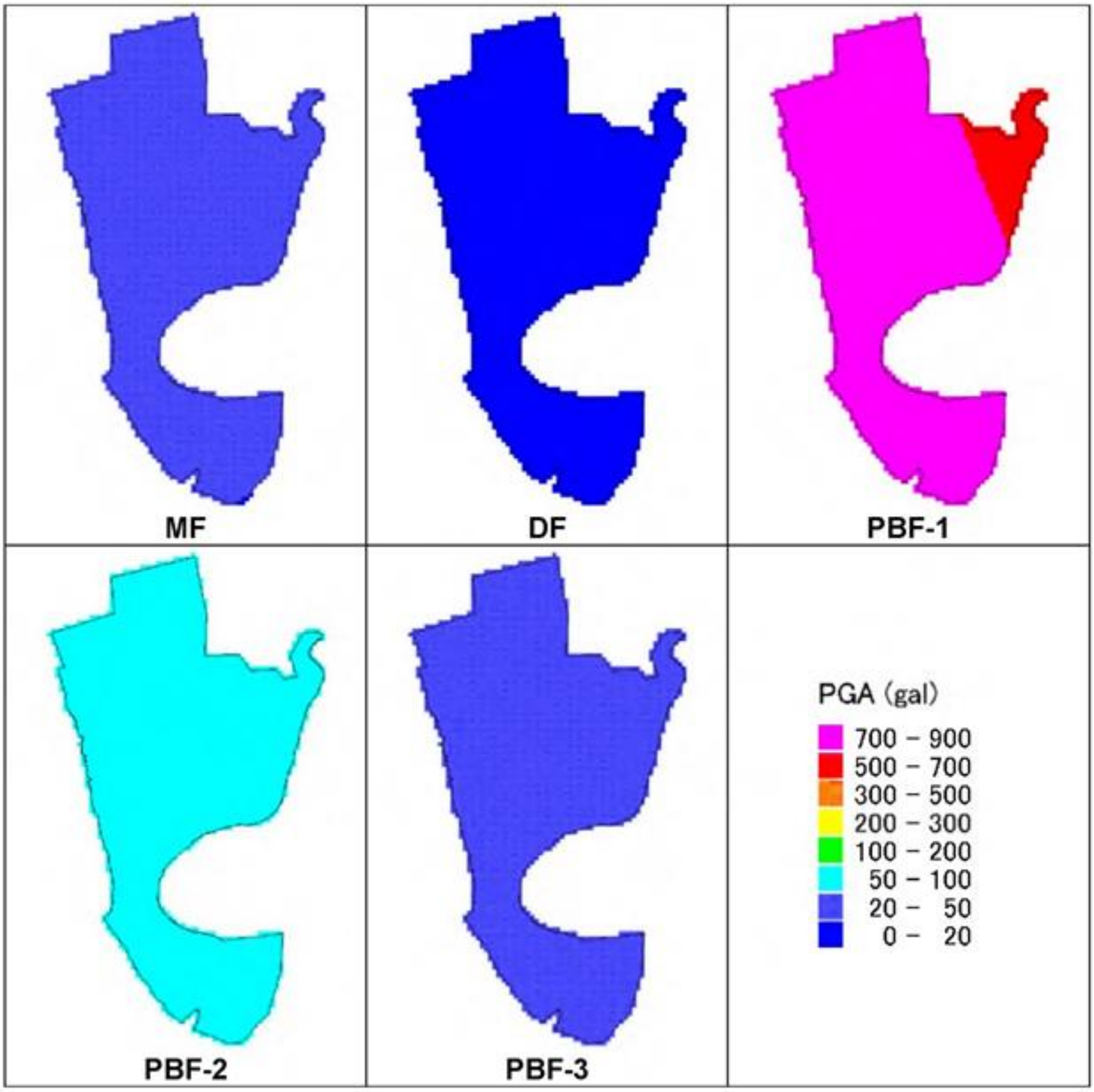


Figure 5-37: PGA at engineering base rock in Chattogram (CDMP, 2009)

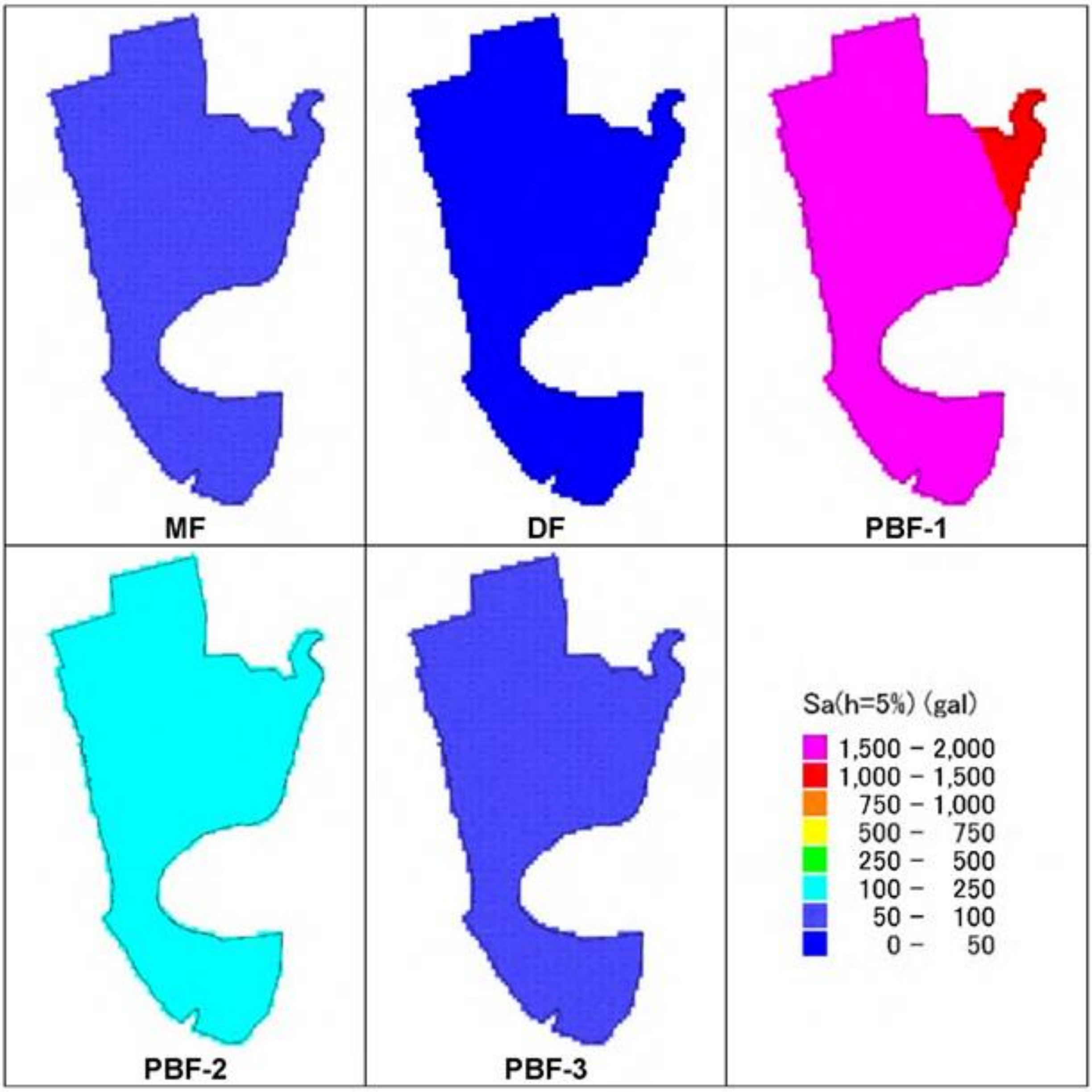


Figure 5-38: SS for 5% damping at engineering base rock in Chattogram (CDMP, 2009)

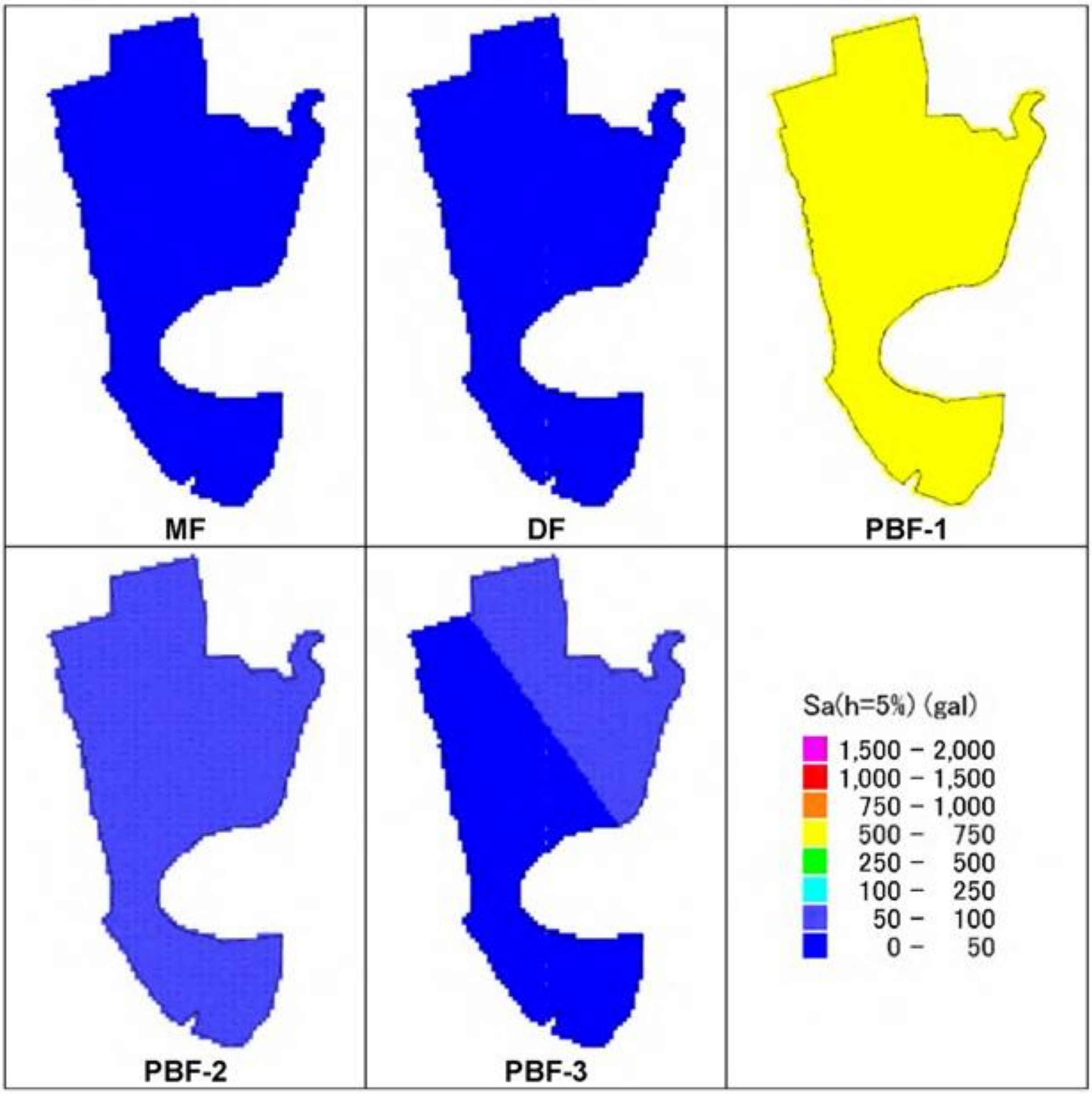


Figure 5-39: S1 for 5% damping at engineering base rock in Chattogram (CDMP, 2009)

5.9.2 Local Site Effect

Two local site effects are important for consideration in earthquake hazard assessment: site amplification and liquefaction potential. Due to site amplification, the level of acceleration of the base rock is amplified while propagating through the soft upper soil layers. The amplified motion causes structures to be subject to stronger vibration. Due to liquefaction, saturated cohesionless soil loses its capacity to bear the pressure of the overlying structures. The steps for assessing local site effects are described below.

5.9.2.1 Determination of shear wave velocity

Measurement of shear of velocity at different depths of the underlying soil is necessary to analyze the effect of local site on the induced seismic vibration. Shear wave velocity may be measured by P-S log machine, Crosshole equipment, Seismic Cone Penetration Test, Microtremor etc. However, in Bangladesh SPT is the most common sub-soil investigation method. Imai and Tonouchi (1982) proposed the following correlation between SPT N-value and shear wave velocity analyzing a large number of data set.

$$V_s = 97N^{0.31}$$

Using this relation, soil profiles of the bore logs collected in the study may be constructed as shown in following figures (Figure 5-40 to Figure 5-45). Based on the idealized soil profiles 30 m average shear wave velocity of the profiles may be calculated by the following equation.

$$VS_{30} = \frac{30}{\sum \frac{d}{V_s}}$$

VS30 of different soil profiles are shown in Table 5-12. Based on VS30 the sites are further classified as per NEHRP (1997) ground classification. The NEHRP (1997) ground classification is shown in Table 5-13. Based on these idealizations, one site of Kalurghat belongs to ground class E and the other one to class D4. Two sites of KEPZ belongs to D4 and the other two to class D5.

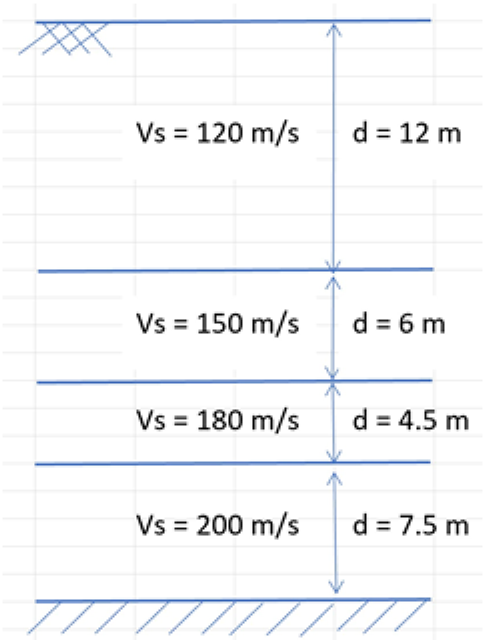


Figure 5-40: Idealized soil profile of Kalurghat site 1

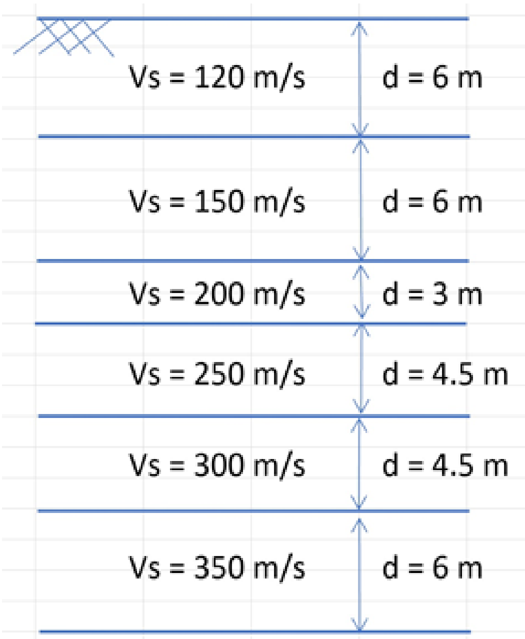


Figure 5-41: Idealized soil profile of Kalurghat site 2

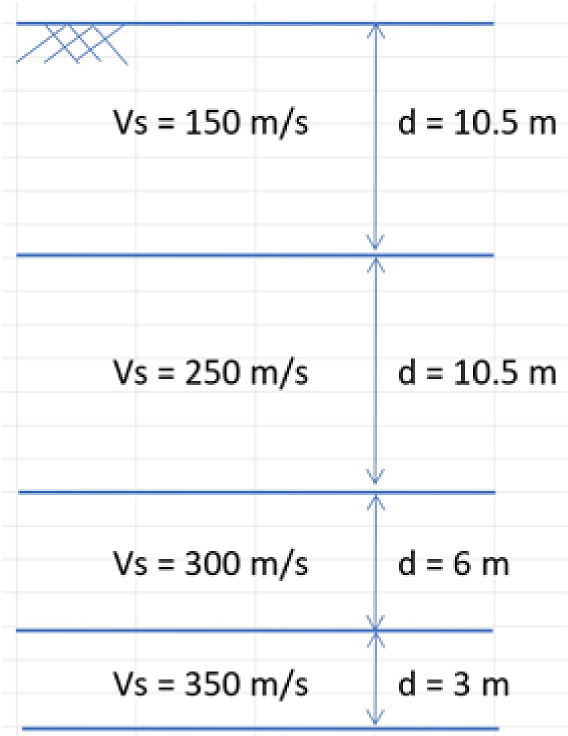


Figure 5-42: Idealized soil profile of KEPZ site 1

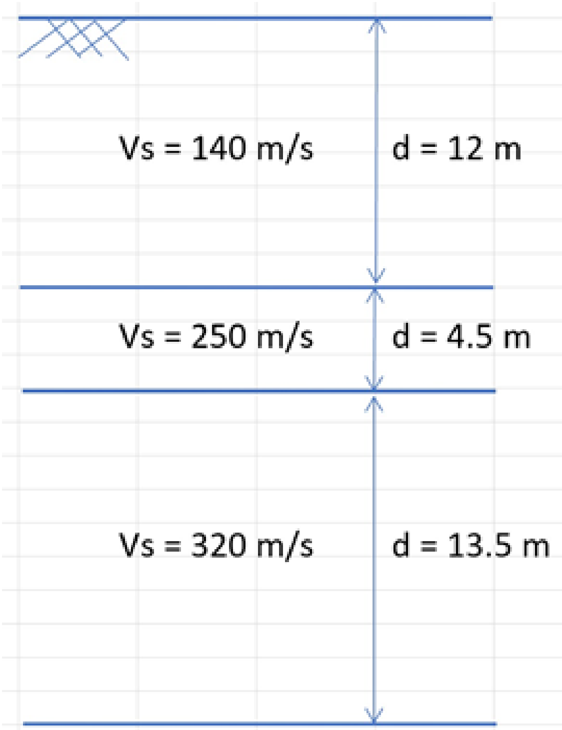


Figure 5-43: Idealized soil profile of KEPZ site 2

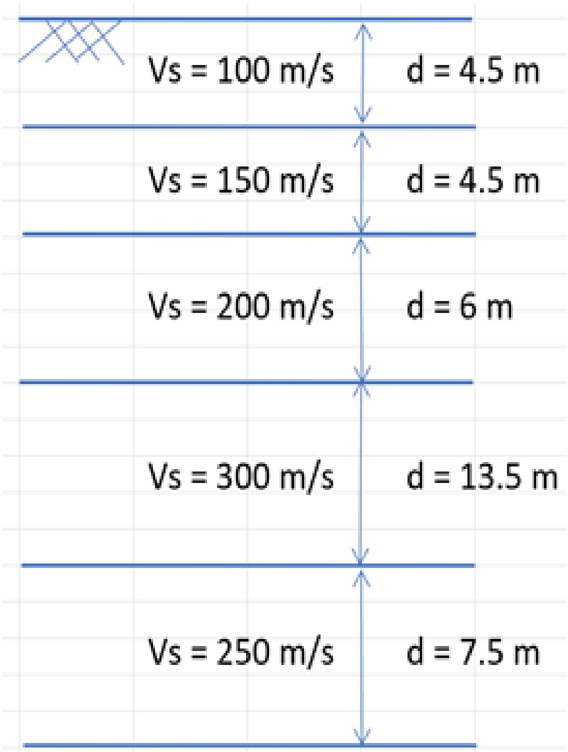


Figure 5-44: Idealized soil profile of KEPZ site 3

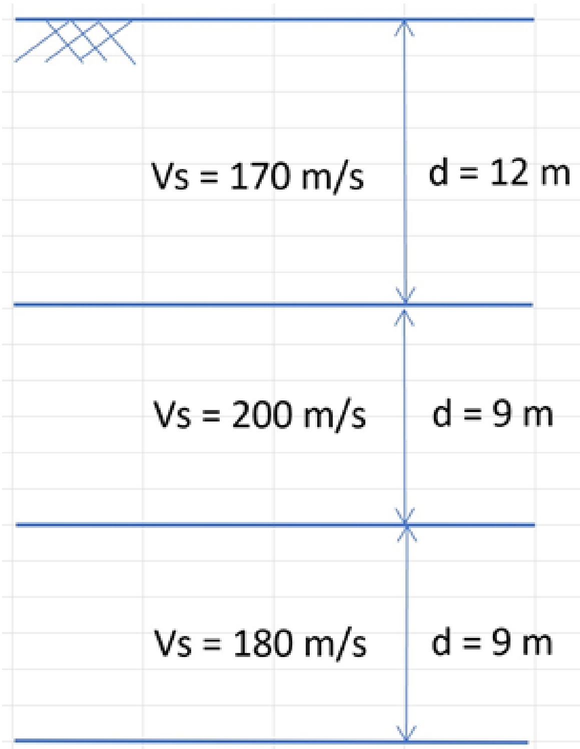


Figure 5-45: Idealized soil profile of KEPZ site 4

Table 5-12: VS30 and NEHRP (1997) Site Class of Different Bore Locations

Site	VS_{30}	Ground Class
Kalurghat – 1	140 m/s	E
Kalurghat – 2	200 m/s	D4
KEPZ – 1	220 m/s	D4
KEPZ – 2	215 m/s	D4
KEPZ – 3	185 m/s	D5
KEPZ – 4	180 m/s	D5

Table 5-13: NEHRP (1997) Ground Classification

Ground Class	Vs30
C	360 - 760 m/sec
D1	300 - 360 m/sec
D2	250 - 300 m/sec
D3	220 - 250 m/sec
D4	200 - 220 m/sec
D5	180 - 200 m/sec
E	- 180 m/sec

5.9.2.2 SITE AMPLIFICATION

Site amplification may be determined by non-linear dynamic analysis of the soil profiles shown above. However, NEHRP provides some suggestive amplification factors based on the ground classes as shown in Figure 5-46. In the CDMP (2009) study the ground class D was further sub-divided into five more sub-classes. Based on the sub-division, NEHRP amplifications may be interpolated as shown in Figure 5-47. Table 5-14 shows the comparison of the amplifications based on NEHRP amplification factors and BNBC 2020 suggested values of S_s and S_1 for different site classes.

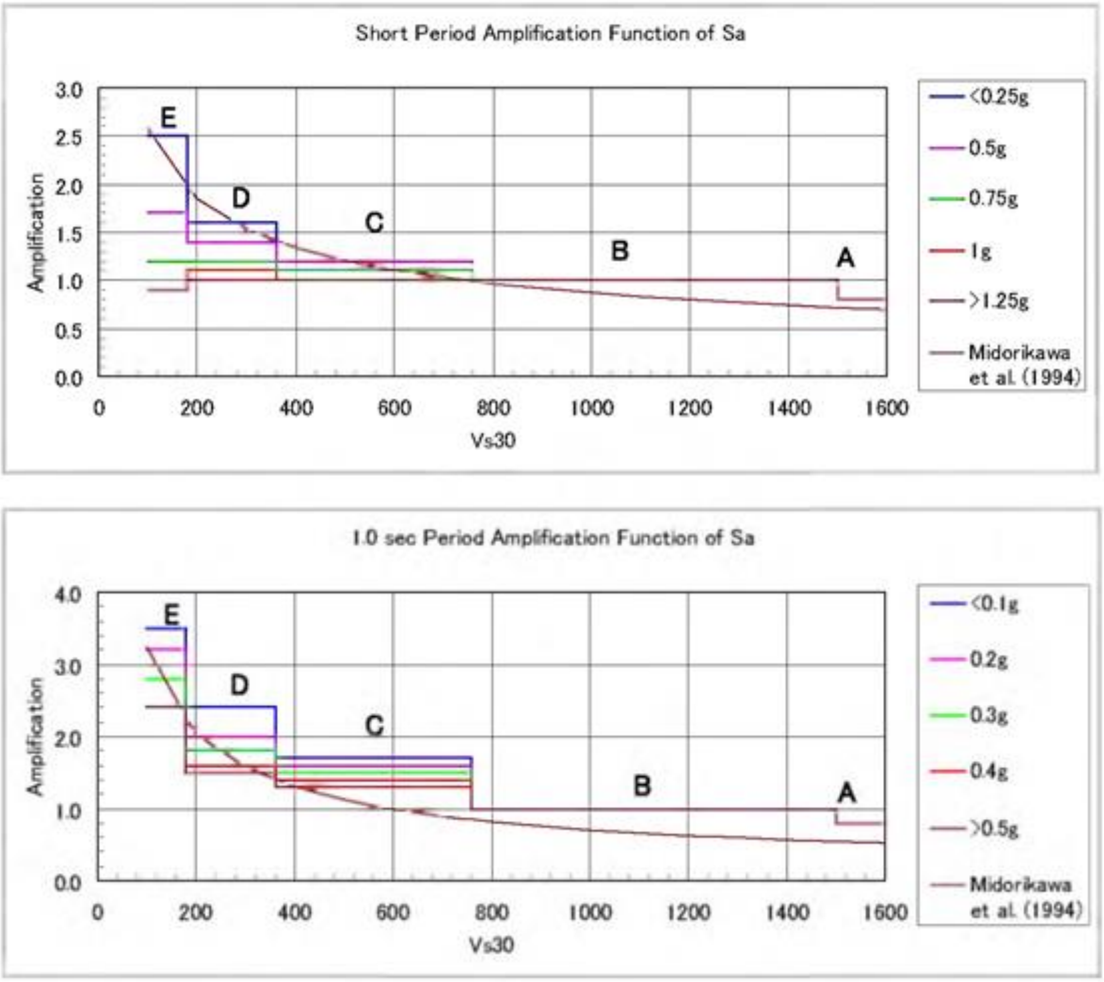


Figure 5-46: Amplification Function from 1997 NEHRP Provisions

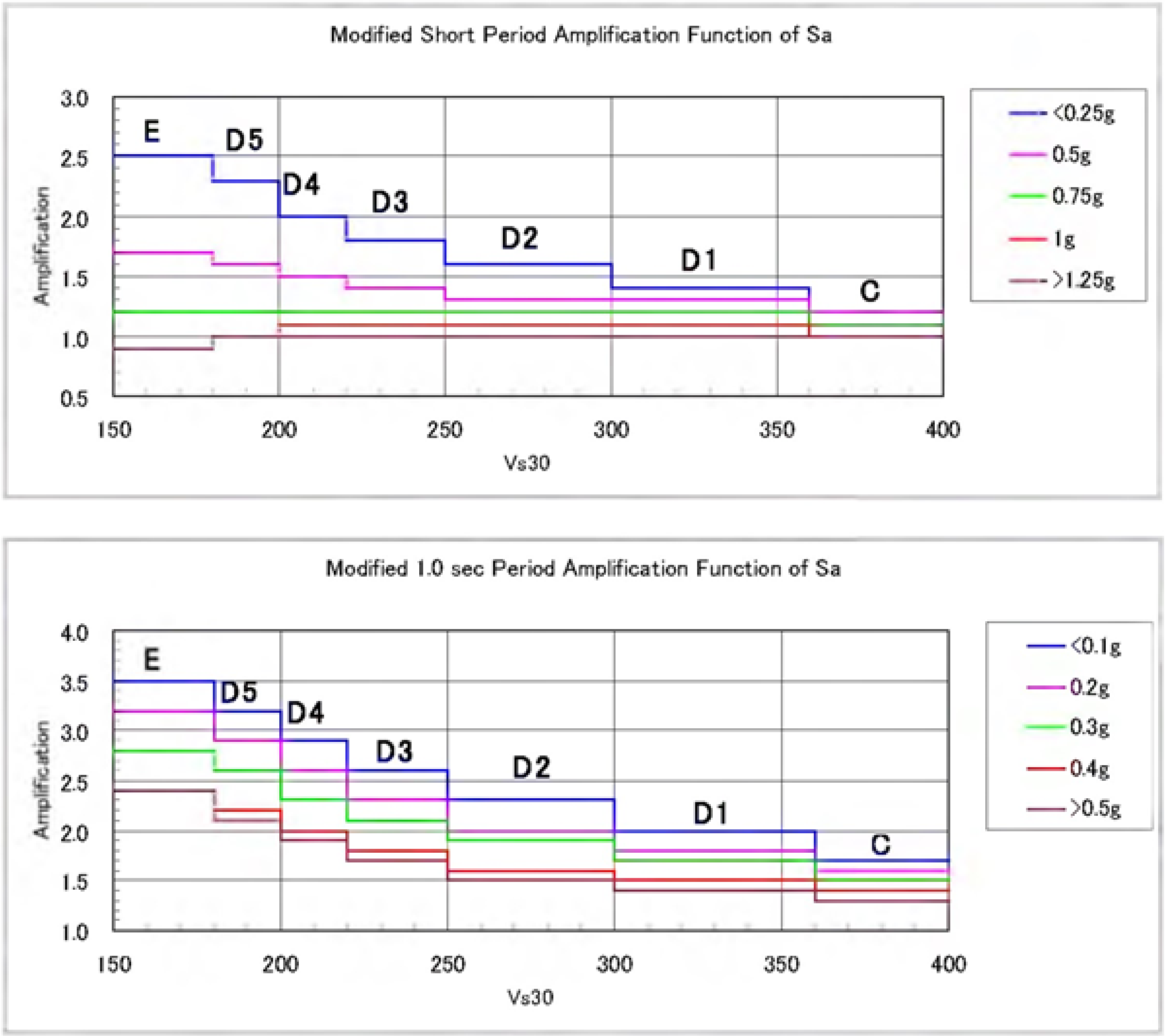


Figure 5-47: Modified Amplification Function

Table 5-14: Amplified SS and S1 based on NEHRP Ground Class and BNBC Site Class

Site	NEHRP Amplification		BNBC 2020 Amplification	
	S_s	S_1	S_s	S_1
Kalurghat – 1	0.84 g	0.79 g	-	-
Kalurghat – 2	0.84 g	0.64 g	0.8 g	0.48 g
KEPZ – 1	0.84 g	0.64 g	0.8 g	0.48 g
KEPZ – 2	0.84 g	0.64 g	0.8 g	0.48 g
KEPZ – 3	0.84 g	0.73 g	0.8 g	0.48 g
KEPZ – 4	0.84 g	0.73 g	0.8 g	0.48 g

5.9.3 Liquefaction Potential

To evaluate liquefaction potential computationally, the liquefaction resistance of soil is estimated by results of dynamic test, SPT, etc. and compared with the shear stress in the soil due to cyclic shaking and high excess pore water pressure during an earthquake. However, the data required for such a computational approach are not available in the present study. To avoid this limitation, in the CDMP (2009) study, an empirical procedure required geologic/geomorphological data, PGA at ground surface, moment magnitude of a scenario earthquake and ground water depth, has been followed. Liquefaction susceptibility from geologic/geomorphologic considerations of Chattogram City is shown in Figure 5-48. From this figure it is observed that liquefaction susceptibility of some areas of Kalurghat is very high. Whereas KEPZ is moderately susceptible to liquefaction.

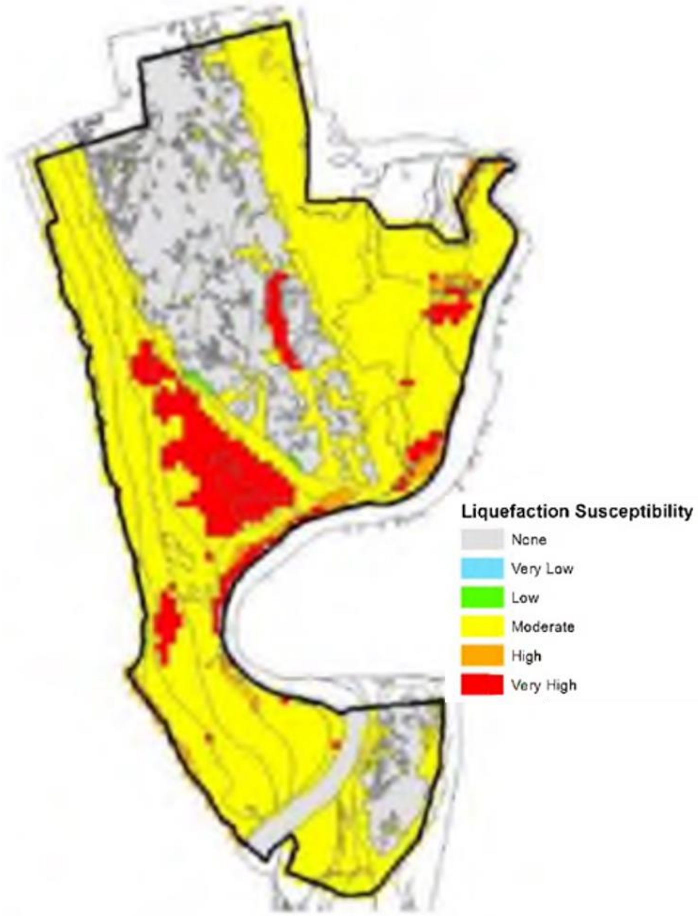


Figure 5-48: Liquefaction susceptibility of Chattogram City (CDMP, 2009)

Liquefiable soils, in general, possess the characteristics shown in Table 5-15 (Yasuda, 1988). Table 5-16 shows these characteristics of different bore location under the study area. From the very limited information of the collected bore hole data, it is found that at some places in Kalurghat there may be very low susceptibility to liquefaction and in the KEPZ there may be some isolated pockets where liquefaction susceptibility may be high.

Table 5-15: Characteristics of Liquefiable Soil

Characteristics	Value
Mean size, D_{50} (mm)	0.02 to 1.00
Fines content (d 0.005 mm)	<10%
Uniformity coefficient, C_u	<10
Relative density, D_r	<75%

Characteristics	Value
Plasticity index, I_p	<10
Earthquake intensity	>VI
Depth	<20 m

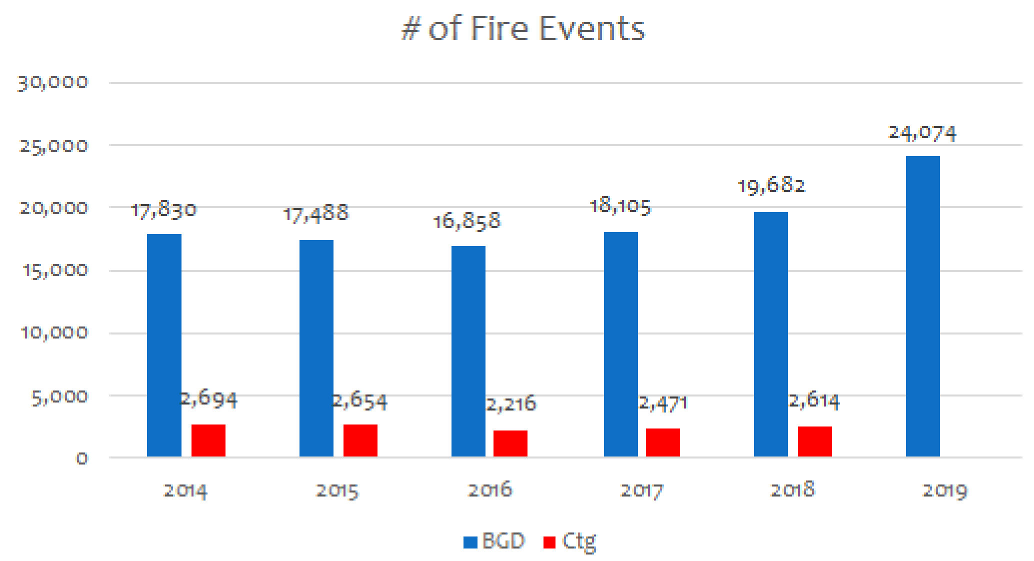
Table 5-16: Characteristics of bore hole location under the study area

Location	BH	Depth, m	D_{50}, mm	Fines %	C_u	D_r %	I_p %	Liquefiability
Kalurghat-1	1	1.5	0.15	16.88	>>10	90	11	No
	2	4.5	0.065	39.67	>>10	90	11	No
Kalurghat-2	1	15	0.25	6.59	3.75	86	35.31	Very low
KEPZ-1	1	2	0.001	100	1.67	87	20	No
	3	2	0.001	100	1.1	87	-	No
KEPZ-2	1	1.5	0.15	47	>>10	-	-	No
	2	1.5	0.2	39	>>10	-	-	No
KEPZ-3	1	1.5	0.16	8	2.23	-	-	High
	2	4.5	0.0045	53	>>10	-	19	No
KEPZ-4	1	3.6	0.0063	55	10	76	17	No
	2	3.6	0.0063	56	10	76	16	No

5.10 Fire Hazard

According to a survey conducted by the Deptt. of Fire Service and Civil Defense, (reported by the Fire department in 2018) around 97 percent of high-rise buildings in Chattogram city lack adequate fire safety measures, posing a serious risk of casualties. Over the preceding decades, fire and fire hazards have become the continual problem in the readymade garments industries of Bangladesh. (Wadud, Huda, & Ahmed - Fire Technology – 2013).

The readymade garment industries are highly competitive from the view point of cost-saving but at the same time considered as a highly valued sector in the economic development of Bangladesh. In RMG industries, the lack of appropriate safety culture and cost-cutting measures often affect the health and safety of the workers (Abdullah, 2005). Clothing is easily flammable and as such fire hazard has become one of the most frequent and damage inducing accidents in these factories in Bangladesh (Ahmed, 2007). Fire is also purported to be the largest cause of on-the-job injuries and fatalities in this sector. Each and every new incident of fire and related damage adversely affects the reputation of the industry abroad. This is because the working conditions in the manufacturing sector in developing countries have become a general cause of concern in many developed countries (Akhter, 2010). Given the importance of fire safety in the garment sector, there have been concerted efforts from the government, the industry lobby (Bangladesh Garments Manufacturers and Exporters Associations, BGMEA) and the international buyers of the apparel products, to improve the fire safety culture and this has indeed reduced the fire incidents and losses significantly (Alam, 2006; J and T, 2009). KEPZ is mostly protected from fire hazards as they have their own fire station. On the other hand, the Kalurghat area is more susceptible to fire hazard. The comparison of Fire events and Losses between Bangladesh and Chattogram is presented in Figure 5-49.



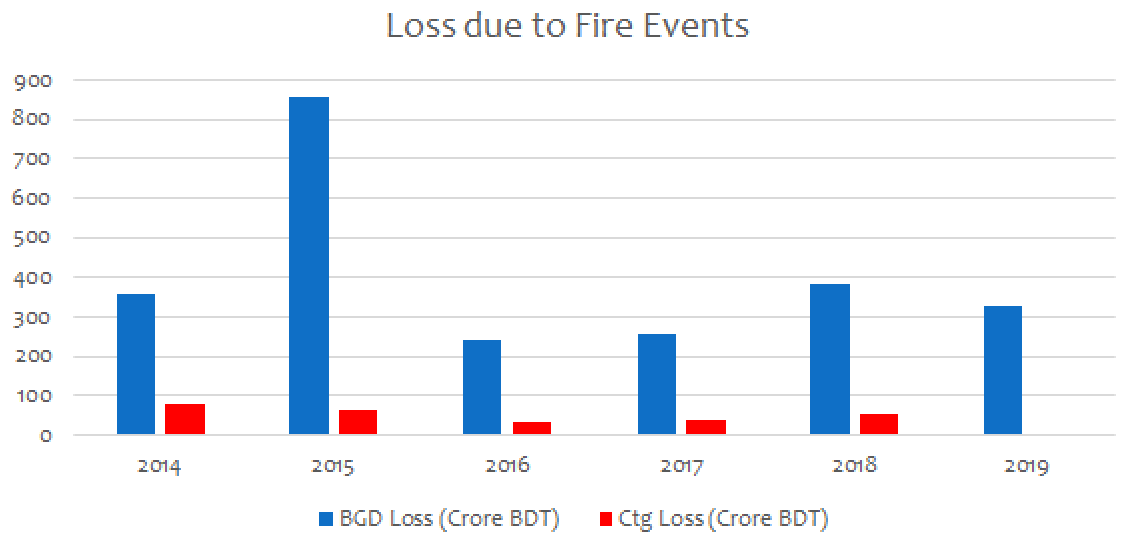


Figure 5-49: Number of Fire events (above) and Loss due to Fire events (below)

5.11 Infectious Disease (COVID-19)

Having inadequate health care systems and poor socio-economic infrastructure, Bangladesh has been braving to contain the impact of the current COVID-19 pandemic since March 2020. To curb the diffusion of COVID-19, the local government has responded to the outbreak by enforcing a set of restricted measures on economic and social activities across the country (Siam et al. - Clinical Epidemiology and Global Health - 2021). As many as 29 districts in Bangladesh including Dhaka, Chattogram, Rajshahi, Khulna and a few others in the border areas got high COVID-19 transmission (DGHS, 2021).

As per Government restrictions and from buyers' obligations, KEPZ and Kalurghat industries imposed measures on health restrictions quite strictly as it was found during the field survey. KEPZ also has their own medical center and quarantine facility and almost all the industries pay their staff during quarantine times. But very few industries in Kalurghat follow these Covid safety guidelines due to lack of monitoring from the Government authorities. Most of the industries are not maintaining social distancing for their workers inside the working premises. Based on survey results of only 20 industries taken as sample for other hazards, it would be optimistic to prepare a realistic Covid-19 Risk Map for Kalurghat Study area.

Chapter 6: Risk Profiling

This chapter describes how risk profile is developed by assessing the vulnerability and exposures of different disaster events of Flood, Water logging, Cyclone, Salinity, Earthquake, Fire and Covid-19. This chapter includes tabular information of scenario- based hazard score, normalized hazard vulnerability indicators and their weighted scores, different exposure ratings in tabular form the respective hazards.

6.1 Development of Flood Risk Profile

For this study, flood hazard has been assessed in three scenarios using 1D hydrodynamic model. These scenarios were calculated in average year (2.33), 25- and 50-year return periods. After analyzing the inundation and water extent, the 50-year flood has been assigned flood hazard score(H) of 1 while other flood hazard scores were calculated correspondingly with the 50-year flood and these are presented in the following Table 6-1. The respective flood hazard maps of 2.33, 25 and 50-year return periods are already presented in Chapter 5:.

Table 6-1: Flood hazard scoring in different return period

Sl. No.	Scenario ID	Return Period (Year)	Flood Hazard score (H)
1	Flood scenario 1	2.33	0.0466
2	Flood scenario 2	25	0.5
3	Flood scenario 3	50	1

6.1.1 Flood Vulnerability Assessment

To identify the flood vulnerabilities both for KEPZ and Kalurghat area, 7 (seven) vulnerability indicators were considered. These indicators were Number of floors, Construction year/age, Plinth height, Number of basements, Drainage Condition, Structural typology, and State of maintenance etc., and all these data were collected from the field survey. The weights in the scale of (0 to 1) are given according to the impact of these factors. Weighted list of these factors is shown in Table 6-2, which was based on expert opinion and lessons learned from field experience.

Table 6-2: Flood vulnerability Indicators and weightage

Flood Vulnerability Indicators	Weighted Value
Plinth Height	0.4
Drainage Condition	0.3
Number of floors	0.1
State of maintenance	0.1
No of Basements	0.05

Structural typology	0.03
Construction Year/age	0.02

After identifying these indicators, the collected data were normalized as presented in Table 6-3.

Table 6-3: Normalization of flood vulnerability indicators

Plinth Height		Drainage Condition		No. of Floor		State of maintenance		No. of Basement		Structure typology		Construction Year	
OD	*AV*	*OD*	*AV*	*OD*	*AV*	*OD*	*AV*	*OD*	*AV*	*OD*	*AV*	*OD*	*AV*
>=5	0.1	No congestion	0.1	>=5	0.1	Excellent	0.1	0	0.1	RCC	0.1	>=2006	0.33
4-4.99	0.25	Moderate	0.5	4	0.25	Good	0.5	1	0.5	Steel	0.2	1991-2005	0.67
3.01-3.99	0.5	Severe	1	3	0.5	Moderate	0.75	>=2	1	URM	1	<=1990	1
2.01-2.99	0.75			2	0.75	Poor	1						
<=2	1			1	1								

*(*OD= Observed Data, AV = Assigned Value)*

Plinth Height: The height of the plinth level of the surveyed Industries is considered as a key component of physical vulnerability to flooding occurrences and damage in the study areas. In this study, the plinth level height of buildings is considered in 5 classes, where higher plinth level buildings are less susceptible to flood hazard and were assigned a lesser vulnerability value on a scale of 1.

Drainage Condition: Adjacent drainage refer to the drainage system located next to an industry. The congestion status was assessed by field visit, interview, satellite image inspection and model results. Overall drainage congestion status in Kalurghat Industrial area is more severe than that of in KEPZ. The qualitative responses were segregated into four nos. of classes and then were assigned to numeric terms to same scale of 1.

No of Floors: When a structure is affected by flood, it is a general practice that people and assets are relocated to an elevated place, preferably to the upper floors in the same building as the surroundings are inundated. Keeping this practice in mind, no of floors were considered as an indicator for this analysis assuming buildings having higher number of floors are less predisposed to flood hazard. These values were also assigned to 5 number of classes and then were assigned to numeric values on a scale of 1. This indicator was used in a prior Physical flood vulnerability assessment study by *Usman Kaoje, Abdul Rahman, Idris, Tam, & Mohd Sallah – that was published in International Journal of Disaster Resilience in the Built Environment – 2020.*

State of maintenance: It is imperative that households, industries, and city authorities pay attention to regular building maintenance to minimize risk of flooding (*Fatemi et al.- Sustainability - 2020*). The maintenance status of the industries was assessed during field visits and were recorded in qualitative terms in four categories. These terms were transferred to numeric values (scale of 1) for further analysis.

Nos. of Basement: The presence or absence of a basement-window or an airbrick can determine whether building interiors get flooded or not. (*Custer & Nishijima - Natural Hazards – 2015).* Structures having basements are more vulnerable than buildings having no underground basements. Basement information was collected from the baseline survey in August 2020, and further verified during RVS survey in January 2021.

Structure typology: The extent of flood damage depended on the physical attributes such as building typology i.e. buildings with durable materials experienced low damage from floods (*Fatemi et al.- Sustainability - 2020*). Most of the building located in Kalurghat and KEPZ are made of either RCC or steel frame. Few builds found with Unreinforced masonry (URM), which are assigned to higher vulnerability scores. Steel structures are assigned to slightly higher value than RCC as the steel body gets corrugated in contact with water.

Construction Year/age: Age of industrial buildings is a significant attribute in comprehending the physical vulnerability to inundation in the study areas. This information has been collected from field survey and temporal satellite image analysis. The structures constructed in recent years were assigned with a lower vulnerability value, and older structures were assigned with a higher value on a scale of 1.

Using the vulnerability estimation, the vulnerability maps for the flood hazards were prepared and presented in Figure 6-1 and Figure 6-2.

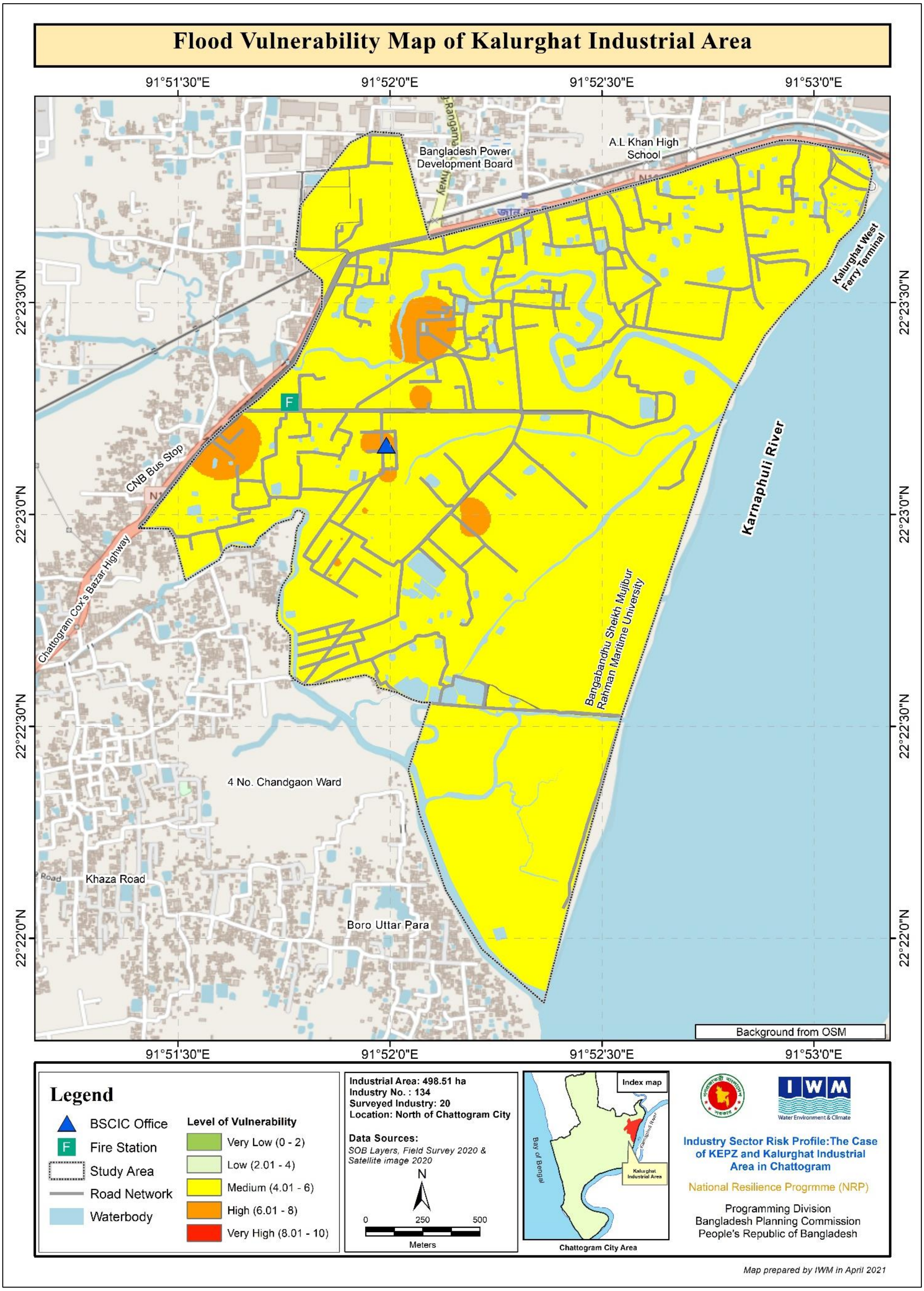


Figure 6-1: Flood Vulnerability Map of Kalurghat Study Area

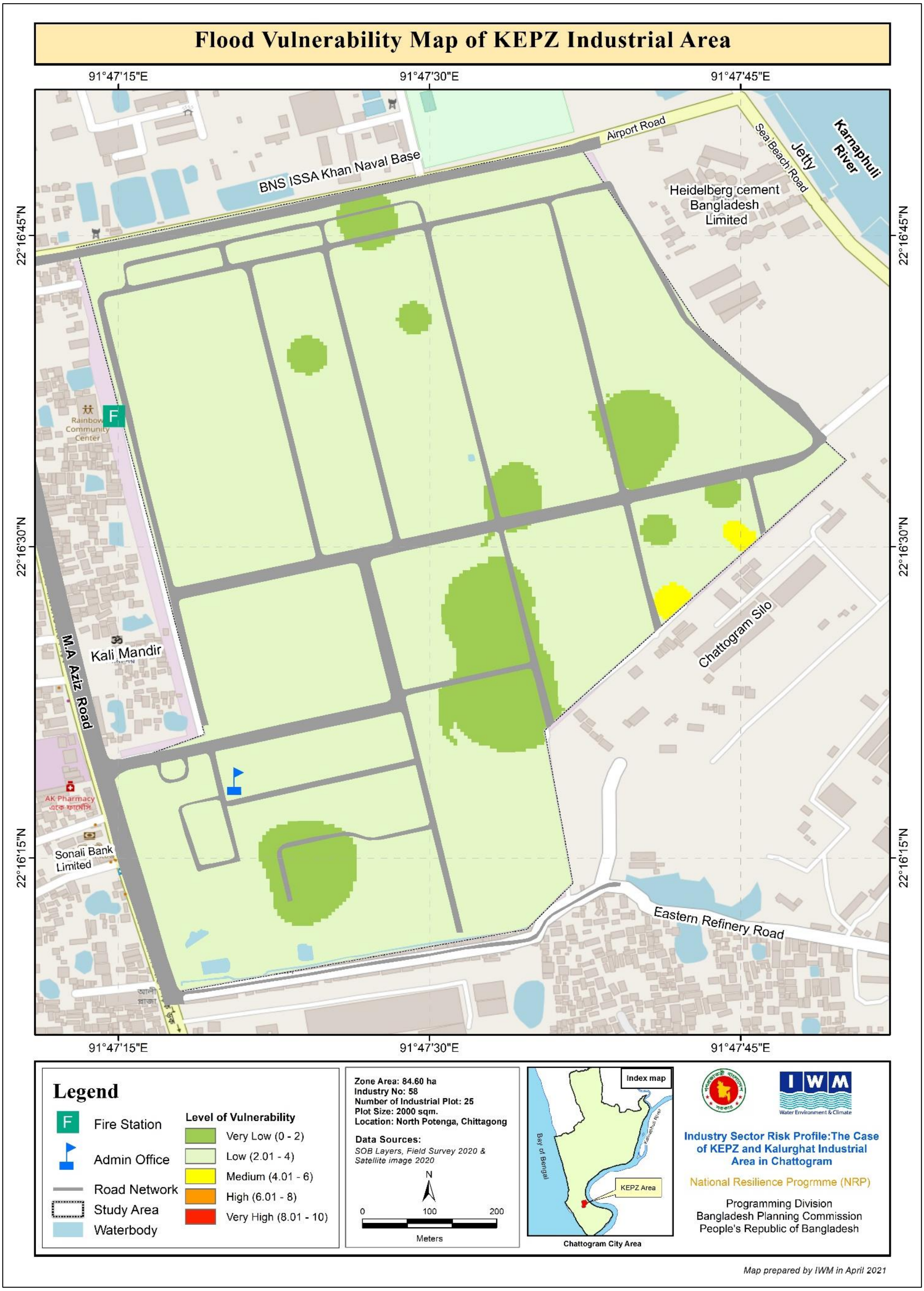


Figure 6-2: Flood Vulnerability Map of KEPZ Study Area

6.1.2 Flood Exposure Analysis

Flood exposure has been assessed by measuring the water depth in a particular location. This depth was calculated by subtracting the land elevation value from the flood water level returned from the hydrodynamic model for the corresponding scenario.

Maximum water level of every single industry was calculated for flood return periods of 2.33, 25 and 50- year. After identifying the water depths, these values were reassigned exposure ratings presented in Table 6-4

Table 6-4: Flood Exposure Rating

Sl. No.	Water Depth (m)	Assigned Value
1	0	0
2	0-1	0.2
3	1.-2	0.4
4	2-3	0.6
5	3-4	0.8
6	>4	1

The Flood exposure maps are presented in Figure 6-3, to Figure 6-8 for Kalurghat and KEPZ Area for different return periods.

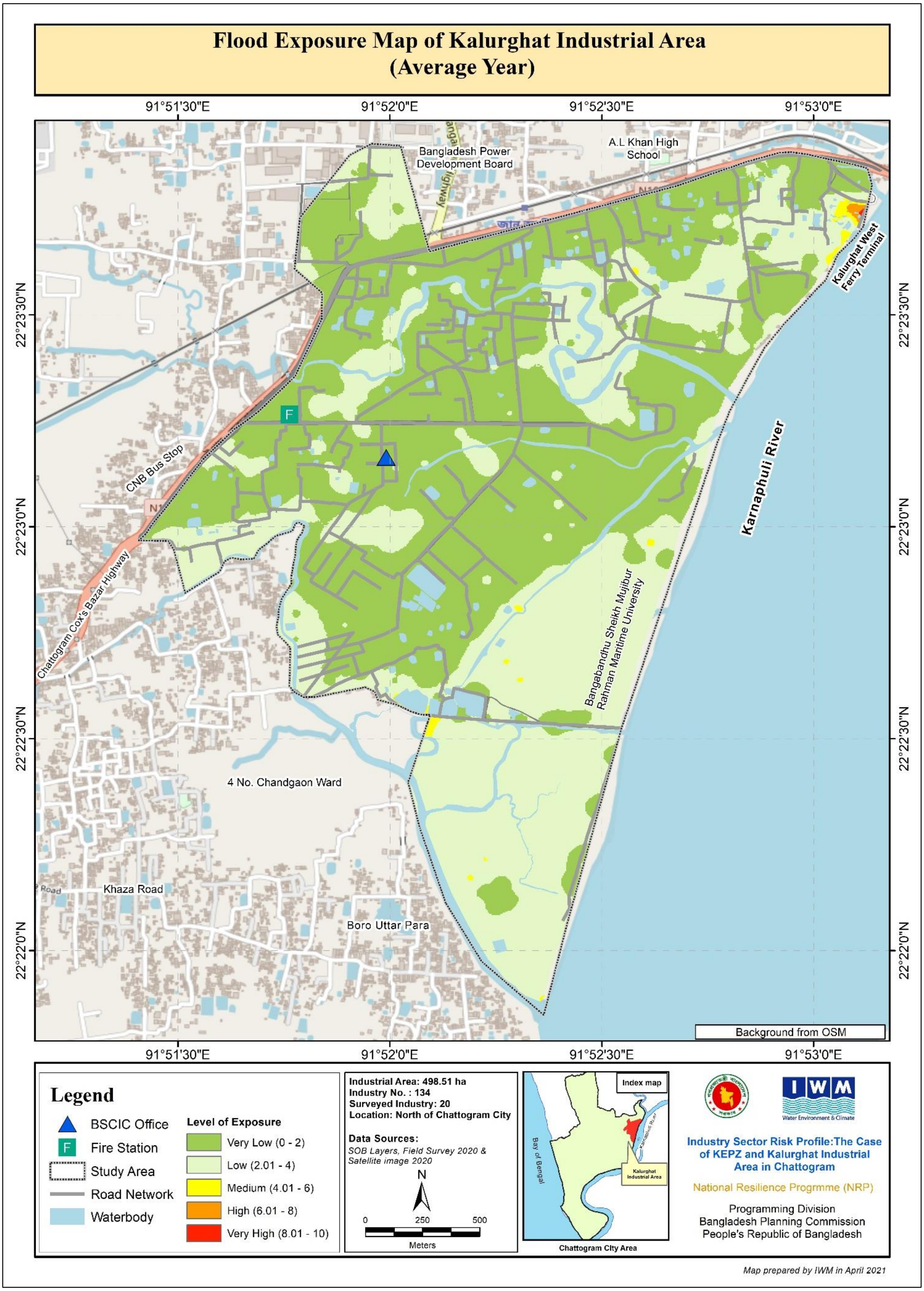


Figure 6-3: Average Year Flood Exposure at Kalurghat Study Area

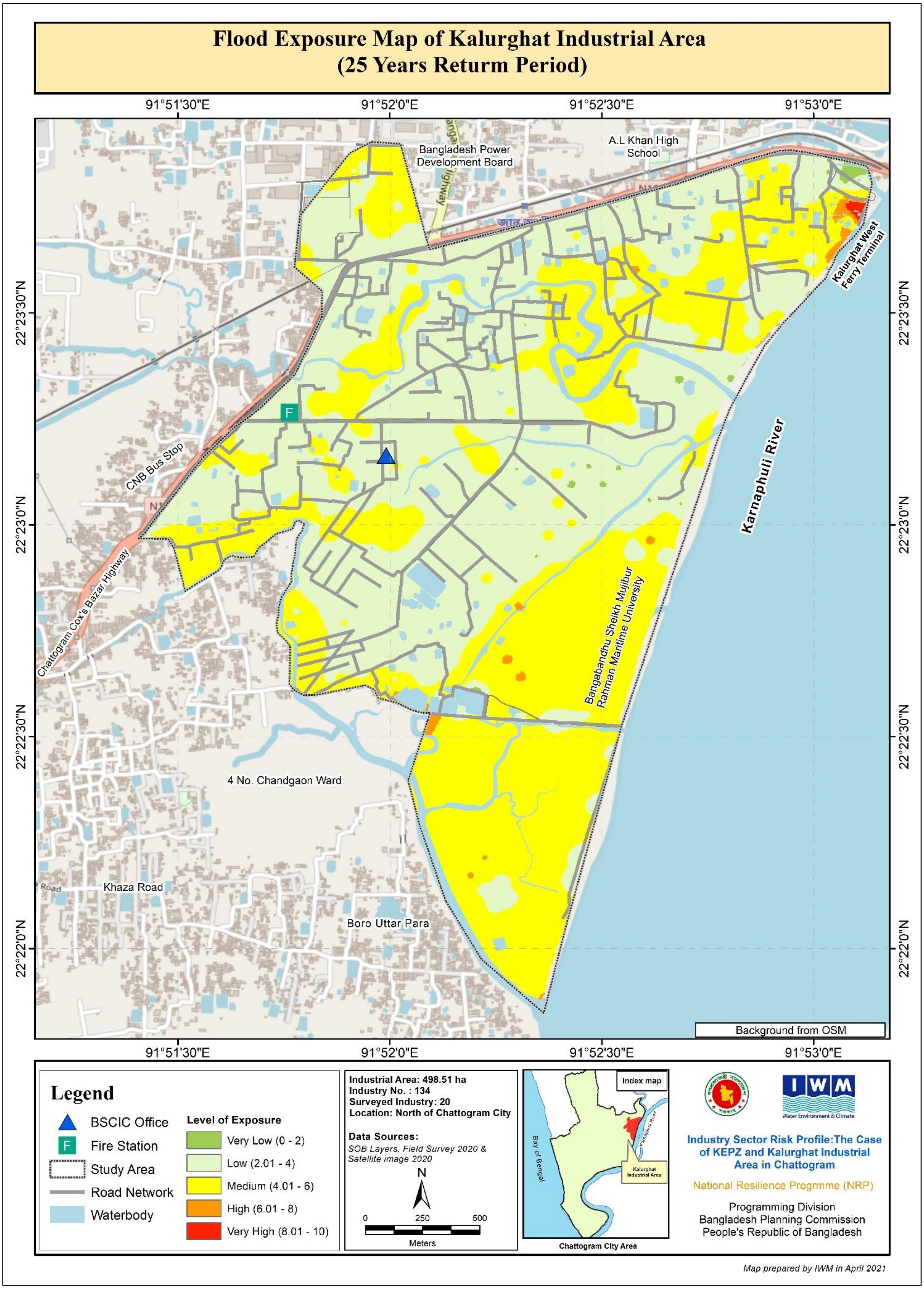


Figure 6-4: 1:25 Year Flood Exposure at Kalurghat Study Area

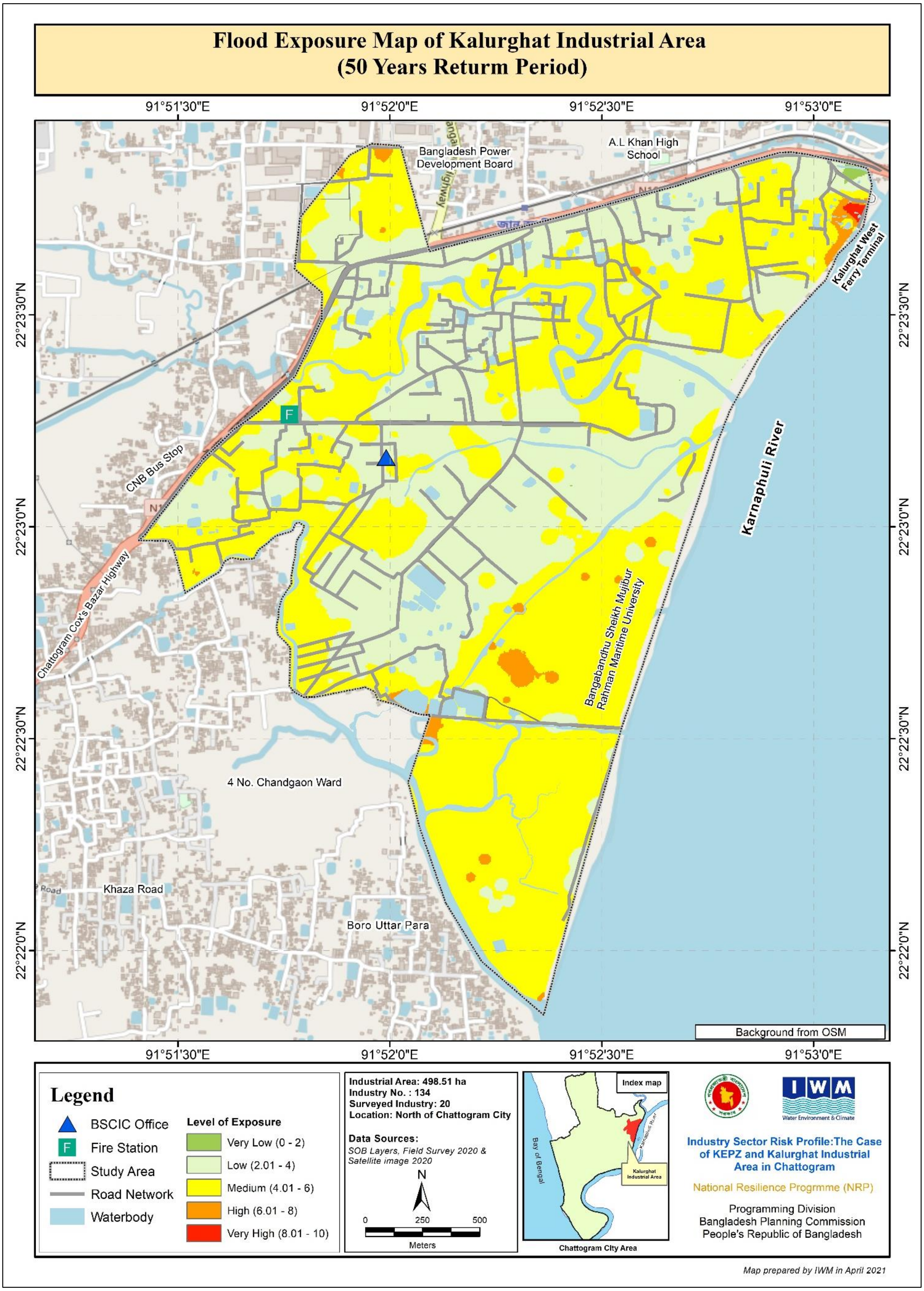


Figure 6-5: 1:50 Year Flood Exposure at Kalurghat Study Area

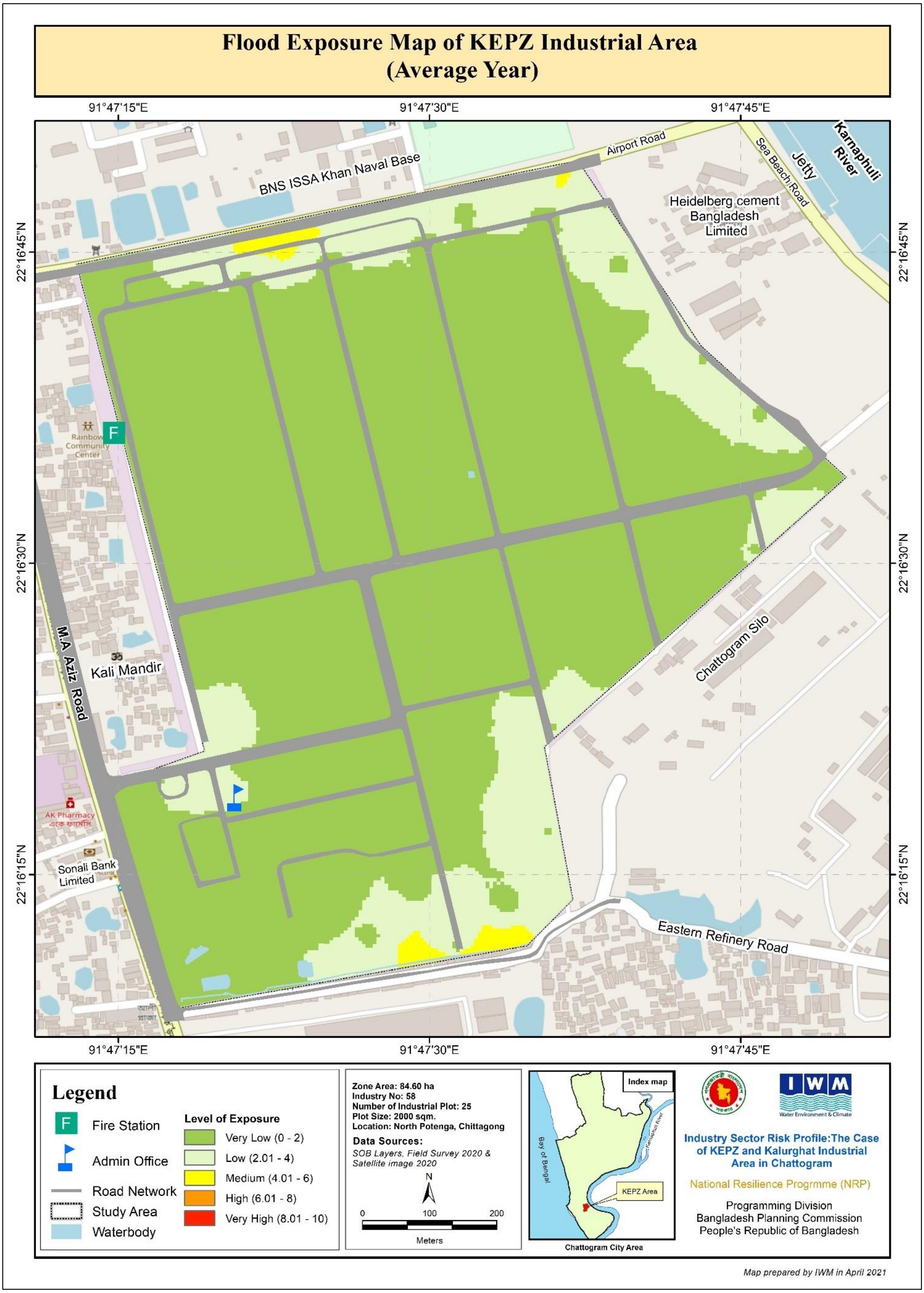


Figure 6-6: Average Year Flood Exposure at KEPZ Study Area

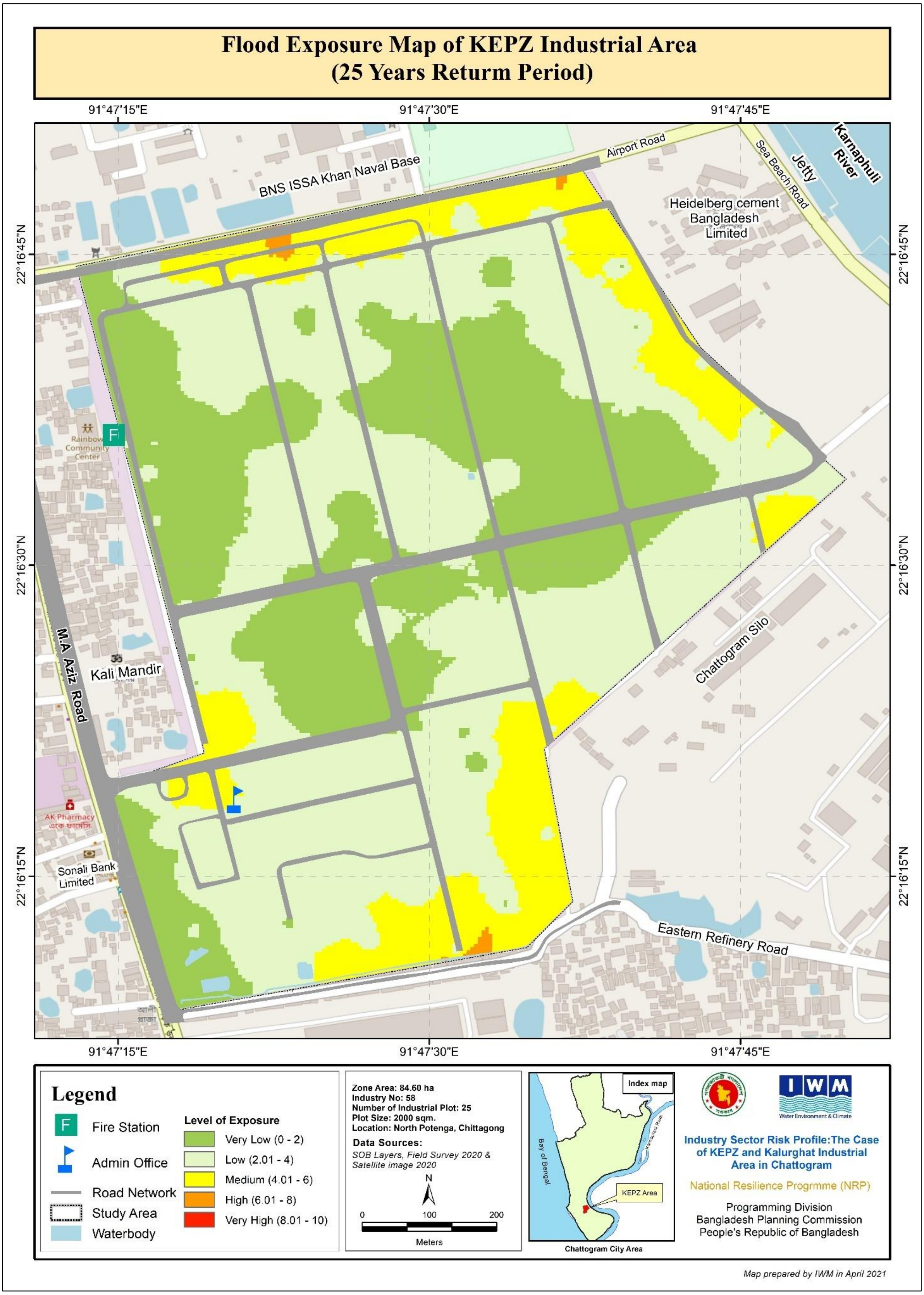


Figure 6-7: 1:25 Year Flood Exposure at KEPZ Study Area

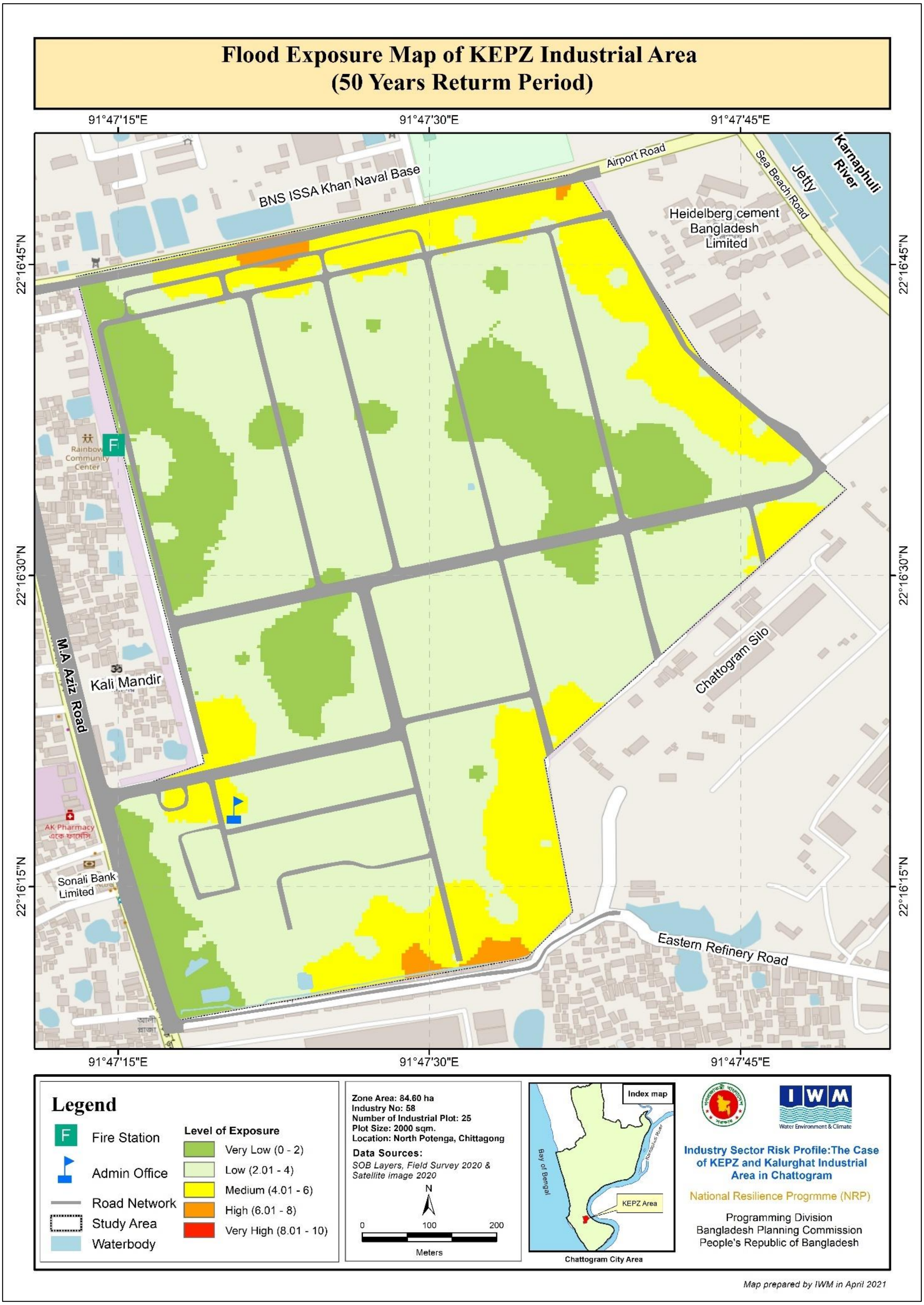


Figure 6-8: 1:50 Year Flood Exposure at KEPZ Study Area

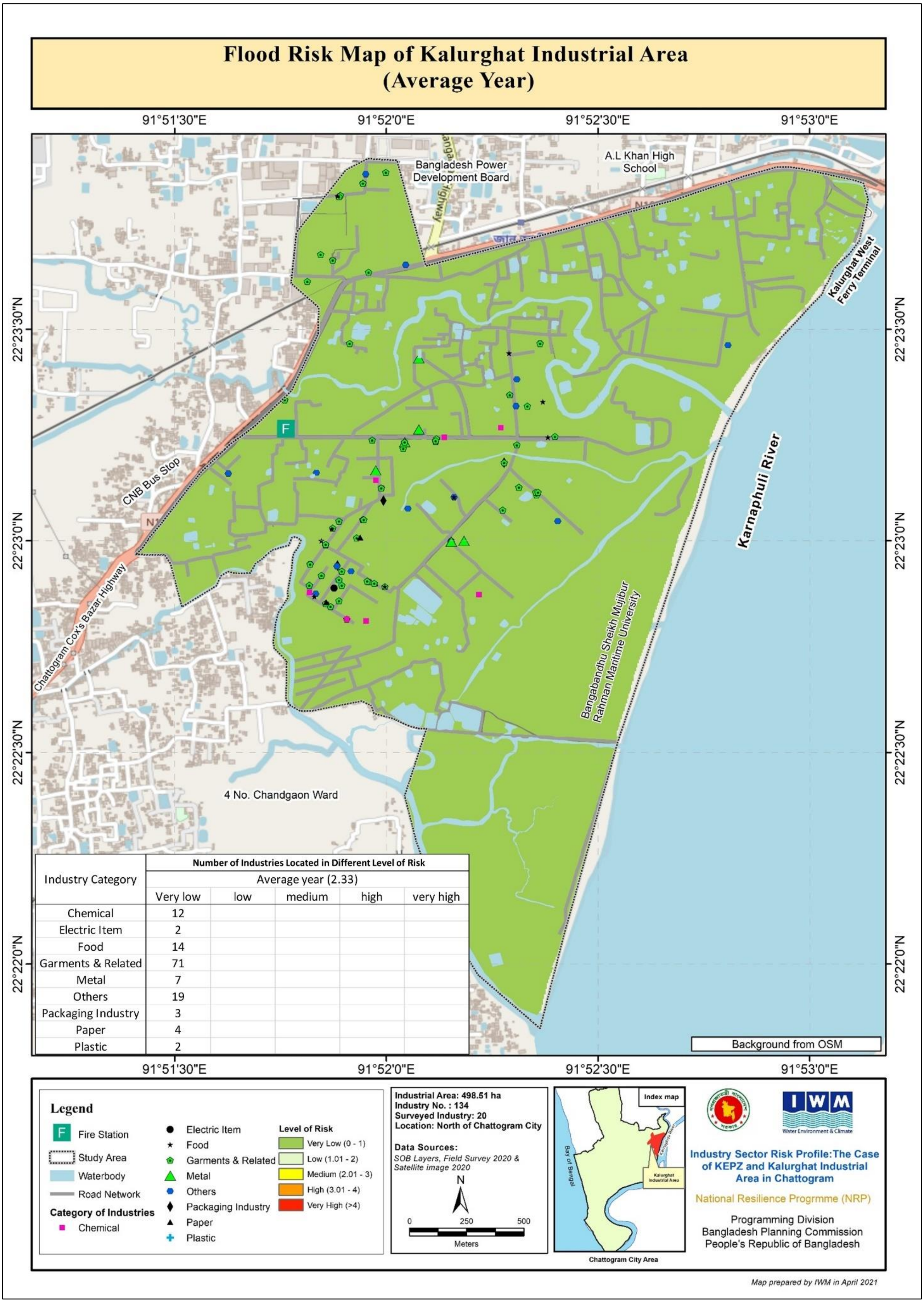
6.1.3 Flood Risk Analysis

Flood Risk was quantified by multiplying three indicators: Hazard, Vulnerability and Exposure.

Flood Risk = *Flood Hazard Score* x *vulnerability score* x *Exposure(normalized)*

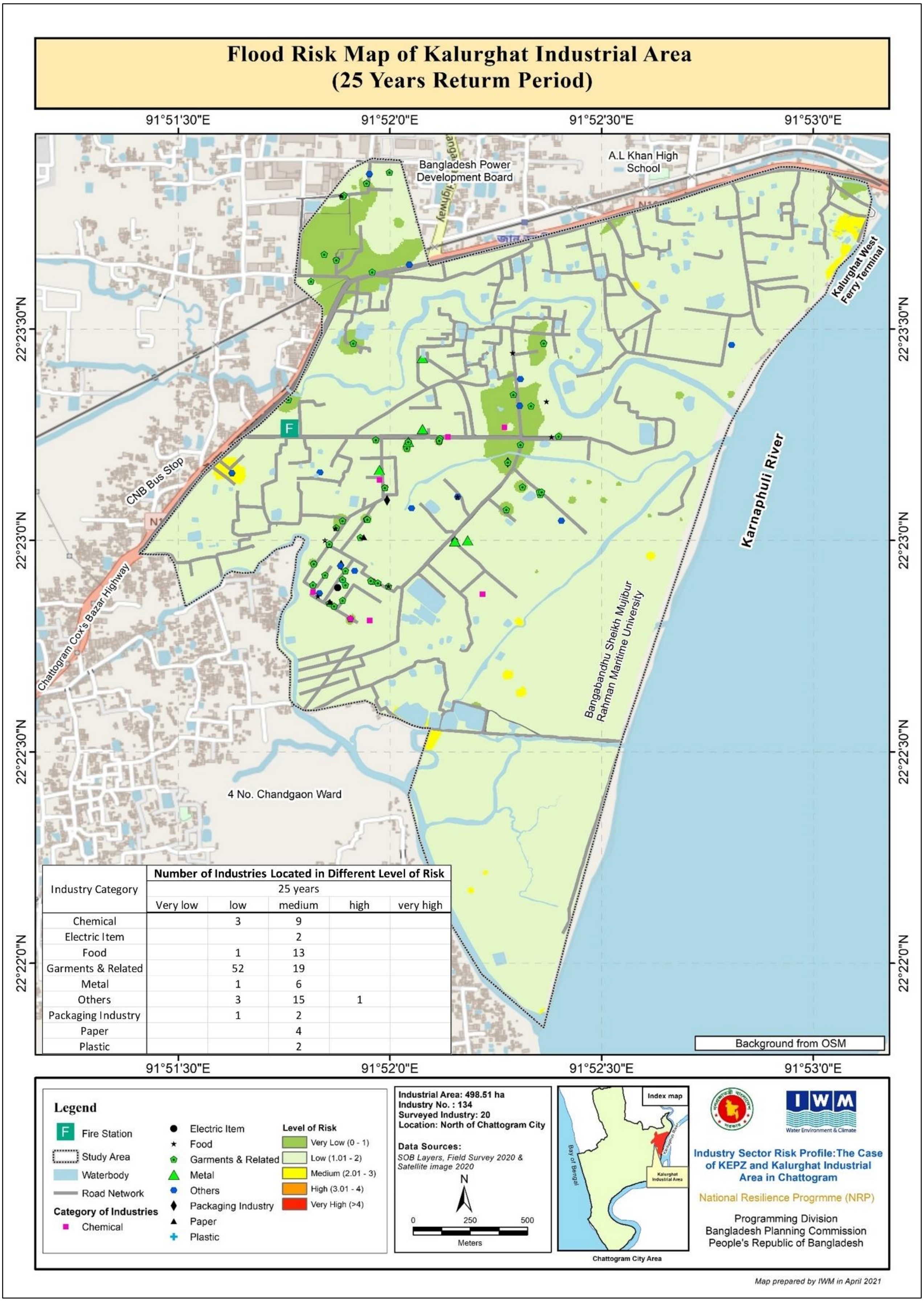
As vulnerability and exposure returned values on a scale of 1, and hazard value was without unit, the flood risk value also returned the value on a scale of 1, then were transformed to a scale of 10.

The Industrial Flood Risk maps were prepared using industrial locations (x, y) with risk factors using interpolation method IDW in GIS. The Flood risk were categorized into 5 classes- Very low, Low, Medium, High & Very high for mapping. These risk maps are presented in Figure 6-9, Figure 6-10 and Figure 6-11 for Kalurghat Industrial Area and Figure 6-12, Figure 6-13 and Figure 6-14 for KEPZ Area.



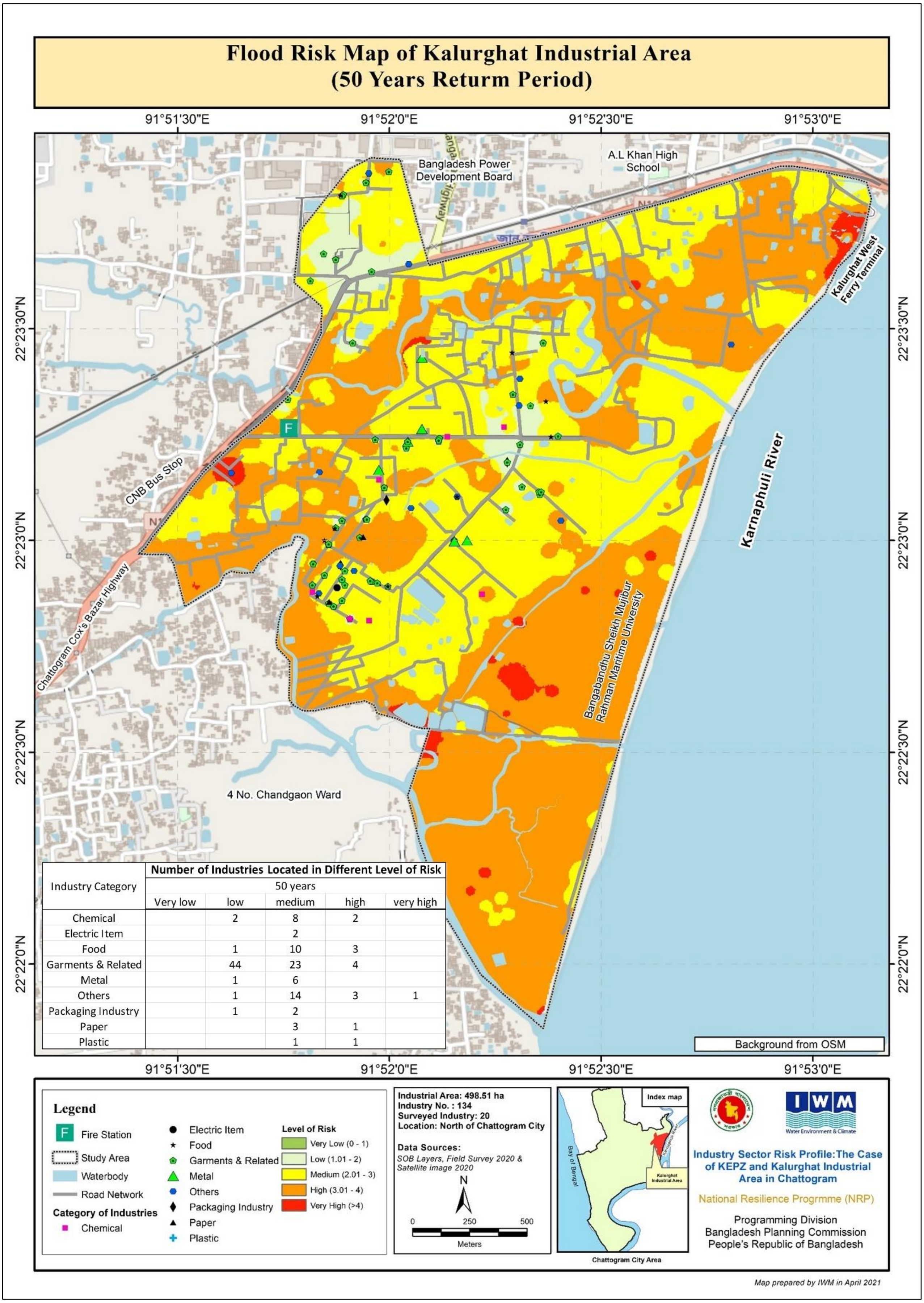
Industry Category	Number of Industries Located in Different Level of Risk				
	Average year (2.33)				
	Very low	low	medium	high	very high
Chemical	12				
Electric Item	2				
Food	14				
Garments & Related	71				
Metal	7				
Others	19				
Packaging Industry	3				
Paper	4				
Plastic	2				

Figure 6-9: Flood Risk Map of Kalurghat Industrial Area in Average year condition



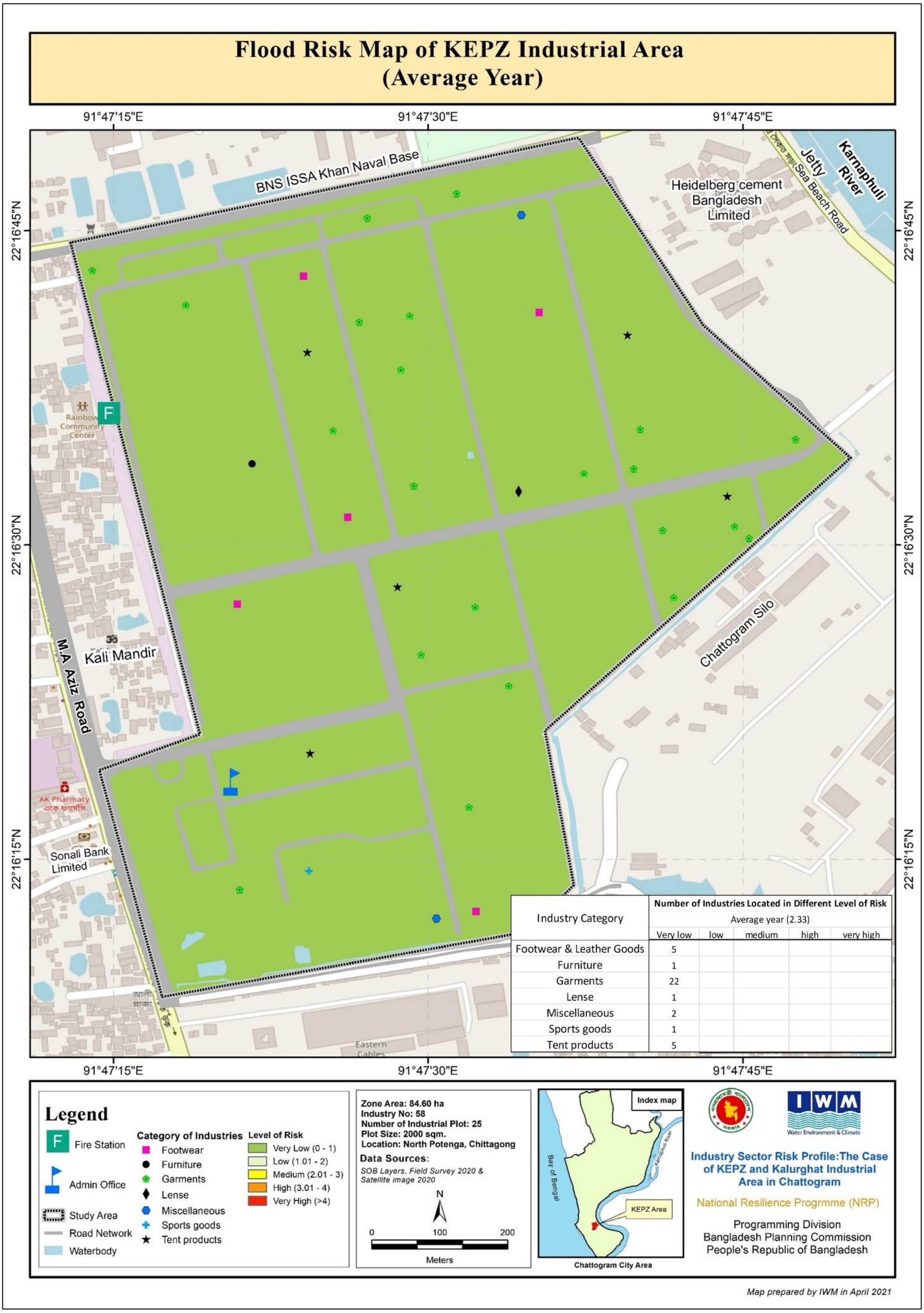
Industry Category	Number of Industries Located in Different Level of Risk				
	25 years				
	Very low	low	medium	high	very high
Chemical		3	9		
Electric Item			2		
Food		1	13		
Garments & Related		52	19		
Metal		1	6		
Others		3	15	1	
Packaging Industry		1	2		
Paper			4		
Plastic			2		

Figure 6-10: Flood Risk Map of Kalurghat Industrial Area at 1: 25-year return period



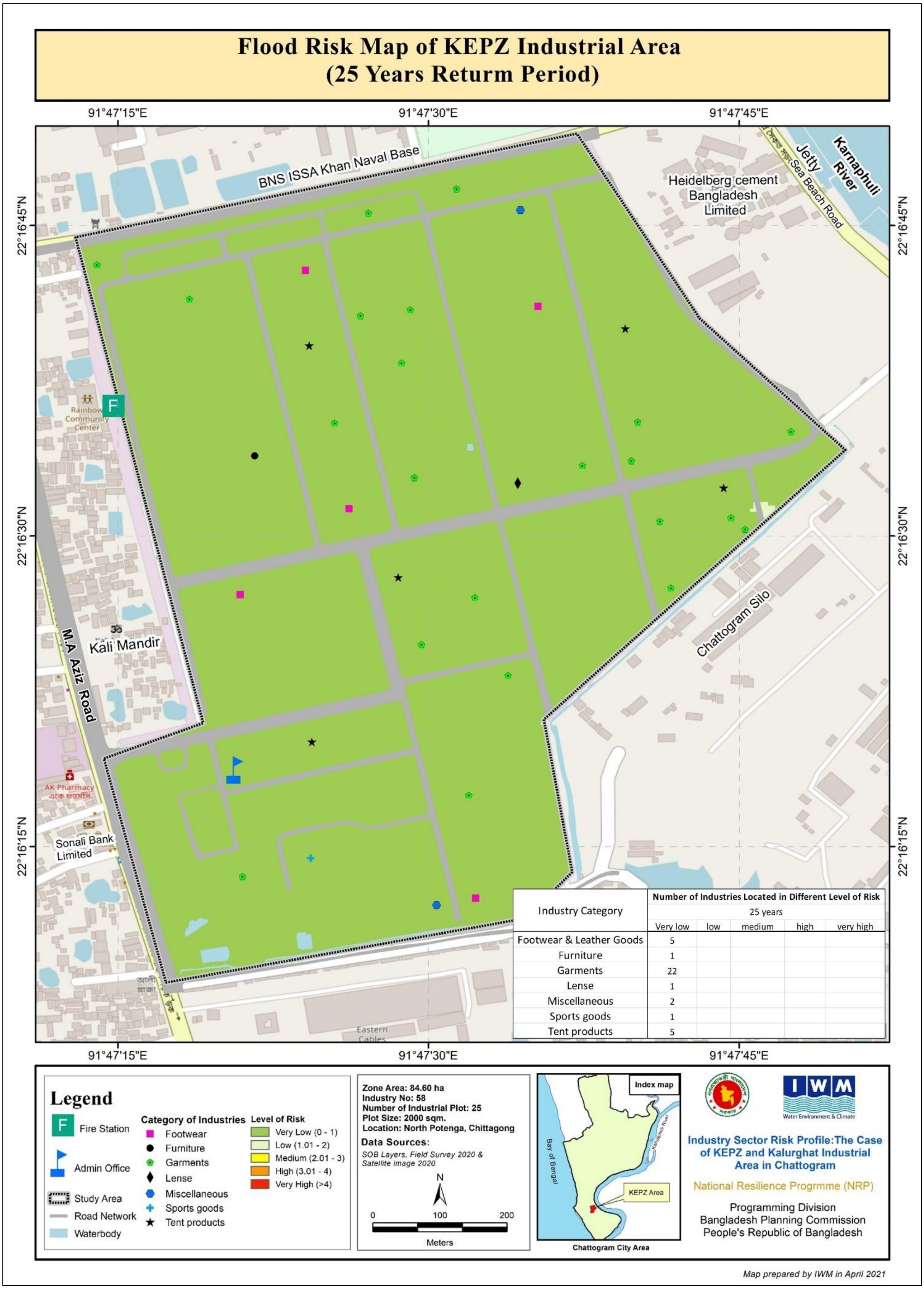
Industry Category	Number of Industries Located in Different Level of Risk				
	50 years				
	Very low	low	medium	high	very high
Chemical		2	8	2	
Electric Item			2		
Food		1	10	3	
Garments & Related		44	23	4	
Metal		1	6		
Others		1	14	3	1
Packaging Industry		1	2		
Paper			3	1	
Plastic			1	1	

Figure 6-11: Flood Risk Map of Kalurghat Industrial Area at 1: 50-year return period



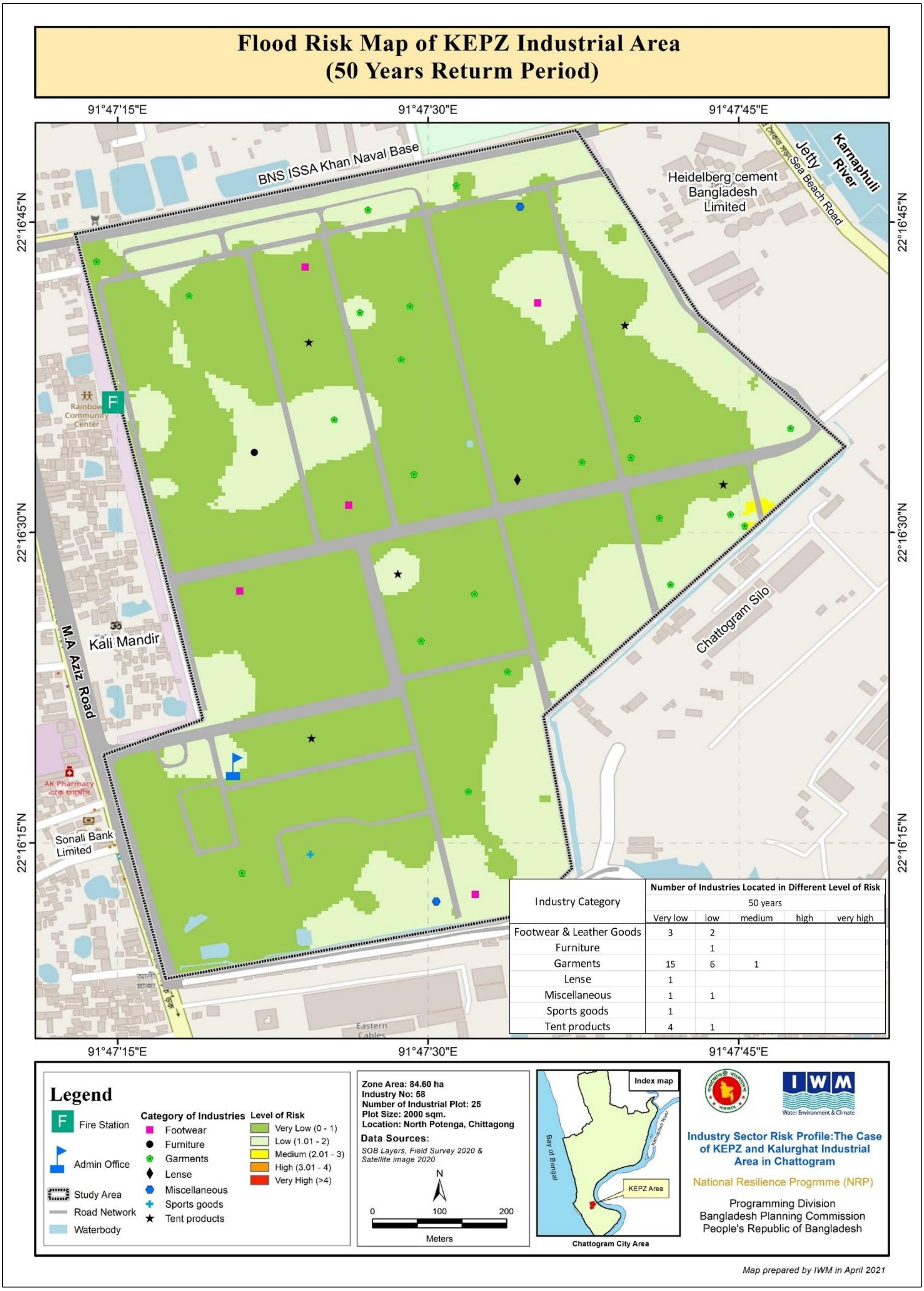
Industry Category	Number of Industries Located in Different Level of Risk				
	Average year (2.33)				
	Very low	low	medium	high	very high
Footwear & Leather Goods	5				
Furniture	1				
Garments	22				
Lense	1				
Miscellaneous	2				
Sports goods	1				
Tent products	5				

Figure 6-12: Flood Risk Map of KEPZ Area in Average year condition



Industry Category	Number of Industries Located in Different Level of Risk				
	25 years				
	Very low	low	medium	high	very high
Footwear & Leather Goods	5				
Furniture	1				
Garments	22				
Lense	1				
Miscellaneous	2				
Sports goods	1				
Tent products	5				

Figure 6-13: Flood Risk Map of KEPZ Area at 1: 25-year return period



Industry Category	Number of Industries Located in Different Level of Risk				
	50 years				
	Very low	low	medium	high	very high
Footwear & Leather Goods	3	2			
Furniture		1			
Garments	15	6	1		
Lense	1				
Miscellaneous	1	1			
Sports goods	1				
Tent products	4	1			

Figure 6-14: Flood Risk Map of KEPZ Area at 1: 50-year return period

6.2 WATER LOGGING RISK PROFILE

Water logging hazard has been assessed under different scenarios using 1D hydrodynamic model where water logging was estimated for Average-year, 25-year and 50-year return periods. On a scale of 1, 50-year return periods were considered as the most severe water logging. The hazard scores were calculated in correspondence with the 50-year water logging is presented in the following Table 6-5.

Table 6-5: Water Logging hazard scoring in different return period

Sl. No.	Scenario ID	Return Period (Year)	Water Logging Hazard score (H)
1	scenario 1	2.33	0.0466
2	scenario 2	25	0.5
3	scenario 3	50	1

6.2.1 WATER LOGGING VULNERABILITY

Seven vulnerability indicators were considered to identify the water logging vulnerability both for KEPZ and Kalurghat area. These indicators are:

- Drainage Condition
- Plinth height
- State of maintenance
- Structural typology
- Number of basements
- Number of floors
- Construction year/age

After identifying the above parameters, weights were given based on the impact which induce drainage/water logging hazards. It is mentionable that the drainage condition is the most important determinant of understanding the waterlogging severity. Weighted lists of these indicators are shown in Table 6-6 based on the expert opinion and lesson learned from field visits.

Table 6-6: Water Logging vulnerability Indicators and weightage

Sl No.	Water Logging Vulnerability Indicators	Weighted Value
1	Drainage Condition	0.4
2	Plinth Height	0.3
3	State of maintenance	0.1
4	Structural typology	0.08

Sl No.	Water Logging Vulnerability Indicators	Weighted Value
5	No of Basements	0.06
6	Number of floors	0.04
7	Construction Year/age	0.02

After identifying these indicators, the collected data were normalized as presented in Table 6-7

Table 6-7: Normalization of water logging vulnerability indicators

Drainage Condition		Plinth Height		Structure typology		State of maintenance		No. of Basement		No. of Floor		Construction Year	
OD	AV	OD	AV	OD	AV	OD	AV	OD	AV	OD	AV	OD	AV
No congestion	0.1	>=5	0.1	RCC	0.1	Excellent	0.1	0	0.1	>=5	0.1	>=2006	0.33
Moderate	0.5	4-4.99	0.25	Steel	0.2	Good	0.5	1	0.5	4	0.25	1991-2005	0.67
Severe	1	3.01-3.99	0.5	URM	1	Moderate	0.75	>=2	1	3	0.5	<=1990	1
		2.01-2.99	0.75			Poor	1			2	0.75		
		<=2	1							1	1		

*(*OD= Observed Data, AV = Assigned Value)*

Based on the values obtained from the table above the Water Logging Vulnerability Maps were prepared and presented in Figure 6-15 and Figure 6-16.

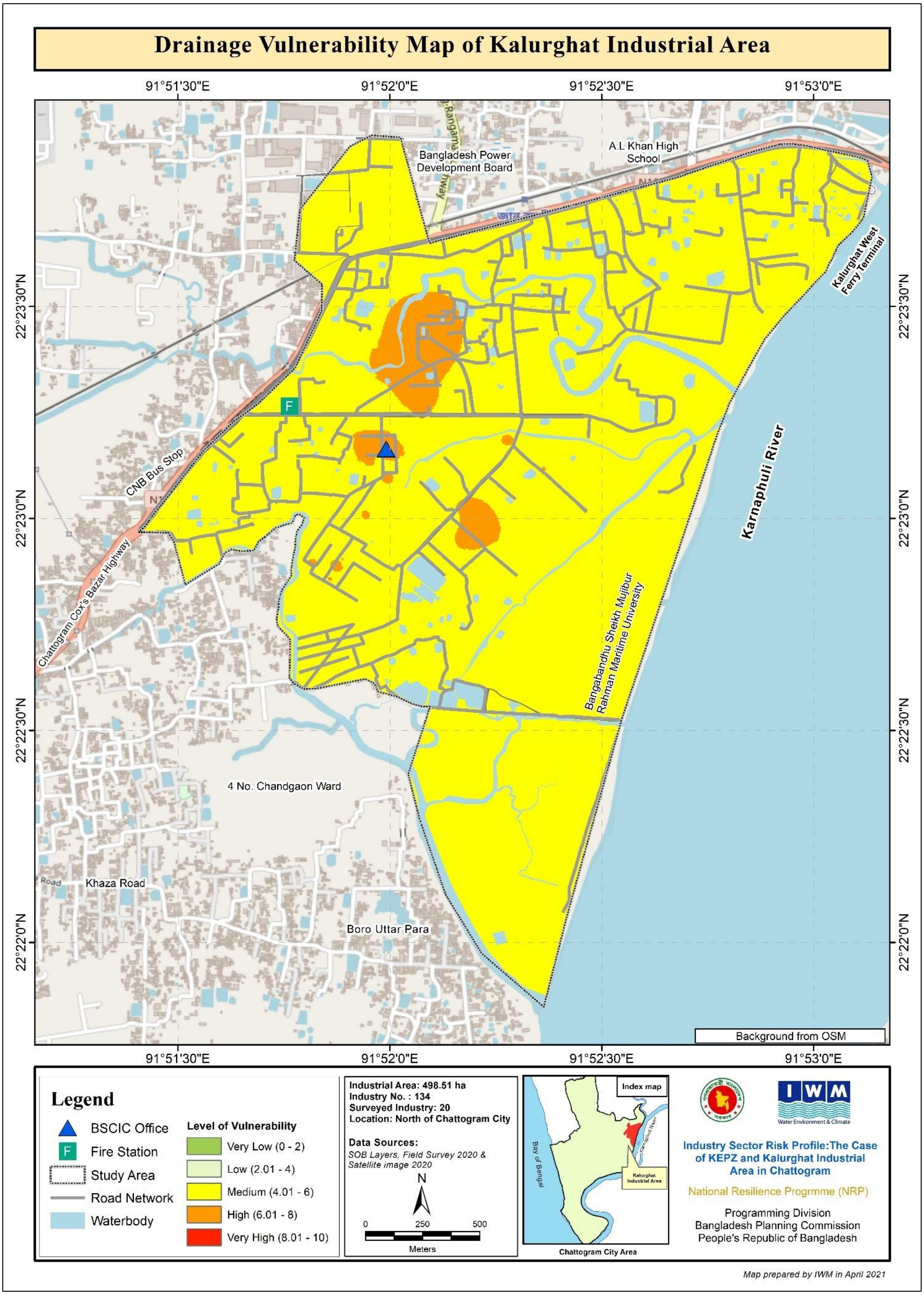


Figure 6-15: Drainage/Water Logging Vulnerability Map, Kalurghat Study Area

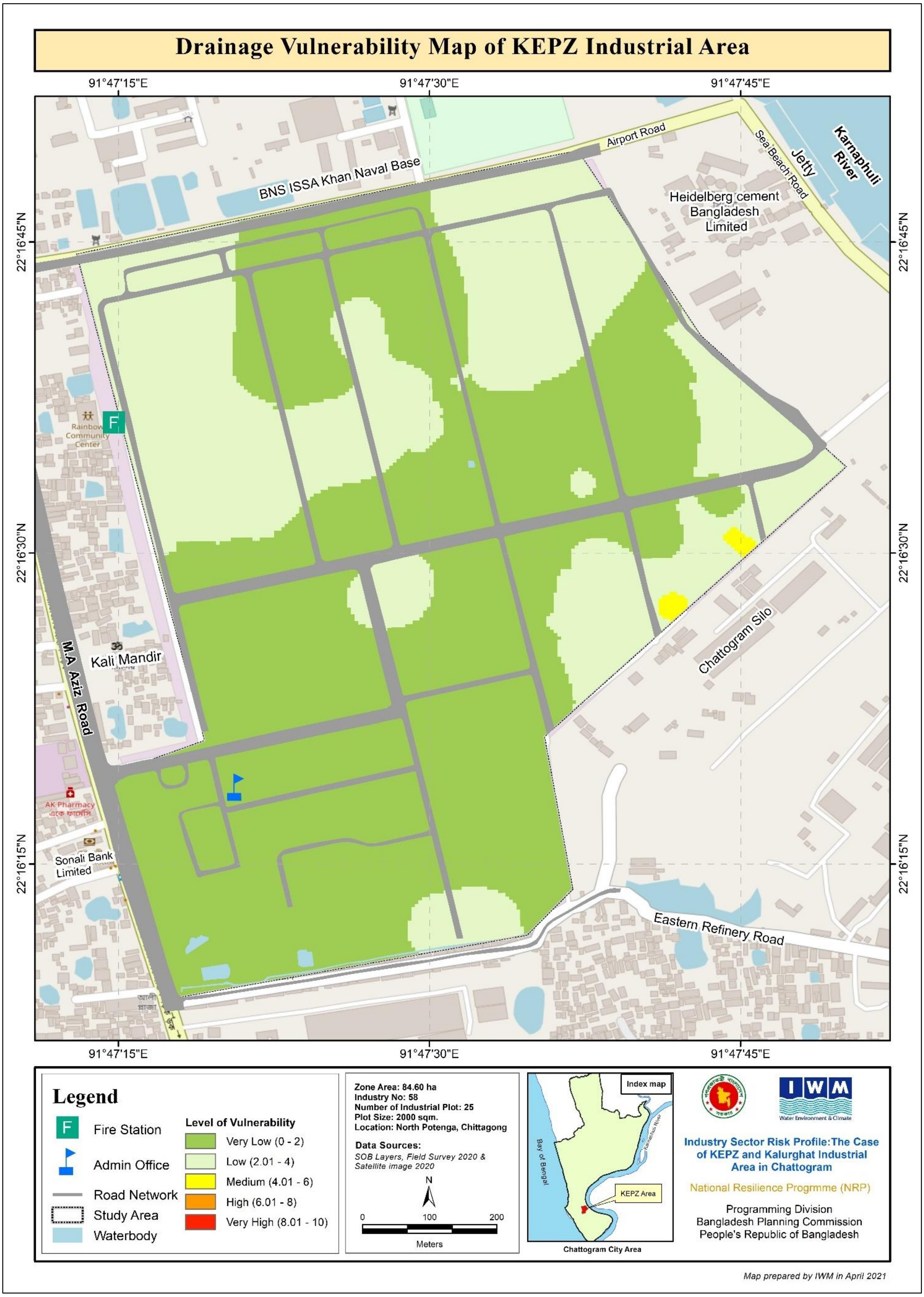


Figure 6-16: Drainage/Water Logging Vulnerability Map, KEPZ Study Area

6.2.2 WATER LOGGING EXPOSURE ANALYSIS

Water logging exposure has been assessed by measuring the water depth for a particular area. This depth was calculated by subtracting the land elevation value from the level of water logging returned from the hydrodynamic model for the corresponding scenario.

Maximum water level of every individual industry was calculated for four rainfall return periods (Avg.-year, 25-year and 50-year). After identifying the water depths, these values were reassigned to normalized value on a scale of 1 as shown in the following Table 6-8.

Table 6-8: Water logging exposure ratings

Maximum water level (m)	Normalized Value
0	0
0.01-1	0.2
1.01-2	0.4
2.01-3	0.6
3.01-4	0.8
>4	1

Based on the values obtained from the table above the Water Logging exposure Maps for two areas were prepared and presented in Figure 6-17 to Figure 6-22.

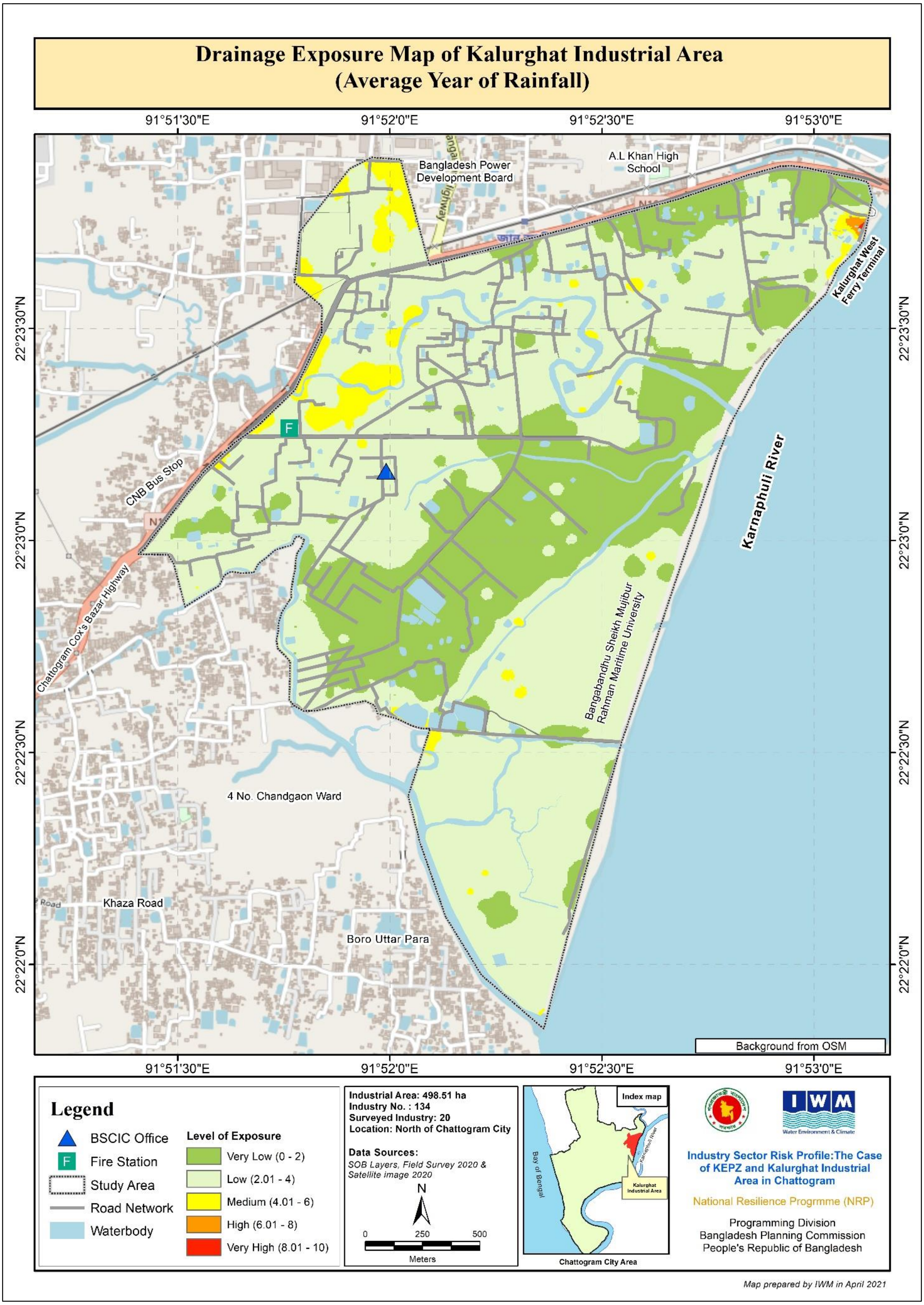


Figure 6-17: Avg.-year Water Logging Exposure, Kalurghat Study Area

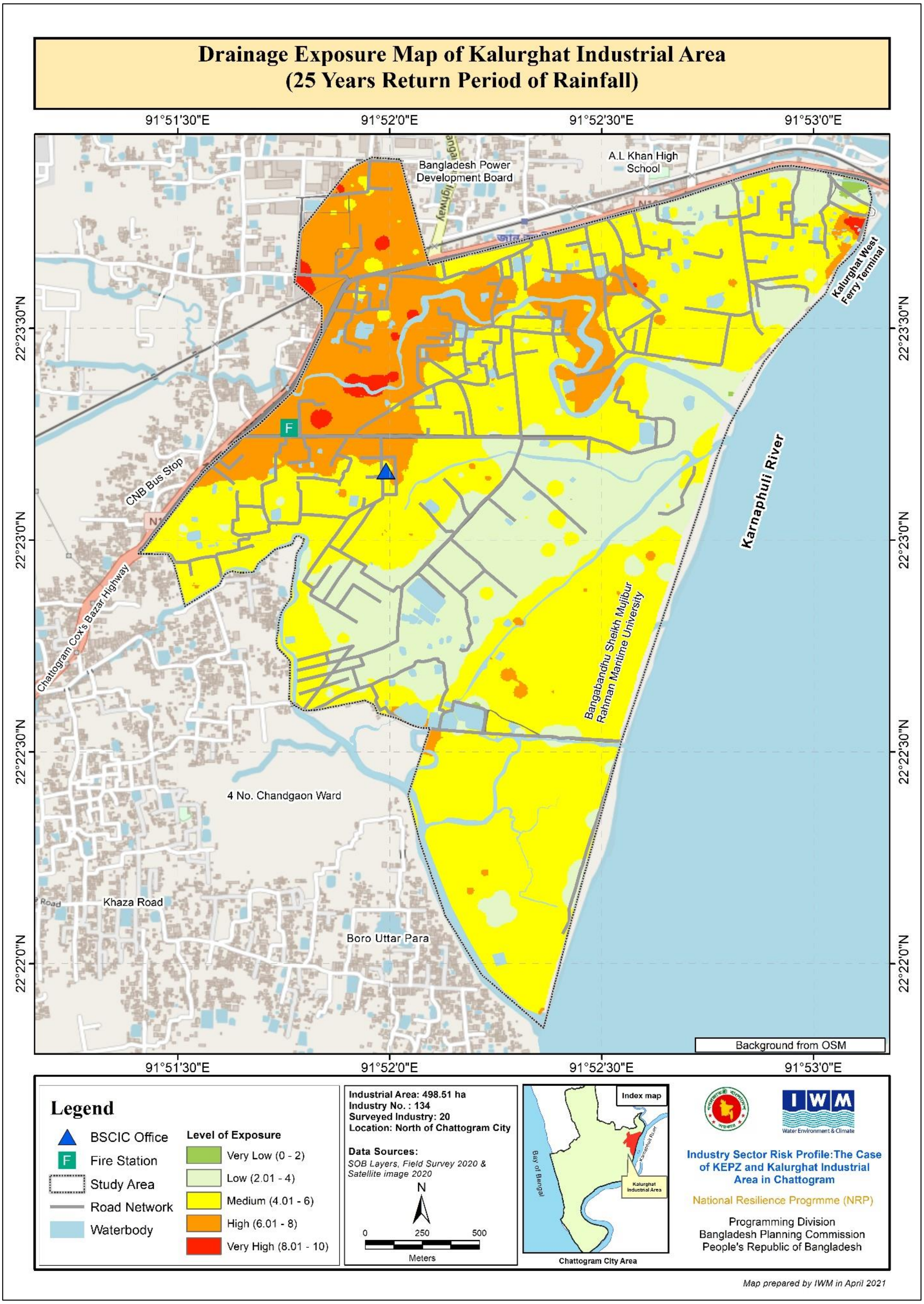


Figure 6-18: 1 in 25-year Water Logging Exposure, Kalurghat Study Area

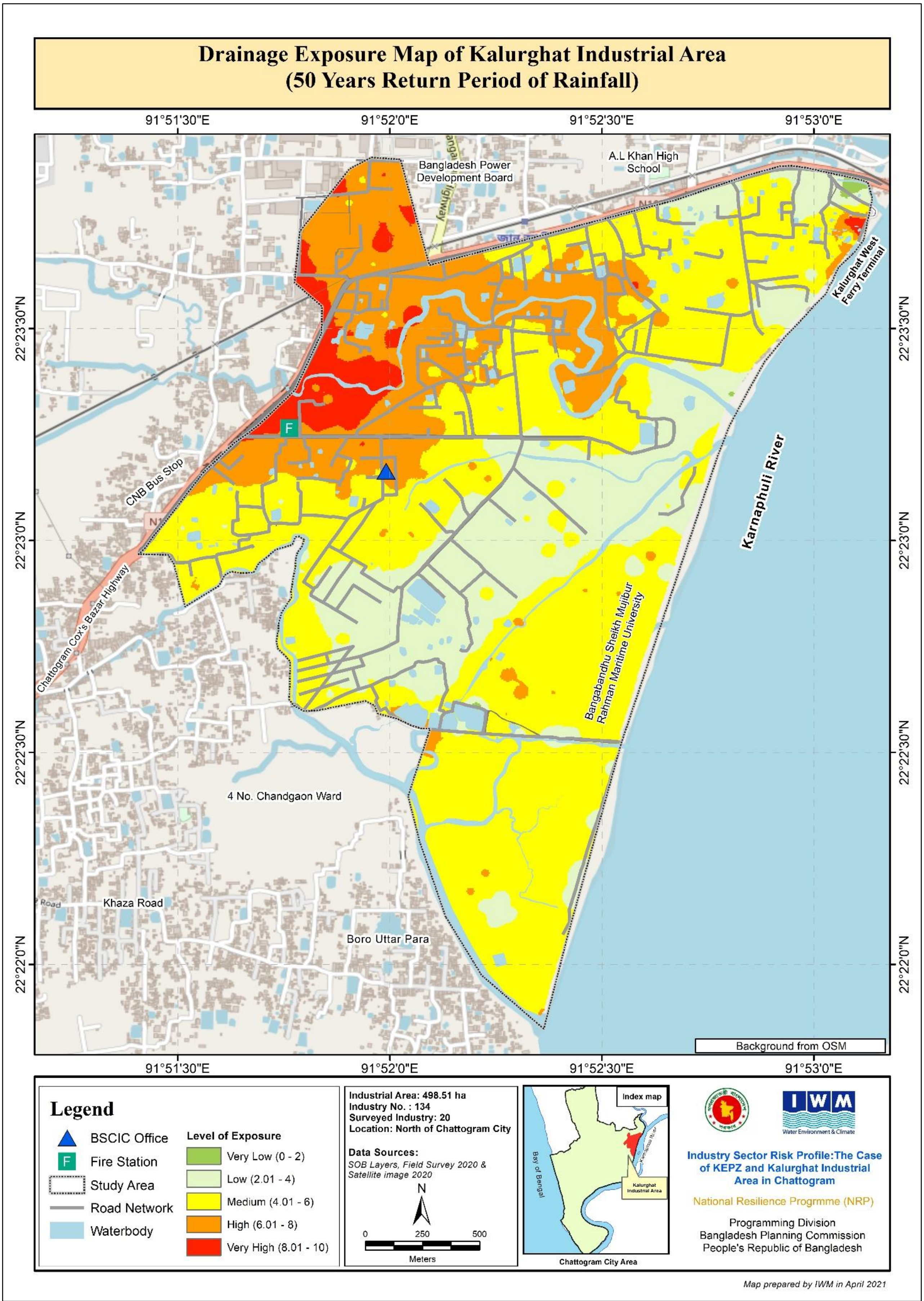


Figure 6-19: 1 in 50-year Water Logging Exposure, Kalurghat Study Area

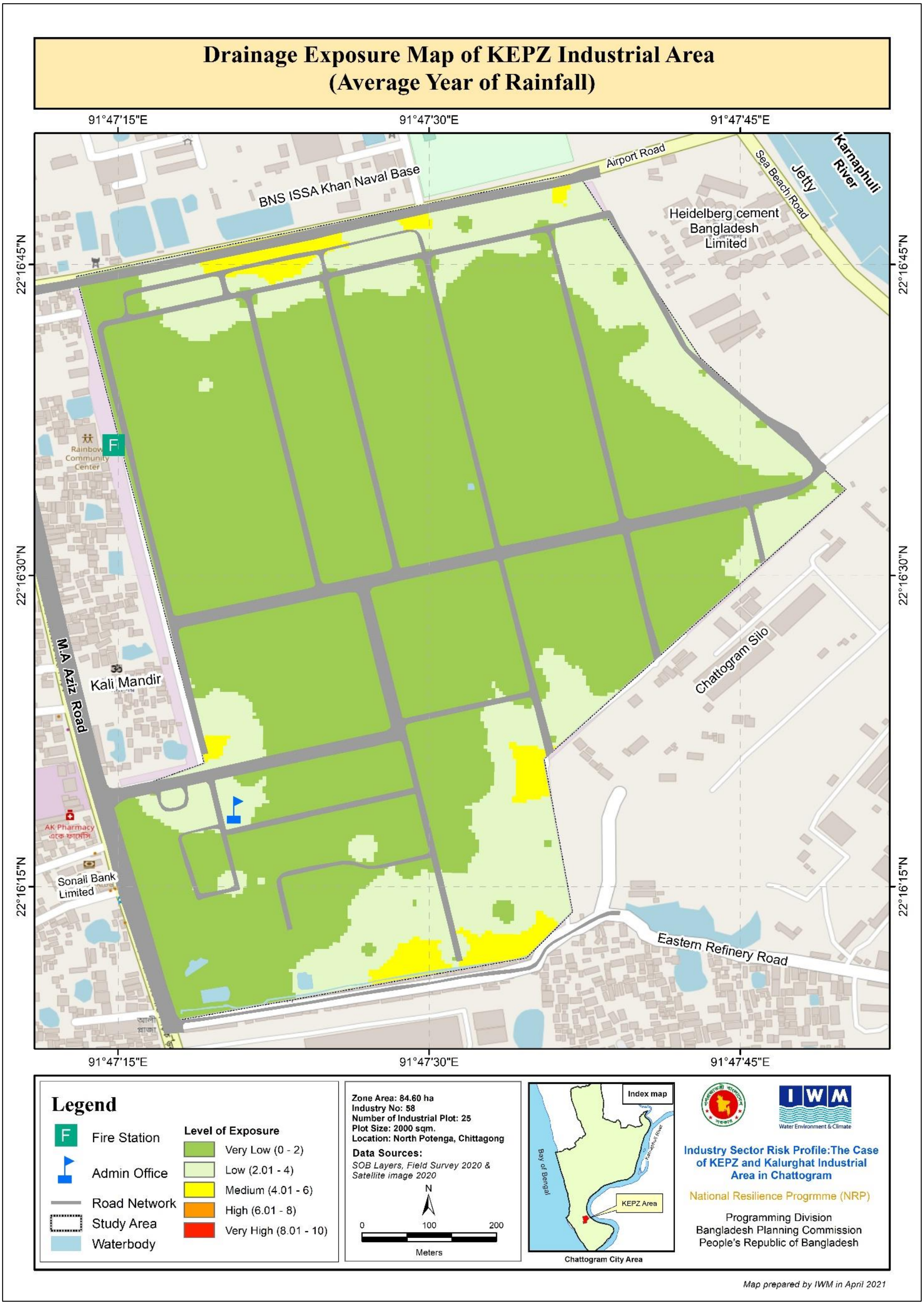


Figure 6-20: Average Year Water Logging Exposure, KEPZ Area

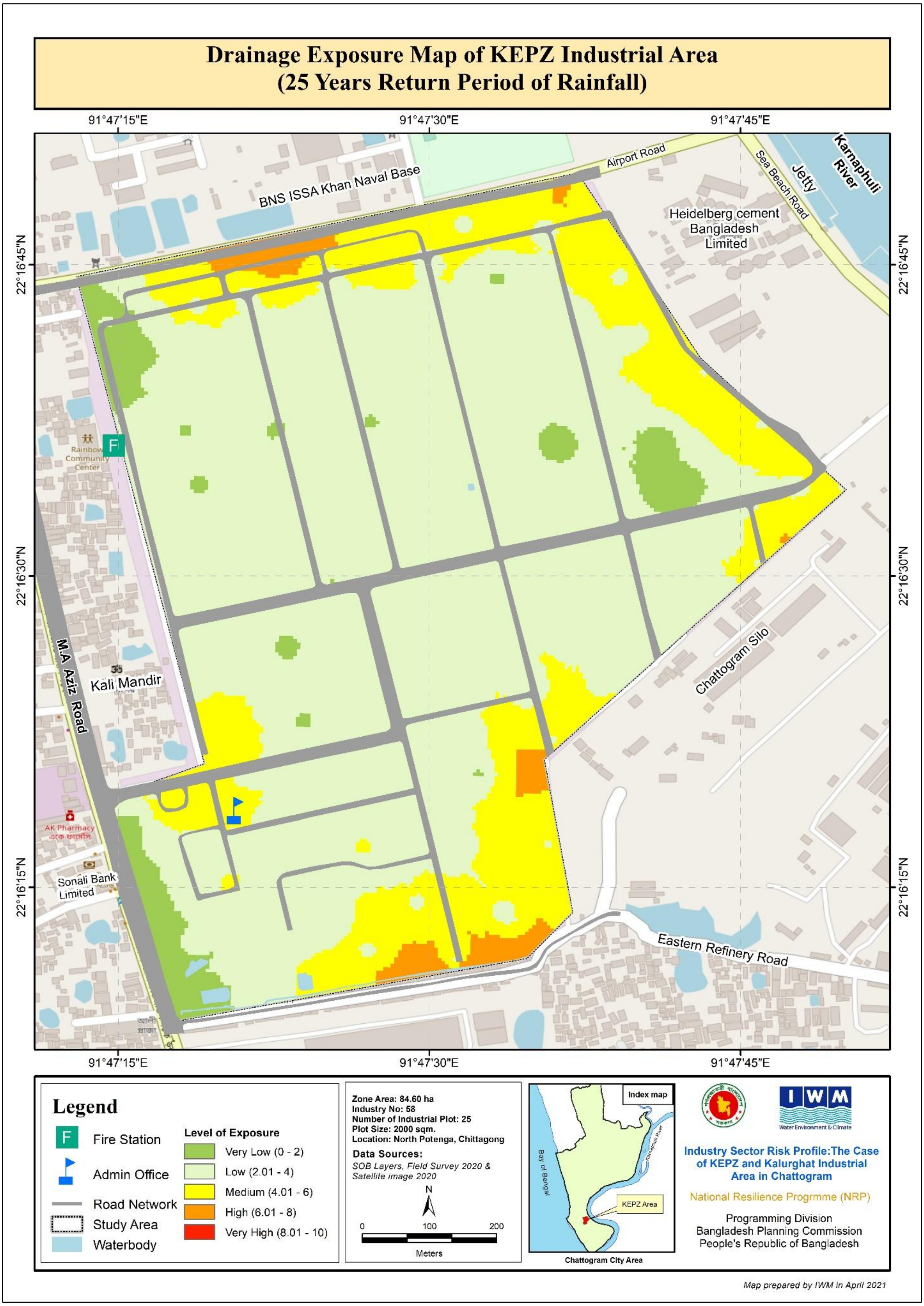


Figure 6-21: 1 in 25-year Water Logging Exposure, KEPZ Area

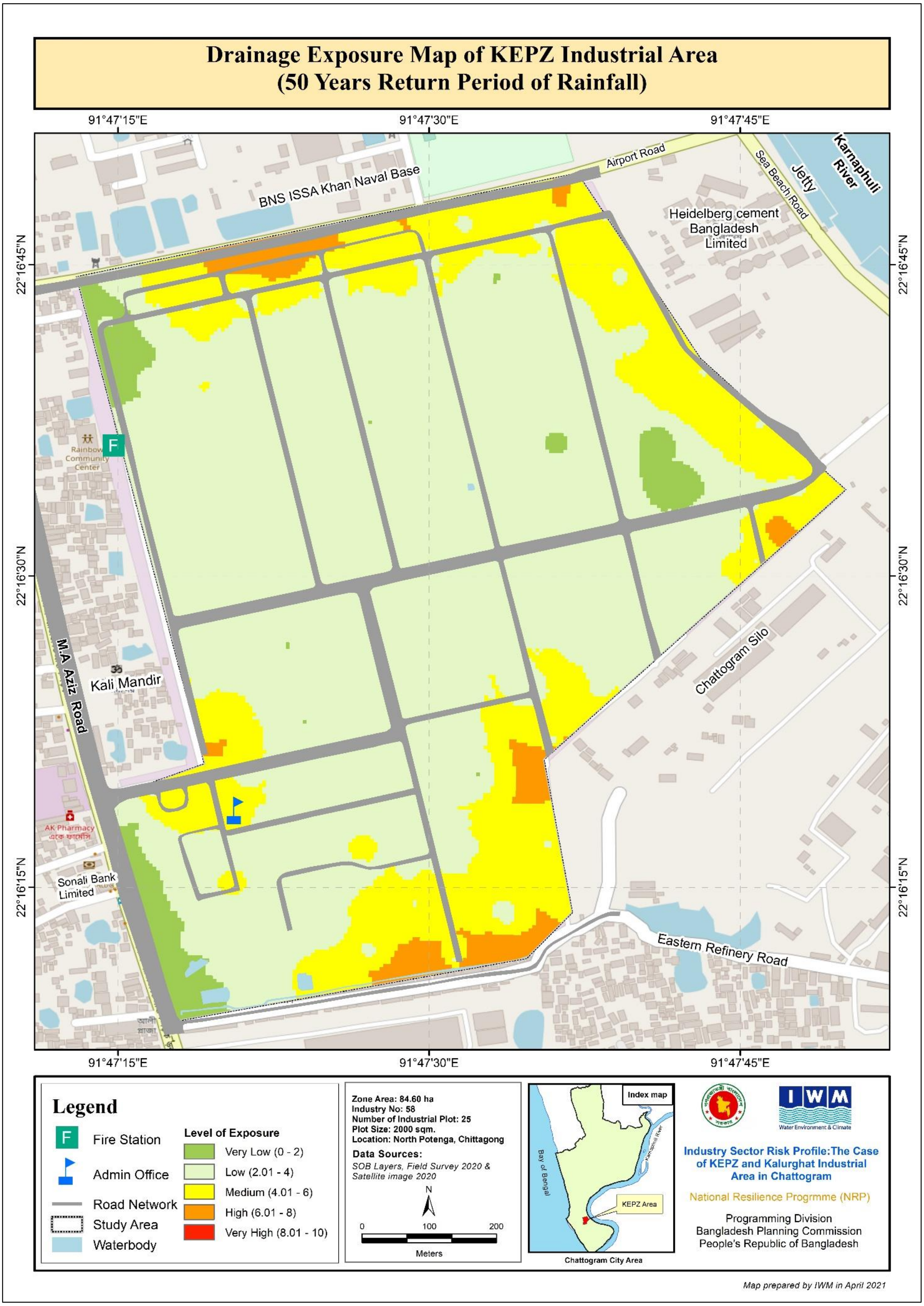


Figure 6-22: 1 in 50-year Water Logging Exposure, KEPZ Area

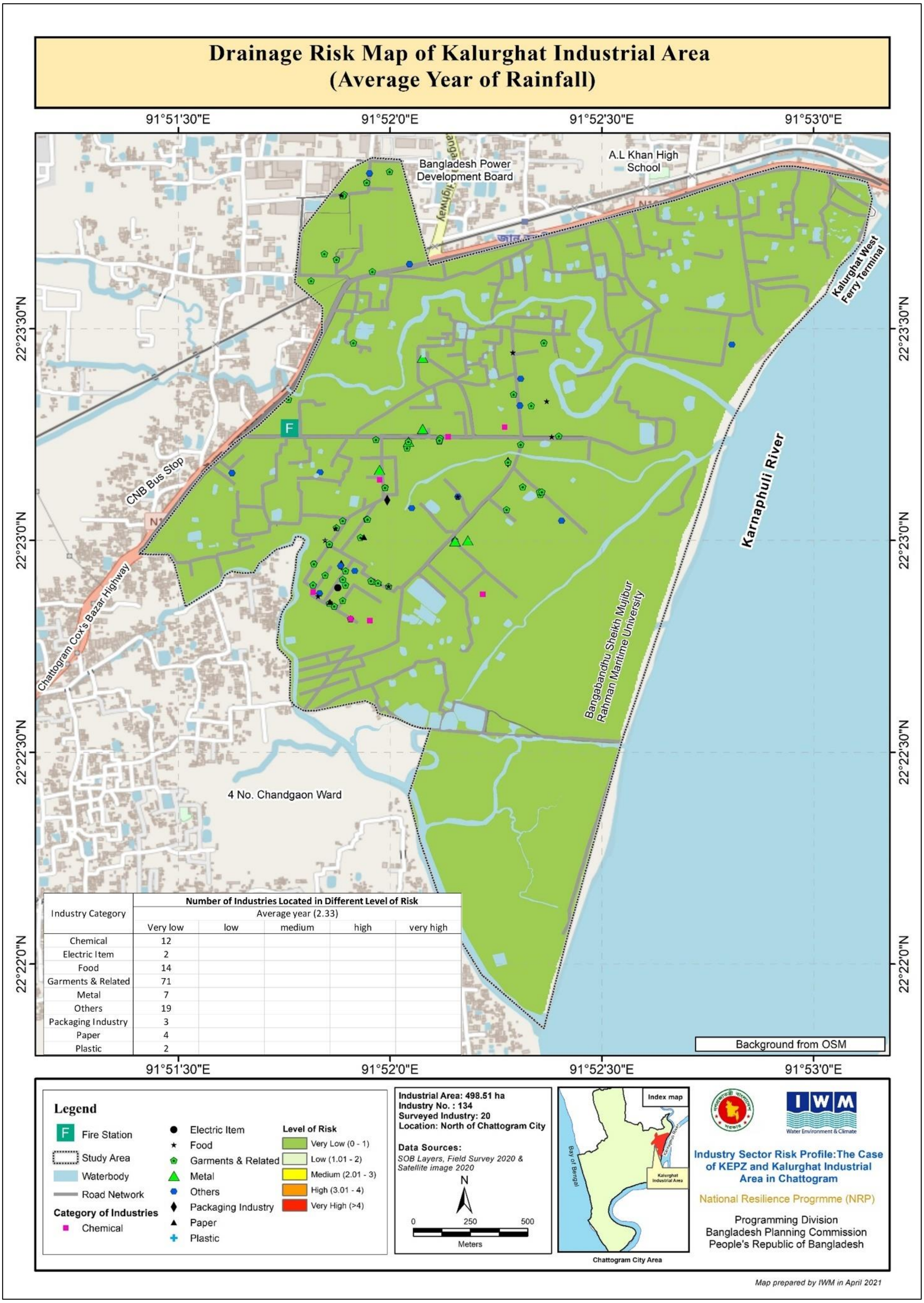
6.2.3 Water Logging Risk Analysis

Water logging hazard was quantified by multiplying three indicators: Hazard, Vulnerability and Exposure.

Water logging Risk = Water logging Hazard Score x vulnerability score x Exposure(normalized)

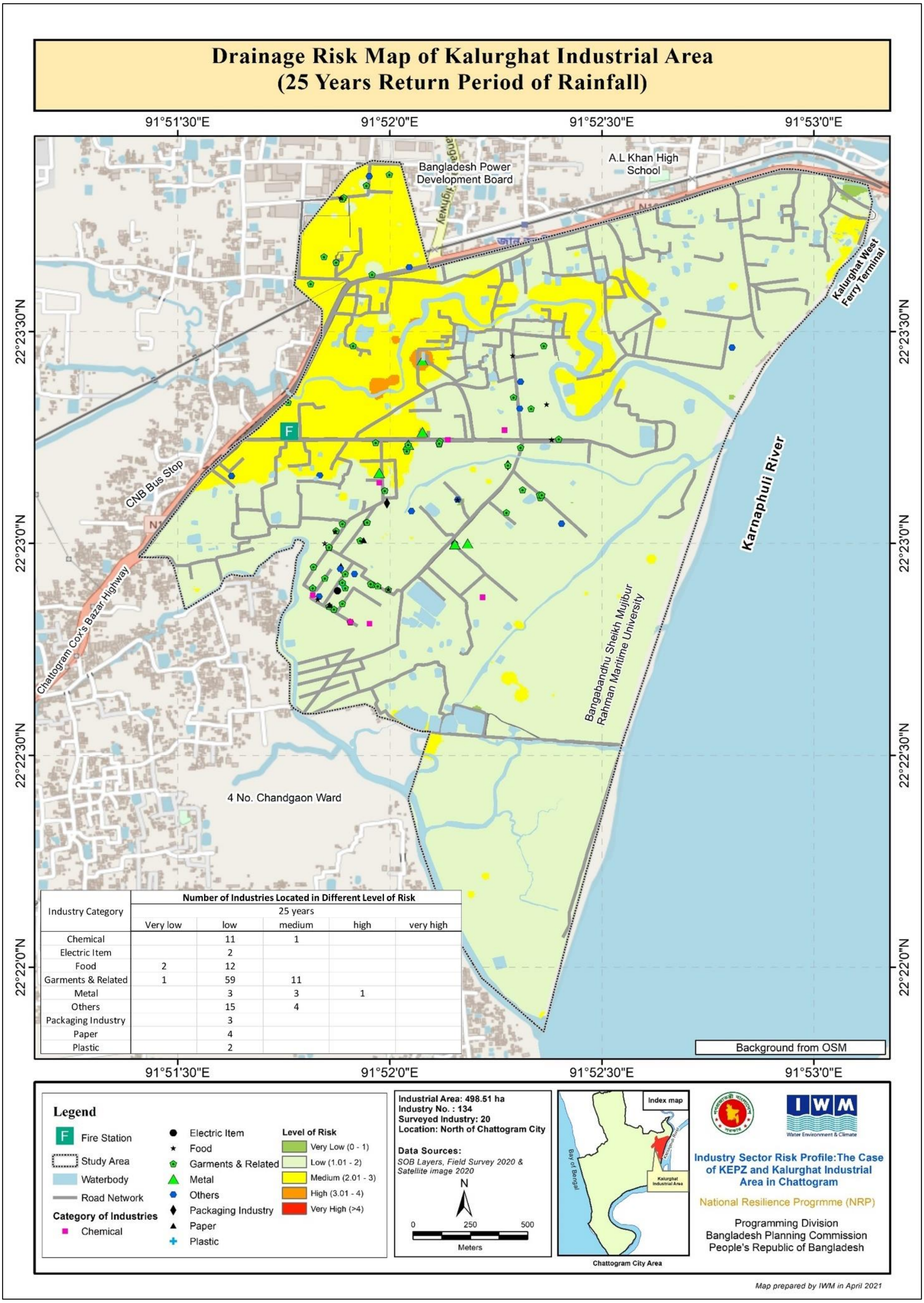
As vulnerability and exposure returned values on a scale of 1, and hazard value was unitless, the Water Logging risk value also returned the value on a scale of 1, then were transformed to a scale of 10.

Raster of risk was prepared using industrial point (x, y) location's risk factor data utilizing IDW interpolation method. The water logging risks were categorized into 5 classes- Very low, low, medium, high & very high for mapping. These risk maps of Kalurghat and KEPZ Area are presented in the following Figure 6-23 to Figure 6-28 for Kalurghat and KEPZ Area for different return periods.



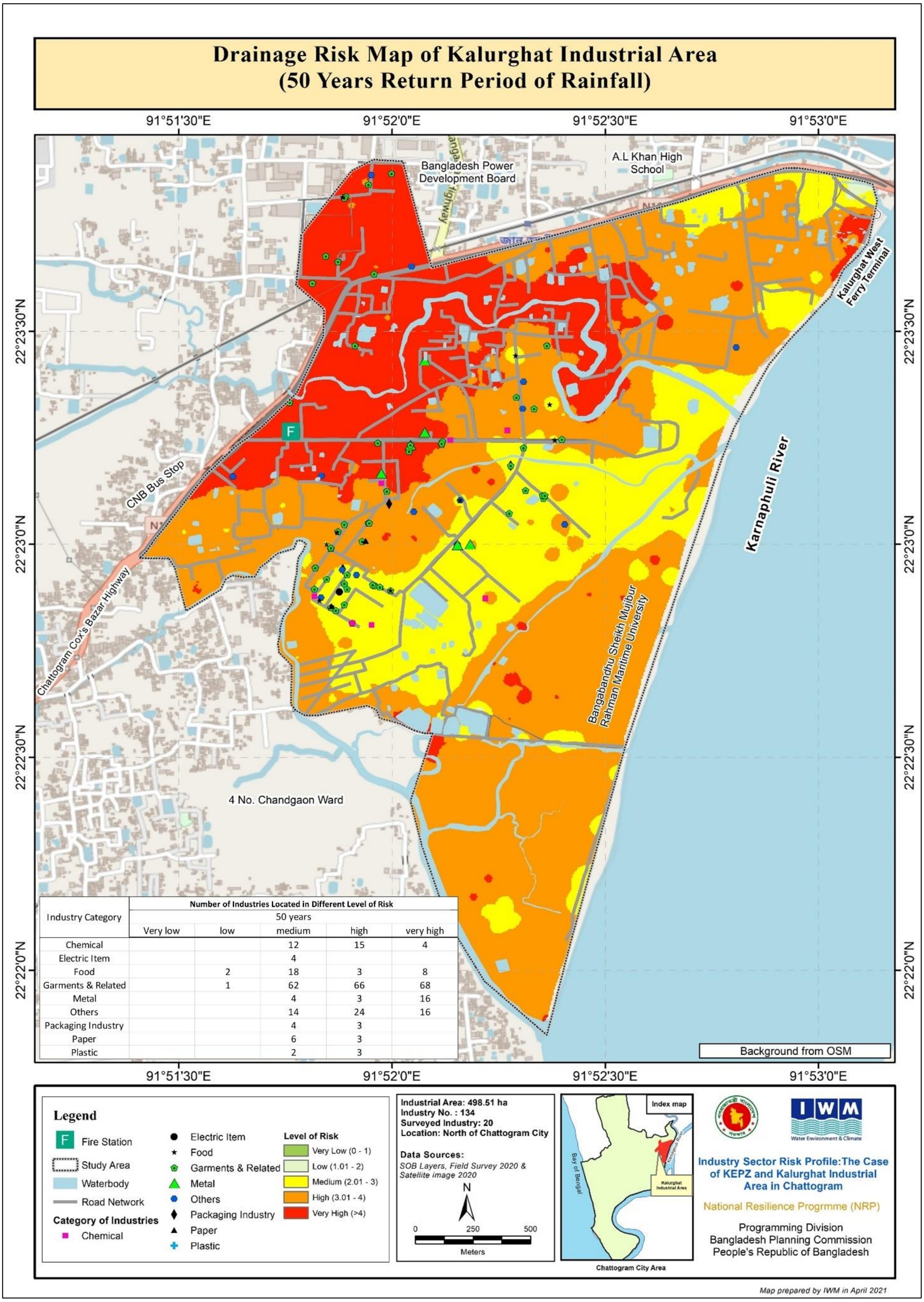
Industry Category	Number of Industries Located in Different Level of Risk				
	Average year (2.33)				
	Very low	low	medium	high	very high
Chemical	12				
Electric Item	2				
Food	14				
Garments & Related	71				
Metal	7				
Others	19				
Packaging Industry	3				
Paper	4				
Plastic	2				

Figure 6-23: Avg.-year Water Logging Risk Map, Kalurghat Study Area



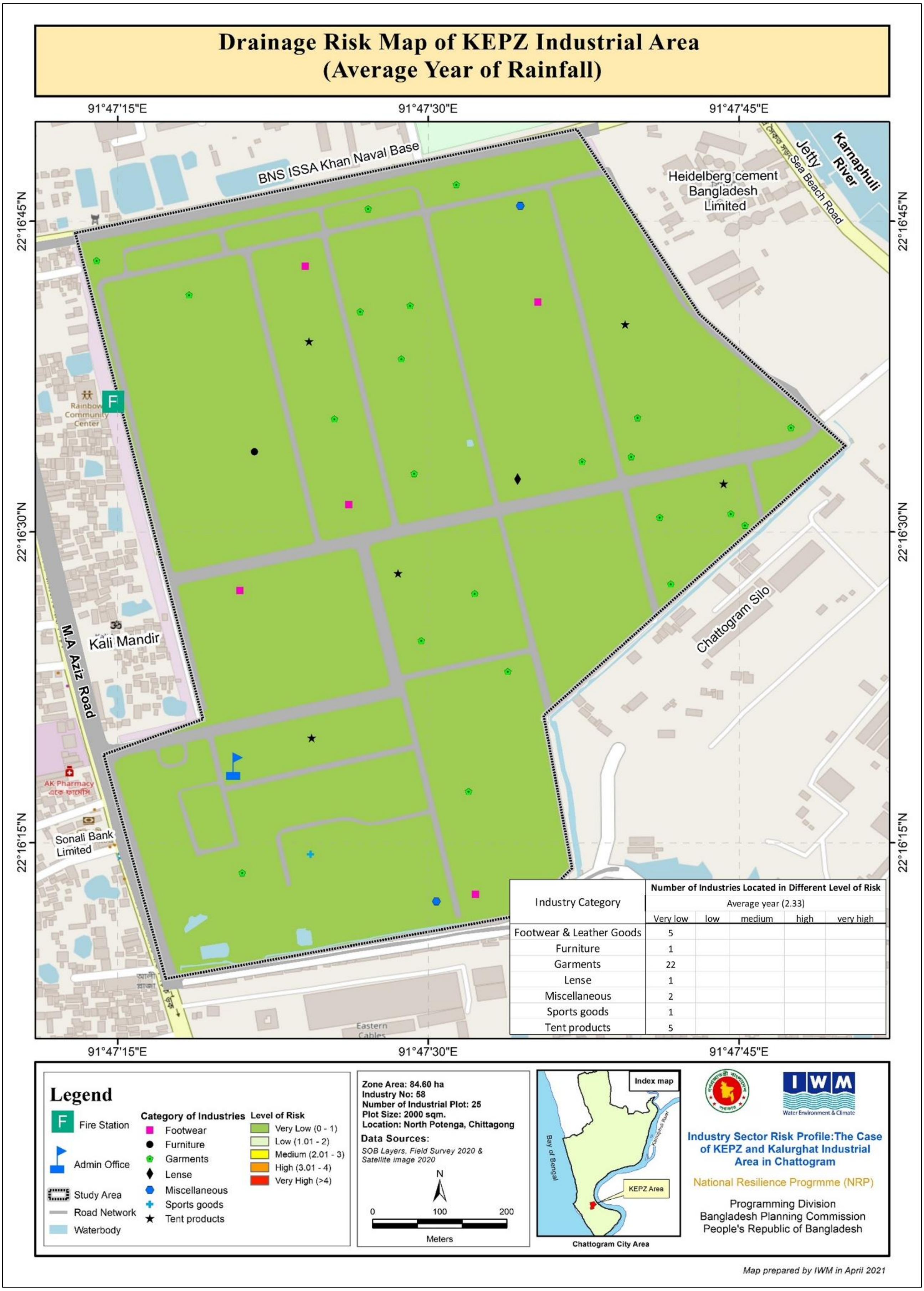
Industry Category	Number of Industries Located in Different Level of Risk				
	25 years				
	Very low	low	medium	high	very high
Chemical		11	1		
Electric Item		2			
Food	2	12			
Garments & Related	1	59	11		
Metal		3	3	1	
Others		15	4		
Packaging Industry		3			
Paper		4			
Plastic		2			

Figure 6-24: 1 in 25-year Water Logging Risk Map, Kalurghat Study Area



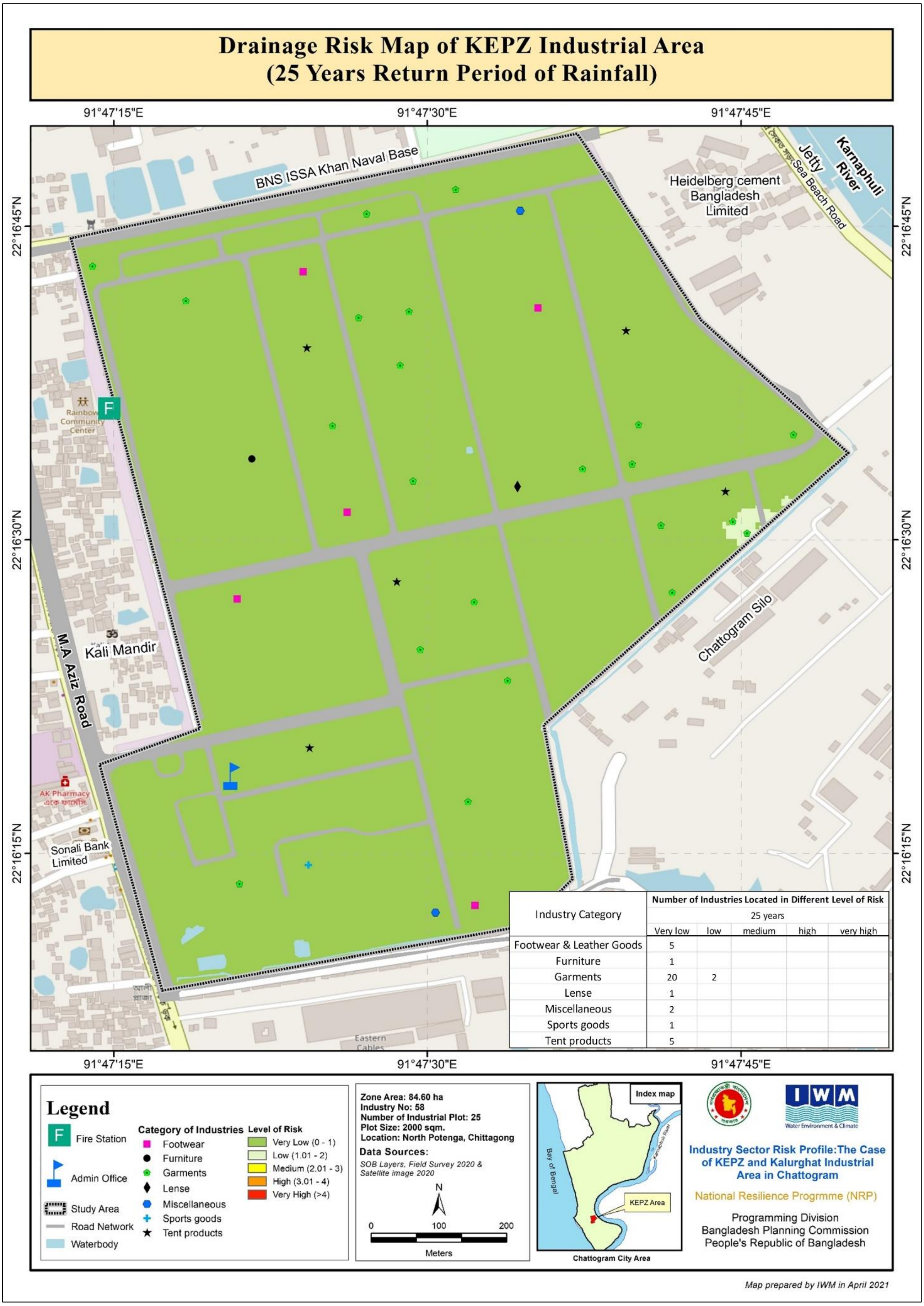
Industry Category	Number of Industries Located in Different Level of Risk				
	50 years				
	Very low	low	medium	high	very high
Chemical			12	15	4
Electric Item			4		
Food		2	18	3	8
Garments & Related		1	62	66	68
Metal			4	3	16
Others			14	24	16
Packaging Industry			4	3	
Paper			6	3	
Plastic			2	3	

Figure 6-25: 1 in 50-year Water Logging Risk Map, Kalurghat Study Area



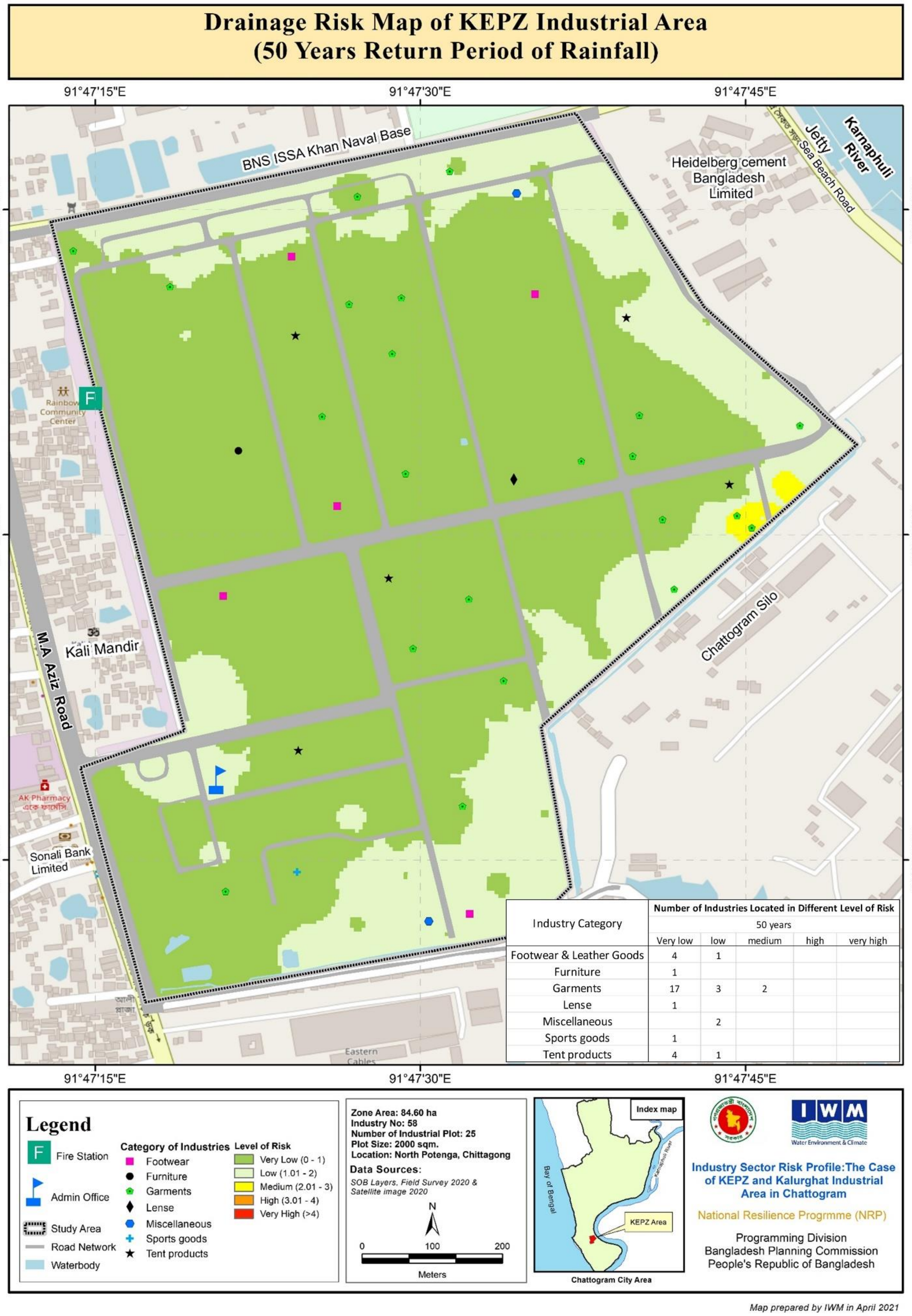
Industry Category	Number of Industries Located in Different Level of Risk				
	Average year (2.33)				
	Very low	low	medium	high	very high
Footwear & Leather Goods	5				
Furniture	1				
Garments	22				
Lense	1				
Miscellaneous	2				
Sports goods	1				
Tent products	5				

Figure 6-26: Avg-year Water Logging Risk Map, KEPZ Study Area



Industry Category	Very low	low	medium	high	very high
Footwear & Leather Goods	5				
Furniture	1				
Garments	20	2			
Lense	1				
Miscellaneous	2				
Sports goods	1				
Tent products	5				

Figure 6-27: 1 in 25-year Water Logging Risk Map, KEPZ Study Area



Industry Category	Number of Industries Located in Different Level of Risk				
	50 years				
	Very low	low	medium	high	very high
Footwear & Leather Goods	4	1			
Furniture	1				
Garments	17	3	2		
Lense	1				
Miscellaneous		2			
Sports goods	1				
Tent products	4	1			

Figure 6-28: 1 in 50-year Water Logging Risk Map, KEPZ Study Area

6.3 Cyclone Risk Profile

For this study, Storm Surge Model has been used in three scenarios (in 2.33, 25 and 50-year return period) using 1D hydrodynamic model. After analyzing the inundations of these scenarios, the 50-year cyclone has been assigned cyclone hazard score(H) of 1, other cyclone hazard scores were calculated in correspondence with the 50-year cyclone is presented in the following Table 6-9.

Table 6-9: Cyclone hazard scoring in different return period

Sl. No.	Scenario ID	Return Period (Year)	Cyclone Hazard score (H)
1	Cyclone scenario-1	2.33	0.0466
2	Cyclone scenario-2	25	0.5
3	Cyclone scenario-3	50	1

6.3.1 Cyclone Vulnerability Assessment

Cyclone vulnerability is defined as how people or societies are likely to be affected by cyclone events, that is the sensitivity of the community, industries or people to cyclones considering the socio-economic, environmental and physical component.

Eight vulnerability indicators were considered to identify the cyclone vulnerability both for KEPZ and Kalurghat area:

1. Distance from coastline
2. Structural typology
3. Roof type
4. Number of floors
5. Construction Year/age
6. Drainage Condition
7. Plinth Height
8. State of maintenance

After identifying these indicators, weightages were assigned according to the impact of these variables, based on expert opinion and lessons learned from field experience. Weighted list of these factors is presented in Table 6-10.

Table 6-10: Cyclone vulnerability factors and weightage

Cyclone Vulnerability factors	Weighted Value
Distance from coastline	0.33
Structural typology	0.2
Roof type	0.16
Number of floors	0.15
Construction Year/age	0.05
Drainage Condition	0.05
Plinth Height	0.03
State of maintenance	0.03

In the next step, observed indicator data were assigned to a normalized value as shown in Table 6-11 below.

Table 6-11: Normalization of cyclone vulnerability indicators

Distance from coastline		Structure typology		Roof type		No. of Floor		Constructio n Year		Drainage Condition		Plinth Height		State of maintenance	
OD	*AV*	*OD*	*AV*	*OD*	*AV*	*OD*	*AV*	*OD*	*AV*	*OD*	*AV*	*OD*	*AV*	*OD*	*AV*
<=2000	0.95	RCC	0.1	RCC	0.1	>=5	0.1	>=2006	0.33	No congestion	0.1	>=5	0.1	Excellent	0.1
2001-4000	0.9	Steel	0.2	Metal	0.3	4	0.25	1991-2005	0.67	Moderate	0.5	4-4.99	0.25	Good	0.5
4001-6000	0.85	URM	1			3	0.5	<=1990	1	Severe	1	3.01-3.99	0.5	Moderate	0.75
6001-8000	0.80					2	0.75					2.01-2.99	0.75	Poor	1
8001-10000	0.75					1	1					<=2	1		
10001-12000	0.7														
12001-14000	0.65														
>=14000	0.6														

*(*OD= Observed Data, AV = Assigned Value)*

Distance from coastline: The coastal areas are at the forefront to face the force of high-speed winds and storm surges associated with the cyclones originating from the Bay of Bengal, the closer the area to the coastline more is the probability being affected and vice versa (*Alam, Sammonds, & Ahmed - Science of The Total Environment - 2020*).

In this study, distances of every industry from the coastline were calculated in GIS, then divided into 8 (eight) categories, and assigned a value of scale 1 (one). Industries located nearer to the coastline were assigned the higher vulnerability scores.

Roof type: Contrary to popular belief, sometimes houses are blown over during the cyclone. Instead, they are pulled apart by winds moving swiftly around and over the building. Cyclones lowers the pressure on the outside and creates suction on the walls and roof, effectively causing the equivalent of an explosion. (*Ankush Agarwal, CYCLONE resistant building architecture, 2007*). Metal roofs are little more susceptible against wind and weather than RCC tops because of inadequate fastening devices, inadequate sheet thickness and insufficient frequencies of fasteners in the known areas of greater wind suction. Therefore, Metal and RCC roofs were assigned the vulnerable factors of 0.3 and 0.1 respectively. The Cyclone vulnerability maps are presented in Figure 6-29 and Figure 6-30.

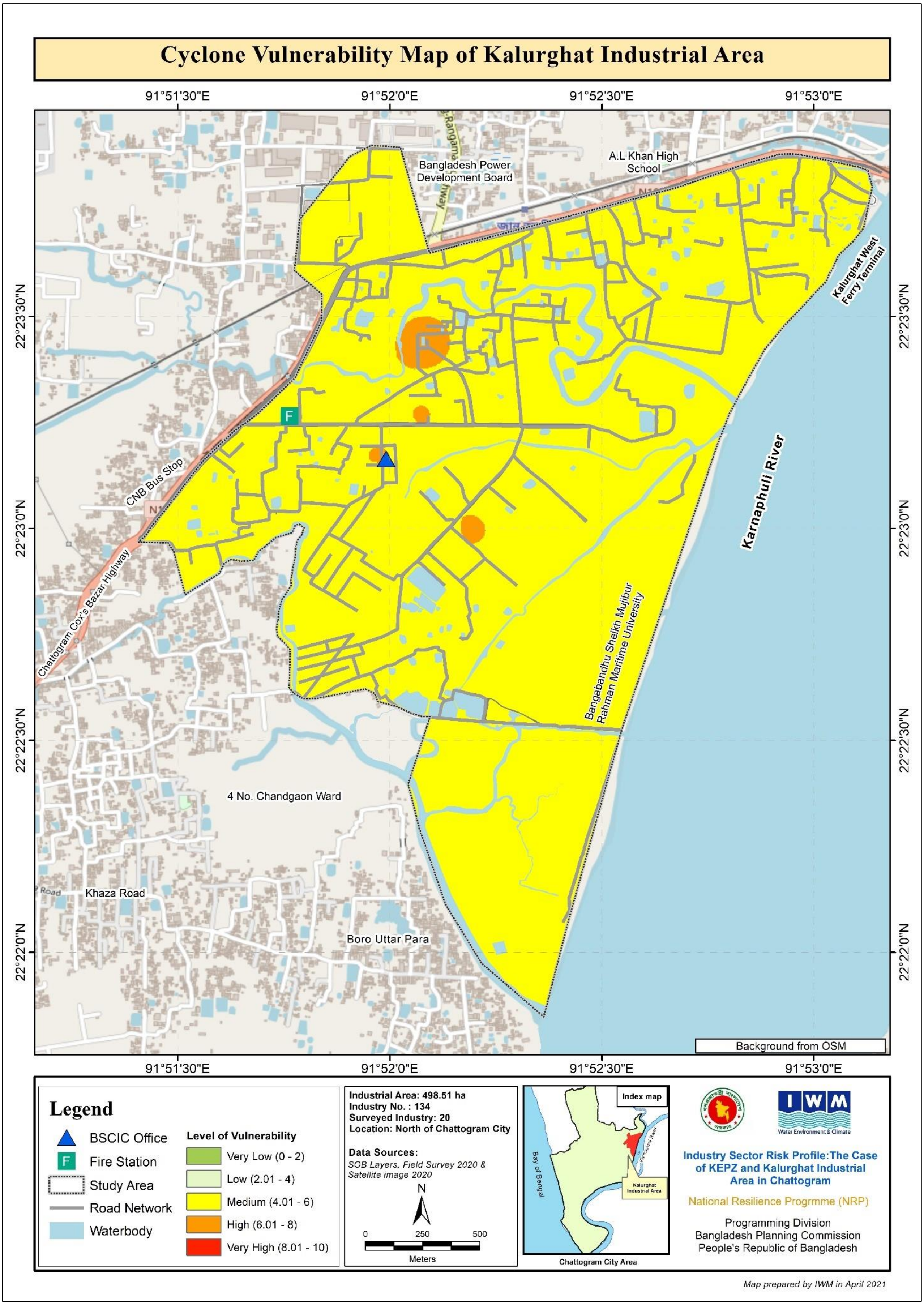


Figure 6-29: Cyclone Vulnerability Map, Kalurghat Study Area

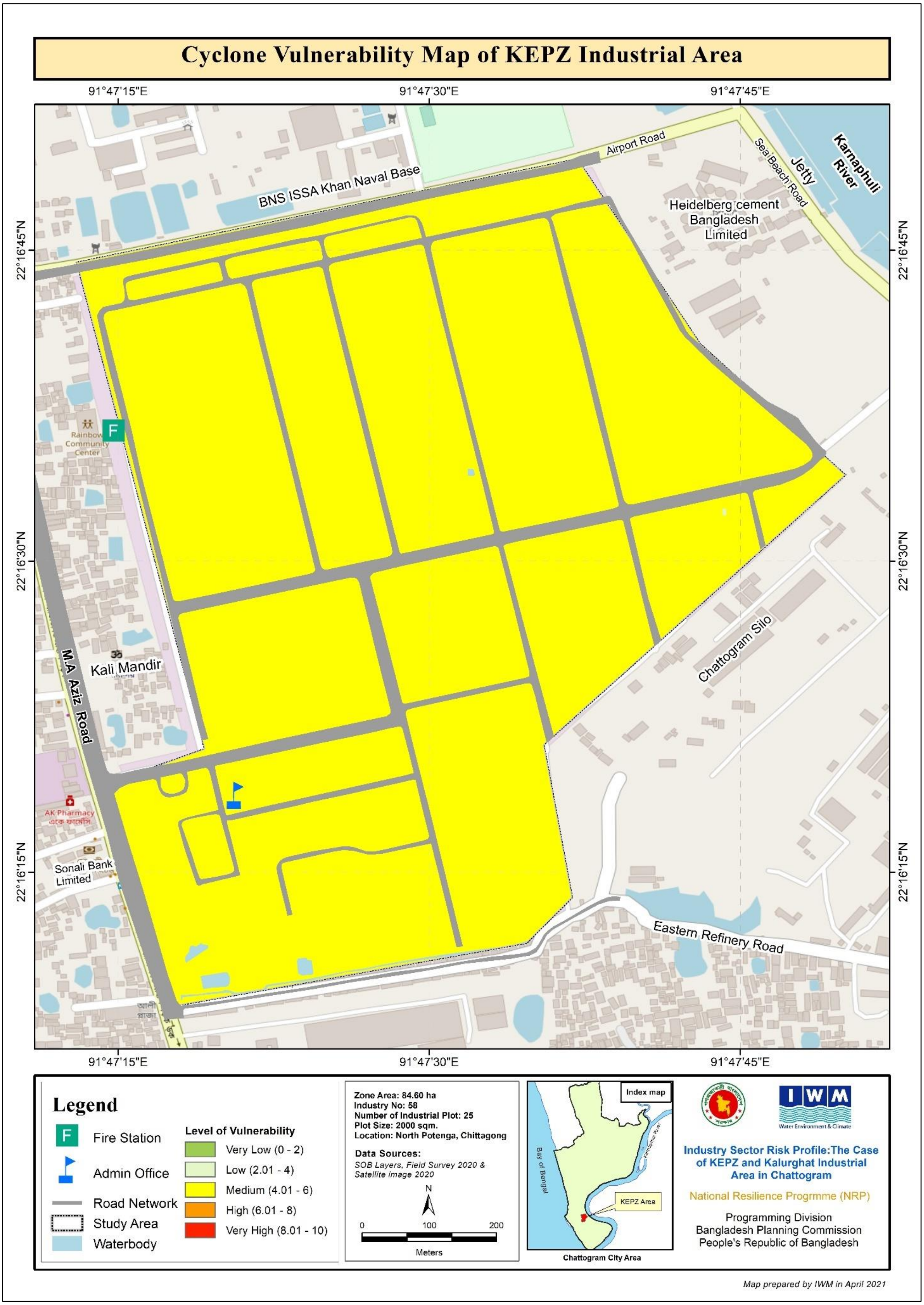


Figure 6-30: Cyclone Vulnerability Map, KEPZ Study Area

6.3.2 Cyclone Exposure Analysis

Cyclone exposure has been assessed by measuring the water depth in a particular location. This depth was calculated by subtracting the land elevation value from the water surge level returned from the hydrodynamic model for the corresponding scenario.

Water depth of every single industry was calculated for four Cyclone return periods 2.33, 25- and 50-year. After identifying the depths, these values are normalized as shown in Table 6-12 below.

Table 6-12: Cyclone exposure

Water Depth (m)	Normalized Value
0	0
0.01-1	0.2
1.01-2	0.4
2.01-3	0.6
3.01-4	0.8
>4	1

The prepared Cyclone exposure maps are presented in Figure 6-31 to Figure 6-36.

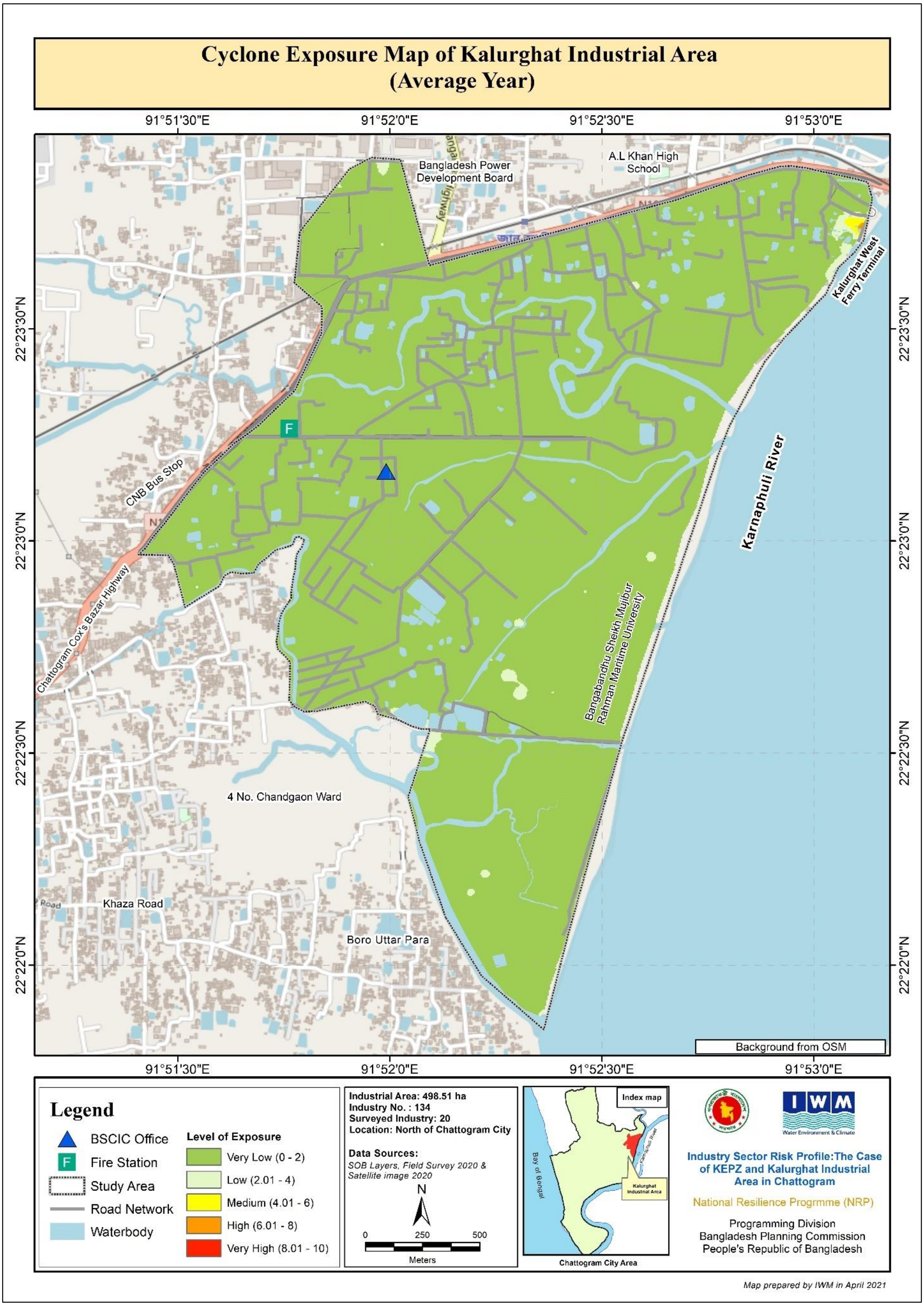


Figure 6-31: Avg.-year Cyclone Exposure Map, Kalurghat Study Area

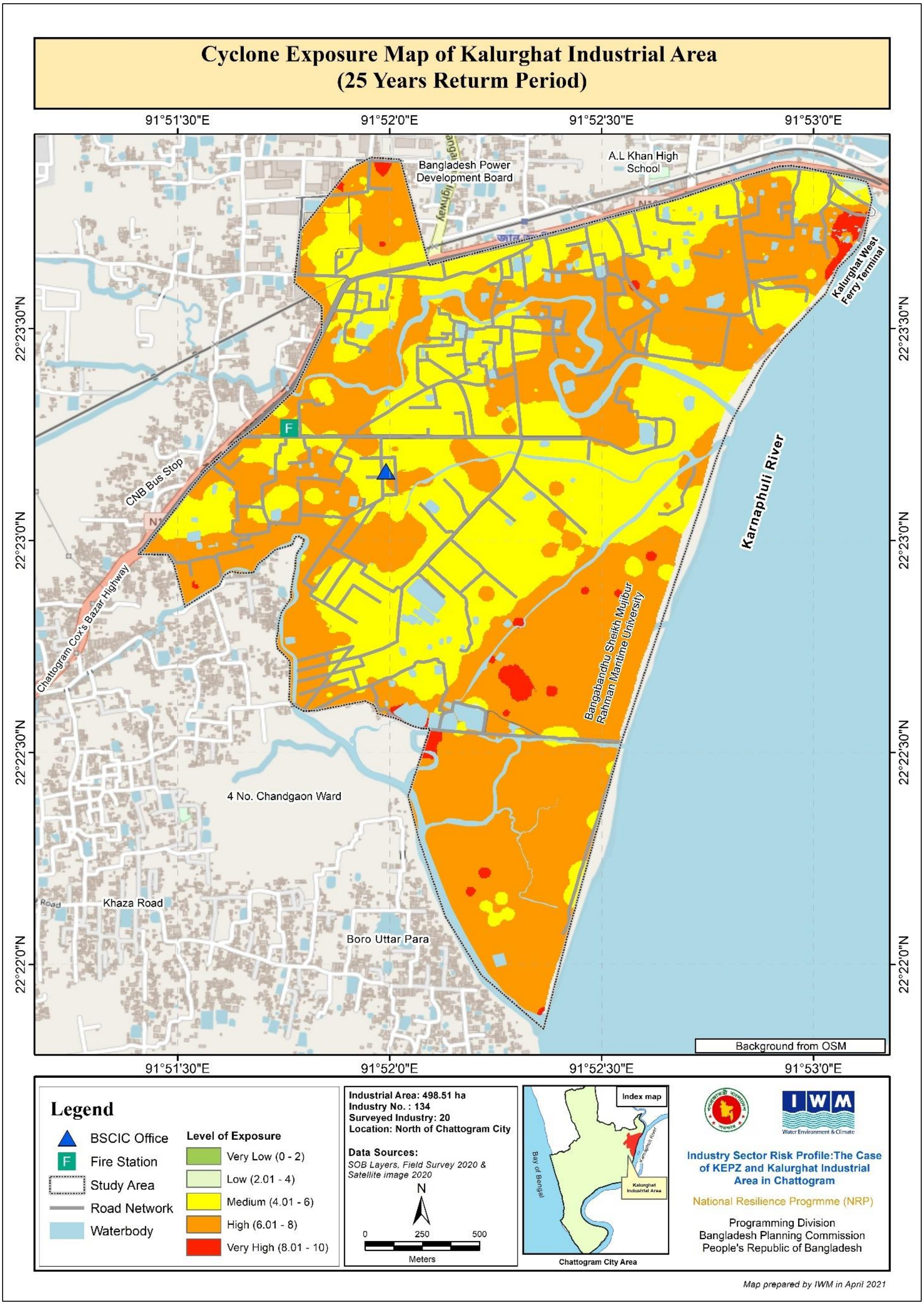


Figure 6-32: 1 in 25-year Cyclone Exposure Map, Kalurghat Study Area

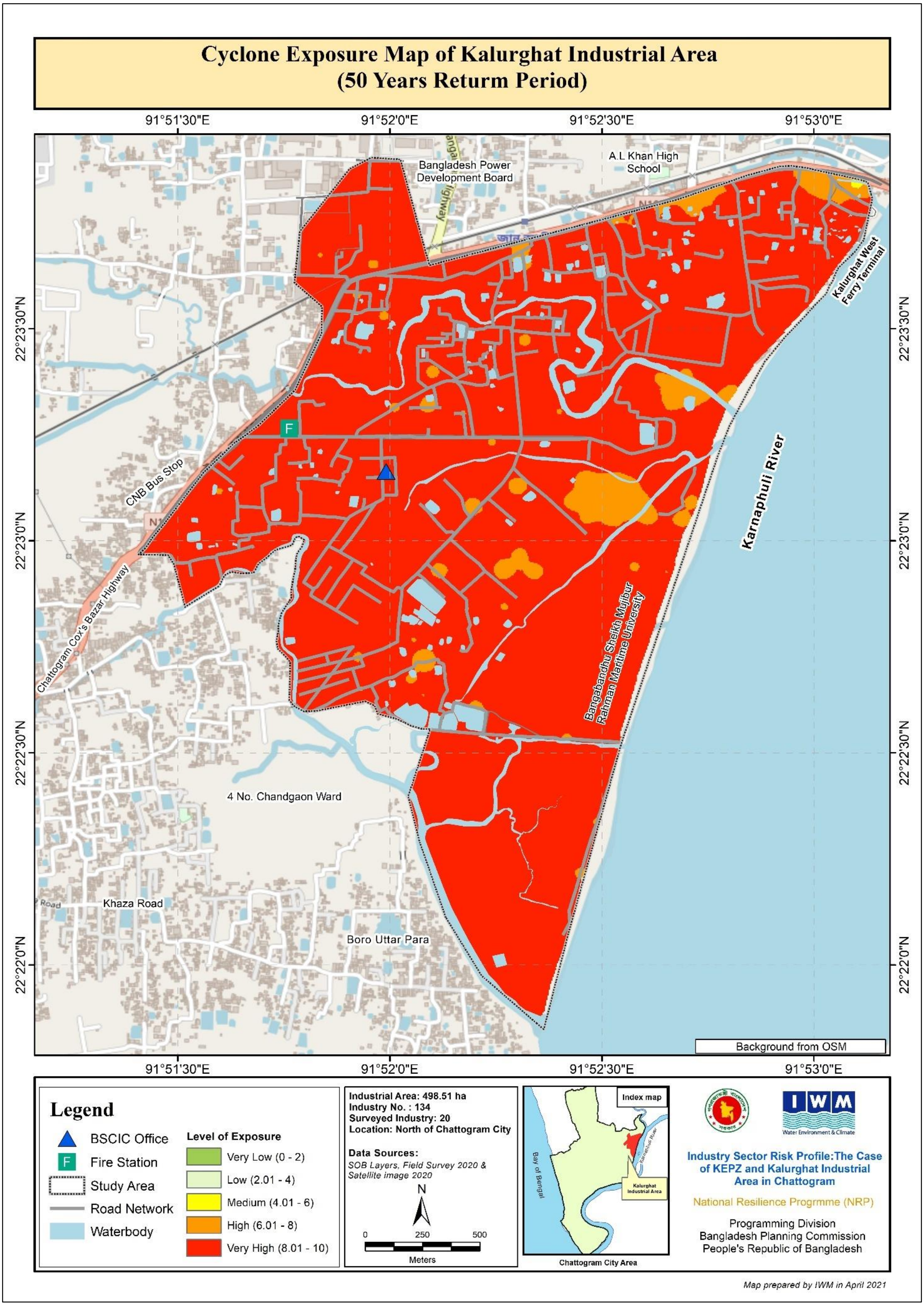


Figure 6-33: 1 in 50-year Cyclone Exposure Map, Kalurghat Study Area

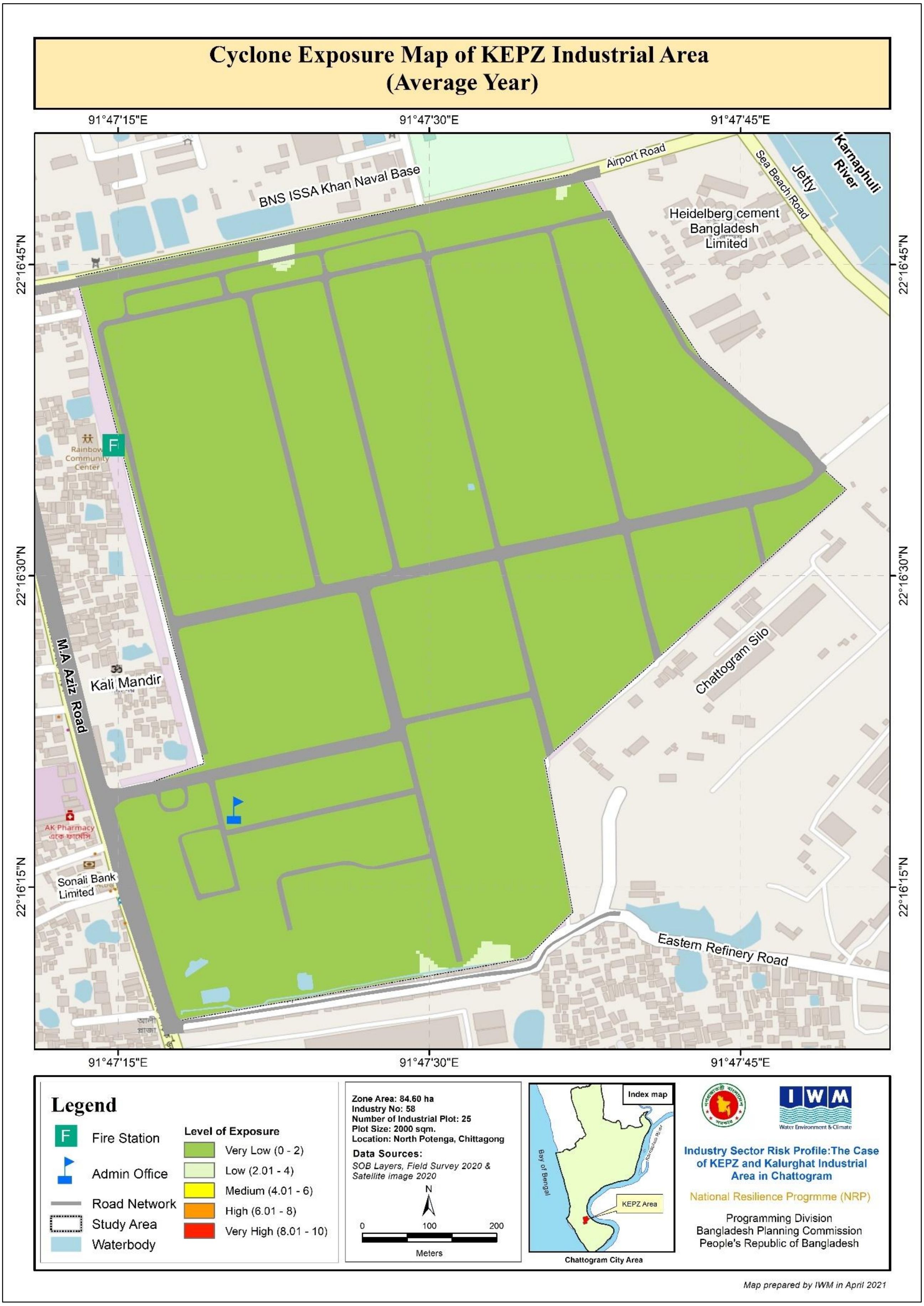


Figure 6-34: Avg.-year Cyclone Exposure Map, KEPZ Study Area

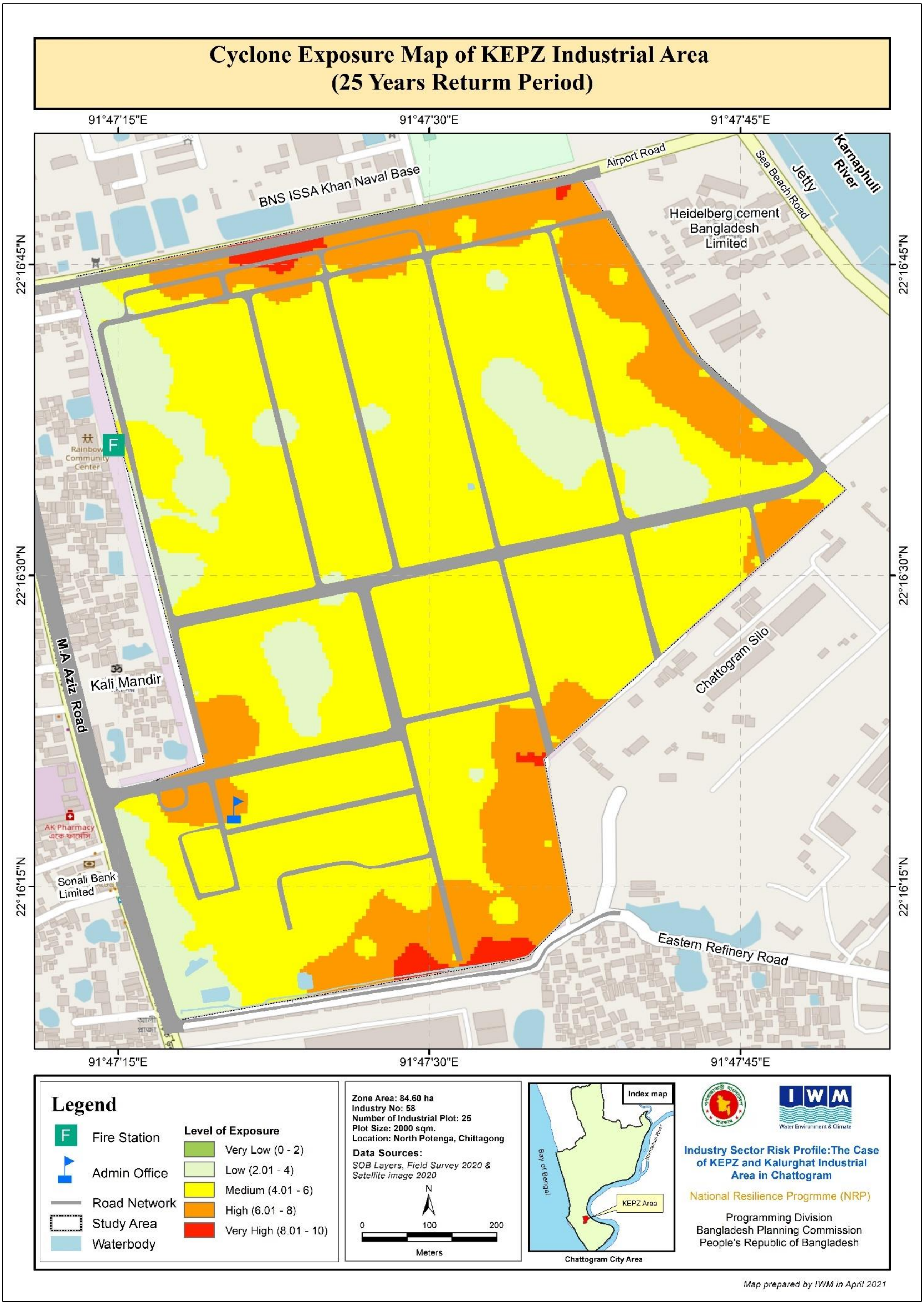


Figure 6-35: 1 in 25-year Cyclone Exposure Map, KEPZ Study Area

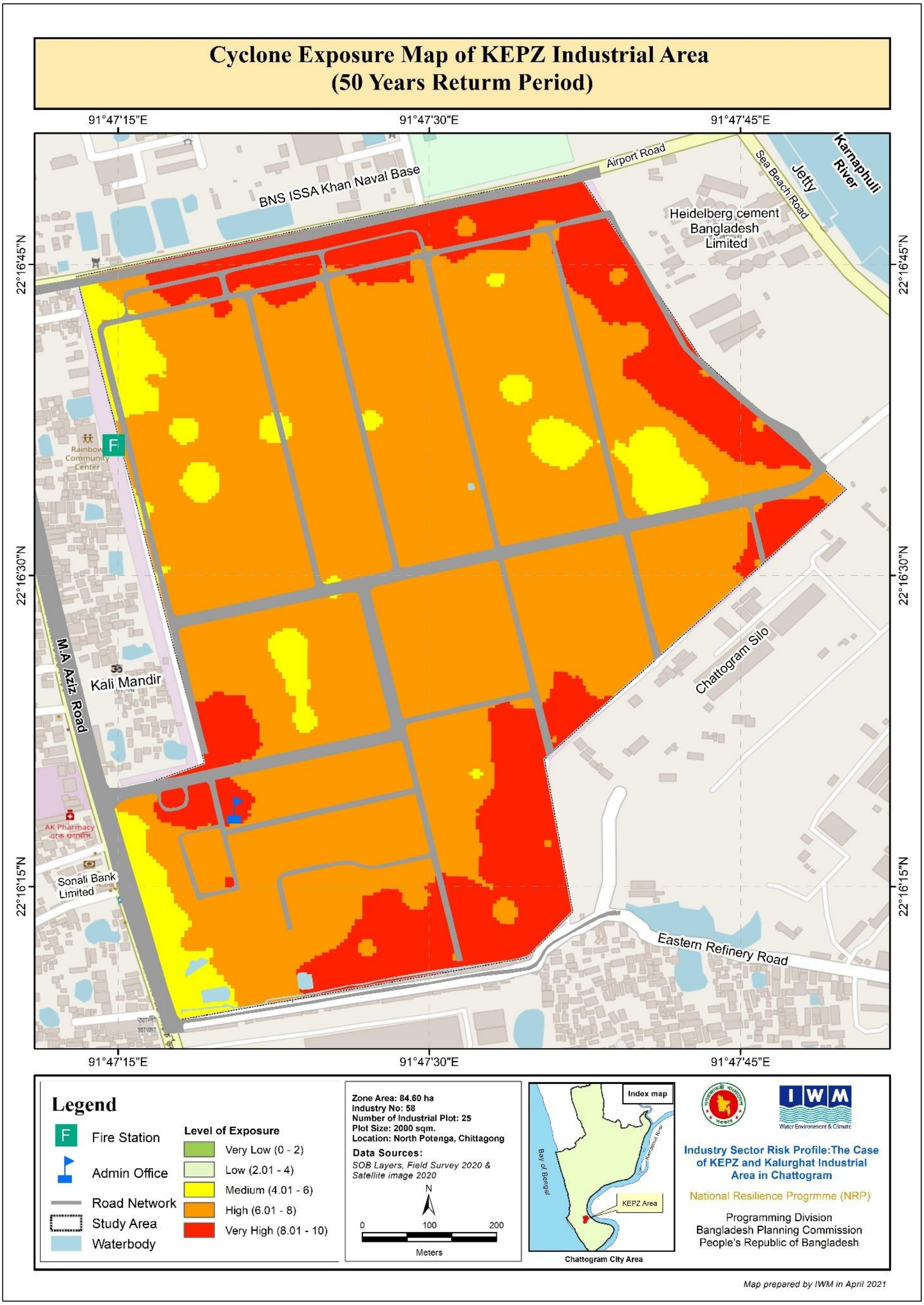


Figure 6-36: 1 in 50-year Cyclone Exposure Map, KEPZ Study Area

6.3.3 CYCLONE RISK

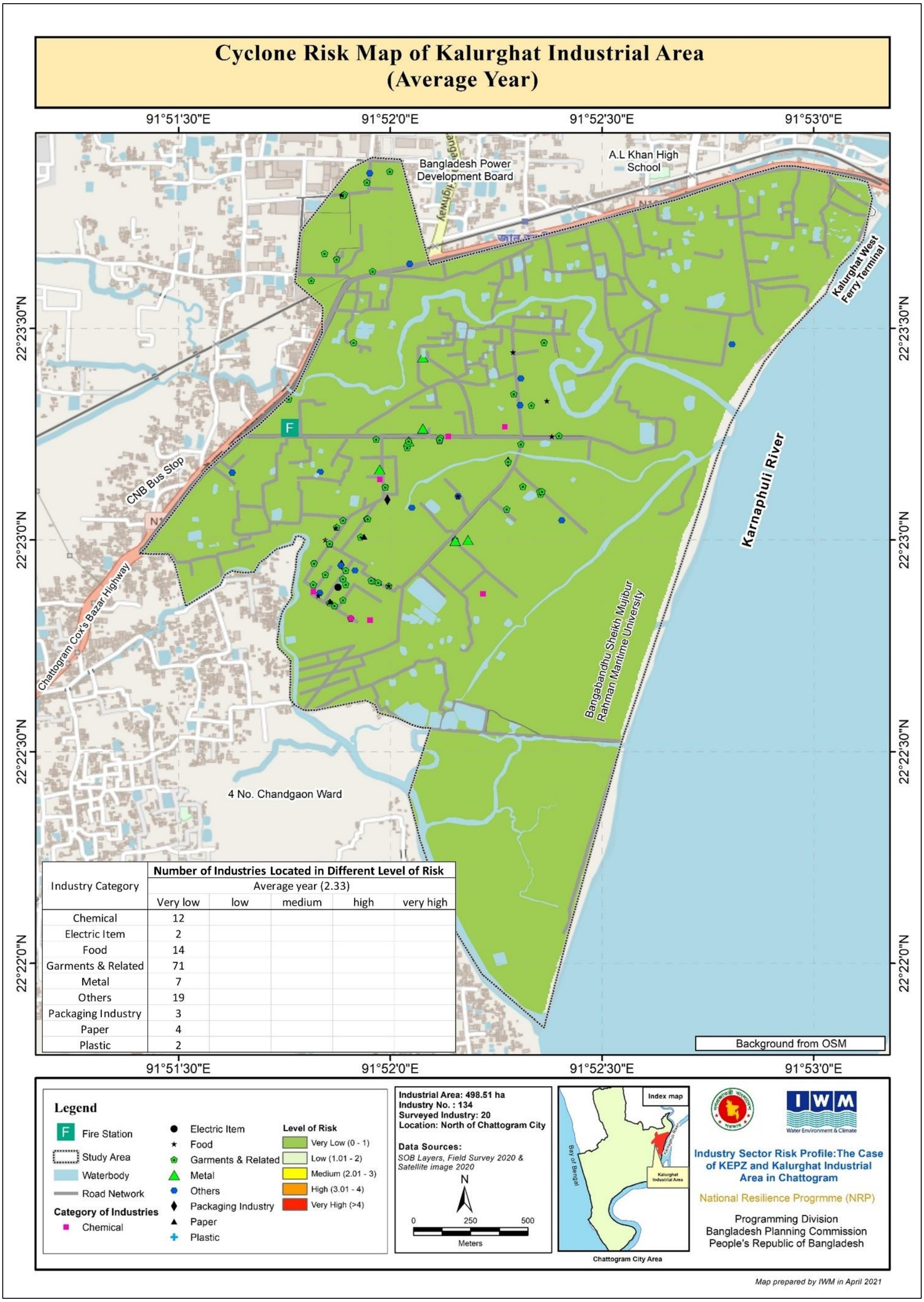
Cyclone Risk was estimated by multiplying three indicators of Hazard, Vulnerability and Exposure.

Cyclone Risk = Water Surge Hazard Score x Vulnerability score x Exposure(normalized)

As vulnerability and exposure returned values on a scale of 1, and hazard value was unitless, the cyclone risk value also returned the value on a scale of 1, then were transformed to a scale of 10.

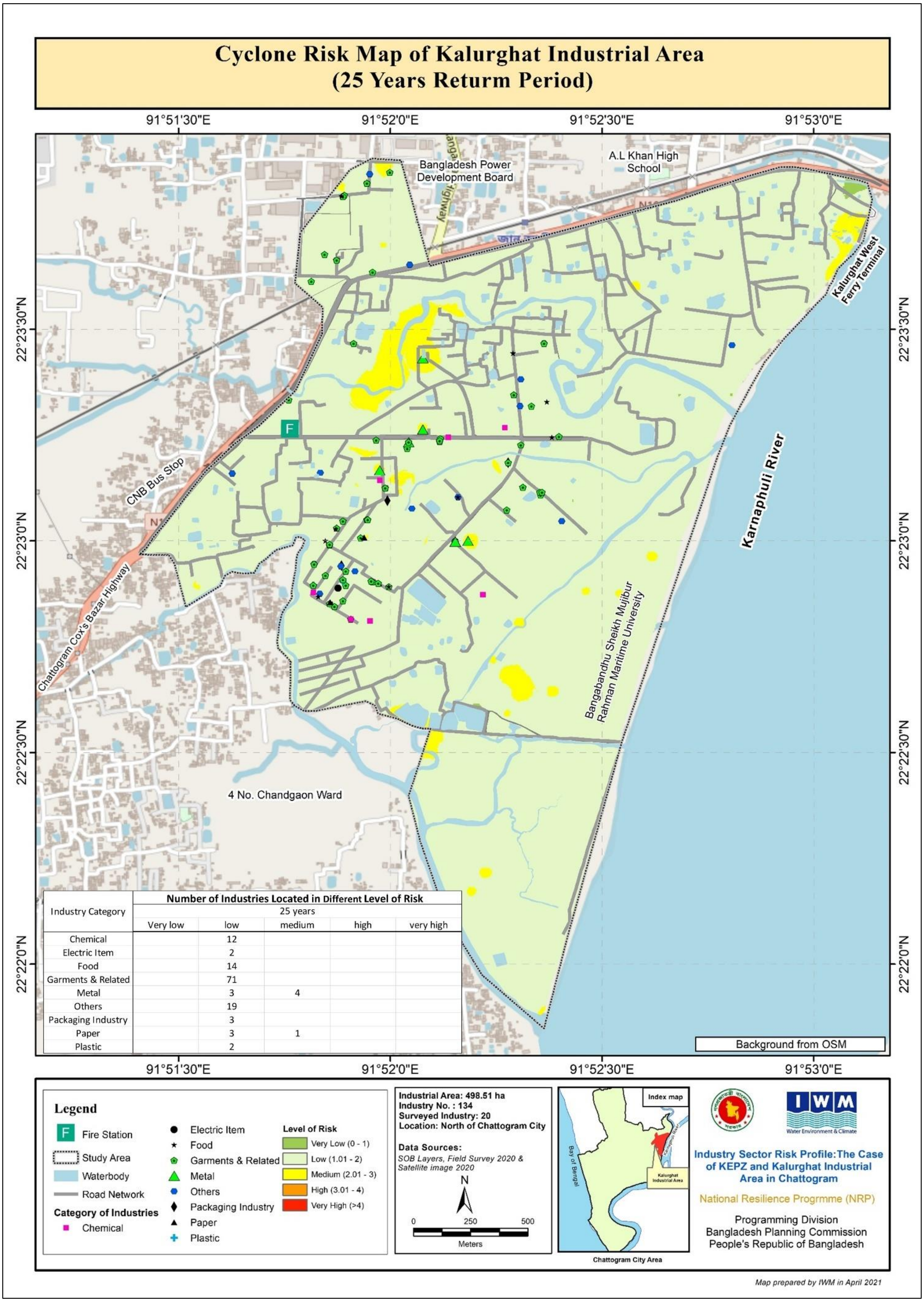
Raster of risk was prepared using industrial point locations (x, y), risk factor data utilizing IDW interpolation method in GIS environment. The Cyclone risk were categorized into 5 classes- Very low, low, medium, high & very high for mapping.

The prepared Cyclone Risk maps are presented in Figure 6-37 to Figure 6-39 for Kalurghat Area, and Figure 6-40, to Figure 6-42 for KEPZ area.



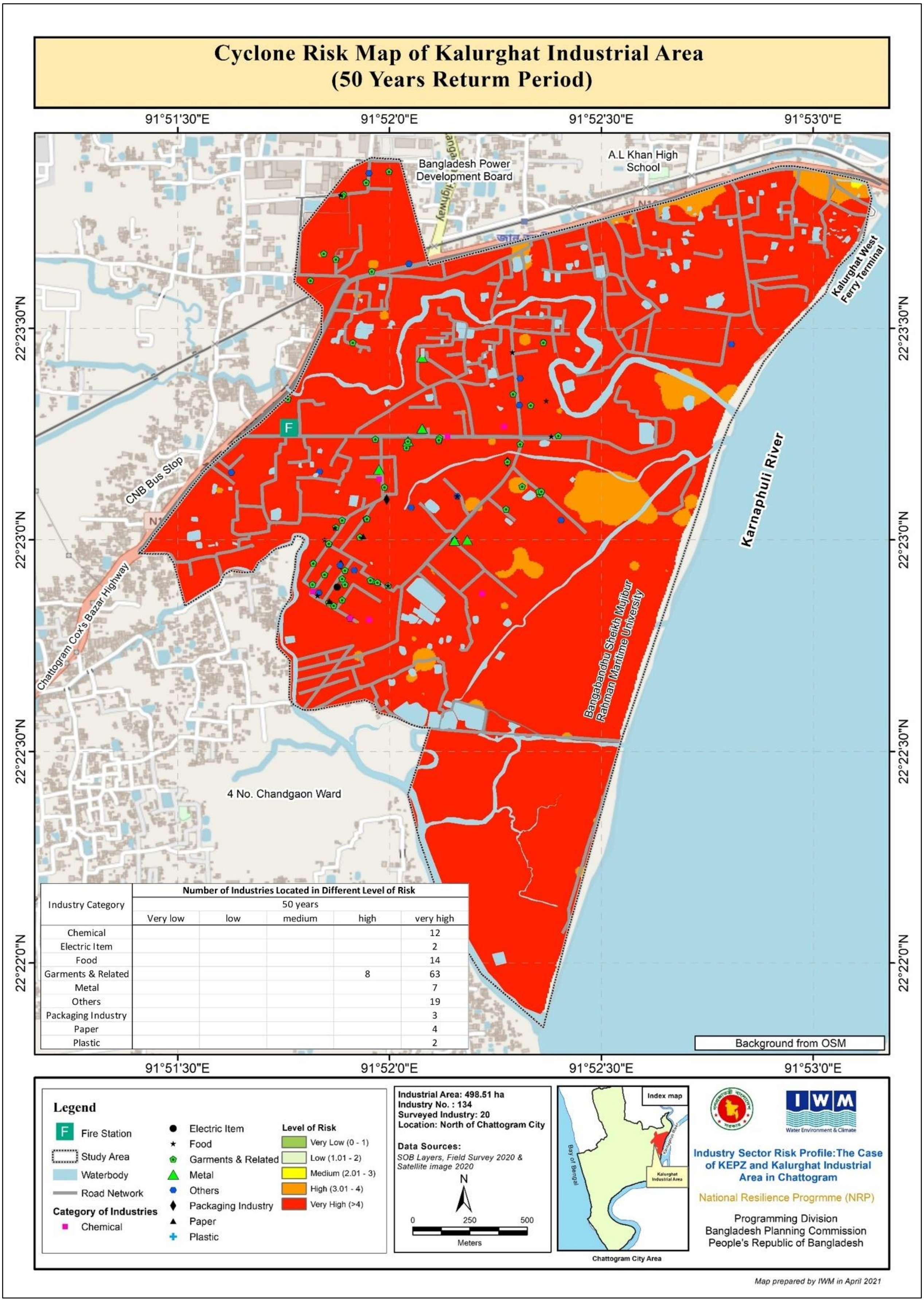
Industry Category	Number of Industries Located in Different Level of Risk				
	Average year (2.33)				
	Very low	low	medium	high	very high
Chemical	12				
Electric Item	2				
Food	14				
Garments & Related	71				
Metal	7				
Others	19				
Packaging Industry	3				
Paper	4				
Plastic	2				

Figure 6-37: Cyclone Risk Map of Kalurghat Industrial Area in Average year condition



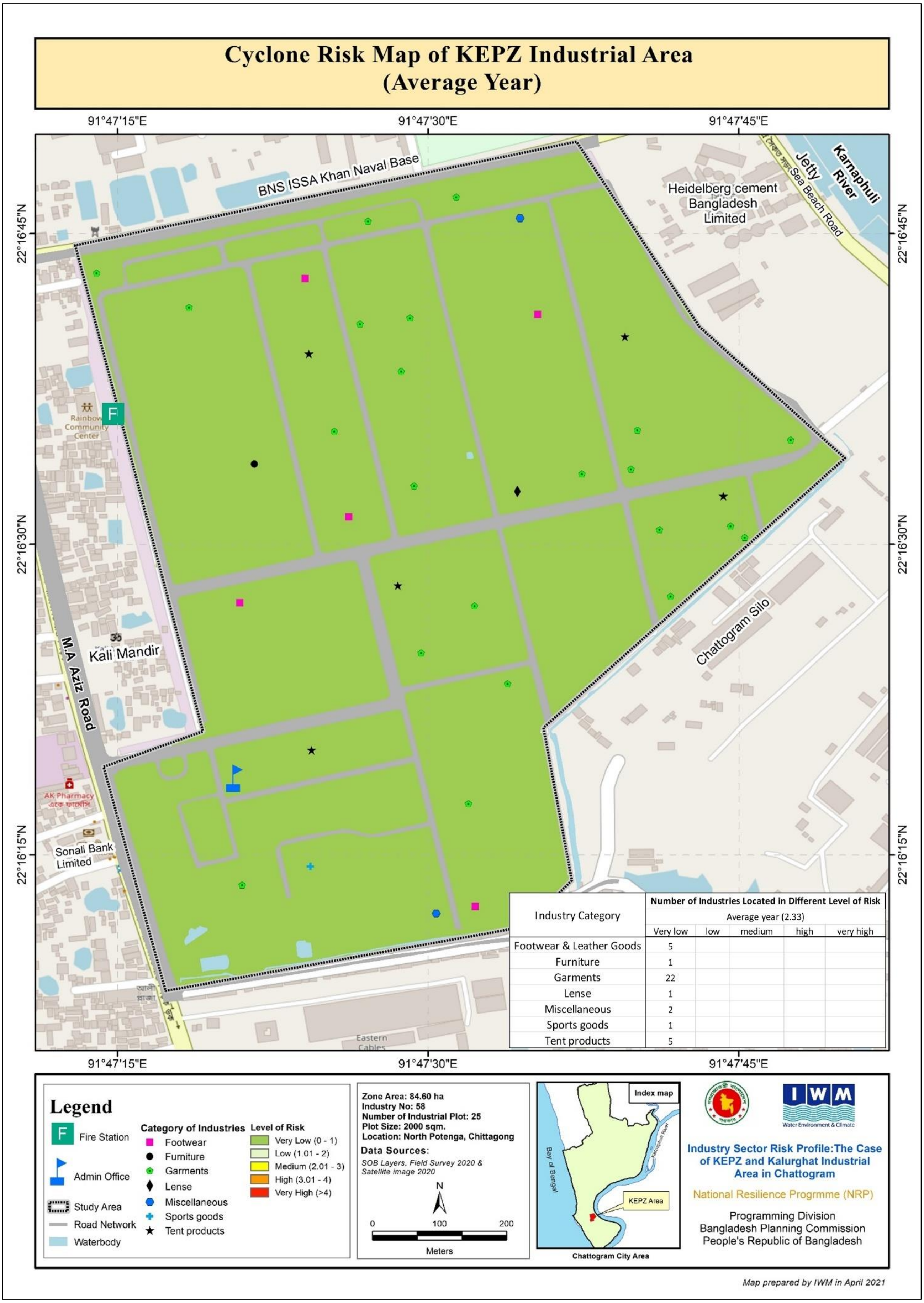
Industry Category	Number of Industries Located in Different Level of Risk				
	25 years				
	Very low	low	medium	high	very high
Chemical		12			
Electric Item		2			
Food		14			
Garments & Related		71			
Metal		3	4		
Others		19			
Packaging Industry		3			
Paper		3	1		
Plastic		2			

Figure 6-38: Cyclone Risk Map of Kalurghat Industrial Area at 1: 25-year return period



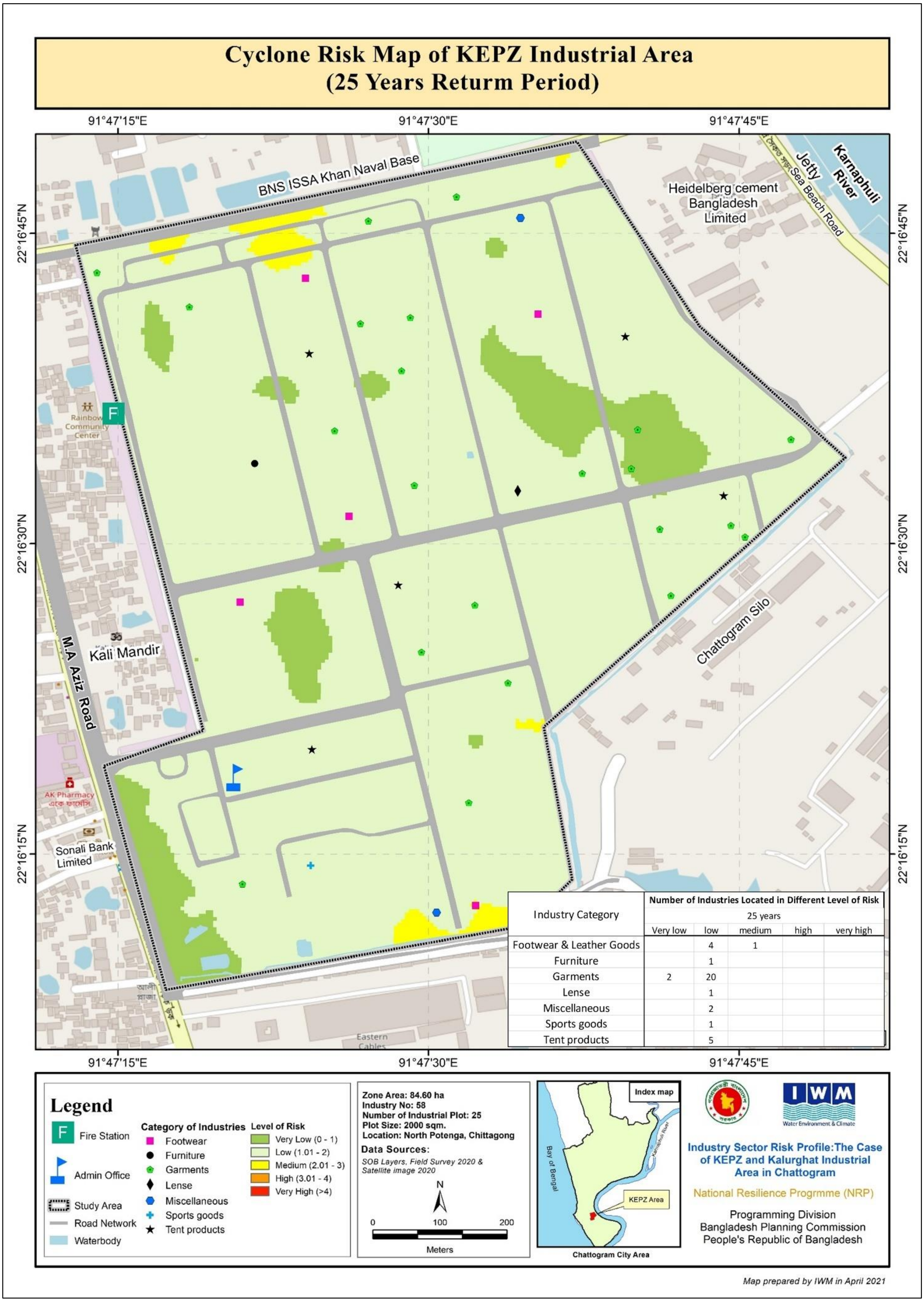
Industry Category	Number of Industries Located in Different Level of Risk				
	50 years				
	Very low	low	medium	high	very high
Chemical					12
Electric Item					2
Food					14
Garments & Related				8	63
Metal					7
Others					19
Packaging Industry					3
Paper					4
Plastic					2

Figure 6-39: Cyclone Risk Map of Kalurghat Industrial Area at 1: 50-year return period



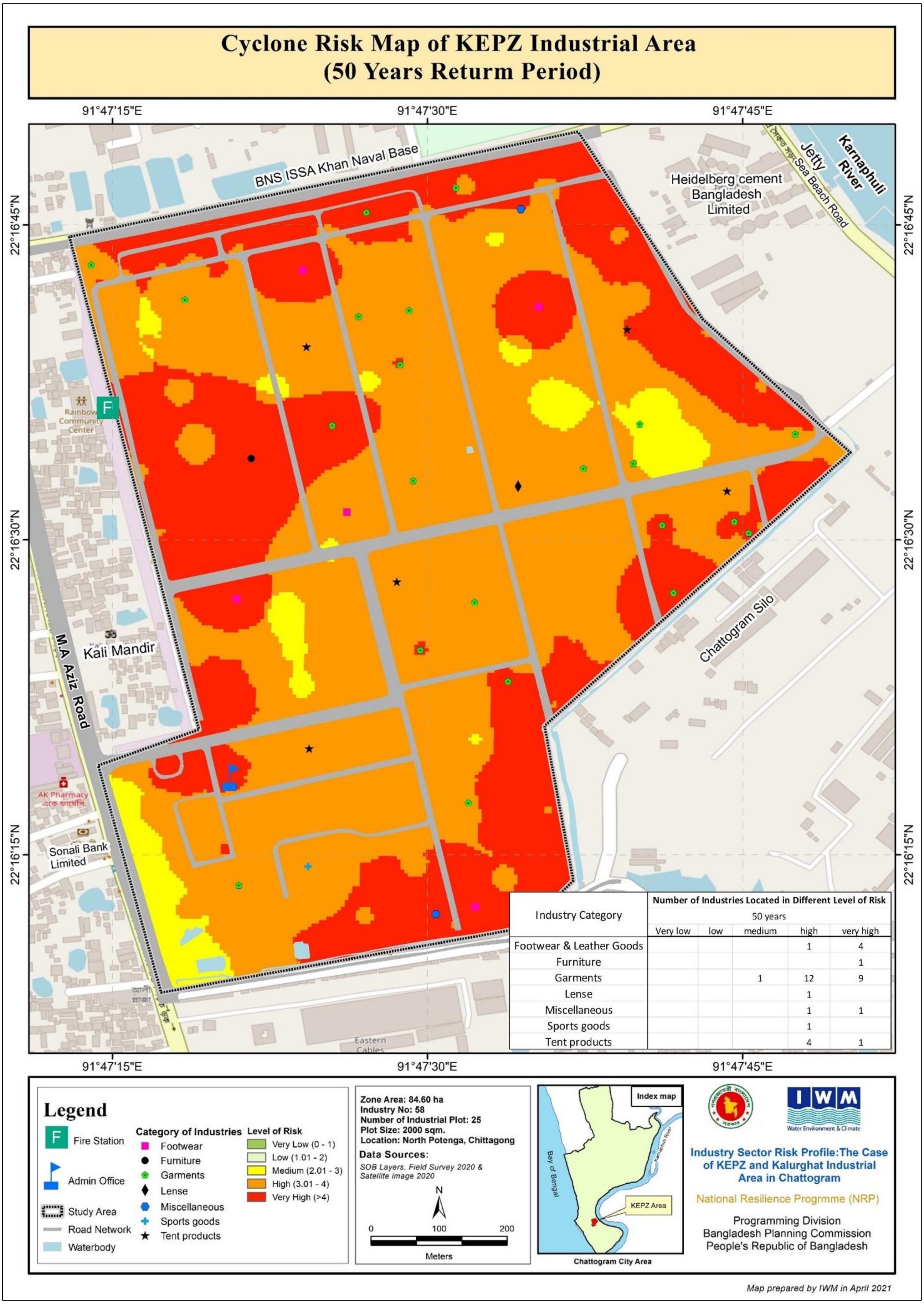
Industry Category	Number of Industries Located in Different Level of Risk				
	Average year (2.33)				
	Very low	low	medium	high	very high
Footwear & Leather Goods	5				
Furniture	1				
Garments	22				
Lense	1				
Miscellaneous	2				
Sports goods	1				
Tent products	5				

Figure 6-40: Cyclone Risk Map of KEPZ in Average year condition



Industry Category	Number of Industries Located in Different Level of Risk				
	25 years				
	Very low	low	medium	high	very high
Footwear & Leather Goods		4	1		
Furniture		1			
Garments	2	20			
Lense		1			
Miscellaneous		2			
Sports goods		1			
Tent products		5			

Figure 6-41: Cyclone Risk Map of KEPZ at 1: 25-year return period



Industry Category	Number of Industries Located in Different Level of Risk 50 years				
	Very low	low	medium	high	very high
Footwear & Leather Goods				1	4
Furniture					1
Garments			1	12	9
Lense				1	
Miscellaneous				1	1
Sports goods				1	
Tent products				4	1

Figure 6-42: Cyclone Risk Map of KEPZ 1: 50-year return period

6.4 SALINITY RISK PROFILE

KEPZ is located adjacent to the Karnaphuli river. During the field visit, it was informed that the EPZ draws water from the river throughout the wet seasons and is treated by the Water Treatment Plant (WTP) of KEPZ. A portion of water is also being supplied to the Chattogram EPZ (CEPZ).

On the other hand, during the dry seasons, KEPZ collects the required water from 22 number of wells (pumps) owned by the authority. No individual water pump is owned by any industries.

Both surface and groundwater contain different types of materials, mostly salt and iron. The WTP treats the water as per WASA guidelines for supplying to the industries. As KEPZ is self-dependent with their own water sources, hence the salinity risk profile was only applied for the Kalurghat Industrial area.

Output of the salinity model depended on discharge from the Kaptai dam in dry seasons in three return periods (average year, 25 and 50-Year). Developing a risk profile required salinity model results which are called the salinity hazards. The procedure of preparing the salinity risk profile is described below-

Use of salinity model Result: The Salinity model delivered the salinity along the river under different scenarios. The intensity of salinity near to the sea was the highest and vice versa. A series of points were generated along this line with an interval of 500 meter.

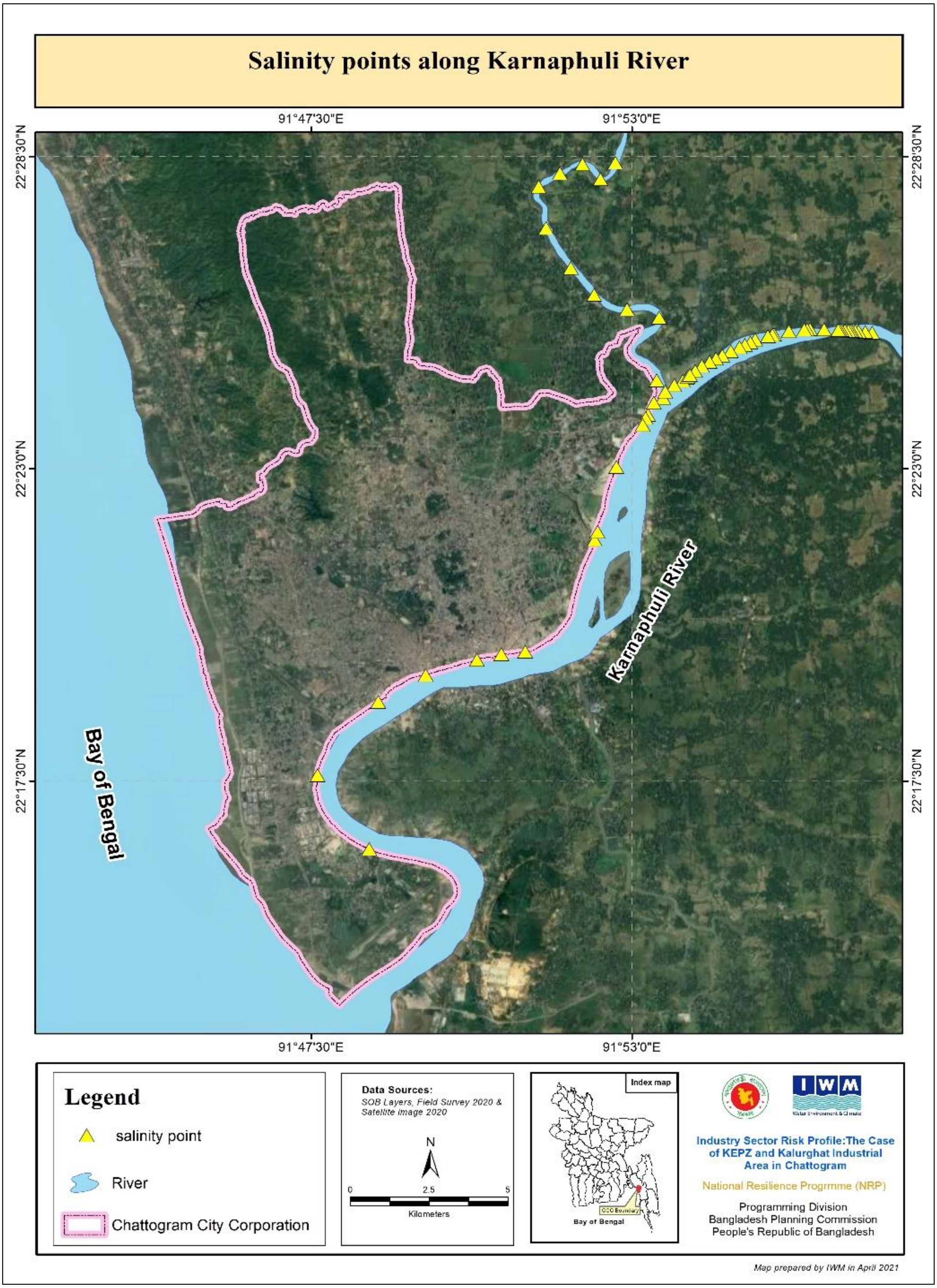


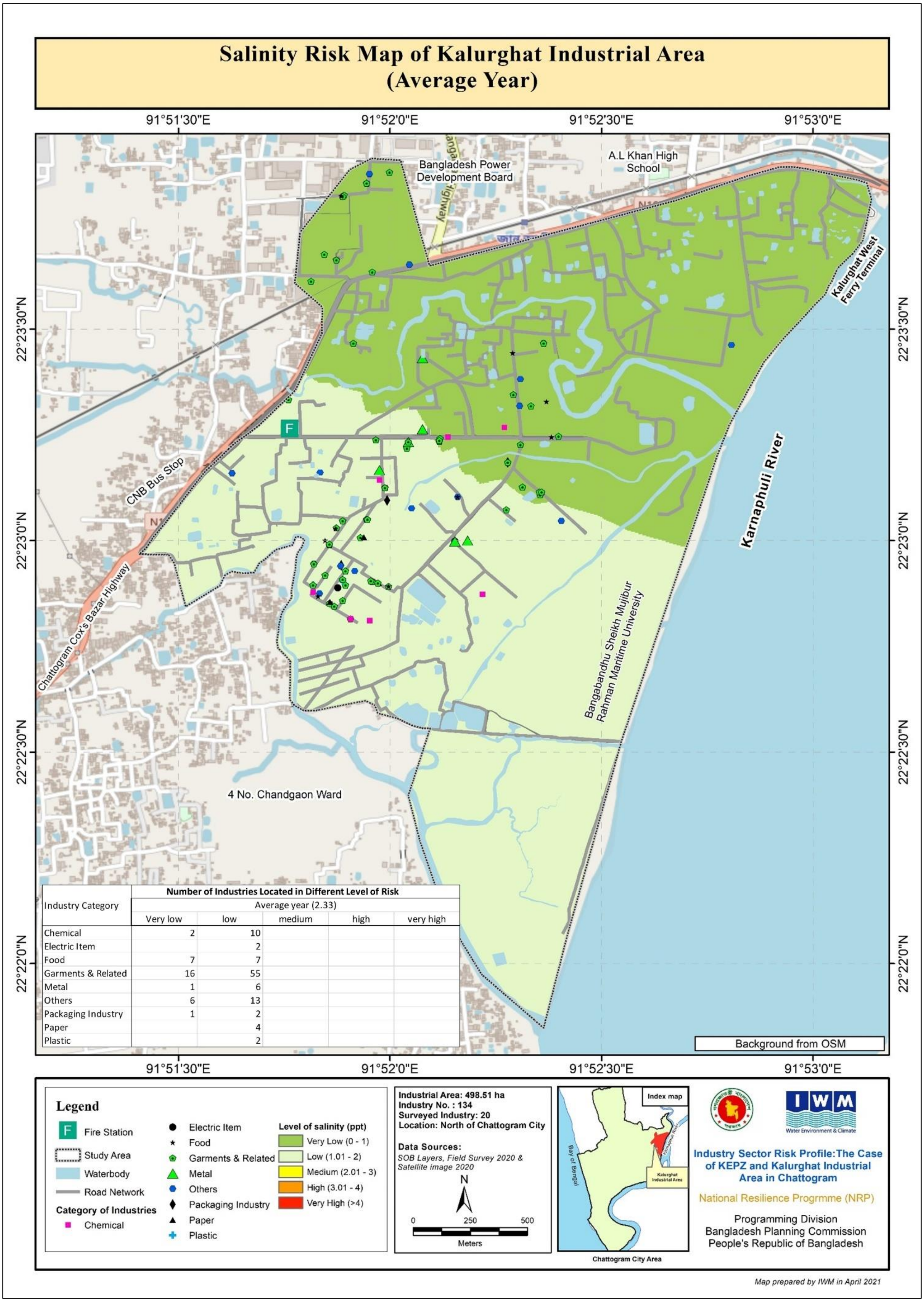
Figure 6-43: Salinity points along Karnaphuli River

Each of these point data contained salinity attribute of Avg-year, 1 in 25 year and 1 in 50-year salinity.

Creating industrial salinity profile:

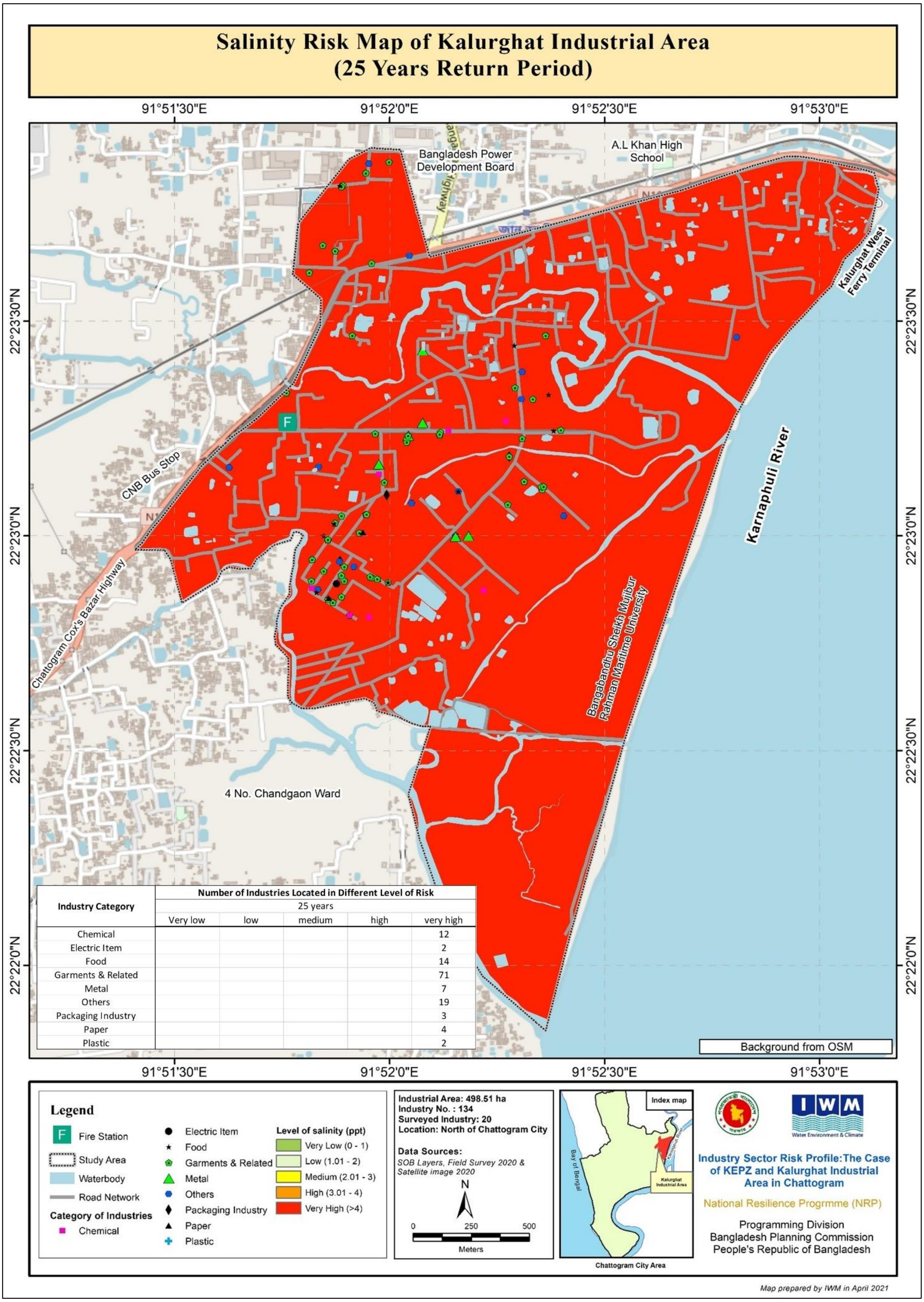
The salinity values are transferred from the river to each industrial location with the shortest distance from the industry to the Karnaphuli river considering each industry collects water from the nearest location of Karnaphuli river.

Preparation of Salinity Raster Data: With the corresponding salinity attribute, the industrial vector information was converted to raster data using Inverse distance weighted (IDW) interpolation method in GIS System for Kalurghat study area. The Salinity Risks maps of Kalurghat are showed in the following Figure 6-44, Figure 6-45 and Figure 6-46.



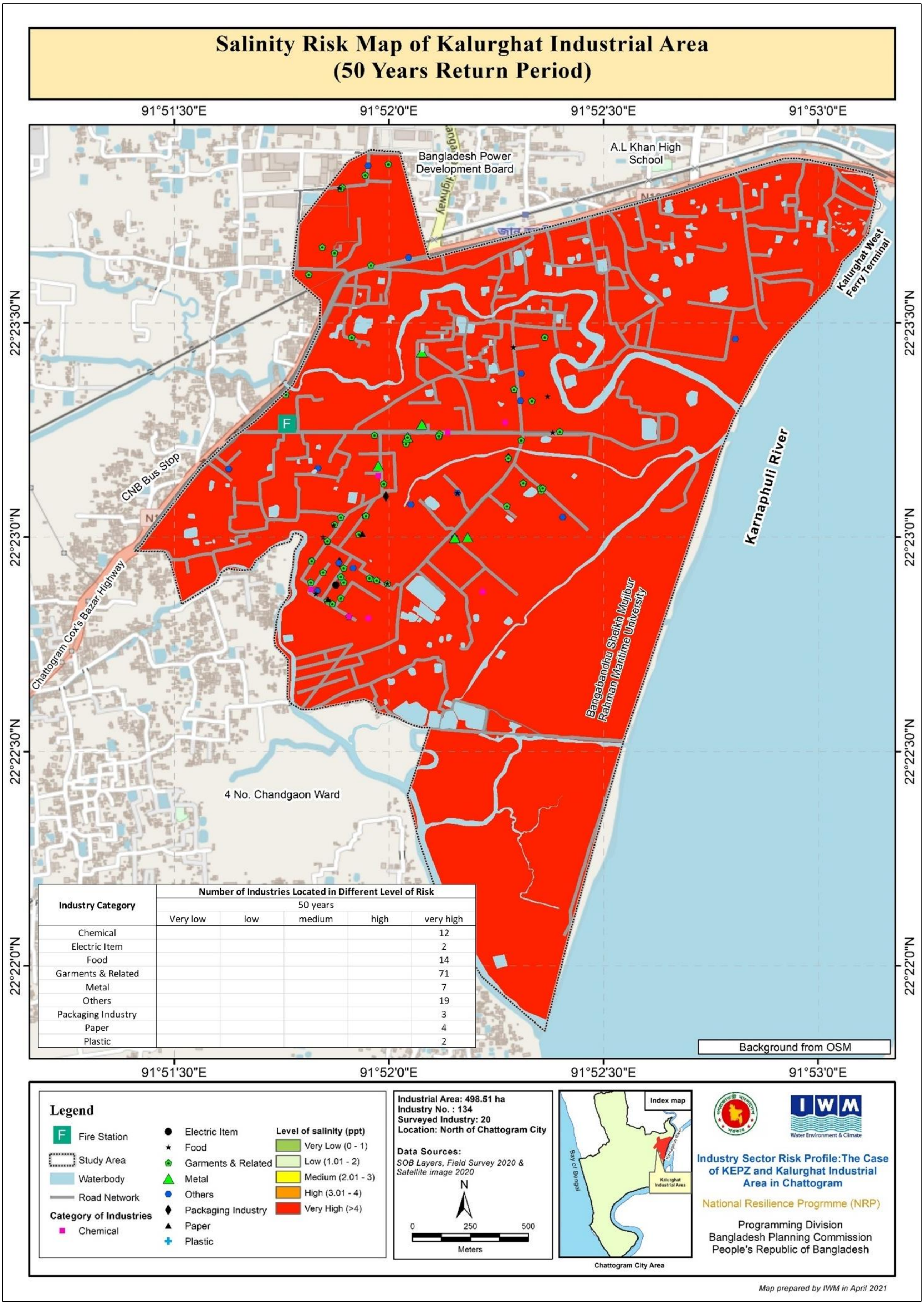
Industry Category	Number of Industries Located in Different Level of Risk				
	Average year (2.33)				
	Very low	low	medium	high	very high
Chemical	2	10			
Electric Item		2			
Food	7	7			
Garments & Related	16	55			
Metal	1	6			
Others	6	13			
Packaging Industry	1	2			
Paper		4			
Plastic		2			

Figure 6-44: Salinity Risk Map of Kalurghat Industrial Area for Average Year



Industry Category	Number of Industries Located in Different Level of Risk				
	25 years				
	Very low	low	medium	high	very high
Chemical					12
Electric Item					2
Food					14
Garments & Related					71
Metal					7
Others					19
Packaging Industry					3
Paper					4
Plastic					2

Figure 6-45: Salinity Risk Map of Kalurghat Industrial Area for 25 years



Industry Category	Number of Industries Located in Different Level of Risk				
	50 years				
	Very low	low	medium	high	very high
Chemical					12
Electric Item					2
Food					14
Garments & Related					71
Metal					7
Others					19
Packaging Industry					3
Paper					4
Plastic					2

Figure 6-46: Salinity Risk Map of Kalurghat Industrial Area for 50 years

6.5 FIRE RISK PROFILE

Significant loss to industries occurs through fire hazard. Whether large or small, fire causes personal suffering, damage to plants, equipment and buildings, and loss of business.

Fire risk can be assessed in many ways. In this study the external investigation in terms of accessibility and industry type was implied to assess the risk of fire.

Karnaphuli EPZ area was developed as an Industrial area therefore most of the industries are well equipped with fire safety logistic and certification. The IWM team found very little problem during the field visit in KEPZ. On the contrary, Kalurghat Industrial area is not well organized and was the subject to carry out the fire safety assessment.

Two major factors were used to assess fire risk:

1. Distance & travel time (along the road network) to the industries from the fire stations.
2. Risk of fire hazard based on industry type (raw materials and the products).

Accessibility of the industries were calculated by measuring the distance of industry structures from the 5 (five) numbers of fire stations along the road network considering the shortest path. Later these distances were converted to the travel time using vehicle speed per hour. Synthesizing the normalized travel time with the industry type factor, risk factors were calculated for each industry structure. This risk factor has been introduced as Fire Risk Factor (FRF).

Several steps were followed to carry out the fire hazard risk assessment in Kalurghat Industrial area; which are described in Figure 6-47 below:

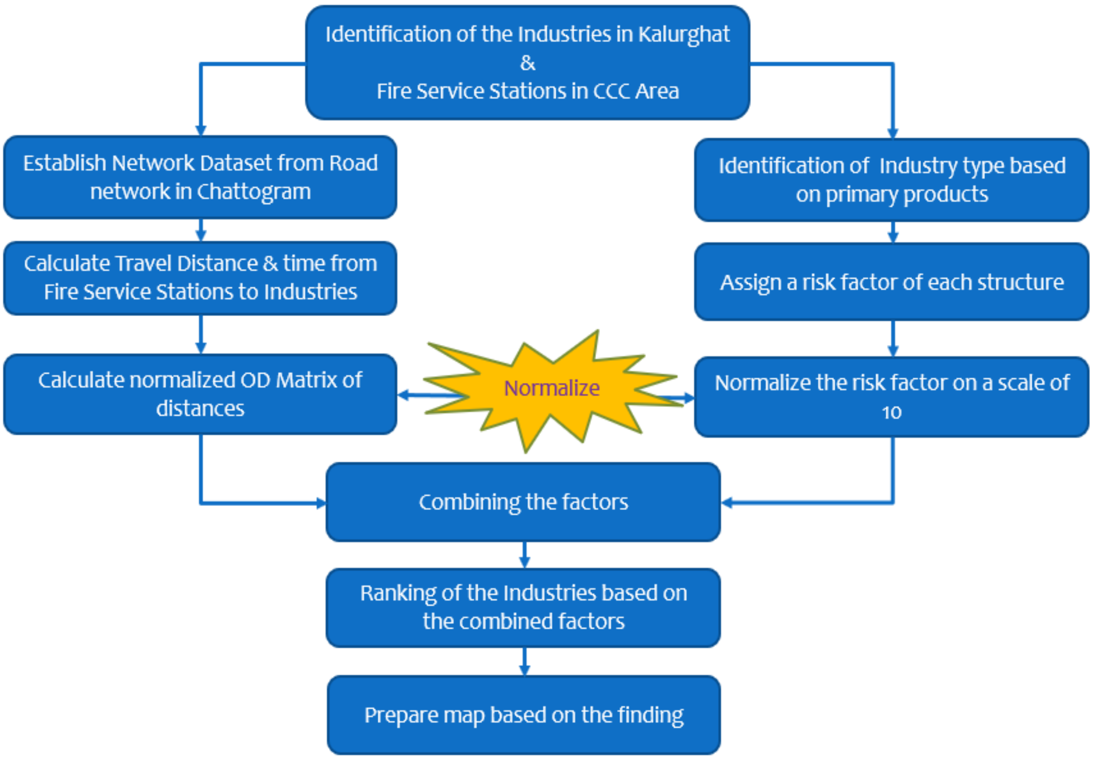


Figure 6-47: Methodology of Fire hazard Risk Assessment

Step-1: Identification of the Industries in Kalurghat & Fire Service Stations in CCC Area: There were twenty numbers of industries selected as samples in Kalurghat. Later, Kader Trading Company was also included in this study as a fire incident occurred on 31st December 2020. Total 134 nos. Structures were taken in Kalurghat into consideration.

Total five fire stations were considered for this study. Nearest fire station in this area is Kalurghat Fire Station. Other fire stations located in the different parts of Chattogram City were considered for the Kalurghat Industrial Area for the analysis are:

1. Kalurghat (the nearest located Fire station)
2. Agrabad
3. Bayazid
4. Nandankanan
5. Chandanpura

Step-2a: Establish Network Dataset from Road network in Chattogram

Network datasets are well suited to model transportation networks. They are created from source features, which can include simple features (lines and points) and turn and store the connectivity of the source features. In this study road centerline of Kalurghat area, and major road artery for other fire service stations were used. The relation between road width and travel speed is presented in Table 6-13.

Table 6-13: Relation of Road Width to Travel Speed

Road width	Speed (Kilometer per hour)
20 m ++	40
16-20 m	35
11-15 m	30
5-10 m	25
<5m	20

From these travel speeds, and road length of a segment (which was calculated from GIS map's geometry), travel time of each road segment was derived using the following equation.

Travel Distance= Velocity x Travel Time.

The output travel time was the key variable of this study. The travel time was used as an impedance for the network dataset.

Step-3a: Calculate Travel Distance & time from Fire Service Stations to Industries

Using the network dataset, location of fire stations and industrial structures, a tool named "Closest Facility" in GIS was used. The closest facility solver measured the cost of traveling between incidents and facilities and determined which are nearest to one another. The closest facility solver displayed the best routes between incidents and facilities and reported their travel costs. Using this tool, the travel time of each structure was identified.

Total number of routes are 5 fire stations multiplied by 134 industries which is equal to 670. The results of this analysis are travel time and travel routes from each industry to each fire station. The computed travel times were weighted based on the following Table 6-14.

Table 6-14: Travel distance weighted factor from Fire Stations

Fire Station	Distance from Kalurghat (Km)	Weightage factor
Kalurghat	0	1.000
Agrabad	7.181	0.139
Bayazid	5.160	0.194
Nandankanon	5.138	0.195
Chandanpura	3.934	0.254

Step-4a: Calculate normalized OD Matrix of travel time

In this step, the travel times were scaled on a scale of 10; i.e., the lowest travel time was assigned a value of 1, and highest value was assigned to 10.

The formula was used for normalization according to the following equation-

$$x_{normalized} = (10\text{-}1)\ \{(x - x_{minimum})\ /\ (x_{maximum} - x_{minimum})\} + 1$$

After normalization to 10 scale, a single industry returned 5 travel times, as 5 fire stations were considered. The travel times were averaged to accumulate a single value for an industry. The output table was known as the OD Matrix of travel time.

Step-2b: Identification of Industry type based on primary products

Kalurghat Industrial area is a mixed type of industrial zone. There are small industries and large industries, and there are deviations in their product types. The industries were classified considering their main products. The product information was collected from the field survey and secondary data sources.

Step-3b: Assign a risk factor of each industry

Kalurghat industrial area covers diverse types of industries, therefore the primary product varies in terms of combustibility of their primary product. Kent Fire Department has a guideline aligned with International Fire Code (IFC) Section 3203, where products were classified into five categories based on their flammability. According to that guideline, the industries located in Kalurghat were classified and assigned a risk factor based on their primary product. The Class-I Commodities were assigned with lower risk factor of 0.2, whereas the High-Hazard Commodities were assigned with highest risk factor of 1 as shown in Table 6-15. Total 8 industries out of 134 have been categorized in the High Hazard Commodity group, those are mostly chemical and consumer product type industries.

Table 6-15: Risk Factor of the industries based on their category

Sl No.	Category	Assigned Risk factor (0-1)
1	Class-i Commodities	0.2
2	Class-ii Commodities	0.4
3	Class-iii Commodities	0.6
4	Class-iv Commodities	0.8
5	High-Hazard Commodities	1

Step-4b: Normalize the risk factor on a scale of 10

The risk factors assigned to the industries were taken on a scale of 10 in this stage. This was done to match with the Origin and Destination (OD) travel time factor.

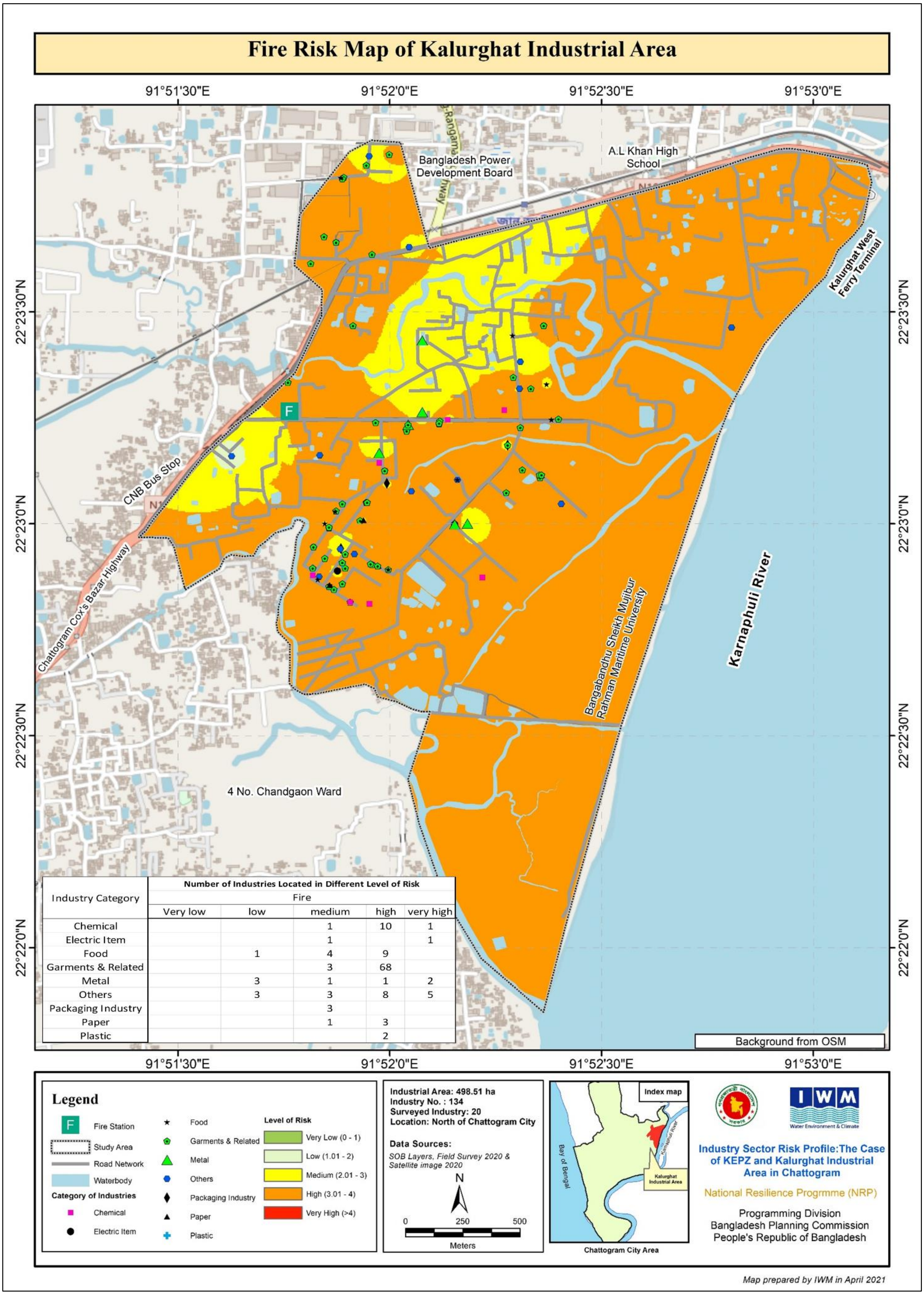
Step-5: Combining the travel time and industrial type factors.

The normalized factors were combined to return the risk factor of each structure. This combination was done by a simple arithmetic sum, which indicated that both these factors were given an equal 50%-50% weightage.

Step-6: Ranking of the Industries based on the combined factors

Combined risk factor was returned on a scale of 20. Then the factor was returned to factor on a scale of 10 by dividing the values by 2. The outcome risk factor is termed as Fire Risk Factor (FRF) of the corresponding Industry.

FRF of each 134 nos. of industries were calculated. The higher value indicates the higher risk of fire incidents in terms of accessibility and product type. The point data were converted to surface using interpolation method in GIS. The Fire risks were categorized into 5 classes- Very low, Low, Medium, High & Very high for mapping. The prepared Fire Risk Map for Kalurghat Industrial Area is presented in Figure 6-48.



Industry Category	Number of Industries Located in Different Level of Risk — Fire				
	Very low	low	medium	high	very high
Chemical			1	10	1
Electric Item			1		1
Food		1	4	9	
Garments & Related			3	68	
Metal		3	1	1	2
Others		3	3	8	5
Packaging Industry			3		
Paper			1	3	
Plastic				2	

Figure 6-48: Fire Risk Map of Kalurghat Industrial Area

6.6 Earthquake Risk Profile

Due to Chattogram's proximity to a plate boundary fault and existence of historical records of damage caused by large earthquakes, it is well understood that the seismic risk of Chattogram should be seriously considered. Earthquake risk may be categorized for different probabilities of earthquake. Earthquake probabilities may be expressed in standard terminology as defined in ASCE-41(2017) shown in Table 6-16. BSE-2N is basically the code prescribed hazard level of Maximum Considered Earthquake. Spectral parameters of other hazard levels may be related to the BSE-2N hazard level according to ASCE-41(2017). Table 6-17 shows the S_s and S_1 values for different hazard levels at Seismic Zone 3, where Chattogram belongs, for Site Class A and Site Class B.

Table 6-16: Standard Seismic Hazard Levels.

Hazard Level	Probability	Return Period
BSE-2N	2% in 50 years	2,500 years
BSE-2E	5% in 50 years	1,000 years
BSE-1N	10% in 50 years	500 years
BSE-1E	20% in 50 years	250 years

Table 6-17: SS and S1 for different hazard levels in Seismic Zone 2

Hazard Level	Site Class A		Site Class B	
	S_S	S_1	S_S	S_1
BSE-2N	0.7	0.28	0.84	0.42
BSE-2E	0.525	0.21	0.63	0.315
BSE-1N	0.466	0.186	0.56	0.28
BSE-1E	0.35	0.14	0.42	0.21

6.6.1 Earthquake Vulnerability Assessment

Earthquake vulnerability assessment may be conducted in various methods. In the CDMP study (2009) vulnerability and risk assessment was based on the HAZUS based approach. However, detailed numerical analysis of different types of structures is necessary to develop fragility curves to be used in that method. Detailed information of exposed value of the structure and the replacement cost are necessary. The HAZUS based approach is expensive both in terms of money and time. For the present study a simplified approach as prescribed in FEMA-154 (2015) is adopted. According to FEMA-154, seismicity of an area is defined as shown in Table 5-17. Here, S_s and S_1 are defined as those for Site Class B. Comparing Table 6-18 and Table 6-19, hazard levels may be related to the level of seismicity as shown in Table 6-20. The probable magnitude mentioned in this table has been inferred from Table 5-14.

Table 6-18: Seismicity based on SS and S1

Seismicity Region	S_S	S_1
Low	$S_S < 0.25$ g	$S_1 < 0.10$ g
Moderate	$0.25\text{ g} \le S_S < 0.50$ g	$0.10\text{ g} \le S_1 < 0.20$ g
Moderately high	$0.50\text{ g} \le S_S < 1.00$ g	$0.20\text{ g} \le S_1 < 0.40$ g
High	$1.00\text{ g} \le S_S < 1.50$ g	$0.40\text{ g} \le S_1 < 0.60$ g
Very high	$1.50\text{ g} \le S_S$	$0.60\text{ g} \le S_1$

Table 6-19: Hazard Level and Seismicity Level for Chattogram

Earthquake Type	Return Period, T	Probable Magnitude, M_w	Seismicity
Rare	$100\text{ years} < T$	$8 \le M_w$	High (H)
Moderately Rare	$250\text{ years} < T \le 1000\text{ years}$	$7 \le M_w < 8$	Moderately High (MH)
Frequent	$T \le 250\text{ years}$	$M_w < 7$	Moderate (M)

Based on the defined seismicity, risk scores as prescribed in FEMA-154 (2015) may be assigned to different types of structures as shown in Table 6-20.

Table 6-20: Risk Scores for Different Types of Structures

Building Type	**C2**			**C3**			**S3**			**URM**		
Seismicity	H	MH	M	H	MH	M	H	MH	M	H	MH	M
Basic Score	2.0	2.1	2.5	1.2	1.4	2.0	2.6	2.9	3.5	1.0	1.2	1.7
Severe Vertical Irregularity	-1.0	-1.1	-1.2	-0.7	-0.8	-1.0	-1.1	-1.2	-1.4	-0.7	-0.8	-1.0
Moderate Vertical Irregularity	-0.6	-0.6	-0.7	-0.4	-0.5	-0.6	-0.7	-0.8	-0.9	-0.4	-0.5	-0.6
Plan Irregularity	-0.8	-0.9	-1.0	-0.5	-0.6	-0.8	-0.9	-1.0	-1.2	-0.4	-0.5	-0.7
Non-Ductile detailing	-0.7	-0.7	-0.4	-0.1	-0.1	-0.3	-0.8	-0.7	-0.2	0.0	-0.1	-0.1

6.6.2 Seismic Risk Profile

Statistical and geographic distribution vulnerability scores of the surveyed buildings in KEPZ and Kalurghat areas are shown in Figure 6-49 to Figure 6-60. From these figures it is evident that in all the cases Kalurghat buildings are at greater risk than those at KEPZ. For a rare event, buildings at both the study areas are at higher risk which is expected as the code specific demand on a building is of lower hazard level. However, for moderately rare event which correspond to the code prescribed loading, only 22% buildings at KEPZ and 7% buildings at Kalurghat are less likely to be damaged. The basis of this is a cutoff score of 2 as suggested in FEMA-154 (2015). Even for a frequent seismic event only 30% buildings at KEPZ and 9% buildings at Kalurghat scored above the cutoff level.

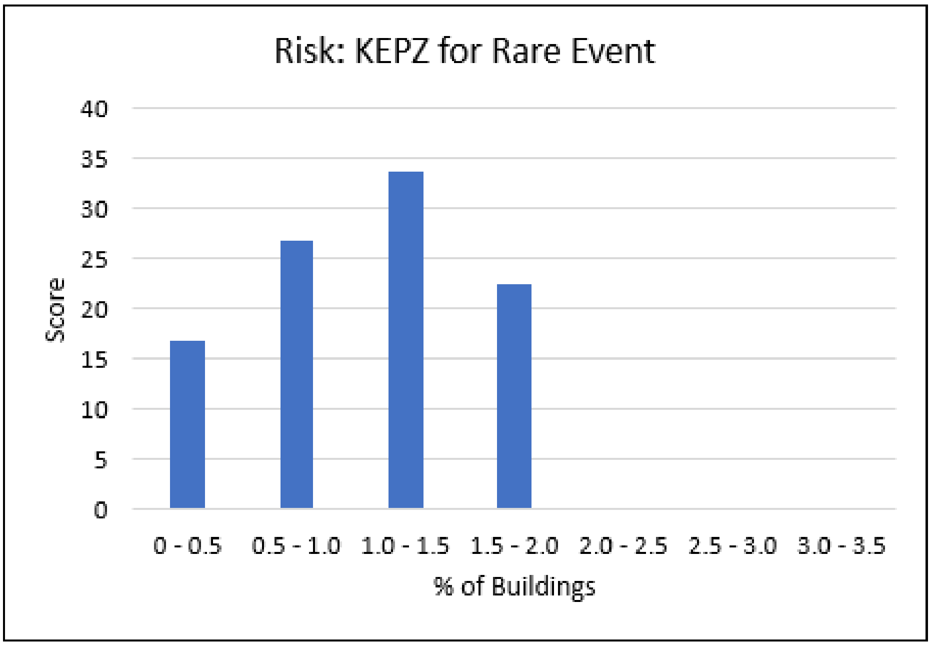


Figure 6-49: Statistical distribution of risk scores of the KEPZ buildings for a rare event

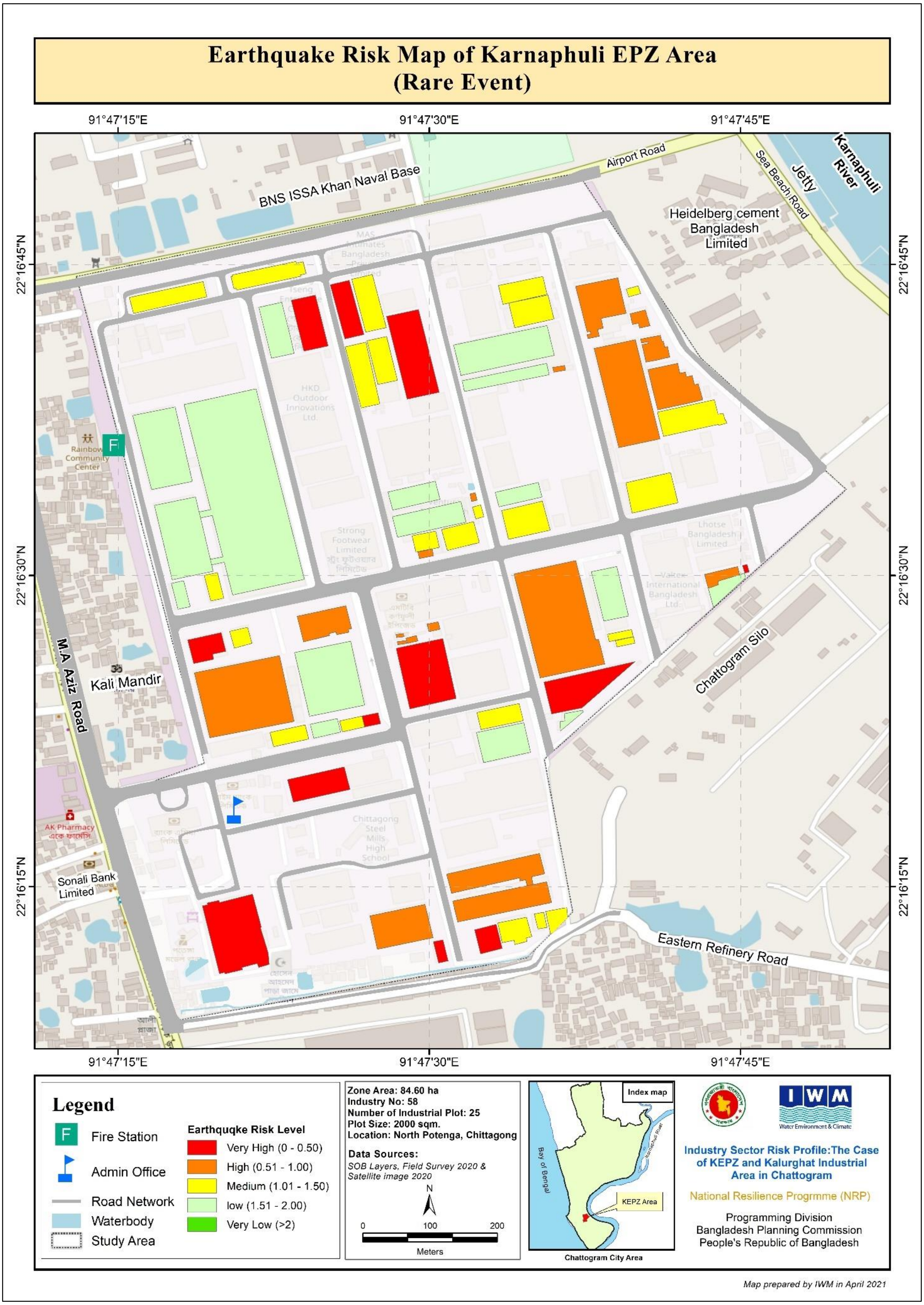


Figure 6-50: Geographic distribution of risk of the KEPZ buildings for a rare event

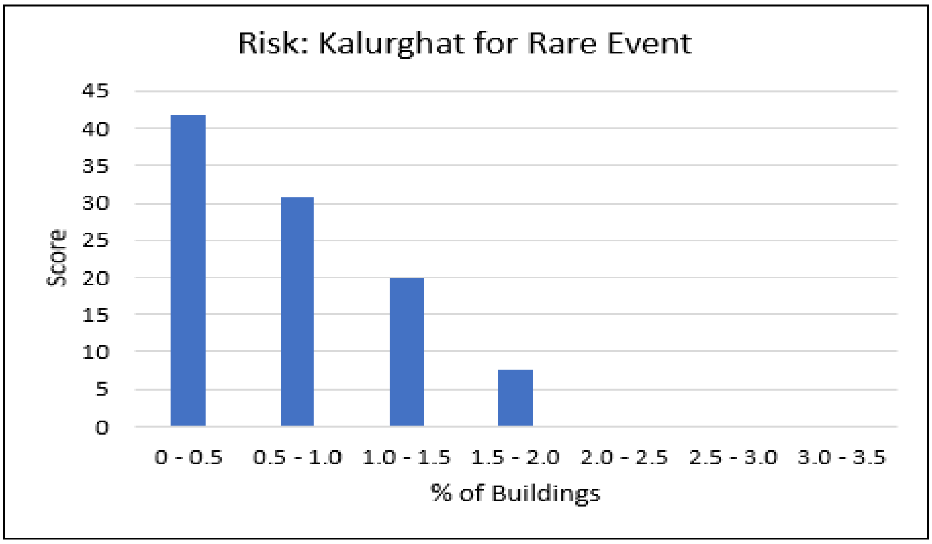


Figure 6-51: Statistical distribution of risk scores of the Kalurghat buildings for a rare event

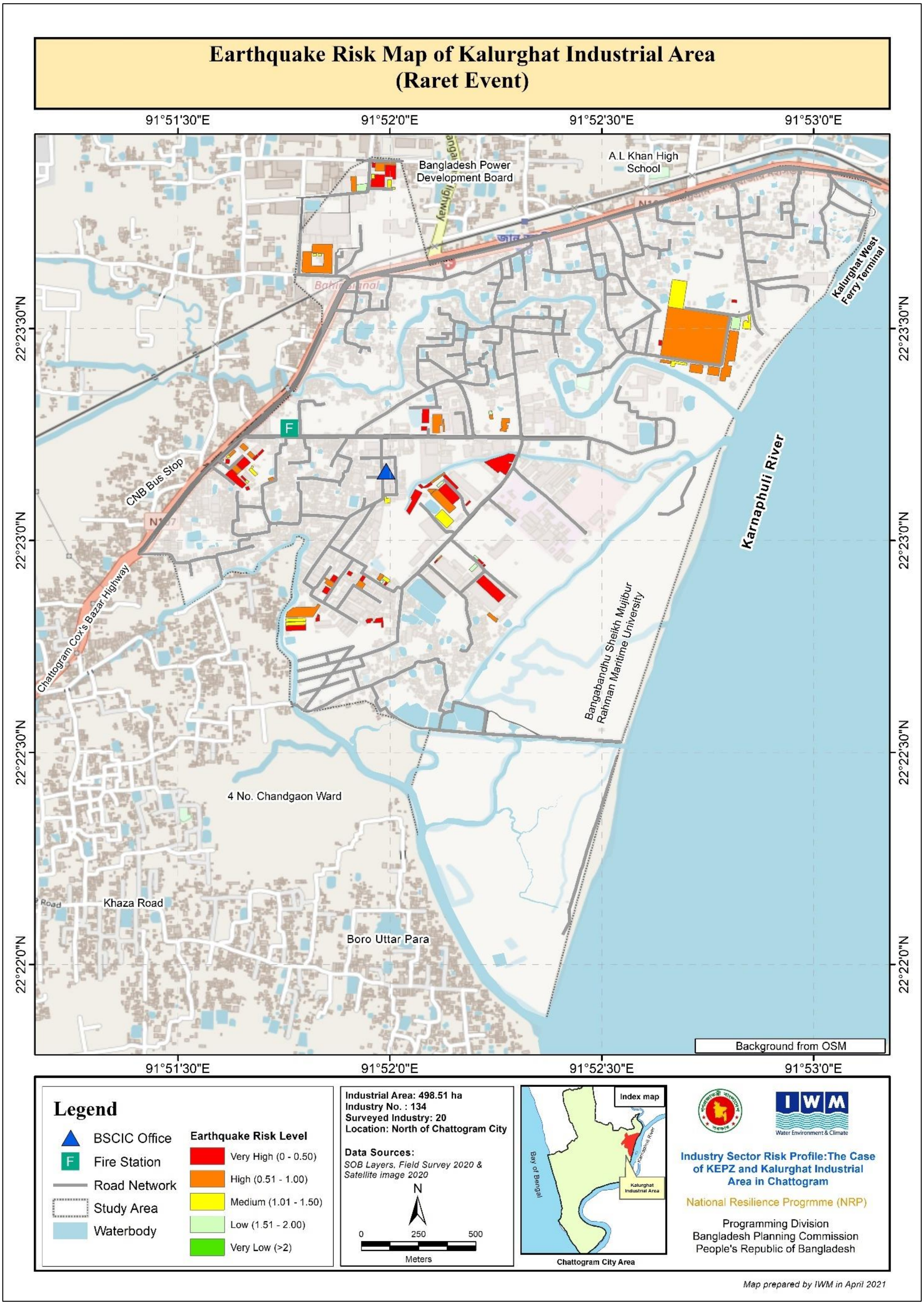


Figure 6-52: Geographic distribution of risk of the Kalurghat buildings for a rare event

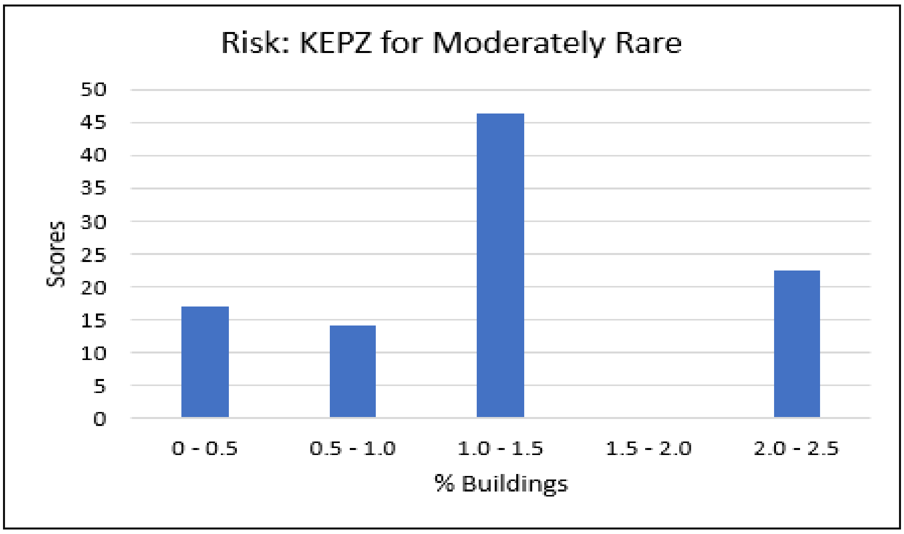


Figure 6-53: Statistical distribution of risk scores of the KEPZ buildings for a moderately rare event

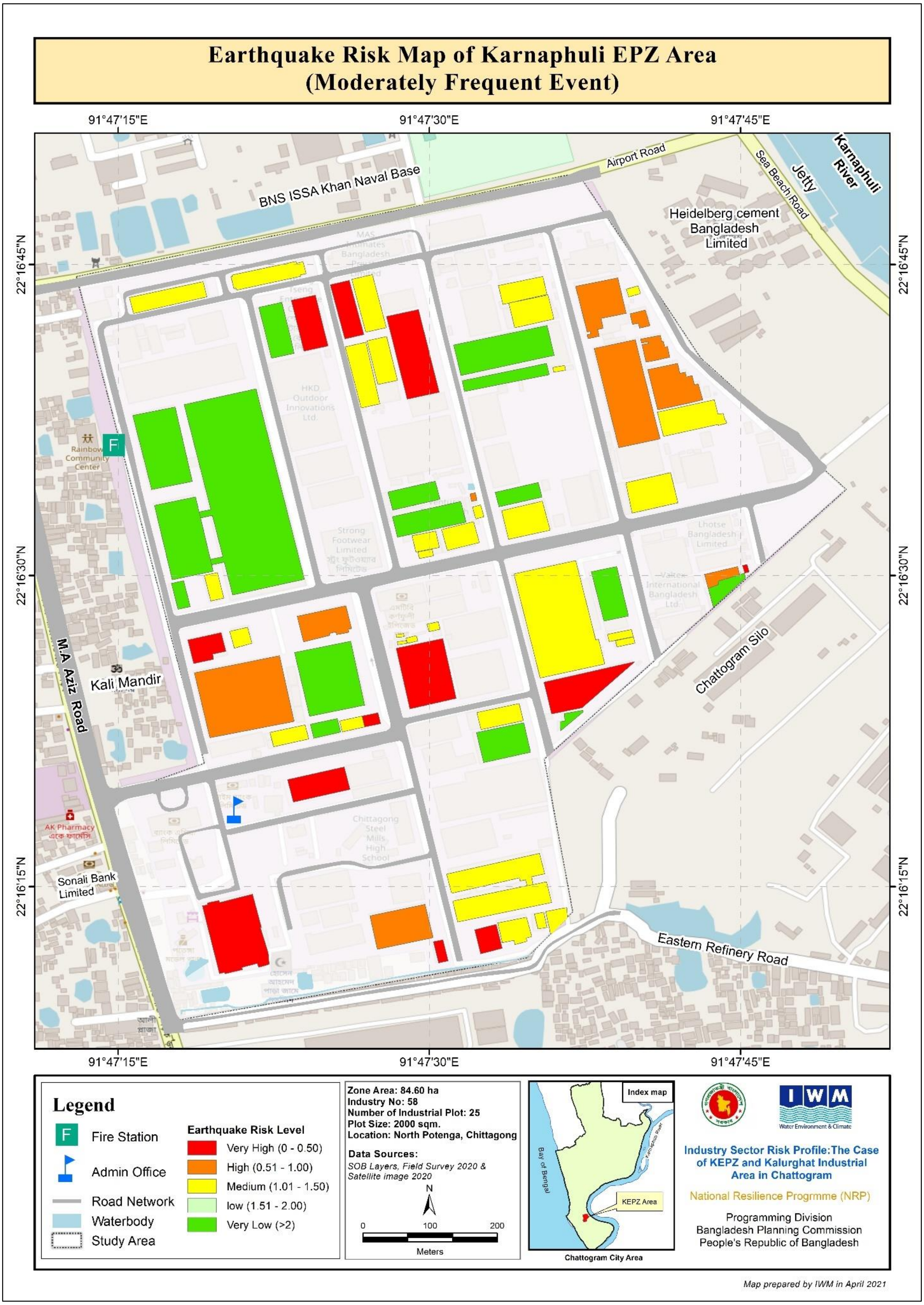


Figure 6-54: Geographical distribution of risk of KEPZ buildings for a moderately rare event

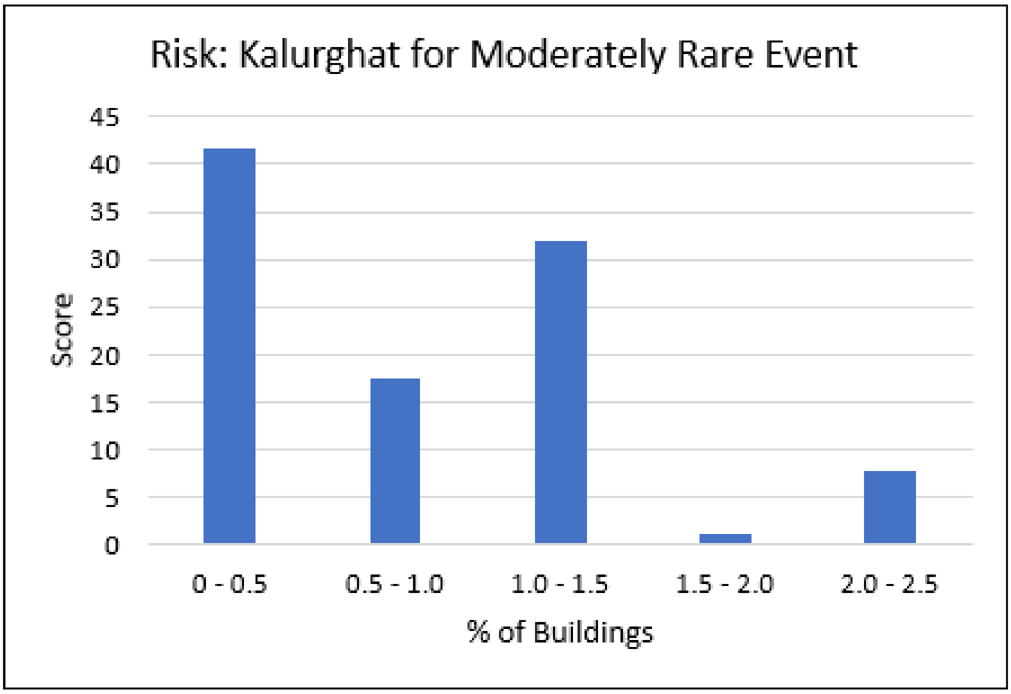


Figure 6-55: Statistical distribution of risk scores of the Kalurghat buildings for a moderately rare

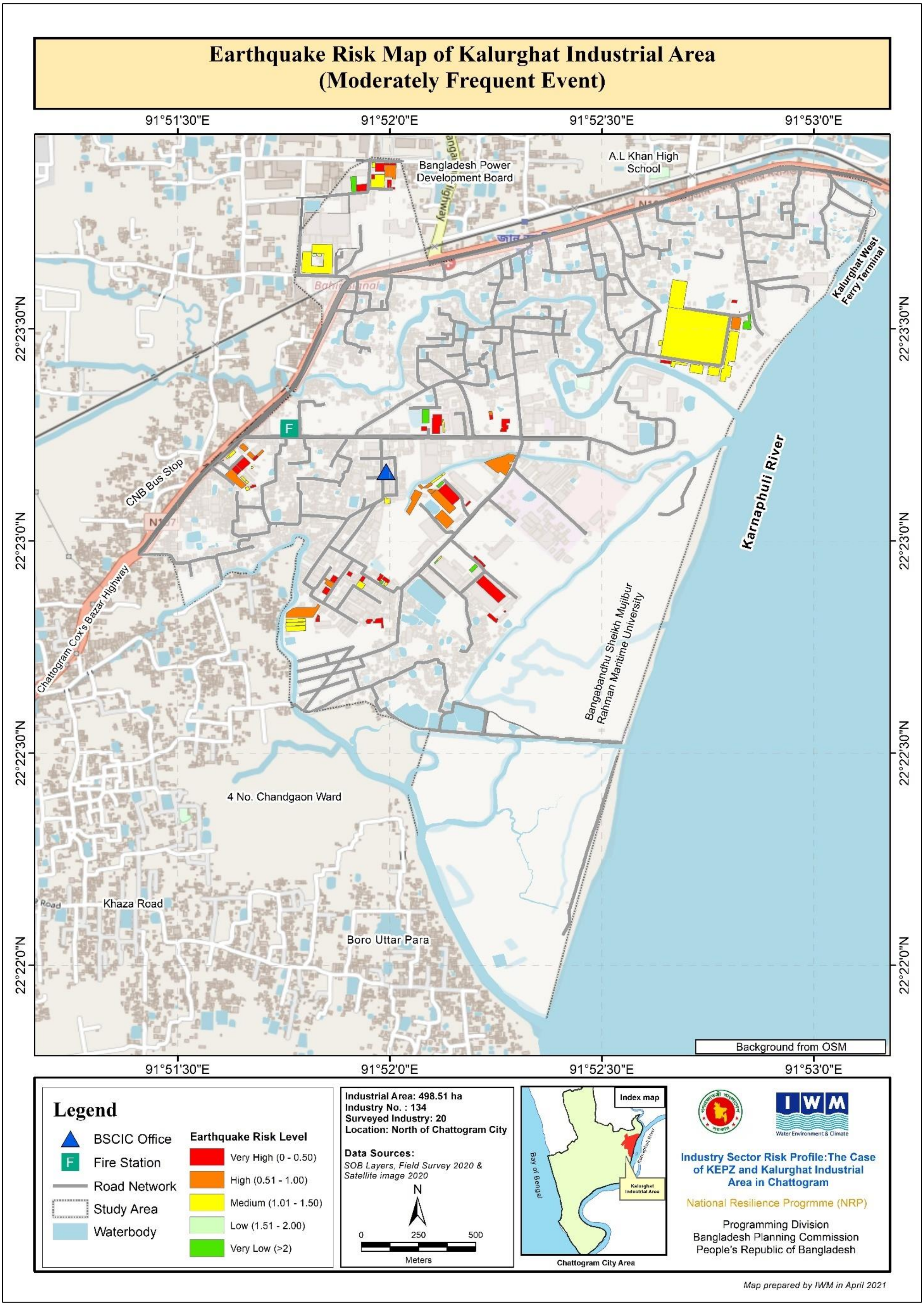


Figure 6-56: Geographical distribution of risk of Kalurghat buildings for a moderately rare event

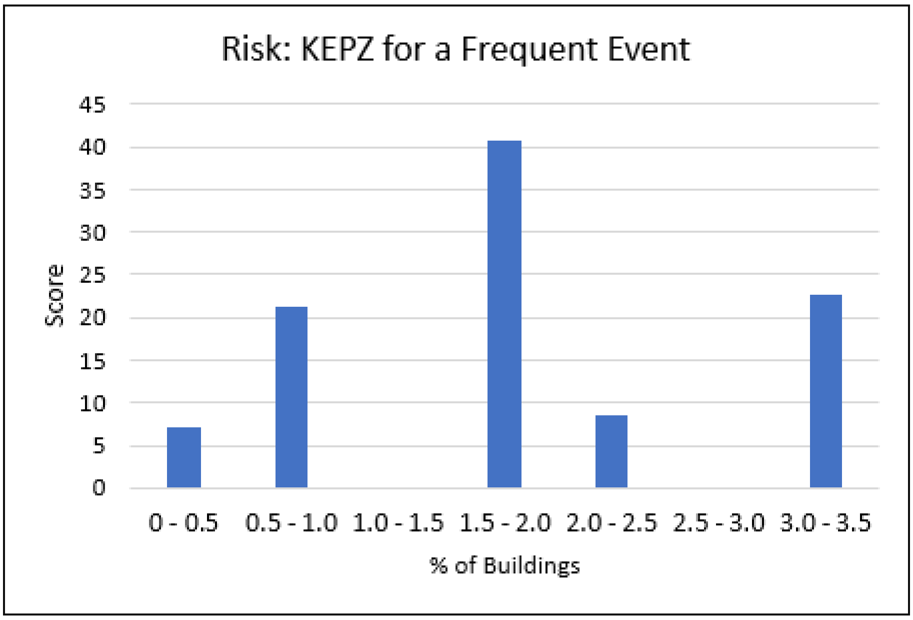


Figure 6-57: Statistical distribution of risk scores of the KEPZ buildings for a frequent event

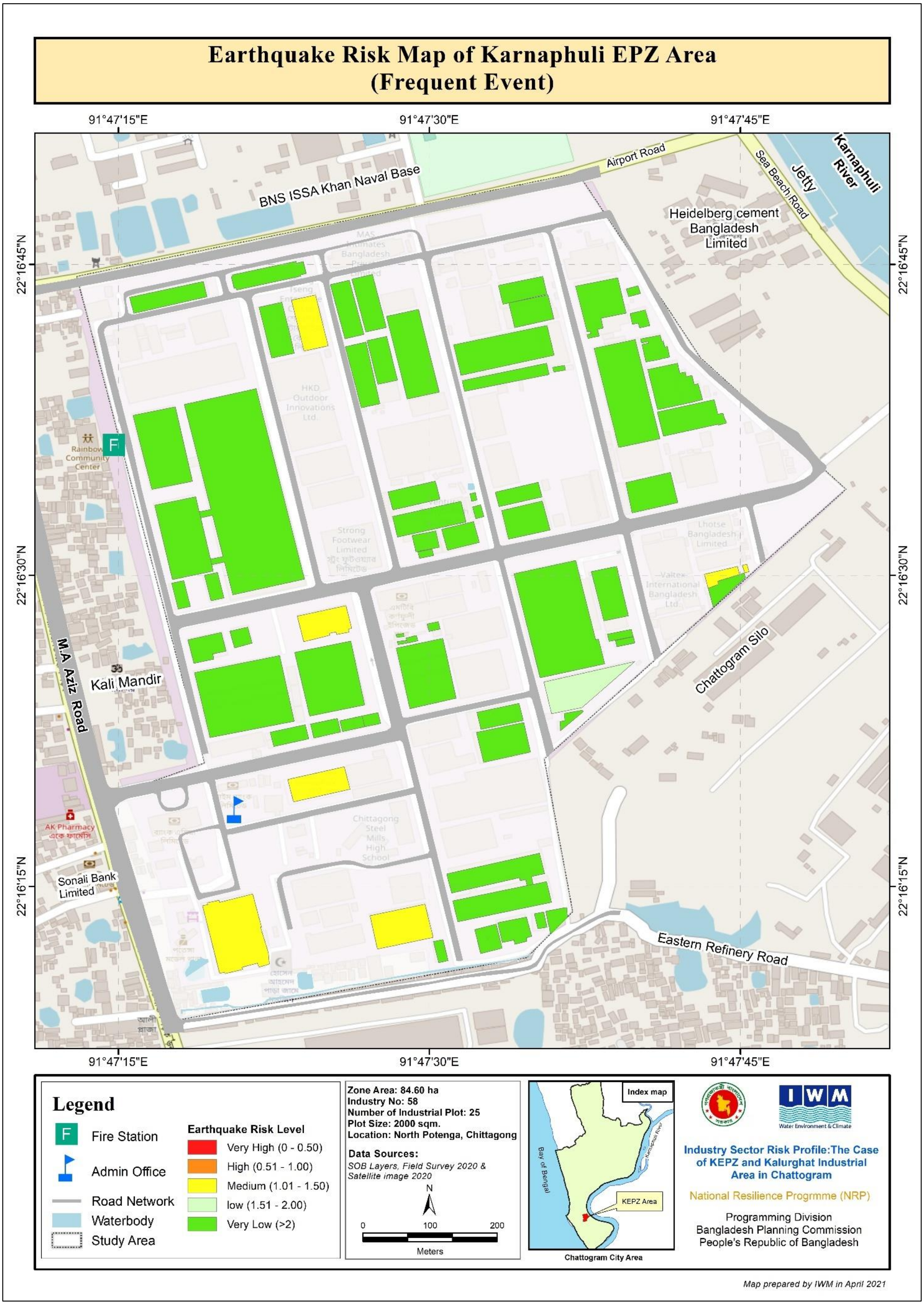


Figure 6-58: Geographical distribution of risk of KEPZ buildings for a frequent event

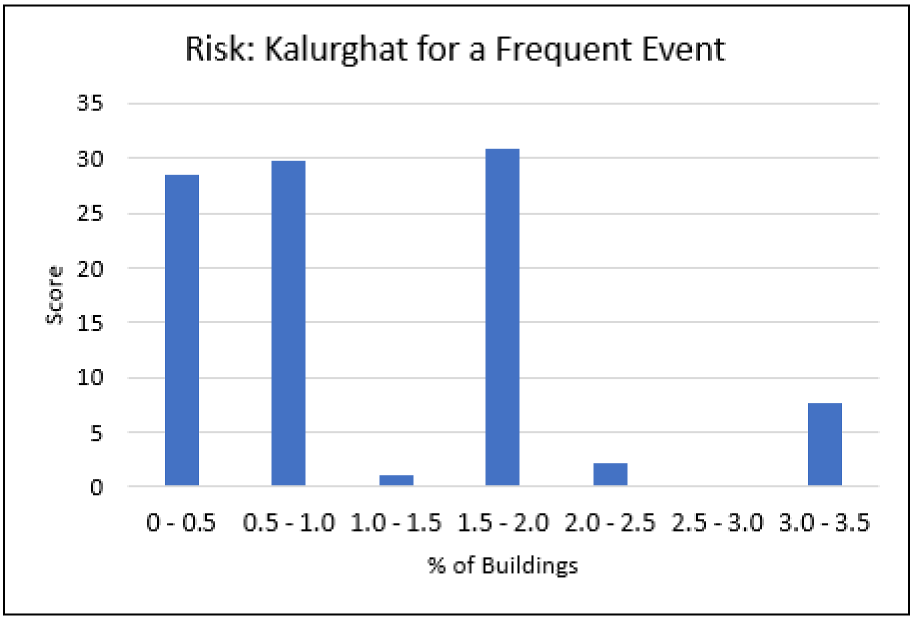


Figure 6-59: Statistical distribution of risk scores of the Kalurghat buildings for a frequent event

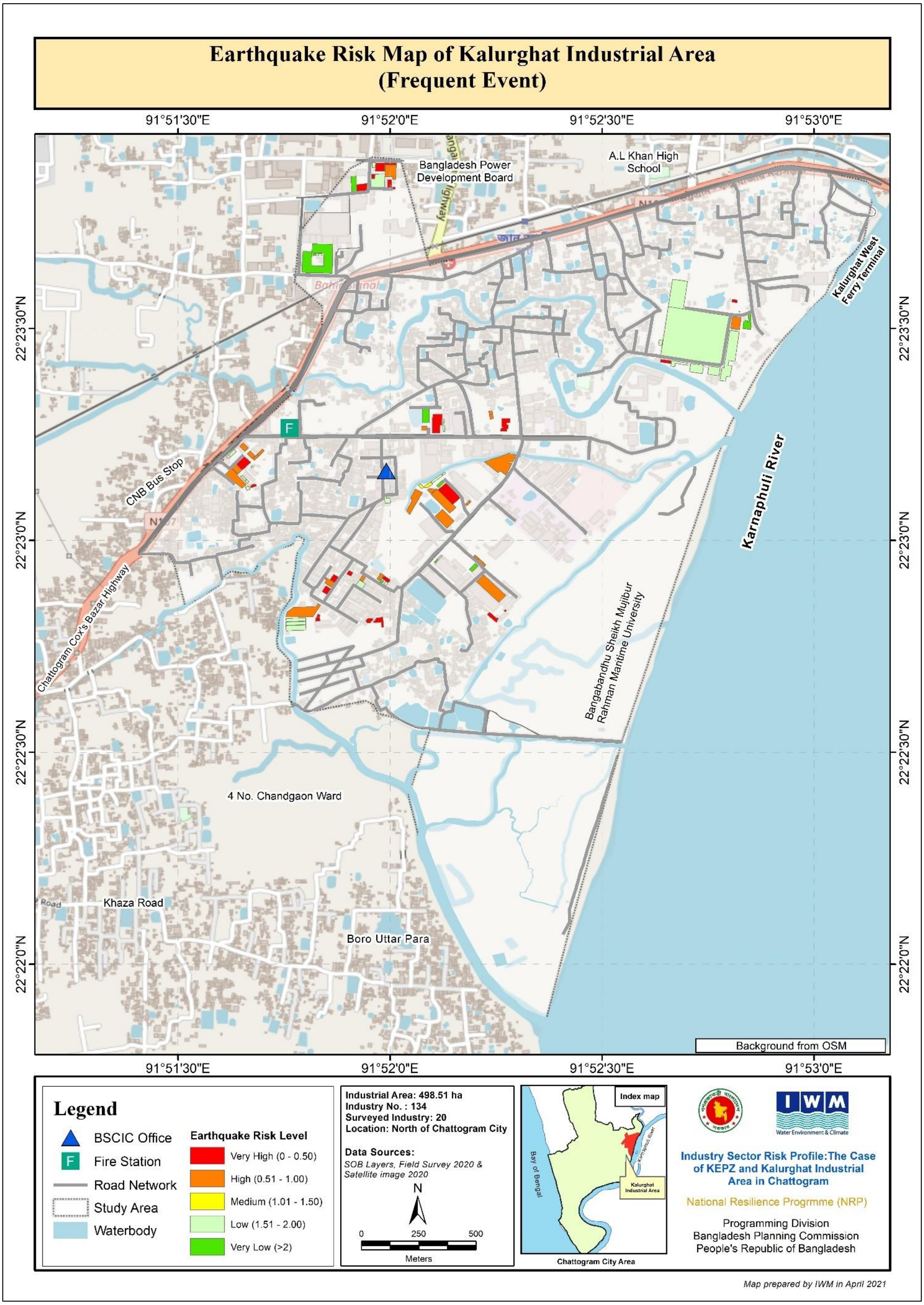


Figure 6-60: Geographical distribution of risk of Kalurghat buildings for a frequent event

6.7 DEVELOPMENT OF COVID-19 RISK PROFILE

The outbreak of Coronavirus infection 2019 vis-à-vis COVID- 19 pandemic has already spread all over the world and emerged as a major public health threat. COVID-19 is a highly transmittable and pathogenic viral infection caused by severe acute respiratory syndrome coronavirus. This novel pathogenic virus emerged in Wuhan, China in November 2019, and has rapidly spread around the world. In Chattogram a total 19,708 number of confirmed cases were found (upto 23 March 2021). The daily total cases in Bangladesh are shown in following Figure 5-61.

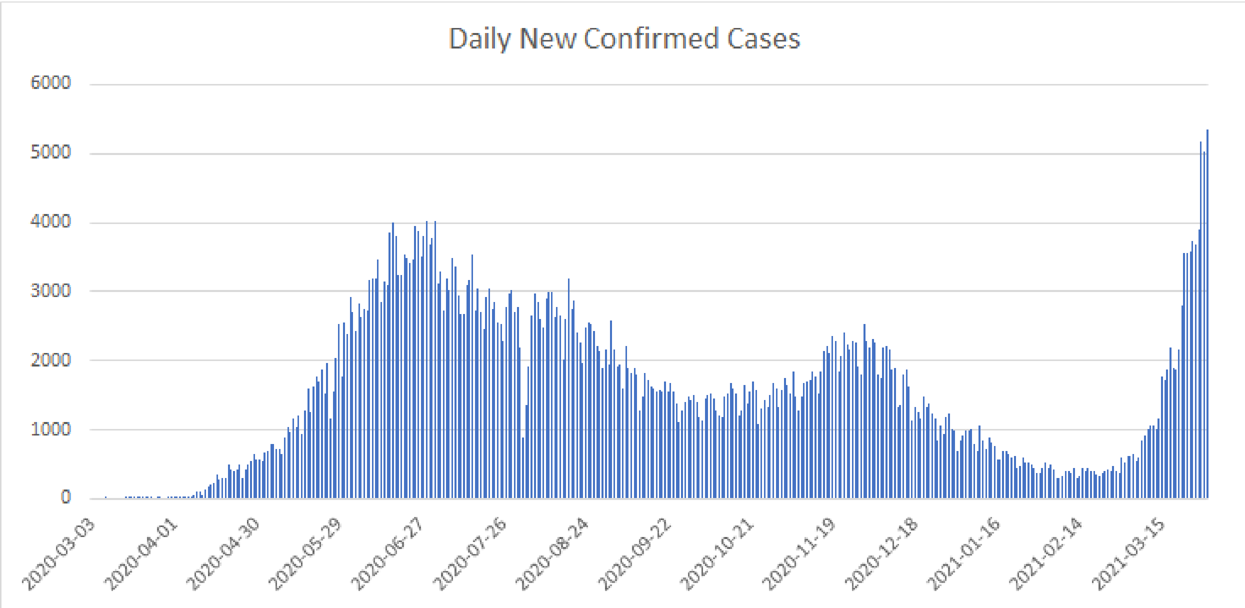


Figure 6-61: Daily confirmed COVID-19 cases in Bangladesh until 30 March 2021 (Source: IEDCR)

With a view to assess the COVID-19 risk in the study areas located in Chattogram, a questionnaire survey was conducted during August 2020 for 37 numbers of industries in KEPZ and 20 numbers of sample industries in Kalurghat. This COVID-19 risk assessment is done based on the data collected from KEPZ and Kalurghat industries. But it was found that the information on Covid-19 for Kalurghat is insufficient and lacks reliability. Hence only for KEPZ area the analysis was done.

A total of 14 numbers of indicators were used to assess the risk of this disease and each of these indicators was provided with weightages as presented in Table 6-21.

Processing of the field Data: Two types of data were collected from the field; those are qualitative and quantitative. Qualitative values include the response like yes or no. Each positive response was normalized to a value of 0 and negative responses were assigned as 1.

The numeric (i.e. quantities data) responses were normalized using the following Equation-

$$x_{\text{normalized}} = (x - x_{\text{minimum}}) / (x_{\text{maximum}} - x_{\text{minimum}})$$

At the end of this process, the value of each indicator was returned on a scale of 1.0. These indicators were then aggregated using a weighted average method for each industry using the following method. COVID-19 risks were categorized into 5 classes- Very low, low, medium, high & very high for mapping.

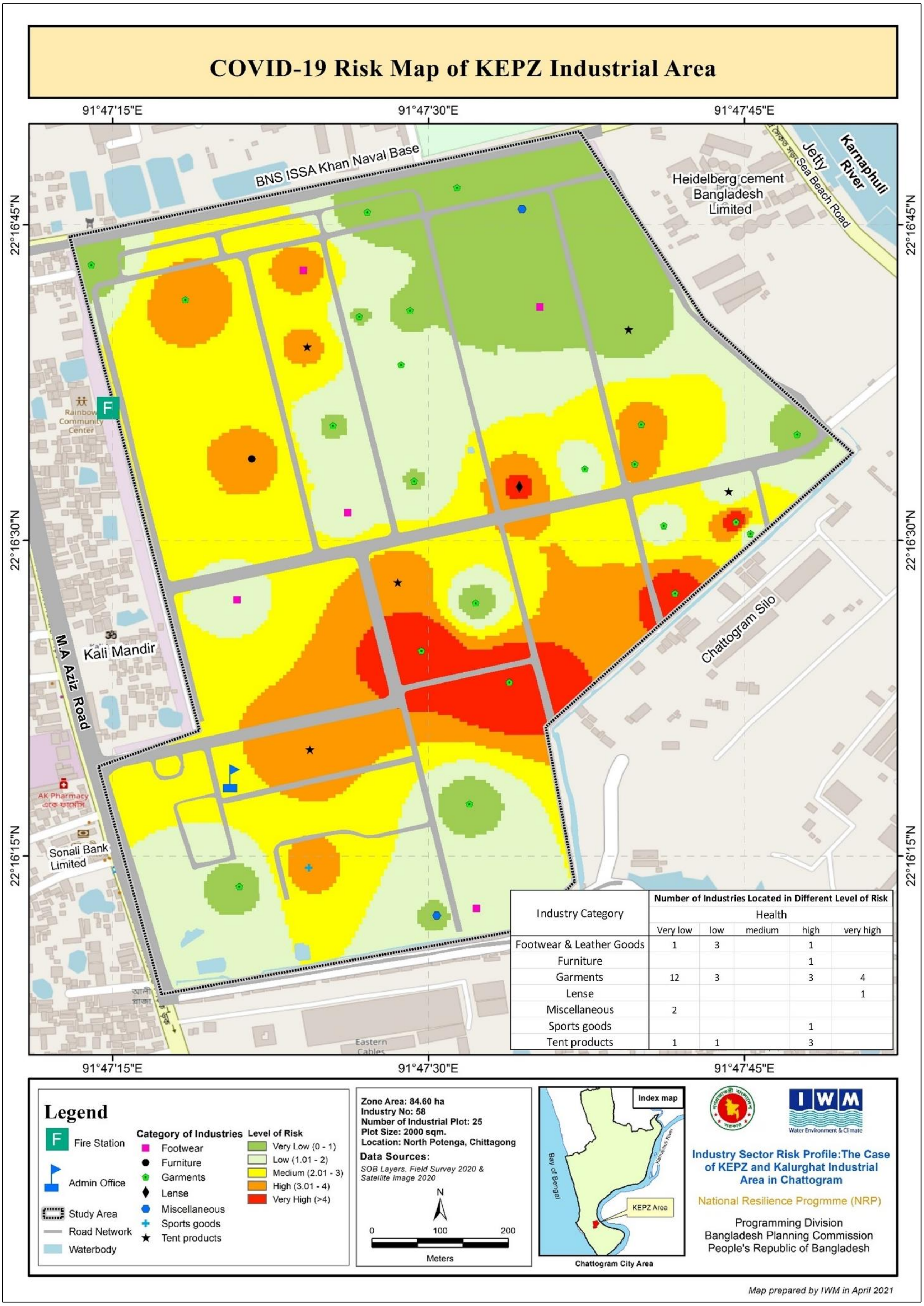
$$w = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i}$$

w_i – the corresponding weight for each item

Table 6-21: Indicators used to assess the risk from COVID-19

Type of indicator	Sl	Indicators	Weightage
Qualitative Indicators	1.	Personnel trained in infectious disease surveillance	*0.05*
	2.	Do you have epidemic (such as Corona) preparedness and response	*0.06*
	3.	Availability of Emergency stocks of drugs, vaccines, and supplies, at all times in past 1 year	*0.02*
	4.	Do you have budget line for epidemic response	*0.1*
	5.	Do you have central epidemic management committee	*0.08*
	6.	Do you have central rapid response team for epidemics	*0.02*
	7.	Training on health and safety	*0.03*
	8.	Isolation Maintained	*0.07*
	9.	Have you provided masks	*0.05*
	10.	Have you provided PPE	*0.02*
	11.	How many workers got infected	*0.07*
Quantitative Indicators	12.	How many workers died	*0.08*
	13.	How long the industry was closed.	*0.02*
	14.	What percentage of Salary was paid during the time the industry was closed?	*0.33*

Derived risk point data were converted to grid data using Inverse distance weighted (IDW) method in ArcGIS. Prepared COVID-19 risk maps are presented in Figure 6-62 below for KEPZ area.



Industry Category	Number of Industries Located in Different Level of Risk				
	Health				
	Very low	low	medium	high	very high
Footwear & Leather Goods	1	3		1	
Furniture				1	
Garments	12	3		3	4
Lense					1
Miscellaneous	2				
Sports goods				1	
Tent products	1	1		3	

Figure 6-62: Health Risk Map (COVID-19), KEPZ Study Area

6.8 Development of Multi-Hazard Risk Profile

An industry may be subjected to multiple hazards based on its geographic locations and poor access to the required safety facilities. It depends on expert judgements to give weights of the Hazards, which would vary based on industry type, its raw materials, products and many other factors. Hence, preparing multi-hazard risk profile is to be done by the industry itself.

An exercise has been done under the study using equal weightage to all the hazards. The results in the form of GIS maps are presented in Figure 6-63 to Figure 6-68.

The numbers of industries in different risk zones under different scenarios in Kalurghat study area is presented in Table 6-22 below. The table show the numbers by industry types which fall in which risk zone (very high, high, medium, low and very low).

Table 6-22: Number industries in Risk Zones, Kalurghat

Industry Category	Average year Risk Levels					25 years Risk Levels					50 years Risk Levels				
	Very low	low	medium	high	very high	Very low	low	medium	high	very high	Very low	low	medium	high	very high
Chemical	6	6						12						4	8
Electric Item	1	1						2						2	
Food	12	2						14						10	4
Garments & Related	39	32						71						46	25
Metal	5	2						7						3	4
Others	11	8						19						14	5
Packaging Industry	3							3						2	1
Paper	4							4						1	3
Plastic		2						2						1	1
Total	11	122	1	0	0	0	109	24	1	0	0	0	99	31	4

Similarly, the numbers of industries in different risk zones under different scenarios in KEPZ are found out and presented in Table 6-23 below.

Table 6-23: Number industries in Risk Zones, KEPZ area

Industry Category	Average year (2.33)					25 years					50 years				
	Very low	low	medium	high	very high	Very low	low	medium	high	very high	Very low	low	medium	high	very high
Footwear & Leather Goods	5					3	2					3	2		
Furniture	1						1						1		
Garments	17	5				14	4	4				15	3	4	
Lens		1					1						1		
Miscellaneous	2					1	1					1	1		
Sports goods	1						1						1		
Tent products	5					2	3					2	3		
	31	6				20	13	4				21	12	4	

The distribution of industries in Very Low, Low, Medium, High and Very High-risk zones for the both Kalurghat and KEPZ area is presented in Table 6-24 for average year, 25- and 50-year condition.

Table 6-24: Distribution of Industries by Risk-Zone of Multi-hazards

Risks Levels	Kalurghat Study area			KEPZ Study area		
	Avg. Yr	25-Yr	50-Yr	Avg. Yr	25-Yr	50-Yr
Very High			38%			
High			62%			11%
Medium		100%			11%	32%
Low	40%			16%	35%	57%
Very Low	60%			84%	54%	

The area distribution of risk levels of different hazards at average year return period of Kalurghat Industrial area is shown in Table 6-25.

Table 6-25: Area distribution of Risk levels at average year return period of Kalurghat Area

Hazard	Very Low		Low		Medium		High		Very High	
	Area (ha)	% of Total Area	Area (ha)	% of Total Area	Area (ha)	% of Total Area	Area (ha)	% of Total Area	Area (ha)	% of Total Area
Flood	498.80	100	-	-	-	-		-	-	-
Cyclone	498.80	100	-	-	-	-		-	-	
Water Logging	498.80	100	-	-	-			-	-	-
Salinity	228.56	45.82	270.24	54.18	-	-		-	-	
Multi-Hazards	**402.77**	**80.75**	**96.03**	**19.25**	**-**	**-**	**-**	**-**	**-**	**-**

Hazard	Very Low		Low		Medium		High		Very High	
	Area (ha)	% of Total Area	Area (ha)	% of Total Area	Area (ha)	% of Total Area	Area (ha)	% of Total Area	Area (ha)	% of Total Area
Fire Incidence			1.68	0.34	65.03	13.04	432.06	86.62	0.03	0.007

The area distribution of risk levels of different hazards at 25- year return period of Kalurghat Industrial area is shown in Table 6-26.

Table 6-26: Area distribution of Risk levels at 25-year return period of Kalurghat Area

Hazard	Very Low		Low		Medium		High		Very High	
	Area (ha)	% of Area	Area (ha)	% of Area	Area (ha)	% of Area	Area (ha)	% of Area	Area (ha)	% of Area
Flood	27.39	5.49	466.64	93.55	4.77	0.96	-	-	-	-
Cyclone	0.75	0.15	480.14	96.26	17.91	3.59	-	-	-	-
Water Logging	0.98	0.20	401.62	80.52	94.51	18.95	1.69	0.34	-	-
Salinity	-	-	-	-	-	-	-	-	498.80	100
Multi-Hazards	**-**	**-**	**-**	**-**	**493.56**	**98.95**	**5.24**	**1.05**	**-**	**-**

The area distribution of risk levels of different hazards at 50- year return period of Kalurghat Industrial area is shown in Table 6-27.

Table 6-27: Area distribution of Risk levels at 50-year return period of Kalurghat Area

Hazard	Very Low		Low		Medium		High		Very High	
	Area (ha)	% of Area	Area (ha)	% of Area	Area (ha)	% of Area	Area (ha)	% of Area	Area (ha)	% of Area
Flood	-	-	19.01	3.81	213.77	42.86	256.98	51.52	9.03	1.81
Cyclone	-	-	-	-	-	-	21.34	4.28	477.46	95.72
Water Logging	-	-	0.91	0.18	112.64	22.58	267.15	53.56	118.10	23.68
Salinity	-	-	-	-	-	-	-	-	498.80	100
Multi-Hazards	**-**	**-**	**-**	**-**	**0.57**	**0.11**	**221.92**	**44.49**	**276.31**	**55.40**

The area distribution of risk levels of different hazards at Average year return period of KEPZ area is shown in Table 6-28

Table 6-28: Area wise Risk levels at Average year return period of KEPZ Area

Hazards	Very Low		Low		Medium		High		Very High	
	Area (ha)	% of Area	Area (ha)	% of Area	Area (ha)	% of Area	Area (ha)	% of Area	Area (ha)	% of Area
Flood	82.64	100	-	-	-	-	-	-	-	-
Cyclone	82.64	100	-	-	-	-	-	-	-	-
Water Logging	82.64	100	-	-	-	-	-	-	-	-

Hazards	Very Low		Low		Medium		High		Very High	
	Area (ha)	% of Area	Area (ha)	% of Area	Area (ha)	% of Area	Area (ha)	% of Area	Area (ha)	% of Area
Salinity	32.01	38.73	7.87	9.52	4.42	5.35	7.14	8.64	31.17	37.71
Multi-Hazards	**78.08**	**94.48**	**4.56**	**5.52**	**-**	**-**	**-**	**-**	**-**	**-**
Covid-19	13.24	16.02	23.50	28.44	28.89	34.95	12.73	15.40	4.29	5.19

The area distribution of risk levels of different hazards at 25-year return period of KEPZ area is shown in Table 6-29.

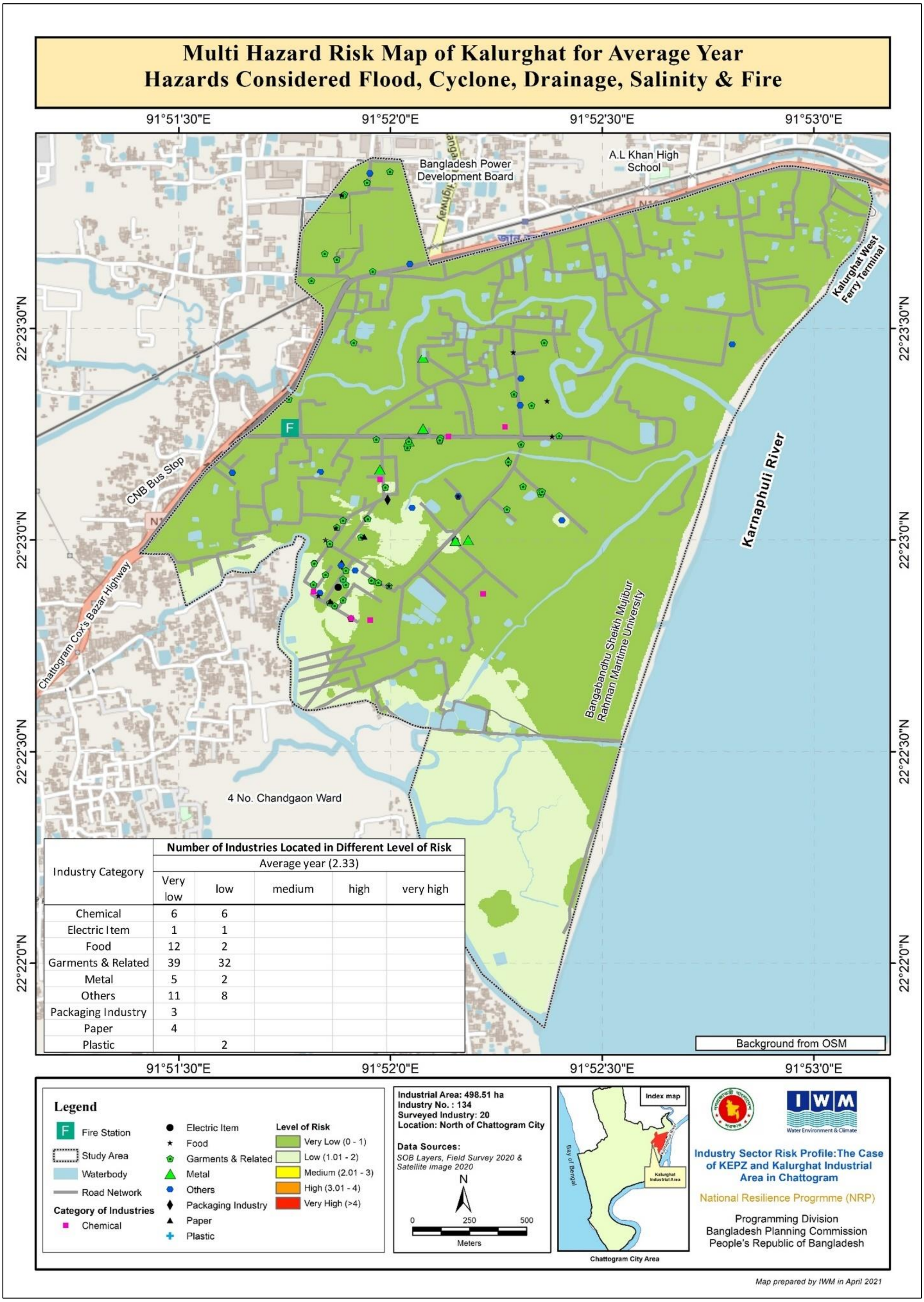
Table 6-29: Area distribution of Risk levels at 25-year return period of KEPZ Area

Hazards	Very Low		Low		Medium		High		Very High	
	Area (ha)	% of Area	Area (ha)	% of Area	Area (ha)	% of Area	Area (ha)	% of Area	Area (ha)	% of Area
Flood	82.58	99.93	0.06	0.07	-	-	-	-	-	-
Cyclone	-	-	-	-	7.09	8.58	73.70	89.19	1.85	2.24
Water Logging	82.39	99.70	0.25	0.30	-	-	-	-	-	-
Salinity	32.01	38.73	7.87	9.52	4.42	5.35	7.14	8.64	31.17	37.71
Multi-Hazards	**28.85**	**34.90**	**53.14**	**64.30**	**0.66**	**0.80**	**-**	**-**	**-**	**-**

The area distribution of risk levels of different hazards at 50-year return period of KEPZ area is shown in Table 6-30

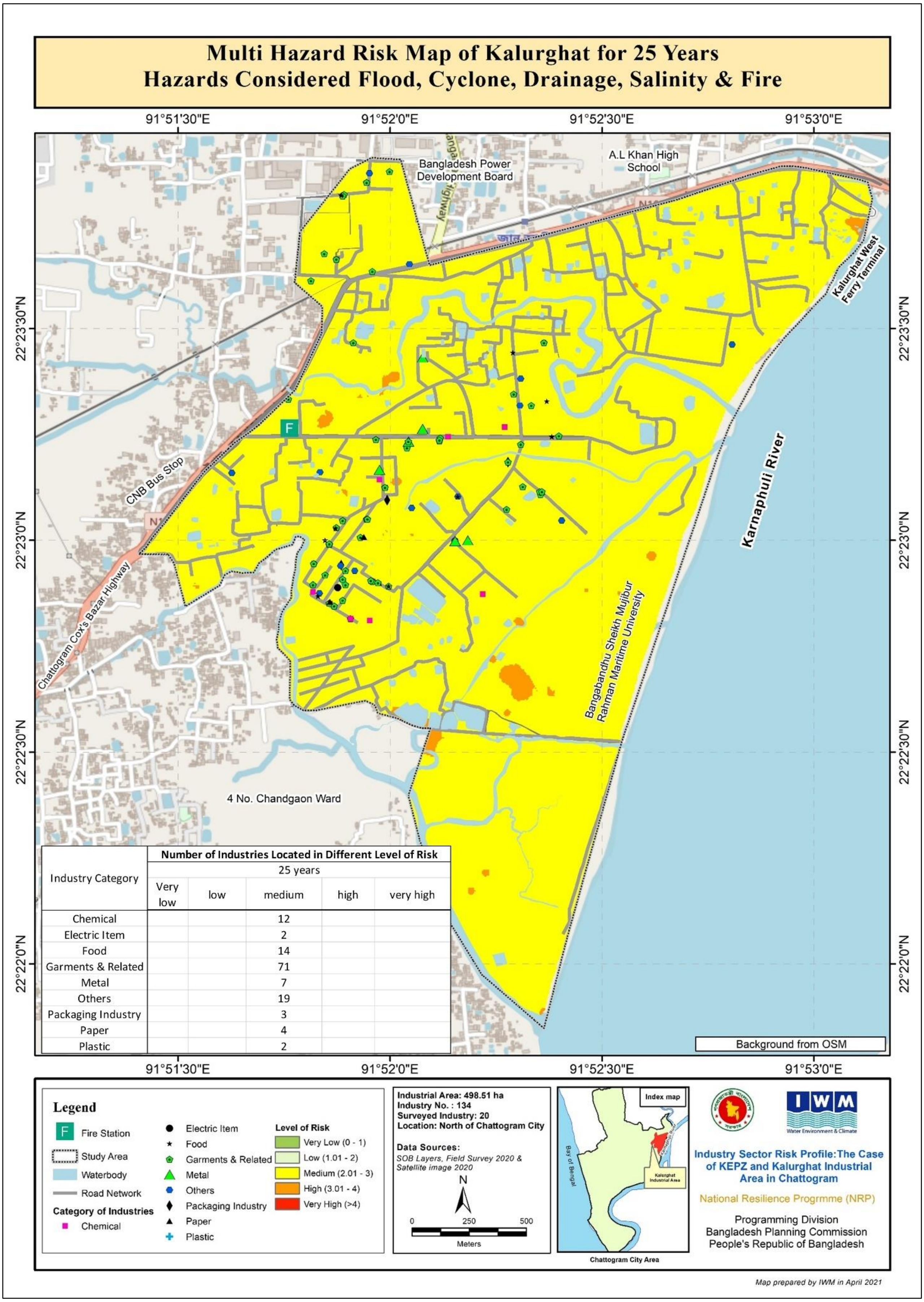
Table 6-30: Area distribution of Risk levels at 50-year return period of KEPZ Area

Hazards	Very Low		Low		Medium		High		Very High	
	Area (ha)	% of Area	Area (ha)	% of Area	Area (ha)	% of Area	Area (ha)	% of Area	Area (ha)	% of Area
Flood	57.77	69.91	24.77	29.97	0.10	0.12	-	-	-	-
Cyclone	-	-	-	-	4.80	5.81	48.41	58.58	29.43	35.61
Water Logging	59.64	72.17	22.61	27.36	0.39	0.47	-	-	-	-
Salinity	32.01	38.73	7.87	9.52	4.42	5.35	7.14	8.64	31.17	37.71
Multi-Hazards	**-**	**-**	**44.98**	**54.43**	**37.20**	**45.01**	**0.46**	**0.55**	**-**	**-**



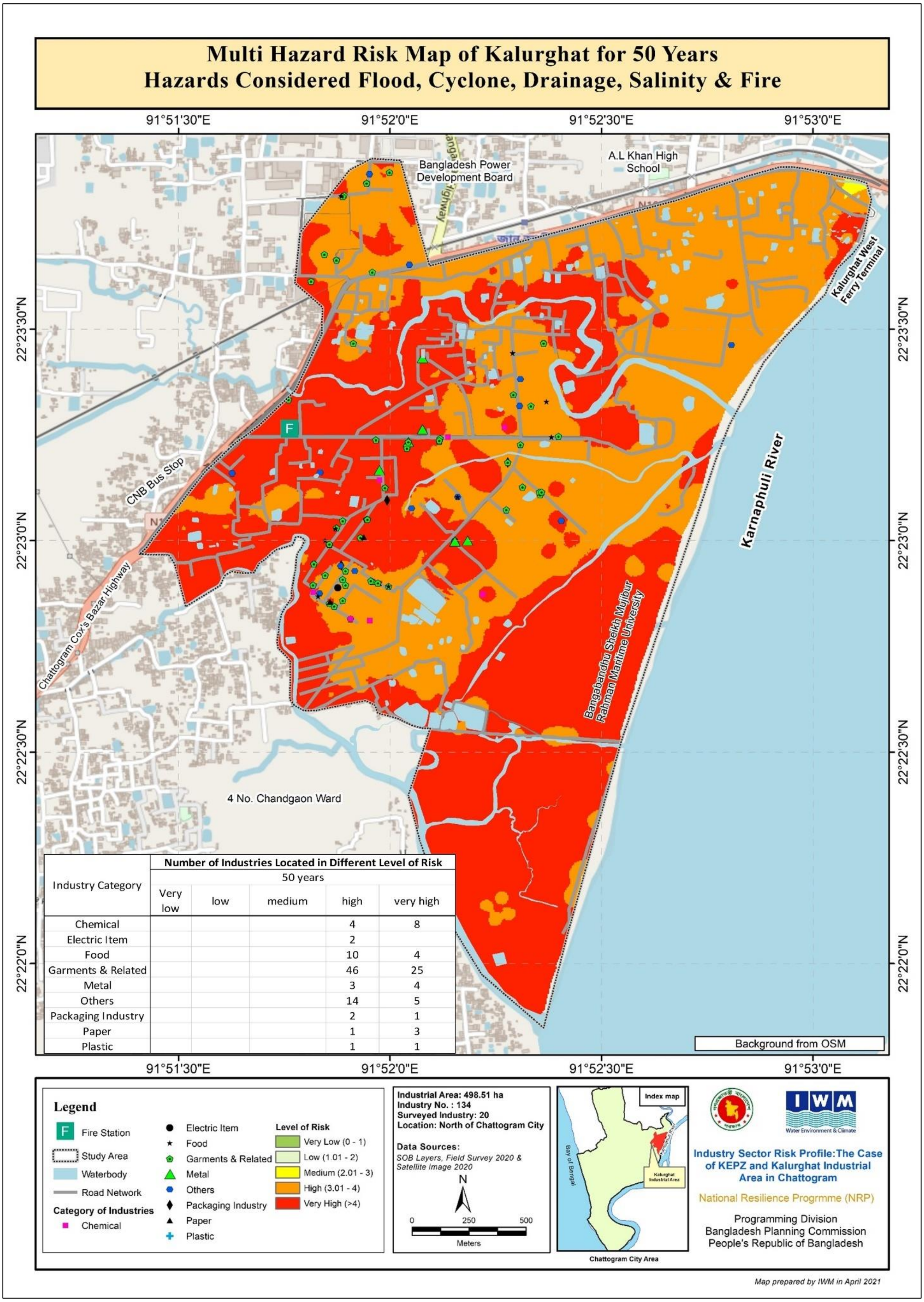
Industry Category	Number of Industries Located in Different Level of Risk — Average year (2.33)				
	Very low	low	medium	high	very high
Chemical	6	6			
Electric Item	1	1			
Food	12	2			
Garments & Related	39	32			
Metal	5	2			
Others	11	8			
Packaging Industry	3				
Paper	4				
Plastic		2			

Figure 6-63: Multi-hazard Risk Profile of Kalurghat Study area, Average Year



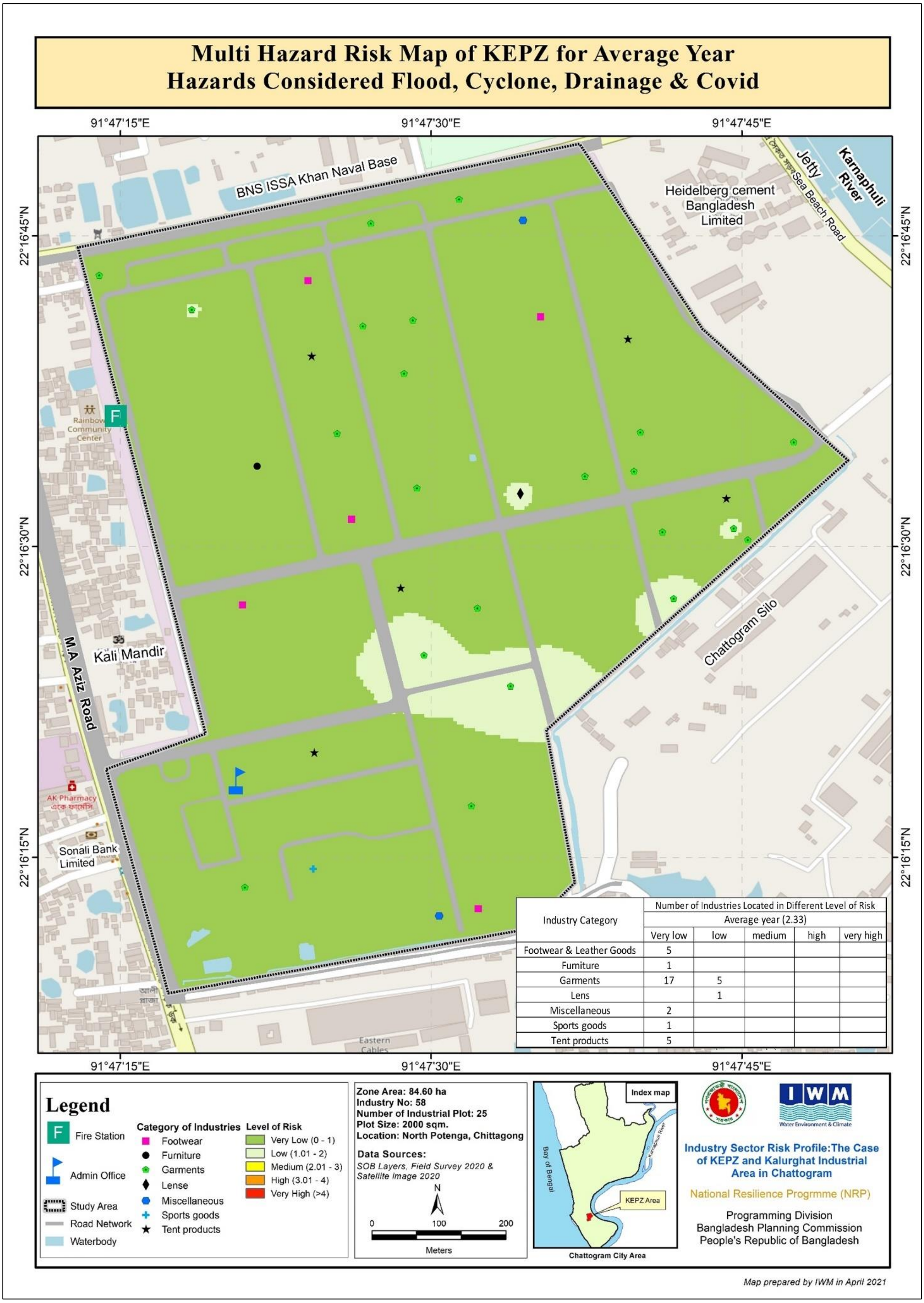
Industry Category	Number of Industries Located in Different Level of Risk				
	25 years				
	Very low	low	medium	high	very high
Chemical			12		
Electric Item			2		
Food			14		
Garments & Related			71		
Metal			7		
Others			19		
Packaging Industry			3		
Paper			4		
Plastic			2		

Figure 6-64: Multi-hazard Risk Profile of Kalurghat Study area, 25-Year



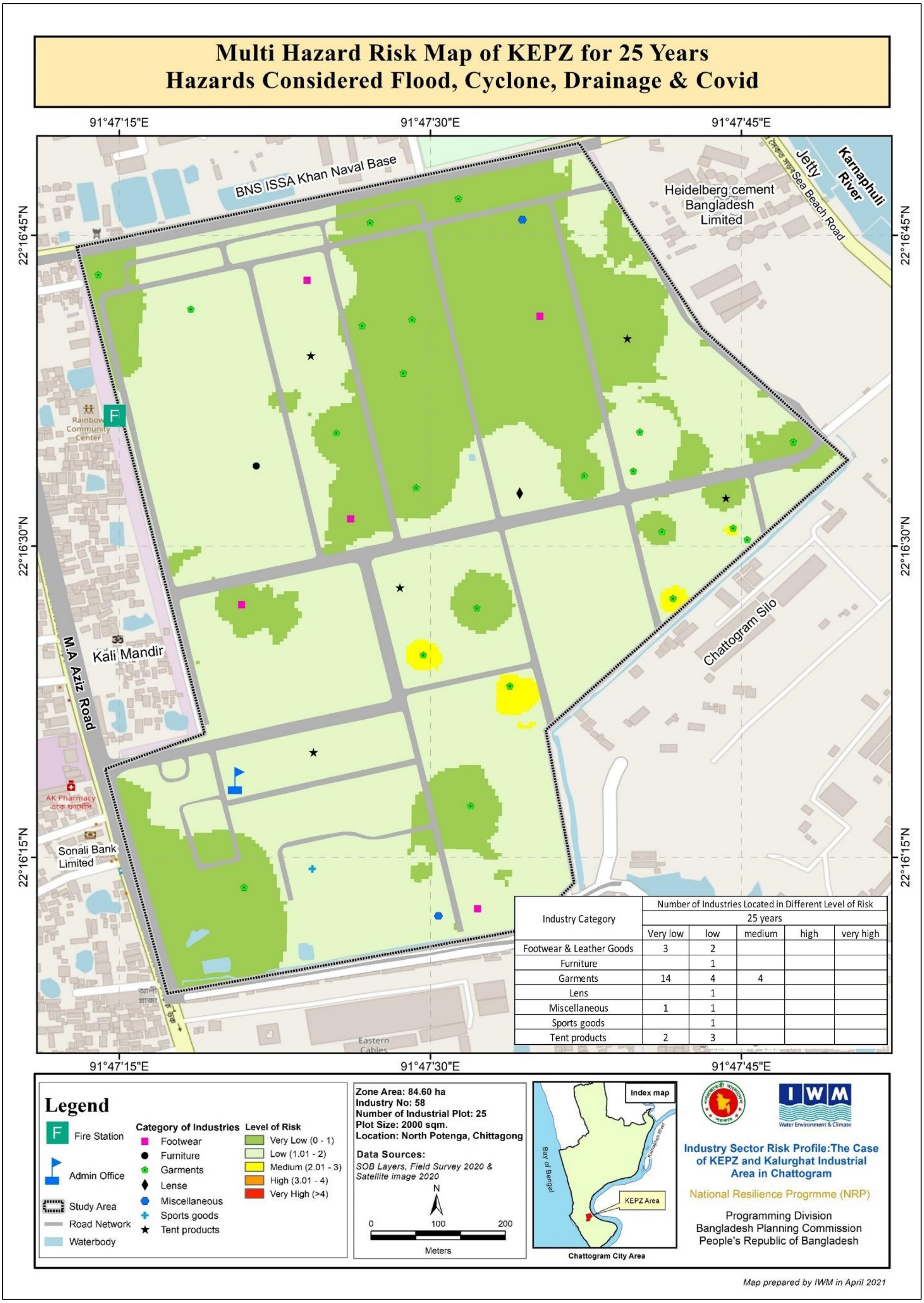
Industry Category	Number of Industries Located in Different Level of Risk – 50 years: Very low	low	medium	high	very high
Chemical				4	8
Electric Item				2	
Food				10	4
Garments & Related				46	25
Metal				3	4
Others				14	5
Packaging Industry				2	1
Paper				1	3
Plastic				1	1

Figure 6-65: Multi-hazard Risk Profile of Kalurghat Study area, 50-Yr



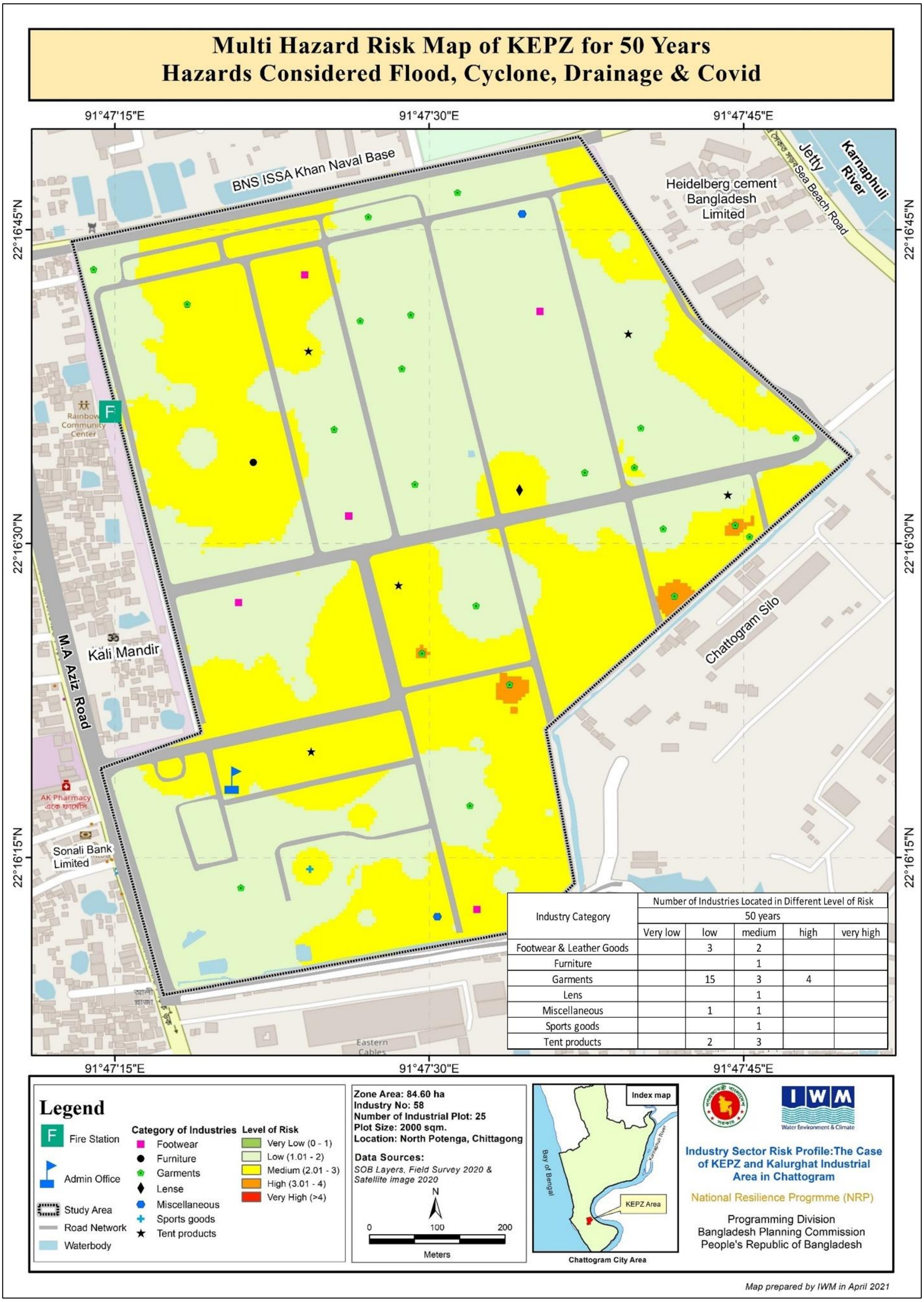
Industry Category	Number of Industries Located in Different Level of Risk				
	Average year (2.33)				
	Very low	low	medium	high	very high
Footwear & Leather Goods	5				
Furniture	1				
Garments	17	5			
Lens		1			
Miscellaneous	2				
Sports goods	1				
Tent products	5				

Figure 6-66: Multi-hazard Risk Profile of KEPZ Study area, Average year



Industry Category	Number of Industries Located in Different Level of Risk				
	25 years				
	Very low	low	medium	high	very high
Footwear & Leather Goods	3	2			
Furniture		1			
Garments	14	4	4		
Lens		1			
Miscellaneous	1	1			
Sports goods		1			
Tent products	2	3			

Figure 6-67: Multi-hazard Risk Profile of KEPZ Study area, 25-year



Industry Category	Number of Industries Located in Different Level of Risk				
	50 years				
	Very low	low	medium	high	very high
Footwear & Leather Goods		3	2		
Furniture			1		
Garments		15	3	4	
Lens			1		
Miscellaneous		1	1		
Sports goods			1		
Tent products		2	3		

Figure 6-68: Multi-hazard Risk Profile of KEPZ Study area, 50-year

Chapter 7: Key Findings BCP and Recommendations

This chapter describes the key findings from hazards analysis, vulnerability and exposure assessment, and finally from the risk assessment of Flood, Storm-Surge and Cyclone, Water logging, Salinity, Earthquake, Fire and Infectious diseases like Covid-19. Based on the study findings, a few recommendations are made to protect industry sector from the hazards. Short- and long-term proposals have been made in this chapter to be executed by the GOB and relevant authorities.

7.1 Key Findings

The key findings of the study based on the results of Hazards and Risks analysis for Flood, Cyclone, Water Logging, Salinity, Earthquake, Fire incidence and Covid-19 disease are described in the following sub-sections:

7.1.1 Flood Hazards

The flood risks are low in 93% area at 25-year return period and 40% area will be in medium Risk and 52% area will be at high Risk with climate change impacts. In case of KEPZ area the Flood Risks will be Very Low for 99% area in 25-year return period, and in case of 50-year event 70% area will be in Very low risks and 30% area will be in Low Risks in KEPZ area. According to the results and findings, it has been estimated that the Kalurghat Industrial Area is more vulnerable to the Flood Risks in the Climate Change Conditions. To reduce the risk of this area, the river side of this area will need to be fully protected by the embankment.

7.1.2 Water Logging

The hazard risks will be very low in 100% area in average year condition, 99.70% area will be very low in 25-year return period, and 72% area will be very low, and 27% area will be low risk in 50-year return period in KEPZ area. Similarly, the hazard risk of Kalurghat will be very low in 100% area in average year condition, 80.5% area will be in low risk, 18.95% will be medium risk and remaining will be high risk in 25-year return period, and 22.58% area will medium risk, 53.56% will be high risk and 23.68% will be high risk in 50-year return period.

7.1.3 Cyclone Hazards

The hazard Risks will 100% area will be very low in average year condition, 8.58% area will medium risk, 89.19% will be high risk and 2.24 will be very high risk in 25-year return period, and 5.81% are will medium, 58.58% area will be high, and 35.61% area will be very high risk in 50-year return period for KEPZ area. Similarly, 100% area will be very low risk in average year condition, 96.25% are will low risk and 3.5% area will be high risk in 25-year return period, and 4.28% area will be high risk and 95.72% area will be very high risk in 50-year return period for Kalurghat Industrial area.

7.1.4 Salinity Hazards

It has been observed from the model that the salinity around Kalurghat Industrial Area and KEPZ are along Karnaphuli river are decreases with increase of discharge from Kaptai HEPP, moreover salinity increases with increase of flow in Karnaphuli River. If the Kaptai HEPP release 200m3/s in average year condition, the salinity

Risk will be low, whereas in 25 and 50-year return period with the same release and climate change condition considered the salinity Risk will be very high in both Kalurghat and KEPZ area along Karnaphuli River.

Acceptable level of (1 ppt) salinity level is found around in Kalurghat Area in the average year (2.33-year return period) condition. In the 25-year and 50-year return period, the 1 ppt salinity line will be propagated towards the upstream by 5.86 and 6.39km respectively.

7.1.5 Earthquake

Local site amplification analysis shows that industrial infrastructure both in the Kalurghat Industrial Area and KEPZ may be subject to higher ground acceleration compared to the code specified earthquake motion. From limited bore hole information, it was found that some places in Kalurghat may possess very low susceptibility to liquefaction and there are some isolated pockets in the KEPZ where liquefaction susceptibility may be high. Statistical and geographic distribution vulnerability scores of the surveyed buildings in KEPZ and Kalurghat areas show that in all the cases Kalurghat buildings are at greater risk than those at KEPZ. For a rare event, buildings at both the study areas are at high risk. For moderately rare event which correspond to the code prescribed loading, only 22% buildings at KEPZ and 7% buildings at Kalurghat are less likely to be damaged. Even for a frequent seismic event only 30% buildings at KEPZ and 9% buildings at Kalurghat scored above the cutoff level.

7.1.6 Fire Hazard

In the study, fire hazard has been assessed based on the travel time and accessibility computed from the fire stations to the industrial locations.

It is observed that in Kalurghat area out of 134 industries, 9 industries are in Very High Risk Zone, 101 in High Risk Zone, 17 in Medium Risk Zone and remaining industries are in low risk zone.

7.1.7 Covid-19

It has been observed that 46 numbers of people were exposed to the Covid-19 out of 67,713 people in KEPZ until August 2020. The percentage of exposed is very small. Considering the other indicators for assessing vulnerability and risk of Covid-19 of the employees of KEPZ industries, there were 62% of employees are in low risk and 38% are in high risk of Covid-19. More precautionary measures to be taken to reduce the risks of Covid-19.

7.2 Business Continuity Plan

Business Continuity Plan (BCP) is essential to continue the industrial activities at the event of disaster. BCP is the process involved in creating a mechanism of preventing and recovering resources and assets from potential threats to an Industry during the disaster. The plan ensures that personnel and assets are protected and can function quickly in the event of a disaster. Each Industry follows their own BCP.

An area specific Business Continuity Plan (BCP) should be developed for both Kalurghat and KEPZ areas based on risk profiles developed in the present study. The hazard risk profiles will help to identify necessary measures required for continuity of businesses for different types of hazards. The present study has amply demonstrated how different industries are impacted by various types of hazards.

In formulation of a BCP, this location specific as well as industry specific impacts of hazards can be effectively considered by risk profiling.

According to the FEMA Business Continuity Plan Template guideline (https://arlingtonva.s3.amazonaws.com) and the IBM Business Continuity Plan guidelines (https://www.ibm.com), the industrial BCP can be prepared considering following items.

1. Identification of Critical Business Functions

   Critical business functions are the critical activities that an Industry must maintain in a continuity situation, when there is a disruption to normal operations, it should comply with the legal requirements and supported life-safety.

   It requires to identify specific functions need to be resumed, business process, logistic supports & resources, point of contact and alternates, external supporting organizations/vendors, important documents, records such as policies and procedures, insurance information and payroll, list of members and their contract information etc. For critical support, the activities should be operable from either inside or outside of the office as applicable.

2. Disaster Risk Assessment: Each Industry requires to assess the disaster risks using the risk profile and the assumptions gathered from information of hazard, probability (highly, likely, possibly and non-likely), magnitude (catastrophic, critical, limited and negligible), and the national warning notice/signals, intensity of disaster event, duration, and risk level such very high, high, medium, low and very low etc.

3. Business Impact Analysis: It is the process of determining how the risks will affect their operations. The industry will identify functions and related resources which are important and monetary and time-sensitive issues.

4. Business Recovery Plan: The industry will identify and implement steps to recover the losses such as potential losses in terms of assets and revenue due to the risks. This to be done by Implementing safeguards and procedures to mitigate the risks of continuing the business.

   A continuity team might be created. This team will devise a plan to manage the disruption situation from disaster. And the team must be trained and tested through exercises to go over the plan and strategies.

5. Plan Activation Procedure: The Management of Industry will initiate the implementation of the Business Continuity Plan as below:

   - Plan Activation During Normal Business Hours

Employees may be instructed to go home to await further instructions or to move to the alternate site or to work at home if the facility is available. Furthermore, communications instruction on where and when to report for work which will use the communication procedures.

- Plan Activation Outside Normal Business Hours

  If an event occurs outside normal business hours, the management of Industry will activate the suitable Business Continuity which will be noticed to the employees.

6. Internal Communication Procedures: Activation of Internal communication is vital for the business continuation. The communication procedure requires to keep contact details of employees, buyers so that the management can communicate easily during and post disaster events.
7. Plan for available Transport facility: During the business continuity, transport facility should be ensured for the employees. This facility should be arranged from its own transports or from vendors. In the case of Infectious diseases like Covid-19, staff pick up and drop by Industry's own vehicle or by hired vehicle with safety measures as per the relevant guidelines.
8. Plan Deactivation of Business Continuity Plan: Plan deactivation is the process of discharging the alternate facility and restoring usual business operations which sometimes may not exactly come out the original situation. Most of the cases all of the units, machineries, equipment, as IT systems and protocols need to re-initiated or reestablishment. Subsequently a recovery plan will need to be prepared for the losses of assets and resources during the disaster event.

   Critical business functions must be restored in priority sequence based upon the classification and criticality of the function. The following elements are typically completed prior to plan deactivation.

   - Replacement of the damaged equipment, renovate the building/structure if required, supplying raw materials and transportation arrangements needed for the resumption efforts. Some standby equipment of facilities may be considered during the hazard seasons.
   - Temporarily suspend non-critical functional resources, as necessary, to support the resumption efforts.

9. Government Incentives: In some cases, government offers incentives to recover the losses due to the disaster events. To continue the business, the weak industries may be provided government incentives to continue their operations. During the Covid-19 pandemic situation most of the industries both local and jointly local and international companies received incentives to continue their business operations.
10. Bank Loan: Bank loan with easy terms and conditions can be considered during and after the disaster event which will be included in the business continuation plan. Bank loan can help to re-establishment/re-construction or rebuilding the industries operations and compensate the potential losses by the disasters so, that the business can be continued. Relevant agencies of the GoB can facilitate the easy term bank loans to the affected industries.

The industries may also come up with a checklist that will include key details such as emergency contact information and list of resources the continuity team may need.

The industries should also test the BCP itself whether it works or not. It should be tested several times to ensure it can be applied to many different risk scenarios. This will help identify any weaknesses in the BCP which can then be identified and corrected.

The relevant policies and acts may add clauses to make BCP mandatory for each industry which would be developed based on the Hazard Risk Profiles.

7.3 RECOMMENDATIONS

This study is a pioneering exercise for further Risk Reduction measures in the industrial sector of Bangladesh by making Risk Profiles which could be utilized by the investors, industrial planners, policy makers, development planners and other stakeholders. There have been limitations of data, time and durations. However, from the findings of the study, to achieve the objective of the project, measures, including but not limited to those are mentioned below as recommendations:

- Recommendation 1: Macro level Industrial Risk Zoning:
    - Conduct the study for all non-EPZ industrial areas phase by phase with priority settings.
    - Conduct similar studies for all the EPZs of Bangladesh phase by phase.
    - BEPZA, BEZA and other industry relevant national organizations and stakeholders to be involved and made aware of the Hazard Risk Studies and its uses.

  The above two could be done at macro level first and then find the areas for detailed studies based on priorities.
- Recommendation 2: Micro level Industrial Risk Zoning:
    - Based on the macro level Risk Zoning the zones for microlevel Risk Zoning list to be prepared with priorities.
    - Each EPZ, either existing or planned, should make a detailed Hazard Risk Profile for the investors and make it publicly available, if the government or relevant policy permits.
- Recommendation 3: Develop an Online GIS based interactive Risk Profiling System:
  The analysis done under this study can be converted into a GIS based web application which can perform Risk Analysis for any specific location based on preset hazard list and industry parameters. The application shall be capable of query and visualization of risk zones for selected industries in a specific geo-location on map.
- Recommendation 4: Mainstreaming the Risk Profile uses for industrial investments and clearance by incorporating it in Industrial Acts:
    - All the industrial acts available in Bangladesh should add clauses mentioning the use of Hazard Risk Profile where applicable.
    - Clearance for industrial approvals might be given a mandatory requirement on Hazard Risk Profile values.

- Recommendation 5: Awareness about Hazard Risk Profile:
    - After preparing the Hazard Risk Profiles for industrial zones, those should be circulated through the proper channels of the government. For mass circulation, those could be made downloadable from public web sites of the relevant government organizations.
    - BEZA, Ministry of Planning, Ministry of Commerce, Ministry of Industries, Ministry of Disaster Management and Relief and other relevant Ministries and organization should be made aware of the need of the Hazard Risk Profile for secured industrial investments.
- Recommendation 6: To mitigate the Earthquake Risk, followings are to be taken into considerations:
    - Micro-zonation of KEPZ and Kalurghat Area is required. Extensive soil testing, with appropriate methods to determine dynamic soil properties, is necessary.
    - Based on the micro-zonation studies, site specific detail area plan and design guidelines should be proposed for the industrial areas.
    - Building code enforcement mechanism should be introduced in the industrial areas.
    - Detail vulnerability assessment program should be carried out in the industrial areas. Priority based retrofitting program should be initiated to make the existing infrastructure earthquake resilient.
- Recommendation 7: To reduce the Epidemic Hazard Risks, followings are to be considered:
    - Health Insurance of the industry workers to be promoted - this can be made on participatory contribution from employer and employees.
    - Epidemic contingency - each industry could be given instructions/advice to prepare contingency plans of epidemic situations detaining how the situation could be managed.
    - Central Epidemic Insurance Plan - all the industries of EPZ can make group epidemic insurance funds which could be utilized during such situations in planned and coordinated ways.
- Recommendation 8: Bangladesh Delta Plan 2100 (BDP 2100) has six specific goals from which the first one “Ensure safety from floods and climate change related disasters” is very relevant to this study. The outcome of this study, the “Risk Profiles for Industry Sector” could be pursued to be considered in Delta Plan 2100.
- Recommendation 9: The investment priorities of BDP 2100 include flood protection, river erosion control, river management including river training and navigability, urban and rural water supply and waste management, and urban flood control and drainage. It is recommended that Hazard Risks Zoning under this study could include there.
- Recommendation 10: To reduce Fire Hazard Risk, followings are to be considered:
    - Visible fire hydrants should be placed along the streets in Kalurghat.

- Effective width of the road in front of BSCIC Industrial Office in Kalurghat is only 15 ft. Fire department access roads require 20 ft (6.1 m) of unobstructed width, therefore it is recommended to widen the road.
- More Fire Stations need to be established in the study area by assessing the suitable and required locations.

- Recommendation 11: Industry and Hazard Specific Business Continuation Plan (BCP):
    - Each industry must prepare their BCP based on the raw materials, products, exposure, vulnerability and risks from hazards. It should be specific to Hazard and Type of the industry.
    - BCP could be made mandatory to get the clearances of the industry. It might be included in the industrial policy.
- Recommendation 12: Ensuring the Protection Levels
    - Relevant organization (BWDB, CCC, CDA etc.) should pursue to implement and maintain the full-scale flood and cyclone surge protection in Kalurghat Industrial Area along the Karnaphuli.
    - Industrial Locations should be established inside the Protected Area.
- Recommendation 13: Water Logging
    - Drainage system of the Kalurghat area should be improved by establishing khal/drainage networks operational. Restoration/Recovery of Noakhal, Uttara Khal, Balukhali Khal, Uttara Khal located around Kalurghat Industrial Area should be implemented.
    - To reduce Water logging risk in KEPZ: A TSP Fertilizer Factory is located adjacent to the south-eastern boundary of KEPZ. During its operation, the industry releases sludge that reaches to the drainage networks of KEPZ. As a result, the drainages of KEPZ do not operate at its full capacity and waterlogging situations occur. To overcome this situation, the drainage network of KEPZ should be completely segregated from other outside drainages. Until this segregation is done, a periodic removal of the sludges is proposed as a temporary solution. Restoration/Recovery of Gupta Khal and other drainage near KEPZ area is recommended.
- Recommendation 14: Enforcement of cyclone resilient construction/reconstruction/extension of structure/building/occupancies should be implemented.
- Recommendation 15: Fire hazard
    - Establishment of more Fire Stations in Kalurghat Area and establishment of adequate numbers of Fire Station.

  - Effective width of the road in front of BSCIC Industrial Office in Kalurghat is only 15 ft. Fire department access roads require 20 ft (6.1 m) of unobstructed width, therefore it is recommended to widen the roads where possible.
- Recommendation 16: Covid-19
  - Implement of Novel Coronavirus (Covid-19) Guideline-DGH and WHO guidelines for each Industry.
  - Establishment of Quarantine Centers for the staffs of Industries of both KEPZ and Kalurghat.
  - Health Insurance of the industry workers to be promoted - this can be made on participatory contribution from employer and employees.

Policy Recommendations:

- Policy Recommendation 1: Industrial Land Zoning
  - Government should delineate industrial zones considering hazard risks. During issuance of clearance for construction of any industrial structure, the policy should check the risk zone specific to the type of industry which is exposed to the location specific hazards.
  - Land Zoning is important considering the risk for establishing an industry. Government should delineate the industrial zones considering the risks for the whole country.
  - For new establishments of industries, the government should provide clearance considering the type of industries and the suitable locations which comply with the acceptable levels of hazards and risks.
  - This will strengthen the disaster management efforts of the Government by considering it an instrument for building land use planning for industrial establishments for reduction of disaster risks and hazards in the Industrial sector.

- Policy Recommendation 2: Inclusion of Industrial Risk Profile in Relevant Acts and Policies

  - The study proposes to include Industrial Risk Profile in relevant Acts, such as, Economic Zone Act 2010, Bangladesh Export Processing Zones Authority Act 2018, Bangladesh Environment Conservation Act, 1995, Disaster Management Act, 2012, National Disaster Management Plan (2021-25), Standing Orders on Disaster, 2019. For establishing new industries, environmental, disaster regulations, climate change risks and issues should be addressed according to the Bangladesh Industrial Policy 2016. There are scopes for the risk profile to be brought into consideration within these Acts. It is proposed here to include clauses on the disaster risks for establishment/development of a new Industry. The disaster risk identified by the risk profile specific to the industry types and the locations in the industrial land zoning should be considered in this context.

- Policy Recommendation 3: No increase of Hazard: The construction of industries should follow a policy of **"Do not increase hazard"** by building it on such a location and with production to aggravate any hazard.

  - It should be ensured that any implementation protection measures do not exacerbate disaster risk in other areas.
  - For a large industrial establishment, a detailed Disaster Impact Assessment (DIA) is required.

  - Inclusion of HAZARD BASED Emergency Response: Emergency response for each specific hazard could be included in industry policies and Disaster Management Act.
  - Each industry should have its emergency response procedure which comply with the governmental disaster emergency plans. The industry's own plan should include specific conditions that will activate the plan, a clear chain of command and orders of responsibilities, a list of specific emergency functions and who will perform each of them, evacuation procedures, including evacuation routes and emergency exits, and procedures.
  - The personnel of industries should be given training on emergency procedures, preparation of real-time response with unannounced drill and to conduct post-mortem to improve the preparedness.
  - Remain aware of the government meteorological organization's warning protocols. When a warning is issued, be aware of the meaning of such a warning and be prepared to clearly communicate its implications to the staff members of the industry.

- Policy Recommendation 4: Hazard based Insurance: Some risks can be hardly mitigated, even some are not manageable may be because of its geographic locations or something else. In such cases Insurance can be made mandatory for both physical and life losses.

  - Consider insurance policy to cover potential losses to the industrial establishments. While insurance does not prevent injuries or deaths, or save communities, it can reduce financial losses and enable industries to recover from the effects of hazards and to regain its functions more quickly. It may also help reconstruction and replacement of damaged buildings, other related components.

- Policy Recommendation 5- Industrial Loan: The industrial loans from financing organizations, both government and non-government, may include consideration of Risk Profile in their criteria. For high-risk areas loans might be restricted to discourage the risky investment.

- Policy Recommendation 6: Earthquake Risk Reduction Program: The Government may consider undertaking a nationwide Earthquake Risk Reduction Program. Along with the emergency facilities, the industry sector should be given priority in this program. As almost the entire supply-chain of the industry sector of the country depends on connectivity with the Chattogram Port, the earthquake risk reduction efforts should be conducted in the Chattogram City Corporation area on a priority basis. Following actions might be considered.

- Micro-zonation of KEPZ and Kalurghat Area is required. Extensive soil testing, with appropriate methods to determine dynamic soil properties, is necessary.
- Based on the micro-zonation studies, site specific detail area plan and design guidelines should be proposed for the industrial areas.
- Building code enforcement mechanism should be introduced in the industrial areas.
- Detail vulnerability assessment program should be carried out in the industrial areas. Priority based retrofitting program should be initiated to make the existing infrastructure earthquake resilient.

Action Matrix

Based on the above findings, the following actions are suggested to be made by involving the relevant stakeholders:

Issue/Action/Recommendation	Policy/Plan/Regulation	Relevant Agency/Ministry
Long-term		
Industrial Risk Zoning	National Plan for Disaster Management (NPDM) 2021 - 2025	Ministry of Industries, Disaster Management & Relief, Ministry of Lands;
Development Climate Change Impact and Disaster Risk Profiles for EPZ and non-EPZ Industrial areas in the country phase by phase.	National Plan for Disaster Management (NPDM) 2021 – 2025	Prime Minister's Office, Disaster Management & Relief, Ministry of Industries
Should carryout Disaster Impact Assessment (DIA) for new construction/reconstruction/ extension of Industrial establishment.	Inclusion in Disaster Management Acts-2012/ Industry Act/BEZA or BEPZA Acts	Ministry of Disaster Management & Relief, Ministry of Industry, Prime Minister's Office
Enforcement/Reconstruction/Construction of flood protection works for the industries located in coastal area in Bangladesh.	Flood control and prevention schemes under 2021-2025 (8th Five Year Plan)	Ministry of Water Resources
Improve Waterlogging and Drainage facilities in Industrial locations (EPZ & Non EPZ Industrial Areas)	2021-22-Annual Development Programme (ADP) for Physical Planning Sector	Ministry of Industries, BEZA, BEPZA
Establishment of Desalination Plant for the Industrial Areas located in Coastal Area.	May be included in 8th Five Year Plan (2020-2025)	Ministry of Industries
Development of risk sensitive detail area plan for industrial areas all over the country	PPTA based on relevant area master plan	Ministry of Industries
Launch an Earthquake Risk Reduction Program (ERRP) for the Industry Sector:	NPDM	Ministry of Industries in association with Ministry of

Issue/Action/Recommendation	Policy/Plan/Regulation	Relevant Agency/Ministry
HVRA, Building Code Enforcement Mechanism, Retrofitting Program etc.		Disaster Management & Relief
Establishment of sufficient Fire Stations in Kalurghat Area	Include in 8th Five Year Plan in Public Order and Safety	Ministry of Home Affairs Department of Fire Services and Civil Defense
Mainstreaming the Risk Profile uses for industrial investments and clearance incorporating it into the Industrial Acts:	Inclusion in BEZA/BEPZA and Industry Acts.	Prime Minister's Office, Ministry of Industry, Ministry of Law. Ministry of Disaster management and Relief
Implementation of Business Continuity Plan (BCP).	Inclusion in BEZA/BEPZA and Industry Acts	Prime Minister's Office, Ministry of Industry, Ministry of Law. Ministry of Disaster management and Relief
Each Industry should follow Hazard based Emergency Response guidelines.	Inclusion in Disaster Management Acts-2012/ Industry Act/BEZA or BEPZA Acts	Ministry of Disaster Management & Relief, Ministry of Industry, Prime Minister's Office
Develop an Online GIS based interactive Risk Profiling System	Include in 8th Five Year Plan	Ministry of Industries, BEZA, BEPZA
Short term		
Enforcement/Reconstruction/Construction of Flood Protection Works for Kalurghat Area.	2021-22-Annual Development Programme (ADP) for Water Sector	Bangladesh Water Development Board (BWDB), Chattogram Development Authority (CDA), Chattogram City Corporation (CCC)
Restoration/Recovery of Gupta Khal and other drainage near KEPZ area, and restoration/Recovery of Noakhal, Uttara Khal, Balukhali Khal, Uttara Khal located around Kalurghat Industrial Area.	2021-22-Annual Development Programme (ADP) for Physical Planning Sector	Chattogram City Corporation (CCC), Chattogram WASA and Chattogram Development Authority.
Enforcement of cyclone resistant construction of structure /buildings/ occupancies etc. in KEPZ area and Kalurghat Industrial Area.	2021-22-Annual Development Programme (ADP)-for Govt owned structures/buildings & Private owned structure building enforced by Private Companies	BEPZA, Ministry of Housing and Public Works, Private Companies.

Issue/Action/Recommendation	Policy/Plan/Regulation	Relevant Agency/Ministry
Increase discharge from Kaptai HEPP to improve the salinity situation KEPZ Area and in Kalurghat area.	May include in Kaptai HEPP operational Regulations/ Guidelines	Power Development Board (PDB), Chattogram Chambers Commerce and Industries (CCCI)
Micro-zonation of KEPZ and Kalurghat Area	Within the scope of National Plan for Disaster Management (NPDM) 2021 - 2025	Ministry of Industries in association with Ministry of Disaster Management & Relief
Development of site-specific infrastructure design guidelines for KEPZ and Kalurghat Area	PPTA based on Bangladesh National Building Code (BNBC) 2020	Ministry of Industries in association with Ministry of Housing and Public Works
Introduce Building Code Enforcement mechanism for KEPZ and Kalurghat Area	Project Preparatory Technical Assistance (PPTA)	Ministry of Industries; Department of Inspection for Factories and Establishments (DIFE)
Initiate priority-based detail vulnerability assessment and retrofitting programs for KEPZ and Kalurghat Area	May be incorporated in the revised 8th Five Year Plan	Ministry of Industries; Department of Inspection for Factories and Establishments (DIFE)
Implement of Novel Coronavirus (Covid-19) Guideline-DGH and WHO guidelines in each Industry.	Bangladesh Preparedness and Response Plan for COVID-19	KEPZ, CCCI, DG Health. Local Authority.
Establishment of Quarantine Centers for the staff, personnel of Industries of KEPZ and Kalurghat Area and other EPZ and Industrial Zones separately.	Bangladesh Preparedness and Response Plan for COVID-19	DG Health, Local Authority. KEPZ and CCCI.

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Appendix-A

Industrial Survey Questionnaire

Questionnaire Form for Industry Survey

Planning Commission, GOB, has initiated a project with funding from UNDP to develop Disaster and Climate Change Risk Profile of Industry Sector in Bangladesh

The aim of this study is to develop a risk profile of industry sector in order to provide industrialist, decision-makers and authorities an effective planning approach for minimizing loss and damage caused by climate change and natural disasters. The risk profile will provide a comprehensive view of hazard, risk and uncertainties for selected natural disasters in a changing climate, with projections for the period 2030-2050.

The collected data will be used to assess the vulnerability of the industry sector and estimate potential damage due to climate change and natural disasters. This would help to generate risk profile of industry sector in terms of hazards to be used for developing strategies to address identified disaster and climate related risks including investment opportunities.

Completion of this questionnaire is entirely voluntary, and the information collected will be anonymous.

The information might be collected using mobile app/smart-device.

Contact for Further Information

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Respondent Information

Name of Respondent	Hasan Mahmud	Designation:	Manager (HR)
Respondents' Cell Number:	01725101968	Phone	
Respondent Email:	hnbd@niitakayama.co.uk		

Interviewer Information

Name of Interviewer: SRZ | Designation: Jr GIS & RS Analyst

Cell Phone Number: 01521473288

Smart Device Used: ☑ Mobile Phone ☐ Tablet ☐ Laptop

Used offline/Online ☐ On line ☑ Offline | Device Brand:

Industry Survey

1. General Information

1.1 Id-Serial: 22 | 1.2 Survey Date: 24/08/20

1.3 Name of Industry: Sheng Tseng Enterprise Company Limited

1.4 Type of Industry: Footwear and Leather

1.5 Operational Date: 11.04.2011

1.6 Principal Product(s): Shoe accessories

1.7 Industry Address: Street/Lane: 51-54

Section: 02 | Ward: 40

PS/Thana: North Patenga | District: Chattogram

EPZ Name: Karnaphuli EPZ

1.8 Geographical Location Latitude: Deg: Min: Sec:

Longitude: Deg: Min: Sec:

1.9 Total Land (Acres): 6000 | 1.10 Total Investment (BDTx1000):

1.11 Current Status: ☑ Active ☐ Not Active

1.12 Photograph of the Site: File Name:

2. Business Information

2.1 Business Type: 4 | *1. Sole proprietorship, 2. Partnership, 3. Corporation, 4. Limited Liability Company (LLC), 5 Others*

2.2 Investor Type: ☐ National ☑ International ☐ Both

2.2 Name of CEO/MD/Director: Mr. Chen Yu-Chuan

2.3 Contacts: Cell Phone: 01725101468 Telephone: Fax:

Email:

3. Activity Information

3.1 Daily Production Capacity: Units:

3.2 Sources of Electricity (select one): ☐ PDB ☐ Generator ☐ Both ☑ Others, Specify [ ]

3.3 Water Source used: ☐ Supplied Water (CWASA), ☐ Surface Water (River/Khal)

☐ Water Treatment Plant (desalination), ☐Owned Deep Tube well

☐ Hired Deep Tube well, ☐ Recycled Water, ☑ Others, Specify [KEPZ Water Treatment Plant]

4. Waste Management

4.1 Waste Type: ☑ Solid, ☐ Liquid ☐ Gaseous ☑ Sound ☐ No waste

4.2 How Waste are managed:

Solid	Liquid	Gaseous	Sound
☐ Recycle/Reuse	☐ ETP (individual)	☐ Chimney	☑ Insulator
☐ onsite disposal	☐ ETP (central)	☐ Bag Filter	☐ Silencer
☑ offsite disposal	☐ Setting Tank	☐ Scrubber	☐ Canopy
☐ Incinerator	☐ Others	☐ Fume Extraction	☐ Muffler
☐ Landfill		☐ Others	☐ Others
☐ Others			

4.3 Liquid Waste Disposal into: ☐River/Sea ☐ Drainage Canal ☐ Open Space, ☐ CC dump, ☐ others

4.4 If ETP, where to dispose the treated water? ☐River/Sea ☐ Drainage Canal ☐ Others [ ]

5. Disasters & Hazards:

5.1 What are the disaster Risks identified in past years?

☒ Flood ☐ Cyclone

☐ Tidal surge ☐ Earthquake

☐ Salinity ☐ Landslides

☑ Water Logging ☐ Fire incidence

Infectious/Communicable diseases

☐ Other [ ]

5.2 Losses by recent disaster events

Year	Disaster Event	Level of Disaster (Sever/moderately sever, not sever)	Casualties (number)	Financial Loss (BDTx10^3)
01.01.2019	Flood	not severe	0	0

5.3 Vulnerability Level of different Disaster Events:

Disaster	Vulnerability Level (High/medium/low)
Flood	Low
Cyclone	Low
Tidal surge	Low
Earthquake	Low
Salinity	High
Landslides	Low
Water logging	Low
Fire incidence	Low
Others	

5.4 What disaster events are more often likely to be happened?

- ☐ Flood
- ☐ Cyclone
- ☐ Tidal Surge
- ☐ Earthquake
- ☐ Salinity
- ☐ Landslides
- ☑ Water Logging
- ☐ Fire incidence
- ☐ Others

5.5 Is there any monitoring facilities for potential disaster Events?

- ☐ Surface water observation
- ☐ Earthquake (seismic)
- ☐ Rainfall
- ☑ Temperature
- ☐ Wind Speed
- ☐ Humidity
- ☐ Fire Alarm
- ☐ Sounds hazard
- ☐ Air Pollution
- ☐ Other

5.6 Facility to protect from disaster Risks

- ☑ Health Facilities
- ☑ Adequate Open Space
- ☑ Fire Fighting
- ☐ Fire Hydrant
- ☑ Flood Protection Work (Embankment/polder)
- ☐ Others

5.7 Emergency Response Facilities

- ☐ On-site Health Facilities
- ☑ Fire Fighting

☐ Others

5.8 Is there any official warning system for the Industrial Communities/workers? ☑ Yes, ☐ No

and how: Alarm

5.9 Do you have any Business Continuity Plan during disaster? ☑ Yes, ☐ No

5.10 How is the response from Local people: ☑ Instant ☐ Medium ☐ Slow ☐ No

511 How is the response from local authorities: ☑ Instant ☐ Medium ☐ Slow ☐ No

5.12 Is there any compensation received from Government organization/other organization? ☐ Yes, ☑ No

5.13 Infectious/Communicable diseases related preparedness and response.

- Personnel trained in Infectious disease surveillance
- ☑ yes ☐ No

Do you have epidemic (such as Corona) preparedness and response: ☑ yes ☐ No

If yes:

- Emergency stocks of drugs, vaccines, and supplies, at all times in past 1 year. No
- Do you have budget line for epidemic response: ☑ yes ☐ No
- Do you have central epidemic management committee: ☑ yes ☐ No
- Do you have central rapid response team for epidemics: ☑ yes ☐ No
- Training on health and safety: ☑ yes ☐ No

If no, why you do not feel to have a plan for infectious diseases related preparedness and response

Reason 1:

Reason 2:

Reason 3:

Response to COVID 19 outbreak

- How did you respond to COVID 19?

Closed the Industry: ☐ Yes, ☑ No

if Yes: Isolation maintained: ☑ Yes, ☐ No

Have you provided Masks: ☑ Yes, ☐ No

Have you provided PPE: ☑ Yes, ☐ No

How many workers got infected: 0

How many workers died: 0

if No: How long the industry was closed (days): 30

Have you paid salary: ☐ No

☑ Yes [Full ✓ or %]

Loss due Covit 19: Million BDT ______________Million USD_________

Potential Loss: Million BDT ______________Million USD ________

What is your opinion to face the challenges regarding to preparedness and response for infectious diseases management?

1.
2.
3.
4.

6. Communication Facilities

6.1 Communication Facilities: ☑ Road ☐ Water ways ☐ Railway ☐ Airway

6.2 Status of Connecting Roads: ☑ Good ☐ Poor ☐ No

6.3 Status of Connection Waterway ☐ Good ☐ Poor ☑ No

6.4 Transport Facilities ☑ Container ☐ Ship/Cargo

6.5 Container Handling facilities ☐ Pontoon ☐ Jetty ☐ Platform ☐ others

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Appendix-B

Rapid Visual Screening Questionnaire

Checklist for Rapid Visual Screening (RVS)

1. **Name of the Interviewer** ______________________
2. **Industry Name** 32
3. **Structure ID** Idle machine warehouse.
4. **Geographical Coordinate (DD in WGS84):** Lat 22°16'23, Long 91°47'24
5. **Occupancy**
   - Assembly
   - Commercial
   - Residential
   - Industrial
   - Office
   - School
   - Utility
   - ✓ Warehouse
   - Emergency Service
6. **Ownership of the building**
   - Public
   - ✓ Private
7. **No. of Story** *(Above Grade)* : 1
8. **No. of Story** *(Below Grade) (if not type 0)*: 0

   Idle machine room = 38.1M × 19.8M (125ft × 65ft)
9. **Floor Area** *(Approximate in square ft) (Write in sequence, i.e. GF+1st Floor+2nd Flood so so)*

   Total = 8,119 sqft

   GF: 8,119 1st Floor: 2nd Floor: 3rd Floor: 4th Floor: 5th floor :
10. **Building Type** *(Please look for the question at supporting document)*
    - C2 - Concrete Shear Wall Building
    - C3 - Concrete Frame With Masonry Infill Walls
    - URM - Unreinforced Masonry Building
    - SI - Steel Moment Resistant Frame
    - ✓ S2 - Braced Steel Frame
    - S3 - Light Metal Building
    - S5 - Steel Frame With Unreinforced Masonry Infill Wall
    - W1 - Wood Light Frame
    - W1A - Multi-Storey Multi-Unit Residential (Plan Area > 3000 sq. ft)
    - W2- Wood Frame Commercial & Industrial (Plan Area > 5000 sq. ft)
11. **Severe Vertical Irregularity** *(Please look for the question at supporting document)*
    - Short Column
    - Soft Storey / Weak Storey
    - Out of Plane Setback (if the cantilever portion is greater than 2 feet)
    - ✓ None
12. **Moderate Vertical Irregularity** *(Please look for the question at supporting document)*

- In Plane Setback
- Split Level
- Sloping Site
- ✓ None

13. **Plan Irregularity** *(Please look for the question at supporting document)*
    - Torsional Irregularity
    - Reentrant Corner
    - Out of Plane Offset (only exterior)
    - Non-Parallel System
    - Diaphragm Opening
    - ✓ None

14. **Pounding Potential** *(Please look for the question at supporting document)*
    - Floors are not aligning vertically
    - Minimum gap doesn't meet
    - ✓ None
    - The building is at the end of a row of three or more buildings
    - One building is two or more stories taller than the adjacent building

15. **Falling Hazard** *(Please look for the question at supporting document)*
    - Unsupported Water Tank
    - Heavy Cladding
    - Flower Pot at Roof
    - Unsupported Parapet
    - Masonry Tower
    - ✓ None
    - Cornices
    - Chimney

16. **Geological Hazard** *(Please look for the question at supporting document)*
    - Loose Fill
    - Organic Soil
    - Landslide
    - ✓ None

17. **Significant Damage**
    - Visibly Sagging Beam/ Floor/ Slab
    - Visibly Broken Beam/ Column
    - Sloping Floor
    - Large Exterior Cracks
    - Visible Distress From Previous Earthquake
    - Visible Fire Damage
    - Visible Foundation Elements with Large Cracks
    - Foundation Elements Exposed Due to Significant Erosion of Adjacent Soil
    - ✓ None

18. **Is Mortar Eroding Away?**
    - Yes
    - ✓ No

19. **Is There Any Exposed Rebar?**
    - Yes
    - ✓ No

20. **Is There Any Member Corroded?**
    - Yes
    - ✓ No

21. **Extent of Review**
    - ✓ Partial
    - All side

22. **Interior Inspection**
    - ✓ Visible
    - Entered
    - None

23. **Take photo** Yes

Appendix-C

Contact details of the respondents from Kalurghat & KEPZ industries

Contact details of the respondents from Kalurghat industries-

Name of Industry	Respondent Name	Designation	Phone number	e mail
Base Textiles Limited	Jahirul islam	Deputy manager	01979170001	jahir@basetextile.com
Al Ittefaq Trxtiles Ltd.	Asm Kawsar	DGM	01711483162	alittefaq@gmail.com
Maf Shoes Limited	Muhammad zakir hussain	Manager Admin	01985559216	zakir.hussain@mafshoes.com
Aramit cement limited	Muhammad ismail hasan	Deputy manager (Admin and HR)	01777700870	hassan.hrd@aramitgroup.com
United chemical and pharmacitical Limited	Rabiul hasan chowdhury	Factory manager	01912807428	rabiul79@yahoo.com
Gazi wires limited	Md. Abu Said	Senior Administrative Officer	01717511000	Abusaid97@gmail.com
Meridian Foods Limited	Engr. Md. Foyzul Hasan	AGM Factory Operations	01709662886	foyzul.islam@meridiangroupbd.com
Resimix Industries Ltd	Haradhan Chandra Nag	Factory Incharge	01819335979	hnag2009@gmail.com
Olympic Milk Food Packaging Industries (pvt.) LTD.	Md. Nigamul Haq	Senior executive	01847282354	
Reliance Can Industris (Pvt) Ltd.	A.K.M Enayet Ullah	Chairman	01754337733	Relianceac@gmail.com
Mir plup and paper industry	Anwarul Islam	General Manager	01715307229	
National Metal Industry	Kollan datta	Factory incharge	01819644103	
Fabian Thread LTD.	Md. Monir hossain	Assistant manager (Admin, Hr)	01713442342	compliance@fabiangrp.com
Moon star paints & chemical industry	Md. Azim uddin	Head R &D	01708805011	moonstarpaints@gmail.com
Reliance Box Industries Ltd.	Meer Abdul Latif	Factory Manager	01874224592	
Bengal Sack Corporation LTD.	Eng. Probir Chandra Sikdar	AGM	01716621712	bscl@tkgroupbd.com
Berger Paints Bangladesh Ltd.	Engr.Md.Faridul Alam	Manager-Engineering	01755677154	farid@bergerbd.com
Transcom Beverage Limited	Md Junaed Rahman	Eng, Maintenance in Charge	01841797794	junaed.rahman@tbl.transcombd.com
Usmania Glass Sheet Factory	Md Masudul Alam	M Admin	01817531341	info@ugsflbd.com
Chittagong Jute Manufacturing Company Ltd	Md Toufiqul Islam	Deputy Manager Admin	01554 633139	toufiqulislam927@gmail.com

Contact details of the respondents from KEPZ -

Name of Industry	Respondent Name	Designation	Phone number	e mail
Arrow Fabrics (Pvt.) Ltd.	Shama Prasad Chakroborty	DGM-HR & ADMIN	01876626583	SHAMA@ARROWJEANS.COM
Bangladesh Pou Hung Industrial Limited	Md. Ashraf Hossain Khan (Nayeem)	Section cheif HR	01829676525	hr@bdpouhung.com
BD Designs Private Limited	Shahbuddin Ahmed	Director Admin	01713311827	Shahbuddin@bddesignsltd.com
Bestec BD LTD.	Mohammad Zahidun Nobi	Manager HR	01819625768	zahid@bestecbd.com
Campvalley Global Ltd.	Hasan Parvez	GM (HR & Admin)	01710595819	parvez.chr@campvalleyglobal.com
CBC Optical Industries BD Co. Ltd.	Md. Abdul mannan patwari	Senior manager admin and accounts	01755682890	mannan@coibd.com
Corvo cycles LTD.	Bokhtiyer Jamal	Manager HR	01613007070	hr@corvoltd
Denim Expert LTD.	Sukanta Chowdhury	Manager HR & compliance	01312501 402	sukanta@denimexpert.com
Eusebio Sporting BD Ltd.	Zamshedul Islam	Assistant Manager HR	01670535498	
Geebee (Bangladesh) Ltd.	MA Naser	Manager Admin	01610407702	Admin1gbbl@geebeegarments.ae
Hela Clothing Bangladesh Limited	Sankar Kanti Chowdhuri	Manager HR Admin	01717068017	shankar@variantbd.com
HKD Outdoor Innovation Ltd.	Mr Delwar Hossain	AGM	01740219195	delwar.hrcmpl@hkdbd.com
Intimate Apparels Ltd.	Mahmudul hasan	Executive hr and compliance	01819335746	hasancompliance@intimateapparelsbd.com
Kenpark Bangladesh Apparels (Pvt.) LTD.	Rezaul Mostafa Galib	Head of HR	01729063454	ahmed.galib@kenparkbangladesh.com
Lhotse Bd Ltd.	Noktro barua	Deputy director	01819385878	
Liberty Poly Zone (BD) Ltd.	Md Arafat Uddin	Assistant Manager Compliance	01813243523	ronymircpg@gmail.com
M/S Finesse Apparels Limited	Subir Das	Manager	01716692292	subir18bd@yahoo.com
Mars Sportswear Limited	Mohammed Arman Chowdhury	Manager	01841579050	arman@marsapparels.com
Mas Intimates Bangladesh (Pvt.) Limited	Kasshaful Haque	Manager (HR& Admin)	01844040415	kasshafulh@masholdings.com
Naturab Assessories Bangladesh (Pvt.) Ltd.	Shiv Shankar Chowdhury	HR manager	01708493239	sankar@naturbd.com
OFMA Camp Ltd.	Daulat Hasan	Manager compliance	01704042760	

Name of Industry	Respondent Name	Designation	Phone number	e mail
Paolo Footwear (BD) Ltd	Shahabuddin Bhuyan	AGM	01713363382	monju@paolo-inll.com
Park (Bangladesh) Company Limited	Sumon Bhattacharje e	Manager HR Adin & MIS	01819171948	Sumon.pbc@parcorp.co.kr
Shah Amanat Accessories Ltd.	Nakhatra barua	Deputy director	01819385878	Nakhatra@lhotsebd.com
Sheng Tseng Enterprise Co. LTD.	Hasan mahmud	Manager HR	01725101468	Hr-bd@niitakayama.co.uk
Strong Footwear LTD.	Md.irfan	In charge (hr and admin)	01882650544	
Trendex Furniture Industry Co. Limited	Md. Ziaul Karim	Manager HR Admin	01918714882	zia@lacquercraft.com
Trident Cycles Company Limited	Bakhtiyer Jamal	Manager HR	01613007070	hr@corvoltd.com
Vancot Limited	Ashim kumer	DGM Hr compliance and admin	01708134356	vencot.ashim@shingroup.com
Vantura (Bangladesh) Limited	Mr.Bahar uddin chow	Admin Manager	01714117273	Ventura_admin@cliftogroupbd.com
Whitex Garments(Banglades h) Pvt. Ltd.	Avisek barua	Section incharge and compliance	01755639685	Avishek@whitexgarments.com
World Ye Apparels (BD) Limited	Sanjit barua	Manager-accounts and finance	01777701388	sanjit@worldye.net
Xin Chang Shoes (BD) Ltd.	Md. Arifur Rahman	Chief HR	01911728096	bdhr-ctg6@goldenchang.com
Young Zhen Metal Industries Ltd.	Toukir ahmed	GM	01847228286	Toukir@lsitwn.com
ZANT Accessories Limited	Md Moshuil Alom	Sr Manager HR & Commercial	01715460683	moshiul@zantaaccessories.com

Appendix-D

Survey Data

Appendix-E

Feedback on Draft Final Report

Feedbacks from the DFR and responses

(comments were arranged not on the basis of seniority)

Commented by	Comment	Response from IWM
Md Zafar Ullah, Project Director, Urban Resilience Project (URP)	I. RAJUK is presently conducting extensive sub-soil investigations in preparing risk-sensitive land use planning in the Urban Resilience Project. Similar investigations may be recommended in the industrial areas. II. How mathematical data were collected? III. Analysis required on the whole Chattogram for Earthquake data.	I. Agreed to the suggestion. A similar type of survey RVS has been carried out for this study. II. Hydro-meteorological data for water and hazard simulation modeling was collected from BWDB, CPA, SoB, BMD, DDM, IWM, and many other organizations. IWM also collected data under different prior projects in Chattogram. III. Agreed to the suggestion, but it was out of the scope of the study.
Dr. Sirajul Islam, Professor, North South University	I. Which IPCC Scenario IWM used for this study? II. Did IWM conduct any downscaling of the IPCC scenario? If yes, which method did they use?	I. RCP (Representative Concentration Pathway) 8.5 was used for this study. II. RCP 8.5 was downscaled for Bay of Bengal using a statistical model in a separate study conducted by IWM.
Farida Parveen, Deputy Director, DAE	Which return period is used?	The return periods used for Flood, Cyclone & Tidal Surges, Water Logging were Average year, 25 years and 50 years.

Commented by	Comment	Response from IWM
Md. Ashraful Kabir, Chief Engineer, BEPZA	EPZ and other related Acts should be reviewed, such as BEPZA act 1980.	Following Acts have been reviewed. • The Bangladesh Export Processing Zones Authority Act, 1980 • Disaster Management Act, 2012 • National Disaster Management Plan (2021-25) • Standing Orders on Disaster, 2019
Md Mafidul Islam, Chief of General Economics Division (GED)	I. Need improvement on the recommendation. II. Follow protection level suggested in Delta Plan III. Freshwater supply in Chattogram city will be under threat in 2030-50, that should have come in this report. IV. Why did this study not cover the full Chattogram?	I. The recommendations have been improved in this Final Report. II. Protection level should be maintained. But risk was considered with protection failure case. III. Freshwater supply is out of scope of the Risk profile project, however detailed study will be required to identify the water demand for the specified time period. IV. UNDP risk profile covered two types of industrial zones- EPZ and non EPZ zones. Full Chattogram city is not within the scope of this project.
Md. Khushid Alam, Assistant Resident Representative, UNDP Bangladesh	I. The study is successful in bringing the agenda forward. II. Recommendations should be more refined.	I. IWM is extremely delighted to bring the issue forward to the policy makers, with the support of the Planning Commission and UNDP. II. The recommendations have been improved in the Final Report.

Commented by	Comment	Response from IWM
Khandker Ahsan Hossain, Chief, Programming Division	I. Recommendations should be action oriented. II. Risk Profile for other industries should also be prepared in future.	I. The recommendations have been improved in Action Matrix under Section 7.3 in the Final Report. II. Agreed to the suggestion. More such studies are required. It is recommended and included in policy brief.
Mohammad Anamul Haque, General Manager, KEPZ	I. Waterlogging is a problem in KEPZ during rainy seasons; it needs specific guidelines on waterlogging. II. Protection for existing EPZ should be recommended.	I. Water logging recommendation on KEPZ have been included in Section 7.3. II. Added in the recommendation Section 7.3.
Mohammad Jainul Bari, Secretary, Planning Division	I. Appreciated the study. II. The study is important for addressing disaster risk in development investment. III. Encouraged to address the comments. IV. Advised to ensure the government. standard. V. Encouraged further detail study.	We appreciate for the remarks and suggestions. IWM team is committed to support the Planning Commission in such studies always in future. Further studies for EPZ and non EPZ industrial area are recommended in macro and micro level.
Mohammad Hasan Arif (Joint Secretary) Bangladesh	I. In the study, areas of two different natures, (i) an organized industrial area such as an Export Processing Zone (EPZ) or an Economic Zone **(Karnaphuli EPZ, Chattogram)**, and (ii) a less organized industrial area **(Parts of Kalurghat industrial area in Chattogram)** were selected.	I. These two areas- KEPZ and Kalurghat were selected in consultation with NRP project office. The study areas have been selected by the client in Chattogram City as the city cover more hazards such as Cyclone, tidal surge, salinity with the impacts of sea level rise. This was further discussed in inception workshop held in Chattogram and the KEPZ and

Commented by	Comment	Response from IWM
Economic Zones Authority (BEZA)	(a) These two areas are within the same city and only 20 kilometers apart; (b) Kalurghat is termed as a less organized area but it was developed by BSCIC and there are many less organized areas in Bangladesh than this; (c) The two areas are within the same seismic and climate zone. So, it would be better if another zone is selected from a less organized industrial area of Savar, Gazipur or Narayanganj which would provide true pictures of risk and disaster parameters of two diversified zones of different areas.	Kalurghat were selected out of 5 areas- Fouzdarhat Industrial Area, Sholoshohor Industrial Area, Kalurghat Industrial Area, Chattogram EPZ and Karnaphuli EPZ.
	II. The title of the study is "Developing Disaster and Climate Change Risk Profile of Industry Sector in Bangladesh" which indicates the study for overall Bangladesh, but the data was collected from one city only. So, it is not rational to term this as national study as the study does not represent the whole country. So, the title needs to be changed according to study scope. If the name of Bangladesh is mentioned, at least another 2 to 3 divisions with different conditions need to be incorporated.	II. The suggestion is right. However, as per the contract, these areas supposed to be within Chattogram district, and the selection of the area were finalized during the Inception Meeting in Chattogram. The Title of the Study has been Changed to **"Industry Sector Risk Profile: The Case of KEPZ and Kalurghat Industrial Area in Chattogram"** by instruction from the Project Manager, NRP, Programming Division, Planning Commission.

Commented by	Comment	Response from IWM
	III. The impact of disaster and risk are not in same magnitude on small, medium, large or green industries. It would be better if such impact can be discussed in the report.	III. We agree with the statement. The risk maps have been prepared based on intensity and impacts of hazards on industries.
	IV. For more than one year, the whole world including Bangladesh is experiencing the pandemic of Covid-19. Besides taking lives of more than three million people, this pandemic has shattered the global value chain and brought about unprecedented recession due to cessation of economic activities. The report was also produced during the pandemic time. However, there is very limited discussion about Covid-19, its impact and way-out.	IV. COVID-19 was not included in the list of hazards as per the ToR when the project commenced in February 2020. The pandemic hit Bangladesh in March 2020. However, during the pandemic and lockdown period, the Project Director requested to include COVID-19 as a hazard, but neither the project cost nor additional resources were allocated to carry out the risk assessment. Even with these limitations, IWM consultant team assessed available information related to the COVID-19 and carried out the tasks in consultation with disaster management experts. Note that, the epidemic management information was collected through the questionnaire survey.
	V. Most of the recommendations provided in the report are too generalized. There is no (a) specific timeframe to implement those recommendations, (b) mention of which ministries/divisions/organizations are responsible for implementing those and (c) priority of those activities as per need and fund.	V. The recommendations have been improved. The names of connecting organizations are mentioned in the Action Matrix of Policy Briefs.

Commented by	Comment	Response from IWM
	VI. Disaster and risk do not pose impact in the same magnitude to all and so gender-aware approaches addressing challenges women in manufacturing sectors face during and after disasters are vital. Such approach is also mentioned in the National Disaster Management Plan (2021-25) formulated by Ministry of Disaster Management and Relief. However, such approach is absent in the report. It is important to conduct gender-sensitive needs assessments, finance women-owned SMEs through disaster risk financing and enhance market access.	VI. We understand that disasters affect men, women, children, and disable persons differently. However, the Internal Sharing Workshop took place on 21 July 2020 it was decided that Social and gender issues would be excluded from the scope of this project. We have mentioned that limitation in section 1.7 of the report as well.
	VII. For effective control and mitigation of risk and disaster, it is recommended to use technology measures that harness digital technologies to improve data quality, offer predictive analytics, enhance monitoring and communication, and provide real-time information. For these, we need to encourage ICT updates by firms, enhance supply chain resilience and visibility utilizing new technologies, enhance disaster preparedness of industrial infrastructure with new technologies, use innovative technologies to fast-track asset damage	VII. The study deployed state of the art ICT technologies for topography survey (Terrestrial Laser Scanner, Drone) and prepare the GIS maps from point cloud elevation data presented in Section 4.1.2.4 ; Questionnaire survey was conducted through ODK (Open Data Kit) mobile app connecting with real time server; Hydrodynamic simulation models (Section 5.1) were used for Flood, Cyclone, Water logging, Salinity hazard assessment. IWM team also used high end GIS network analysis for fire risk assessment (Section 6.5). All of these are mentioned throughout the report. Development of a GIS based Interactive Risk Profiling System is proposed in this report in Policy Recommendation (Action Matrix) under Section 7.3.

Commented by	Comment	Response from IWM
	assessments and insurance claims payouts. However, these innovative measures are not properly addressed in the report.	
	VIII. Business continuity plan refers to maintaining business functions or quickly resuming them in the event of a major disruption and outlines procedures and instructions an organization must follow in the face of such disasters which covers business processes, assets, human resources, business partners and more. For this, it is vital to promote business continuity plan (BCP) at the firm, inter-firm, and industrial park levels, help industries maintain global value chains through risk-informed trade regimes or cross-border BCP initiatives, promote resilient industrial park development through risk-informed guidelines and regulations, minimize infrastructure disruption in industrial parks by integrating resilience principles into infrastructure system design and devise appropriate financing mechanism for these activities. Although the concept of BCP is	VIII. Details of the Business Continuity plan has been updated in Section 7.2

Commented by	Comment	Response from IWM
	mentioned in the report but the details of such plans are not illustrated.	
	IX. Government of Bangladesh already formulated Disaster Management Act, 2012, National Disaster Management Plan (2021-25), Standing Orders on Disaster, 2019 and other policy guidelines. The report should review the appropriateness of those policy guidelines and scopes for further improvement in the light of world best practices.	IX. Have been updated in Section 7.3 as per the suggestion.
	X. Industry resilience policy and actions require a whole sector approach and strategic public-private partnerships. Collaboration between national and local governments, public agencies, public infrastructure operators, manufacturing firms along multiple supply chains, industry associations, industrial park operators, and financial institutions can strengthen the competitiveness benefits of industry resilience actions. This report should recommend detailed roles and actions for these key stakeholders.	X. This will work under existing Government monitoring and regulatory setup among stakeholders, donors and NGOs etc.

Commented by	Comment	Response from IWM
	XI. Regarding insurance this report recommended that insurance policy can be introduced to compensate for the financial losses of the hazards which cannot be avoided such as cyclones, storm surges and earthquakes. This concept is not elaborated in detail. The government insurance agency, Sadharan Bima Corporation, provides different insurance policies including fire insurance policy with allied perils, industrial all risks policy, business interruption policy etc. The report should mention which insurance policies are already in practice and which new policies should be introduced for industrial risk and disaster mitigation.	XI. The Insurance policy have been updated in Section 7.3
	XII. Many technical terms are used in the report and many readers may not have clear ideas and conceptions about those terms. To give a brief idea about the major terms, a separate "Glossary" section should be added in the report which will make it more meaningful to all concerned including the policymakers and industrialists.	XII. Separate Glossary section has been added in the report before the introduction chapter(page-x). A Detailed list of abbreviations has also been added from page vii to page ix.
	XIII. It would be helpful for the readers to get better ideas about the report if the questionnaires used in	XIII. To carry out the study, two field surveys were conducted- (i) Industry survey & (ii) Rapid Visual Screening Survey. Both the questionnaires & name of respondents have been attached in the following appendices- • Appendix-A: Industrial Survey Questionnaire

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	the report and names of the respondents are provided.	• Appendix-B: Rapid Visual Screening Questionnaire • Appendix-C: Contact details of the respondents from Kalurghat & KEPZ industries
	XIV. Proper wording and grammatical accuracy should be maintained for making the report an acceptable one.	XIV. Wording and grammatical accuracy have been improved in the final report.
Dr. Mahfuz Kabir, Director (Research) Bangladesh Institute of International and Strategic Studies (BIISS)	I. Since the study aims at conducting a multi-hazard risk profile of the selected industrial areas, it is possible to prepare a composite risk index by providing the weight of each hazard. Then the value of the index and rank of the industrial site can be provided. It will help both policymakers and investors understand a comprehensive picture of the risks without going into technical details of each of the hazards.	I. We agree with the proposal. To make a novel methodology on risk profile preparation, a multi hazard risk profile has been prepared using equal weightage. However, the industrial policy makers, disaster specialists and related stakeholders will decide and assign the appropriate weightage of the hazard.
	II. Bangladesh Industrial Policy 2016 and other policies and laws clearly mention that for establishing new industries environmental regulations and issues related to climate change risks must be addressed. It should be mentioned in the introductory part.	II. As per suggestion, this has been included in Section 7.3.
	III. Pictures of the study team, interview, etc., and interview checklist can be placed in the appendix instead of the main report.	III. The questionnaire, database, name of respondents etc. are included in the appendix section. Other items which were considered important have been placed inside the report.

Commented by	Comment	Response from IWM
	IV. Policy guidelines and recommendations are still generic. They should be based on the technical findings and specific to the EPZs and selected industrial sites of the study. Specific and detailed recommendations should be suggested on KEPZ and water logging issues.	IV. Recommendations have been improved in the final report. Water logging recommendation on KEPZ have been included in Section 7.3.
Dr Tariq Bin Yousuf, Project Director, Urban Resilience Project-DNCC Part	Very comprehensive study- individual risk profiling, vulnerability assessment of the possible hazards is done. Also found a multi-hazard risk map considering flood, cyclone, drainage, salinity and fire. But found missing the multi-hazard risk map considering earthquake, cyclone, fire etc. and their cascading effect. We have examples of the Great East Japan Earthquake and Tsunami 2011. The existing capacity, preparedness and response plan needs to be assessed. Based on that Emergency Response Plan has to be developed. GIS based hazard and risk maps are produced. But GIS based emergency management systems have to be suggested. What will be the strategy or action plan if such events happen? What will be the contingency plan? Disaster response is a multi-sectoral and multi-layer command and control system based. How the risk maps will be used as a decision-making tool? Risks are identified and shown in the hazard map. How do these industrial zones make them resilient? Some suggestions are needed. How does this study outputs complement the different master plans or development projects of Chittagong City?	The Multi-hazard risk map includes all the respective hazards. We also agree that existing capacity, preparedness, response, and emergency management plan need to be prepared by each industry. In the study only risk profiles are prepared as per the contract.

Appendix-E

Industries Photos

Meeting with Social /Environmental Counsellors and Director (Labour & IR) of KEPZ authority

Industry Level Data Collection of Xin Chang Shoes (BD) Ltd. in KEPZ Area

Data Collection of United Chemical in Kalurghat Area

Survey of Land and Structure point cloud (x,y,z data) collection

Reference Station: Survey of Bangladesh (SOB) BM 5992


Establishment of GCPs in the Kalurghat Industrial Area