Urban Hydrology Guide

Water Availability, Flood Protection and Stormwater Run-Off

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Contents

INTRODUCTION URBAN HYDROLOGY

In recent years, urban flooding has increased with growing population size. Here we will discuss the influence of urbanization, impacts of intense rain events, and what is being done to protect lives by managing flood events.

In 2017, the United Nations published a report which said that the current world population of 7.6 billion is expected to reach 8.6 billion in 2030, 9.8 billion in 2050 and 11.2 billion in 2100. A further UN report, published in 2018 said that 55% of the world's population lives in urban areas, and this is expected to increase to 68% by 2050.

The growth of urban areas represents an enormous challenge to the management of water, and features heavily in the UN's sustainable development goals. Urbanization increases both water demand and the area of impervious surfaces – highways, pavements, roofs, parking lots etc. Coupled with the impacts of climate change, this has an impact on water availability, flood protection and stormwater run-off; each of which will be discussed in this guide.

The development of effective plans to manage the future impacts of urbanization necessitate a comprehensive monitoring program to:

- establish current conditions
- enable modelling of future scenarios
- facilitate automatic responses to preset conditions
- to provide alarms when dangerous conditions arise.

Urban hydrology monitoring will therefore also be featured in this guide. However, the importance of a catchment-wide approach when building an urban hydrology plan will be emphasized. Monitoring the whole catchment informs an understanding of the relationships between urban areas and the rest of the catchment. Consequently, the benefits of initiatives higher in the catchment can be monitored downstream - planting trees, reconnecting rivers to floodplains and restoring wetlands for example.

Flood Protection: A Mission to Reduce Risk

Flood Protection Approaches

In many parts of the world weather conditions can vary from extreme drought to extreme precipitation, with significant seasonal variability. As a result, water management systems need to be designed to cope with a wide variety of conditions, while accommodating the future impacts of climate change, population growth, infrastructure development etc.

In the past, most changes to water resources have been implemented to meet the specific needs of urban populations and local farmers. Today, a catchment-wide approach is generally preferred so that the impacts of changes can be more accurately assessed, and the relationships between different parts of a catchment can be taken into consideration. This approach also allows flood protection to extend beyond reactive measures such as flood barriers in urban areas to proactive initiatives, higher in the catchment, to minimize peak flows.

“Flood management plans are created to reduce risk; from minor events such as flooding on city streets, and from larger events such as those in which water escapes river banks, threatens public safety and damages domestic and/or commercial properties.”

Flood Protection Measures

Infrastructure Development

Infrastructure development generally results in an increase in surface area covered by concrete and asphalt, with less ground for soakaway, resulting in higher water flow rates into rivers. Initiatives are therefore focused on finding ways to lower peak flows. For example, trees can be planted higher in the catchment to reduce water flow downhill. This also helps to filter nutrients and sediment in run-off; to increase carbon sequestration, and to create new habitats. Buffer strips alongside rivers have a similar effect and if they are fenced, help to prevent livestock damage to the channel. Swales and other systems can increase local storage in urban areas, and the protection or creation of porous surfaces can help precipitation soak into the ground.

Sustainable urban drainage systems (SUDs)

Sustainable urban drainage systems (SuDS) can be included at the design stage of a project or retrofitted to existing infrastructure. SuDS are designed to capture, delay the dispersal of, discharge or absorb surface water. Some are above-ground natural features, and others are below-ground storage tanks; all designed to slow down the flow of surface water, hold it back (attenuation) and store it so that it can infiltrate into the ground or evaporate, rather than being discharged into the nearest watercourse or sewer. If the ground is already saturated and infiltration is not possible, the drainage scheme should ensure that water is discharged in a controlled way without damaging the environment.

Temporary Storage

The temporary storage of flood water represents an opportunity to recycle and reuse the captured water, which reduces the need to use treated drinking water for non-potable purposes. Rainwater reuse systems range from simple rain barrells to sophisticated systems for rainwater harvesting. Typical uses for harvested rainwater include toilet flushing or vehicle washing.

Drains and Ditches

Drains and ditches provide an important pathway for water removal during periods of high flood risk. It is therefore essential to maintain these resources to ensure that there are no blockages and that water can flow freely. These activities are greatly enhanced by mapping the resources so that effective inspection and maintenance programs can be planned and implemented.

Flood Relief Channels, Stormwater Vault, and Catchment Basins

Flood relief channels provide vital capacity during flood events, helping to divert water away from valuable assets and citizens. However, such channels require ongoing maintenance with operations such as erosion repairs, sediment removal, vegetation management on the levees, and debris removal from the water. Stormwater vaults and catch basins can be installed to increase capacity and facilitate sedimentation, which also helps reduce pollutant concentrations. Low water dams can be constructed to assist with the collection and removal of debris. Flood channels generally contain floodgate structures connected to a sump area or basin - these floodgates act as a one-way valve to prevent flood water from backing up into a river.

Reservoirs

Reservoirs can be utilized to assist with flood protection; providing temporary storage capacity to reduce peak flow. Stored stormwater can be released at a later time once the period of high flood risk has passed. This activity necessitates effective monitoring of water resources to prevent downstream flooding and protect public safety, whilst also minimizing the effects on lakeside properties. To meet this challenge, it is necessary to monitor inflows and reservoir releases, along with water level and precipitation data from a catchment-wide network of monitoring stations.

Droughts

Drought is a major challenge in many mountainous areas, however, the rapidly changing weather conditions of this environment, coupled with the effects of climate change, means that extreme weather conditions are becoming more prevalent. In comparison with lower lying areas, mountain rivers and creeks are fast-flowing with greater potential for sudden changes in flow rate. Consequently, it is necessary to operate a network of precipitation gauges and continuous flow monitors. Data from a monitoring network can be fed into a software model which is able to raise alarms and identify long-term trends. In addition, streamflow data can be used for operational strategies, water quality issues, and water rights administration.

Software Models

Software models enhance the ability to predict the impacts of climate change, population growth and development, and thereby inform future development of flood protection schemes with measures such as improved real-time monitoring and alarm systems, increased storage capacity, new flood relief channels and raised levies. These models can also inform town planning activities, helping to determine the requirement for porous surfaces and water storage in new developments.

Summary

Flood Protection: A Mission to Reduce Risk

5 KEY POINTS:

1. Today, a catchment-wide approach is generally preferred so that the impacts of changes can be more accurately assessed.

2. Flood management plans are created to reduce risk; from minor events such as flooding on city streets, and from larger events such as those in which water escapes river banks.

3. Sustainable urban drainage systems (SuDS) can be included at the design stage of a project or retrofitted to existing infrastructure. Drains and ditches provide an important pathway for water removal during periods of high flood risk.

4. Drought is a major challenge in many mountainous areas, however, the rapidly changing weather conditions of this environment, coupled with the effects of climate change, means that extreme weather conditions are becoming more prevalent.

5. Software models enhance the ability to predict the impacts of climate change, population growth and development, and thereby inform future development of flood protection schemes with measures such as improved real-time monitoring and alarm systems.

For more information , please visit:

http://www.ott.com/en-us/applications/flood-warning-5/

Water Availability

Improving Water Resource Management

Most developed countries draw water from groundwater, rivers and reservoirs for treatment to achieve drinking water quality standards. However, despite the costs of this process, much of the produced water is used for purposes other than drinking – industrial processes, agricultural irrigation, watering lawns, washing etc. In addition, water demand is growing, due to population growth, while water resources are under increasing pressure from issues such as climate change. Clearly, there is a requirement for improved management of water by protecting water resources, reducing leakage and waste, and lowering water consumption.

Catchment-wide assessment of watersheds is necessary in the development of effective water resource management plans. This facilitates the identification of existing water resources and the planning of any new resources that may be required – dams, reservoirs, water towers, pump stations, pipelines etc. Once operational, all resources should be monitored closely for process optimization purposes. For example, the costs of moving water across large distances can be high, so resources should be managed to minimize this requirement, and where necessary it may be advantageous for neighbouring authorities to share resources during periods of high demand or low availability.

Meteorological measurements play an important role in water resource management. Water demand increases in the warmer months and is reduced by precipitation; as citizens stop watering their lawns for example. However, in dry periods, water use increases, evaporation from reservoirs increases and reservoir recharge is lower. In some years, a lack of precipitation results in drought conditions and this is a natural part of the climate in many regions.

Insufficient precipitation can have serious impacts on groundwater, reducing aquifer recharge and thereby reducing stream baseflow, which reduces water availability and increases the concentration of pollutants. Drought and/or poorly managed abstraction can also lead to land subsidence and salt water intrusion.

In mountainous areas, the gradual melting of the high-country snowpack sustains the water flow in mountain streams and rivers throughout the year. However, insufficient snowpack results in low stream flows, which can fail to meet the demands of normal water consumption. Snow data and reports are generated by automatic monitoring stations at snow survey sites. In the USA these reports include specific information regarding snow water equivalent (water volume in the snowpack), snow depth, precipitation, temperature, and other weather-related data in hourly, daily, monthly, and yearly increments.

Water Quality

Raw water quality can vary considerably, particularly in surface water resources, and this can result in significant increases in the cost of water treatment. Consequently, water management systems should have the ability to draw supply from the best source at any moment in time, and to blend supplies if necessary. This requires effective monitoring of resources, including for example, turbidity monitoring where it is possible to draw water from different depths in a reservoir.

Water Conservation

A key feature of a water conservation strategy is consumer education. This can be achieved with leaflet drops, school visits, regular contributions to local newspapers and radio stations, web-based water conservation advice, and the provision of free water efficiency devices. A wide range of the latest household appliances are available to help domestic users reduce consumption. These include washing machines, dishwashers, shower heads, inserts for toilet cisterns etc. In the UK, water companies provide free education material and tools to help their customers reduce consumption, but this has resulted in a backlash in the media because around 20% of all treated water is lost through leakage from ageing pipes before it even reaches the consumer, so the rehabilitation of pipes is a major feature of the UK's water availability strategy.

One of the most effective ways to lower domestic consumption is to install a metered supply, especially where excessive consumption is penalized financially. Smart meters help to improve the visibility of usage data and also reduce the cost of data collection. Additionally, in many countries hosepipe or sprinkler bans are imposed during periods of drought to lower demand.

Water Reuse

Water reuse offers an important opportunity to increase water availability. Following a variety of treatment processes, wastewater is discharged into rivers and the quality of the discharge is monitored to ensure that it remains within the plant's consent. This water can then form part of the water intake at a drinking water treatment plant. Nevertheless, some authorities have created wetlands which treat the wastewater discharge before it re-enters the water cycle. Wetlands perform a number of beneficial roles. Firstly, they improve water quality – particularly suspended solids and nutrients. Secondly, they act as a water storage facility, contributing to the overall water resource capacity, and thirdly, they provide a habitat for wildlife.

Reducing Water Consumption

Looking forward, reductions in average household water consumption will be necessary, but this can only be achieved through concerted effort by all stakeholders including governments, water suppliers, regulators, water rights holders and industrial or academic innovators. Water efficiency will have to be monitored continuously and the proportion of supplies that are metered will have to increase. This will help to influence consumer behaviour and thereby initiate the development of water saving technologies. Water labelling of water-consuming products (similar to energy rating) will help to promote efficiency, and planning rules should require new developments to be water efficient - through community rainwater harvesting and water reuse for example.

Summary

Water Availability

5 KEY POINTS:

1 Water demand is growing, due to population growth, while water resources are under increasing pressure from issues such as climate change.

2 The costs of moving water across large distances can be high, so resources should be managed to minimize this requirement, and where necessary it may be advantageous for neighboring authorities to share resources during periods of high demand or low availability.

3 Insufficient precipitation can have serious impacts on groundwater, reducing aquifer recharge and thereby reducing stream baseflow, which reduces water availability and increases the concentration of pollutants.

4 Water management systems should have the ability to draw supply from the best source at any moment in time, and to blend supplies if necessary.

5 Water resource management strategies commonly include:

- catchment-wide assessments
- meteorological measurements
- improving water quality
- water reuse
- reducing water consumption

For more information , please visit:

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Stormwater

Stormwater Runoff Challenges

Stormwater presents a particular threat to water quality because it often has a direct path to a water resource, rather than soaking through soil beforehand. Potential pollutants in stormwater and runoff include gas, oil and other motor vehicle liquids, soil sediment, leached fertilizers including phosphates and nitrates, bacteria from animal waste, and organic materials in yard waste. As urban areas grow, non-porous areas expand, and the volume of stormwater runoff increases, representing a threat to water resources.

Stormwater passes through ditches and pipes before being flushed into streams and waterways, or it may soak into the ground - often carrying contaminants that can harm fish and other aquatic life as well as contaminating aquifers. Runoff during larger storms can also erode stream banks and create a build-up of sediment and debris.

Pollution Prevention Tactics and Strategies

Many different organizations are responsible for preventing pollution from stormwater, and in some instances this is a legal obligation. Organizations may also be responsible for the maintenance of stormwater runoff treatment facilities, and many different types exist. Storm drains often employ traps to collect debris, and retention ponds help to slow the flow and cause sedimentation. Grass lined ditches provide biological filtration, and chemical treatment or filtration

systems may also be employed. All of these facilities require regular maintenance.

In addition to the drains which collect runoff from impervious surfaces such as highways, roofs and concreted areas, there are also drains which handle both runoff and wastewater/sewage. These combined sewer systems collect rainwater runoff, domestic sewage, and industrial wastewater in the same pipe. Under normal conditions, these systems transport all of the wastewater to a treatment plant, where it is treated and discharged to a water body. However, during periods of heavy rainfall or snowmelt, the wastewater volume can exceed the capacity of the drain or treatment plant, resulting in an overflow in which excess wastewater passes directly to streams, rivers, or other water bodies. These overflows, called combined sewer overflows (CSOs), contain stormwater as well as untreated human and industrial waste, toxic materials and debris. As such they represent a major environmental threat and stormwater resilience needs to be designed into the system so that CSOs can be avoided. In addition, effective precipitation and water level monitoring networks need to be in place with the capability to raise alarms when necessary. Some systems have been designed to utilize these alarms to implement flood alleviation measures, such as pumping excess water to temporary storage facilities.

As discussed in the flood protection section of this guide, the creation of buffer strips alongside rivers can help to lower the negative water quality impacts of stomwater. Initiatives such as this generally require the cooperation of all stakeholders including landowners, local authorities, planners and developers.

Summary

Stormwater

5 KEY POINTS:

1. Stormwater presents a particular threat to water quality because it often has a direct path to a water resource, rather than soaking through soil beforehand

2. As urban areas grow, non-porous areas expand, and the volume of stormwater runoff increases, representing a threat to water resources.

3. Stormwater passes through ditches and pipes before being flushed into streams and waterways, or it may soak into the ground - often carrying contaminants that can harm fish and other aquatic life as well as contaminating aquifers.

4. Many different organizations are responsible for preventing pollution from stormwater, and in some instances this is a legal obligation.

5. Organizations may also be responsible for the maintenance of stormwater runoff treatment facilities, and many different types exist such as:
    - Storm drain traps
    - Catchment ponds
    - Grass lined ditches

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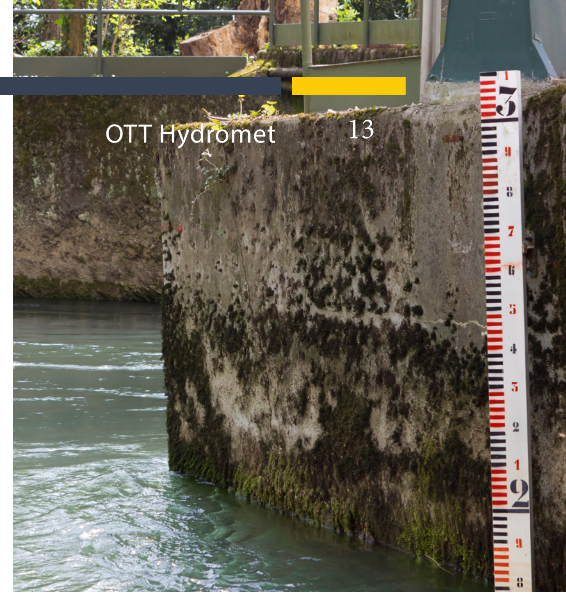
Urban Hydrology Monitoring



Monitoring and communications technologies have advanced considerably in recent years, which has enabled those responsible for monitoring precipitation, water level and flow to be better prepared for adverse conditions.

Often, it is the location and intensity of precipitation that contributes to the speed with which flooding occurs. However, flooding can also result from blocked watercourses, so whilst a network of precipitation gauges can provide the earliest warning of a potential flood, water level and flow monitors form an essential component of early warning systems. At a local level, water level monitors in a low lying or marsh area can initiate text messages to the cell phones of local citizens to enable the timely placement of flood barriers near susceptible properties. On a larger scale, catchment-wide networks of monitors can feed real-time data into cloud-based data management systems so that a range of flood protection measures can be initiated, depending on the level of alarm.

Case Study: Harris County (USA) Flood Warning System

Intense periods of rainfall are not uncommon in Harris County given its closeness to the Gulf of Mexico and influences from both stalling frontal systems in the spring and autumn, and tropical weather systems in the summer. Hourly rainfall rates can often exceed 75-100 mm with the highest known hourly rainfall rate of 175mm recorded in 2009. The Harris County Flood Warning System employs 153 different OTT monitoring stations delivering near real-time data in a user-friendly format to decision markers, emergency management authorities, the National Weather Service, and the citizens of the region; to protect life and property with targeted flood warnings.

For detecting rate of rise at designated gauge locations, the OTT RLS (Radar Level Sensor) and CBS (Compact Bubbler System) measure water level using proven non-contact water level measurement techniques which are unaffected by rising flood waters.

This critical data is transmitted in real-time and can be viewed on the Harris County Flood Warning System website: http://www.harriscountyfws.org/. Flood warning information is also available to the public via a mobile app. “There is a lot of confidence in the system now compared to several years ago when vast amounts of data were being lost due to data contention and the maintenance of the field equipment was inadequate,” says Jeff Lindner Director of Hydrologic Operations at the District. “With the current system it is an anomaly to have incorrect data.”

The implementation of OTT sensors with a reliable monitoring system for water levels has allowed the Harris County Hydrologic Division to begin focusing on the collection of discharge measurements, which are needed to maintain and adjust rating curves vital to flood forecasting efforts.

Further examples of urban hydrology monitoring are available at www.otthydromet.com.

Case Study: Portsmouth (UK) Flood Alleviation System

In late 2014, Southern Water completed a major project to reduce the risk of sewer flooding in parts of Portsmouth and Southsea. Substantial works were undertaken to divert runoff and tidal ingress, and a 'smart' hydrometeorological monitoring system was installed to enable prompt diversion of excess water during periods of high rainfall. Sewer level monitoring is now undertaken in real-time and intelligent raingauges (Pluvio2) combine with radio telemetry to inform a computer based catchment-wide water model. This decision support system provides advance notice for staff at the Eastney pumping station that diverts large quantities of water to storage tanks during periods of heavy rain. Through the development of a smart sewer network, Southern Water has dramatically reduced the risk of flooding in Portsmouth whilst also delivering substantial environmental benefits.

OTT Adcon radio telemetry delivers monitoring data, which includes the Pluvio2 raingauges, to a catchment software model. Summarizing, Rob McTaggart, technical lead at MWH says: "Collaboration with the community, and other stakeholders in Portsmouth, made it possible for the project consortium to design and implement a solution that separated surface water to provide resilience, significantly boost flood protection and benefit the environment with the minimum of new infrastructure. Clearly, the flood alleviation scheme has been a success and as a result, the pumps at Eastney are called into action less often.

"The early warning system appears to be working very well. Some of the rainfall prediction data, provided by external sources, can sometimes provide erroneous projections because of the localized nature of precipitation events, so it is important to have a sufficient number of raingauges to 'calibrate' projections and deliver the level of precision required."

Common Resources

USGS Flood Tools

FEMA Risk MAP Flood Risk Products

EPA National Stormwater Calculator

OTT Hydromet Flood Warning

Hydromet Cloud: Real-Time Data Access

OTT HydroSystems

Common Resources

[EPA Green Infrastructure Modeling Tools]

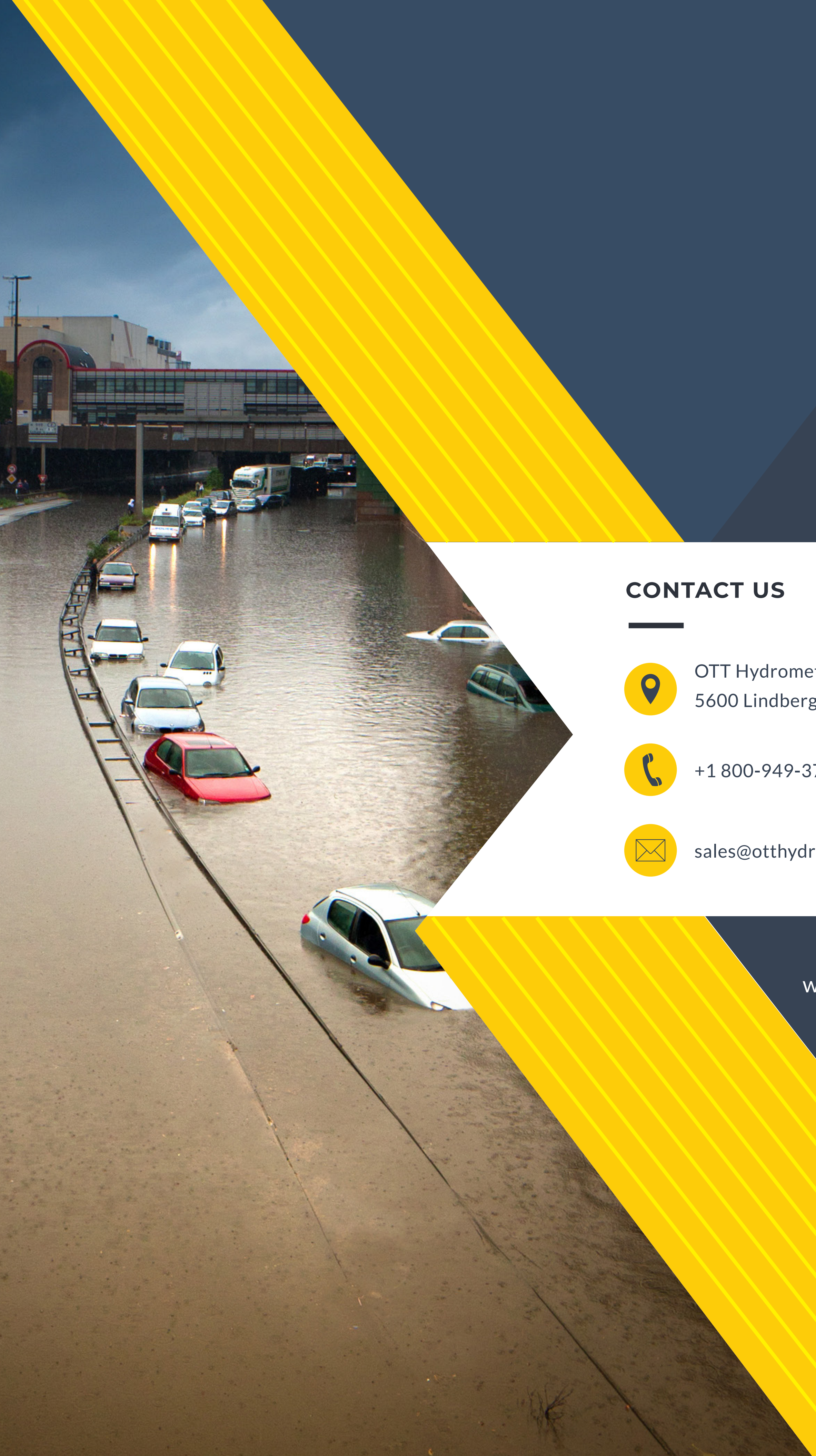
[Tools to help coastal communities analyze and assess vulnerabilities of sea level rise, storm surges, and sinking lands.]

[USGS Water Availability and Use Science Program]

[NYS Mesonet: First Weather Tower Installation]

[Managing storm water with the Internet of Things]

[NIDIS Data, Maps & Tools]



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