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DEPT.: **CIVIL ENGINEERING**

COURSE: **CVE 505 – WATER RESOURCES ENGINEERING**

ASSIGNMENT

1. The occurrence and proportion of the water resources of the earth.

Water resources are natural resources of water that are potentially useful. Uses of water include agricultural, industrial, household, recreational and environmental activities. All living things require water to grow and reproduce.

97% of the water on the Earth is salt water and only three percent is fresh water; slightly over two thirds of this is frozen in glaciers and polar ice caps. The remaining unfrozen freshwater is found mainly as groundwater, with only a small fraction present above ground or in the air.

Fresh water is a renewable resource, yet the world's supply of groundwater is steadily decreasing, with depletion occurring most prominently in Asia, South America and North America, although it is still unclear how much natural renewal balances this usage, and whether ecosystems are threatened. The framework for allocating water resources to water users (where such a framework exists) is known as water rights.

Water is distributed across earth. Most water in the Earth's atmosphere and crust comes from the world ocean's saline seawater, while freshwater accounts for only 2.5% of the total. Because the oceans that cover roughly 78% of the area of the Earth reflect blue light, the Earth appears blue from space, and is often referred to as the *blue planet* and the *Pale Blue Dot*. An estimated 1.5 to 11 times the amount of water in the oceans may be found hundreds of miles deep within the Earth's interior, although not in liquid form.

The oceanic crust is young, thin and dense, with none of the rocks within it dating from any older than the breakup of Pangaea. Because water is much denser than any gas, this means that water will flow into the "depressions" formed as a result of the high density of oceanic crust. (On a planet like Venus, with no water, the depressions appear to form a vast plain above which rise plateaux). Since the low density rocks of the continental crust contain large quantities of easily eroded salts of the alkali and alkaline earth metals, salt has, over billions of years, accumulated in the oceans as a result of evaporation returning the fresh water to land as rain and snow.

As a result, the vast bulk of the water on Earth is regarded as *saline* or *salt water*, with an average salinity of 35‰ (or 3.5%, roughly equivalent to 34 grams of salts in 1 kg of seawater), though this varies slightly according to the amount of runoff received from surrounding land. In all, water from oceans and marginal seas, saline groundwater and water from saline closed lakes amount to over 97% of the water on Earth, though no closed lake stores a globally significant amount of water. *Saline* groundwater is seldom considered except when evaluating water quality in arid regions.

The remainder of the Earth's water constitutes the planet's *fresh water* resource. Typically, fresh water is defined as water with a salinity of *less than 1 percent that of the oceans* - i.e. below around 0.35‰. Water with a salinity between this level and 1‰ is typically referred to as *marginal water* because it is marginal for many uses by humans and animals. The ratio of salt water to fresh water on Earth is around 40 to 1.

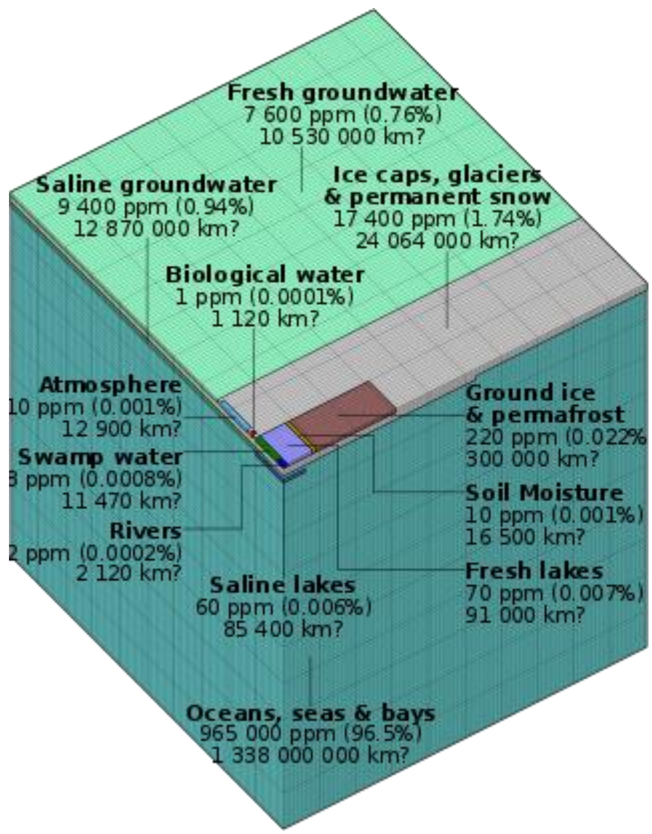
The planet's fresh water is also very unevenly distributed. Although in warm periods such as the Mesozoic and Paleogene when there were no glaciers anywhere on the planet all fresh water was found in rivers and streams, today most fresh water exists in the form of ice, snow, groundwater and soil moisture, with only 0.3% in liquid form on the surface. Of the liquid surface fresh water, 87% is contained in lakes, 11% in swamps, and only 2% in rivers. Small quantities of water also exist in the atmosphere and in living beings. Of these sources, only river water is generally valuable.

Although the total volume of groundwater is known to be much greater than that of river runoff, a large proportion of this groundwater is saline and should therefore be classified with the saline water above. There is also a lot of *fossil* groundwater in arid regions that has never been renewed for thousands of years; this must not be seen as renewable water.

However, fresh groundwater is of great value, especially in arid countries such as India. Its distribution is broadly similar to that of surface river water, but it is easier to store in hot and dry climates because groundwater storages are much more shielded from evaporation than are dams.

In countries such as Yemen, groundwater from erratic rainfall during the rainy season is the major source of irrigation water.

Because groundwater recharge is much more difficult to accurately measure than surface runoff, groundwater is not generally used in areas where even fairly limited levels of surface water are available. Even today, estimates of total groundwater recharge vary greatly for the same region depending on what source is used, and cases where fossil groundwater is exploited beyond the recharge rate (including the Ogallala Aquifer[6]) are very frequent and almost always not seriously considered when they were first developed.



A graphical distribution of the locations of water on Earth

2. Current flood disaster in Nigeria

With the current rise in water level in the River Niger axis and increased persistent rainfall, Nigeria might experience flood disaster higher than the 2012 flood episode, the National Emergency Management Agency (NEMA) has warned. The alarm came after the Nigeria Hydrological Service Agency (NHSA) alerted NEMA, after receiving a distressed call revealing that all indices that led to the 2012 flood disaster has manifested and the level of water in the River Niger at the confluence of Lokoja was currently at 10.1m, as against 9.43m in 2012.

The agency further revealed that current water was being discharged at 21, 326 cubic metres, as against 19, 762 cubic metres in 2012, putting Kebbi, Niger, Kwara, Kogi, Edo, Anambra, Rivers, Bayelsa and Delta states at high risk of flooding in the River Niger axis, while Adamawa, Benue and Taraba states are at risk on the River Benue axis. Director General of NEMA, Mustapha Maihaja, during an emergency stakeholders meeting in Abuja, said: "It is clear that all indices that resulted in the 2012 flood disaster has manifested.

"However, there is no information yet from Lagdo Dam on any preparation for discharge, but with the current spate of rainfalls across the region, there is no guarantee that the Cameroonian Government would not discharge." He said the agency was invigorating its enlightenment campaign in frontline states in an aggressive manner, such that anyone living in flood plain areas would be well informed of the dangers.

The Nigerian Meteorological Agency has urged 11 state governments to take pro-active action against imminent flooding.

The appeal was contained in a statement signed by Eva Azinge, the Head of Corporate Communications, Public Relations Unit, National Weather Forecasting and Climate Research Centre of NiMet, in Abuja on Monday.

"The affected States include: Akwa Ibom, Bauchi, Benue, Borno, Cross River, Delta, Kaduna, Kwara, Nasarawa, Yobe and Zamfara," Azinge said.

Azinge said NiMet had predicted flooding in the 11 states due to the cumulative high intensity rainfall in those parts of the country in June and July.

She added that with the current rainfall, there were prospects of flooding in August and October.

She said in the statement: “After thorough analyses of rainfall data from our observatories nationwide for June and July, soil moisture has either reached saturation, or near saturation levels.

“This is due to cumulative high intensity rainfall in some parts of the country in June and July.

“This means that floods should be expected in these areas because the soil is no longer able to absorb more rainwater in the coming weeks which coincide with the peak rainy season.”

classify flood to be of five major classes

(i. Flash flood: This flood type gives the least amount of warning time. They are characterized as a rapid and significant rise in water level due to a sudden and intense heavy rainfall event. These floods occur when rainfall rates are so high that the ground cannot absorb the water quickly enough to prevent significant runoff and are especially common in areas with steep slopes. Flash floods can also occur due to a dam or levee failure. These floods can occur in less than an hour and can destroy structures, down trees and wash out roads with little to no warning time. Although flash floods may not last as long or cover as large of an area as other floods, the sudden onset and strength of the water give them the ability to create devastation in a very short period of time.

(ii. River flooding: this occurs each year in many parts of the world, on a slower time scale than flash flooding. They are caused when water runoff collects in the rivers and streams eventually reach levels that overflow the banks. When this occurs, the flood can cover an enormous area and affect downstream areas even if they didn’t receive much rain themselves. Although river flooding can be predicted, its effects, even over a longer period of time, can cause extensive damage to riparian settlements.

(iii. Coastal flooding: These floods occur when ocean water is pushed inland. Hurricanes and tropical storms can cause large waves and actually raise the sea level, creating storm surge along beaches. Earthquakes can displace large amounts of water that causes waves called tsunamis to rush inland. On a much smaller scale, extremely high tides, sometimes associated with a full moon can cause minor coastal flooding.

(iv. Urban flooding: These can be caused by flash, river or coastal flooding but most commonly, it is caused by high rainfall rates over developed areas that do not have the ability to absorb the water or poorly maintained drainages. Urbanization can increase water runoff as much as 2 to 6 times over what would occur on natural terrain. These floods can cause high economic damages to businesses and homes.

(v. Areal flooding: Areal floods are the most common flood threat in many cities close large natural lakes and are very similar to urban floods. Areal flooding results in standing water in low-lying areas and open fields. They often occur due to heavy rainfall over a larger area in a short period of time. Additionally, a prolonged period of rainfall can also lead to this flooding, often causing dangerous inundation of low lying areas. Agricultural losses can occur with these floods and in addition, stagnant water can serve as a breeding ground for insects and disease.

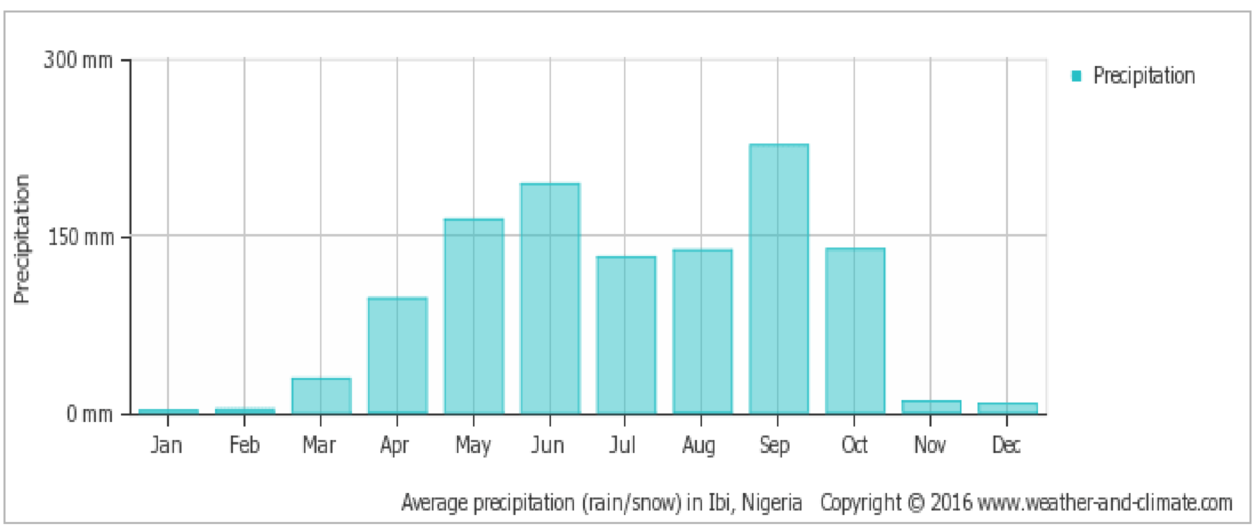
Folorunsho and Awosika (2001) as well as Ologunorisa (2004) reported that floods do occur in Nigeria in three main ways; coastal flooding, river flooding and urban flooding. Coastal flooding occurs in the low lying belt of mangrove and fresh water swamps along the coast. River flooding occurs in the flood plains of the larger rivers, while sudden, short-lived flash floods are associated with rivers in the inland areas where sudden heavy rains can change them into destructive torrents within a short period. And urban flooding on the other hand occurs in towns, on flat or low-lying terrain especially where little or no provision has been made for surface drainage, or where existing drainage has been blocked with municipal waste, refuses and eroded soil sediments (Folorunsho and Awosika 2001; Ologunorisa, 2004). Although many of the different types of floods mentioned above occurred in Nigeria but Etuonovbe (2011) believed that flooding occurs throughout Nigeria in the following forms; Coastal flooding, River flooding, Flash floods, Urban flooding, Levee burst, Dam breakage, Dam spills. Flood occurrences and consequences in Nigeria Floods are natural phenomenon that occurs frequently, the frequency of flooding in an area is commonly described by the average interval (in years) between occurrences of such flooding. For example, a flood that occurs around 5 times in 25 years is said to have an average recurrence interval of 5 years (5 years’ flood). There is need to remember that it will not necessarily occur regularly every 5 years. There is also one in five chances that such a flood will occur during any one year. Although a much bigger flood such as a 100 years’ flood is expected to happen rarely, there is still one in a hundred chances that a flood of that size will happen in any one year (Emergency Management

Australia, 2014). In Nigeria, flood disaster has been perilous to people, communities and institutions. In 2010, Usmanu Danfodiyo University, Sokoto, and other parts of the state have been affected by flooding chasing the inhabitants away and so many places were swept way. Infact the University has students remain at home for four months due to damage of the bridge which is the only way linking the University with the city, this incident affected the academic activities of the university for that period of time (Etuonovbe, 2011). Flood disaster is not a recent phenomenon in Nigeria. Its destructive tendencies are sometimes enormous. Its occurrences have been reported in Ibadan (1985, 1987, 1990 etc.), Osogbo (1992; 1996; 2002), Yobe (2000) and Akure (1996; 2000; 2002; 2004; 2006). The coastal cities of Lagos, Port Harcourt.

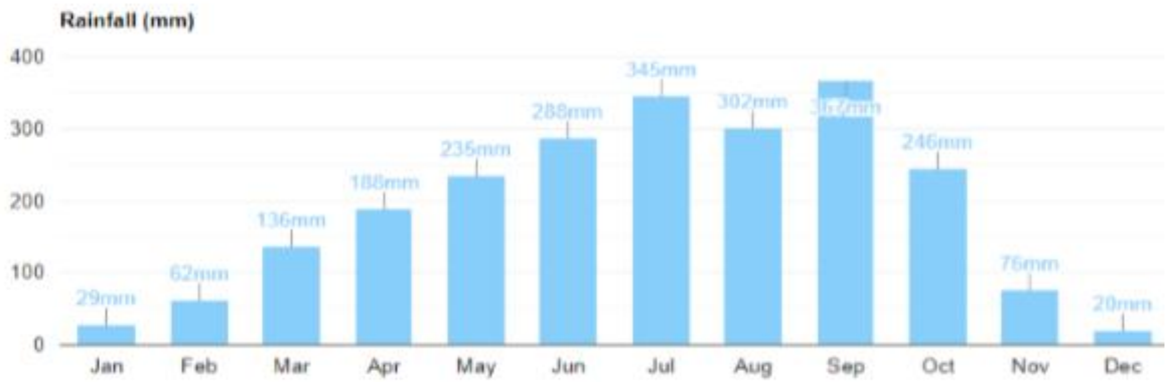
Average monthly snow and rainfall in Abuja (millimeter)

- A lot of rain (rainy season) falls in the months: May, June, July, August, September and October.
- Abuja has dry periods in January, February, November and December.
- On average, September is the wettest month.
- On average, January is the driest month.
- The average amount of annual precipitation is: 999.9 mm (39.37 in)

This is the mean monthly precipitation over the year, including rain, snow, hail etc. Show average precipitation in Abuja in Inches »



Average rainfall Port Harcourt, Nigeria



Average rainfall in January: **29mm**
Average rainfall in February: **62mm**
Average rainfall in March: **136mm**
Average rainfall in April: **188mm**
Average rainfall in May: **235mm**
Average rainfall in June: **288mm**
Average rainfall in July: **345mm**
Average rainfall in August: **302mm**
Average rainfall in September: **367mm**
Average rainfall in October: **246mm**
Average rainfall in November: **76mm**
Average rainfall in December: **20mm**

Wettest month (with highest rainfall) is **September** (367mm). Driest month (with lowest rainfall) is **December** (20mm).

Average rainfall Jos, Nigeria

Average rainfall in January: **0mm**
Average rainfall in February: **1mm**
Average rainfall in March: **17mm**
Average rainfall in April: **77mm**
Average rainfall in May: **180mm**
Average rainfall in June: **194mm**
Average rainfall in July: **298mm**
Average rainfall in August: **280mm**
Average rainfall in September: **218mm**
Average rainfall in October: **53mm**
Average rainfall in November: **4mm**
Average rainfall in December: **2mm**

Wettest month (with highest rainfall) is **July** (298mm). Driest month (with lowest rainfall) is **January** (0mm).

3&4. What is the history of flooding in these states of Nigeria and the Proffer modalities to prevent the reoccurrence of flooding.

Flood control methods are used to reduce or prevent the detrimental effects of flood waters.[1] Flood relief methods are used to reduce the effects of flood waters or high water levels.

Causes of floods

Floods are caused by many factors or a combination of any of these generally prolonged heavy rainfall (locally concentrated or throughout a catchment area), highly accelerated snowmelt, severe winds over water, unusual high tides, tsunamis, or failure of dams, levees, retention ponds, or other structures that retained the water. Flooding can be exacerbated by increased amounts of impervious surface or by other natural hazards such as wildfires, which reduce the supply of vegetation that can absorb rainfall.

Periodic floods occur on many rivers, forming a surrounding region known as the flood plain.

During times of rain, some of the water is retained in ponds or soil, some is absorbed by grass and vegetation, some evaporates, and the rest travels over the land as surface runoff. Floods occur when ponds, lakes, riverbeds, soil, and vegetation cannot absorb all the water. Water then runs off the land in quantities that cannot be carried within stream channels or retained in natural ponds, lakes, and man-made reservoirs. About 30 percent of all precipitation becomes runoff[1] and that amount might be increased by water from melting snow. River flooding is often caused by heavy rain, sometimes increased by melting snow. A flood that rises rapidly, with little or no warning, is called a flash flood. Flash floods usually result from intense rainfall over a relatively small area, or if the area was already saturated from previous precipitation.

Severe winds over water

Even when rainfall is relatively light, the shorelines of lakes and bays can be flooded by severe winds—such as during hurricanes—that blow water into the shore areas.

Unusual high tides

Coastal areas are sometimes flooded by unusually high tides, such as spring tides, especially when compounded by high winds and storm surges.

Effects of floods

Flooding has many impacts. It damages property and endangers the lives of humans and other species. Rapid water runoff causes soil erosion and concomitant sediment deposition elsewhere (such as further downstream or down a coast). The spawning grounds for fish and other wildlife habitats can become polluted or completely destroyed. Some prolonged high floods can delay traffic in areas which lack elevated roadways. Floods can interfere with drainage and economical use of lands, such as interfering with farming. Structural damage can occur in bridge abutments, bank lines, sewer lines, and other structures within floodways. Waterway navigation and hydroelectric power are often impaired. Financial losses due to floods are typically millions of dollars each year, with the worst floods in recent U.S. history having cost billions of dollars.

Benefits of flooding

There are many disruptive effects of flooding on human settlements and economic activities. However, flooding can bring benefits, such as making soil more fertile and providing nutrients in which it is deficient. Periodic flooding was essential to the well-being of ancient communities along the Tigris-Euphrates Rivers, the Nile River, the Indus River, the Ganges and the Yellow River, among others. The viability for hydrologically based renewable sources of energy is higher in flood-prone regions.

Detection

This is the method used for remote sensing the disasters. Detection of disasters such as floods, earthquakes, and explosions are quite complex in previous days and range of detection is inappropriate. But, it came to possibilities by using Multi temporal visualization of Synthetic Aperture Radar (SAR) images. But to obtain the good SAR images perfect spatial registration and very precise calibration are necessary to specify changes that have occurred. Calibration of SAR is very complex and also a sensitive problem. Possibly errors may occur after calibration that involves data fusion and visualization process. Traditional image pre-processing cannot be used here due to the On-Gaussian of radar back scattering, but a processing method called "cross calibration/normalization" is used to solve this problem. The application generates a single disaster image called "fast-ready disaster map" from multi-temporal SAR images. These maps are generated without user interaction and helps in providing immediate first aid to the people. This process also provides image enhancement and comparison between numerous images using data fusion and visualization process. This proposed processing includes filtering, histogram truncation and equalization steps. The process also helps in identifying the permanent waters and other classes by combined composition of pre-disaster and post-disaster images into a color image for better identity.[2]

Methods of flood management

Some methods of flood control have been practiced since ancient times. These methods include planting vegetation to retain extra water, terracing hillsides to slow flow downhill, and the construction of floodways (man-made channels to divert floodwater). Other techniques include the construction of levees, lakes, dams, reservoirs, retention ponds to hold extra water during times of flooding.

Dams

Many dams and their associated reservoirs are designed completely or partially to aid in flood protection and control. Many large dams have flood-control reservations in which the level of a reservoir must be kept below a certain elevation before the onset of the rainy/summer melt season to allow a certain amount of space in which floodwaters can fill. Other beneficial uses of dam created reservoirs include hydroelectric power generation, water conservation, and recreation. Reservoir and dam construction and design is based upon standards, typically set out by the government. In the United States, dam and reservoir design is regulated by the US Army Corps of Engineers (USACE). Design of a dam and reservoir follows guidelines set by the USACE and covers topics such as design flow rates in consideration to meteorological, topographic, streamflow, and soil data for the watershed above the structure .

The term dry dam refers to a dam that serves purely for flood control without any conservation storage (e.g. Mount Morris Dam, Seven Oaks Dam).

Diversion canals

Floods can be controlled by redirecting excess water to purpose-built canals or floodways, which in turn divert the water to temporary holding ponds or other bodies of water where there is a lower risk or impact to flooding. Examples of flood control channels include the Red River Floodway that protects the City of Winnipeg (Canada) and the Manggahan Floodway that protects the City of Manila (Philippines).

Floodplains and groundwater replenishment

Excess water can be used for groundwater replenishment by diversion onto land that can absorb the water. This technique can reduce the impact of later droughts by using the ground as a natural reservoir. It is being used in California, where orchards and vineyards can be flooded without damaging crops, or in other places wilderness areas have been re-engineered to act as floodplains.

River defences

In many countries, rivers are prone to floods and are often carefully managed. Defenses such as levees, bunds, reservoirs, and weirs are used to prevent rivers from bursting their banks.

A weir, also known as a low head dam, is most often used to create millponds, but on the Humber River in Toronto, a weir was built near Raymore Drive to prevent a recurrence of the flood damage caused by Hurricane Hazel in October 1954.

Coastal defenses

Coastal flooding has been addressed with coastal defences, such as sea walls, beach nourishment, and barrier islands.

Tide gates are used in conjunction with dykes and culverts. They can be placed at the mouth of streams or small rivers, where an estuary begins or where tributary streams, or drainage ditches connect to sloughs. Tide gates close during incoming tides to prevent tidal waters from moving upland, and open during outgoing tides to allow waters to drain out via the culvert and into the estuary side of the dike. The opening and closing of the gates is driven by a difference in water level on either side of the gate.

Self-closing flood barrier

The self-closing flood barrier (SCFB) is a flood defense system designed to protect people and property from inland waterway floods caused by heavy rainfall, gales or rapid melting snow. The SCFB can be built to protect residential properties and whole communities, as well as industrial or other strategic areas. The barrier system is constantly ready to deploy in a flood situation, it can be installed in any length and uses the rising flood water to deploy.

Temporary perimeter barriers

When permanent defenses fail, emergency measures such as sandbags, hydro sacks, flood stop flood barriers or portable inflatable tubes are used.

In 1988, a method of using water to control was discovered. This was accomplished by containing 2 parallel tubes within a third outer tube. When filled, this structure formed a non-rolling wall of water that can control 80 percent of its height in external water depth, with dry ground behind it. Eight foot tall water filled barriers were used to surround Fort Calhoun Nuclear Generating Station during the 2011 Missouri River Flooding. Instead of trucking in sandbag material for a flood, stacking it, then trucking it out to a hazmat disposal site, flood control can be accomplished by using the onsite water. However, these are not fool proof. A 8 feet (2.4 m) high 2,000 feet (610 m) long water filled rubber flood berm that surrounded portions of the plant was punctured by a skid-steer loader and it collapsed flooding a portion of the facility.

In 1999, a group of Norwegian engineers founded and patented Aqua Fence, a transportable, removable, and reusable flood barrier which uses the water's weight against itself. Aqua Fence removable flood panels protect cities and public utilities.

A similar technology is the Water-Gate Flood barrier, a rapid-response barrier which can be rolled out in a matter of minutes that self-deploys using the weight of water to hold it back.

5. Recent flooding in other parts of the world.

USA (TEXAS)

Severe flooding in Central and South Texas has prompted Texas Governor Greg Abbott to declare a state of disaster in 18 counties. Some areas recorded more than 13 inches (330.2mm) of rain in 48 hours to 16 October, causing river levels to jump dramatically. The Llano River at Llano rose by around 35 feet in just 24 hours to reach near-record levels. “Texas is taking immediate action to respond to the threat of recent severe weather and flooding across the state,” said Governor Abbott. “We have made available all necessary resources to respond as quickly and effectively as possible to this disaster, and to assist those in harm’s way. I thank all our first responders and local officials on the ground in these communities for their efforts to assist fellow Texans during this dangerous event.” Counties included in the disaster declaration are: Bastrop, Burnet, Colorado, Fayette, Hood, Jim Wells, Kerr, Kimble, La Salle, Live Oak, Llano, Mason, McMullen, Nueces, Real, San Patricio, Travis, and Williamson. Evacuations have been carried out in several areas including Kingsland, Marble Falls, Cottonwood Shores and the City of Burnet. Raging floodwaters have destroyed a bridge over the Llano river in Kingsland, Central Texas.

Flood Summary

Last updated: October 17, 2018
Event: Texas, USA, October 2018
Date: October 7, 2018
Type: Flash flood, River flood
Cause: Extreme rainfall, Long-term rainfall
Heavy rain between 07 and 09 October caused flooding in western areas of Texas. Local media reported that 4 people are missing after the South Llano River broke its banks in the city of Junction, situated about 140 miles (225 kilometers) west of Austin. Further heavy rain from 14 October caused further flooding. The Lano river broke its banks in Llano and Kingsland. One person reportedly died in flood water near the eastern shore of Lake Lyndon B. Johnson in Burnet County.

Magnitude

River level
9.51 metres Llano River near Junction - October 8 to October 8, 2018 Llano River near Junction reached 31.2 feet on 08 October, above the 31 feet major flood stage.
River level
7.39 metres Llano River at Llano - October 8 to October 8, 2018 The Llano River at Llano reached 24.26 feet on 08 October, its 5th highest ever level and above major flood stage of 23 feet.

River level

12.16 metres Llano River at Llano - October 16 to October 16, 2018 The Llano river at Llano rose around 35 feet (10.67 m) in just 24 hours, reaching 39.91 feet early on 16 October. This is the highest level since the floods of 1935 when the Llano reached 41.5 feet (12.64m). Major flood stage is 26 feet (7.92 m).

River level

211.65 metres Colorado River at Lake Travis - October 17 to October 17, 2018 The Colorado River at Lake Travis reached 694.4 feet (211.65 m) on 17 October, just below major flood stage of 695 feet, prompting a Flash Flood Warning for the Lake Travis area.

Rainfall level

319.53 mm in 48 hours Lampasas - October 14 to October 16, 2018 Figures from NWS 12.58 inches

Rainfall level

306.83 mm in 48 hours Harper - October 14 to October 16, 2018 12.08 inches

Rainfall level

336.29 mm in 48 hours Valley Spring - October 14 to October 16, 2018 13.24 inches

Rainfall level

327.15 mm in 48 hours Castell - October 14 to October 16, 2018 12.88 inches

Damages

Fatalities

3 people Junction - October 8 to October 9, 2018 As of 16 October 1 person was still missing

Fatalities

1 person Lake Lyndon B. Johnson - October 16 to October 16, 2018

BRITAIN

The risks of tidal flooding are worsening across much of Britain – and that is leading to more protective barriers being put in place, by Claudio Accheri and Laurie Goering for the Thomson Reuters Foundation.

LONDON, Sept 6 (Thomson Reuters Foundation) – Four decades ago, when storms blew in the North Sea and sent high tides surging toward London, sirens sounded in the city.

“People were told not to work or sleep in basements. They used to move buses to higher ground. All these contingency plans had to be in place,” remembers Steve East, an engineering manager for the British Environment Agency.

But since 1982, when the Thames Barrier – London’s pioneering flood protection wall – came into use, central Londoners have scarcely had to think about flood risks.

“Today if London is threatened by a tidal surge, we stop the surge here and London carries on with its normal day-to-day business,” said East, the engineering manager for the barrier, which spans the Thames in Woolwich in southeast London.

As climate change brings more extreme rainfall, higher tides and stronger storms, flood risks are rising across Britain – and flood protection barriers are rising as well.

Ipswich in eastern England will put into operation its first tidal barrier this winter, part of a 66-million-pound ($86-million) flood protection system designed to defend the town against growing threats, officials there say.

Other British towns, including the east coast port of Boston, are planning barriers of their own, said Andrew Usborne, the project manager for the Ipswich barrier, on the River Orwell.

The moveable barriers – which retract into the riverbed floor when not in use and are raised only when needed – are being built not just because of rising risks but because they increasingly make financial sense, Usborne said.

In Ipswich, "this was the cheapest and preferred option," he said.

Walls built along the waterfront, long used to protect the city, now need to be raised to meet growing risks "but nobody's ever going to accept a metre of wall all through the centre of town", he said.

The new barrier, which sits on piles driven 60m (66 yards) into the chalky soil, will protect about 1,200 homes and more than 400 businesses from the kind of storm expected to hit every 300 years, he said – and rising climate change risks have been taken into account.

Across Britain, "where it is financially and technically appropriate, like here, we will have barriers," he predicted.

London's Thames Barrier – a 520m span of steel gates, piers and abutments that looks as if it might have been inspired by the Sydney Opera House – has now been used more than 180 times to protect central London from tidal floods, East said.

The rate of use has been increasing – at one point, it was closed on 24 consecutive tides – but that increasing crescendo of closures "was always expected," the engineer said.

The structure was designed to last until 2030 – but assessments suggest it will now last until 2070, when a new barrier will need to be put in place, he said.

For now, however, the barrier remains an effective bulwark, keeping 1.25 million Londoners – and 300 billion pounds worth of infrastructure – above the rising tide, officials say.

“Until the 1920s, people actually died in floods in central London – and the real catalyst for the Thames Barrier and the rest of the tidal defence system was the floods of 1953, where over 350 people died,” East said.

6. Provide names of water and weather resources agencies and organization at three

i. Local/State
ii. National
iii. International

LOCAL/ STATE

• Kaduna State Water Resources Agency

• Rivers State Water Resources Agency

• Lagos State Water Resources Agency

NATIONAL

• Nigeria Hydrological Services Agency (NIHSA)

• Nigerian Integrated Water Resources Commission

• National Water Resources Institute (NWRI)

• River Basin Development Authorities (RBDA's)

INTERNATIONAL

• World Meteorology Organization WMO

• Integrated Water Resources Management IWRM

• Canadian Water Resources Management CWRM