SRI DURGA MALLESWARA
SIDDHARTHA MAHILA KALASALA
An Autonomous College in the Jurisdiction of Krishna University
A College with Potential for Excellence
Sponsors: SIDDHARTHA ACADEMY OF GENERAL AND TECHNICAL EDUCATION

**A PROJECT REPORT**

**ON**

# FLOOD FREQUENCY ANALYSIS USING GUMBEL'S DISTRIBUTION METHOD IN PRAKASAM BARRAGE

**SUBMITTED TO**

**DEPARTMENT OF PHYSICS**

**UNDER THE GUIDENCE OF**

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**An Autonomous College in the jurisdiction of Krishna University**

**Accredited at 'A++' level by NAAC.**

# DECLARATION

We declare that the present work entitled "**FLOOD FREQUENCY ANALYSIS USING GUMBEL'S DISTRIBUTION METHOD IN PRAKASAM BARRAGE**" is a bonafide record of the research work carried out by us and no part of the discussion has been presented earlier for any Degree, Diploma and any other similar title.

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**"FLOOD FREQUENCY ANALYSIS USING GUMBEL'S DISTRIBUTION METHOD IN PRAKASAM BARRAGE"**.

The utility of this for me lies in the fact in that it helps me to gain some practical application and knowledge of the subject.

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# AbstrAct

Flood frequency analysis is the most important statistical technique in understanding the nature and magnitude of high discharge in a river. The objective of frequency analysis is to relate the magnitude of events to their frequency of occurrence through probability distribution. The study which was carried in Vijayawada aimed at Prediction of Flood frequency analysis of Krishna river of Prakasam barrage at Vijayawada using Gumbel's method. These are estimated using historical data from 2007-2020(14 years) of Prakasam Barrage which were collected from Flood Control on Irrigation of Vijayawada. The probability of the flood out comes to be for 5 years and 10 years is 778097.2 Cusecs and 870141.5 Cusecs respectively.

# 1.FLOODS

## 1.1-Introduction

A flood is an overflow of water that submerges land that is usually dry. Floods are an area of study of the discipline hydrology and are of significant concern in agriculture, civil engineering and public health. Human changes to the environment often increase the intensity and frequency of flooding, for example land use changes such as deforestation and removal of wetlands, changes in waterway course or flood controls such as with levees, and larger environmental issues such as climate change and sea level rise.

Flooding may occur as an overflow of water from water bodies, such as a river, lake, or ocean, in which the water overtops or breaks levees, resulting in some of that water escaping its usual boundaries, or it may occur due to an accumulation of rainwater on saturated ground in an areal flood. While the size of a lake or other body of water will vary with seasonal changes in precipitation and snow melt, these changes in size are unlikely to be considered significant unless they flood property or drown domestic animals.

Floods can also occur in rivers when the flow rate exceeds the capacity of the river channel, particularly at bends or meanders in the waterway. Floods often cause damage to homes and businesses if they are in the natural flood plains of rivers. While riverine flood damage can be eliminated by moving away from rivers and other bodies of water, people have traditionally lived and worked by rivers because the land is usually flat and fertile and because rivers provide easy travel and access to commerce and industry. Flooding can lead to secondary consequences in addition to damage to property, such as long-term displacement of residents and creating increased spread of waterborne diseases and vector-bourn diseases transmitted by mosquitos.

### 1.1.1-Types of Floods

**1.Flash Floods** are fast-moving waters that sweep everything in their path. They are caused by heavy rainfall or rapid snow thaw. Flash floods usually cover a relatively small area occur with little to no notice, generally less than six hours. The rapid water torrents can move large objects like cars, rocks, and trees.

**2.Coastal Floods** are caused by strong winds or storms that move towards a coast during high tide. When powerful waves breach the coast's dune or dike, the area is usually flooded. Coastal regions with fewer defences and lower elevations are the most affected. The best time to repair the breach is during low tide.

**3. River floods** are characterized by gradual riverbank overflows caused by extensive rainfall over an extended period. The areas covered by river floods depend on the size of the river and the amount of precipitation. River floods rarely result in loss of lives but can cause immense economic damage.

**4. Urban floods** occur when the drainage system in a city or town fails to absorb the water from heavy rain. The lack of natural drainage in an urban area can also contribute to flooding. Water flows out into the street, making driving very dangerous. Although water levels can be just a few inches deep, urban floods can cause significant structural damage.

**5. Pluvial floods** form in flat areas where the terrain can't absorb the rainwater, causing puddles and ponds to appear. Pluvial flooding is similar to urban flooding, mainly in rural areas. The agricultural activities and properties in areas where pluvial floods have occurred can be serious affected.

### 1.1.2-Causes

**1.Massive rainfall:** Drainage systems and the effective infrastructure design aid during heavy rains. They help the drainage of excess water into reservoirs in an easy way. But in cases of heavy rainfall, the systems stop working. Thus, flood is caused.

**2.Overflowing of the rivers:** The people living along the river always have a risk of life from the overflowing of the Rivers. To prevent such a situation, a string of dams are built. However, if these dams are not managed properly, they may cause flooding and huge damage.

**3.Collapsed Dams:** In the event of huge rainfall, the dams built begin to collapse. Thus, causing the flood situation to become even critical for the people living around.

**4.Snow Melt:** The cutting of trees in a reckless manner i.e. deforestation is also a major cause of man-made flooding. Trees prevent soil erosion and also the loss of crops. The vegetation is also enriched as a result of more and more trees. This also blocks the massive flow of rain, thus preventing flooding.

**5.Climate Change:** The climatic changes caused due to human practices also add to the risk of flooding. Human beings cut trees in a large number, thus affecting the process of photosynthesis. Thus, increased level of carbon-di-oxide in the atmosphere cause changes in climate posing threats of natural disasters like floods etc.

**6.Emission of Green House Gas:** The burning of fossil fuels, the industrial influences, the pollution all is depleting the level of the ozone layer and increasing the level of greenhouse gases, becoming a major cause of man-made flooding.

### 1.1.3-Effects

The adverse effects of flooding include:

- Loss of human life
- Property and infrastructure damage
- Road closures, erosion, and landslide risks
- Crop destruction and livestock loss
- Threats to salmon and other aquatic species
- Health risks due to water contamination
- Housing displacement
- Economic impacts

## 1.2-Floods in India

Among all the disasters that occur in India, floods are the most commonly occurring natural disasters due to the irregularities of the Indian monsoon. Flood is most prevalent and costliest natural disaster in the world which devastates both life and economy at a large extent. Any flow which is relatively high and which overflows the natural or artificial banks in any reach of the river is called flood.

About 75% of the annual rainfall in India is concentrated in 3 - 4 months of the monsoon season. Flood, an excess of water, can be caused by heavy rainfall followed by inadequate capacity of rivers to hold the water within their banks. According to National Flood Commission, about 40 million hectares of land area is prone to flood in the country.

On an average, the area affected by floods annually is about 8 million hectares, out of which the cropped area affected is about 3.7 million hectares. India witnesses flood due to excessive rain which then results in overflow of rivers, lakes and dams, which adds to cause large amounts of damage to people's lives and property.

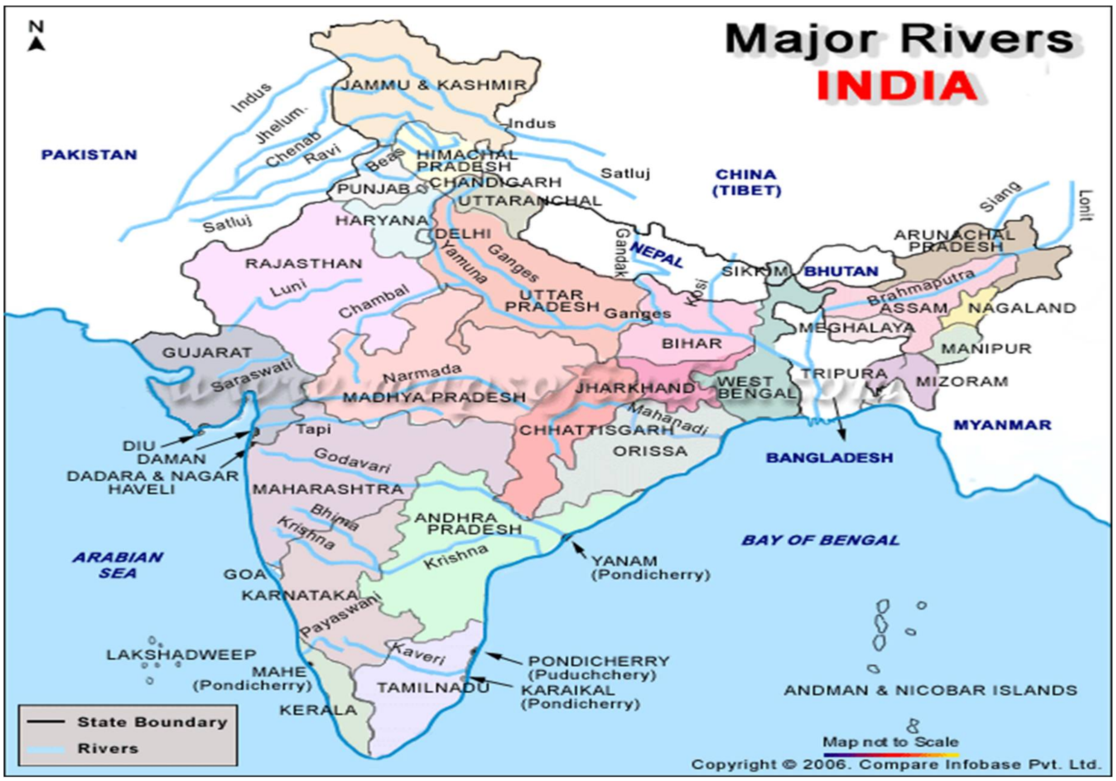


Figure 1.2: Map-Major Rivers of India

### 1.2.1-Regions in country prone to Floods

India can be broadly divided into the following four regions for a study of flood hazard. In addition the Andaman and Nicobar Islands and Lakshadweep have peculiar characteristics, which result in drainage congestion, flooding and erosion in coastal areas.

**1. The Brahmaputra River Region** This region consists of the rivers Brahmaputra and Barak and their tributaries, and covers the states of Assam, Arunachal Pradesh, Meghalaya, Mizoram, Manipur, Tripura Nagaland, Sikkim and the northern parts of West Bengal. The catchments of these rivers receive very heavy rainfall which occurs mostly during the months of May – June to September. As a result, floods in this region are severe and quite frequent.

Further the hills, where these rivers originate, are fragile and susceptible to erosion and thereby cause exceptionally high silt discharge in the rivers. In addition, the region is subjected to severe and frequent earth quakes, which causes numerous landslides in the hills and upset the regime of the rivers. The predominant problems in this region are cloud bursts followed by flash floods, soil erosion in the watershed and bank erosion along the rivers, flooding caused by the spilling of rivers over their banks, drainage congestion and the tendency of some of the rivers to change either courses. The plain areas of the region suffer from the inundation caused by spilling of the Brahmaputra.

**2. The Ganga River Region** The river Ganga has many tributaries, the important ones being Yamuna, Sone, Ghaghara, Raphti, Gandak, Burhi Gandak, Bagmati, Kamla Balan, Adhwara group of rivers, Kosi and theMahananda. It covers states of Uttarakhand, Uttar Pradesh, Jharkand, Bihar, south and centralparts of West Bengal, Punjab, parts of Haryana, Himachal Pradesh, Rajasthan, Madhya Pradeshand Delhi.

The rainfall increases from west to east and from south to north. The flood problem ismostly confined to the areas on the northern bank of the river Ganga. Most of the damage iscaused by the northern tributaries of the Ganga. In the north – western parts of the region andsouthern parts of West Bengal, there is a problem of drainage congestion. The flooding anderosion problem is serious in in the states of Uttar Pradesh, Bihar and West Bengal. The problemof flooding and drainage congestion is getting accentuated due to large scale encroachment of flood plains flood plains of the rivers for habitation and various development activities.

**3.The North – West River Region** The main rivers in this region are the Indus, Sutlej, Beas, Ravi, Chenab and Jhulem. These rivers are the tributaries of the Indus. They carry quite substantial discharges during the monsoon and also large volumes of sediment. They change their courses frequently and leave behind vast tracts of sandy waste.

This region covers the states of Jammu and Kashmir, Punjaband parts of Himachal Pradesh, Haryana and Rajasthan. Compared to the Ganga and Brahmaputra regions, the flood problem is relatively less in this region. The major problem is that of inadequate surface drainage which causes inundation and water logging over vast areas. Indiscriminate use of water for irrigation and development of low lying areas and depressions has created problem of drainage congestion and water logging.

**4. The Central India and Deccan Region** Important rivers in this region are Narmada, Tapi, Mahanadi, Godavari, Krishna and Cauvery. These rivers are mostly well defined and stable courses. They have adequate capacities within the natural banks to carry the flood discharge except in delta area. The lower reaches of the important rivers on the east coast have been embanked, thus largely eliminating the flood problem.

However, the embankments need to be raised and strengthened to latest standards to continue to provide protection against floods and erosion. This region covers the states of Andhra Pradesh, Telangana, Karnataka, Tamil Nadu, Kerala, Orissa, Maharashtra, Gujarat and parts of Madhya Pradesh. The region does not have serious flood problem except that some of the rivers in Orissa state namely Mahanadi, Brahmini, Baitarniand Subarnarekha are prone to floods every year.

The delta and coastal areas of the states on the east coast periodically face flood and drainage problems in the wake of monsoon depression and cyclonic storms. The problem is accentuated when the floods synchronize with high tide. The rivers Tapi and Narmada, are occasionally in high floods affecting areas in the lower reaches in Gujarat.

## 1.3-Floods in Andhra Pradesh

### 1.3.1-About the state

Andhra Pradesh, one of the 28 states of India, is situated in the southeast part of the country, it is the seventh-largest state in India, covering an area of 162,970 sq. km (62,920 sq. mi). It is the tenth most populous state, with 49,386,799 inhabitants. The state is bordered by Telangana in the north-west, Chhattisgarh and Odisha in the north-east, Karnataka in the west, Tamil Nadu in the south, and to the east lies the Bay of Bengal. Andhra Pradesh has a coastline of 974 km – the second-longest coastline among the states of India, after Gujarat – with jurisdiction over almost 15,000 sq. km of territorial waters. The small enclave of Yanam, a district of Puducherry, lies to the south of Kakinada in the Godavari delta on the eastern side of the state.

The state is made up of the two major regions of Rayalaseema, in the inland south-western part of the state, and Coastal Andhra to the east and northeast, bordering the Bay of Bengal. The state is divided into twenty-seven districts, nine of which are located in Coastal Andhra and four in Rayalaseema. The largest city and commercial hub of the state is Visakhapatnam, located on the Bay of Bengal, with a GDP of US$43.5 billion; the secondlargest city in the state is Vijayawada, located on the banks of the Krishna River, which has a GDP of US$3 billion (as of 2010). The economy of Andhra Pradesh is the seventh-largest state economy in India with Rs 8.70 lakh crore in gross domestic product and a per capita GDP of Rs 142,000. Andhra Pradesh state is rich in water resources. River Godavari is the largest and broadest river in southern India, which originates at Trimbakeshwar near Nasik in Maharashtra. River Krishna enters the state at Alampur after having originated at Mahabaleshwar in Maharashtra. Tungabhadra is an important tributary of the river Krishna. Nagarjunasagar Dam at Nandi Konda, Srisailam project at Srisailam, and Prakasam barrage at Vijayawada are constructed on this river. Pennar, Vamsadhara and Nagavali are other important rivers. All the rivers are rain-fed and of great economic significance because they are the source of hydropower and irrigation.

The two major lakes in the state are the Kolleru and Pulicat. While the Kolleru lake lies in the delta between the rivers Krishna and the Godavari, the Pulicat lake is located in the southern tip of the Nellore district, close to the sea. Andhra Pradesh state is rich in reservoirs and tank resources. Andhra Pradesh hosted 121.8 million visitors in 2015, a 30% growth in tourist arrivals over the previous year, making it the third mostvisited state in India. The state's natural attractions include the beaches of Visakhapatnam, hill stations such as the Araku Valley and Horsley Hills, and the island of Konaseema in the Godavari River delta.

### 1.3.2-Major Rivers

All the rivers in Andhra Pradesh are rain-dependent and they have large currents in the rainy season and low currents in summer. Some rivers are even dry in summer.

The major rivers in Andhra Pradesh are the Godavari, Krishna, Tungabhadra, Pennar, Manjira, Nagavali, and Vamsadhara.

#### 1.3.2.1-Godavari

The river Godavari originates in the Western Ghats in the Nasik district of Maharashtra.The Godavari and its tributaries flow through the states of Maharashtra, Karnataka, Madhya Pradesh, Orissa and Andhra Pradesh. The recorded peak discharge of Godavari at Dhawaleshwaram was noted to be 85,000 cubic meters per second (30 lakh cusecs (2000-2020)).

#### 1.3.2.2-Krishna

The Krishna is the second largest river in the State. The traditional source of the river is a spout from the cow's mouth in the ancient temple of Mahadev in Mahabaleswar in Maharashtra at an elevation of 1337m and it flows 780-km before it enters Andhra Pradesh. The length of the Krishna River is 1400-km. The total catchment is 2,59,000-sq-km. The river gets most of its water from the Western Ghats. The river drains the areas of Maharashtra, Karnataka, Andhra Pradesh and Telangana.

#### 1.3.2.3-Vamsadhara

The Vamsadhara flows between Mahanadi and Godavari. The river originates in Lanjigarh in the Kalahandi district of Odisha, flowing 254km before joining the Bay of Bengal at Kalingapatanam in AP. The catchment area of the river is 10,830 square kilometers. Vamsadhara river basin covers an area of 8015 square kilometers in the state of Odisha and 2815 square kilometers in Andhra Pradesh. One of the major tributaries of the Vamsadhara River is Mahendratanaya, which originates Gajapati district of Odisha. It joins the main river in the state of Andhra Pradesh, upstream of Gotta barrage.

#### 1.3.2.4-Nagavali

The Nagavali river lies within the geographical co-ordinates of north latitude 18°10′ to 19° 44′ and east longitudes of 82° 53′ and 84° 05′. It is surrounded by Vamsadhara in the north, Champavati and Peddagedda in the south, the Godavari in the west, and the Bay of Bengal in the east. It drains parts of the districts of Kalahandi, Rayagada and Koraput of Odisha and Srikakulam, Vizianagaram and Visakhapatnam of Andhra Pradesh state. The total catchment area is 9510 sq km. The Nagavali river originates near the Lakhbahal in the Kalahandi district at an elevation of about 1300m. The total length of the river is 256 km out of which the first 161 km is in Odisha and the rest in Andhra Pradesh. The important tributaries are Barha, Baldiya, Satkalnala, Sitagurha, Srikona, Jhanjavati (Odisha-AP), Gumidigedda, Vottigedda, Suvarnamukhi, Vonigedda, Vagavathi and Relligedda (north Andhra).

#### 1.3.2.5- Pennar

Pennar,or Penna, rises in the Thenanahesava hill of the Nandidurg range in Karnataka, flowing through Kolar and Tumkur districts of Karnataka and enters Andhra Pradesh in the Hindupur taluk of Anantapur district, running eastwards before draining into the Bay of Bengal near Nellore. It is 597 kilometres long. Its drainage basin is 55,213 km2, of which 6,937 km2 is in Karnataka and 48, 276 km2 in Andhra Pradesh. The river basin lies in the rain shadow region of Eastern Ghats and receives an annual average rainfall of 500mm.

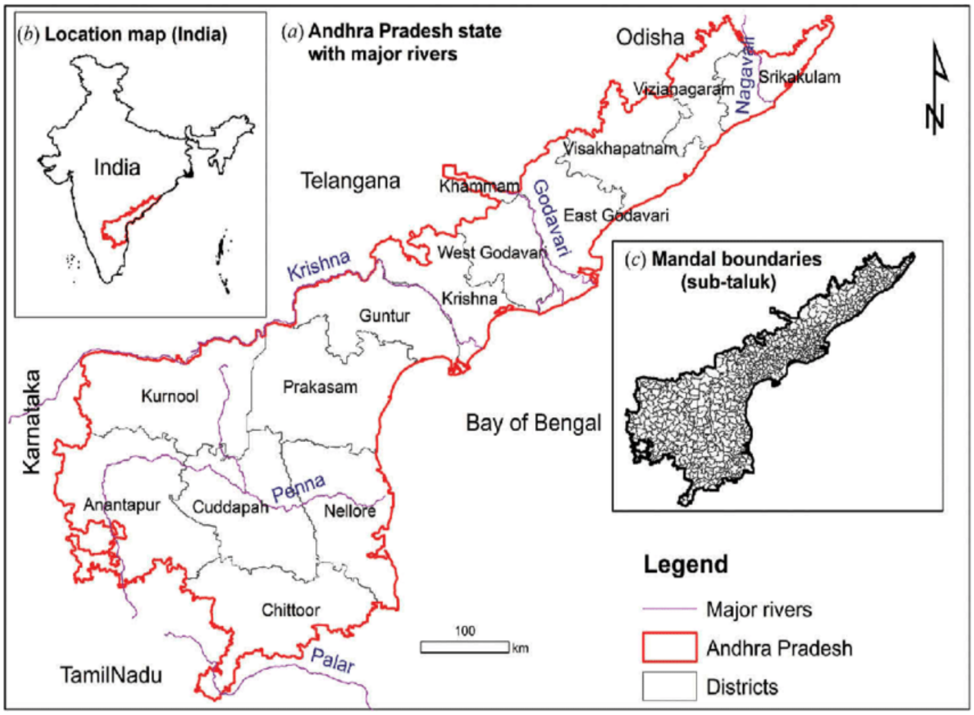


**Figure 1.3: Map-Major Rivers in Andhra Pradesh**

## 1.3.3-History of floods

In Andhra traditionally, the flood problem had been confined to the flooding of smaller rivers. But the drainage problem in the coastal delta zones has worsened, multiplying the destructive potential of cyclones and increasing flood hazards. A critical factor is the maintenance of irrigation systems. On several occasions, deaths have been caused by breaches in tanks and canals as well as over-flooding caused by silting and growth of weeds.

Traditionally the flood plains of Godavari, Krishna, Vamsdhara and Nagavalli have been subjected to floods due to heavy rains in the upstream catchment areas, but occasionally floods have been observed in smaller rivers as well. Cyclone induced heavy rains have been one of the prominent reason for floods in the state. The Godavari floods of 2006, Krishna floods of 2009, Floods in 2018 and 2019 were some of the most harrowing floods experience the state has felt in the recent past.

Some of the major floods that impacted the state between 2000 to 2020 are

**2006 Godavari Floods:** Torrential rains since 02-August 2006 caused widespread flooding in Andhra Pradesh. The floods also caused widespread damage to property, standing crops, flood control embankments and other basic infrastructure. The flood level in river Godavari had risen up to 70 feet at Bhadrachalam, the highest ever in the past two decades. Responding to the emergency situation, NRSC tasked the satellites and prepared multiple flood maps to assist in rescue and relief operations.

**2009 Krishna Floods:** Heavy rains in the catchments of Krishna, Tungabhadra rivers during the first week of October 2009 triggered by a deep depression in the Bay of Bengal caused severe floods in Andhra Pradesh affecting many districts. Kurnool town was submerged in the backwaters of the Srisailam dam due to unprecedented inflows. The flood situation remained grim in the villages situated on the banks of the Krishna river in the district due to heavy discharge of water from Nagarjunasagar dam into the downstream. The earliest coverage of IRS-AWiFS satellite data of 4th and 5th October 2009 were procured and analysed by NRSC. Flood inundation maps were prepared showing the flood extent in the affected villages. The maps were disseminated to State and Central government departments in near real-time mode at regular intervals so as to aid the Government in relief and rescue operations.

# 2.KRISHNA BASIN

## 2.1-Introduction

The Krishna Basin extends over the states of Andhra Pradesh (29.81%), Maharashtra (26.36%) and Karnataka (43.8%). Krishna Basin is having a total area of 258948 sq. km which is nearly 8% of the total geographical area of the country. The basin has a maximum length and width of about 701 km and 672 km and lies between 73°17' to 81°9' east longitudes and 13°10' to 19°22' north latitudes. The basin is roughly triangular in shape and is bounded by Balaghat range on the north, by the Eastern Ghats on the south and the east and by the Western Ghats on the west. The Western Ghats form the main watershed in the Region between the Bay and Arabian Sea rivers. The basin falls under division-All drainage flowing into Bay of Bengal and Region-Rivers draining in Bay of Bengal, delineated primarily based upon drainage of rivers to outlet. Major part of the basin (75.86%) is covered with agricultural area. Approximately 10% of the basin area is covered by forest, wasteland covers around 7% of the total basin area and around 4% of the basin area is covered by water bodies. Average annual surface water potential of this basin has been assessed at 78.1 BCM. Out of this, 58.0 BCM is utilizable water. The overall catchment of the basin comprises of 7 sub-basins, which have been further clustered into 391 watersheds each of which represents a different tributary system.

The salient features for the basin are listed in Table

| SI.NO. | Features | Description |
|---|---|---|
| 1 | Basin Extent | 73° 17' to 81° 9' E<br>13° 10' to 19° 22' N |
| 2 | Area (Sq.km) | a) 254750.14 (GIS based calculated)<br>b) 258948 (Reported Area) |
| 3 | States in the basin | Karnataka (43.83%),<br>Andhra Pradesh (29.81%) and<br>Maharashtra (26.36%) |
| 4 | Average Annual Rainfall (mm) | 859.11 |
| 5 | Average Annual Maximum Temperature (o C) | 32.14 |
| 6 | Average Annual Minimum Temperature (o C) | 20.52 |
| 7 | Number of villages | 27967 |
| 8 | Highest Elevation (m) | 1903 |
| 9 | Avg. Annual Water Potential (BCM) | 78.12 |
| 10 | Number of Sub-basins | 7 |
| 11 | Number of Watersheds | 391 |
| 12 | Number of water resources structures | Dams-660<br>Barrages-12<br>Weir-58<br>Anicuts-6<br>Lifts-119<br>Power House-35 |
| 13 | Highest Dam | Srisailam (N.S.R.S.P) Dam -145m |

| | | |
|---|---|---|
| 14 | Longest Dam | Narayana Pura Dam - 10.64 km |
| 15 | Highest Barrage | Thembu Barrage - 8.13 m |
| 16 | Longest Barrage | Hipparagi Barrage - 5460 m |

Table 2.1: Features of Krishna Basin


Figure 2.1: Map-Krishna Basin

## 2.2-Climate

The Krishna basin has a tropical climate. The climate is dominated by the southwest monsoon, which provides most of the precipitation for the basin. High flow in the rivers occurs during the months of August-November and the lean flow season is from Aril to May. Climate types range from per-humid through dry sub-humid in the west through semi-arid in the central and eastern parts of the basin. The south-central part of the basin is truly arid.

The region with its north-south elongation and typical arrangement of the major relief features, responds differently to the monsoon currents and thus exhibits sub-regional climate variations within this tropical monsoon zone. Western Ghats exert considerable influence as a climate barrier or rather a divide in the spatial distribution of climate attributes, the temperature, rainfall and relative humidity etc. Around the year, four distinct seasons occur in the basin. They are 1) the cold weather, 2) the hot weather, 3) the south-west monsoon, 4) the post monsoon. The cold weather season from mid-October to mid-February is generally pleasant in the entire basin. The western and the north-eastern regions are colder than the rest of the basin .In the hot weather season, the heat is unbearable in the central, northern and eastern regions of the basin .It is comparatively pleasant in the western-most parts. The south-west monsoon sets in by mid-June and ends by mid-October. During this period, the basin receives about 80% of its total annual rainfall. After the withdrawal of the south-west monsoon in the middle of October, the weather clears up gradually and it is cool thereafter.

## 2.3-Rainfall

Like most other parts of India, the Krishna basin receives its maximum rainfall during the south-west monsoon. The monsoon winds strike the west coast of the Indian peninsula from the west and south-west and strike the Western Ghats or the Sahyadri Range, which present an almost uninterrupted barrier ranging from 610 m to 2,134 m in height. According to the India-WRIS database the average annual rainfall in the Krishna basin for the period of 1969 to 2004 is 859 mm. The south-west monsoon sets in the middle of June and withdraws by the middle of October. About 90% of annual rainfall is received during the Monsoon period, of which more than 70% occurs during July, August and September. The distribution of annual average rainfall for Krishna basin has been shown in Map 4. Western parts of the basin receive maximum rainfall. However, around 203 blocks of 30 districts (16-Karnataka, 8-Andhra Pradesh & 6-Maharashtra) falling in the basin are drought prone.

## 2.4-Major Rivers

River network or drainage channels which flow from higher reaches to lower levels often follow the topography and slope of the terrain. They flow towards the sea or lake waters. The network of drainage constitutes a watershed or catchments. It consists of River and Streams.

- The Krishna is the second largest eastward draining interstate river in Peninsular India. The Krishna River rises from the Western Ghats near Jor village of Satara district of Maharashtra at an altitude of 1337 m just north of Mahabaleshwar. The total length of river from origin to its outfall into the Bay of Bengal is 1400 km. Its principal tributaries joining from right are the Ghatprabha, the Malprabha, the Koyna, the Venna, the Varna, the Panchganga,the Dudhganga and the Tungabhadra whereas the Bhima, the Musi and the Munneru are principal tributaries joining the river from left.
- The Ghataprabha rises in the Western Ghats at an altitude of 884 m and flows eastwards for a length of 283 km. Two of its tributaries, the Hiranyakeshi and the Markandeya, also rise in the Western Ghats and flow through Maharashtra and Karnataka.

- The Malaprabha rises in the Western Ghats, at an altitude of about 793 m, about 16 km west of Jamboti in the Belagum district of Mysore. The river flows first in an easterly and then in a northeasterly direction and joins the Krishna at an elevation of about 488 m, about 306 km from its source.

- The Tungabhadra, an important tributary of the Krishna, is formed by the union of the Twin Rivers Tunga and Bhadra, which rise together in the Western Ghats at Gangamula at an elevation of about 1196 m. The united river Tungabhadra flows for about 531 km in a generally north-easterly direction, through Karnataka and Andhra Pradesh and joins the Krishna beyond Kurnool at an elevation of about 264 m. The total drainage area of the Tungabhadra is 71417 sq km. Like the Bhima, it drains about 206 km length of the Western Ghats.

- The Bhima also rises in the Western Ghats at an about 945 m and flows south-eastwards through Maharashtra and Mysore. It has a total length of 861 km and falls into the Krishna about 26 km. north of Raichur at an altitude of 343 m.

- The Musi rises at an altitude of about 661 m in the Medak district of Andhra Pradesh. It flows through Hyderabad city and runs mostly west to east until it is joined by the Aleru. Then it flows south-wards and drops into the Krishna near Wazirabad, at an elevation of about 61 m. When it confluences with Krishna River, Musi River have already flown for 267 km.

## 2.5-Sub-Basins

The Krishna basin is split into 7 sub-basins namely Bhima lower sub-basin (9.28%), Bhima upper subbasin (17.58%), Krishna lower sub-basin (15.5%), Krishna middle sub-basin (8.73%), Krishna upper sub-basin (21.4%), Tungabhadra lower sub-basin (16.31%), and Tungabhadra upper sub-basin (11.2%) (Map 13), each of which represents a different tributary system. The percentage area covered by sub-basins in the basin is shown in Figure 4. Major tributaries contributing to various Sub-basins in the basin are-

- **Bhima lower sub-basin**-
  Bhima, Don, Bori, Chikka, Chinamageri, Dodda Halla, Dogi Halla, Gandori, Garaganji Halla, Hippargi Halla, Hire Halla, and Kanga rivers.
- **Bhima upper sub-basin** -
  Bhima, Bor and Dodda Halla rivers.
- **Krishna lower sub-basin**-
  Krishna, Pakhal or Munneru, Musi, Kongal, Halia, Bukler, Aler, Akeru, Palleru, Shamirpet Vagu, and Yesvantapuran Vagu rivers.
- **Krishna middle sub-basin**-
  Krishna, Bhimanapalli Vagu, Chinna Vagu, Dindi, and Pedda Vagu rivers.
- **Krishna upper sub-basin**-
  Krishna, Ghatprabha, Malaprabha, Chikodi Halla, Dudhganga, Vedganga, Kappur Halla, Jabapur Halla, Adda Halla, Agrani, Badachi Halla, Beeni Halla,Betgeri Halla, chail Halla, Don rivers.
- **Tungabhadra lower sub-basin-**
  Tungabhadra, China Hagari, Dodda Halla,garchi Vanka, Hagari, Kanigana Halla, Komativani Vanka, Nari Halla, sindhnur N rivers.
- **Tungabhadra upper sub-basin-**
  Tungabhadra,Vardha,Kumadvati,Karala Halla,Dodda Halla,Hire Halla,Vadagatte Halla rivers

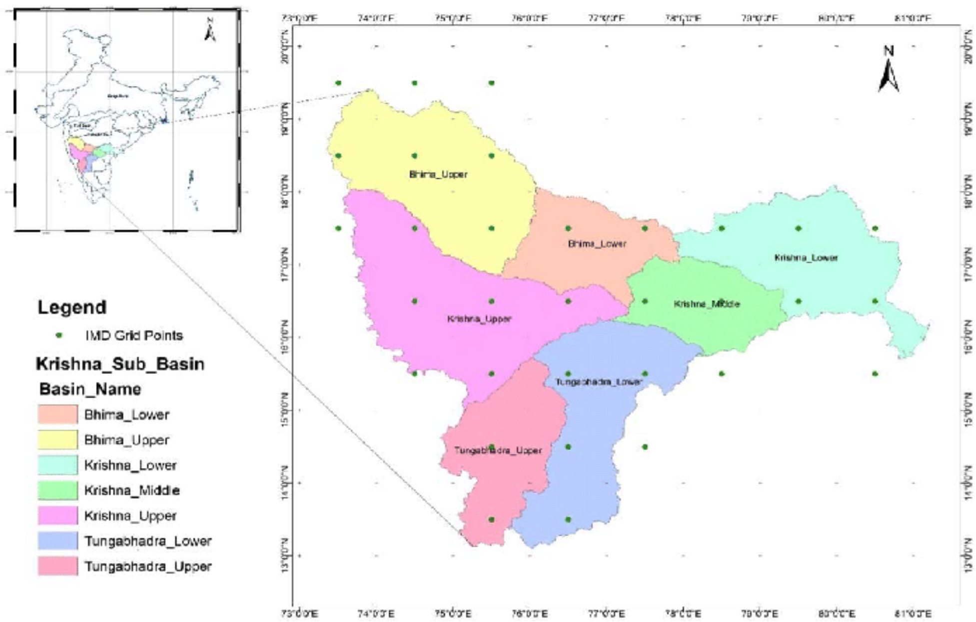


**Figure 2.5: Map-Krishna Sub-Basins**

## 2.6-Watersheds

Sub-basins could be sub divided into smaller hydrological units namely, watershed for water resources management at larger scale (micro level). Watershed is a natural hydrological entity that covers a specific areal expanse of land surface from which rainfall flows to a defined drain, channel, stream or river at any particular point. Watershed should be delineated purely on the basis of hydrologic principles. Size of the watershed is governed by the size of stream and its boundaries.

Seven sub-basins of Krishna basin have been further classified into 391 Watersheds each of which represents a different tributary system for size ranging from 278 Sq Km to 976 Sq Km with maximum number of watersheds falling in Krishna Upper Sub-basin. Number of watersheds and the range of size for the Sub-basins are mentioned in Table

| SI.NO | Sub-Basin | Area(sq.km.) | No of Watersheds | Size range of Watersheds |
|---|---|---|---|---|
| 1 | Bhima Lower | 23652.70 | 36 | 396 – 929 |
| 2 | Bhima Upper | 44793.32 | 71 | 351 - 940 |
| 3 | Krishna Lower | 39494.33 | 59 | 277 – 971 |
| 4 | Krishna Middle | 22229.12 | 36 | 341 – 963 |
| 5 | Krishna Upper | 54504.77 | 85 | 322 – 964 |
| 6 | Tungabhadra Lower | 41556.48 | 59 | 357 – 976 |
| 7 | Tungabhadra Upper | 28519.41 | 45 | 331 - 924 |

**Table 2.6-About Sub-Basins**

## 3.1- Objective of the study

The study aims to access the flood frequency of the area based on analysis of the available data information.
Following objectives are formulated to achieve the aim:

1.Consider the impacts of flood hazards in all planning processes that address current and future land uses within the planning area.
2.Considering the annually maximum inflows of Prakasam Barrage which was constructed on Krishna river based on data given from 2009 to 2021(15 years).
3.Using the Gumbel's distribution, the study which was carried in Vijayawada aimed at Prediction of Flood frequency analysis of Krishna river of Prakasam barrage at Vijayawada.

## 3.2-Study area

The structure of the Prakasam Barrage runs nearly 1223mm across the great Krishna River. The great thing about this barrage is that this river links the Krishna district on which the city of Vijayawada is located with the nearby Guntur District. Even, the barrage acts as the road bridge between these two districts in the state of Andhra Pradesh. The city of Vijayawada holds the pride of hosting the three canals that are connected with the barrage – Bandar canal, Eluru canal and Ryves canal. The Barrage was necessitated to be constructed to meet the demands of the increased irrigation ayacut of 13 Lakhs acres. It has total 76 pillars in which, 70 pillars fall under Guntur and 6 pillars fall under Krishna district.

The idea of construction of barrage across the Krishna River arose as early as 1798 when India was under British Rule. Even though, initiatives began in the year 1839, the plan was endorsed by the East India Company Board of Directors only on the 5th of January 1850. The construction began in the year 1852 and was accomplished in 1855.

Later, the state government of Andhra built a bridge in the name of Tanguturi Prakasam, who was the first Chief Minister of the state and the project was concluded in the year 1957 and from thereon it was helpful for irrigating nearly 1.2 million acres of agricultural land. The construction actually began on the 13th of February 1954 and it was operational from the 24th of December 1957.

The great thing about this construction is that it was built just within 3 and half years with the best quality and affordable cost. Yes, the project cost was just Rs.2.78 crores during that period. Even, this barrage is supplying water to the Buckingham Canal, which is being used as irrigation water supply canal. The Prakasam Barrage holds the pride of being one of the major irrigation projects in entire South India.


**Figure 3.2: Map of study area-Prakasam Barrage**

The additional features of Prakasam Barrage are shown in below table:

| SI.NO. | Features | Description |
|---|---|---|
| 1 | Basin | Krishna |
| 2 | Year of completion | 1954 -1957 |
| 3 | Latitude and Longitude | Latitude - 16° - 30'N<br>Longitude - 80° - 37'E |
| 4 | Length of Barrage | 1233 M |
| 5 | Storage capacity (in Mcm) | 3.071 TMC |
| 6 | Purpose | Irrigation and water supply |
| 7 | Catchment area | 97055 Sq miles |
| 8 | Total annual yield in the catchment | 13.08 Lakh acres |
| 9 | Number of gates | 70 |
| 10 | Size of gates | 12.19 x 3.66 M |

**Table 3.2-Features of Prakasam Barrage**

# 4.FLOOD FREQUENCY ANALYSIS

## 4.1-Introduction

Climate change has had extreme impacts in the world. Climate change is widely recognized as a major man-made global environmental challenge and it is also treated as threat. Climate change has massive implications on both natural resources and livelihoods of people. The available evidence indicates that the negative consequences to key economic sectors. Rainfall behaviour, intensity, and frequency have all changed as a result of climate change (Ramachandran et al., 2019). According to Intergovernmental Panel on Climate Change (IPCC) the flood impacts would be region specific based on the variability of climate scenario (Field et al., 2012). During the twentieth century, floods occurred at an unprecedented rate in the majority of the world drainage basins (Perry, 2000).

Flood, as a dynamic hydraulic hazard has caused damage on both socioeconomic conditions and the environment at diverse scales. Analyzing flood vulnerability is crucial for reducing losses and building community resilience. Flood frequency analysis is a statistical method of examining the frequency and magnitude relationships. The Flood Frequency Analysis (FFA) estimates the magnitudes of hydrological variables that correspond to specific frequencies or recurrence intervals. Different strategies are employed in hydrological probability distributions (Salajegheh et al., 2008).Dams, levees, and channel modifications are examples of structural measures, which reduced the flood flows and their consequences (Watson and Biedenharn,2000)

According to the United States Geological Survey (USGS), a recurrence interval is a time period over which the specific flood event or magnitude will occur, and it is a crucial factor in flood control, emergency preparedness, land use regulation and insurance considerations. The use of historical data in flood frequency analysis has been demonstrated in several research publications.

The flood frequency analysis is vital for vulnerable areas in Krishna basin of the study area, where numerous flood disastrous flood events (2009, 2016, 2019, 2020 and 2021) occurred in recent past. The Krishna is Peninsular India's second largest eastward draining interstate river basin is prone to recurring floods in the deccan plateau covering large areas in the States of Maharashtra, Karnataka, Telangana and Andhra Pradesh.

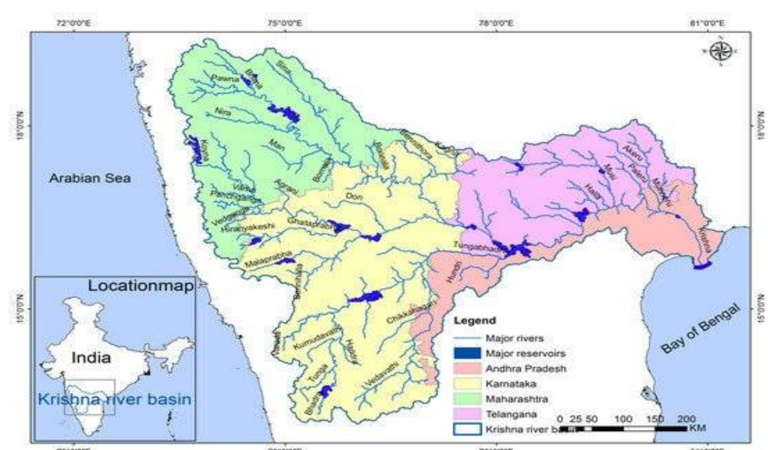


Figure 4.1: Krishna River Basin (Source: MPDI)

The Krishna Basin is bounded to the north by the ridge that separates it from the Godavari basin, to the south and east by the Eastern Ghats, and to the west by the Western Ghats. The basin has a roughly triangle shape, with its base at the Western Ghats, apex at Vijayawada, and the Krishna itself forming the median. All of the major tributaries that drain the triangle's base flow into the Krishna River in the upper two-thirds of its length. The total length of river is 1400 km from origin to its outfall into the Bay of Bengal. The Ghatprabha, Malprabha, and Tungabhadra are its main tributaries that join from the right, while the Bhima, Musi, and Munneru enter from the left. The majority of the basin is covered by agricultural land, accounting for 75.86 %, and water bodies cover 4.07 % of the basin.The Krishna drains an area of 2,58,948 sq.kms, which is roughly 8% of the country's entire geographical area. The river gets most its water from the western ghtas.

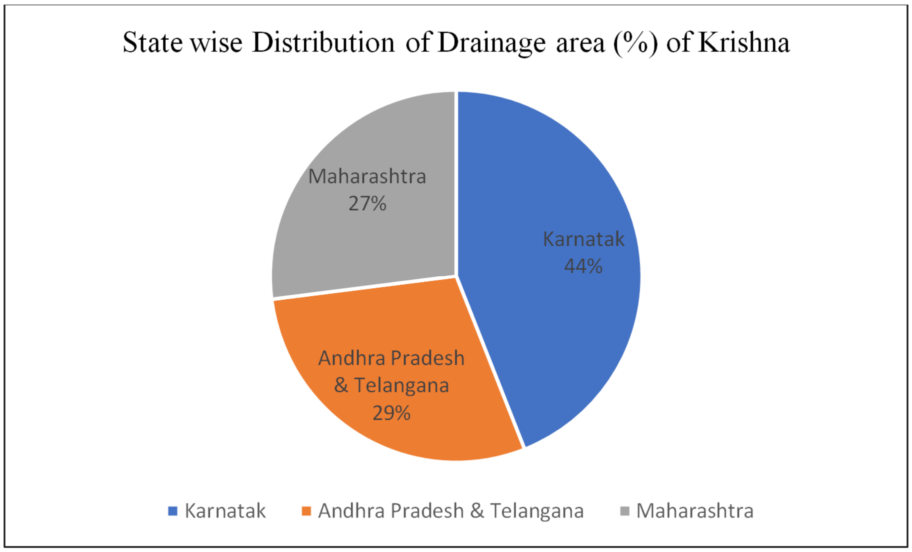


**Figure 4.1.1: State Wise Distribution of Drainage area**

Flooding has been a recurring phenomenon in the studied area, resulting in significant losses of life as well as public and private property. The major cause of floods are torrential rains in the upper catchment area, although cyclone/deep depression-induced rains have been one of the major common causes of floods.

## 4.2-Hydrological Characteristics of River Krishna

Heavy rainfall in the Krishna and Tungabhadra River catchments during the first week of October, 2009, triggered by a deep depression in the Bay of Bengal, caused devastating floods in Andhra Pradesh, affecting many district. The critical factor is the lack of proper maintenance of irrigation structures. Human loss and property loss have occurred on numerous occasions as a result of breaches in tanks and canals, as well as over-flooding, which causes silting and weed growth.

The Krishna basin receives 784 mm of rain each year on average. The South West Monsoon arrives around the middle of June and departs by the end of October. During the Monsoon season, around 90% of the annual rainfall occurs, with more than 70% falling during July, August, and September. The Central and State Governments undertake hydrological observations throughout the basin. The Central Water Commission operates 53 gauge-discharge stations in the basin. Furthermore, gauge-discharge data are accessible at 80 sites designated by the respective state governments and the Central Water Commission has nine (9) flood forecasting stations in the basin. The river surface water potential is 78.1 $km^3$ and its ground water potential is 26.41 $km^3$.The Prakasam barrage in Vijayawada has a maximum designed flood discharge of 11,90,000 Cusecs. During the October 2009 floods, the observed maximum flood discharge was 1087422 cusecs.

## 4.3-Methodology for frequency analysis

Flood frequency analysis is a technique commonly used to relate the magnitude of extreme runoff or river flow events to their frequency of occurrence through the use of probability distribution functions. It is very important for providing flood model discharges, which could then be used in levee design, flood insurance programmes, and stream restoration project works (chow et al.1988).Hydrologists apply flood frequency analysis to predict flow values corresponding to specified return periods or probabilities along a river.

14 years of yearly maximum peak flow time series data from the Prakasam barrage gauge station near Vijayawada due to a shortage of data. The highest annual stream flow data was obtained from the Water Resource Department (WRD) of the Government of Andhra Pradesh's flood control cell. For flood frequency analysis, we used peak flow data from a hydrometric station from Prakasam barrage has been used.

There are many methods for determining flood return period such as Gumbel's method, Hazens method, California method, and so on, but for more accuracy in flood modelling, most researchers utilised Gambles method. In 1941, Gumble devised the extreme value distribution method for determining flood frequency. (Krishan and Roy, 2016; Bhagat, 2017).

Gumbel's distribution is a probabilistic statistical theory. It is used as a maximum number distribution model among various samples. It can be used to forecast future natural disasters such as floods, earthquakes, and droughts. To make a probabilistic future prediction, the Gumbel's distribution method of frequency analysis requires at least ten years of yearly maximum historical data. Another term for it is the generalised extreme value distribution method. This is the most effective method for statistically analysing Flood Frequency. The Gumbel frequency distribution approach was used in this study to predict the flood frequency analysis.

The 14 years annually maximum peak discharge data was used to execute the flood frequency analysis (FFA). In flood frequency curve X axis represents the return period, and Y axis represents the annually maximum peak discharge values. The Gumbel distribution flood frequency analysis was completed based on the equation number (1) and return period was calculated using the equation number (6)

## 4.4-Gumbel’s Distribution

The Gumbel’s Distribution time (T) dependent probability frequency analysis equation is (1):

$$X_T = \bar{X} + K.\sigma_x \quad (1)$$

Where $X_T$ is Gumbel’s Distribution in reference to return period; $\bar{X}$ is the mean value; $\sigma_x$

Is the standard derivation; and “K” is the factor of frequency in Gumbel method.

The mean value and $\sigma_x$ are derived form the equation (2 and 3):

$$\bar{\bar{X}} = \frac{\sum X}{N} \quad (2)$$

Where "X" is the discharge value, $\bar{\bar{X}}$ is the mean of the discharge and "N" is the number of samples.

$$\sigma = \sqrt{\frac{\sum_{(i-1)}^{n}(Xi-\bar{\bar{X}})^2}{n}} \quad (3)$$

Where $\sigma$ = standard deviation, "n" is the number of sample, "Xi" is the each value of the sample and $\bar{\bar{X}}$ is the mean value of this sample.

The "K" value was calculated using the following equation (4):

$$K = \frac{Y_T-\bar{\bar{Y}}_n}{S_n} \quad (4)$$

Where $Y_T$ is the reduced variate which is calculated by using the equation (5): the $S_n$ and $\bar{\bar{Y}}_n$ value have been used from

Gumbel's extreme value distribution chart that depends on the sample size.

$$Y_T = -\left[Ln.Ln.\left(\frac{T}{T-1}\right)\right] \quad (5)$$

Where "T" is the predicted time period

$$P = \frac{(m-a)}{(N-a-b+1)} \quad (6)$$

Where "P" is the plotting position, "m" is the rank, "N" is the lowest order of the sample and "a and b" are the constant value.

| **Year** | **Max Discharge (cusecs)** | **Rank (m)** | **p=m/(n+1)** | **T=1/p** |
|---|---|---|---|---|
| 2009 | 1087422 | 1 | 0.067 | 15.0 |
| 2010 | 1022219 | 2 | 0.133 | 7.5 |
| 2019 | 749981 | 3 | 0.200 | 5.0 |
| 2020 | 717216 | 4 | 0.267 | 3.8 |
| 2007 | 556618 | 5 | 0.333 | 3.0 |

| | | | | |
|---|---|---|---|---|
| 2018 | 437623 | 6 | 0.400 | 2.5 |
| 2013 | 420131 | 7 | 0.467 | 2.1 |
| 2008 | 411000 | 8 | 0.533 | 1.9 |
| 2016 | 139610 | 9 | 0.600 | 1.7 |
| 2012 | 107750 | 10 | 0.667 | 1.5 |
| 2014 | 91250 | 11 | 0.733 | 1.4 |
| 2015 | 42316 | 12 | 0.800 | 1.3 |
| 2011 | 21750 | 13 | 0.867 | 1.2 |
| 2017 | 14818 | 14 | 0.933 | 1.1 |

**Table 4.4 Max. Discharges and its computation**

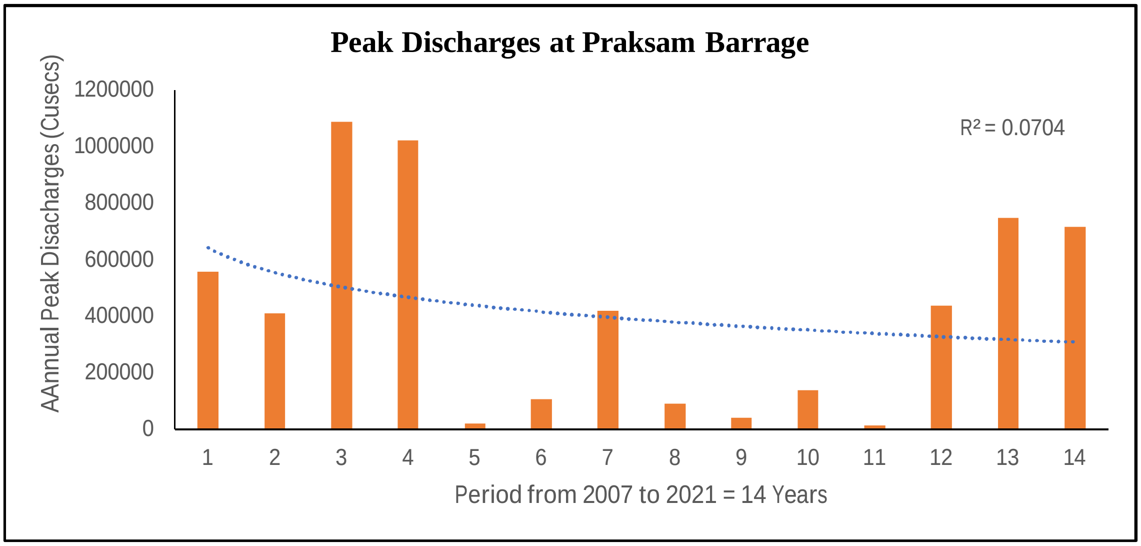


**Figure 4.4: Yearly Peak Discharge data from 2007 to 2021**

During this study, the recorded maximum discharge data was arranged in descending order. The rank (M) was assigned based on the discharge volume (Table 1). The first (1) rank was assigned for the highest discharge value i.e. 1087422 cusecs and the lowest rank (14) was assigned for the lowest discharge value i.e. 14818cusecs. The return period (P) was calculated by considering the Gumbel's equation and FRA (Xt = 415693.1 Cusecs), $\sigma$ (Standered Deviation =369381.7) was calculated form the peak discharges data from the equation (2 and 3).

To complete the XT (FFA) and $\bar{X}$ (mean), $\sigma$ (Standard deviation) was calculated from the peak discharge data using the equation (2 and 3)

The "K" value of this study was calculated based on equation (4). In the "K" value equation Sn and $\bar{\bar{Y}}_n$are the constant values taken from the Gumbel's distribution chart (sample wise constants were obtained). "YT" value was generated using the equation (5) which was used for calculating the K value. After that, all computed data was used to generate the flood frequency of this study area.

**Table 4.4.1 Return Period Analysis by using Gumbel's distribution**

| Return period (T) | YT | K | Xt (cusecs) |
|---|---|---|---|
| 5 | 1.4999 | 0.9811 | 778097.2 |
| 10 | 2.2504 | 1.2303 | 870141.5 |
| 50 | 3.9019 | 3.8671 | 1844142 |
| 150 | 5.0073 | 4.9626 | 2248797 |
| 200 | 5.2958 | 5.2486 | 2354421 |

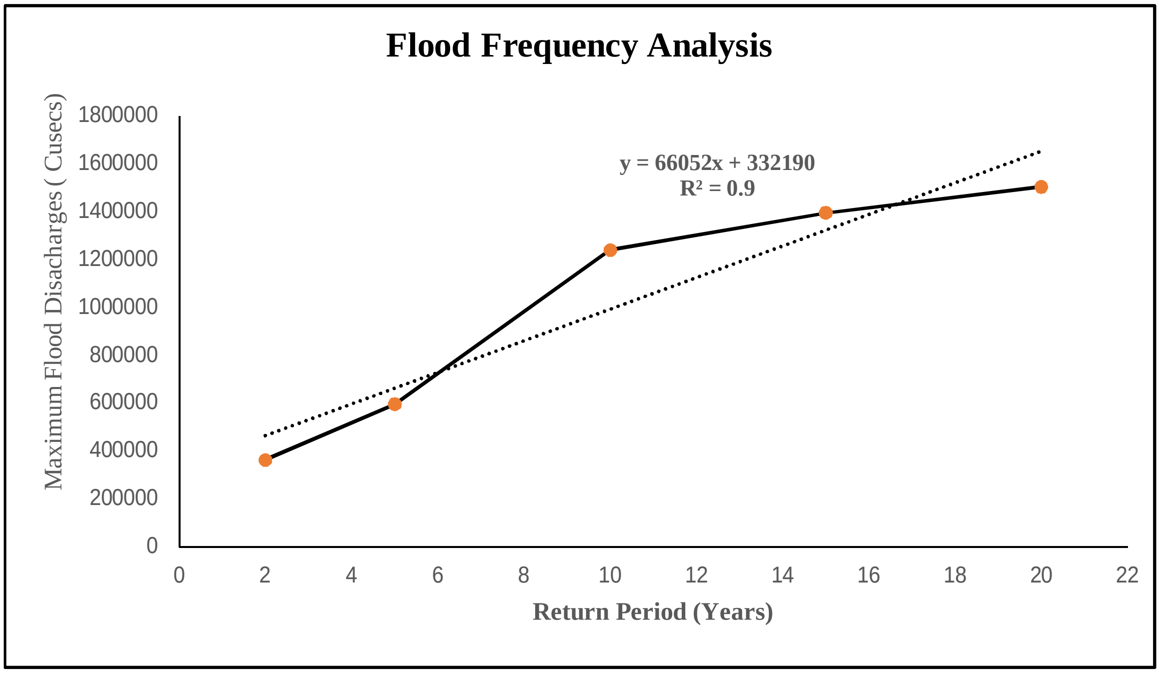


**Figure 4.4.1: Flood Frequency Analysis**

The flood frequency analysis was carried out by adapting the above methodology. In this study area, flood is a normal phenomenon occurring during the rainy seasons (July to Nov). 14 years historical data (2007 – 2021) was used to complete this study (Table 1). From the tabulated data, it was observed that the highest peak discharge value was 1087422 Cusecs (2009) and the lowest peak discharge value was 14,818 Cusecs (2017). This classification is completely based on the leaner method (Fig.3) where $R^2$ value is 0.0704.

The maximum return period (P) value of this analysis was 14 and the minimum value was 1.499 Cusecs which was calculated based on Gumbels return period equation (Table 2). The probability positions value was calculated (Table 1) by inversing the return period (1/p). The highest 1/p value was 15 years and the lowest was 0.93. The maximum discharge data were plotted on figure 1.

The present data mean discharge values and SD values were used to calculate the $Y_T$, K and final $X_T$ (flood frequency) for this study. The $Y_T$ (equation 5), K (equation 4) and $X_T$ (equation 1) were separately calculated depending upon the X and σ. In this study, the flood frequency analysis return period was taken for 2,5, 10, 15,20. According to the XT equation, the flood frequency discharge value was generated Table 2 for the study area. Then, T and XT value were plotted on the graph (Fig. 4) where $R^2$ = 0.9826. The $R^2$ value of this scatter plot has justified that Gumbel's statistical distribution method is suitable for analysing the flood frequency. The X-axis of this graph shows the return period and the Y-axis is the discharge value (Fig. 4).

### 4.5-Comparison between Linear Regression & Gumbel's Distribution Methods

Figure 5 and table 3 illustrate a comparison of FFA analysis using linear regression and Gumbel's methodologies. The forecasting/prediction of both methodologies showed the same pattern, with Gumbel's method slightly overestimating, while taking long return period( above five years). Both methods showing increasing trend, with respect to return period. Gumbel's method illustrates the gradual increasing trend (slope=257006 Cusecs) in relation to the return period. In both methodologies, flood discharge was lesser for a short return period compared to a long return period. Mean square error ($R^2$) approximately equal in both methods with slight variation (0.04). Flood frequency may increase with respect to the return period, according to these statistical studies.

**Table 4.5 Calculation of Return Period by using two Statistical analysis**

| Return Period (T) | Flood Discharges in Cusecs (Linear Regression) | Flood Discharges in Cusecs (Gumbel Distribution) |
|---|---|---|
| 2 | 315560 | 363164 |
| 5 | 741259 | 595420 |
| 10 | 1063288 | 1239523 |
| 15 | 1251663 | 1394519 |
| 20 | 1385318 | 1503043 |
| 25 | 1488988 | 1586634 |

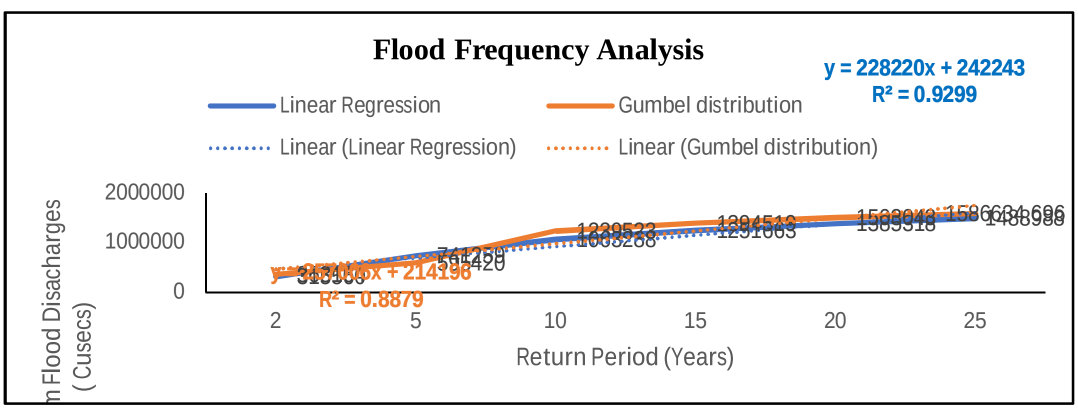


**Figure 4.5-Flood Frequency Analysis: Comparison between Linear & Gumbel**

As a result, the output shows that both methods are better suited to the data from Prakasam barrage gauging station, which was used to estimate Flood Frequency Analysis of Krishna River. By predicting the flood frequency (Gumbels) in the areas surrounding Krishna river of study area, the flood for the next 10 years will be 1239523 Cusecs, and the predicted flood discharge for the next 25 years will be 1586634 Cusecs. The expected flood from 2 to 25 years has also indicated a consistent growing tendency in selected Prakasam barrage station.These findings will be used extensively in the subsequent chapters of the current study to create a flood inundation map.

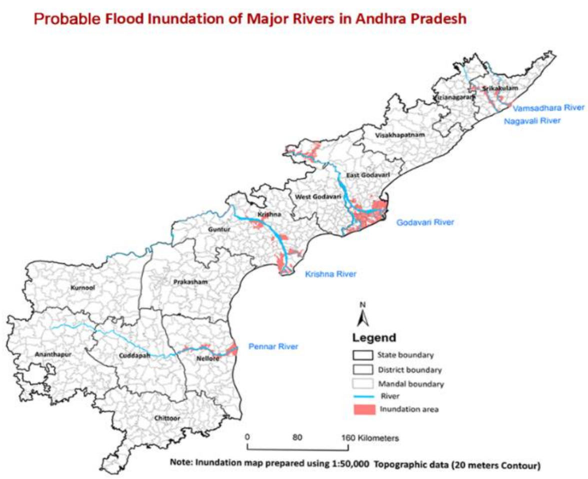


**Figure 4.5.1-District wise Mandals/Municipal Corporations/Villages/Population/Families prone to floods in Andhra Pradesh.**

| S.No | Major Rivers | Maximum Inflow (cusecs) | No. of Mandals | No. of Villages | No. of Municipal Corp./Towns | Population | No. of Household | Barrage/Reservoir | 1st Warning (cusecs) | 2nd warning (cusecs) | 3rd warning (cusecs) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Vamshadara | 2,50,000 | 16 | 229 | 1 | 6,14,083 | 1,57,266 | Gotta | 40,000 | 80,000 | 1,06,000 |
| 2 | Nagavali | 2,00,000 | 12 | 222 | 3 | 1,66,449 | 6,48,485 | Totapalli | 30,000 | 40,000 | 60,000 |
| 3 | Godavari | 30,00,000 | 46 | 621 | 6 | 26,56,266 | 7,34,016 | Dowaleswaram | 10, 00,000 | 13, 00,000 | 17, 00,000 |
| 4 | Krishna | 12,00,000 | 43 | 344 | 4 | 15,05,744 | 4,35,079 | Prakasam | 3,96,000 | 5,66,000 | - |
| 5 | Penna | 9,00,000 | 14 | 113 | 2 | 6,37,632 | 1,73,639 | Somasila | 9,00,000 | | |
| **Total** | | | **131** | **1529** | **16** | **55,80,174** | **21,48,485** | | | | |

**Table 4.5.1-District wise Mandals/Municipal Corporations/Villages/Population/Families prone to floods in Krishna River region.**

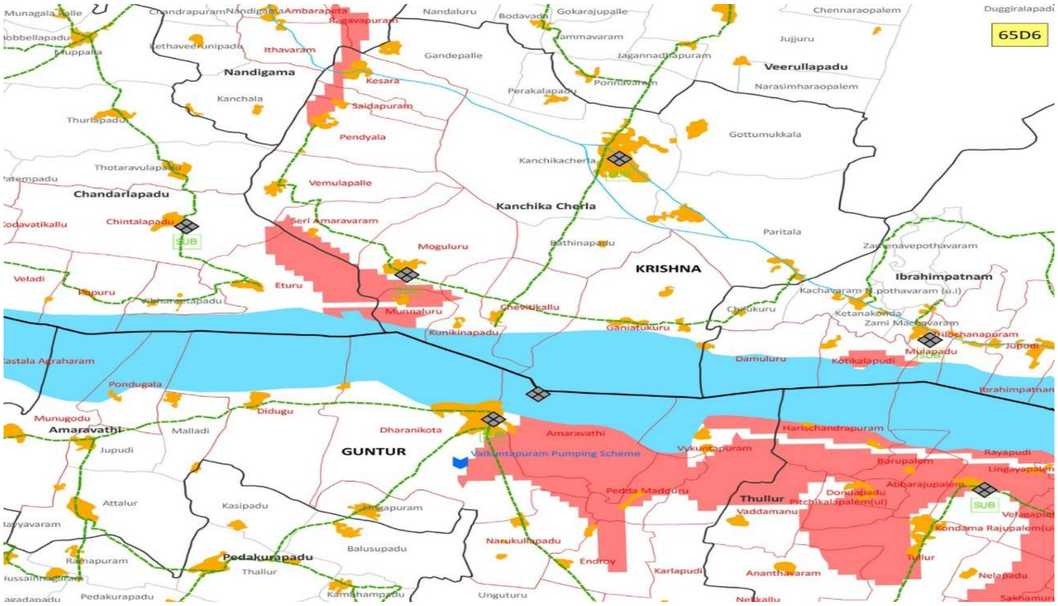


Figure 4.5.2

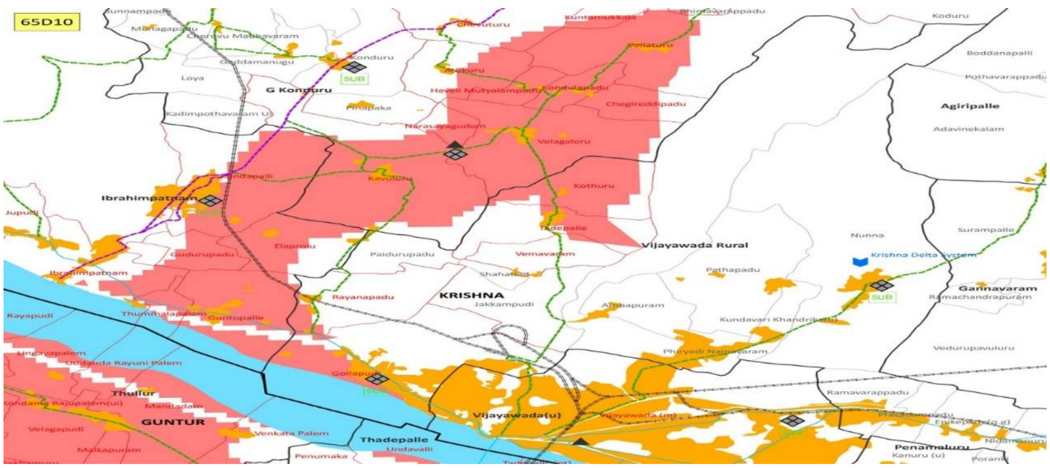


Figure 4.5.2-Inundation Map

| Inflow in Cusecs | District | No. of Mandals | No. of Villages | No. of Municipal Corp./Towns | Population | No. of Household |
|---|---|---|---|---|---|---|
| **3 Lakh** | Guntur | 16 | 66 | 1 | 245310 | 68541 |
| | Krishna | 17 | 68 | 1 | 325342 | 97076 |
| | **Total** | **33** | **134** | **2** | **570652** | **165617** |
| | | | | | | |
| **Up to 4 Lakh** | Guntur | 17 | 81 | 2 | 305626 | 85177 |
| | Krishna | 18 | 77 | 1 | 343720 | 102615 |
| | **Total** | **35** | **158** | **3** | **649346** | **187792** |
| | | | | | | |
| **Up to 5 Lakh** | Guntur | 17 | 92 | 2 | 352405 | 99247 |
| | Krishna | 18 | 96 | 1 | 377144 | 111944 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | **Total** | **35** | **188** | **3** | **729549** | **211191** |
| | | | | | | |
| **Up to 6 Lakh** | Guntur | 17 | 93 | 2 | 362109 | 102004 |
| | Krishna | 18 | 96 | 1 | 377144 | 111944 |
| | **Total** | **35** | **189** | **3** | **739253** | **213948** |
| | | | | | | |
| **Up to 8 Lakh** | Guntur | 19 | 120 | 2 | 470560 | 133038 |
| | Krishna | 18 | 105 | 1 | 400346 | 118675 |
| | **Total** | **37** | **225** | **3** | **870906** | **251713** |
| | | | | | | |
| **Up to 10 Lakh** | Guntur | 21 | 151 | 2 | 607041 | 172449 |
| | Krishna | 20 | 164 | 1 | 695760 | 203403 |
| | **Total** | **41** | **315** | **3** | **1302801** | **375852** |
| | | | | | | |
| **Up to 12 Lakh** | Guntur | 21 | 154 | 2 | 614654 | 174481 |
| | Krishna | 22 | 190 | 2 | 891090 | 260598 |
| | **Total** | **43** | **344** | **4** | **1505744** | **435079** |

**Table 4.5.2-Probability of Mandals/Villages/Population prone to floods according to 3 Lakhs to 12 lakhs of inflows.**

# 5.ConClusion

According to the last 14(2007-2020) years history, the maximum outcome in 2009, the amount of flood discharge is 1087422 Cusecs. And the second maximum flood discharge outcome in 2010 with the amount of flood discharge 1022219 Cusecs. By using the Gumbel's method calculated the value for the future prediction which may include the surrounding areas of the Vijayawada. Gumbel's method is the best method for the prediction of flood in the future. The estimated flood discharge for the coming 5 years will be 778097.2 Cusecs and will be the estimated flood discharge for the coming 10 years be 870141.5 Cusecs.

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