GOVERNMENT OF INDIA

MINISTRY OF IRRIGATION AND POWER

REPORT OF THE EXPERT COMMITTEE ON FLOODS FOR DELTAIC AREAS OF KRISHNA, GODAVARI AND GUNTUR DISTRICTS OF ANDHRA PRADESH

VOLUME I

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GOVERNMENT OF INDIA
Ministry of Irrigation & Power
Expert Committee on Floods in Andhra Pradesh.

New Delhi, the 6th January 1966.

From

Shri A. C. Mitra,
Chairman,
Expert Committee on Floods in Andhra Pradesh,
New Delhi.

To

The Secretary to the Government of India,
Ministry of Irrigation and Power, New Delhi.

SIR,

1. The Government of India, Ministry of Irrigation and Power *vide*, their Resolution No. DW.V. 501 (1)/64, dated the 9th October, 1964 constituted an Expert Committee on Floods to examine the recurring flood problem of the rich coastal deltaic areas of Andhra Pradesh in the districts of Godavari, Krishna and Guntur and to suggest comprehensive plans for controlling floods in the coastal rivers like Budameru, Thammileru and Yerrakalva, and for inundation caused by floods in the Kolleru lake and the deltaic drains.

On behalf of the Committee, I am forwarding herewith the report of the Committee.

2. The report comprises three volumes. Volume I contains descriptive portion, Volume II appendices and Volume III maps. Volume I is further sub-divided into various parts according to the subject dealt with therein.

3. Volume I has five parts.

Part I deals with subjects of general nature like constitution, terms of reference of the Committee and brief description of Andhra Pradesh with special reference to Krishna and Godavari deltas.

Part II deals with Kolleru lake Basin. It describes in detail :—

(*i*) Main features and Flood Problems.

(*ii*) Damage by floods.

(*iii*) Rainfall.

(*iv*) Works already carried out and contemplated.

(*v*) Suggestions made by the public.

(*vi*) Examination of various proposals for flood control.

(*vii*) Recommendations.

(*viii*) Priorities.

Part III deals with the drains of Krishna Western delta lying in Guntur District. Like Part II this also gives similar information regarding these drains.

Part IV deals with the drains of Godavari Central and Eastern deltas lying in East Godavari district. The information furnished is similar to that given in Part III.

Part V deals with the summary of the report and recommendations.

4. Volume II contains appendices.

5. Volume III contains maps, L—Sections and Cross Sections of major drains lying in Krishna Western and Eastern deltas, Godavari Eastern, Central and Western Deltas.

6. On behalf of the Committee, I have great pleasure in recording our thanks to the officers of the Irrigation Department of Andhra Pradesh Government, particularly to Shri P. T. Malla Reddy, Chief Engineer, Major Irrigation and General, P.W.D., Andhra Pradesh for making arrangements for the visits of the Committee Members to the flood-affected areas, for providing required data to the Committee and also for preparing estimates of the proposalls The Committee is grateful to Shri N. C. Rai Sircar, Director, India Mateorological Department, Madras, for supplying and analysing the rainfall data.

The Committee greatly appreciates the work done by the Flood Control Directorate, Central Water and Power Commission for carrying out the various hydrological and other studies and in compiling the report. The useful work done by the Central Water and Power Research Station, Poona in carrying out the intricate model experiments is gratefully acknowledged.

Yours faithfully,

(Sd.) A. C. MITRA.

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PART I
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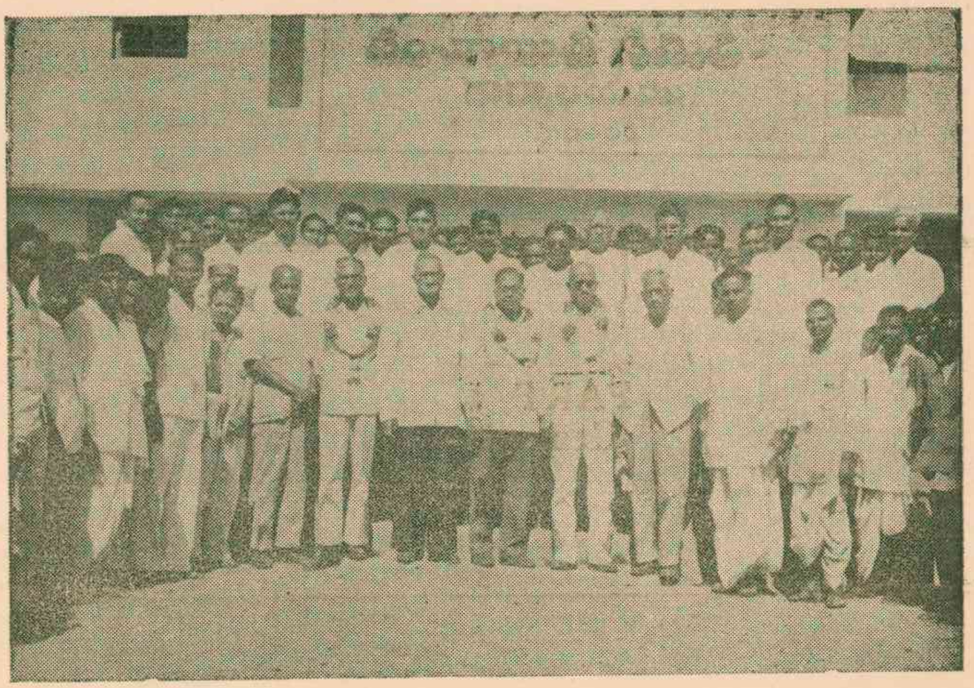


The Expert Committee for Floods in Coastal and Deltaic areas of Andhra Pradesh, 1964.
From L. to R. are,: (1) Sri P. T. Malla Reddy, Chief Engineer, Major Irrigation and General, P. W. D., Andhra Pradesh, (2) Sri P. N. Kumra, Member-Secretary, (3) Sri D V. Joglekar, Member, (4) Sri A. C. Mitra, Chairman, (5) Sri U. Ananda Rao, Member and (6) Sri G. A. Narasimha Rao, Member.

CHAPTER I.—INTRODUCTORY.

1.1 CONSTITUTION OF THE COMMITTEE

The rich coastal deltaic areas of Andhra Pradesh in the districts of Godavari, Krishna and Guntur, are subject to floods every year, principally from the rivers like Budameru, Thammileru and Yerrakalva. These floods are causing immense damage to crops and other private properties besides disrupting rail and road communications for considerable periods. Plans for ameliorating the situation have been under consideration for nearly half a century now. The recent floods have high-lighted the need for immediate action for solving this recurring problem. Therefore, the Government of India, in the Ministry of Irrigation and Power, *Vide* Resolution No. DW.V. 501 (4) / 64, dated 9th October, 1964 constituted an Expert Committee on Floods for suggesting a comprehensive plan for controlling the floods.

The Committee consists of the following officers :—

1. Shri A.C.Mitra, Engineer-in-Chief, Uttar Pradesh, Lucknow ... ... *Chairman*
2. Shri U.Ananda Rao, Consultant, Ministry of Irrigation & Power, Madras. .. *Member*
3. Dr. D.V. Joglekar, Honorary Consultant, Ministry of Irrigation & Power, Poona ... ... *Member*
4. Shri G.A. Narasimha Rao, Additional Secretary, P.W.D., Andhra Pradesh, Hyderabad. .. .. *Member*
5. Shri M.Klasema, Chief Engineer-Director, Netherlands ... ... *Member*
6. Shri R.D.Dhir, Chief Engineer, Central Water & Power Commission, New-Delhi ... ... *Member-Secretary*

Subsequently, there was a change in the incumbancy of the Chief Engineer, Flood Control, Central Water and Power Commission. Therefore, the Government of India, Ministry of Irrigation and Power, *vide* Resolution No. DW.V.501 (4)/64, dated 10th November 1964, nominated Shri P.N.Kumra, Chief Engineer, Flood Control, Central Water & Power Commission, as Member-Secretary of the Committee instead of Shri R.D.Dhir.

1.2. TERMS OF REFERENCE

The terms of reference for the Committee are as follows :

(*i*) To suggest a comprehensive Plar for control of floods in the coastal rivers like Budameru, Thammileru and Yerrakalva by construction of detention reservoirs or by diversion into adjoining valley or any other methods.

(*ii*) To consider and recommend proposals for lowering the flood level of Kolleru lake either by improving the outfall channel Upputeru or by pumping or by both.

(*iii*) To consider and recommend proposals for improving the drainage system in the area and ;

(*iv*) Any other recommendation that the Committee desires to make for prevention of floods and inundation.

1.3. VISITS OF THE COMMITTEE

The first visit of the Committee to Flood-affected areas in Andhra Pradesh was from 31st October to 2nd November 1964. During this visit, the Committee inspected the Budameru Diversion Channel, head regulator of the diversion channel, some reaches of Yenamadurru drain and the Thammileru river.

The second visit of the Committee was from 20th to 27th December, 1964. During this visit the Committee inspected some of the important deltaic drains of Guntur district like Tungabhadra drain, Repalle main drain, Nallamada, Kollimerla, Romperu and Perali drains. The Committee also inspected sites of dams proposed by the Andhra State on the rivers Budameru, the Yerrakalva and the Thammileru. The Upputeru and the sites of the proposed straight cuts as well as some important drains in Krishna Eastern delta regions and some of the minor rivers like Gunderu were also visited.

The third inspection of the Committee was from 15th to 18th February, 1965. During this period, the Committee inspected a portion of Biccavolu drain, Kakinada salt creek, Tulyabhaga drain, Coringa river and Teki drain in Godavari Eastern delta, Kunavaram, Kowsika, Rameswaram moga and Shankaraguptam drains. of Godavari Central Delta.

Mr. M. Klasema came to India on 31-3-1965 and so could not join the Committee in the above three inspections. Mr. Klasema, however, visited the area from 2-4-1965 to 8-4-1965 when he inspected Kolleru Lake, Upputeru, Yenamadurru drain and certain important drains like Tungabhadra, Repalle, Romperu and Shankaraguptam and certain straight cuts into the sea.

The Committee members except Shri U. Ananda Rao visited Poona, Central Water and Power Research Station from 9th April to 11th April, 1965 and studied the working of the model of the Kolleru Lake, the Upputeru and the proposed straight cuts.

CHAPTER II.—ANDHRA PRADESH WITH SPECIAL REFERENCE TO KRISHNA AND GODAVARI DELTAS.

2. 1. ANDHRA PRADESH

2. 1. 1. Location:

The State of Andhra Pradesh is situated on the Eastern side of the Indian Peninsula between Longitudes 76° 50′ E to 84° 50′ E and latitudes 12° 14′ N to 19° 54′N. The State has an area of 2,74,540 sq. K.M. (1,06,000 sq. miles) and a population of about 36 millions as per 1961 census. It is the fifth largest in area and the fourth most populous State in the Indian Union (*See* Plate 1.)

2. 1. 2. Topography.

Geographically, the State can be divided into three natural regions (*i*) the coastal plains (*ii*) the Eastern ghats, and (*iii*) the Peneplains.

2.1.2.1. The coastal Plains.

The State has a long coast line, popularly known as the Coromandal coast, extending over a length of about 870 K.M. (540 miles) from Pulicat lake in the south on the borders of Madras State to Rushikulya in the north on the borders of Orissa State. The coastal area for a considerable distance inland chiefly comprises of mangrove swamps and sand dunes rising from 9 to 15 metres (30 to 50 ft.) above sea. Between the swampy and the upland areas, lie the two deltas formed by the rivers Krishna and Godavari which flow into the Bay of Bengal cutting across the range of hills known as the Eastern ghats. The Krishna delta starts from below Vijayawada 72 K.M. (45 miles) inland, where the river cuts a gap through a gnessic ridge. The Godavari delta commences from below Dhowlaiaswaram which is about 64 K.M. (40 miles) inland.

The land in the above delta regions is very fertile growing irrigated paddy crop over 2 million acres. The slope of the Country is, however, varying from 1 in 4200 at the head of delta to 1 in 7500 in the lower part of the delta, and this is mainly responsible for its poor drainage Characteristics.

2.1.2.2. The Eastern Ghats.

This is a range of scattered hills running more or less parallel to the coastal line at a distance of about 80 miles away from it in the interior. This forms the boundary between the peneplained Deccan Plateau and the coastal Plains. Some of the hills in this range reach elevations of 910 to 1520 metres (3,000 to 5,000 ft.) above Mean Sea Level. A number of Medium sized coastal rivers such as the Budameru, the Thammileru, the Yerrakalva, the Thandava, the Varaha, etc., take their origin from these hills and flow eastwards to join the Bay of Bengal either through the Kolleru Lake or direct. Major rivers like the Krishna, the Godavari and the Pennar make their way into the sea cutting wide gaps through this hill range.

2.1.2.3. The Peneplains.

The Peneplains lie to the west of the Eastern Ghats and consist of a part of the Deccan plateau with its level varying from +710 Mts. to 122 Mts. (+2000′ to +400′). Some parts are however more than 710 Mts. (2,000′) high above the sea level. The landscape presents reddish or brown plains with scattered thorny shrubs and rivers are practically dry for more than half the year. There are a number of tanks in the region which are formed by bunding the small valleys and considerable areas are being irrigated under the same.

2.1.3. Climate.

There are three seasons in Andhra Pradesh, *viz.*, the hot summer followed by tropical monsoon and a pleasant winter. The summer extends from March to June. The monsoon from July to November and the winter from December to February. May is the hottest month of the year.

The maximum temperature varies from 38° c to 49° c (100° F to 120° F) and the mean daily minimum temperature is about 18° C (64° F). The areas lying in the immediate vicinity of the sea are generally cooler during summer months and warmer during winter months.

2.1.4. RAINFALL.

The average rainfall of Andhra Pradesh is about 890 mm. (35 inches). Normally, the higher precipitations of 1524 mm. to 1778 mm. (60 to 70 inches) are recorded in the Eastern Ghats. There are two monsoons, *viz.*, the south-west and north-east. The south-west monsoon starts in the middle of June and continues up to September, and the north-east monsoon begins at the end of September and continues till December.

2.1.5. STORMS AND DEPRESSIONS.

The storms and depressions which develop in the Bay of Bengal during monsoon season, move acrose the coastal areas of Andhra Pradesh, causing heavy to very heavy rains. These storms are the main cause of floods in these areas and the area is most affected during the months of May to November and is practically free from disturbances during the period December to April. In the north coastal Andhra Pradesh, most of the cyclonic storms occur in the month of October, whereas in the south coastal area these occur mainly in the month of November. On an average, about two disturbances in a year which cause floods in the State, are expected. Most of these occur in the months of September and October. Usually more rainfall is due to depressions in the Bay of Bengal than due to cyclonic storms. North Coastal area is more affected by storms and depressions than the south.

The 1964 *Floods.*

As a result of depression formed in the Bay of Bengal which moved westwards across Andhra Pradesh, there were heavy rains between the 27th of September and 1st of October 1964 in the districts of Guntur, Krishna, East and West Godavari, causing unprecedented floods. The heaviest rainfall occurred on 28th and 29th September.

A note on storms and depressions responsible for heavy rains in Andhra Pradesh as supplied by Shri N.C. Rai Sircar, Director, India Meteorological Deptt: Regional Meteorological Centre, Madras is given in Appendix G.

2.1.6. IMPORTANT RIVERS OF ANDHRA PRADESH.

Andhra Pradesh has as many as 35 rivers, big and small, flowing through it. The most important of them are the Godavari, the Krishna and the Pennar (*See* plate 2). These rivers take their origin in the neighbouring States of Maharashtra and Mysore and after traversing through Andhra Pradesh find their way into the Bay of Bengal.

There are smaller rivers like the Vamsadhara, the Thandava, the Nagavalli, the Varaha, etc., which rise in the Eastern ghats, and pass through a narrow coastal strip of Andhra Pradesh and fall into the Bay of Bengal.

A brief description of the big rivers is given below :—

2.1.6.1. GODAVARI RIVER.

The Godavari is the largest river in the region. It has its origin in the Western Ghats near Nasik only 80.5 K.ms. (50 miles) from the Arabian sea. The river enters Andhra Pradesh about eight miles East of Bilohi town. After flowing nearly 1360 K.ms. (845 miles) across the Deccan Plateau, it enters the delta at Polavaram and drops into the Bay of Bengal after traversing another about 105 K.ms. (65 miles) in Andhra Pradesh. The main tributaries of this river are the Purna, the Manjira, the Pranahita, the Indravati and the Sabari. The latter three together account for about 70 per cent of the total flow of the river. At its exist from the Eastern ghats the river flows through a 2 mile long narrow gorge with a width of 183 metres (200 yds.) to 275 metres (300 yds.) only. Further down at Dhowlaishwaram, the river is about four miles wide. Below this town, it divides into two branches, the Gautami and the Vasista. The river is navigable throughout the year for a distance of 386 K.ms.(240 miles) from its mouth. The river has a catchment area of 3,14,401 sq. K.ms. (1,21,500 sq. miles). The maximum recorded flood discharge at Dowlaishwaram is

88,100 cu. metres/Sec. (31.20 lakh cusecs) in 1953 which is more than that of the Ganga, though the latter has a catchment area more than thrice that of the Godavari. During summer, however, the discharge of the Godavari goes down very much.

2.1.6.2. KRISHNA RIVER.

The Krishna rises in the western ghats, about 1220 metres (4,000 ft) above sea level near Mahabaleshwar in Maharashtra State. Its catchment area lies in the States of Maharashtra, Mysore and Andhra Pradesh. The river enters Andhra Pradesh 4 miles below Kadlur Village. After traversing a length of nearly 1,400 K.ms. (870 miles) it drops into the Bay of Bengal, about 100 K ms. (62 miles) below Vijayawada. At Vijayawada, where an anicut has been built, it emerges from a narrow gorge to flow in a flat delta area. The more important of its tributaries are the Yerla, the Koyna, the Warna, and Id Ganga, the Ghataprabha, the Malaprabha, the Bhima the Tungabhadra and the Musi. For a major part of its course, the river flows in a steep and narrow channel. The catchment area of the Krishna is about 2,52,000 Sq. K.ms. (97,050 Sq. Miles). The rainfall in its head reach is more than 2,540 mm. (100 inches), in the central plateau it varies between 508 mm. to 762 mm. (20 to 30 inches) and in the delta area it increases again from 762 mm. to 1270 mm. (30 to 50 inches). The maximum flood discharge observed so far at Vijayawada anicut is about 33,800 cu. metres /sec. (11.9 lakh cusecs) in 1903.

2.1.6.3. PENNAR RIVER.

The Pennar also rises in the Western ghats. After traversing a length of 395 K.ms. (370 miles) through Mysore and Andhra Pradesh, it falls into the Bay of Bengal north-east of Nellore. The river enters Andhra Pradesh about one mile below Kurugode village. The major tributaries of this river are the Chitravati, the Papaghni, the Sagileru, and the Cheyyaru. The river has a catchment area of 50,000 sq. K.ms. (19,325 sq. miles) with a mean annual rainfall of about 645 mm. (27 inches). Its maximum observed discharge is 14,700 cu. metres/sec. (5,20,000 cusecs). Floods in this river which generally occur during the months of July and August, and again in October and November are flashy.

2.2. THE DELTAIC DISTRICTS OF THE KRISHNA AND THE GODAVARI.

The districts lying in the deltas of the Krishna and the Godavari are :—

1. East Godavari district.
2. West Godavari district.
3. Krishna district, and
4. Guntur district.

These are marked in Plate 2.

A brief description of each of these districts is given below :—

2.2.1. EAST GODAVARI DISTRICT.

2.2.1.1. *Description.*

The East Godavari district is situated along the East Coast between 16° 31′ and 18° 30′ of the Northern latitude and 81° 30′ and 82° 33′ of the Eastern longitude. It consists of 12 taluks ; (1) Rajahmundry, (2) Ramachandrapuram, (3) Peddapuram, (4) Kakinada,(5) Tuni, (6) Amalapuram (7) Razole (8) Pithapuram (9) Rampachodavaram (10) Yellavaram (11) Prathipadu and (12) Kothapeta. The two taluks of Rampachodavaram and Yellavaram lie in the Agency. The area of the district is 10,829 sq. Kms. (4,181 sq. miles) and its population is about 26 lakhs as per statistical abstract of Andhra Pradesh 1961. The highest peak is " Papikonda " or Bison hill which is 1,280 meters (4,200 ft.) high. The southern part of the district is flat and exceedingly fertile, being formed by the silt carried down by the Godavari. This area is under irrigation. Nearly half the district is covered by the Eastern ghats.

The headquarters of the district is Kakinada which is a sea port town of commercial importance. Rajahmundry, a large town is situated on the left bank of the Godavari.

2.2.1.2. *Climate.*

The district is generally healthy. The climate is comparatively equable except in April, May and June, when it is very hot.

2.2.1.3. *Rainfall.*

The average rainfall of the district is 1151 mm. (45.32 inches), 1044 mm. (42.74 inches) in the plains and 1240 mm. (48.87 inches) in the Agency area. Cyclonic storms some times occur during the latter part of the year, bringing heavy rain which goes to swell the average. The first 4 months of the year are practically rainless, but in May there is usually a fair fall. More than half of the annual rainfall is brought by the south-west monsoon, while most of the rest falls in October and November. The distribution, however, differs markedly, especially at the latter season in various parts of the district.

The rainfall statistics from 1870 to 1949 are given in table No. 1.1.

TABLE No. 1.1

Rainfall in mm. (inches)

Section	Dry weather (January to March)	Hot weather (April and May)	South-west monsoon (June to September)	North-east monsoon (October to December)	Annual
Agency area	40.8 (1.61)	99.0 (3.90)	897 (35.27)	206 (8.11)	1242.8 (48.89)
Western Part	27.2 (1.07)	71.4 (2.81)	668 (26.29)	288 (11.35)	1054.6 (41.52)
Northern Part	25.2 (0.99)	75.6 (2.98)	606 (23.91)	298 (11.77)	1014.8 (39.65)
Eastern delta area ..	25.4 (1.00)	58.5 (2.30)	657 (25.88)	385 (15.17)	1126 (44.35)
District average ..	32.8 (1.29)	82.4 (3.24)	766 (30.23)	268 (10.56)	1149.20 (45.32)

2.2.1.4. *Rivers*

The Godavari is the Chief river of the district. The renowned British Engineer, Sir Arthur Cotton had constructed on Godavari at Dowlaiswaram, an anicut a century ago. The Central and Eastern Deltas are irrigated by the Canals taking off from above the anicut. Below the anicut, the river splits up into two branches, the Gautami Godavari and the Vasista Godavari forming, in between them, the Central delta area. The Vynateyam Godavari is a subsidiary branch of Vasista Godavari which divides the Central delta into two parts. The Godavari delta is one of the main food producing areas in the State.

Yeleru is the second important river in the district.

2.2.2. WEST GODAVARI DISTRICT.

2.2.2.1. *Description*

The West Godavari district is situated between 80°45′ and 81° 40′ longitude and 16° 30′ and 17° 30′ latitude. The area of West Godavari district is 7,710 sq. K.ms. (2,980 sq. miles) and its population is about 20 lakhs (Census of India 1961).

The district comprises of Ellore, Chintalapudi, Tadepalligudem, Kovvur, Polavaram, Tanuku Narsapur and Bhimavaram taluks. Narsapur, Bhimavaram and Tanuku taluks are purely deltaic, Kovvur, Chintalapudi and Polavaram are mainly upland while Ellore and Tadepalligudem are partly upland and partly deltaic.

2.2.2.2. *Climate*

The climate on the whole is healthy. The hilly areas of Polavaram taluk are a little cooler than the plains in the months of December and January. Some portion of Polavaram taluk is agency tract where cases of maleria fever exist.

2.2.2.3. *Rainfall*

The average annual rainfall is about 1,012 mm. (39.85″). Rain begins generally in May. From February to April the rainfall is rather scanty. The southwest monsoon generally gets in by the second week of June and the rainfall during the month is fair. July to October is the heaviest monsoon period when all the staple wet and dry crops are raised. Timely rains in this period are conducive to the growth of crops and scarcity of rains affects the cultivation under tanks. November is a partly wet month while December is comparatively dry.

The table No. 1.2. shows the distribution of rainfall in the several parts of the district, from 1870 to 1949 :—

TABLE NO. 1.2.

Rainfall in mm. (inches)

Section	Dry weather (January to March)	Hot weather (April and May)	S.W. monsoon (June to September)	N.E. monsoon (October to December)	Annual total
Delta	19.6 (0.77)	56.9 (2.24)	660.0 (26.0)	311.00 (12.24)	1047.5 (41.25)
Upland	28.7 (1.13)	91.2 (3.59)	720.8 (28.38)	229.9 (9.05)	1070.6 (42.15)
District average ..	20.8 (0.82)	58.4 (2.30)	675.0 (26.60)	258.0 (10.13)	1012.2 (39.85)

2.2.2.4. *Rivers.*

The Godavari is the main river of this district. There are other small hill streams which drain off water from the upland taluks and are also used for irrigation. Narsapur, Bhimavaram and Tanuku taluks and portions of Ellore, Tadepalligudem and Kovvur taluks are irrigated by the canal system which takes off from above the Godavari anicut. A portion of Ellore taluk lies in the Krishna Eastern Delta and is irrigated by Ellore canal which starts from the Barrage over the Krishna river at Vijayawada. The rivers like the Byneru, the Yerrakalva, the Gunderu and the Thammileru are the more important sources. The Kolleru lake is an extensive shallow depression to the south of Ellore taluk and to the west of Tadepalligudem and Bhimavaram taluks. It extends in to the adjoining Krishna district also. The only outlet from Kolleru to the sea is the Upputeru which is on the boundary between Krishna and West Godavari district. Ellore is the headquarters of the district.

2.2.3. KRISHNA DISTRICT.

2.2.3.1. *Description.*

The Krishna district is situated between 15°43′ and 17°10′ of the northern latitude and 80°0′ and 81° 33′ of the eastern longitude. The area of the district is 8,740 sq. K.ms. (3,378 sq. miles) Its population is about 21 lakhs as per 1961 census. The district consists of:

(1) Delta comprising the taluks of Bandar, Divi, Gudivada, Kaikalur and portions of Vijayawada and Gannavaram taluks.

(2) Uplands comprising the upland taluks of Nandigama, Jaggayyapet, Tiruvur and Nuzvid and the upland portions of Vijayawada and Gannavaram taluks.

Masulipatnam or Bandar, the headquarter town of the district is a sea-port. Vijayawada, situated at the head of the delta is a very important town due to its position and its being a prominent railway centre. Another important place is Gudivada which is connected with Masulipatnam, Vijayawada, Nuzvid, Ellore, Tiruvur, Pamarru and Narsapur by a network of canals and roads.

2.2.3.2. *Climate.*

The climate of the district is generally healthy. Bandar maintains almost equable climate being on the sea coast. But, in Vijayawada and other upland areas surrounded by hills, there will be severe heat in summer. From April to June most of the district will be hot.

2.2.3.3. *Rainfall.*

The average rainfall is about 925 mm. (36.42″). July to November may be taken as the heaviest monsoon period. From January to April the rainfall is always nominal. Rains commence in May. The rainfall in June is appreciable. November is some times a wet month. The south-west monsoon is the more important one. So far there is no satisfactory irrigation system in the upland portions of the district which suffer frequently from drought. The table No. 1.3 shows the distribution of rainfall in the several parts of the district from 1870 to 1949.

TABLE No. 1.3.

Rainfall in mm. (*inches*)

Section of the district	Dry weather (January to March)	Hot weather (April and May)	S.W. monsoon (June to September	N.E. monsoon (October to December)	Annual Total
Krishna Delta ..	25.9 (1.04)	53.0 (2.08)	568.0 (22.39)	311.0 (12.25)	958.0 (37.76)
Upland	24.4 (0.96)	58.0 (2.28)	632.0 (24.85)	178.0 (7.01)	892.4 (35.10)
District average ..	25.4 (1.00)	55.4 (2.18)	600.0 (23.62)	244.5 (9.63)	925.3 (36.43)

2.2.3.4. *Rivers.*

The district is called after the river Krishna which flows for about 161 K.ms. (100 miles) forming boundary between the Krishna and Guntur districts. The river joins the sea to the south of Masulipatnam by two principal mouths. The enormous mass of silt it carries in flood has been estimated to be sufficient to cover daily an area of 13 Sq. K.ms.(5 sq. milles) to a depth of 0.305 m. (1 ft.) . The silt, has, in the course of ages, been deposited in the form of a wide alluvial delta extending far into the sea and sloping gradually away from the banks of river with an average fall of 1 in 293 (18 ft. per mile). At Vijayawada, 75.6 K.ms. (47miles) from its mouth, an anicut was constructed across the river in a gorge, 1190 metres (3900 ft.) in width and its waters are turned into a network of irrigation channels that spread throughout the delta. The Muniyeru, a tributary of the Krishna above the Vijayawada anicut has an anicut at polampalli and irrigates a large extent in the Nandigama taluk.

Besides the big river, there are a few hill streams which drain the upland taluks and are also used for irrigation. Of these the Thammileru running between Ellore taluk and Nuzvid taluk and the Budameru are the most important. The Kolleru lake is an extensive shallow depression extending into West Godavari District. In Krishna District it lies mostly in the Kaikalur taluk, of which it forms the Northern Boundary.

The delta is generally flat and in some places along the coast, there are uncultivable swamps where the land is above the sea level. The district contains some of the most fertile lands of the State suitable for rich rice crops. Lankas formed due to accumulation of sand and alluvium brought down by the river are chiefly cropped with Tobacco and Jowar. The sea-coast is fringed with a wide belt of sand, sometimes extending several miles inland.

2.2.4. GUNTUR DISTRICT.

2.2.4.1. *Description.*

The Guntur district lies between 15°-18', and 16°50' northern latitude and 79°10' and 80° 55' eastern longitude. Its area is 15,027 sq. K.ms. (5802 sq.miles) and its population is about 30 lakhs.

The district consists of 9 taluks,(1) Guntur,(2) Sattenapalli,(3) Tenali,(4) Repalle,(5) Bapatla(6) Ongole (7) Narsaraopet (8) Vinukonda and(9) Palnad. The district may be broadly divided into three regions i.e. (*i*) the Delta (*ii*) the stony uplands and hills (*iii*) the Black Cotton Plains. The taluks of Tenali, Repalle, Bapatla and a small area in Guntur taluk form the deltaic portion of the district. The remaining taluks and a major portion of Guntur taluk comprise of upland regions and open plains of black cotton soil. There are no forests worth the name in the district. In the sandy tract of Bapatla taluk there is a large tract of Soapnut-jungle. The sandy areas of Bapatla and Chirala taluks are famous for Cashewnuts. Casurina plantations are extensively carried on, in the Bapatla, Repalle and Ongole taluks along the coast. Guntur, Tenali, Repalle, Bapatla, Chirala are some of the important places in Guntur district.

About 69% of the population depend on Agriculture. Paddy is the chief foodcrop. Chillies, groundnut and tobacco are the chief commercial crops. Tabacoo, turmeric and chillies of the district find markets in foreign countries like England, America and Russia. The world famous variety of Ongole breeding bulls is from Ongole tract of this district.

2.2.4.2. *Climate.*

The climate is generally hot in summer except in deltaic taluks. The coastal areas are liable to be affected by cyclones. For the upland taluks of Vinukonda and Palnad, rainfall is the only source for irrigation. Tenali taluk which is deltaic and rich can be said to be the granary of the district. The climate on the whole is healthy.

2.2.4.3. *Rainfall.*

The average rainfall of the district during the period from 1870 to 1949 amounts to 828 m.m. (32.59 inches). From December to April the rainfall is nominal, slight showers fall at the end of May and the monsoon actually sets in June. July to November may be regarded as the heaviest monsoon period. The Table No. 1.4 gives the distribution of the rainfall in the several parts of the district from 1870 to 1949.

TABLE NO. 1.4.

Rainfall in mm. (inches).

Section of the district.	January to March.	April and May.	S.W. monsoon (June to September).	N.E. monsoon (October to December).	Annual total.
(1)	(2)	(3)	(4)	(5)	(6)
Delta.					
Tenali	86.9 (3.42)	55.6 (2.19)	596.0 (19.51)	120.0 (4.74)	758.0 (29.86)
Repalle	67.0 (2.64)	93.7 (3.69)	101.8 (27.63)	331.5 (13.05)	1,194.0 (47.01)
Bapatla	48.5 (1.91)	49.8 (1.96)	547.6 (21.56)	161.0 (6.34)	806.9 (31.77)
Average	67.5 (2.66)	66.3 (2.61)	582.0 (22.90)	204.0 (8.04)	919.8 (36.21)
Upland.					
Guntur	88.6 (3.49)	36.1 (1.42)	454.1 (17.84)	122.2 (4.81)	700.0 (27.56)
Sattenapalle	49.5 (1.95)	51.8 (2.04)	408.0 (16.06)	106.4 (4.19)	615.70 (24.24)
Narasaraopet	45.2 (1.78)	28.0 (1.10)	387.4 (15.25)	143.8 (5.66)	604.4 (23.80)
Vinukonda	27.4 (1.08)	34.8 (1.37)	395.0 (15.55)	99.8 (3.93)	557.0 (21.92)
Palnad	53.0 (2.09)	51.0 (2.01)	502.7 (19.79)	149.4 (5.88)	755.1 (29.77)
Average	49.8 (1.96)	45.5 (1.79)	427.7 (16.84)	103.8 (4.09)	626.8 (24.68)
Ongole	59.4 (2.34)	65.3 (2.57)	362.7 (14.28)	152.9 (6.02)	640.3 (25.21)
District average ..	23.9 (0.94)	56.1 (2.21)	473.5 (18.64)	274.3 (10.80)	827.8 (32.59)

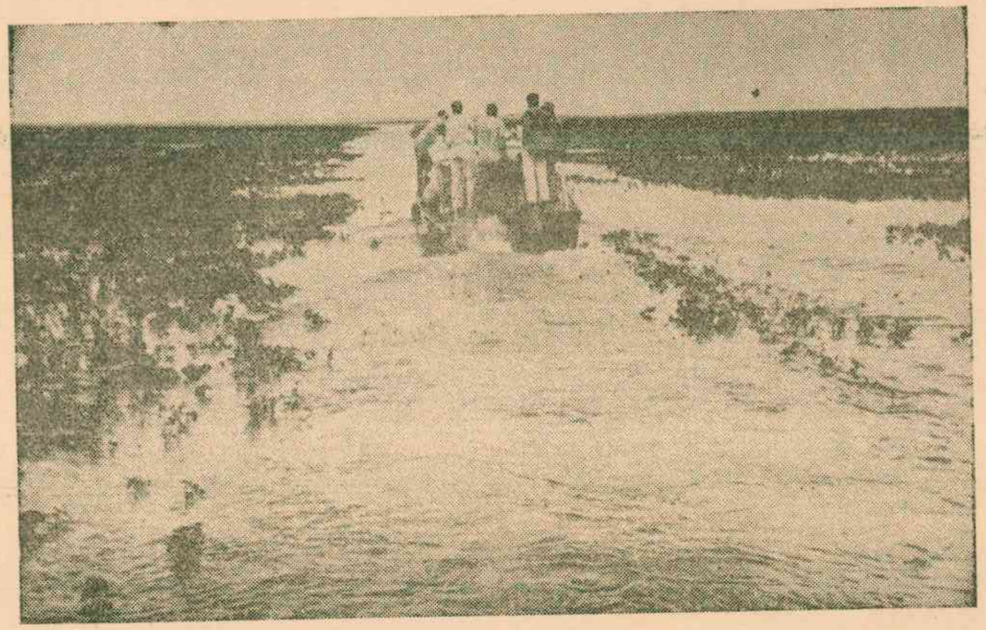
The south-west monsoon from June to October is the most important and its failure affects the food supply although the north-east monsoon, occuring from October onwards, if favourable would mitigate the scarcity to a considerable extent. The drought is always felt in the upland, portion of the district where there is hardly any irrigation facility at present especially in the taluks of Vinukonda, Palnad and Narsaraopet and in the western portion of the district especially in the Sattenapalli taluk where the soil is red and rocky and where the crops do not yield normal outturn unless there is good rainfall at short intervals.

2.2.4.4. *Rivers.*

The rivers Gundlakamma, Naguleru and Chandravanka are the important rivers of the district. The perennial river Krishna washes the northern portion of the eastern boundaries of the district. The Krishna river enters the district in the Palnad taluk and falls into the Bay of Bengal forming the boundary between Krishna and Guntur districts for about 161 k.ms. (100 miles). From the head sluice at Sitanagaram, the main canal for this delta begins and a network of channels is formed irrigating the taluks of Tenali, Repalle, Bapatla and Guntur. The Musi river flows through the southernmost part of the district in the Ongole taluk.

Krishna West Bank Canal and Commamur Canal which join the Buckingham Canal are being used for navigation.

PART II
Kolleru Lake Basin



The Kolleru Lake during Floods.

CHAPTER I—MAIN FEATURES AND FLOOD PROBLEMS.

1.1. KOLLERU LAKE.

The Kolleru lake is a natural depression of land between two major rivers, *viz.*, the Godavari on the east and the Krishna on the west. It is located partly in Krishna district (Gudivada and Kaikalur taluks) and partly in West Godavari district (Ellore, Tadepalligudem and Bhimavaram taluks, *See* Plate 9). The lake is nearly 32.2 kms. (20 miles) away from the sea (shortest distance) and it is connected to the sea by a narrow water-way called the Upputeru (*See* Plate 11). The total area of the lake at an elevation of 3.05 metres (+ 10′) above mean sea level is about 901 sq. kms. (348 sq. miles).

1.2. KOLLERU LAKE BASIN.

1.2.1. The lake receives drainage from a catchment of nearly 4,760 sq. kms. (1,839 sq. miles), out of which 3,400 sq. kms. (1,314 sq. miles) is upland and 1,360 sq. kms. (525 sq. miles) is deltaic, through a number of small rivers and drains emptying into it. The main rivers are the Budameru, the Ramileru, the Thammileru and the Gunderu (*See* Plate 3). The hydrological particulars of the main rivers as well as drains which enter Kolleru lake are given in Appendix—A.

1.2.2. The deepest bed level of Kolleru lake is —0.91 metres (—3.00 ft.). The lake level goes above 1.53 metres (+ 5.0 ft.) almost every year during monsoon season. The highest water level so far recorded is 3.26 metres (+ 10.7 ft.) in the flood season of 1964.

The Kolleru bed and the adjoining fields above elevation 0.91 metres (+ 3.00 ft.) and 1.53 metres (+ 5.00 ft.) are cultivated in both crop periods but the first crop below elevation 2.10 metres (+7.0 ft.) suffers damage due to flooding very frequently, *i.e.*, almost in alternate years. Between elevation 0.91 metres and 1.53 metres (+3.0 and +5.00 ft.) only the second crop is grown whilst below levation 0.91 metres (+3.00 ft.) no cultivation is done.

1.2.3. A notable feature of the lake is that it is not affected by tides. During flood season when water level in the lake is high the effect of the tide does not travel up the Upputeru beyond a short distance near the sea. During non-monsoon period the tide travels further up but even when the lake level is as low as 0.91 metre (+3.0 ft.), this tide does not reach beyond the railway bridge at 11 kms. (mile 6/3) from the lake. Thus the marginal lands of Kolleru lake are not affected by the sea water.

1.2.4. The water spread area and the capacity of the lake at various levels are given in the Table No. 2.1.

TABLE No. 2.1.

Water level of the lake in metres (ft.)	Water spread in sq. kms. (sq. miles).	Capacity between successive levels in M.C.M.S. (M.cft.)	Total capacity in M.C.M.S. (M. cft.) above 0.905 metres (+3.00 ft.)
(1)	(2)	(3)	(4)
0.91 (+3.00) ..	350 (135)		
1.22 (+4.00) ..	415 (160)	118 (4,156)	118 (4,156)
1.53 (+5.00) ..	492 (190)	137 (4,856)	255 (9,012)
1.83 (+6.00) ..	596 (230)	165 (5,840)	420 (14,852)

TABLE No. 2.1-(*Contd*).

Water level of the lake in metres (ft.)		Water spread in sq. kms. (sq. miles).	Capacity between successive levels in M.C.M.S. (M.cft.)	Total capacity in M.C.M.S. (M. cft.) above 0.905 metres (+3.00 ft.)
(1)		(2)	(3)	(4)
2.14 (+7.00)	..	674 (260)	194 (6,830)	614 (21,682)
2.44 (+8.00)	..	713 (285)	214 (7,590)	828 (29,272)
2.74 (+9.00)	..	816 (315)	237 (8,350)	1,065 (37,622)
3.05(+10.00)	..	902 (348)	267 (9,510)	1,332 (47,132)
3.28 (+10.70)	..	954 (367)	193 (6,818)	1,525 (53,950)

On an average an area of 77.6 sq. kms. (30 sq. miles) of land gets submerged for every 0.30 metre (one foot) rise in the water level.

1.2.5. The maximum water levels recorded in the Kolleru lake for the last 50 years from 1916-1965 are given in the Table No. 2.2.

TABLE No. 2.2.

Showing the maximum water levels in Kolleru Lake from 1916 *to* 1965.

Date and year.		Max. lake levels in ft. above M.S.L.	Date and year.		Max. lake levels in ft. above M.S.L.
(1)		(2)	(1)		(2)
2-11-1916	..	10.40	29-10-1928	..	6.44
2-10-1917	..	7.30	10-10-1929		4.80
1-1-1918	..	3.20	23-10-1930	..	7.10
31-11-1919	..	5.90	15-11-1931	..	7.80
16-10-1920	..	3.60	15-11-1932	..	8.70
25-9-1921	..	6.90	27-10-1933	..	7.70
29-11-1922	..	4.44	21-8-1934	..	5.10
25-11-1923	..	6.60	21-9-1935	..	6.40
7-10-1924	..	7.00			
18-10-1925	..	7.90	18-9-1936	..	5.50
21-1-1926	..	4.60	13-9-1937	..	3.20
16-11-1927	..	5.60	8-9-1938	..	7.30

TABLE No. 2.2-(*Contd*).

Date and year.		Max. lake levels in ft. above M.S.L.	Date and year.		Max. lake levels in ft. above M.S.L.
5-11-1939	..	9.60	12- 8-1951	..	6.90
27- 8-1940	..	7.60	23-10-1952	..	4.50
21-10-1941	..	7.60	28-10-1953	..	6.30
23-10-1942	..	6.00	7-10-1954	..	7.50
30-10-1943	..	7.30	7-11-1955	..	8.00
			8- 8-1956	..	8.10
3-11-1944	..	8.40	1- 9-1957	..	8.90
7- 9-1945	..	6.00	29-10-1958	..	8.30
23-11-1946	..	6.20	12- 9-1959	..	9.90
29-10-1947		7.10	6-10-1960	..	8.10
25-11-1948	..	6.70	14-10-1961	..	7.90
			21- 9-1962	..	9.50
5-11-1949	..	9.40	2-11-1963	..	9.00
7- 9-1950	..	7.00	11-10-1964	..	10.70
			28 9-1965		6.00

1.2.6. FLOOD PROBLEM IN KOLLERU BASIN.

The State Engineers have calculated on the basis of Ryve's formula assuming that the rainfall is equally distr.buted over the entire catchment area and that the maximum peak discharge contributed by the rivers and drains flowing into the Kolleru lake during monsoon season can be of the order of 3,130 cu. metres per sec. (1,10,920 cs.) (*See* Appendix A). The lake has only one outlet, the Upputeru river, which flows into the sea. The discharging capacity of Upputeru at 3.05 metres (+ 10.00 ft.) of the lake level is only 319 cu. metres per sec. (11,250 cs.) at road bridge [*See* Appendix E (ii) & E (iii)]. This capacity of the Upputeru river is quite inadequate to discharge the flood waters flowing into the Kolleru lake,with the result that the water level in the lake rises sever l feet and remains high for long periods causing serious damage to crops and property in a large area adjoining the lake.

The Yenamadurru drain joins the Upputeru below Lakshmipuram lock. During floods, the Yenamadurru drain carries a maximum discharge up to 566 cu. metres/sec. (20,000 cusecs). Very often it so happens that Yenamadurru drain is in peak flood when Kolleru lake level is at its maximum. In such cases the flow in the Upputeru river from the Kolleru lake is hampered and the extent and period of submersion of cultivable lands bordering Kolleru lake along the inflowing rivers and the Upputeru river is increased. The high level in Kolleru lake backs up and reduces the discharging capacity of the deltaic drains flowing into Kolleru lake or into the Upputeru and this results in submersion of crops along these drains as well.

The rivers and drains flowing into the Kolleru lake (*See* Plate 3) and their floods and flood problems are being described hereafter.

1.3. BUDAMERU RIVER.

1.3.1. The Budameru river rises at 564 metres (El.1850′) above mean sea level in the range of hills round about Zammalavolu Durgam at 80°—36′E longituds and 16°—57′ N latitude in Tiruvur taluk of Krishna district and about 51.5 kms. (32 miles) north of Vijayawada town. The river flows southwards for about 47 kms. (29 miles) before it turns east and runs parallel to Krishna river for about 10 kms. (6 miles). In its eastern course it crosses the Ellore canal through Enikapadu under tunnel. It then flows north-east for about 55. kms. (34 miles) in the sha low valley between Ellore and Ryve's canals before it joins Kolleru lake. Many major and minor tributaries join the river during its course. Total length of the river is about 113 kms. (70 miles).

1.3.2. The total catchment area of the river is 1889 sq. kms. (729 sq. miles) out of which 1335 sq. kms. (516 sq. miles) is upland and 550 sq. kms. (213 sq. miles) is deltaic. The catchment area of the river in the upper reaches upto the Ellore canal crossing comprises mountainous and dry lands, and lands irrigated under tanks ; the bed fall of the river is 1.13 metres per km. (6 ft. per mile) in the upper reaches and 0.228 metres per km. (1.2 ft./mile) in the lower reaches.

The river is practically dry during most part of the year except during monsoon season. The maximum discharge observed in the river during 1964 at the diversion site was of the order of 1135 cu. metres/sec. (40,000 cusecs) [*See* Appendix C-1 (*vi*).]

1.3.3. The maximum peak flow of the river calculated by Ryve's formula taking the value of the coefficient as 600 for upland and 92 for deltaic catchment is 1200 cu. metres/sec. (42,281 cusecs).

Whenever there is a high incidence of rainfall floods occur in the river. Because of inadequate carrying capacity of the river, even a small flood spills over its banks and inundates large areas of marginal lands, causing considerable damage to crops. The floods also affect part of the city of Vijayawada by submerging low lying areas. This being the biggest river of the Kolleru lake it contributes maximum towards the rise of its levels and consequent submergence of areas.

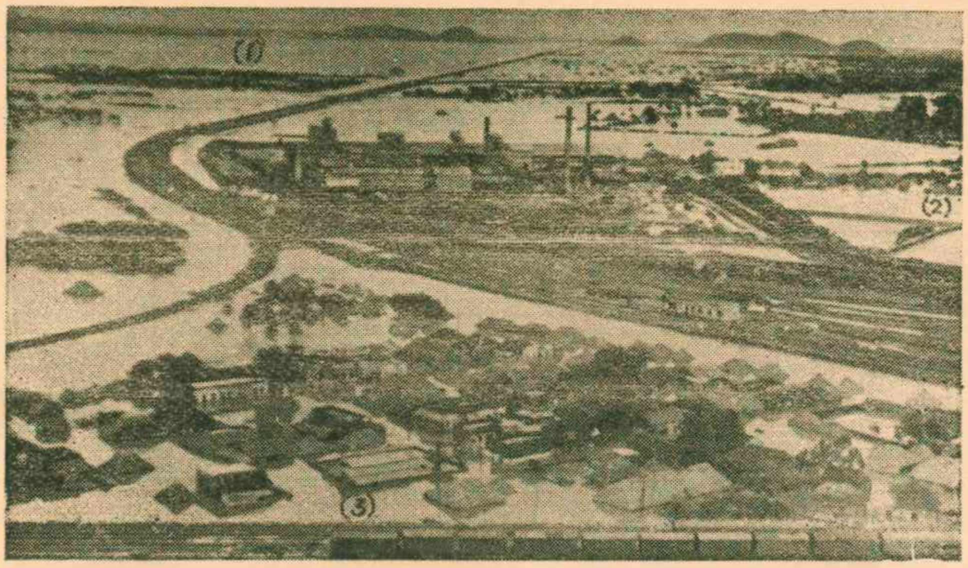
1.4. THAMMILERU RIVER.

1.4.1. Thammileru is the second biggest river which falls into the Kolleru. It rises at EL 305 metres (1,000 ft.) near Pothuvarigudem, a village in Telangana about 89 kms. (55 miles) north of Ellore at latitude 14°—59 N. longitude 80°—55 E. After flowing for about 38.6 kms. (24 miles), it enters the plains near Chinnampeta village and runs in a southern direction after taking an " S " bend. It branches off into two arms known as East Thammileru and West Thammileru just above the Ellore town. These two branches cross Ellore canal and fall into Kolleru lake after flowing for about 9.66 kms. (6 miles) and 11.27 kms. (7 miles) respectively in the delta-lands below Ellore Canal. The total length of the river is 109 kms. (68 miles). During its course it traverses through the districts of Khammam, Krishna and the West Godavari. The bed of the river in its upper reaches is rocky whereas in the lower reaches it is sandy and clayey. The upland catchment area of the river upto Ellore canal is 1199.17 sq. kms. (463 sq. miles). The deltaic catchment for the East and West Thammileru is 155.4 sq. kms. (60 sq. miles). The total catchment is 1354.57 sq. kms. (523 sq. miles).

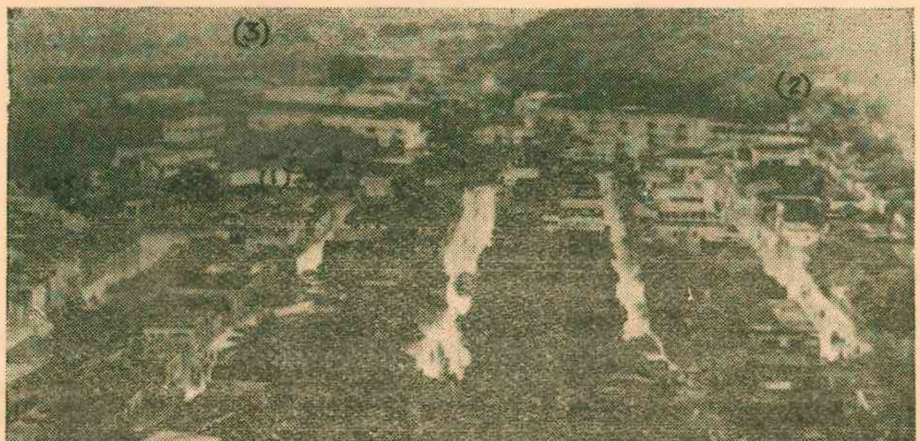
1.4.2. The maximum discharge so far recorded at Nagireddigudem near Errampalli is 492 cu. metres per sec. (17,400 cusecs) [(*See* Appendix C-2. *ii*)]. Near Errampalli there is a dam site proposed about 21 miles downstream from the origin of the river. The maximum discharge ever recorded in East and West Thammileru are 351 cu. metres/sec. (12,395 cusecs) and 307 cu. metres per sec. (10,840 cusecs), respectively. [*See* Appendix C 2 (*iv*).]

1.4.3. Floods in the Thammileru river occur fairly frequently. During high floods, due to insufficient carrying capacity of the river, it spills over and inundates marginal lands causing heavy damage to crops and property. In addition, it contributes substantially to the submergence of cultivated land around Kolleru lake.

When the river is in spate it endangers the safety of Ellore town.

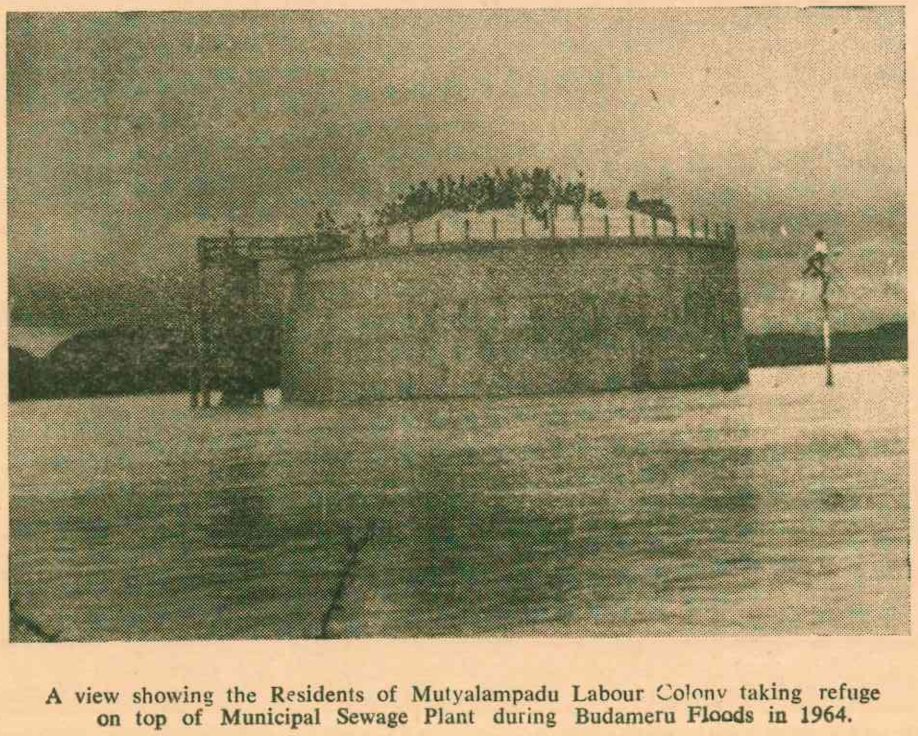


Aerial view showing, (1) Mutyalampadu Labour Colony (Ajitnagar Colony), (2) Kedareswaripeta adjancent to Andhra Cement Factory and (3) Rajarajeswaripeta in Vijayawada Town affected by Budameru Floods during 1964.

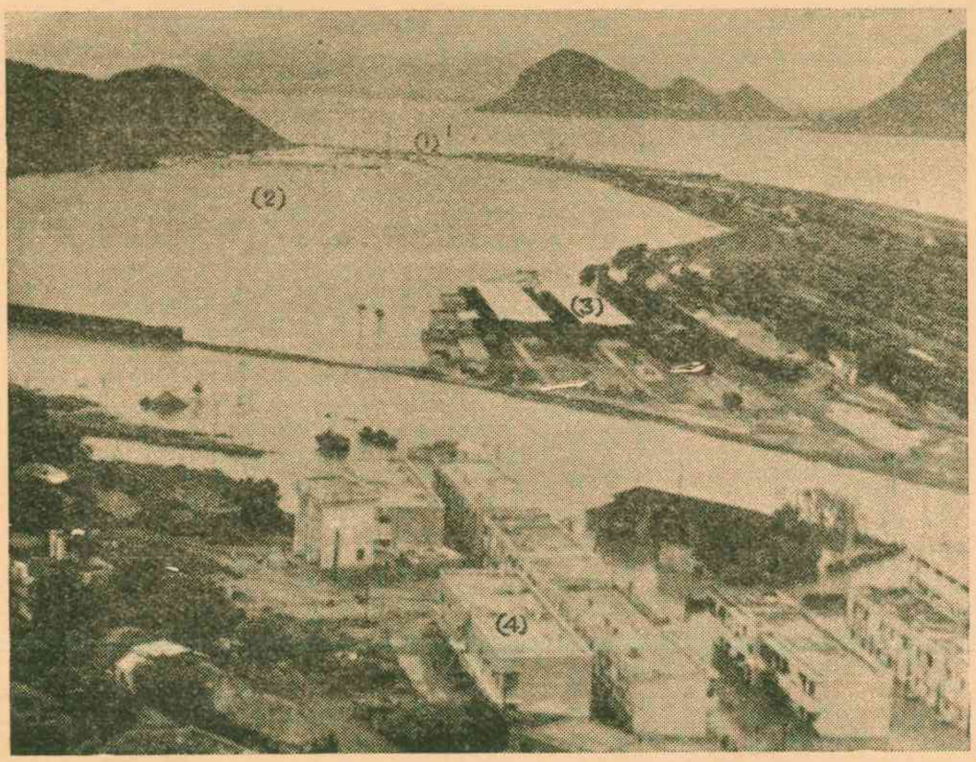


This is not Venice! This is an Aerial view of Vijayawada Town showing (1) Wynchipeta, (2) Gandhi Hill and (3) Railway Station during 1964 with the Flood Waters of Budameru flowing through the Streets.

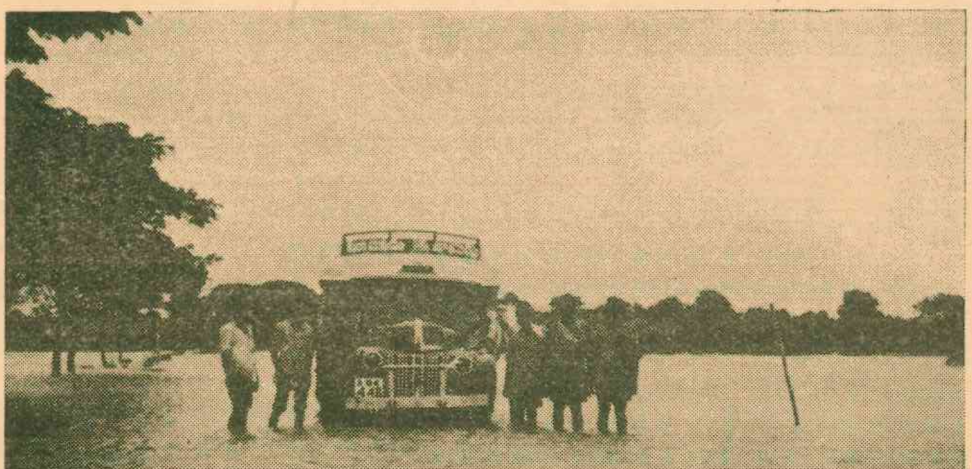
A view of Islampeta in Vijayawada Town inundated by Budameru Floods in 1964.



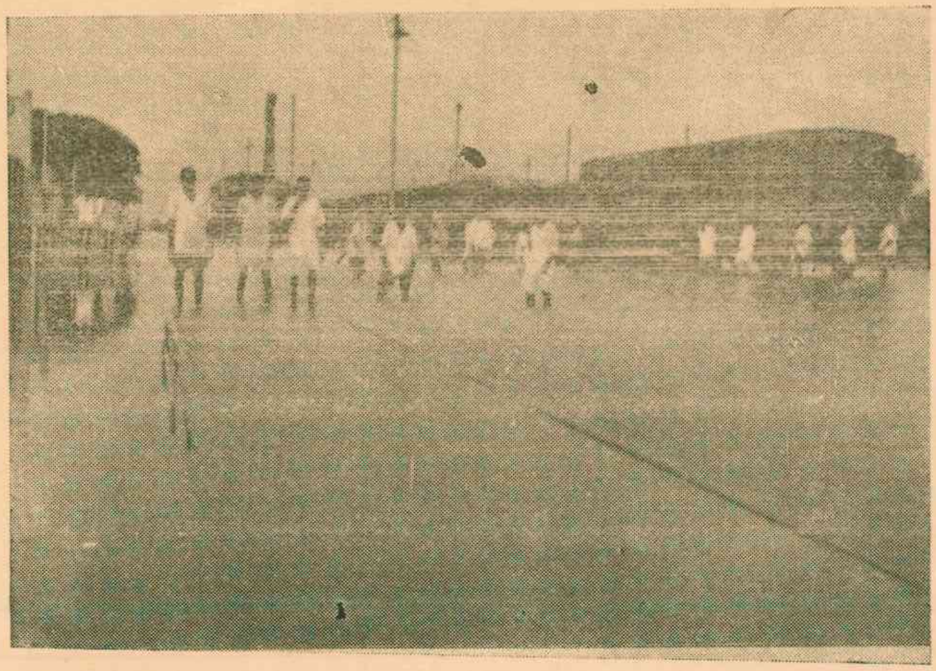
A view showing the Residents of Mutyalampadu Labour Colony taking refuge on top of Municipal Sewage Plant during Budameru Floods in 1964.



Aerial view showing, (1) Nainavaram Road, (2) Milk Project Buildings, (3) Railway Extension Yard and (4) Railway Quarters in Vijayawada Town inundated by the Flood Waters of Budameru Floods of 1964.



Eluru-Gudivada Road under Budameru Waters near Puttagunta.



View showing Flood Waters of Thammileru entering the Eluru Railway Station Yard.

A view showing Flood Waters of Thammileru Floods flowing through the streets in Eluru Town disrupting the Road Traffic.

View showing a Street in Eluru Town Flooded by Thammileru during 1964.

Another view showing Thammileru Flood Waters inundating Eluru Town.

1.5. RAMILERU RIVER.

1.5.1. The river Ramileru rises at an altitude of about 426.7 metres (1,400 ft.) above mean sea level near Dalagattu in Krishna district. After flowing for a length of about 56 kms. (35 miles) in upland and deltaic regions, the river finally falls into the Kolleru lake. The total catchment area of the river is about 308 sq. kms. (119 sq. miles). Out of this the upland catchment area is 266.8 sq. kms. (103 sq. miles) and delta catchment area is about 41 sq. kms. (16 sq. miles).

1.5.2. There is no observed discharge for this river. The maximum discharge as calculated by Ryve's formula with C at 500 for upland catchment is 342.3 cubic metres/sec. (12,089 cusecs) and for the deltaic catchment with value of C at 92 is 16.5 cubic metres (584 cusecs), the total being 358.8 cubic metres per sec. (12,673 cusecs).

1.5.3. The river has a steep bed slope in the upland area and very flat in the deltaic regions. The river, when it rises in floods, causes some flooding in cultivated lands and also adds to the rise of Kolleru lake.

1.6. GUNDERU RIVER.

1.6.1. The river Gunderu rises near the village Bandacharla in Chintala Pudi taluk of West Godavari district at an elevation of about 152.5 metres (500 ft.) above M.S.L. It passes through Chintalapudi taluk and Ellore taluk of West Godavari district before it falls into Kolleru lake, on its northern side. Immediately after crossing the Southern Railway line, Gunderu branches off into two drains, viz. Kovvali drain and Pothunuru channel. These drains after crossing Ellore canal individually fall into the Kolleru lake. The river drains an area of 539 sq. kms. (208 sq. miles) in the upland region and 93 sq. kms. (36 sq. miles) in the deltaic region. The calculated maximum peak flow in the river by the Ryve's formula for the upland catchment is of the order of 446 cubic metres per sec. (15,800 cusecs) and for the deltaic catchment 28 cubic metres per sec. (1,004 cusecs), the total being 474 cubic metres per sec. (16,804 cusecs).

1.6.2. During the monsoon, there are sudden flashy floods in the river causing inundation to marginal lands. In addition, it adds to the floods of Kolleru lake in raising its level.

1.7. DRAINS.

In addition to the above rivers there are a number of drains (*See* Plates 5 and 6) which join Kolleru lake, submerging the marginal paddy fields. A brief description of the most important ones is given below —

1.7.1. Krishna District.

1.7.1.1. *Kaikalur Swamp Drain I.*

The drain takes its origin near Korlapad Channel and flows for about 11.27 kms.(7 miles) from south-west to north-east before joining Kolleru lake. The total catchment area of the drain is 13 sq. kms. (5 sq. miles). It has a calculated peak flow of about 7.60 cubic metres per sec. (269 cusecs).

1.7.1.2. *Kaikalur Swamp Drain II.*

The drain has a catchment area of 25.9 Sq. kms. (10 Sq. miles) with a peak discharge of 12.1 cubic metres per sec. (427 cusecs).

1.7.1.3. *Motur Channel Drain.*

The Motur Channel drain takes its origin near the crossing of the Polaraj Canal and the Gudivada Cowtaram Road and flows in a north-easterly direction before entering Kolleru Lake. It has a drainage area of about 47 sq. kms. (18 sq. miles) upto its infall into Kolleru lake with a maximum peak discharge of 17.9 cubic metres per sec. (632 cusecs). Just before the drain crosses the Gudivada Motur road, it is joined by a small drain called Kuduru—Iellapudi drain.

1.7.1.4. *Chandrayya drain.*

Chandrayya drain is one of the major drains which joins Kolleru lake. It takes its origin on the left bank of Ryve's Canal near Viravalli village. The total length of the drain is about 32.2 kms. (20 miles). It has a drainage area of 114 sq. kms. (44 sq. miles). with a peak discharge of 31.9 cubic metres per sec. (1146 cusecs).

1.7.2. WEST GODAVARI DISTRICT.

1.7.2.1. *Pedapadu drain.*

This drain rises near the left bank of Ellore Canal in West Godavari district. After flowing for about 7 miles it falls into Kolleru lake. It has a catchment area of about 21 sq. kms. (8 sq. miles) with a calculated peak flow of about 32 cu. metres/sec. (1146 cusecs).

1.7.2.2. *Vatlur Drain.*

The Vatlur drain is about 10.46 kms. (6½ miles) long and has a catchment area of 25.9 sq. kms. (10 sq. miles). Its calculated maximum peak flow is about 12.1 cubic metres per sec. (427 cusecs). It joins Kolleru lake from north-east after crossing Ellore Canal.

1.7.2.3. *Mondikondu drain.*

This drain rises in the delta regions of Godavari district and drains finally into Kolleru lake. It has a total catchment area of 51.8 sq. kms. (20 sq. miles) with a calculated peak flow of 24.2 cubic metres per sec. (854 cusecs).

1.7.2.4. *Pandicodu Drain.*

This drain rises on the left bank of junction Canal in the West Godavari district. The total length of the drain is about 33.6 kms. (13 miles). It drains a catchment area of 93.5 sq. kms. (36 sq. miles) with a maximum peak flow of 35.8 cubic metres/sec. (1,264 cusecs).

1.7.2.5. *Siddapuram drain.*

This drain has a catchment area of 25.9 sq. kms. (10 sq. miles) with a maximum peak flow of 12.1 cubic metres per sec. (427 cusecs) in the West Godavari district.

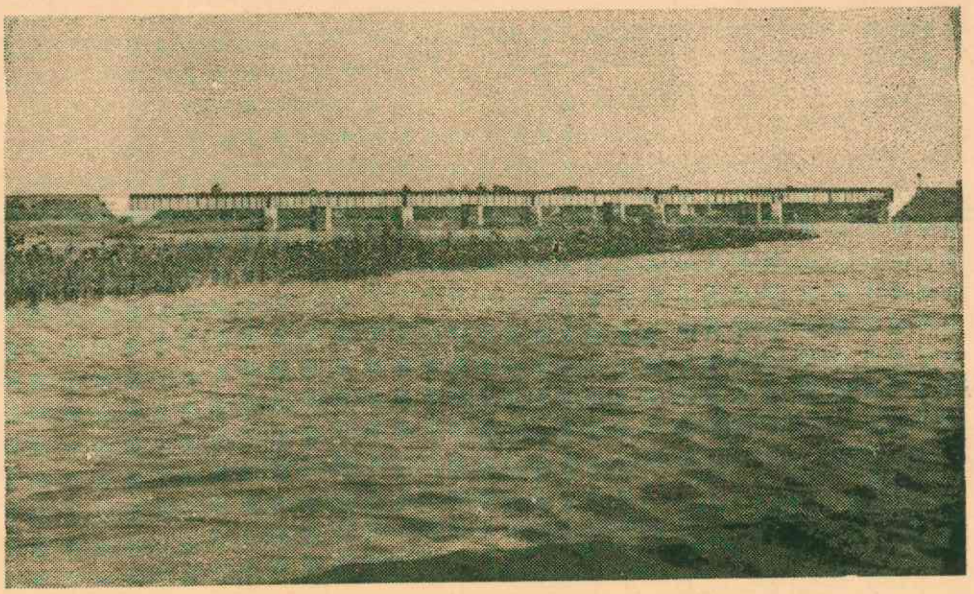
1.7.2.6. *G.W. Drain.*

This is one of the major drains joining Kolleru lake in the West Godavari district. The catchment area of this drain is about 93.5 sq. kms. (36 sq. miles) and its calculated peak flow is 35.8 cubic metres per sec. (1,264 cusecs).

1.8. UPPUTERU RIVER.

1.8.1. Upputeru river is the only outlet to Kolleru lake. This takes off in two arms called Perantala Kanuma and Juvvikanuma. These arms join after flowing for about 6.4 kms. (4 miles) whereafter this is known as Upputeru river. The Upputeru forms boundary between Krishna and West Godavari districts. The Upputeru flows for a distance of 63 kms. (39 miles) through the plain low lying land upto its outfall into the sea, near Chinnagollapalem (See Plate 11). The discharging capacity of Upputeru for various levels of the lake is given in Table No. 2. 3. The correlation curve between the levels of the lake and Upputeru at M 6/6 is given in Appendix-E (ii).

[*Statement*]



View of Upputeru near the Railway Bridge at M. 6/3.

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TABLE NO. 2.3.

Water level in Kolleru lake at Kolletikota in metres (in ft.)	Corresponding water level in Upputeru d/s of the road bridge in metres (in ft.).	Discharge in Upputeru in cu. metres/sec. (in cusecs).
0.914 (+3.00)	0.705 (2.31)	96 (3,400)
1.22 (+4.00)	0.985 (3.23)	116 (4,100)
1.52 (+5.00)	1.265 (4.15)	136 (4,800)
1.83 (+6.00)	1.55 (5.07)	160 (5,650)
2.14 (+7.00)	1.83 (5.99)	188 (6,650)
2.44 (+8.00)	2.11 (6.91)	227 (8,000)
2.74 (+9.00)	2.39 (7.83)	271 (9,550)
3.05 (+10.00)	2.77 (8.75)	318 (11,250)

1.8.2. The Upputeru river has a surface fall of about 0.0735 metre/km. (0.4′/mile) for a length of 9.65 kms. (6 miles) below the railway bridge and a much flatter slope of 0.16′ per mile in lower reaches. (See plate 16)

1.8.3. When the Kolleru lake rises, the level in Upputeru also rises submerging a large area of land on the margin along its banks. In years of heavy rainfall the lake remains high for long periods. This results in submersion of land for long periods and consequently in the loss of the first crop.

1.9. *Drains entering Upputeru.*

There are a number of drains originating from Krishna Eastern Delta and Godavari Western Delta which fall into Upputeru directly (See Plate 11). The following are the main drains.

1.9.1. KRISHNA EASTERN DELTA.

1.9.1.1. *Pullava drain.*

The pullava drain starts from the point where Appapuram channel joins Kaikalur channel. It flows North-east for about 4.83 kms. (3 miles) and then turns east. It is joined by two tributary drains Eduruva drain and Annava drain. It empties into Upputeru about one mile upstream of Tadinada lock. Its total length is about 13 kms. (8 miles) and the total catchment it intercepts is 30.90 sq. kms. (11.90 sq. miles). The estimated maximum discharge is 17 cubic metres/second (598 cusecs).

1.9.1.2. *Dammidi drain.*

This drain is about 10.65 kms. (6 miles and 5 furlongs) in length and runs parallel to and close to Polaraj canal. It collects its drainage from a catchment area of 8.61 sq. kms. (3.33 sq. miles) and contributes a peak discharge of 6.7 cubic metres per sec. (233 cusecs) during flood periods.

1.9.1.3. *Pedacommileru drain.*

This is a major tributary of Upputeru. It has its origin at the road culvert along the highway connecting Gudivada and Anpumilli, near Kakaravada channel. It runs nearly North-east for 25.7 kms. (16 miles and 4 furlongs) and falls into Upputeru, about 1.2 kms. (6 furlongs) downstream of Tadinada lock. Along its course it receives the discharge from some minor drains. Its catchment area is 90 sq. kms. (34.87 sq. miles) in extent. During high floods it carries a maximum discharge of 21.9 cu. metres/sec. (791 cus.).

1.9.2. GODAVARI WESTERN DELTA.

1.9.2.1. *Chinakapavaram Drain.*

This takes its origin from the V.W. Canal, West of Chinakapavaram village. It flows south-west for about 4.83 kms. (3 miles) and turns due West, parallel to Gudivada-Bhimavaram railway line. It joins Upputeru about 0.6 kms. (3 furlongs) upstream of the road bridge. Its total length is about 10.46 kms. (6 miles and 4 furlongs) and it has a catchment area near its confluence with Upputeru of 29.7 sq. kms. (11.46 sq. miles). The peak discharge of this drain is 11.3 cubic metres/second (400 cusecs).

1.9.2.2. *Mallava Kodu drain.*

This starts from Ajjamur Canal West of Ajjamur, descends down south for 11 kms. (6 miles and 6½ furlongs) and enters Upputeru near Elurupadu lock. Its catchment area at its tail is only 9.1 sq. kms. (3.82 sq. miles) and correspondingly it takes down only 3.74 cubic metres/second (132 cusecs) to Upputeru.

1.9.2.3. *Addala Nagadindi Drain.*

This starts from Jakkaram channel one mile downstream of the rail culvert, flows South-west half the distance bends west, and joins Upputeru one mile north of Kalvapudi village. At its lower reaches it is known as Addala creek.

1.10. YARRAKALVA RIVER.

1.10.1. The Yarrakalva river originates at an elevation of 1200 ft. above mean sea level from the Eastern ghats at a latitude of 17°-14′ north and longitude 80°-51′ East. It flows through the centre of West Godavari District in its first 20 miles. During its course, it receives several tributaries namely the Jalleru, Byneru and Pulivagu. The river crosses the great northern trunk road near Anantapalli. It also crosses the southern railway line at 41.5 kms. (25 miles 6½ furlongs). After flowing for 134 kms. (83 miles). it crosses the Godavari Ellore canal under an aqueduct near the place called Nandamuru. On the downstream of the aqueduct, this river is called Yenamadurru drain. This drain after flowing for a length of about 60.0 kms. (37 miles) falls into Upputeru at kms. 47 (29 miles) of Upputeru (See Plate 3).

1.10.2. The catchment area of the Yerrakalva at Nandamuri aqueduct is 2,330 sq. kms. (900 sq. miles) and 2590 sq. kms. (1000 sq. miles) at the in fall of Yenamadurru drain into the Upputeru. The catchment area in the upper reaches is mostly mountainous and full of forests. In the lower reaches, the catchment area is being cultivated and irrigated under the Bandakattu canal system. During very high floods some flow of the Yerrakalva goes into the Kolleru lake also. The river is generally in floods from June to October. It frequently inundates areas lying up-stream of the Nandamuri aqueduct. In addition, damage is caused to railway and roads during years of heavy floods.

CHAPTER II—DAMAGE BY FLOODS.

(Krishna Eastern Delta and Godavari Western Delta including Kolleru basin).

2.1. During monsoon season whenever there is heavy rainfall in the upland catchment the water level in the Budameru, Thammileru, Ramileru Gunderu etc., rise high due to their inadequate carrying capacity and inundate large tracts of low lying areas, causing heavy damage to standing crops. Sometimes, the flood banks breach and cause damage to national highways, railways and bridges.

2.2. Sometimes the catchment areas of these rivers receive rainfall simultaneously and so these are in floods almost at the same time. On such occassions they cause a rise of the level of the kolleru lake. This rise of the lake level results in submergence of the marginal lands. Further, it increases inundation of the area along the deltaic drains due to backing up of water, and this results in damaging the cultivated lands and crops, along these drains as well.

2.3. The Kolleru lake has only one outlet, the Upputeru river which carries the flow of Kolleru lake to the sea. The discharge capacity of the Upputeru river at lake level of +3.05 m. (+10.00 Ft) is only 318 cu. met/sec. (11,250 cusecs). The Yenamadurru drain which joins the Upputeru about 8 miles upstream of its outfall into the sea carries a maximum flood discharge of 576 cubic metres per sec. (20,000 cusecs). The flow from this drain backs up into the Upputeru river and obstructs its flow as the capacity of the Upputeru down stream of the junction is inadequate for discharge of both. This results in heading up of water Level in Upputeru river and consequently rises the water level of Kolleru lake. This inundation damages the crops on large areas of fertile Paddy fields.

2.4. Flood damage particulars for the Krishna Eastern Delta, Godavari Western Delta and Kolleru basin were supplied by the State P.W.D. for 10 years from 1955 to 1964. From this, it has been seen that on an average an area of about 90,000 acres was affected every year. About 67,000 metric tonnes of food grains valued at Rs. 2.56 crores were lost every year due to floods

During these ten years (1955 to 1964), 1956 was the worst year in Krishna Eastern Delta, when as much as about 1,59,000 acres were submerged. Next worst year was 1964, when 1,20,000 acres of land were affected by floods. In the Godavari Western delta, 1959 was the worst year, when about 90,000 acres were submerged. Next was the 1964, when about 78,000 acres were inundated.

The worst year for this area taken as a whole was 1964 when about 2 lakh acres were damaged. The food grains lost during this year amounted to about 1.50 lakh metric tonnes valued at Rs. 5.6 crores. A statement of damage particulars for Krishna Eastern Delta and Godavari Western Delta including Kolleru lake basin is given in Appendix. F (i).

On account of low rainfall during 1965, the Kolleru lake rose only upto a level of +6.0 ft. during the flood season, with the result that there was practically no drainage congestion in the area. It has been informed that on this account the yield of crops in the area increased by 30%. The desirability of keeping the Kolleru Lake level low for reducing the drainage congestion is thus obvious.

CHAPTER III—RAINFALL

3.1. Rainfall is being observed by the State P.W.D. at the following stations situated within the catchment of Kolleru lake. These stations are shown in plate 3.

1. Tiruvur.
2. Nuzvid.
3. Vijayawada.
4. Gudivada.
5. Gannavaram.
6. Kaikalur.
7. Chintalapudi.
8. Ellore.
9. Nandigama.

3.2. From the examination of rainfall data from 1925 to 1964 for the above stations it is observed that the months of January and February are almost dry months and the total rainfall is negligible. During the next three months, from March to May, though there is some rainfall, this does not contribute much flow into the lake.

3.3. June to September are the four months of south-west monsoon and the majority of the rainfall in these four months varies from 432 mm. (17″) to 1448 m.m. (57″). Due to very heavy rainfall in this season, the rivers rise suddenly. The rivers overtop their banks. This results in flooding of marginal lands causing heavy damage to standing crops and property and sometimes loss of human life also.

3.4. There are cyclonic depressions in this area during the months of September to November. During these storms which last from 1 to 7 days, rainfall of high intensity is observed. When these come, the Kolleru lake is generally full and so these cause heavy damage to crops and property.

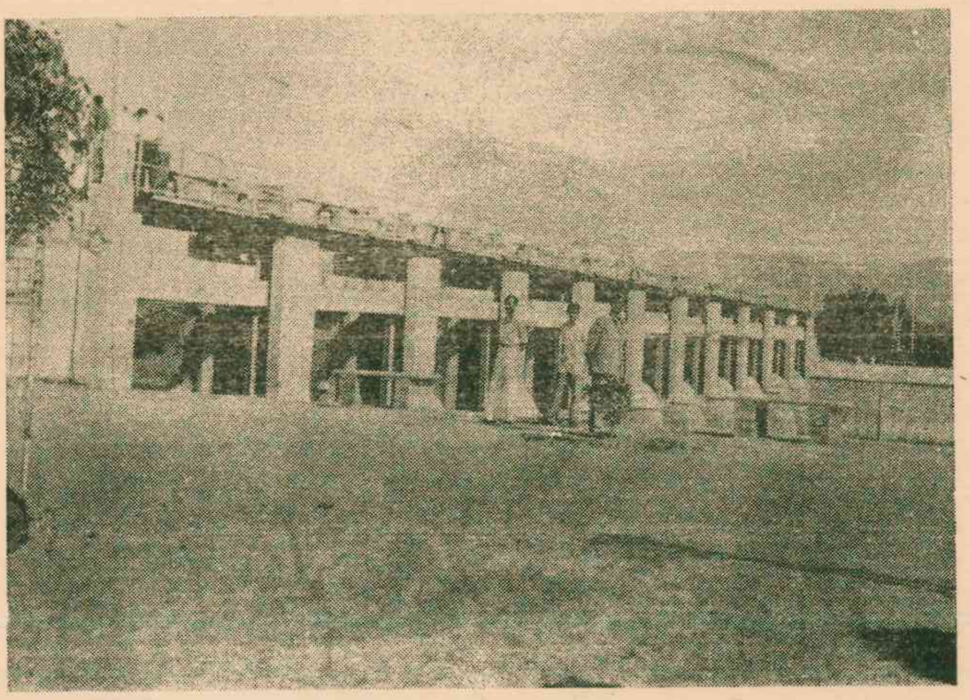
3.5. The mean annual rainfall for Kolleru lake basin for the last 40 years works out to 933 m.m. (36.72 inches).

3.6. The table No. 2.4 shows the annual rainfall in the sub-basins of Kolleru basin (from 1925 to 1964).

TABLE No. 2.4.

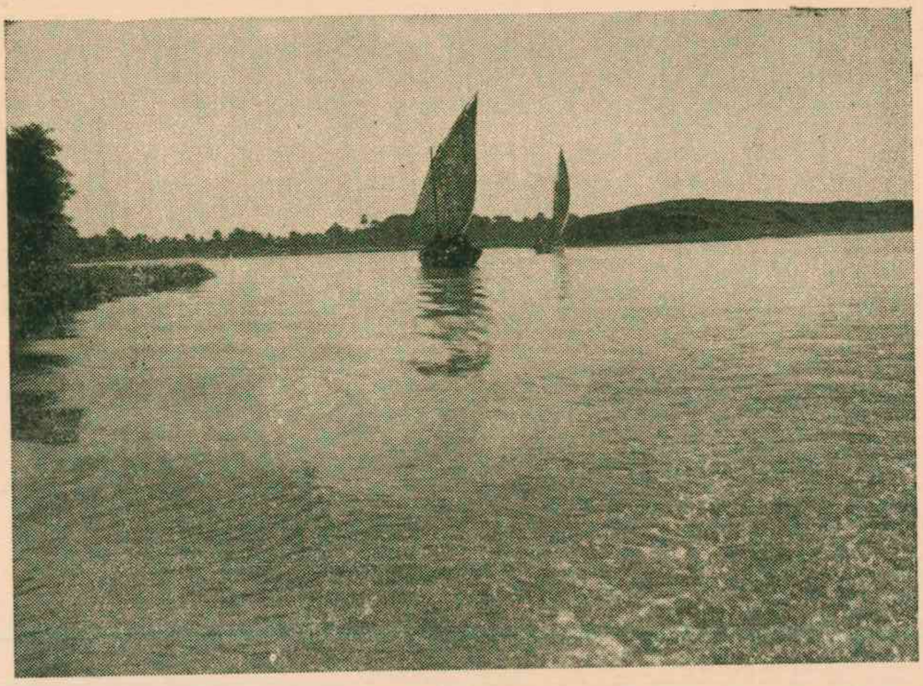
Sub basin	Gauge Station	Rainfall in inches	Average for the sub basin in inches
(1)	(2)	(3)	(4)
1. Budameru ..	.. (1) Tiruvur	37.65	35.48
	(2) Vijayawada	38.35	
	(3) Gannavaram	34.33	
	(4) Gudivada	37.82	
	(5) Kaikalur	31.87	
	(6) Nandigama	32.83	
2. Ramileru ..	.. (1) Nuzvid	35.17	35.17
3. Thammileru ..	.. (1) Chintalapudi	38.54	38.26
	(2) Ellore	37.97	
4. Gunderu ..	.. (1) Ellore	37.97	37.97

3.7. A statement showing the rainfall from January to May, June to October and November to December for all the above station, for each year during the 40 years (from 1925 to 1964) is given in Appendix. D (i).

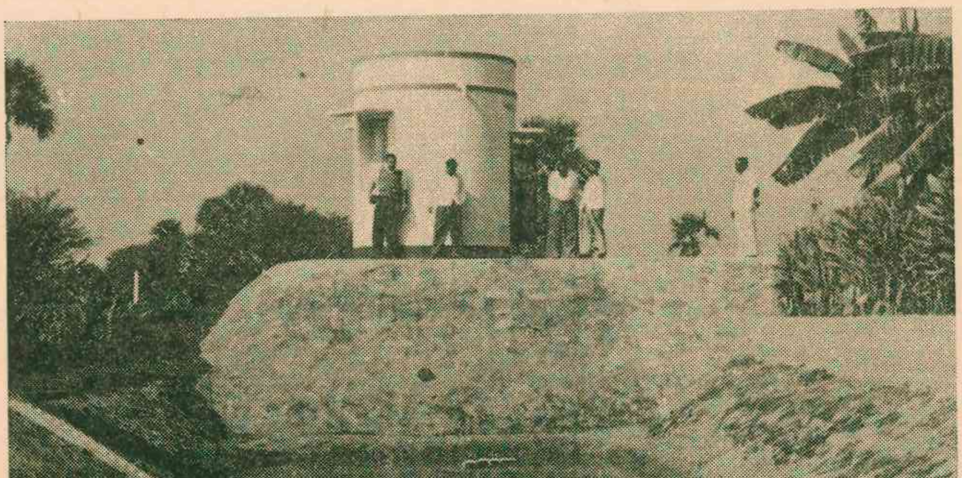


The Diversion Regulator across the Budameru.

The Budameru Diversion Channel with its Banks breached during 1964 floods.



View of Upputeru at the infall of Elurupadu Straight Cut M. 11/3.



Automatic Water Level Recording Station Downstream of the Road Bridge at M. 6/6 of Upputeru.

CHAPTER IV—WORKS ALREADY CARRIED OUT AND CONTEMPLATED

4.1. BUDAMERU RIVER.

4.1.1. WORKS ALREADY CARRIED OUT AND THEIR EFFECT.

4.1.1.1. *Budameru diversion schemes.*

In order to reduce the inflows into the Kolleru lake and flooding of fields on either side of its banks, a diversion canal for diverting 212 cu. metres/sec. (7500 cusecs) of water of Budameru into Krishna river was completed in the year 1960 and has been under operation thereafter. In order to assess the effect of this work, the discharge data of Budameru river at the diversion point has been examined from 1960 to 1964.

During the year 1960 the maximum flood discharge observed is the river at the diversion point was only 89.3 cub. metres/sec. (3125 cusecs) and never exceeded this in the whole of the monsoon period. All the water of the river was diverted into Krishna through the diversion canal except 7.22 m. cu. metres (255 m. cft.) passed down for feeding tanks lower down and for direct irrigation of lower ayacut.

In the year 1961 the maximum discharge of the river at the diversion regulator site was only 5017 cusecs. In order to meet the requirement of irrigation commitment, 10.86 m. cu. metres (383.00 M. cft.) of water was passed down into the river Budameru and the rest was diverted into the Krishna.

In the year 1962, the daily maximum discharge in the river Budameru did not exceed 212 cu. metres/sec. (7500 cusecs) except for 5 hours on 9-9-1962. During this period the maximum discharge at the diversion point was 250 cu. metres/sec. (8823 cusecs). All the water of the river was diverted to Krishna except 47 m. cu. metres (1624 m. cu. ft.) which was allowed into Budameru. Out of 47 m. cu. metres (1624 m. cu. ft.) 16.3 m. cu. metres (576 m. cu. ft.) were used for feeding lower down tanks and direct ayacut for irrigation and 29.7 m. cu. metres (1048 m. cu. ft.) were passed into Kolleru Lake.

In the year 1963, the maximum discharge observed in the river Budameru at diversion point exceeded 212 cu. metres/sec. (7500 cusecs) for 57½ hours only on 23-8-63, 23-10-63 and 24-10-63. The maximum discharges were 350 cubic metres/sec. (12318 cusecs), 407 cu. metres/sec. (14,400 cusecs) and 758 cu. metres/sec. (26,800 cusecs) respectively. In this year, the amount of water passed down into the river Budameru was 125 m. cu. metres (4403 m. cu. ft.) Out of this 16.7 m.cu. metres (588 m. cu. ft.) were to feed the lower down major tanks and direct ayacut and the remaining 108.5 m. cu. metres (3815 m. cu. ft.) went into the Kolleru lake.

During 1964, the daily discharges were not more than 212 cu. metres/sec. (7500 cusecs) except for 30 hours i.e. from 8 a.m. on 28-9-64 to 2 p.m. on 29-9-64. Though the designed discharge capacity of the regulator and canal was only of the order of 710 cu. metres/sec. (25000 cusecs) and 212 cu. metres/sec. (7500 cusecs) respectively, the maximum discharge passed through the regulator was 807 cu. metres/sec. (28,470 cs.) and through the diversion into Krishna was 316 cu. metres/sec. (11,125 cusecs), 2716 m. cu. ft. of water was let down into the Budameru river from the Diversion Regulator. Out of this, 588 m.cu. ft. were for irrigation of ayacut and 2128 m.cu. ft. went into the Kolleru lake.

During 1964, due to unprecedented floods, the guide banks u/s of regulator towards Nandigama and the bunds on both banks of the diversion canal breached in several places inundating a large area of cultivated lands and causing heavy damage to standing crops and public properties. The above discharge figures etc. are given in the table No. 2.5.

The above would show that the diversion had been effective in diverting most of the waters of the Budameru into the Krishna except some surplus water of 29.7 m. cu. metres (1048 m. cft.) in 1962, 108.5 m. cu. metres (3815 m. cft.) in 1963 and 60.4 m. cu. metres (2128 m. cft.) in 1964 which flowed into the lake [See. Appendix-C1 (iv) to C1 (vi)].

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4.1.1.2. *Flood Banks along Budameru river.*

There are flood banks along Budameru river from Ellore canal crossing to Kolleru lake on both sides for a distance of 54.6 Km. (34 miles) for preventing submersion of marginal lands from floods in Vijayawada, Gannavaram, Gudivada and Kaikalur taluks (See. plates 12 and 12-A).

These embankments breached by overtopping during the floods of 1964 and caused considerable damages to cultivated areas and other property.

4.1.2. PROPOSALS UNDER CONTEMPLATION.

The following proposals are under Contemplation with the State Government.

4.1.2.1. *Reservoirs:*

(*i*) A detention reservoir across Budameru river near Nandigama.

This would have a storage capacity of 43.5 M. Cu. Metres (1,500 M. Cu. ft.) at F.R.L. +46.2 Metres (+ 152.00). Catchment area here is 527 sq. Kms. (204 sq. miles).

(*ii*) A reservoir across Budameru near Chandragudem with a storage capacity of 30.58 m. cu. metres (1080 M. cu. ft.) at F.R.L.+67 metres (+220.00). Catchment area here is 180 sq. Kms. (69.89 sq miles).

(*iii*) A reservoir across Budameru near Tolukodu with a storage capacity of 1123 M. cu. ft. at F.R.L.+68.6 metres (+225) and with a catchment area of 197 sq. Kms. (76 sq. miles).

(*iv*) A reservoir across Budameru at Vellatur with a storage capacity of 1508 M. Cu. ft. at F.R.L +402.2 metres (+132.00).

(*v*) A reservoir across Budameru at Veerapanenigudem with a capacity of 71.9 M.cu. metres (2540 M. Cu. ft.)

(*vi*) A reservoir across Budameru at Reddigudem village with a storage capacity of 12 M.cu. metres (425 M.cu. ft.).

(*vii*) A reservoir across Kondavagu near Gauravaram with a storage capacity of 6.1 M.cu. metres (215 M. cu. ft.).

(*viii*) A reservoir across Budameru at Badava village with a storage capacity of 78.4 M.cu. metres (2770 M.cu. ft.).

(*ix*) A reservoir across Pulivagu near Madavaram with storage capacity of 80.7 M.cu. metres (2850 M. cu. ft.).

(*x*) A reservoir across Loyavagu near Madavaram with a storage capacity of 7.2 M.cu. metres (256 M.cu. ft.).

4.1.2.2. *Flood Banks.*

Forming flood banks on both banks from Mutyalampadu to Ellore canal crossing along the Budameru river for a length of 8.25 Kms. (5 miles 1 furlong).

4.2. RAMILERU RIVER:

4.2.1. WORKS ALREADY EXECUTED AND THEIR EFFECT.

There are no works which have been executed.

4.2.2. PROPOSALS UNDER CONTEMPLATION WITH THE DEPARTMENT.

4.2.2.1. *Reservoirs:*

A reservoir across Ramileru near Mirzapuram with a storage capacity of 13.5 M. cu. metre (475 M.cu. ft.).

4.3. GUNDERU RIVER :

4.3.1. Works already executed and their effect.

There are no works which have been executed.

4.3.2. Proposals under contemplation with the Departmene.

A reservoir across Gunderu near Badarala with a storage capacity of 27.5 M. cu. metres (971. M.cv. ft.)

4.4. THAMMILERU RIVER.

4.4.1. Works already executed and their effect.

(*i*) There are flood banks on West Thammileru from mile 0/4 to mile 7/4 (i.e. 4 furlongs from the point of bifurcation of East and West Thammileru). These are working satisfactorily.

4.4.2. Proposals under contemplation with the State Government.

The following proposals are under contemplation with the State Government.

4.4.2.1. *Reservoirs.*

(*i*) A reservoir across Thammileru river near Errampalli with a storage capacity of 85 M. cu. metres (3000 M. cu. ft.).

(*ii*) Reservoir at Edavally across Thammileru with a storage capacity of 31.2 M. cu. metres (1100 M. cu. ft.).

(*iii*) Reservoir at Vijayarai across Thammileru with a storage capacity of 34 M. cu. metres (1200 M. cu. ft.).

4.4.2.2. *Flood banks :*

Constructing flood banks along Thammileru river from the escape across Ellore Canal to Kolleru lake for a length of 9.66 K. M. (6 miles).

4.5. UPPUTERU RIVER :

4.5.1. Works under Execution.

Widening and deepening of Upputeru river for 15000 cusecs capacity at lake level of +7.00 M. S. L. from mile 6/3 to 12/2. This work is in progress.

4.5.2. Proposals under contemplation.

(*i*) Clearing of the two arms of the outlet *viz.* Juvvikanuma and Perantala Kanuma of all weed growth and widening their margin by about 45.8 metres (150 ft.) on either side.

(*ii*) Separating Yanamadurru Drain from Upputeru by putting a cross bund across Upputeru below Mile 28/0.

(*iii*) Widening and deepening of Upputeru river from mile 12/2 to Mile 28/0 upto Lakshmipuram lock and having a straight cut from there to sea.

(*iv*) To straighten the awkward bends in the river Upputeru. (See plates 13 and 13-A, 13 B. & 13 C.)

4.6. YERRAKALVA RIVER :

4.6.1. Works already Executed and their effect.

No works have been executed on this river.

4.6.2. PROPOSALS UNDER CONTEMPLATION.

4.6.2.1. *Reservoirs :*

(*i*) A reservoir across Yerrakalva at Anumunilanka about 8.05 K. ms. (5 miles) U/s. of Anantapally with a storage capacity of 132 M. cu. m. (4680 M. cu. ft.).

(*ii*) A reservoir across Yerrakalva near Appalarajugudem with a storage capacity of 27.2 M. cu. m. (960 M. cu. ft.).

(*iii*) A reservoir across Byneru a tributary of Yerrakalva near Ramanujapuram with a storage capacity of 56.6 M. cu. m. (2000 M. cu. ft.).

(*iv*) A reservoir across Pulivagu, a tributary of Yerrakalva near Krishnapuram village with a storage capatity of 6.5 M. cu. m. (230 M. cu. ft.).

(*v*) A reservoir across Yerrakalva at Dondapadu with a storage capacity of 12.3 M. cu. metres (433 (M. cu. ft.).

(*vi*) A reservoir across Yerrakalva near Krishnapalem with a storage capacity of 6.3 M. cu.m. (224 M. cu. ft.).

(*vii*) A reservoir across Yerrakalava near Swaranavarigudem with a storage capacity of 3.7 M. cu. m. (132 M. cu. ft.).

(*viii*) A reservoir across Yerrakalva near Sanjeevaraya Palem with a storage capacity of 25.7 M. cu. m. (1260 M. cu. ft.).

(*ix*) A reservoir across Yerrakalava at Rajavaram with a storage capacity of 31.2 M. cu. m. (832. M. cu. ft.).

CHAPTER V—SUGGESTIONS MADE BY THE PUBLIC

5.1. The Expert Committee on Floods visited the flood affected areas in Kolleru Basin during November—December, 1964. During the course of their visit, the Committee received as many as 84 representations from the Public, both from individuals and Panchayat bodies of that area. These representations contain the outstanding flood problems and suggestions offered for adopting remedial measures against floods.

Some of the suggestions are of general nature while others are of specific nature. These are briefly discussed as below :—

5.2. GENERAL NATURE :

(*i*) Construction of detention reservoirs across Budameru River.

(*ii*) Construction of a reservoir across Pulivagu a tributary of Budameru.

(*iii*) Construction of a reservoir across Thammileru.

(*iv*) Raising and strengthening of Thammileru flood banks.

(*v*) Construction of a reservoir across Yerrakalva and its tributaries.

(*vi*) Construction of a reservoir across Ramileru.

(*vii*) Formation of flood banks on Ramileru.

(*viii*) Construction of a reservoir across Gunderu.

(*ix*) Providing one more outlet from Kolleru to sea.

(*x*) Widening, deepening and straightening of Upputeru River for improving its discharge capacity.

(*xi*) Separating Yenamadurru drain from Upputeru.

5.3. SUGGESTIONS OF SPECIFIC NATURE:

The following are the main specific suggestions mentioned in the representations :—

5.3.1. BUDAMERU RIVER.

5.3.1.1. *Construction of detention reservoirs :*

(*i*) At Nandigama (4 representations).

(*ii*) Near Badava village (2 representations)

(*iii*) At Tholukodu (2 representations).

NOTE :- There was one representation against the proposal of locating the reservoir near Tholukodu.

(*iv*) Near Ganapavaram village (one representation).

(*v*) At the site of existing diversion regulator (2 representations).

5.3.1.2. *Raising and strengthening of Embankments :*

(*i*) Budameru flood banks be raised and strengthened (7 representations).

(*ii*) Bunds be extended upto Pedayadlagadi (2 representations).

(*iii*) Budameru flood banks should be extended upto Kolleru lake (3 representations).

5.3.1.3. *Improvements to Budameru diversion canal.*

(*i*) The existing diversion canal be widened and breaches in its embankments be repaired (3 representations).

(*ii*) One more diversion canal be excavated at a suitable reach (3 representations).

5.3.1.4. *Construction of Reservoir across tributaries of Budameru.*

Construction of a tank at Loya across Loyavagu (one representation).

5.3.2. THAMMILERU.

5.3.2.1. *Construction of detention Reservoir across Thammileru.*

(*i*) Near Errampalli (Three representations).

(*ii*) In Chintalapudi taluk (one representation).

5.3.2.2. *Extension and formation of flood banks.*

(*i*) Extending the flood banks of Thammileru river upto Kolleru lake (2 representations).

5.3.3. GUNDERU.

5.3.3.1. *Construction of Reservoir across Gunderu stream.*

Near Vagivada (2 representations).

5.3.3.2. *Construction of an anicut across Gunderu stream.*

At Badarala (2 representations).

5.3.3.3. *Improvements to Gunderu stream.*

(*i*) Widening and deepening of Gunderu from Akividu upto its outfall into Kolleru (Two representations).

(*ii*) Enlarging the waterway of bridges over Mudikondan and Desapaduvagu. drain (1 representation).

(*iii*) Dredging out the shoals and silt deposits from the bed of Gunderu channel (one representation).

(*iv*) Putting a regulator across Gunderu near Jagannathapuram (one representation).

5.3.4. UPPUTERU.

5.3.4.1. *Providing extra outlet to Kolleru.*

(*i*) Excavating another wider drain for Kolleru in the area laying between Kaikalur and Upputeru to join the sea *via* Baggeswara Goustulu.

(*ii*) Excavation of one more outlet for draining Kolleru direct to the sea through Atapaka village (3 representations).

(*iii*) Re-excavating and restoring Kavadikodu drain, which is one of the three outlets of Kolleru lake (2 representations).

5.3.4.2. *Proposals for altering the course of Upputeru.*

(*i*) Diverting the Upputeru drain through Pedalanka drain in Bandar Taluk, Krishna District (2 representations).

5.3.4.3. *Improvements to Upputeru River.*

(*i*) Formation of flood banks on either side of Upputeru, upto its outfall (one representation).

(*ii*) Dredging out the shoals from Upputeru river bed, especially at mile 5/3 (2 representations).

(*iii*) Clearing the two outlets ; Juvvikanuma and Perantalakanuma, of the weed growth (one representation).

5.3.5. *Other drains discharging into Kolleru Lake.*

(*i*) Diverting Polaraju drain from Manukondepadu and opening a straight cut to sea (one representation).

(*ii*) Deepening the drain from Kaikalur and joining it with Kolleru (one representation).

(*iii*) Effecting repairs to Chandrayya drain. (one representation).

5.3.6. YERRAKALVA.

5.3.6.1. *Construction of detention reservoirs across Yerrakalva river.*

(*i*) Near Appalarajugudem (6 representations).

(*ii*) Near Anumunilanka, 5 miles upstream of Anantapalli (7 representations).

NOTE :- 4 representations were received objecting to the construction of a reservoir across Yarrakalva near Anantapalli.

5.3.6.2. *Construction of detention reservoirs across the tributaries of Yerrakalva.*

(*i*) Across the river Byneru, near Ramanujapuram (one representation).

(*ii*) Across Pulivagu at Krishnapuram (one representation).

(*iii*) Across Jalleru (one representation).

CHAPTER VI-EXAMINATION OF VARIOUS PROPOSALS FOR FLOOD CONTROL

6.1. KOLLERU LAKE LEVELS

Water levels in the Kolleru lake are being observed at several places. Continuous record is, however, available for the last 50 years at Perantala Kanuma which is the point of off-take of the Upputeru. The gauge is subject to wave action, but no observations of wave heights are being made nor any correction is being applied to the gauges. The study of the gauges at Perantala Kanuma Mouth has shown that the lake is at minimum levels during the months of March and April and at maximum levels during the months of September and October. The minimum recorded level is zero, i.e. the sea level and the maximum level is 3.26 metres (+10.7 ft.). A statement showing the maximum lake levels from 1916 to 1965 is given in table No. 2.2.A frequency study of the maximum levels has been made. The following are the results of this study :—

Maximum lake level Above M.s.L. Metres (ft.)	*Mean period of occurrence (Return period in years)*
1.53 (+5.00)	1.12
1.83 (+6.00)	1.47
2.14 (+7.00)	2.28
2.44 (+8.00)	3.95
2.74 (+9.00)	5.89
3.05 (+10.00)	13.90

It would be seen that the lake attains a level of +1.53 metres (5 ft.) almost every year, +2.14 metres (7.00ft.) alternate years, +2.44 metres (8ft.) once in 4 years, and 3.05 metres (+10ft.) once in 14 years. The area of water spread at +1.53 metres (5.00ft.) is 492 sq. kms. (190 sq. miles). This increases to 910.0 sq. kms. (348 sq. miles) at + 3.05 metres (+10.00). The yearly maximum lake levels and the annual average monsoon rainfall have been plotted on a graph (See Plate 10). This indicates that during the past 10 years the lake has risen above +2.44 metres (8 ft.) every year submerging atleast 738 sq. kms. (285 sq. miles) whereas in the previous 39 years, it had risen to this level only once in six years.

6.2. The possible causes of this remarkable increase in the frequency of occurrence of high levels of the lake may be one or more of the following factors :—

1. Excessive inflows
2. Inadequate outflow
3. Reduction in the capacity of the lake due to silting.

6.3. The remedial measures for reducing damage from floods could, therefore, comprise of:

(*i*) Proposals for control of floods in rivers flowing into the Kolleru basin like the Budameru, the Thammileru and the Yarrakalva by construction of detention reservoirs or by diversion into the adjoining valleys or any other method.

(*ii*) Proposals for lowering the flood levels of the Kolleru lake either by improving the outfall channel the Upputeru, or by pumping, or by both.

(*iii*) Other measures for reducing inundation.

The above proposals are discussed in the following paragraphs :—

Proposals for control of floods in rivers of the Kolleru Basin.

6.4. The catchment area of the Kolleru basin is about 4740 sq. kms. (1839 sq. miles). This can be divided under two broad categories :

(*i*) *Catchment of drains of deltaic area :* 518 *sq. kms* (200 *sq. miles*).

There are a number of drains which originate around Kolleru lake and fall directly into the lake. These have all their catchment area in delta. Most of these are small in size and short in length. There is no scope nor any advantage of having detention reservoirs or diversions in these drains. However, on some drains which submerge large areas during floods by overflowing their banks, flow conditions can be improved by deepening and widening to suitable sections.

(*ii*) *Catchment of streams and rivers which bring water both from upland as well as from deltaic catchment.*

The total catchment area of these streams is 4,246 sq. kms. (1639 sq. miles) and comprises :

(1) Budameru-Catchment area 1889 sq. kms. (729 sq. miles)
(2) Thammileru-catchment area 1355 ,, (523 ,,)
(3) Ramileru-catchment area 308 ,, (119 ,,)
(4) Gunderu-catchment area 632 sq. kms. (244 ,,)
(5) Other small streams - 62 ,, (24 ,,)

6.4.1. BUDAMERU :

Of all the rivers flowing into the Kolleru lake this has the largest catchment area, *viz.*, 1889 sq. kms. (729 sq. miles). In this catchment there are as many as 111 tanks having a total capacity of 43 m.cu.m. (1525 m.cft.) and irrigating an area of 30,280 acres.

The catchment area of the Budameru can be divided into three reaches. First is from its source up to the diversion point, second reach from the diversion point down to the crossing of the river with the Ellore canal and the third lying between Ellore Canal crossing and Kolleru lake. The catchment in the first and second reaches is upland whereas in the third reach it is all deltaic.

6.4.1.1. *Reach from source down to Diversion point.*

6.4.1.1.1. *Diversions.*—(*a*) A diversion channel has already been constructed near Valagaleru and is in operation since 1960. (*See* plate 3). The river at the existing diversion site near Valagaleru has an entirely upland catchment area of 673 sq. k.ms. (260 sq. miles). On account of higher intensity of rainfall in the uplands, the contribution from this catchment can be taken as 50 per cent of that of the entire catchment. The designed maximum discharge of the diversion is 212cu. metres/second(7,500 cus.),and that of the regulator at this place is 703cu. metres/sec. (25,000 cs.). The maximum discharge which arrived at the diversion channel as calculated was 39,595 cs. in 1964. [*See* Appendix C1 (*vi*)]. The maximum discharge which arrived at the diversion site during the period 1960 to 1964, and those passed down into the Budameru are given below. The total contributions made by this reach of the Budameru to the Kolleru lake during the monsoon seasons in the years 1960 to 1964 are also given in Table No. 2.5.

TABLE No. 2.5

Year	MAXIMUM DISCHARGE AT DIVERSION AND REGULATOR IN CS.		TOTAL QUANTITY OF WATER DURING MONSOON AT REGULATOR SITE IN M.C. FT.				Corresponding rise in level of Kolleru. Metre(ft.)	Computed rise in Kolleru lake level if diversion did not exist. Metre (ft.).
	U/s including diversion.	Going D/s into Kolleru lake.	Quantity U/s of the regulator.	Through diversion channel	Quantity let down for irrigation.	Balance passed into Kolleru.		
1960 ..	3125	Nil.*	4760	4505	255	Nil	Nil	0.17(0.6)
1961 ..	5017	Nil.*	8476	8093	383	Nil	Nil	0.30(1.06)
1962 ..	8823	2923@	10449	8825	576	1048	0.04(0.13)	0.40(1.3)
1963 .	26800	19750@	12161	7758	588	3815	0.15(0.50)	0.46(1.5)
1964 ..	39595	28470@	4652	1936	588	2128	0.09(0.30)	0.15(0.5)

*Except some for irrigation.
@including some for irrigation.

This shows that the diversion has been quite effective in substantially reducing the inflow from Budameru into Kolleru lake and thus reducing the extent of flooding in the Kolleru basin.

During 1959, the Kolleru lake remained high for a long time. The diversion channel did not exist at that time, but if it had been functioning during that year, all the waters of Budameru upto the diversion point would have flowed into the river Krishna as the maximum discharge (5940 cs.) at the diversion that year was less than the discharging capacity of the diversion [*See* Appendix-C1 (*i*)]. The total quantity of water that passed at the diversion point into the Kolleru lake that year in the absence of the diversion was 6590 m. cu. ft. which raised the lake level by 0.86 ft. If the diversion channel had been functioning during that year also, the rise would have been less by 0.86 ft. and this would have meant considerable reduction in the lake level and in the area flooded.

(*b*) The question as to whether increase in the diversion capacity would be beneficial and physically and financially feasible has been examined. Such increase can be effected in three ways :

(*i*) by increasing the capacity of the existing diversion channel length 11.9 km. (7.44 miles).

(*ii*) by providing another diversion channel falling into the Krishna 3.2 Kms. (2 miles) upstream of the Krishna Barrage.

(*iii*) by providing another diversion channel falling into the Krishna 6.4 kms. (4 miles) down stream of the Krishna Barrage.

(*i*) *Increasing the capacity of existing diversion channel :*

A comparision of the maximum flood levels of the Budameru near the diversion point and the Krishna has shown that a total drop of 2.9 metres (9.50 ft.) was available during 1903 floods and 3 6 metres (11.80 ft.) during 1964 floods. This shows that when the Krishna and the Budameru are in high floods a fall of not less than 1 in 4400 (1.2 ft. per mile) is available. The present diversion can, therefore, work satisfactorily under all conditions of flow of Krishna River and its discharging capacity can be increased by widening the channel.

A flood routing study was made to rout 1964 floods assuming diversion channel capacity at 424.8 cu. metres/sec. (15,000 cusecs).The study has indicated as a result of such increase that the lake level would be reduced only by 0.03 metre (0.105 ft.) and the duration of submergence above +7.00 would be reduced by only one day. This is insignificant.

Flood routing studies further show that during the six year period 1959 to 1964 when the lake level rose to the elevation +8.00 and above every year, and above elevation +9.00 in four out of the six years, the Budameru diversion would not at all have been required to divert more than 7,500 cusecs (its present capacity) in the years 1959, 1960 and 1961 and would have had to pass higher discharge (if capacity were increased) for only 5 hours in 1962, 37½ hours in 1963 and 30 hours in 1964. As mentioned already, the effect of such increased diversion in reducing the Kolleru Lake level would be insignificant.

Increasing capacity of the existing Diversion channel to 15,000 cusecs would cost about Rs. 90 lakhs and would require the acquisition of valuable cultivated land. The benefits would not at all be commensurate with the expenditure involved.

(*ii*) *Excavating another diversion channel* 3.2 *kms.* (2 *miles*) *upstream of Krishna Barrage :*

Record of flood levels indicate that the maximum flood level of the Krishna at the proposed outfall point was +72.99 whilst the maximum flood level in the Budameru at the proposed diversion point observed in 1964 was 63.96 which is 9 ft. lower. This proposal therefore is not feasible.

(*iii*) *Providing another diversion channel* 6.4 *kms.* (4 *miles*) *D/S of the Krishna Barrage :*

Here again records of high flood levels show that the maximum flood level in the Krishna at the proposed outfall point was +63.83 against a maximum flood level in the Budameru at the diversion point (the crossing of the Budameru with Nuzvid-Vijayawada Road) was of +59.60 in

1964, which is over 4 ft. lower. The diversion channel would have to pass through very costly built up areas, so even if the diversion were to function during periods when the Krishna was low, the cost of the scheme would be prohibitive and the benefit insignificant and uncertain.

6.4.1.1.2. *Detention Reservoirs.*—The State Government have considered several reservoir schemes. These have been enumerated earlier under Chapter IV. A detailed project report of none of these was available to the Committee. As such, it has not been possible to technically examine any of the schemes but only a broad study has been made from the salient features of the schemes supplied by the Chief Engineer, Andhra Pradesh—(Appendix L.).

The reservoir sites are all located in the catchment area lying upstream of the diversion point. These schemes were prepared mainly for irrigation purposes, and therefore, would have to be revised to cater for flood control purposes. Flood routing studies for the discharge of 1964 were carried out for a reservoir at the proposed Nandigama site with the diversion channel functioning. It was found that for absorption of flood waters, a storage capacity of 1,300 m. cft. would be required. To accommodate this and to take care of a likely reduction in the capacity due to siltation etc., it would be desirable to provide a reservoir or reservoirs having a flood storage capacity of about 2,000 m. cft.

The State Government have recently made preliminary studies for other reservoirs on the Budameru, one at Chandragudam and the other at Tolukodu. The reservoir on Chandragudam is estimated to provide a flood storage capacity of 1337 m. cft. at M.W.L. at a cost of Rs. 66 lakhs. The reservoir at Tolukodu is estimated to have a capacity of 1423 mcft. at a cost of Rs. 46 lakhs. Main hydraulic features of these reservoirs are given in Appendix L. Before finally deciding the reservoir sites, the State will have to carry out detailed investigation and studies. In order that the reservoirs provide effective flood storage capacity of about 2,000 mcft., the reservoir sites should be as near to the diversion site as possible and should preferably be on the main stream.

6.4.1.2. *Second reach of Budameru from Diversion point down to Ellore canal Crossing.*

6.4.1.2.1. Out of the total upland catchment of 1335 sq. km. (516 sq. miles) the catchment up to the diversion point is 672 sq. km. (260 sq. miles) and the rest of 663 sq. kms. (256 sq. miles) is up to the crossing of Budameru with the Ellore Canal. This is nearly half of the total upland catchment. Since the intensity of monsoon rainfall in this catchment is also fairly high, the contribution made by this catchment to Budameru may be assumed as about 30% of the total catchment.

A minor stream joins the Budameru about 3 miles (4.8 kms.) upstream of Budameru crossing with the Ellore Canal. Another tributary called Chinnalavagu joins the Budameru at a distance of 0.6 km. (3 furlongs) upstream of Kesarapalli aqueduct.

6.4.1.2.2. *Detention Reservoirs.*—The State Government has not so far prepared any flood detention reservoir scheme for this reach of the river. There are however two tanks in the catchment of the Budameru in this reach. These are called Brahmayyalingam tank and Sagguru Amani tank (*See* Plate 3). The State Government have examined the possibility of increasing the storage capacity of these tanks. The Brahmayyalingam and Sagguru Amani tanks surplused a considerable amount of water during 1960 to 1964 which shows that there is scope for increasing the storage capacity of the tank to the extent economically feasible.

The existing combined storage capacity of Brahmayyalingam tank and Sagguru Amani tank at F. T. L. conditions is only 351 m. cft. The State P. W. D. considers that this capacity can be increased to 891 m. cft. at M. W. L. The additional storage of 540 m. cft. now proposed will be available for flood absorption. A statement showing the F. T. L. and M.W. L.capacity of the tanks at present and proposed is given in the Appendix K.

From the statement, it is seen that the proposed storage can absorb a discharge of 6,250 cusecs flowing for one day. This will provide some relief to lower areas from flooding during periods of heavy rains by absorbing peak floods.

The cost of these measures has been estimated to be about Rs. 8 lakhs. It would be advisable to commence regular gauge and discharge observations for these two tanks and to examine in detail the extent to which the storage capacity of these two tanks can be increased economically.

6.4.1.2.3. *Other measures.*—There are two other proposals for this river which can help in reducing local damage from floods. These are described below—

(*a*) The river near Vijayawada flows in a loop and causes a lot of damage. The loop can be straightened to avoid submersion of valuable areas and hence this proposal is recommended (*See* plate 3). The approximate cost of this proposal is estimated at Rs. 31 lakhs.

(*b*) There is a proposal to form flood banks from Mutyalampadu to Ellore Canal crossing for a distance of about 8.05 kms. (5 miles) along both the banks of the Budameru. Details of this scheme are not available for examination The effect of these embankments on drainage of the adjoining areas and on reduction of the valley storage of Budameru need to be examined before deciding to implement this measure.

6.4.1.3. *Reach from Ellore Canal crossing down to the Kolleru Lake.*

6.4.1.3.1. Catchment area of the river in this reach is 550 sq. kms. (213 sq. miles). This is all in deltaic area. Discharges of Budameru are available at Vaddigudem about 2 miles u/s of its confluence with the Kolleru lake during 1960 (19-9-1960 to 24-9-1960), 1961 (24-9-1961 to 30-9-61) and 1962 (7-9-1962 to 15-9-1962). A comparative study of available discharge records of the Budameru at the diversion site and at Vaddigudem shows that the discharge at the latter site is nearly twice that observed at the former site during 1960 and 1961 and about 1½ times during 1963. From this it can be inferred that about twice the discharge that passed the diversion site has entered into Kolleru lake which tends to confirm the assumption that contributions from the catchment area downstream of the diversion down to Ellore Canal crossing is approximately 30 per cent and there-after down to Kolleru lake is 20 per cent. No measure for reducing inflows into the lake from this reach are feasible. The water has to go into the lake.

6.4.1.3.2. There are embankments on both banks of the Budameru from Ellore Canal crossing up to the lake. It is observed that in certain reaches these do not have adequate free board. This needs to be checked up. The heights should also be checked against back water from the lake. A proposal for raising and strengthening of the embankments has to be worked out. The cost of these works have not yet been estimated.

6.4.2. THAMMILERU RIVER.

6.4.2.1. As already mentioned, next to Budameru, this is the second biggest river of the Kolleru basin. Out of its total catchment area of 1354 sq. kms. (523 sq. miles), the upland catchment is 1199 sq. kms. (463 sq. miles), and the delta catchment is only 155 sq. kms. (60 sq. miles). This river contributes considerably to the rise in the level of Kolleru lake. In addition, the floods cause inundation of Ellore town.

From the discharge observations at Nagireddigudem near Errampalli dam site, it is seen that the river was in floods for about 48 hours on 28th and 29-9-1964, when maximum discharge of the order of 492 cu. m./sec. (17,400 cusecs) passed. [See Appendix C-2 (*i*) and C-2 (*ii*)]. The maximum discharge which flowed near Ellore town through the West and East Thammileru escapes was about 593 cu. m./sec. (20,940 cusecs).

6.4.2.2. *Diversion.*

No diversion of the river to other basins is possible.

6.4.2.3. The State Government has indicated certain reservoir sites across the river Thammileru which have been mentioned in Chapter IV. However, no details are available except in the case of Errampalli. At present, the State is considering construction of a reservoir at this site, of limited capacity for irrigation purposes only. Preliminary studies carried out by the State have indicated that the capacity of reservoir at this site can be increased by 3000 mc. ft. for flood absorption besides irrigation.

There was hardly any data available for routing the floods of 1964 through the reservoirs. However, broad examinations have indicated that on constructing this reservior the peak flood of 1964 can be reduced by 5000 cusecs. This would provide some relief from floods in the lower catchment to some areas and particularly to Ellore town. The peak inflow into the lake would also be reduced though the duration will be increased. The present project which is mainly for irrigation would have to be recast for flood detention. The cost of this reservoir is estimated at Rs. 200 lakhs. Broad features of this reservoir are given in Appendix L.

6.4.2.4. *Other measures :*

(*i*) For the protection of Ellore town, flood embankments along the East Thammilleru as proposed by the State Government are necessary. West Thammileru is already embanked.

(*ii*) Waterway under the Railway bridges and under the canal escape channel need to be examined particularly in the case of East Thammileru. During the floods of 1964, these caused considerable afflux.

6.4.3. RAMILERU RIVER :

This river has a catchment area of 308 sq. k.m. (119 sq. miles). No flood control scheme on this river has been executed. There is a proposal for a reservoir near Mirjapuram (catchment area about 100 sq. miles) with a storage capacity of about 13.5 m. cu. m. (475 mcft.). This is said to be based upon study of maps only. The contribution towards moderation in floods of Kolleru lake due to this reservoir will be very small. A reservoir on this river may be useful from irrigation point of view and also for preventing submersion of marginal lands along its course.

6.4.4. GUNDERU RIVER :

This river also falls directly into the Kolleru lake. It has a catchment area of 632 sq. k.m (244 sq. miles). There is a proposal of the State Government of constructing a reservoir near Badarala for irrigation purposes but the storage capacity is stated to be 27.5 m.cu.m. (971 mcft.) This is too small to be of any use for reduction in flood heights. Moreover this. does not provide any significant moderation in flood levels of the Kolleru lake. A reservoir on this river may be useful from an irrigation point of view and also for reducing submersion of marginal lands along its course.

6.4.5. YERRAKALVA:

6.4.5.1. *Detention Reservoirs :*

During heavy floods the river causes inundation in some reaches which lie upstream of Nandamuru aqueduct. In the reach downstream of this aqueduct it is called new Yenamadurru drain. In the tail reach it backs up into the Upputeru and causes reduction in the discharging capacity of the Upputeru. This causes significantly greater and longer submersion of areas around the Kolleru lake and the Upputeru.

The maximum discharge observed at the Appalarajugudem reservoir site on 28-9-1964 was 464 cu.metres/sec. (16390 cusecs) [*See* Appendix C3 (*iii*)], and at Nandamuru aqueduct, it was of the order of 450 cu.metre/second (15762 cusecs), [*See* Appendix C3(*v*)].

The State Government has prepared several schemes for reservoirs across the Yerrakalva including its tributaries. These are enumerated in Chapter IV. Out of these, a reservoir at Anumunilanka, and that at Appalarajugudem village are under active consideration of the State Government. The catchment area at Anumunilanka site is 1950 sq. kms. (752 sq. miles). The storage capacity of a reservoir at this site is estimated at 132.5 m.cu.metres (4680 mcft.) (*See* Appendix L). The catchment area of Appalarajugudem reservoir is only 430 sq.kms. (155 sq, miles). The storage capacity of a reservoir at this site is estimated at 960 mcft. Salient features of the reservoir at Anumunilanka is given in Appendix L. From the flood storage point of view, a reservoir at Anumunilanka is better than at Appalarajugudem on account of a higher storage capacity. By absorbing the peak discharges and allowing moderated flow from the reservoir into the river below, it would be possible to reduce flooding of marginal areas along the banks of the river and also reduce the influence of Yenamadurru drain over Upputeru. This would likewise reduce the backing up effect of Upputeru into the Kolleru lake.

A reservoir or reservoirs of 3,000 mcft., to 4,000 mcft. may, therefore, be provided for flood control, if possible at Anumunilanka or higher up at Appalarajugudem or at both. A reservoir on Byneru may also be considered.

The State Government has worked out the rough cost of a reservoir scheme at Anumunilanka for a capacity of 4,680 mcft. to be of the order of Rs. 260 lakhs.

6.4.5.2. There was a suggestion of diverting a part of the flood waters of Yerrakalva into the river Godavari. The State P.W.D. has examined two proposals for diverting 20,000 cusecs from Yerrakalva to Godavari. The first proposal was to have a diversion from a point just above Nandamuru aqueduct. F.S.L. in the Yerrakalva at this site was at R.L. + 32.00 and the channel was to be a contour channel. The length of this channel came to 7 miles and this was to join the Vasista Godavari about 9 miles below the Vijjeswaram anicut. But the F.S.L. of the diversion channel at its infall into Godavari works out to +26.00. From the study of M.F.Ls. of the Godavari at the infall of the proposed diversion channel for the last 8 years, it was found to be much higher than +26.00. Therefore, this proposal was not feasible.

The second proposal was to have the off-take point for the diversion channel about one furlong downstream of the G.N.T. Road bridge on Yerrakalva near Anantapalli. The F.S.L. of this proposed channel at the point of off-take would be +98.50. The channel traverses along the required contour over a length of 31 miles 6 furlongs and its outfall into the Godavari would be at a place 17 miles above the anicut. The F.S.L. of the proposed channel at its outfall would be +81.30, whereas the M.F.L. of Godavari river recorded during 1953 was +80.30. Therefore, it would be feasible to have a diversion channel from Yerrakalva from a point higher up on the river above Nandamuru aqueduct (*See* plate 3).

A preliminary estimate prepared, based on the top sheet studies, by the State P.W.D., indicates that the scheme would cost about Rs. 3.76 crores.

At present, about (13,600 wet and 6,400 dry) 20,000 acres of marginal land is getting submerged between Anantapalli road bridge and Nandamuru aqueduct. In addition, about 5,000 acres of wet land is being submerged by the floods of Yerrakalva downstream of Nandamuru aqueduct. It would be possible to avoid submersion of the above mentioned land with the proposed diversion channel. But as the cost of the scheme is too high, the Committee feels that it would not be economically justified.

6.5. PROPOSALS FOR LOWERING THE FLOOD LEVELS OF THE KOLLERU LAKE.

6.5.1. INCREASING CAPACITY OF UPPUTERU.

6.5.1.1. *Extent of increase required :*

As mentioned earlier, the Upputeru connects the lake with the sea. The present capacity of the Upputeru at various levels of the lake has been given in Table No. 2.3. According to this, the present capacity of the Upputeru at road bridge is only 188 cu.metres/sec (6650 cusecs) at R.L. +2.14 metres + (7.00′) of the lake at Kolletikota. (See table No. 2.3) Against this, the calculated maximum peak inflow during flood season is over 2,830 cu.m./sec. (one lakh cusecs). The resultant rise in the lake level causes an increase in the area submerged.

Although the lands adjoining Kolleru lake are cultivated in dry periods as far down as +0.91 metre (+3 ft.) contour the people are used to consider submergence of lands during every flood season up to R.L. + 1.52 metres (+5 ft.) as a normal occurrence. It should, therefore, be sufficient from the agricultural point of view if the level of the lake could be kept down in normal years to a level not higher than + 1.52 metres (+5 ft.). Owing to the high rate of maximum inflow and the physical and economic limitations to the increase of outflow capacity, it is impracticable in years of abnormally heavy rainfall to prevent lands below the level of +7.00 ft, from submersion for periods well in excess of one week resulting in damage to crops. Efforts were, therefore, made to find out ways and means of ensuring that in years of heavy rainfall submergence of areas above the level of +7.00 ft. did not exceed one week. In the few years of exceptionally heavy rainfall, however, submergence up to some what higher levels, say upto elevation +8.00 and for a little longer than one week, might have to be tolerated.

In the past ten years, excessive submergence occurred during 1959 and again in 1964. In 1959, the lake reached level of +10 ft. whereas in 1964, it touched +10.7 ft. [*See* Appendix C-5 (*i*) and C5 (*ii*)]. For devising measures to improve the present condition, 1964 was adopted as the representative year of exceptionally heavy rainfall.

A study was made assuming increase of Upputeru discharge capacity to 425 cu. metres/sec. (15000 cusecs) below road bridge for a lake level of +7.00 ft. (at Kolletikota). During 1964, the lake was at or above +7.00 ft. for 55 days with the present Upputeru capacity of 6650 cusecs at or above the lake level of +7.00 ft. [*See* Appendix C5 (*ii*).] The routing of 1964 floods with the improved capacity showed that the lake level would rise to a maximum level of + 2.75 metres (9.00′) instead of 3.26 metres (10.70 ft.) and that it would remain above +2.14 metres (+7.00 ft.) for 22 days instead of 55 days with present capacity. The lake would be above +8.00 for 13 days. Further studies were then made by assuming an increase in the capacity of the Upputeru to 566 cu. metres/sec (20,000 cusecs) at +2.14 metres (+7.00 ft.) of the lake. The flood routing for this capacity showed that the lake level would still rise to 2.56 metres (8.40 ft.) and would remain above +2.14 metres (+7.00 ft.) for 15 days, and woud be above 2.54 metres (+8.00 ft.) for 7 days.

The lands along the banks of Upputeru are very fertile and are under paddy cultivation. Acquisition of about 4000 acres of this land would be necessary to increase the capacity to 566 cu. metres/sec. (20,000 cusecs). Acquisition of such large areas of very fertile paddy land is expected to create serious opposition from the public, so the extent of widening of the Upputeru will have to be decided with considerable caution. It would appear that increasing the capacity above 536 cu.meters/sec (20,000 cusecs) would be out of question. Moreover, the maintenance cost of Upputeru for a very big discharge is also an important point for consideration as this disharge will flow very rarely, only for a few days in the few years of exceptionally heavy rainfall. The average flow for the flood season will be much lower. For examining proposals for increasing the capacity of Upputeru 566 cu. metres/sec. (20,000 cusecs) has, therefore, been taken as the upper limit. It must be remembered in this connection that there would be some reduction in the duration and depth of submergence of the land at or above +2.14 metres (+7.00 ft.) due to the construction of detention reservoirs on the rivers of Kolleru basin as already suggested in para. No. 6.4.1.2.2.

During 1959 the gauge readings for Kolleru lake at Kolletikota are available on alternate days at irregular time intervals. The gauge readings are available daily at Perantala Kanuma mouth (M. 4/6) but at irregular time intervals. As there is not much difference between the lake levels at Kolletikota and Perantala-Kanuma mouth, the readings at the latter site havebeen inter-polated for the lake levels. A hydrograph is drawn with these levels and lake levels, are obtained at regular time intervals and inflows into the lake have been calculated from these readings. The ratingcurve of 1964 at road bridge has been utilised for finding the inflows into the lake as no discharge observations were made during this year.

During this year the lake level remained above 2.14 metres (+7 ft.) for 115 days, above 2.44 metres (+8 ft.) for 109 days ,and above 2.74 metres (+9 ft.) for 60 days [*See* Appendix C5 (*i*)]. These periods of submergence were even longer than those during 1964 floods. Flood routing studies have been made to ascertain the effect of improvement in the capacities of the Upputeru to 425 cu.metres/sec (15,000 cusecs) and to 566 cu.metres (20,000 cusecs) at +7.00 ft. of the lake level under the 1959 flood conditions and with the Budameru diversion of 7,500 cusecs assumed to be functioning. (This diversion was not in operation in 1959 as it was completed in 1960). These show that with 15,000 cusecs capacity of the Upputeru, the lake level would rise to a maximum level of 2.36 metres (7.75′). It would remain at or above 2.14 metres (+7ft.) for 15 days from 2.13 metres to 2.36 metres (+7′ to 7.75′). The routing study made for the increased capacity of 566 m.cu.metres (20,000 cusecs) showed that the lake level would rise to 2.28 metres (7.48 ft.). It would remain at or above +2.14 metres (+7′) for 9 days. The Appendix J, gives the relevant information, both for 1959, as well as for 1964.

This table shows that 1964 would be worse than 1959 even if the Upputeru were improved to 15,000 cusecs or 20,000 cusecs. It would also be seen that the improvements to the Upputeru would considerably reduce the duration and maximum levels of the lake, although the aim of not more than 7 days submergence at or above +7.00 level cannot be achieved for the exceptionally heavy 1964 floods. The improvements to Upputeru cusecs for 15,000 cusecs capacity as proposed by the State Government, are shown in plates 13, 13-A, 13-B and 13-C.

6.5.1.2. *Measures required for increasing capacity:*

For improving the capacity of Upputeru, it would need to be (*a*) widened and deepened where necessary, (*b*) the severe meanders, etc., would have to be straightened and (*c*) a straight cut into the sea at a suitable site would have to be provided (*See* plate 11). The major quantity of earth will have to be dredged as the area is either under water or is swampy. The water way of the rail and road bridges on the Upputeru would likewise have to be increased to correspond to the increased bed width of the river.

6.5.1.2.1. *Widening and deepening:*

The earth obtained from excavation would be used in raising the adjoining land and also for raising and completing the bunds on both banks of the Upputeru itself. The top level of the bunds along the Upputeru would be kept at +4,88 metres (16.00 ft). This would provide enough free board even when the lake would rise to +3.05 metres (10.00 ft.). Embankments against back water would have to be provided on the drains joining the Upputeru for a suitable distance. This would be necessary because when Upputeru is high, the drains would not be able to discharge into the river for that period, and the water would rise in the drains. To prevent the adjoining area from submergence, the drains would have to be provided with sluices and also lock gates in these cases where the drains are used for navigation. Pumping arrangements for relieving drainage congestion during high level conditions of Upputeru, may have to be provided on certain drains joining the Upputeru. It would be better, if parallel catch water drains on both sides of Upputeru could be provided to take the discharge of these drains to outfall further downstream into the Upputeru but this might create a lot of problems as considerable additional land would have to be acquired on both banks of Upputeru which are highly developed ; moreover several drainage crossings under irrigation channels, etc., would be required. Construction of such works in the low lying-marshy lands would also be difficult and expensive. As such, construction of a parallel drain is not considered feasible but the matter may be examined further by the State Government.

6.5.1.2.2 *Straightening of meanders.*—The sever meanders in the Upputeru would also have to be removed. Such meanders exist at Kms. 17.7, 20.9, 27.4, 32.2, and 33.8 (mile 11/0, 13/0, 17/0, 20/0 and 21/0). This would reduce the length of Upputeru by about 6.44 Km. (4 miles) and thus improve the overall slope.

6.5.1.2.3. Straight cut into the sea:

(*a*) The most radical solution from a technical point of view would be digging an entirely new outlet, running in a straight line from the lake to the gulf of Bengal. This outlet would have a length of less than 32.2 Kms. (20miles) or about half the length of the existing outlet, which is 59.5. Kms. (37miles). It seems, however, that such a solution resulting in crossing numerous canals, drains, roads and a railway track and passing through valuable cultivated land, would never be feasible either from an administrative or a financial point of view.

Theoretically, there seem to be only three suitable sites for a straight cut, giving better prospects:

(*i*) Widening Upputeru including both Kanumas between 0 Km. and 19.3 Km. (0 and 12 miles) and making a long straight cut from there to the sea (Plate 11).

This solution shows, however, still the same disadvantages as a straight canal from the lake to the sea, as enumerated above.

(*ii*) Widening Upputeru, including both Kanumas between 0 Km. and 32.2 Km. or 33.8 Km. (20 or 21 miles) near Pedalanka and making a straight cut from there to the sea. (See Plate 11).

This cut could link up with an existing straight cut that crosses Bantumilli canal about 8 Km. (5 miles) west of Lakshmipuram Lock by an under tunnel. Because this crossing for the Upputeru might prove to be difficult, an alternative would be shifting Lakshmipuram Lock to the west side of the new Upputeru straight cut and to have the area between the old and the new Upputeru irrigated separately by an inlet sluice from the new branch.

(*iii*) Widening and straightening Upputeru down to 45 Km or 46.7 Km. (miles 28 or 29) just upstream of confluence with Yenamadurru drain, and making a straight cut to the Bay of Bengal. (See Plate 11).

In this case it has to be decided whether in order to obviate the adverse effect of flood discharge of Yenamadurru drain backing up into Upputeru and reducing its discharging capacity a bund should be placed across the Upputeru immediately downstream of off-take of the straight cut.

(*b*) Stability of the outlet into the sea.

It is desirable to get an insight into the conditions required for stability of outlets into the Bay of Bengal. Some of the existing outlets seem to have travelled over quite a distance along the coast before they became more or less stabilised. others seem to have been barred by littora sand drift. In this connection, the solution given under (ii) above seems to have hopeful aspects because an existing outlet there has remained stable for more than 30 years already. But even here widening of the outlet and changing of its regime may change the situation. A straight cut near 45 Kms. or 46.7 Kms. (miles 28 or 29) as suggested under item (iii) would have the advantage that a large tidal basin would be created in the very wide part of Upputeru beyond the straight cut, and such a basin promote a rather strong tidal current in the straight cut during periods of low discharge, thus keeping the outlet and its debouchment into the sea at the required depth.

(*c*) Model tests described in Appendix H have shown that a discharge of about 18,500 cusecs at road bridge with lake level+7 ft can be passed through Upputeru by widening and deepening the river section, increasing the waterway of the road and railway bridges, removing the meanders and providing a 400 ft. wide straight cut near mile 29 into the sea. Model experiments have shown that for constructing a bund across the Upputeru near mile 29 to isolate Y Drain from the Upputeru in order to prevent the backing of water during floods so as to obtain a discharge of 7,500 cusecs at the road-bridge with lake level+7, a 400 ft. wide cut would be needed. Such a bund would however disturb the tidal regime during dry weather which has apparently maintained the present Upputeru with little or no silting. In addition, navigation facilities across the bund would have to be provided for fishing craft that use the river.

Considering all these factors, placing of the bund across the Upputeru for isolating Y Drain is not recommended.

6.5.1.3. An approximate estimate for improving the capacity of the Upputeru is about Rs. 8.5 crores for 425 cu. metres/sec (15,000 cusecs) capacity and Rs. 11.10 crores for 566 cu. metres sec (20,000 cusecs) capacity (Appendix J).

As mentioned earlier, it would be desirable for the capacity of the Upputeru to be improved to 566 cu. metres/ sec (20,000 cusecs) but as the work involved is very large and expensive, it would be advisable to increase the capacity to 425 cu. metres/sec (15,000 cusecs) in the first instance and to watch the effects before improving the capacity further to 20,000 cusecs. As the cost of land is rising every day due to increase in pressure on land, the land required for 20,000 cusecs capacity of the Upputeru may be acquired straight away.

6.5.1.4. At present the tides from the sea travel along the Upputeru upto about mile 20 during floods, and upto about mile 7 during dry season. With the proposed increase in the capacity of the Upputeru, it is likely that the tides might travel higher up particularly at times when the lake level is low, and it s not entirely inconceivable that these might even enter the lake, thereby adversely affecting the adjoining land due to salinity. It would therefore be advisable to keep a watch by making salinity observations, over the effect of the phased programme for increasing the capacity of the Upputeru. In case the tides are found to travel up beyond the road bridge, construction of a regulator with navigation lock at a suitable place on the Upputeru may have to be considered before carrying out the next phase of the programme.

6.5.2. PUMPING FROM THE KOLLERU LAKE.

The levels of the Kolleru lake can be lowered by increasing the discharge of the Upputeru by pumping. This proposal has been studied in fair detail for a pumping capcity of 10,000 cusecs. and 15,000 cusecs.

he carrying capacity of the Upputeru river and other works along the Upputeru would have to be improved to the same extent as discussed earlier *i.e.*, 15,000 cusecs at lake level of +7.00. (see plates 13 to 13c)

A pumping station for a capacity of 10,000/15,000 cs. and a regulator across the Upputeru will be required just below the confluence of the two Kanumas. In addition, a navigation lock would be necessary to allow the boat from the lake into the Upputeru river and sea. For studying the effect of pumping, it has been assumed that the pumping will commence when the lake starts rising above +4.00. The pumping would continue till the lake rises to a level at which the capacity of the Upputeru with gravity flow is 10,000 cs. If Upputeru were to be improved to 15,000 cs. capacity at +7.00 of the lake this condition would be reached at R. L. +5.82 and so pumping would continue till a level of +5.82 is reached in the lake and then it would be suspended and the regulator opened. It would again be resumed when the lake comes down to +5.82 and continued until lake reaches a level of +4.00. The routing study of 1964 floods has shown that lake would rise with such pumping to a maximum level of +8.51 against the level of +9.00 that would be reached without pumping. The period of submersion above +7.00 ft. would be reduced to 17 days against 22 days without pumping.

A rough estimate has been prepared for the cost of pumping scheme. The pumps would work for 60 days during a year like that of 1964. To keep the size of the pumping station within reasonable limits, it would be desirable to have pumps of 1,000 cs. capacity each. Pumps of such large capacity are not being manufactured in India at present. For running these pumps, 87,30,000 K.W.H. of power will be required for a year like 1964. The cost of this proposal has been estimated to be of the order of Rs. 3.73 crores exeluding the cost of improvements to Upputeru. The annual cost of pumping would come to about Rs. 49 lakhs. The abstract for various items is given in Appendix M.

A study of pumping 15,000 cs. instead of 10,000 cs. has also been made. With this capacity, the period of submersion above +7.00 for a year like that of 1964 reduces to 13 days. The cost of both capital as well as running charges have increased by about 41% and 43% respectively as compared with a pumping capacity of 10,000 cs. (Details are given in Appendix M1 and M2 in Vol. II).

The capital as well as the working cost of the proposal of pumping, merely to reduce the maximum level reached in peak flows or the number of days the lake level exceeds a level of +7.00 ft. during peak floods, is so high that such a proposal is not justified on economic considerations.

It may however, be mentioned that damage to crops occurs not only due to submersion but also due to drainage congestion which results in reduction in yields. Damage due to drainage congestion occurs when the lake level is +5.00 or more and this situation occurs even during years of normal average rainfall. During such period it may prove advantageous to keep the level of the lake low by pumping.

From the rainfall data of 22 years (1943 to 1964) available for Kolleru lake basin, a normal monsoon rainfall year has been worked out using the Theisson's Polygon method. From this it is seen that the mean weighted average monsoon rainfall in the catchment is 38.51 " which is nearly the same as in the year 1944 when the weighted average rainfall comes to 37.50." Therefore the year 1944 has been taken as normal average rainfall year.

During this year the gauge data for the lake was available on alternate days at irregular time intervals as in 1959. The daily gauge data available at Perantal-akanuma mouth(M 4/6) has been utilised to interpolate the gauge levels at Kolletikota. This has been plotted and gauge levels at regular intervals have been read. The rating curve of Upputeru for 1964 at the road bridge has been utilised for finding the in flows into the lake during this year.

Studies for pumping 6,000 cs. 8,000 cs. and 10,000 cs. have been made for this year of normal rainfall. During 1944 a lake level of +8.40 has been recorded. But by pumping 6,000 cs, 8,000 cs. and 10,000 cs. into the Upputeru (improved to 15,000 cs. at lake level +7.00) the lake level comes down to 6.92, 6.20 and 6.10 respectively and the duration of submergence at or above

+5.00 comes down from 103 days to 36 days for a pumping capacity of 6,000 cs, 29 days for 8,000 cs. and 28 days for 10,000 cs. whereas the period of pumping required would be 77 days, 74 days and 73 days for pumping 6.000 cs. 8.000 cs- and 10,000 cs. respectively. The capital cost would be of the order of Rs. 2.4 crores for 6,000 cs.pumping 3.06 crores for 8.000 cs. and 3.73 crores for 10,000 cs. The working cost for pumping 6,000 cs., 8,000 cs. and 10,000 cs. would be of the order of Rs. 31 lakhs, Rs. 41 lakhs and Rs. 49 lakhs respectively. From the comparative study of the details shown in Appendix-0, it may be seen that 8,000 cs. pumping scheme seems to be more useful and economical than 6,000 cs. or 10,000 cs. as the reduction in the lake level and period of submergence are more in this case of pumping 8,000 cs. than for pumping 6,000 cs. The effect on lake level and period of submergence as between 8,000 cs. and 10,000 cs. pumping is not appreciable. Therefore, 8,000 cs. pumping may be adopted for normal years.

It may be mentioned here that the lake level would have been further reduced had the Budameru diversion scheme been functioning during that year.

This would result in reclamation of more areas and consequent more and better crop.

The estimated cost of these pumping schemes are given in Appendix M3, M4 and M1.

6.5.3. OTHER SUGGESTIONS FOR REDUCING INUNDATION.

6.5.3.1. *Constructing bunds around Kolleru lake.*

The suggestion to reduce submergence from Kolleru lake by constructing bunds all around the lake either at 1.53 metres (+5 ft.) or at the 2.14 metres (+7 ft.) contour line has been examined. Constructing bunds on the 1.53 metres (+5 ft.) contour line would mean less amount of submerged area for storage of the flood waters. For accommodating discharge as flowed during the year of 1964, the lake would rise to a level of 4.3 metres (+14 ft.). If the bunds were constructed on the 2.14 metres (+7 ft.) contour, the water level would rise to 3.7 metres (+12 ft.). In this case, the areas submerged in the lake would be comparatively more than in the case of bunds on +5 ft. contour.

In both cases, the bunds would have to be very high and expensive and a considerable area would have to be used as borrow area for dike-building material. Building bunds may ease the requirements for discharge. It introduces, however, new difficulties.

During floods there generally blows a strong wind upto 35 knots velocity either from the west or from the east. On a wide lake like Kolleru, in periods of floods, the friction between air and water causes the top layers of the lake to travel to the leeward shore. In deep lakes this will not cause any harm since the water can travel back along the bottom and there will be no appreciable difference in water level between the windward and the leeward shore resulting from this wind action. In shallow lakes like Kolleru lake, however, the water is hampered in its way back and the result is that a substantial difference in water level can arise from a long lasting strong wind. This means that if the bunds were to be built, these bunds would have to be provided with a free board sufficient to withstand this set up due to wind. Besides free board such a strong wind as may be expected here lasting more than a day would not only cause the water level of the lake to attain certain slope, it would generate waves also. These waves reach the leeward bund and they will run up along its slope. For that reason again an extra free board would be necessary and since these waves have to dissipate their energy, they would strongly attack the slope of the bund. This means that the entire bund around the lake should have a free board of several feet, and the slope should be protected by an expensive stone pitching. But even if bunds have been built along the +7ft. contour line, with their crest at a level several feet above the calculated lake level of +12 ft. (say at +20 ft), then this will only mean that the surrounding area is safe during floods that are equal to or less severe than the 1964 flood. If, however, a higher flood occurs, this might well result in overtopping and ultimately in breaching of the bunds. Such a collapse of the bunds would be far more disastrous than graduall submergence without bunds.

In addition, the construction of bund would create other problems also. The water leval reaching such levels would require backwater bunds for considerable length and of adequate height along the inflowing drains, streams and rivers. Construction of high bunds along the Upputeru would also be required so as to contain the flowing water and save the marginal area. This would result in more drainage congestion along the Upputeru and risk of breaches. On a rough estimate, the cost of providing bunds at +5.00 contour line and other appurtenant works would be of the order of 7.0 crores excluding land acquisition. Considering the serious disadvantages of such a proposal, construction of contour embankments around the Kolleru lake for restricting the submerged area is not recommended.

6.5.4. SILTING OF KOLLERU LAKE :

A study of the maximum lake levels of the Kolleru lake show that during the last 10 years, the frequency of occurrence of high lake levels has been comparatively much higher than in the previous 39 years. This may be due to several factors. It may be that parts of the lake bed have been cultivated and separated from the lake by bunds; the valley storage formerly available in the inflowing rivers may have been reduced by the construction of marginal embankments ; or the reason may be gradual siltation of the lake due to normal silt brought by the inflowing streams augmented by deforestation or adoption of harmful practices of cultivation etc.

No contour surveys of the lake appears to have been carried out for a long time. The one existing is very old (see plate 9). Hence, it cannot be said whether this rise in lake levels during recent years is partly or wholly due to siltation or other causes.

It is necessary that a fresh contour survey of the lake be carried out immediately. In order to ascertain the rate of siltation, this survey be repeated every tenth year. It would be advisable that silt observations be made on the bigger streams like Budameru, Thammileru, Gunderu, Ramileru and Upputeru also.

CHAPTER VII—RECOMMENDATIONS.

The main recommendations emerging from the examination of various suggestions and proposals mentioned in the previous chapter are :

7.1 DRAINS OF DELTAIC AREA:

Most of the drains are small in size and short in length. There is no scope nor advantage in having any detention reservoir or diversion in these drains. However, on some drains which submerge large areas during flood conditions can be improved by deepening and widening to suitable sections. All drains should be brought to their design section and maintained in that condition.

7.2 BUDAMERU RIVER.

7.2.1 (*a*) DIVERSION CHANNEL—

(*i*) The present diversion channel has been beneficial. Increasing the discharging capacity of this diversion or the construction of another diversion channel to secure any substantial reduction of flood damage or submergence are not recommended. Till the construction of reservoirs bye-pass be provided in the embankments up-stream of the Diversion for passing the water in excess of the capacity of the Diversion and regulator.

7.2.2. (*b*) DETENTION RESERVOIRS—

(*i*) A reservoir or reservoirs for storage of flood waters having a flood storage capacity of about 2,000 m.cft. be provided. The reservoirs should be located as near to the diversion site as possible, and should preferably be on the main stream.

(*ii*) The capacities of the Brahmayyalingam tank and Saggeru Amani tank be increased so as to provide a flood absorption capacity of 500 m.cft. or more.

7.2 3. (*c*) OTHER MEASURES—

(*i*) A straight cut in the Budameru in the loop near Vijayawada with flood embankments tied to high grounds on both ends be provided.

(*ii*) The existing embankments be raised and strengthened wherever necessary.

7.3. THAMMILERU RIVER

7.3.1. (*a*) RESERVOIRS—

A reservoir at Errampalli with 3,000 m.cft. capacity for flood control in addition to any capacity required for irrigation be provided.

7.3.2. (*b*) OTHER MEASURES

(*i*) Adequate flood embankments along the river in the vicinity of Ellore town be provided.

(*ii*) The Waterway under the Railway bridge on the East Thammileru be suitably increased.

(*iii*) The capacity of East Thammileru escape at its crossing with Ellore Canal be improved by lowering the crest and/or increasing the waterway.

7.4. RAMILERU RIVER AND GUNDERU RIVER—

Reservoirs on these rivers would not be of much use for Kolleru flood relief but they may be useful for irrigation purposes and also for preventing submersion of marginal lands along its course.

7.5. YERRAKALVA RIVER—

7.5.1. (*a*) DIVERSION—

The proposal of diverting water of Yerrakalva from a suitable site Up-Stream of Anantapalli road bridge into the Godavari is technically feasible but uneconomical.

7.5.2. RESERVOIRS—

A reservoir or reservoirs of an effective storage capacity of 3,000 to 4,000 m.cft. for flood control, at Anumunilanka or higher up at Appalarajugudem or at both be provided. A reservoir on Byneru may also be considered.

7.6. UPPUTERU RIVER—

(*i*) The capacity of the Upputeru may be increased to 20,000 cusecs. In the first instance, excavation may be done for 15,000 cusecs.

(*ii*) A straight cut into the sea be provided near mile 29 of the Upputeru which is just upstream of the confluence of the Yenamadurra drain.

While carrying out improvements in the capacity of the Upputeru, careful watch be kept on the travel of sea tides by regular salinity tests. In case there is any indication of the tide travelling beyond the bridge, construction of a regulator with navigation lock arrangements as a suitable site on the Upputeru be considered before carrying out the next phase of the programme.

(*iii*) There should be flood embankments along the Upputeru on both banks to prevent spilling on to marginal lands. These embankments be constructed from the earth obtained from improvement of the Upputeru itself.

(*iv*) There should be no bund separating Yenamadurru drain from the straight cut of the Upputeru.

(*v*) Embankments be provided for a suitable length along the drains falling into the Upputeru against back-water. Where such embankments are not practicable, sluices/lock gates be provided. Pumping arrangements for relieving congestion during high level conditions of the Upputeru may have to be provided on major drains.

(*vi*) Four Cutter suction dredgers of 22" to 24" size with about 1,000 ft. floating and shore pipe line and other ancillary equipment such as tugs, barges, etc., be obtained for excavation as well as for maintenance of the Upputeru. Two of these dredgers should be sea worthy.

7.7. KOLLERU LAKE—

(*i*) The capital as well as running cost for the proposal of pumping from the Kolleru Lake into the Upputeru, merely to reduce the maximum level that may be reached in a year of high rainfall like 1964, would not be economically Justified. However, the studies have shown that during years of average rainfall like 1944, if pumping from the Kolleru lake for a discharge upto 3,000 cusecs is adopted, the lake will rise to a maximum level lower than +6.2 ft. (due to Budameru diversion). This will mean reclamation of more areas and consequently more and better crop. The studies with the Budameru diversion functioning may be carried out in respect of a number of normal or nearly normal years to obtain the optimum size of Pumping Station and economics there of.

(*ii*) The proposal of putting bunds around the Kolleru lake to prevent submergence of marginal lands is very expensive, involves risk of disastrous breaches, aggravates drainage congestion, so is not recommended.

(*iii*) Survey of the Kolleru lake for ascertaining its capacity be carried out immediately. This be repeated every 10th year for finding out rate of siltation. Silt observations be also made on the bigger streams like Budameru, Thammileru, Gunderu, Ramileru and Upputeru.

7.8. APPROXIMATE COST OF RECOMMENDED MEASURES—

I. RESERVOIRS :

	Rupees in lakhs.
For Flood Control.—	
(*i*) Budameru reservoirs (2,000 to 3,000 m.cft.)	**112.00**
(*ii*) Thammileru—at Errampalli (3,000 m.cft. at M.W.L.)	**200.00**
(*iii*) Yerrakalva—at Anumunilanka (4,680 m.cft. at F.R.L.)	**260.00**
	572.00

	Rs. in lakhs
II. Improving Capacity of Upputeru including Straight Cut—	
(*i*) For 15,000 cusecs Rs. 820.00 lakhs	
(*ii*) For 15,000 cusecs but land for 20,000 cusecs capacity	850.00
	850.00
III. Other Measures :	
Budameru—	
(*i*) Excavating a straight cut near Vijayawada	31.00
(*ii*) Increasing capacity of Brahmayyalingam and adjoining tank (540 m.cft.) ..	8.00
(*iii*) Raising and strengthening flood banks (cost assumed)	10.00
Thammileru—	
(*i*) Constructing embankments near Ellore town (cost assumed)	10.00
(*ii*) Improving the waterways of escape across the East Thammileru and also Railway Bridge (cost assumed)	20.00
	79.00
Grand Total ..	1501.00

Say Rs. 15 crores.

CHAPTER VIII—PRIORITY OF WORKS.

8.1. The total approximate cost of the works as recommended comes to Rs. 15 crores. Improving the capacity of the Upputeru to 15,000 cusecs and excavating straight cut into the sea would involve about 400 million cubic feet of excavation of earth. Atleast 2/3rd of this earth work is expected to be under water or in swampy, waterlogged areas. This will necessarily have to be done by dredgers. For maintenance of the Upputeru also dredgers would be necessary. Due to limitation of funds and equipment, the work may have to be spread over a number of years. It will, therefore, be necessary to take up these works in order of priority.

8.2. UPPUTERU—

The first priority be given to the work of improvement of the Upputeru. For this, it is suggested that in the first instance 2 big dredgers of 22"-24" size, Cutter Suction type, with about 1,000 ft. of floating and shore pipe lines be procured. One of the two dredgers should be sea worthy. These dredgers and other ancillary equipment like tugs, barges, etc., may cost Rs. 1.5 crores. Along with the procurement of this equipment, the land which is required for improvement of the Upputeru to 20,000 cusecs capacity at the road bridge at the lake level at +7.00ft. should also be acquired. This is desirable because the cost of land is rising and also there will be more and more difficulties in acquisition with the increased pressure on land. Simultaneously with the above procurement of equipment and acquisition of land arrangements may be made to take up execution of the work of improvement of Upputeru according to the following programme —

(1) Stage I—

Phase I.

The sectional area of the Upputeru be improved in the entire length for passing 10,000 cusecs at roadbridge with the lake level at +7.00 ft. and a straight cut upto the sea 100 ft. wide be provided. Steps for widening the Railway and road bridges for passing 20,000 cusecs capacity with level at +7.00 be initiated.

Phase II.

In the second phase the section of the Upputeru be improved for passing 12,500 cusecs at road bridge with the lake level at +7.00 and the straight cut be widened to 200 ft.

Phase III.

In the third phase, the section of the Upputeru be increased for passing 15,000 cusecs at the road bridge with lake level at +7.00 and the cut be widened to 400 ft.

(2) Stage II.

Section of the Upputeru be increased to pass 20,000 cusecs at road bridge with the lake level at +7.00.

The cross sections required for each of these phases should be worked out by the State Government and got confirmed by model experiments from the Research Station, Poona.

8.3. THAMMILERU.

On the Thammileru the first priority should be for the construction of marginal embankments on its East Branch for protection of Ellore town. The work of improving the waterway at the escape and the Railway bridge be also given first priority. Construction of reservoir at Errampalli be taken in hand simultaneously.

8.4. BUDAMERU.

The first priority be given to raising and strengthening of the existing embankments. With this the capacity of Brahmayyalingam and the adjoining tanks be also increased as first priority.

The excavation of straight cut at Vijayawada be taken up as second priority. Third priority be given to the construction of one of the reservoirs. Fourth priority should be given to the other reservoir.

8.5. DRAINS FALLING INTO THE KOLLERU LAKE.

The work of improving the drains falling into the Kolleru lake should be given priority.

8.6. YERRAKALVA.

On the Yerrakalva, the reservoir at Anumunilanka be given priority. But it is suggested that it should have second priority inter-se when measures for the entire Kolleru basin are taken account.

8.7. INTER-SE PRIORITY.

Out of the above the following works are recommended to be taken up immediately :—

(*i*) Improvement of drains.

(*ii*) Works for protection of Ellore Town.

(*iii*) Procurement of dredgers and acquisition of land and construction of Phase I for Upputeru.

(*iv*) Reservoir at Errampalli on the Thammileru.

PART III

Drains of Krishna Western Delta in Guntur District

CHAPTER I—MAJOR DRAINS AND DRAINAGE SYSTEM.

1.1. GENERAL DESCRIPTION OF IRRIGATION SYSTEM IN KRISHNA WESTERN DELTA.

1.1.1. The Krishna Western Delta (here-in-after called K.W. Delta) comprises the taluks of Repalle, Tenali, Papatla and a portion of Guntur, all of which lie in Guntur district. The total area irrigated during the Kharif season in this section of the Krishna delta system is 1990Sq. Kms.(4.92 lakh acres). About one-fourth of the ayacut is given irrigation during the rabi season as well. The area is irrigated through the Branch Canals *viz.,* Bank Nizampatnam and Commamur canals which take off from the Krishna Western Main Canal. The K.W. Main canal takes off on the right bank of the river Krishna from above the Prakasam Barrage near Vijayawada. The Main canal as well as the three branch canals are navigable.

1.1.2. The Bank Canal branches off from the Main Canal between K.M.s. 11 and 13 (miles 7 and 8) on the left bank and runs in a south-easterly direction for a distance of about 23K.M.(14 Miles). From about K.M. 23 (14 miles) to the tail end it runs parallel to and in rear of the right flood bank of the river Krishna. The total length of this Branch canal from the bifurcation point is about 74 K.M. (46 miles).

1.1.3. The Nizampatnam and Commamur canals branch off from the main canal between about K.M. 18 and 19 (mile 11 and 12) at Commamur lock about 3 K.Ms. (2 miles) to the north of Duggirala in Tenali Taluk. The Nizampatnam canal runs from North to South through the middle of the delta area for a total distance of about 47 K.Ms. (29 miles) below the place of bifurcation and has its tail-end lock near Nizampatnam in Repalli taluk. This is a tidal lock being connected to the Bay of Bengal. This canal runs over the ridge with irrigation from it on both sides.

1.1.4. The Commamur canal is a contour canal aligned along the western boundary of K.W. Delta system and is practically the dividing line between the upland and deltaic areas in Guntur district. It runs as an irrigation cum-navigation canal for a total length of about 95 K.Ms. (59 miles) from the place of its bifurcation upto Pedaganjam lock in Bapatla taluk. Below this lock, it goes by the name of Buckingham Canal parallel to the coastal line right upto Madras, purely as a navigation canal. Prior to the development of Rail and Road transport, this canal used to be the most important mode of transport for both men and merchandise.

1.1.5. Though the K.W. Delta system was originally intended to irrigate an area of 3,00,000 acres, subsequently due to the growing demand from the people for further development of irrigation and with a view to step up food production and also to increase the State's income on land revenue, several schems had been executed from time to time gradually increasing the area irrigated to the present figure of 1990 sq. Kms. (4.92 lakh acres).

1.2 TOPOGRAPHY AND DRAINAGE CHARACTERISTICS.

1.2.1 The general slope of the country in upland area extending from Eastern ghats to the delta head is nearly 1 in 500. But from the head of the delta to the sea, the slope is even upto 1 in 7,500 and the country is low-lying having poor drainage characteristics. The drainage and flood waters from the irrigated areas in the delta find their way to the sea with considerable difficulty beacause of the flat nature of the country.

1.2.2 For irrigation, a network of canals as briefly described above had to be excavated in this area. Of these, the Commamur Canal, being a contour canal had to be constructed across a number of upland drains for which cross drainage works such as inlets, outlets and under-tunnels were built. However, this formed the first obstruction to the natural drainage in the region. Subsequently for providing transport facilities in this area, the southern railway and the National Highway No. 5 had to be built through the delta area parallel to the coastal line and across the natural valleys, thus forming the second obstruction to the drainage flow. The third obstruction ot the natural drainage is caused by the sand dunes that get formed near the coast at the mouth of the natural streams due to littoral drift of sand.

1.2.3 Further, as the main crop from irrigation is paddy considerable part of the total water applied to the fields through the net work of canals has had to be drained in addition to the run off from the upland and deltaic catchments of the various streams during the monsoon season. Thus, with the increase in the total volume of water to be drained and with the flat nature of the country and obstructions caused to the natural drainage by the contour canal, roads and railway embankments, the areas are frequently subjected to drainage congestion especially in the monsoon season every year. This results in inundation of valuable irrigated and cultivated areas in the delta and uplands adjoining it over long periods causing heavy damage to standing crops and other properties.

1.3 DRAINAGE SYSTEM IN K.W. DELTA.

The area lying in the K.W. Delta has a net work of five main drainage systems. The area lying between the Commamur Canal and Nizampatnam Canal and that between Commamur Canal and the Bay of Bengal is being drained by three drainage systems *viz.*,Romperu, Nallamada and Tungabhadra. These three drainages have both upland and deltaic catchments. The area between the Nizampatnam and Bank Canals is served by two drainage systems *viz.*, Repalle and Bhattiprolu. These drains have purely deltaic catchments. A sketch map showing the irrigation and drainage systems in K.W. Delta area is enclosed (*vide Plate No.* 4).

1.4 MAJOR DRAINS IN K.W. DELTA.

1.4.1 Romperu Drainage System.

The Romperu system carries the flood waters from the upland drains namely Saki affluent Parachuruvagu, Aleru, Apperu and Emileru. The aggregate catchment of the upland drains crossing the Commamur canal and flowing into the Romperu drain is 1050 sq.K.Ms. (405 sq. miles). The deltaic catchment drained by the system is another 235 sq. K.M. (91 sq. miles). The Romperu drainage system was improved in the years 1948 to 1956 at a cost of Rs. 1.2 crores. In this system, two separate drains were excavated from below the Karamchedu under tunnel the left one going towards north-east while the right one towards south-west. The right arm flows along the Karamchedu—Chirala road and crosses this road through a cause-way at K.M. 5.63 (miles 3/4 furlong) and runs in south-westerly direction till it joins the sea near Pedaganjam. A part of the flood waters is also diverted through a straight cut excavated at K.M. 15.5 (mile 9/5) into Kunderu drain which in turn joins the sea near Chinaganjam. The left arm also flow parallel to the Karamchedu Chirala road for about 5K.Ms.(3 miles)whereafter it flows in a north easterly direction till its cross the road coming from Nallamada lock. Thereafter the flood waters are led into the Bay of Bengal through the Perali drain. The peak flow of flood waters discharged through this drainage system into the sea is roughly estimated as 396 cu. metres/sec. (14,000 cusecs).

1.4.2. Nallamada drain.

This drain starts at an elevation of 413 metres (1355 ft.) above M.S.L. in Pasamkonda Reserve forest situated at 4.83 K.M. (3 miles) to the South-West of Nakarikallu village in Narasaraopet taluk in Guntur district and is another important upland drain crossing the Commamur canal at K.M. 65.28 (M/40-4-400 ft.) through an under tunnel consisting of 4 vents of size 4.88 M. × 1.3 M. (16'-0" × 5'-0"). The catchment area of this drain, including all its tributaries such as Nakkavagu Lower Arm, Kondavagu Upper and Lower arms, is about 1045 sq. K.M. (402 sq. miles) up to the point of crossing the canal. The Nakkavagu lower arm which has a catchment area of 171 sq. K.Ms. (66 Sq. miles) flows parallel to Commamur canal from its about K. Ms. 58 (mile 36) on the Western side and joins Nallamada drain just above the under tunnel. About 6 K. Ms. (4 miles) distance below the under tunnel, the Nallamada drain receives Pundla affluent which comes from K.M. 58.34 (mile 36+17 chains) of the left bank of Commamur Canal. This drain flows over a distance of 10.44 K. Ms.(6 miles 4 furlongs) and drains a catchment of 196.5 sq. K.Ms. (76 sq. miles) of which 31.1 sq. K.Ms. (12 sq. miles) is deltaic. After crossing the southern railway line, the Nallamada drain joins the Bay of Bengal through the straight cut called "Nallamada diversion" before excavation of which it used to join the East Tungabhadra drain. The flood discharge' observed in the Nallamada straight cut at "Greg Bridge" on Bapatla - Chandole Road is about 200 cu. metre/second (7,000 cusecs).

1.4.3. Tungabhadra Drain.

This originates from Koretapadu village near Guntur Town and flows under the name of "Guntur Nala" upto its crossing with Commamur canal between K. M. 32.2 and 33.8 (miles 20 and 21) of the latter. Below the canal crossing, the drain goes by the name of "Tungabhadra drain" and flows almost parallel to southern Railway line upto Machavaram where it crosses the latter. Below the railway bridge, the drain is called "East Tungabhadra drain" upto its infall into the Bay of Bengal at a place which is about a mile south-west of Nizampatnam village in Repalle taluk. The total length of the T.B. Drain is 54.75 K.Ms.(34 miles) below the Commamur canal crossing. A number of local drains and affluents join this drain during its course. The Konduru affluent which is purely a deltaic drain and the Kollimerla drain which has considerable upland catchment are two important drains that join the Tungabhadra drain above the Machavaram Railway Bridge. The Yazali affluent and Tenali drain join the E.T.B. drain in the reach below the Railway bridge. This drain has a total catchment area of 1450 sq. K.M. (560 sq. miles) of which 590 sq. K. M. (228 sq. miles) is upland and the rest is deltaic. It is designed for carrying a maximum flood discharge of about 200 cu. metres/second (7,000 c/s) at its tail.

The Kollimerla drain joins Tungabhadra drain near Machavaram. The drain originates at an elevation of 510 metres (1675 ft.) above M.S.L. in the Kondavidu Reserve Forest of Guntur District and flows through the ayacut lands lying between the No. 2 and No. 3 branch channels of Appapuram main channel on the Western side of Commamur canal. This drain receives upland drainage through the Nakkavagu upper arm before it crosses Commamur canal through an under tunnel near Kollimerla village. Below the Commamur canal crossing the drain flows in a south easterly direction for about 8 K.M.(5miles)during the course of which it receives the Jupudi and Doppalapudi affluents coming from North-eastern side. Thereafter, the drain takes a turn towards southern direction and flows almost parallel to Guntur - Bapatla road till about 1.0 K.M. (1/2 mile) beyond Nandur village where it takes right angled bend towards east and crosses the above road before joining the Tungabhadra drain just above the Machavaram Railway bridge. In this reach it receives drainage both from upland and deltaic catchments through Pandrapadu affluent joining it near Vallabharavupalem. The length of the drain from below the Commamur canal crossing upto its confluence with T. B. Drain is about 11 miles. It has got an upland catchment of 715 sq. Kms. (276 sq. miles) above the Kollimerla under tunnel at K.M. 50.63 (31 miles and 3 furlongs). of Commamur canal.

1.4.4. Repalle Main Drain:

The Repalle Main drain takes its origin near a place called Pidaparru in Tenali Taluk and together with the Bhattiprolu drain serves the entire irrigated area lying between the Nizampatnam and Bank canals of the K.W. Delta system. This drain is nearly 51 K.M. (32 miles) long and has total catchment area of about 520 sq. Kms. (201 sq. miles) all of which is deltaic. It crosses the Tenali-Repalle branch Railway line near a place called Jampani. Immediately after, it also crosses the Tenali-Kolluru road. The drain crosses the Bhattiprolu-Tsandole road near Gudavalli village. In between these two road crossings, it receives drainage through Kuchipudi and Langatagumta affluents joining from the right side and through Kangala affluent coming from left side. The last important tributary is the Nagaram south drain which links this drain with Bhattiprolu drain and joins above its crossing the Nizampatnam-Repalle road. Another minor drain by name pragnam [illegible] also joins the Repalle main drain before it finally empties itself into the Bay of Bengal near Dindi village limits through a straight cut 3½ furlongs long excavated recently. The R.M. drain straight cut is designed to carry about 113 cu. metres/second (4,000 c/s) under M.F.L. conditions.

1.4.5: Bhattiprolu drain.

This is also one of the major deltaic drains having no upland catchment. It starts from near Butmalli village, in Tenali taluk and flows over a total distance of 43.5 K. M. (27 miles) before finally emptying into the sea near Kottapalem in Repalle taluk. The Drain flows parallel to Tenali Repalle Branch Railway line between Kollur Road and Bhattiprolu stations and turning towards Western direction it also crosses the railway line some where near Pallikona R. S. Thereafter it flows in a southern direction and crosses the Voleru-Nizampatnam and Repalle-Nizampatnam road in quick succession and flows with serpentine bends before joining the sea near Kottapalem. This drain collects drainage chiefly through Suripalli affluent, Edulakalva affluent, Kuchinapudi affluent and Amudaladivi drain joining from the right side and through Revakampadu affluent and Jagajeru affluents joining from the leftside. It drains a total catchment area of 407 sq.K.M. (157 miles). The maximum flood discharge observed at Isukapalli aqueduct during 1964 floods was about 62 cu. metres/second (2,200 cusecs).

CHAPTER II—RAINFALL PATTERN.

2.1. The average annual rainfall in the K.W. Delta region is about 37 inches (94 cms.). The area receives rainfall under the influence of both the South-West (June to September) and the North-East monsoons (October to December). Generally the area experiences cyclonic weather during the months of September to December. The distribution of rainfall in the K.W. delta region in a normal year is given in Table No. 3.1 monthwise :—

TABLE NO. 3.1.

Month	*Rain fall in millimeters (inches)*
June	101.5 (4.0)
July	152.5 (6.0)
August	152.5 (6.0)
September	152.5 (6.0)
October	178.0 (7.0)
November	114.5 (4.5)
December	15.2 (0.6)
January	7.7 (0.3)
February	10.2 (0.4)
March	10.2 (0.4)
April	15.2 (0.6)
May	38.0 (1.5)
Total ..	948.0 (37.3)

2.2. A statement showing the rainfall from January to May, June to October and November to December each year for 13 Stations in Krishna Western Delta from 1945 to 1964 is given in Appendix D (*ii*). The rainfall statement for the same period mentioned above is also given in Appendix-D (*iii*). Krishna Eastern Delta.

CHAPTER III—FLOODS AND FLOOD PROBLEMS

3.1. The drainage problem becomes generally important in areas where water is given for irrigation as in the case of Krishna and Godavari delta areas in Andhra Pradesh. While developing irrigation on a large scale, the drainage problem has also to be simultaneously tackled. Without a good drainage, no irrigation will be permanent. Now, coming specifically to the drainage problems in the Krishna Western Delta, these are mainly due to (*i*) Obstruction caused to the upland drains by the Commamur Canal and consequent breaches caused to the latter, (*ii*) Obstructions caused by Railway and Road embankments and by sand dunes, (*iii*) inadequate water way available in the existing drainage system to afford quick relief from submersion of flood waters and (*iv*) flat surface falls obtaining because of the flat nature of topography in the delta and due to long and tortuous courses which the drains take before finally emptying into the sea. Though the drainage problems are experienced through out the delta, the problem is more acute in Bapatla taluk as most of the drains carrying the water from the upland taluks find their way through the delta areas of this taluk before finally joining the Bay of Bengal. Most of the upland drainages are intercepted by Commamur Canal from Kollimerla lock up to Pedaganjam lock (M 32 to M 71) within Bapatla taluk limits. These intercepted drains have no direct outlet into the sea but have to collect themselves eighter into Romperu or Nallamada, Kollimerla and Tungabhadra drains and flow along into the sea. The upland drains cross Commamur canal either by inlets and outlets or by under tunnels and syphon aqueducts. As the cross drainage works provided for some of these drains are not having adequate waterway to pass down their maximum flood discharge, there is inundation of cultivable uplands situated adjacent to the Commamur canal on its Western side. The ryots of these areas often make cuts in the canal on both the banks during high floods to prevent their lands from prolonged submersion. The irrigated areas lying towards east of Commamur canal are subject to sudden and extensive flooding due to the breaches thus caused especially because the existing drainage system in the delta is inadequate to meet a situation of this magnitude. The flood problem becomes very acute since most of these upland drains receive their maximum floods simultaneously. The Railway and road embankments in the area also cause obstruction to the rapid flow of the rain waters. The sand dunes near the coast obstruct the free flow to the sea. The sections of the drains are also inadequate to carry the discharge during heavy rains. Their hydraulic condition due to poor maintenance is very deteriorated. The drains are frequently very tortuous. The surface slope of the land in the coastal areas is very flat. All these factors retard flow of the water and accentuate drainage congestion in the rich irrigated delta.

CHAPTER IV—DAMAGE BY FLOODS

4.1. Due to inundation caused over long periods by the flood water in the various upland and deltaic drains in the Krishna Western Delta system, extensive damage occurs to the standing crops and other valuable properties and public utilities resulting in heavy financial losses year after year. The Government are foregoing land revenue by way of grant of remissions to the lands affected by floods. Details of the amounts sanctioned by way of remission, during the last four faslies in the Guntur district as furnished by the District Collector are as shown below :—

Year	*Amount of Remission Granted.*
	Rs.
1959-60	50,478
1960-61	38,117
1961-62	2,05,863
1962-63	8,75,006

Apart from the revenue lost due to the floods, the country is losing foodgrains valued at millions of rupees during these days of scarcity.

4.2. Flood damage particulars were supplied for Krishna Western Delta by the State P.W.D. for 10 years from 1955 to 1964. From this, it has been seen that on an average an area of about 64,000 acres was affected by floods every year. About 48,000 metric tonnes of foodgrains valued at Rs. 1.82 crores were also lost annually due to floods.

Out of these ten years (1955 to 1964) 1964 was the worst affected year when about 1,20,000 acres were inundated by flood waters. During this year, about 90,000 metric tonnes of foodgrains valued at Rs. 3.42 crores were lost. The next worst affected year was 1963 when an area of about 95,000 acres were inundated. Foodgrains of about 71,000 metric tonnes valued at Rs. 2.70 crores were lost by floods. A statement showing flood damage particulars for Krishna Western Delta is given in Appendix F (*ii*).

CHAPTER V—REVIEW OF WORKS ALREADY CARRIED OUT AND CONTEMPLATED

5.1 The improvements already carried out for some of the major drains in K.W. delta system are briefly mentioned below :—

5.1.1. Romperu System:

Improvements to Romperu Drainage system were carried out from 1948 to 1956 at a cost of Rs. 1.2 crores. Under this scheme two separate drains were excavated from below the Karamchedu under-tunnel. One drain goes to the left and the other to the right. The right arm of the drain flows parallel to Karamchedu-Chirala road and crosses the same by a cause-way built at KM. 5.6 (M 3/4) and runs south-west from this point joining the sea near Pedaganjam. At KM. 15.5 (M 9/5) a straight cut was excavated to join Kunderu which in turn goes to meet the sea near Chinaganjam. This straight cut is observed to function satisfactorily. The left arm flows towards east and flows to sea through the Perali drain. Improvements to the Romperu drain and Perali drain were carried out by way of widening, deepening and forming flood banks on either side, besides construction of road bridges, regulators and railway bridges, etc., wherever found, necessary.

Though the improvements already carried out have been able to give partial relief to the lands in the region, still flood problems are frequently experienced as the drainage system has since been silted up heavily.

5.1.2. Nallamada Drain :

This was originally a tributary to E.T.B. drain. But in order to give partial relief from the flood problems a straight cut into the sea, called Nallamada diversion was excavated round about the year 1929. This diversion channel is reported to be functioning well.

5.1.3. Tungabhadra Drain :

The East Tungabhadra drain has previously been improved in the reaches from KM. 32.6 to 54.8 (M 20/2 to 34/0) *i.e.* from the Machavaram Railway bridge up to its confluence with the Bay of Bengal. These improvements, carried out during the years from 1958 to 1961 at a cost of Rs. 23.6 lakhs, comprised of widening the drain and forming flood banks on either side.

The above improvements carried out to E.T.B. drain appear to have had an adverse effect on the Kollimerla drain and Tungabhadra drain upstream of Machavaram Railway bridge since the extent and duration of submergence by flood waters in these drains is found to have increased. This is obviously due to the fact that the E.T.B. drain which used to flow over a wide area is now contained by the flood banks formed under the above improvement scheme. It is therefore, felt necessary to further improve the E.T.B. drain and remove obstructions.

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CHAPTER VI—PRESENT CONDITION OF THE DRAINS

6.1. The present condition and functioning of some of the major drains in Krishna Western Delta system are briefly given below :—

6.1.1. Tungabhadra Drain :

This drain is narrow with too many curves in its course. During high floods, in the absence of flood banks in the reach KM. 0 to 32.2 (M 0/0 to 20), it overflows its margins at a number of places resulting in inundation of standing crops over long periods. Due to high flood levels, the waters also back up for considerable distances, into the other drains joining it, making their funtion ineffective. The duration of the floods in this drain as experienced during the past three years extends over a period of three weeks. The depth of flood waters in the fields has been observed to be 3 to 4 ft. in the villages of Mulukuduru, Chundurupalli, Ponnur, etc. The drainage course from KM. 0 to 32.6 (M 0/0 to 20/2) is very narrow. Though the reach below the Machavaram Railway bridge from KM. 32.6 (M 20/2) up to its infall into the sea (called the E.T.B. drain) was improved, there are still several shoals in the bed of the drain specially from KM. 45 to 46.6(M 28/0 to 29/0) *i.e.*, from the confluence of the Tenali drain to Ralla Kalva Straight cut. The floods in this reach are aggravated due to obstruction caused by these shoals.

There are in all 9 masonry works on this drain along its course and a statement showing the M. F. Ls'. of the drain recorded at these places during 1964 flood season together with corresponding designed M.F.L.'s is given in Appendix N. It is obvious that the observed M.F.L.'s are very much higher than the designed flood levels at every one of these sites.

6.1.2. Kollimerla Drain :

This receives upland drainage mostly through Nakkavagu Upper arm which passes through the Kollimerla under tunnel built at KM. 50.60 (M 31-3-396 ft.) of Commamur canal. This under tunnel consists of 11 vents of size 6.02 metres × 2.16 metres (20′-0″×7′-2″). The computed maximum flood discharge at the site is 540 cu. metres/ Sec (19,070 cusecs). The drain has very flow banks from below the Kollimerla under tunnel to Machavaram Railway bridge where it joins the Tungabhadra drain. Further, there are very large shoals in the drain. The drainage course is stated to be shallow and narrow. Therefore, during flood times the water overflows the low banks and submerges vast areas of paddy fields over prolonged periods, causing damage and hardship to the people living in the areas.

6.1.3. Nallamada Drain :

This collects upland drainage through Nakkavagu lower arm, Kondavagu upper and lower arms and crosses the Commamur canal at KM. 65.0 (M 40-4-00) through an under tunnel consisting of 4 vents of size 4.9 metres × 1.53 metres (16′-0″ × 5′-0″). The available vent way is said to be insufficient to pass down the maximum flood discharge coming from an upland catchment area of 1040 sq. kms. (402 sq. miles) without causing marginal submersion of cultivated lands over prolonged periods. It is stated that the drain is narrow and does not have banks with the result that during flood time, it overflows its margins and causes submersion of irrigated paddy fields causing extensive damages to standing crops. There are also large shoals formed in the drain causing obstruction to flow of water.

The Nakkavagu lower arm at present flows parallel to Commamur canal on the right bank from 58.8 KM. (M 36/2) and joins the Nallamada drain just above the under tunnel.

6.1.4. Romperu System :

The Romperu system carries the flood discharges from the upland drains namely Saki, Parachuruvagu, Karamcheduvagu, Swarna affluent, Aleru, Apperu and Emileru. All these drains including the Romperu system are heavily silted up.

The above mentioned upland drains cause extensive flooding over the lands situated to the west of Commamur canal. This is stated to be due to the inadequate waterway provided at the cross drainage works built across the canal for them.

The present drainage system is found to be inadequate to handle the voluminous quantity of flood flows brought from the upland and deltaic catchments. The maximum duration of submergence of lands is observed to be 18 to 21 days and the depth of submersion ranges from 3 to 4 ft.

The sill levels of the causeway vents built across Romperu right arm for the Karamchedu and Santharavur roads are said to be 2 ft. higher than the bed level of the drain at the places and the drain is therefore observed to be getting choked up easily.

6.1.5. Yazali Drain :

This is one of the important drains in the Krishna Western delta and joins E.T.B. drain at about 2 miles below the Machavaram Railway bridge. It drains a deltaic catchment of about 20 sq. miles lying between the R.B. of Aramanda channel and L.B. of Alavala tank channel. The existing course of the drain is stated to be very narrow and it is not functioning well due to insufficient bed width and silting up of the drain bed. Besides, the flood waters of E.T.B. drain back up into this drain in high floods, thus making the latter ineffective.

6.1.6. Repalle Main Drain :

There are no banks to this drain from K.M. 0. to 6.4 (M 0/0 to 4/0) and the banks available in the reach from KM 7.1 to 14.1 (M 4/3 to 8/6) are low and not to standards. The flood waters therefore spill over the margins causing submersion of lands on either side of the drain.

The drain runs with serpentine bends in the village limits of Amudalapalli village resulting in heading up of flood waters and increasing the duration of flood.

6.1.7 Bhattiprolu Drain :

This drain collects drainage from an area of 157 sq. miles which is purely deltaic. When this drain is in floods, the ayacut lands in the village limits of Chinapulivarru, Tadigiri Padu, Pedapulivarru, Allaparru, Ullipalem and Adavuladeevi, etc. villages get submerged causing damages to standing crops since there are no banks for the drain below KM. 8.0 (M5/0) and the banks available in the reach K.M. 8.0 to 15.5(M 5/0 to 9/5) and for a length of 3.2. KM. (2 miles) above the under tunnel across Vellatur channel are low and not to the required standards.

The drain runs in zig-zag course with a number of circuitous bends in the lower reaches having a length of about 9.6 to 11.3 KMs (6 to 7 miles) upto its infall into the sea. Due to these serpentine bends and tortuous course, the flood waters are found to head up causing submersion of lands on the upstream side besides prolonging the duration of flood which lasts upto 2 to 3 weeks.

6.1.8. Nagaram South Drain :

This runs for a length of 6 miles 5 furlongs linking Bhattiprolu drain to Repalle main drain and drains deltaic catchment of about 31.1 sq. KMs(12 sq. miles). The duration of flood during 1964 season lasted for almost 21 days. When in flood, the Repalle Main drain backs up into this drain making the latter ineffective. As a resu't, the flood waters overflow the margins and submerge the adjoining areas affecting the standing crops.

CHAPTER VII—SUGGESTIONS MADE BY THE PUBLIC.

7.1. During the course of site inspection by the Committee, several members of State Legislature, individual ryots, kisan organisations, political parties and institutions submitted representations and memoranda bringing forth the flood problems experienced in the concerned localities and the recurring damage caused to standing crops and other properties due to the same. The representations also contain certain suggestions regarding the remedial measures. The important and salient suggestions contained in them are given below.

7.1.1. Tungabhadra Drain and its Tributaries :

7.1.1.1. *T.B. Main Drain.*

1. The " Guntur Nalla " *i.e.*, the reach of T.B. drain above Commamur Canal crossing be widened and additional vents be built for the existing under-tunnel at Sangam- Jagarlamudi. (Six representations).
2. The T. B. drain course from Sangamjagarlamudi U. T. up to Machavaram Railway Bridge be deepened and widened. Banks of adequate height be formed on either side. Kinks in the course be straightened. (Six representations).
3. Additional waterway be provided for the Road Bridge on T. B. drain near Nidubrolu. (Two representations).
4. The East Tungabhadra drain, *i.e.*, the reach from Machavaram Railway Bridge up to the infall into the Bay of Bengal be deepened and widened to the required section. Kinks in the course be straightened. Bunds on either side be raised and strengthened. (Nine representations).

7.1.1.2. *Yazali Drain.*

1. Improvements be carried out in the Yazali drain by deepending, widening and forming banks of adequate height on either side. An outfall sluice be provided with flap shutters at the place of its infall into East Tungabhadra drain. (Six representations.)
2. The Yazali drain be improved and diverted into Tenali drain, from where a separate out-let into the sea be provided without its joining E. T. B. drain. (Five representations).
3. The Yazali drain be improved and a seprate diversion channel be dug for the drain joining the same with E. T. B. drain near Ganapavaram lower down. (One representation).

7.1.1.3. *Tenali Drain.*

1. The Tenali drain be widened and deepened to adequate section. Its course near Kajipalem be straightened. Banks be formed on either side. (Three representations).
2. A separate outlet into the sea be provided for the drain without its joining the E. T. B. drain. (Three representations).

7.1.1.4. *Kollimerla Drain.*

1. The courses of Nakkavagu Upper arm, Kondavagu and Jallavagu above Kollimerla U.T. be improved by widening and deepening. All kinks in their courses be straightened. (Five representations).
2. The existing under-tunnel near Kollimerla lock be widened providing adequate water way for the upland drainage. Six vents of the U. T. closed previously be re-opened. (Eight representations).
3. The drainage course from Kollimerla U. T. upto its confluence with T. B. drain above Machavaram Railway Bridge be improved by widening and deepening. Its banks be raised to adequate height and strengthened. (Ten representations).

4. A separate outlet into the sea be provided for the Kollimerla drain without its joining the T. B. drain. (Two representations).

7.1.1.5. *Other Minor Drains.*

1. The Pandikodu and Pedapalle drains be improved by increasing their standards to suit the increased area of irrigation served by them (Four representations).

2. An outfall sluice for Pedapalli drain at the place of its infall into E. T. B. drain be constructed. (One representation).

3. Provision of drainage facilities for areas irrigated by Tollanagu and Ramaraju channels be made. (One representation).

7.1.2. NALLAMADA DRAIN AND ITS TRIBUTARIES:

7.1.2.1. *Nallamada Main Drain.*

1. The drain course from Pedanandipadu up to Commamur Canal crossing be widened and deepened to adequate section. The kinks in its course between Pedanandipadu and Garlapadu be straightened. (Seven representations).

2. The existing under tunnel for the drain across Commamur Canal be widened, providing for the required additional waterway. (Eight representations).

3. The drain course below Commamur Canal crossing up to its infall into the sea be improved by widening and deepening to adequate section. Existing shoals in the drainage bed be removed. Kinks in the course be straightened. Banks be formed and strengthened to adequate height on either side. (Ten representations).

4. A new under-tunnel be built at M. 36 F 2 of Commamur Canal and the Nakkavagu lower arm be connected with Pundla affluent so that its flood waters be led into Nallamada drain through the latter. Thus Nakkavagu lower arm be made to discharge into Nallamada drain at a place about 4 miles below Commamur Canal crossing, instead of just above the U. T. as at present. (Five representations).

7.1.2.2. *Pundla Affluent.*

The Pundla affluent course below the under tunnel proposed above and upto the place of its infall into Nallamada course be improved by widening and deepening to the required sections Bunds be formed for the drain on either side to required height. (Four representations).

7.1.2.3. *Other Minor Drains.*

1. Improvements be carried out to the Nallamada old course joining T. B. drain by way of widening, deepening and forming bunds on either side. (One representation).

2. Widening and banking for Marripudi, Appikatla and other minor drains flowing into Nallamada drain be carried out. (One representation).

7.1.3. ROMPERU DRAINAGE SYSTEM :

Upland drains flowing into Romperu.

7.1.3.1. *Saki Affluent.*

1. The existing U.T. for Saki affluent across Commamur Canal be widened. (Six representations).

2. The kinks in the drainage course be straightened and the drain improved by widening and deepening to the required section from down stream of the U. T. up to its confluence with Romperu. (Eight representations).

3. A separate outlet into the sea be provided for the Saki affluent without joining the Romperu. (Three representations).

7.1.3.2. *Parachuruvagu and Karamchedu affluents.*

1. The existing under tunnel for Parachuruvagu near Kunkalamarru be improved by providing additional waterway. (Three representations).

2. The drainage course from below the U. T. upto its confluence with Karamcheduvagu be improved by widening and deepening. The kinks in its course be straightened. (Four representations).

3. The existing under tunnel of Karamcheduvagu across Commamur Canal be improved providing for additional waterway. Its course below the U. T. be improved by removal of silt and widening. (Six representations).

4. A straight cut to sea be excavated between M. 2/0 and 3/0 of Romperu begining near "Kuruthulu bend" over a distance of about 6 miles to join the Bay of Bengal. The alignment of the straight cut should cross the Bapatla-Chinaganjam Road between Ipurupalem and Perala. (Six representations).

7.1.3.3. *Swarna and Aleru Affluents.*

1. The existing under tunnel for the Swarna affluent across Commamur Canal be improved providing additional waterway. An undertunnel be built across Commamur Canal for the Aleru drain. (Three representations).

2. The drainage courses of both Swarna and Aleru be improved from below the Commamur Canal crossing up to the places of their confluence with Romperu, by widening and deepening to the required section. (Six representations).

3. A separate outlet into the sea be provided for the Swarna and Aleru affluents by improvinig and extending the existing straight cut between Romperu and Kunderu near Vetapalem over a length of about 2½ miles to join the Bay of Bengal near Pulladipalem (Twelve representations).

4. The proposed straight cut channels to sea near Vetapalem and Perala be aligned in such a way that rich and valuable lands belonging to the residents of Kotapalem are not taken away by the Government for excavation. (One representation).

7.1.3.4. *Apperu and Emileru Affluents.*

1. Under tunnels with adequate waterway be built across Commamur Canal for Apperu and Emileru. (Four representations).

2. The courses of these two drains be improved from Commamur Canal crossing up to their confluence with Romperu by widening and deepening to adequate section. (Eight representations).

3. Separate outlets into the Bay of Bengal be provided both for Apperu and Emileru affluent without their joining Romperu. (Three representations).

7.1.3.5. *Kunderu.*

1. Kunderu drain be improved by removal of silt and deepening. Its banks on either side be raised and strengthened adequately. (Five representations).

2. Regulator across Romperu straight cut near Vetapalem be operated so as to allow only that quantity of water into Kunderu which the latter can carry safely to sea. Flood banks be formed for the straight cut below the Regulator. (One representation)

7.1.3.6. *Romperu Main Drain.*

1. The Romperu drain be improved throughout its length by removal of silt, widening and deepening. Its banks be raised to adequate height and strengthened. (Six representations).

2. Existing syphon at Commamur Canal crossing near Pedaganjam lock be improved providing for adequate waterway. (One representation).

3. A separate outlet be provided for the Murukondapadu drain to join the Bay of Bengal near Pachu Mogali Revu without its joining Romperu as at present. (One representation)

NOTE : The tribal people of Stuartpuram have represented against any straight cut channel being aligned through their lands, which form the only means of their livelihood. (One representation).

7.1.3.7. *Perali Drain.*

1. The drain be widened and deepened up to the sea. The banks on either side be raised and strengthened. Shoals be removed from the bed in lower reaches. (Six representations).

2 Revetment be provided for the banks wherever necessary. (Two representations).

7.1.3.8. *General suggestions for the relief from drainage problems in Romperu area.*

1. The possibility of diverting the upland drainage received through Emileru, Apperu, Aleru, Swarna, Parachuruvagu and Sakikalva into Gundlakamma river by excavating a catch drain parallel to Commamur Canal be examined. Separation of upland drainage from entering delta will afford an effective solution for the flood problems now being experienced (Two representations).

2. All the upland drains be improved and maintained for a distance of at least 16.1 K.m. (10 miles) above the Commamur Canal crossings. (One representation).

3. Soil conservation measures be adopted in the catchment areas of the upland drains so that the silting of delta drains is reduced. (One representation).

7.1.4. DRAINAGE FROM PROPOSED AYACUT UNDER NAGARJUNA SAGAR RIGHT CANAL. :

A separate drain be dug parallel to G.N. T. Road so that the drainage from the proposed ayacut lands under Block No. 10 and 11 of N. S. Right Main Canal is led into Gundlakamma river without finding its way into Krishna Western Delta System, through under the Commamur Canal. (Seven representations.)

7.1.5. DRAINAGE FACILITIES FOR AREA UNDER APPAPURAM CANAL.

1. Adequate drainage facilities be provided for areas being irrigated under Appapuram Canal lying to the west of Commamur Canal from its K.M. 33.8 to 64.4 (M. 21 to 40). (Four representations).

7.1.6. REPALLE MAIN DRAIN AND ITS TRIBUTARIES.

1. The Repalle Main drain be improved by widening and deepening to required section. Its banks on either side be raised to adequate height and strengthened by providing revetment where necessary. (Three representations).

2. The old course of R. M. drain be improved by widening and removing the silt. The kinks be straightened. (Two representations).

3. The six mile long tortous course of R. M. drain between Chakkavaripalem, hamlet of Pregnam and Chintarevu of Amudalapalli village be reduced to about 2.0 K.M. (1.M. 2 F.) by digging a straight cut channel.. (Three representations).

4. The waterway for the R. M. drain at Dhulipudi Aqueduct may be increased. (One representation).

5. An outfall sluice be provided for the R. M. drain above its fall into Bay of Bengal to prevent sea water backing up at high tide. (One representation).

6. Repairs may be carried out to all branch drains joining the R. M. drain. (One representation).

7. A new drain be excavated from Kuncham Cheruvu into Uppurevu (*via*) Puluguparra towards south of Nizampatnam so as to prevent accumulation of drainage around Amudalapalle and Nizampatnam villages. (One representation).

7.1.7. BHATTIPROLU DRAIN AND ITS TRIBUTARIES.

1. A straight cut channel be excavated from Gunnamtippa to the Bay of Bengal (*via*) Haripuram so as to reduce the existing eight mile long tortous course of Bhattiprolu drain to about two miles. (Three representations).

2. The main drain and its tributaries be improved by widening and removal of silt. (One representation).

3. The water way for the drain at Isukapalli aqueduct be improved. (One representation).

4. The Guntakolu syphon be improved to take care of diversion of flood waters from Joone drain and Badekaluva. (One representation).

7.1.8. NAGARAM SOUTH DRAIN.

1. Repairs be carried out to Nagaram South drain and an outfall sluice with flap shutter be provided at the place of its infall into Repalle Main drain. (Two representations).

CHAPTER VIII—DESIGN CRITERIA FOR DRAINS OF DELTAIC AREAS.

8.1. Present Criteria for design of Drains :

The design criteria which are being followed for deltaic area drains are explained in detail in the paper, " Drainage problems in Andhra Pradesh by Shri A. R. Venkataraman". Main features of this are discussed below :—

During monsoon, paddy is the predominent crop in the delta area. When rains occur, paddy fields being already full of water, there would be no loss in run-off due to absorption, evaporation, etc. The run-off factor would, therefore, be hundred percent. It has been laid down that the drains should cater, without submergence, for 1" daily rainfall under O. F. L. conditions. This rainfall is expected normally. But during heavy rainfall period, rains up to 3" daily, continuing for 7 days could occur. Under these M. F. L. conditions, the drains should be capable of draining the area in 7 days with submergence not exceeding 12". As per this design criteria the paddy crop even under worst conditions would not be subject to submergence of one foot depth for more than one week at a time. To achieve these conditions, emperical formulae (Straight line and Ryves) for fixing the capacities of the drains have been indicated.

The magnitude and intensity of rainfall is higher in uplands and the country slopes are also steeper in uplands than in the delta lands and so run-off expected for same catchment area would be greater in upland than in delta lands.

For working out the discharge the drains have, therefore, been devided into two broad categories :—

(*i*) Drains having entire catchment area in delta.

(*ii*) Drains having catchment area partly in upland and partly in delta.

The factors which have been laid down for designing the capacity of drains and masonry works for drains of above two categories are discussed below :

8.2 DRAINS HAVING ENTIRE CATCHMENT AREA IN DELTA.

8.2.1. Design of sectional area of the drains (under O.F.L. conditions.)

(*i*) For catchment area up to 5 sq. ml. Q.=27 M

(*ii*) For catchment area from 5 to 20 sq. mile. Q.=115+4 M.

(*iii*) For catchment area above 20 sq. ml. Q.=27 $M^{2/3}$

Note :—'M' is the catchment area in sq. miles.

'Q' is discharge in cusecs.

8.2.2 Design of masonry works of drains (under M.F.L.) condition.

Q.=92 M. $^2/_3$ (M.F.L. being 1′ 0″ above O.F.L. which is, in turn, the lowest ground level.)

8.3 For drains having combined deltaic and upland catchment.

For the discharge from extra deltaic catchment area or upland catchment, a maximum precipitation of 10" in 24 hours and cent percent runoff on an area of 5 sq. miles are assumed. This corresponds to Ryve's formula CM $^2/_3$ with value of 450 or 500 for C. The use of this formula be limited to the design of cross masonry works across contour canals situated at or just above the entry in to the delta. If the maximum flood discharge from the uplands into the delta drains exceeds 20 times the local drainage the latter will be ignored in designing the carrying capacity of the drains since the local drainage cannot discharge into main drains until the flood level in the latter falls considerably.

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In addition to the M.F.L., H.F.L. for the discharges should be calculated as below :—

$Q = C\,(M1 + M2)^{2/3}$

where M1 = Upland catchment area in sq. miles.

M2 = Deltaic catchment area in sq. miles and

$$C = \frac{500\,M1^{2/3}\ \text{(Plus) 3 times the discharge under (O.F.L. conditions.)}}{M1^{2/3} + M2^{2/3}}$$

If the resulting H.F. Ls as per above are found to be very high the necessity for further widening or providing flood banks may be considered in the affected reaches.

For design of masonry works on drains discharge formula as per 8.2.2 above is followed.

8.4 Drains draining dry lands.

The ordinary flood levels in the case of drains draining dry land is kept 0.61 metre (2′ 0″) below the level of the adjoining lands.

8.5 Tidal drains entering into sea.

The tail end portions, *i.e.*, 16.1 to 19.3 K.M. (10 to 12 miles) of drains are subject to tidal action and hence the lands are protected against the flow of salt water either by erecting bunds or by banking the main drains and constructing inlets at the mouth of subsidiary drains. The discharge to be provided for at the outfall into the sea is taken as 9/7 of that assumed in non-tidal portion, *i.e.*, at the upper end of tidal reach. The increase from the normal discharge to 9/7th of the same is made gradually in the tidal reach.

The highest tide is of the order of 1.37 metres (+4.5 ft.) on an average. Therefore, lands below say 1.52 metre (+5.0 ft.) contour in the last reaches of tidal drains cannot be properly be drained off and hence banks are provided for tidal drains upto 1.52 metre (+5.0′) contour and the drainage of the enclosed area let into the main drains through inlets operated at low tide.

8.6. Outfall Sluices :

The M.F.L. of the main drain should be lower than the M.F.L. of the tributaries. If it is not the case, while the upper catchment is being drained the effluents ceases to flow into themain drain and they begin to function only after the flood levels fall sufficiently low in the former. Therefore, the catchment of the tributaries would be under submersion for a longer period than the direct catchment of the major drain and requires speedy relief. However, there are certain limitations *i.e.*, the tidal action of the sea or the tidal river does not admit of seaward flow for half the day even during flood times. The masonry sluices at the mouths of the drains are to be provided with waterway large enough to drain the land side drainage in the quickest possible time, after the floods in the river, subside and are generally designed for run-off of 31 M.M. (2″) in 24 hours, *i.e.* $Q = 92\,M^{\frac{2}{3}}$ within a limited time of 12 hours, but not by continuous flow right through. In other words, the maximum flood discharge is to be doubled. The average head of discharge against low tide level should be worked out for actuals.

8.7. Adequacy of design criteria being adopted at present.

8.7.1. The standards fixed for the capacity of the drains, *viz.* the submergence of areas during heavy rains, should be limited to one foot and period of submergence should not be more than one week at a time, are considered reasonable.

8.7.2. The rainfall figures for the past 20 years (1945-1964) at 52 selected rain gauge stations in the five delta areas, *i.e.*, Krishna Western, Krishna Eastern, Godavari Western, Godavari Central and Godavari Eastern were studied. Statements showing maximum rainfalls recorded in 7 day consecutive period were prepared for these stations. These showed that adoption of 1″ rainfall per day as normal rainfall is quite satisfactory.

8.7.3. The next question was to correlate the rainfall with the empirical run-off as given by formula being adopted at present in the State. For this discharge observations in representative drains were needed. This data was not forthcoming, and so, this correlation could not be checked. It is, therefore, recommended that discharge observations be made for some years in representative drains in the various deltas.

These be correlated with the rainfall intensities and quantities. Based upon these results, the value of coefficient of constants in the formula in vogue be fixed.

8.7.4 Till the correlation between rainfall and run-off is established according to the results of field observations, the design criteria and design formulae as in vogue be followed.

8.7.5 In cases of streams having major upland catchment area like Budameru, Thammileru and Yerrakalva the maximum discharge for upland catchment be taken as $Q = 500\ M^{2/3}$ and for delta catchment as $Q = 92\ M^{2/3}$.

8.7.6. All works which envisage increasing the capacity of the drains should be carried out from tail upstream.

8.7.7. In the case of deltaic drains which have their infall into a major drain coming from uplands or into a river whose flood levels happen to be higher than flood levels of drains, outfall sluices with shutters be provided to prevent backing up of water into small drains. In cases where main drain or the river is likely to remain higher for a considerable period, pumping may be resorted to save the crop from damage.

8.7.8 Normally when a purely deltaic drain falls into another delta drain, there should be no sluice but catch water drains may be provided wherever necessary. If flaps are provided for the deltaic drains falling into another deltaic drain, then there will be drainage congestion. There will also be a chance for the sea-tides to travel up to a longer distance thus adversely affecting larger areas.

8.7.9 Normally no embankments should be provided in the tail end of drains outfalling into the sea. If these have to be provided they should be sufficiently far apart so that the required tidal influx for keeping the drain and the mouth stable is not adversely affected.

8.7.10 The drains in delta areas which have upland catchment be embanked in deltaic reaches.

8.8 EFFECT OF CANAL IRRIGATION ON DRAINAGE OF THE AREA.

There is a large area in delta which is under irrigation from canals. The inhabitants of the area consider that water given for irrigation is one of the main factors which cause drainage congestion. This complaint has been gone into in fair detail. During monsoon when there are heavy rains normally there would be no demand for canal water and the canals would be closed. But there may be cases when rainfall is in limited areas and canal may be running to reduced discharge. Then, the total contribution from canal water would not exceed the designed discharge of the drain. However, there can be exceptional cases when the rainfall is sudden and over the entire catchment area and then canals are also running full. If these exceptional cases are analysed in a little more detail, it will be seen that discharge of canals for the vast area is not significant as compared to the quantity of water due to rainfall falling over this area. So, if the drains are excavated to existing design criteria and are properly maintained, then there would be no drainage congestion due to canal irrigation. It is, however, very essential to check the waterways of across drainage works so that there are no undue affluxes caused during rains.

CHAPTER IX—MAINTENANCE OF DRAINS.

9.1. The site inspection and study of the existing cross sections and longitudinal sections of the drains have shown that the sections and slopes and waterways of cross-drainage works on several of the drains which are causing flooding were less than those given by the empirical formulae fixed by the State. In some cases, the drains were never excavated to the designed sections and in other cases these have silted up due to neglect in maintenance. It is, therefore, recommended that the present condition of the drains be improved according to the design criteria already laid down. This is expected to reduce the flooding considerably.

9.2. Drains be properly maintained to the design standards by :—

(*a*) Providing separate establishment for attending to investigations, improvements and maintenance.

This will ensure more satisfactory and prompt attention than when it is entrusted to the Irrigation maintenance staff. As the work of drains is of difficult and arduous nature, the staff engaged on drains be given some incentive for this. For this, there should be four divisions, two for Krishna deltas and two for Godavari deltas.

(*b*) Providing adequate separate funds for maintenance of the drains :—

The following standard for providing funds for maintenance of drains is recommended :—

(*i*) For deltaic drains having catchment area in upland also, except in the case of Upputeru river and drains of the Kolleru basin, the maintenance funds recommended annually should be on mileage and size basis as given by formula Q × L where 'Q' is the discharge in cusecs and 'L' is length in miles. In the case of drains of Krishna Western delta, the discharge will be as at the Commamur Canal crossing. Roughly, the maintenance cost works out to Rs. 8 lakhs per year.

For maintenance of Upputeru and Kolleru basin drains there should be special estimates.

(*ii*) For the maintenance of delta drains having catchment area in delta only, the funds be fixed at Rs. 1 per acre of the area irrigated. Roughly, the maintenance cost works out to Rs. 22 lakhs per year.

Thus total maintenance cost for delta drains excluding Upputeru would be of the order of 30 lakhs per year.

(*c*) All encroachments in drains be evicted and such cases be dealt with strictly. Fishermen should be prevented from putting up obstructions such as fish stakes, cross bunds etc. across the drains.

(*d*) For the maintenance of drains to proper section dredging specially near the outfalls in the sea would in several cases be necessary. For this, four cutter suction dredgers 12" size with 1000ft. each of floating and shore pipe lines, two dredgers for Krishna delta, and two for Godavari deltas are recommended in the first instance.

(*e*) For maintenance of drains in proper shape, the mogas must be maintained in suitable and regime conditions. For these, the following measures are recommended—

(*i*) Dredging be resorted to where adequate depth for draft is available;

(*ii*) Where adequate depth for required draft for dredging is not available a movable sand pump on pile structures as put in at Nagapatnam (Madras State) be resorted to;

(*iii*) The sites of the mogas be held in position by revetment wherever necessary.

9.8.4. Condition of every drain be reviewed every fifth year and programme be made to bring it to designed standards.

9.8.5. Suitable drainage cess from the beneficiaries for proper maintenance of drains be fixed.

CHAPTER X—RECOMMENDATIONS OF MEASURES FOR IMPROVING THE DRAINAGE SYSTEM IN KRISHNA WESTERN DELTA.

Proposals for improving the drainage system in the delta area can be categorised under (*a*) General and (*b*) Specific. These are discussed below :—

10. 1. GENERAL :—

10 1. 1. RESTRICTING DISCHARGES OF UPLAND DRAINS FOR FLOWING INTO THE DELTA AREAS.

These drains enter the delta after crossing the Commamur Canal. As the delta area is comparatively more costly, being more productive and more densely populated than the Upland area, so in order to reduce damage from floods, the discharge coming from uplands into the delta be kept restricted. Otherwise, almost all the drains in delta, if these have to cater for full flood discharge, will have to be considerably widened and deepened both for earthen sections as well as for masonry works.

To achieve this, the following measures are recommended :—

10. 1. 2. Where there is no complaint of serious flooding in upstream of Commamur Canal the existing waterways of under-tunnels need not be increased at present. Further, investigations may be made when the upstream drainage due to Nagarjunasagar canal has to be dealt with.

10. 1. 3. Where there are serious complaints the cross-drainage masonry works under the Commamur Canal be improved for a discharge given by 92 M 2/3 except in cases where the existing waterways are more than that indicated by this formula.

10. 1. 4. The masonry works should be designed for a velocity of 16 ft. per sec. at designed discharges.

10. 1. 5. The maximum afflux at the cross-drainage works be limited to 4 ft.

10. 1. 6. The works and sections in d/s reaches of such drains whose waterways of under-tunnels have been increased be also improved to accommodate the additional discharge.

10. 1. 7. Masonry works of drains in deltaic areas be also designed for $Q=92\ M.^{2}/_{3}$.

10. 1. 8. On account of higher rainfall intensity and steeper country slope the discharge coming down from Upland near the Commamur Canal can be of the order of $Q=500M^{2}/_{3}$. The water ways for cross-drainage works as recommended above is, however, limited to, $Q=92\ M^{2}/_{3}$. So, for holding up the difference of discharge between the two suitable sites to provide detention basins be investigated. It is further recommended that such of the areas in the detention basins which are likely to get submerged for more than one foot for more than one week be acquired. This is desirable to avoid encroachments and obstructions being put in by the owners. It is also suggested that such areas should also be excluded from localisation. These areas should also be excluded from the ayacut of the Nagarjunasagar Canal.

10. 1. 9. On account of roads and railway crossings, it will not be economical to have a diversion channel 40 miles long running upstream of and parallel to Commamur Canal to carry the upland water into the sea without flowing through the delta area. Moreover, such long drain where the slope is very flat will soon get silted up and the maintenance cost would be quite high. So on account of heavy cost of construction and also of maintenance, this drain is not recommended.

10.1.10. For the same reason as given under para No. 10.1.9 above, construction of a drain upstream of Commamur Canal, parallel to the G.N.T. Road for carrying surplus waters of Nagarjunasagar ayacut into Gundlakamma river is not recommended.

10.2. Specific

10.2.1. Tungabhadra Drain and its Tributaries.

(*a*) Some representations suggested provision of additional ventways for the under-tunnel across Commamur Canal near Sangam Jagarlamudi for Guntur Nalla. It is recommended that the waterways be worked out according to the design criteria and necessary improvement be made. In order to avoid flooding lower down, the Tungabhadra drain down stream of this tunnel be also improved, both for masonry works as well as for drain section.

(*b*) An inlet sluice be provided with flap shutters at the outfall of the Yazali Drain into the East Tungabhadra drain, so as to prevent flood waters backing up into the former.

(*c*) Same representations suggested provision of additional waterway for the under-tunnel near Kollimerla across Commamur Canal. This as well as the drain section in the lower reaches be checked up for the design already recommended and improved upon, if found necessary.

(*d*) The suggestions made for provision of a separate outlet for Kollimerla drain into the sea do not appear feasible, as it cuts through the existing ayacut area. However, feasibility of diverting it through Marripudi drain be examined.

(*e*) The suggestion of diverting Yazali drain into Tenali drain and providing in separate outlet into the sea is not recommended in view of Tungabhadra drain being improved. The results of the improvements be watched.

(*f*) The suggestion of providing a separate outlet into the sea for the Tenali drain without joining East Tungabhadra drain is not recommended for the same reason.

(*g*) The suggestion for providing an outfall sluice for Pedapalli drain at its infall into East Tungabhadra drain is recommended.

(*h*) The suggestion for providing drainage facilities for areas served by Tollanagu and Ramaraju channels is a local problem and be looked into by the State Irrigation Department.

10.2.2. Nallamada Drain and its Tributaries.

(*a*) Eight representations suggested provision of additional waterway for the under-tunnel for Nallamadavagu across Commamur Canal. This should be examined, according to general design principles.

(*b*) The suggestion of constructing a new under-tunnel at mile 36/2 of Commamur Canal for diverting waters of Nakkavagu lower arm into Nallamada drain through Pundla affluent be investigated by the State P.W.D. The Pundla affluent course will also have to be improved to carry Nakkavagu waters besides its own.

10.2.3. Romperu Drainage System.

(*a*) The left and right arms of Romperu drain below Karamchedu under-tunnel were designed to carry half the maximum flood discharge in each. The Romperu left arm was improved to carry a flood discharge of 2,456 cs. with M.F.L. of 10.78 at head and 9.52 at the end.

In the year 1964, a total discharge of about 14,009 cs. have flowed into the Romperu through several cross drainage works across Commamur Canal in the reach from mile 49/1 to 59/1. The maximum flood discharge observed in left arm has been of the order of 9,000 cs. as against 2,456 cs. designed. Thus, the distribution has been found to be 1/3 and 2/3 in the right and left arms respectively against 1/2 and 1/2. Consequently there has been an increase in the M.F.L. of Romperu left arm by about 5 ft. above the designed level resulting in submersion of extensive area of paddy fields. Therefore, it would be necessary to reduce the M.F.L. considerably, say by 3 to 4 feet to reduce the flooding and avoid recurring flood damages to the paddy fields.

There is a suggestion to excavate a straight cut from Romperu left arm to the Bay of Bengal approximately along the Karamchedu-Vadarevu road for diverting flood waters into the sea in a short time. (*See* Plate 4). This proposal has been examined by the State Government. The total length of the proposed diversion channel is about 6½ miles. This would reduce the observed

M.F.F. of 1964 by 3 ft. relieving the submergence of paddy fields. The suggestion is recommended. The exact alignment be finalised by State P.W.D. after carrying out detailed surveys and economic studies. The approximate cost of this proposal has been estimated at Rs. 65 lakhs.

(*b*) The suggestion for providing a separate outlet for Saki affluent into the sea does not appear to be necessary in view of the proposed straight cut from Romperu *vide* (*a*) above.

(*c*) Six representations have asked for providing additional waterway to the under-tunnel of Saki affluent across Commamur Canal. This may be decided according to general principles laid down.

(*d*) Suggestions have been received for providing additional waterway for the existing under tunnel for the Parucheruvagu and Karamcheduvagu across Commamur Canal. This be examined according to general principles already laid down.

(*e*) The suggestion for improving the waterway of the existing under-tunnel for Swarna affluent across Commamuru canal be also examined according to the general principles.

(*f*) The existing straight cut near Vetapalem may be extended to join the sea to carry discharge over and above the safe carrying capacity of Kunderu drain. (*See* Plate 4). In this case, a regulator across Kunderu may become necessary which should allow only that much quantity of water which the Kunderu can carry safely without submersion of marginal areas. In this connection, the alternative proposal to have a link channel i to Kunderu from above the existing regulator be also considered and decision on the two alternatives be taken after carrying out detailed study. This first alternative is estimated to cost Rs. 5 lakhs excluding the regulator across Kunderu.

(*g*) Provision of a separate outlet for Swarna and Aleru affluents to join the sea is not recommended in view of the new straight cut proposed at (*f*) above.

(*h*) The provision of a separate outlet for the Murukondapadu drain into the sea does not appear necessary as Peralidrain is already there.

10.2.4. Proposals for disposal of upland drainage received from Aleru, Apperu and Emileru streams in Krishna Western Delta.

The upland areas adjoining the Commamur Canal are often subjected to submersion over prolonged periods due to the stagnation of flood waters brought by the streams like Aleru, Apperu and Emileru in Krishna Western Delta. At present, there are inlets and outlets across Commanur canal for these streams. The carrying capacity of these structures are inadequate to discharge the flood waters of these streams coming from upland. As the sill level of the inlet weirs are either at or above the F.S.L. of Commamur canal, this results necessarily in submersion of the dry lands adjoining the canal on its right side continuously for a long time. This problem can be relieved by either (*i*) constructing under-tunnels with adequate discharge capacity in place of inlets and outlets or (*ii*) diverting entire flood waters of Aleru, Apperu and Emileru through a diversion channel into Gundlakamma river. (*See* Plate 4).

(*i*) If the under-tunnels are built to carry the entire maximum flood discharge from these streams into the delta which can be of the order of Q =450 M2/3cs. This will necessitate extensives increase in the discharge capacity of the drainage courses through the delta down-stream of the under-tunnels. This proposal would involve acquisition of large areas of costly and highly productive land in the delta areas and hence the cost of this proposal would be prohibitive. The discharging capacity of the under tunnels therefore be limited to a discharge equivalent to Q=92 M 2/3. The cost of the proposal on this basis is about Rs. 9 lakhs.

(*ii*) With regard to the proposal for diverting entire flood waters of Aleru, Apperu and Emileru into Gundlakamma river through a diversion channel, (*See* Plate 4) it may be pointed out that the diversion channel will be about 20 miles and will have to run through the very area for which relief is requested.

Out of these two schemes, the first proposal will cost only Rs. 9.43 lakhs, whereas the second proposal costs about Rs. 1.6 crores. In view of the prohibitive cost and insufficient relief from floods, the second proposal is not justified. Hence, the first proposal be adopted.

10.2.5 Drainage of Nagarjunasagar Canal Ayacut.

The inhabitants of Krishna Western Delta are much concerned about the introduction of irrigation by Nagarjunasagar Canal in upland areas of Guntur district.

It is learnt that about 4 lakhs areas of Guntur district lying towards north of the Commamur Canal is proposed to be brought under irrigation in block Nos. 10 and 11 from the Nagarjunasagar Canal (*See* Plate 15). This area, at the present moment, is an upland area. During Monsoon season, the branch canals to irrigate the above area will carry 3,700 cusecs of water for irrigation of this area. It is felt that with the introduction of irrigation the land will be terraced and the rain water will be more detained than at present. There will be, however, increase in all weather see page water. But, the quantity of this water will be smaller than the carrying capacity of ventways at drainage crossings with the Commamur Canal which are proposed to be improved for a discharge of $Q=92\ M^{2}/_{3}$. Moreover, there is a recommendation for providing detention basins and eliminating the same from the ayacut of the Nagarjunasagar Canal for the difference of $Q=92\ M^{2}/_{3}$ and $Q=500\ M^{2}/_{3}$. As such, the condition in delta areas in post Nagarjunasagar Canal would not, in any way, be worse than at present.

10.2.6 Drainage problem in the irrigated area under Appapuram Channel

The cross drainage works across the Appapuram channel are designed for a maximum discharge capacity adopting $Q=270\ M^{2}/_{3}$ for catchment area up to 5 sq.miles, and $Q=450\ M^{2}/_{3}$ for catchments exceeding 5 sq. miles, whereas those under the Commamur Canal can discharge much less. The waterways under the Appapuram Channel have been found to be adequate as no drainage congestion has been reported for the lands lying above Appapuram channel. But there is serious drainage congestion in the area lying between Appapuram channel and Commamur Canal. During 1963 and 1964, nearly 60% to 70% of the ayacut area was affected due to submersion with consequent damage to crops. The main reason is that the Cross-drainage works built across Commamur Canal in this reach are far below the standards adopted for corresponding works on Appapuram Channel. During 1964, the under-tunnel constructed at Nallamadavagu across Commamur Canal h s actually discharged with a coefficient of $C=70$ in $Q=CM^{2}/_{3}$ i.e., outflow from the under tunnel on Commamur Canal is roughly 1/6th of the inflow entering Appapuram ayacut lands.

It may, however, be mentioned that even before the introduction of Appapuram Canal, this area must have been inundated to the same extent, if not more than at present.

It is not desirable to increase the waterways of cross drainage works under the Commamur Canal and drainage sections and works lower down to cater for the same standards as adopted under Appapuram Channel on account of costly and highly productive delta land that will have to be acquired. However, in order to give relief, to some extent, it is recommended that the under-tunnels in this area, as elsewhere, be improved for $Q=92\ M^{2}/_{3}$ and the main drains which carry water from upland areas be embanked in delta reaches. This will be in accordance with the general principles laid down for all upland drains going through the delta areas.

10.2.7 Repalle Main Drain and its Tributaries.

(*a*) The suggestion of excavation of a straight cut for Repalle main drain between Chakkavaripalli and Chintaparru is not desirable as the proposed alignment cuts across irrigated fields and a major tributary joins R.M. Drain in this reach. This, however, is a local problem and be examined after watching the effects of improvements already suggested.

(*b*) The suggestion of providing additional waterway for Dhulipudi aqueduct be examined according to general principles.

(*c*) The suggestion of providing new drains for irrigated areas situated in Amudalapalli and Nizampatnam villages is of local nature and be examined and decided by the State Irrigation Department.

10.2.8. Bhattiprolu Drain and its Tributaries.

(*a*, The Bhattiprolu drain in its lower reaches runs in a zig-zag course with a number of ser pentine bends. Due to this tortuous course, the flood waters of the drain are not drained off quickly into the sea with the result the flood waters backup submerging the lands on either side. Durin-

1963 and 1964 the M.F.L's. recorded in rear of the Isukapalli undertunnel were +8.25ft. and +7.90 ft. respectively as against the designed M.F.L. of + 6.81 ft. As a result of this heading up of flood waters, an area of about 2,800 acres were submerged over a period exceeding 7 days.

In order to relieve this submergence, a suggestion has been made to excavate a straight cut from "Gunnamtippa" near Bhimavaripalem to the sea. With this proposal, the length of the existing course of 7 miles would be reduced to about 2½ miles. This would improve the surface fall of the drain and facilitate in draining of the flood water, rapidly.

From the preliminary investigation carried out by the State P.W.D., it has been found that the alignment of the proposed cut runs through the plain country in the first four furlongs and through Kottapalem reserve forest area for the next 1 mile 2 furlongs. In the last reach, the channel runs for 5 furlongs through salt beds on the coast. So the land which will come under the proposed cut is not very valuable. However, this suggestion of providing a straight cut for Bhattiprolu drain from Gunnamtippa to sea *via* Haripuram be considered after watching the results of improvements of the drains suggested under general principles (*See* Plate 4). The following points, which are likely to arise with the execution of this proposal be kept in view while finalising this proposal :—

(*i*) Tidal limit may extend higher up than at present and create salinity problem during dry weather.

(*ii*) The tidal energy may not be absorbed in the cut reach as its capacity will be less. This is likely to made the channel unstable.

(*iii*) Flooding due to tides will extend inland.

(*iv*) Forming embankments to restrict flooding may choke the moga due to inadequate flushing.

The cost of providing the straight cut referred to above has been worked out at Rs. 7 lakhs.

CHAPTER XI—PRIORITIES OF WORKS

11.1 The cost of works of the drains in the Krishna Delta is estimated at Rs. 5 crores. Abstract of cost of the various works is given below :—

1. KRISHNA DELTA.

(*i*) Restoring the drains to design standards in	
(*a*) Western Section	Rs. 241 lakhs.
(*b*) Eastern Section	*Rs. 142 lakhs.

*NOTE.—These include a few drains of Central Section as well.

(*ii*) Constructing under-tunnels in place of inlets and outlets across the Commamur Canal for Aleru, Apperu and Emileru streams ..	Rs. 9 lakhs.
(*iii*) Excavating a straight cut from Romperu left arm into sea ..	Rs. 65 lakhs.
(*iv*) Extension of Romperu straight cut near Vetapalem to join the sea ..	Rs. 5 lakhs
(*v*) Excavating a straight cut for Bhattiprolu drain from Gunnamtippa to join sea	Rs. 7 lakhs
(*vi*) Miscellaneous works	Rs. 30 lakhs
Total ..	Rs. 499 lakhs
say ..	Rs. 5 crores

11.2 As already mentioned, for excavation of the drains to standard design sections and for their proper maintenance as also for the excavation of straight cuts, and maintenance of the Mogas, cutter suction dredgers would be needed. As the number of drains is large, atleast 2 dredgers will be needed. As the drains are not very wide, 12″ cutter suction type dredgers with adequate length of pipe line and two tugs and a few barges will be required. The first priority should, therefore be given to procurement of the equipment.

The work of restoring the drains of Western and Eastern Sections to design standards and excavation of straight cuts on the Romperu drain be accorded first priority. Construction of under-tunnels in place of outlets across Commamur Canal for Aleru, Apperu, Emileru etc., be given the second priority. Excavation of straight cut for Bhattiprolu drain be given the third priority.

PART IV

Drains of Godavari Eastern and Central Deltas

CHAPTER—I—MAJOR DRAINS AND DRAINAGE SISTEM.

1.1. TOPOGRAPHY.

1.1.1. The general topography of the Godavari Eastern and Central deltas is similar to that of K. W. Delta system. The average slope of the country from head of these deltas upto the Bay of Bengal is even flatter than in the case of K. W. delta since the Coromandal coast has advanced into the sea from 'Antervedi', at the mouth of Vasista Godavari upto the Kakinada Bay, thus increasing the length of flow for the drainage. Because of the flat and low lying nature of the country, the drainage finds its way into sea with great difficulty.

1.1.2. The infalls for the drains in these deltas are of two types. Some drains join the sea direct viz; the lower Kowsika, Vasalatippa and Kunavaram drains in the central delta; the Tulyabhaga and Biccavole drains in the Eastern delta. These drains are subject to tidal action and their mouths are often affected by the littoral drift of sand. The other drains join the sea through one of the arms of the river Godavari. For example, in the central delta, the Kattunga, Nerellachedu and Antervedi drains have their infall into Vasista Godavari while the Gorinkala, Vada-Revupalli, Shankaraguptam and Panchanadi drains join the Vynatheyam, an arm of Vasista Godavari. Similarly the Teki drain in the Eastern delta joins the Coringa River. Whenever the river is in high floods, the flood waters back up into these drains and cause inundation over the low lying marginal areas. The drainage congestion in these drains is at its worst when the local rains and the floods in the river are experienced simultaneously. The period of flooding over the marginal lands sometimes extends over a period of 30 to 40 days. Sometimes even without local rains, if the river is in floods, certain areas get flooded due to the backing up of the flood waters of the river.

1.1.3. The drains in the central delta have only deltaic catchment whereas there are a few drains in the Eastern delta having both upland and deltaic catchment viz. Biccavolu, West Yeleru, Vetlapalem drains etc. The southern railway embankments and the Samalkot canal in the Eastern Delta cause certain obstruction to the natural drainage from the uplands even though bridges and cross drainage works have been provided for the drains. The sand dunes formed along the coast due to littoral drift of sand are also responsible for the drainage congestion in these areas as they prevent easy and quick flow of drainage water.

1.2. GENERAL DESCRIPTION OF IRRIGATION SYSTEM IN EASTERN DELTA.

1.2.1. The Godavari Eastern delta comprises the Ramachandra Puram taluk and parts of Rajahmundry and Kakinada taluks lying in East Godavari district. This section of the delta is surrounded by the southern railway line on the north, the Bay of Bengal on the east and Goutami Godavari river on the west and South. The total area irrigated in this section of the delta is about 3 lakh acres of which about 2 lakh acres is in the 1st crop season and the balance during the second crop season. The entire irrigation is carried on through three major canals viz. the Bank, Kakinada and Samalkot canals. These canals take off from the Godavari Eastern Main canal. The main canal itself takes off through a head sluice built at the left flank of Dowlaiswaram Anicut across the river Godavari. All the three major canals and a few other branch canals in this system are navigable.

The Bank Canal takes off between Km. 0 and 1.6 (mile 0 and 1) of the Main Canal on the right side and runs along and in rear of the left flood bank of Goutami Goadavari river for a total length of about 63 K.M. (39 miles) and ends at Talla Revu lock on the bank of Coringa river. The Coringa branch canal takes off from the Bank Canal between K. M. 21 and 23, (mile 13 and 14) and runs for a length of about 35 K.M. (22 miles) and has its tail end lock at Manjeru from where it is connected to Coringa River. Injram Canal is a major distributary taking off from the Coringa branch canal between its 34 K.M. and 36 K.M. (miles 21 and 22) on the right side.

The Kakinada canal takes off from the Main Canal on the right bank between K.M. 6 and 8 (miles 4 and 5) and runs for a distance of about 40 K.M. (25 miles) and ends at the Kovvur tail end lock which is connected to Kakinada Bay. The Mandapeta branch canal takes off from

Kakinada canal between its K.M. 9 and 12 (miles 6 and 7) and connects to the Coringa branch near K.M. 39 (M. 24) for navigational purposes. The Kakinada and Mandapeta canals provide irrigation on both sides. The Kovvur lock on the Kakinada canal is also connected to the Manjeru lock on the Coringa canal through a junction canal called Kovvur Manjeru canal. This is also used for navigation purposes, besides serving irrigational needs.

The Samalkot canal which bifurcates from the Main Canal at the same place as the Kakinada Canal runs for a total length of about 60 K.M. (37 miles) along the Rajamundry-Kakinada Road *via* Samalkot and ends near Kakinada where it is connected to the Bay of Bengal. This canal forms the northern boundary of the Godavari Eastern delta and is the demacrating line between the upland and delta area in East Godavari district. The Biccavolu drain, Vetlapalem drain and the West Yeleru drain are some of the upland drains intercepted by this canal. This canal is mostly a navigation Canal with irrigation as a secondary importance.

1.3. DRAINAGE SYSTEM OF GODAVARI EASTERN DELTA.

1.3.1. The area irrigated in the Eastern delta is also mostly served by a network of natural drainage courses. The condition of the drains in the section is also similar to those in the Central delta. There are four major drains and 78 medium and minor drains in the Godavari Eastern delta serving the entire ayacut area of about 2 lakhs acres during the Kharif and 1 lakh acres in Rabi seasons. The total length of the major drains is approximately 140 K.M. (86 miles) and that of the medium and minor drains is about 394 K.Ms. (245 miles). The area lying between Bank and Mandapeta canals is served by Nallur and Kaleru drains which ultimately flow into Teki drain. The area lying between the Bank and Coringa canals is served by the Teki drain and its minor tributaries. The area between Kakinada and Mandapeta, Coringa canals is served by the Tulya bhaga drain and its branches, while that between the Samalkot and Kakinada canals is served by the Biccavole, Vetlapalem, West and East Yeleru drains together with their branches. The Teki Tulya bhaga drains and their branches have purely deltaic catchment while the Biccavole, West and East Yeleru are mostly upland drains having small deltaic catchments after they cross Samalkot canal. The irrigation and drainage system of the Godavari Eastern delta is given in Plate 8. A brief description of important drains is given below:

1.3.2. Biccavole Drain.

As distinguished from the other major drains in the Godavari Eastern delta, Biccavole drain has got both upland and deltaic catchments. The total length of the drain is about 27 K. Ms. (16 miles 5 furlongs) and drains a total area of 655 sq. K.M. (253 sq. miles). The drain starts at 30.4 K.M. (M. 18-7-300 ft.). of Samalkot canal on the right side. It finally falls into a salt creek called Kakinada canal other wise known as Kakinada shipping canal. This drain receives drainage from upland area of Medapadu, Brahmadevam and Boddigunta basins which flow into Samalkot canal through various inlets and the surplus water is allowed to flow into this drain through the Biccavole weir at 30.4 K. Ms. (M 18-7-300 ft.) of Samalkot canal. This drain also serves the irrigated area lying between Kakinada canal and Samalkot canal and absorbs the drainage coming from Vetlapalem weir. The Biccavole drain collects its drainage through a number of tributaries of which the West Yeleru drain is the most important. The other minor drains joining this drain are the new Vulapalli drain, Kankanalacodu drain, Kaikavole drain, East Yeleru and Bhavaram drains. The East Yeleru drain joins this drain at about 27 K.M. (M. 16) and Bhavaram drain joins the salt creek at about 29 K. M. (M 18) after its confluence with the salt creek. The O.F.L. and M.F.L. discharges of Biccavole drain are computed to be about 69 and 287 cu. M/Sec. (2425 and 10,071 cusecs) respectively.

This drain is a natural course and improved for providing better drainage facilities. Several improvements have been made to the drain from time to time but it is still unable to carry the entire peak discharge and consequently causes heavy damages to the crops during heavy floods. The tail reach of the drain is subjected to tidal action.

1.3.3. Tulyabhaga Drain.

The Tulyabhaga drain originates from the right bank of Kakinada canal and flows through the middle of Godavari Eastern delta draining the irrigated area situated between the Kakinada cana and Mandapeta-Coringa canals. In olden days it used to be called Kasyapa Godavari and is believed to be one of the seven branches of Godavari River. It flows over a total length of 49 K.Ms. (30 miles and 4 furlongs) draining a total area of 279 sq. K.Ms. (108-sq. miles). There are 18 small drains falling into this drain in addition to the water from some canal surplus weirs. It receives the excess flood waters of Kakinada canal through the surplus weir at about 12 K.M. (M 7/2) on right bank and from Mandapeta canal through the surplus weir at about K.M. 5 (M 3/2). There is a syphon across this drain at K/ M. 33.4 (M 20-6-255) for Yandamuru Channel. There is also an aqueduct at K.M. 41.4 (M 25-5-125) for the K.M. J. canal near Gorripudi. The drain finally enters the Kakinada Bay through Matlapalem Kalava at a place about 6 K/M. (4 miles) south of Kakinada Port. The O.F.L. and M.F.L. discharges of Tulyabhaga drain at end are computed to be about 35 and 126 cu. M/sec. (1230 and 4443 cusecs) respectively.

1.3.4. Nalluru Drain.

The Nalluru drain rises from the right bank of Mandapeta canal in Jagurupadu village limits just below the bifurcation of Mandapeta canal with Kakinada canal and flows over a total distance of about 23 K/Ms. (14 miles) draining an area of about 135 sq. K/M. (52 sq. miles). This drain runs parallel to Mandapeta canal in easterly direction for a length of 5 K/Ms. (3 miles) and then turns to south eastern direction and falls into Teki drain at 8 K/M. (M 5/0). It is a natural drainage course with catchment on both sides. This drain causes heavy submersion during continuous heavy rains. There is no means of regulating the backed up waters of Teki drain during floods. Standards for the drain are to be fixed up after carrying out necessary investigations. The O.F.L. and M.F.L. discharges of the drain at the end are computed as 11 and 32 cu. M/sec. (376 and 1128 cusecs) respectively. Along with Kaleru drain, this serves the irrigated area lying between Bank and Mandapeta canals to the north of Coringa canal.

1.3.5. Teki Drain.

The Teki drain starts from Teki surplus weir above Alamuru lock of Coringa canal on the right bank. This surplus weir has got regulating arrangements and is allowed to surplus only when the Coringa canal stands above F.S.L. The drain flows over a total length of 41 K/M. (M 25) draining a catchment area of 474 sq. K/M. (183 sq. miles) lying between Mandapeta-Coringa canals in the north and the Bank canal in the South. It falls into Coringa river at Tallarevu lock and finally joins the Bay of Bengal.

This drain collects its drainage through a number of tributaries of which the Nalluru drain is the most important. The other minor drains joining the Teki drain are the Kaleru, Uppumilli, Kunduru, Kapileswarapuram, Macharа, Gangavaram, Andrangi, etc., drains. The tail end reaches of the drain are subject to tidal action. The drain is fairly wide and deep throughout except at junctions and at straight cuts, etc. As this drain falls into Coringa river which is a branch of Godavari it is affected by the flood level of Godavari. When Godavari is in high floods, the waters back up into the Teki drain resulting in inundation of paddy fields on either side of the drain. The drain is banked almost to the entire length but breaches often occur during the flood season. The O.F.L. and M.F L. discharges of Teki drain are computed to be 93 and 278 cu. M./sec. (3294 and 9782 cusecs) respectively.

1.4 GENERAL DESCRIPTION OF IRRIGATION SYSTEM IN CENTRAL DELTA.

1.4.1 The Godavari Central Delta comprises the taluks of Amalapuram, Razole and Kothapeta all of which lie in East Godavari district. This area popularly known as ' Konaseema' is famous for its fertile lands and scenic beauty. The entire area in the Central Delta can be divided into three parts.

The Polavaram Island is surrounded by Goutami Godavari on the north, the Bay of Bengal on the east, and the Bharadwaja arm of Goutami Godavari on the south and west.

The Central Main Island is a triangular portion with its apex in Bobbarlanka and having the Bay of Bengal on the south east, the Vasista Godavari and Vynatheyam rivers on the west the Gautami Godavari and Bharadwaja rivers on the north and north east.

The Nagaram Island is surrounded by the Vynatheyam arm of Vasista Godavari on the east, the Bay of Bengal on the south, Vasista Godavari on the west and Vasista Godavari and Vynatheyam on the north.

1.4.2. A total of about 3 lakh acres is being irrigated in the Central delta. Out of this 2 lakh acres is in the first crop season and the balance in the second crop season. The area is mostly irrigated by three branch canals, *viz.*, the Bank, Amalapuram and Gannavaram canals. The Bank and Gannavaram canals take off from the Godavari Central Main canal, while the Amalapuram bifurcates from the Bank canal. The Main canal itself takes off from the river Godavari at the right flank of Rally Anicut, which is one of the four sections of the Godavari Anicut constructed across the river Godavari at Dowlaiswaram by Sir Arthur Cotton during 1850-60. The main canal and the three branch canals are navigable.

The Bank canal takes off from left bank of the Main canal and runs in a south easterly direction for a length of 14.5 K.m. (9 miles) up to Mandepalli village. From Mandepalli up to its tail end near Pallam Kurru the canal runs parallel to and in rear of the right flood bank of Gautami Godavari. The total length of this canal is about 64.4 K.M. (40 miles).

The Amalapuram canal takes off from the Bank Canal and runs for a total length of about 49.9 K.M. (31 miles) and ends near Challapalle in Amalapuram taluk. From its off take point up to Mukkamala, *i.e.*, in the first 27 4 K.M. (17 miles) of its length the canal commands irrigation only to its western side but below Mukkamala up to the tail end it provides irrigation on both sides.

The Gannavaram Canal bifurcates from the Main canal at Rally lock bridge and runs in rear of the left flood bank of Vasista Godavari. This was originally excavated for a distance of 30.6 K.m. (19 miles) up to the place called Gannavaram, but subsequently was extended into the Nagaram Island by building the famous Gannavaram aqueduct across the Vynatheyam arm of Vasista Godavari. The total length of this branch canal is 67.6 K.m. (42 miles) below its off take.

The Polavaram island was provided with irrigation facilities in the year 1929-1930 by taking off a separate canal above the Annampalli lock weir bridge.

1.5. DRAINAGE SYSTEM OF GODAVARI CENTRAL DELTA.

1.5.1. The area irrigated under the Godavari Central delta system is at present being served mostly by a net work of natural drainage courses. The area lying between the Bank and Amalapuram canals is mostly served by the Palivela, Mukkamala, Vridha Gautami and Kunavaram drains which receive the drainage through a number of other small drains joining them. The area between the Amalapuram and Gannavaram canals is served by the Gorinkala, Upper Kowsika, Lower Kowsika, Vasalatippa and Panchanadi drains which also similarly collect their drainage through some other minor drains. The main drains in the Nagaram island, *i.e.*, the area between the Vasista and Vynatheyam arms of Godavari is served by Sankaraguptam, Vepachettu, Antervedi, Vedabodhi and Nandi drains together with their tributaries. Similarly the area in Polavaram island is served by Kesanakurru, Addala Kalva and other minor drains. As already stated, all the drains in this delta have deltaic catchment only. The irrigation and drainage system in the Godavari Central delta is given in Plate 7.

There are 9 major drains, 21 medium drains and 130 minor drains in the Godavari Central delta. The drainage water from the entire ayacut of 2 lakh acres is served by these drains. The total length of major drains is approximately 151 K.M. (94 miles) and that of the medium and minor drains are about 206 K.M. (128 miles) and 386 K.Ms. (240 miles) respectively.

The important drains of these basins are described in the succeeding paragraphs.

1.5.2. SANKARAGUPTAM DRAIN.

This is one of the important drains of the Nagaram island of the Central delta. It starts near Kattimanda village in Razole taluk and flows parallel to the coastal line for a total length of about 19 K.Ms. (12 miles) collecting drainage from the fields of Kattimanda, Kunavaram, Chintalapalli, Mogali Kuduru, Gudapalli, Ponnamanda, Katrinipadu and B. Savaram villages before its infall into Vynatheyam arm of Vasista Godavari river. The drain runs just North of Sankaraguptam and Kesanapalli villages. It collects drainage through a number of medium and minor drains joining it along the courses. Of these, the Kunavaram drain, which in turn collects its drainage through Chintalapalli No. 1, Mogalikuduru and Gudapalli minor drains, is the most important tributary. The other minor drains that join Sankaraguptam drain are Kattimanda, Ponnamanda No. 1 and Ponnamanda No. 2 drains. The drain has a total catchment area of 69 sq.K.M. (27 sq. miles) and a total length of about 66 K.Ms.(41 miles) including its branches. The designed O.F.L. and M.F.L. discharges of the drain are furnished as 7 and 21 cu. M/sec. (242 and 726 cusecs) respectively. This drain is not investigated and hence its standards are yet to be fixed.

1.5.3 Gorinkala Drain.

This drain originates d/s of Ralli surplus weir on the right bank of Amalapuram canal between K.M. 18 and 19 (miles 11 and 12) and flows for a total length of about 23 K.M. (14 miles) in between Gannavaram and Amalapuram canals *viz.*, Itakota, Ganti and Munganda Villages before emptying itself into Vynatheyam Godavari river near the village Manjavaram in Kothapeta taluk. This collects drainages through three medium branch drains, *viz.*, Ryali Surplus weir drain, Sankhyanadi, Upper Kowsika and Sakurru drains and four minor branch drains, *viz.* Ramachandrapur and Bellampudi surplus weir drains, Ravipadu and Pothavaram drains. Together with its branches the total length of the drainage course is about 53 K.M. (36 miles) with a combined catchment area of 135 sq. K.M. (52.20 sq. miles). The computed O.F.L. and M.F.L. discharge of this drain at the end are furnished as about 11 and 32 cu.M/sec. (377 and 1,131 cusecs) respectively. This drain is to be investigated and its standards fixed.

1.5.4 The Upper and Lower Kowsika Drains

Prior to the construction of the anicuts across the Godavari, the Kowsika which branches off as a spill channel from the Gowtami Godavari played an important part both as a source of irrigation as well as a drainage course. The Kowsika originally traversed nearly the whole length of the delta and was in old days considered to be one of the main branches of the Godavari river. During the development of the canal system the upper portion of the Kowsika was merged into the Amalapuram canal from Palivela to Mukkamala. The waters of Upper Kowsika enter Vynatheyam Godavari *via.*, Sakurru and Gorinkala drains.

After picking up the old courses from the Mukkamala surplus, the Upper Kowsika takes a very zigzag course of nearly 31 K.M. (19 miles) before it is intercepted again by the Bendamurlanka channel from K.M. 51 to 61 (M. 32 to M. 38-1-0) from there it again emerges out as the lower Kowsika drain. After running in a very crooked course for a length of about 16 K.Ms. (10 miles) it finally enters the Bay of Bengal at Rameswaram Moga. On its way it collects drainage through four other Minor drains *viz.*, Allavaram drain, Sirigatlapalli drain, Devaguptam drain and Samanta-Kurru drain, flowing through Amalapuram taluk.

Some of the salient particulars of Upper and Lower Kowsika drains are given in Table No. 4.1.

Table No. 4.1.

Sl.No.	*Name of the drain.*	*Length.* K.M.(M/F)	*Catchment area at the end. sq.K.M. (sq. miles).*	*Flood disch. in cu. met. Sec. (C/S).* *END*	*HFL*	
1.	Upper Kowsika ..	30 (18–6)	19.7 (7.63)	4.14 (146)	12.4 (438)	Joins Vynatheyam Godavari, *via.*, Sakurru & Gorinkala drains.
2.	Lower Kowsika ..	17.10 (10–5)	38.9 (15.00)	4.95 (175)	14.8 (525)	Joins Bay of Bengal near Rameswaram Moga.

These drains have not so far been investigated and hence hydraulic particulars are not available reachwise.

1.5.5. VRIDHA GOUTAMI DRAIN:

This is a major drain running in the valley between Amalapuram and Bank canals over a length of 20 9 K.Ms. (13 miles) before emptying into Goutami Godavari through the under tunnel built at K.M. 74 (M 42/5) of Bank canal. The drain takes its birth near a place called Mukteswaram situated on the Kotipalli Amalapuram Road in East Godavari district. The drain flows generally in a south easterly direction and during the lower reaches of its course flows in a zig-zig manner before joining the Goutami Godavari near Palle Palem. It receives drainage through a number of tributaries of which the Bondakodu drain is the most prominent. The other minor tributaries are (1) Gadilanka drain (2) Kommanapalli drain (3) Panthayi Kodu drain (4) Mummidivaram drain (5) Chintavari Kodu drain (6) Krapa drain (7) Somadevarapalam drain (8) Kothalanka drain and (9) Rajupalem drain. The total length of the drainage course including all the tributaries comes to nearly 55 K. Ms. (34 miles). The drain has a total catchment area of 58 sq. K.M. (22.50 sq. miles). The O.F.L. and M.F.L. discharge of the drain at the end are computed to be about 6 and 19 cu. M/Sec. (215 and 645 c/s) respectively.

1.5.6. KUNAVARAM DRAIN:

This is the most important major drain in the whole of Godavari central delta with a total catchment area of 212 sq. K.M. (81.65 sq. miles). It collects drainage through a number of tributaries of which the old Ainapuram drain, Amalapuram drain and the Rangaraju kodu drain are the most prominent. These three are classified as major drains as they drain an area of more than 52 sq. K.M. (20 sq. miles) each.

The old Ainapuram drain which empties its flood waters into the Kunavaram drain collects the drainage through eight minor drains.

1. Pentayya Kodu drain.
2. Robson Kodu drain.
3. Irumanda drain.
4. Bantumilli drain.
5. Chinnagadavilli dra.
6. Payakarao Kodu dran..
7. Uppalaguptam drain.
8. Katreni cona drain.

The Ranga Raju Kodu drain which also feeds the Kunavaram drain collects its drainage from six minor drains.

1. Amalapuram Major drain. (This in turn gets the drainage water through :
   - (a) Bhatnavalli,
   - (b) Vemavaram,
   - (c) Ananthavaram,
   - (d) Vilasavilli and,
   - (e) Gunnipalli drains,)
2. Ainapuram new drain.
3. New Samansa drain.
4. Old Samansa drain.

Besides the above the Gorganamudi and north Peekileru drains also join the Kunavaram drain direct.

The total length of Kunavaram and its net work of branch drains comes to 110 K.Ms. (68 miles). This drainage system provides outlet for the excess water collected over the fields of Anantavaram. Samansa, Bhimanapalle, Cheyyeru, Ainapuram, Uppalaguptam, Gorganamudi, Gopavaram, Challapalli, S. Yanam and other villages in Amalapuram taluk.

The O.F.L. and M.F.L. discharges of this drain at end are computed to be 14 and 43 cu. M/sec. (508 and 1524 c/s) respectively. The drain joins the Bay of Bengal about two miles south of the place called Brahmasamedyam. The mouth of this outlet is reported to be unstable being effected by littoral drift. The mouth is shifting constantly northwards. It is stated that the mouth is also getting choked and is functioning unsatisfactorily.

1.5 8. VASALA TIPPA DRAIN :

This forms the valley between Bendamur and Amalapuram canals draining a total area of about 70 sq. K.M. (27 sq. miles) and flows for a length of about 21 K.M. (13 miles). It collects drainage through one medium drain, *viz.*, Desakodu drain and seven other minor drains as mentioned below:

1. Dabbandala drain.
2. Rangapuram drain.
3. Gedalacodu drain.
4. Vaddicheruvu drain.
5. Tadikonda drain.
6. Peekileru drain.
7. Zandalacodu drain.

The total length of all the net work of drains comes to about 45 K.Ms. (22 miles). It collects drainage from the ayacut lands of Peruru, Allavaram, Vennechintalapudi, Tadikona, Rangapuram Tandavapalle, etc., villages in Amalapuram taluk. It also receives the surplus from Challapalli weir at about 64 K.M. (M. 40) of Amalapuram canal. The O.F.L. and M.F.L. discharges of this drain at the end have been computed to be 7 and 21 cu. M/sec. (242 and 726 cusecs) respectively. This drain joins the Bay of Bengal at the Rameshwaram Moga where the lower Kowsika drain also enters the sea.

1.5.7. KUMMARA KALVA DRAIN.

This is also a major drain in the Godavari central delta taking its birth near about Mukkamala village and flows over a total distance of about 24 K.Ms. (15 miles) *via.* Kallamilli, Amalapuram, Tollapalem, Edurlupalem villages before falling into Vynatheyam Godavari through an outfall sluice built about 5 K.M. (3 miles) south of Bodasakuru. It collects drainage through two other minor drains *via* Vekkalanka drain and Peruru parallel drain. It drains a total catchment area of about 70 sq. K.M. (27 sq. miles.). The O.F.L. and M.F.L. discharges of the drains at the end are computed to be 7 and 21 cu. M/Sec. (244 and 732 cusecs) respectively.

CHAPTER II—RAINFALL.

2.1. The average annual rainfall during 1870 to 1949 of the East Godavari district is 1150 m.m. (45-32 inches). Cyclonic storms sometimes occur during latter part of the year, bringing heavy rain which goes to swell the average. The first four months of the year are practically without rain, but in May there is usually a fair amount of rainfall. More than half of the annual rainfall is brought by the South-West Monsoon, while most of the rest falls in October and November. The distribution, however differs markedly in various parts of the district as can be seen from the tabular statement given in Table No. 4.2.

TABLE No. 4.2

S. No.	*Zone*	*Rainfall in Millimetres (inches).* Dry Weather (Jan. to March)	Hot Weather (April to May)	South-West Monsoon (June to Sep.)	North-East Monsoon (Oct. to Dec.)	Annual
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1.	Agency ..	40.8 (1.61)	77.2 (3.90)	896.0 (35.27)	206.0 (8.11)	1,240.0 (48.89)
2.	Western ..	27.2 (1.07)	71.3 (2.81)	668.0 (26.29)	283.0 (11.35)	1,054.0 (41.52)
3.	Northern ..	25.15 (0.99)	75.6 (2.98)	606.0 (23.91)	298.0 (11.77)	1,010.0 (39.65)
4.	Eastern ..	25.4 (1.00)	58.4 (2.30)	658.0 (25.88)	385.0 (15.17)	1,126.0 (44.35)
District Average (Average for Plains and Agency).		32.8 (1.29)	82.2 (3.24)	766.0 (30.23)	268.0 (10.56)	1,151.10 (45.32)

Now coming specifically to the Godavari Eastern and Central delta areas the Normal rainfall pattern is given in table No. 4.3 and 4.4 respectively. (Taken from Annexure XII of K.G. Commission's Report).

2.2 GODAVARI EASTERN DELTA.

TABLE No. 4.3.

Month	*Rainfall in millimetres (inches)* Normal	Maximum	Minimum
June	106.6 (4.2)	160.0 (6.3)	25.4 (1.0)
July	234.0 (9.2)	406.0 (16.0)	109.0 (4.3)

Month			Rainfall in Millimetres (inches) Normal		Maximum		Minimum	
August	..	..	170.0	(6.7)	267.0	(10.5)	99.0	(3.9)
September	..	..	170.0	(6.7)	334.0	(13.3)	93.0	(3.7)
October	..	..	244.0	(9.6)	434.0	(17.1)	58.4	(2.3)
November	..	..	73.6	(2.9)	338.0	(13.3)	Nil	
December	..	..	12.7	(0.5)	85.8	(3.4)	Nil	
January	..	..	Nil		76.2	(3.0)	Nil	
February	..	..	5.05	(0.2)	35.6	(1.4)	Nil	
March	..	..	5.05	(0.2)	28.0	(1.1)	Nil	
April	..	..	15.2	(0.6)	66.0	(2.6)	Nil	
May	..	..	50.8	(2.0)	284.0	(11.2)	2.5	(0.1)
	Total	..	1,087.0	(42.8)				

From the above, it may be seen that the rainfall pattern in Eastern Delta is similar to that of Central delta, though the average annual rainfall is a little less.

2.3 Godavari Central Delta.

Table No. 4.4

Month			Rainfall in Millimetres (inches) Normal		Maximum		Minimum	
June	..	..	112.0	(4.4)	239.0	(9.4)	22.9	(0.9)
July	..	..	231.0	(9.1)	353.0	(13.9)	101.5	(4.0)
August	..	..	175.0	(6.9)	277.0	(10.9)	132.0	(5.2)
September	..	..	191.0	(7.5)	249.0	(9.8)	71.1	(2.8)
October	..	..	257.0	(10.1)	426.0	(16.8)	129.5	(5.1)
November	..	..	68.6	(2.7)	264.0	(10.4)	Nil	
December	..	..	20.4	(0.8)	142.0	(5.6)	Nil	
January	..	..	2.5	(0.1)	12.7	(0.5)	Nil	
February	..	..	10.1	(0.4)	48.2	(1.9)	Nil	
March	..	..	5.0	(0.2)	38.1	(1.5)	Nil	
April	..	..	15.2	(0.6)	45.6	(1.8)	Nil	
May	..	..	43.2	(1.7)	168.0	(6.6)	5.1	(0.2)
	Total	..	1,131.0	(44.5)				

From the above it can be seen that most of the rainfall occurs between June and November. The rainfall from December to April is rather negligible. The rainfall in May is considerable.

Both the areas receive rainfall under the influence of both south-west Monsoon (June to September) and North-East Monsoon (October to December). Rainfall statements for Godavari Western Central and Eastern deltas from 1945 to 1964 are given in Appendix D (*iv*), D (*v*) and D (*vi*).

CHAPTER III—FLOODS AND FLOOD PROBLEMS

The floods and flood problems experienced under the various drains in the Godavari Central and Eastern deltas can be attributed to the following causes.

3.1 The average slope of the country from the head of the delta up to the sea is less than one foot per mile. The surface fall obtaining in the lower reaches of the drains is even flatter. Due to the low surface fall, the rate of discharge into the sea is considerably impeded causing drainage congestion over prolonged periods.

3.2 The drains which join the sea direct are affected by the tidal action to a considerable length above their infall. The sea water backs up into the drain during high tide periods and cause obstruction to the free flow of natural drainage. The salt waters even enter low lying irrigated areas situated on the margins of these drains making them saline and unfit for irrigation. The drainage flow is also affected due to the mouths being closed on account of littoral drift of sand. As an example the Biccavole and Tulyabhaga drains in the Godavari Eastern delta and the Panchanadi, Lower Kowsika, Vasalatippa and Kunavaram drains in the Central delta can be cited.

3.3 In the case of drains which have their infall into one or the other branch of Godavari river, the drainage flow is obstructed due to the fact that during the south-west monsoon period the flood level of Godavari river would be higher than the drainage water level in the drains. Consequently, stagnation of flow occurs causing inundation of crops. The result is that there is practically a total loss of crop in the areas where they cannot withstand the period of submersion and in other areas where the crop attained certain growth, the yield is considerably affected. In some cases where outfall sluices are not provided, the Godavari water freely backs up into the drains and cause inundation in the irrigated areas even though there may not be local rainfall.

As an example, the Sankaraguptam drain in the Godavari Central Delta and the Teki drain in the Godavari Eastern delta can be cited under this category.

3.4 The masonry works built across the drains do not have adequate waterway and cause obstruction to the flow. This leads to heading up of flood waters causing inundation.

3.5 In general, the drains on both the deltas are having inadequate sectional area. They are badly silted up. Most of them do not have flood banks to prevent their flood waters from spilling over the margins. Where flood banks exist, they are neither continuous nor are of adequate height, shoals are formed in the beds of the drains at many places. Considerable weed growth is noticeable in most of the drains. These obstruct the flow and aggravate the flood problems in the areas. The drainage courses are found to have serpentine bends at many places. These increase the length of flow and add to poor surface falls.

Now some of the specific flood problems experienced under certain drains in both these deltas are briefly described below :—

3.6 GODAVARI EASTERN DELTA.

3.6.1 Biccavole Drain.

The existing drain section below the confluence of West Yeleru drain is found to be inadequate to carry the combined flood discharge. As a result, the lands adjoining the drain in the villages Domada, Pedapudi, Karakuduru, Achyuta-Pura Trayam, etc., are getting submerged every year during floods. The existing banks for the Biccavole and West Yeleru drains are found to be low and weak. They are getting eroded. During the floods, they are unable to prevent over-topping by the drain waters.

3.6.2 Tulyabhaga Drain.

At a number of places along its course, the drain is not wide enough. As a result, the flood level rises causing submersion of marginal lands when the main drain is in floods, its waters back up into the feeder drains since they do not have any outfall sluices. This results in drainage congestion and prolonged submersion of paddy fields in the area. The highway bridge at Velangi and the old bridge at Gorripudi are causing obstruction to the drainage flow. The former is to be widened and the latter dismantled. The existing aqueduct near Gorripudi built across the drain for the Canal is getting choked up due to tidal action and is causing obstruction to the flow. Consequently the flood level tends to rise, adding to the submersion problem. This aqueduct is either to be reconstructed with increased ventway or dismantled altogether as the KMJ Canal is a purely navigation canal and even this navigation is not much to be seen these days.

3.6.3 Teki Drain.

As in the case of other deltaic drains, the surface fall for the drainage flow in this drain is very flat and in some reaches it is as low as one foot per mile. Consequently, the flow is sluggish causing drainage congestion in the area served.

The Teki drain and its various feeder drains are observed to function well till about the end of June every year. The flood problems under this drain attain serious proportions with the onset of south-west monsoon during the months of July and August and the North-East monsoon in the months of October to December every year.

The Teki drain has its infall into Coringa river (Atreya Godavari) which is a branch of the Gowtami Godavari river. It is a common experience that the flood level of Godavari would attain its maximum during the months of July and August. Consequently, the flood level of Coringa river would also touch the maximum during these months. This rise in flood level in Coringa river has a direct effect on the discharging capacity of Teki drain. The Coringa river waters even back up into the Teki drain and add to the devastating action of the floods under the drain. The damage caused to the tender paddy plants during this period is enormous.

Again in the months of September and October, due to the onset of North-East monsoon the Teki drain is in floods. But its discharging capacity is affected due to the severe tidal action to which Coringa river is subjected to during this part of the year. The level of Coringa river rises steeply on account of tidal effect, even though the Godavari is not in floods during this period. In fact, the water level in Godavari in this part of the year is generally low. As there may not be a feasible remedy for lowering the tidal effect on Coringa river, alternative measures may have to be devised to divert part of the flow in Teki drain from its upper reaches into the river Godavari whose water level would be low by this time.

3.7 GODAVARI CENTRAL DELTA.

3.7.1 Shankaraguptam Drain.

The drainage problems experienced from this are mainly due to ;

(1) Backing up of Flood waters from the main river during monsoon period.

(2) Backing up of tidal waters in summer.

(1) At the place of confluence of the drain with Vynateyam Godavari, the M.F.L. of the river during floods is +6.50 and the M.F.L. of the drain is +3.50. Therefore, the river water backs up into the drain over a considerable length causing drainage congestion. As a result of this, the marginal lands along the drain are subjected to submersion for more than 7 days and above one foot depth, damaging paddy crops.

(2) During summer, due to high tides in the Bay of Bengal, the peak tide level will be of the order of +4.50. The water level being low in the drain during this period, the tidal waters back up into the drain over a distance of about 8 to 10 miles above its infall. As a result of this the marginal lands along the drain are submerged causing salinity to the fields and this would reduce the crop yield.

3.7.2 Panchanadi, Lower Kowsika and Vasalatippa Drains.

The place where all these drains discharge their waters into the Bay of Bengal is known as "Rameswaram Moga." These drains in their lower reaches are subject to tidal action as a result of which the salt waters of the sea enter the tail end ayacut lands which are low lying. These lands become saline and are rendered gradually unfit for irrigation.

It is observed that the Moga has shifted towards south-west by nearly a mile from its original position during the course of the last 40 years. This may probably be due to the strong east wind prevailing in this area. The mouth is also getting closed due to littoral drift of sand thereby making the free flow of the drainage into the sea from the above three streams difficult.

The Rameswaram Moga which was said to be originally near the place Rameswaram was found to be quite stable and functioning well till in the years 1916-18, it was got closed by some interested landlords. Though during the heavy cyclonic rains of September 1923, the storm waters by themselves cut an opening into this closed Moga, the mouth has been observed to shift gradually towards south-west ever since. The present moga is not satisfactorily functioning.

3.7.3 Kunavaram Drain.

The place where Kunavaram drain joins the Bay of Bengal is called Chirrayanam-Brahmasamedyam Moga. This Moga during the recent years is observed to be moving Northward owing to the sand movement from the south. Due to the tidal action and unsatisfactory functioning of the mouth, this drain is affecting ayacut lands in six villages *viz.*, Kunavaram, Gopavaram, Challapalli, S. Yanam, Uppalaguptam and Gollavilli.

CHAPTER IV—DAMAGE BY FLOODS.

4.1 As already stated in the previous chapters, the flood problems of the drains in East Godavari district are directly linked up with the floods in Godavari river, as the inundation of irrigated areas is mostly due to the flood waters of the river backing up into the drains. The Godavari flood is an annual feature. The maximum flood level ever recorded after the construction of anicuts in the year 1852 was experienced in the year 1953 when it touched 5.95 metres (19.5 ft.) over the crest of the anicut i.e. +17.75 metres(58.25 ft. MSL) at Dhowlaiswaram on 16th August 1953 corresponding to a discharge of about 81,000 cu. metres/sec. (28.59 lakh cusecs).

4.2 Flood damage particulars were supplied for Godavari Eastern Delta by the State P. W. D. for 10 years from 1955 to 1964. From this it has been seen that on an average, about 33,630 acres of land were submerged. About 29,000 metric tonnes of food grains valued at Rs. 1.10 crores were lost every year by floods.

Out of these 10 years, 1959 is the worst affected year when 70,600 acres of land were submerged. About 53,000 metric tonnes of foodgrains valued at Rs. 2.01 crores were lost in this year. Next worst affected year was 1964 when 68,000 acres of land were inundated. During this year, food grains of about 51,000 metric tonnes, valued at Rs. 1.94 crores were lost by floods. A statement showing flood damage particulars for Godavari Eastern Delta for 10 years from 1955 to 1964 is given in Appendix-F (*iv*).

4.3 Flood damage particulars for Godavari Central Delta were supplied by the State P.W.D. for 10 years from 1955 to 1964. From this, it has been seen that on an average, about 21,000 acres of lands get submerged every year. Food grains of about 15,840 metric tonnes valued at Rs. 60.19 lakhs are being lost annually due to these floods.

Out of these 10 years (1955 to 1964), 1959 was the worst year when about 34,000 acres of land were affected by floods. During this year about 25,500 metric tonnes of food grains valued at Rs. 97 lakhs were lost. Next worst year is 1958 when about 28,400 acres of land were inundated. In this year, about 21,200 metric tonnes of food grains valued at about Rs. 81 lakhs were lost. A statement showing flood damage particulars for Godavari Central Delta is given in Appendix-F (*iii*).

CHAPTER V—WORKS ALREADY CARRIED OUT AND CONTEMPLATED.

5.1 It can generally be stated that improvements to drains in both these delta sections have not so far received the attention they deserve due to the non-availability of the required staff and funds. Even the routine maintenance of removing the silt and weed growth and repairs to the banks appears to have not been carried out in some of the drains due to meagre allotment of funds.

5.2 The greatest threat to the Godavari delta areas is from the floods in Godavari River. To protect the lowlying irrigated areas in the delta from the devastating action of the furious Godavari flood waters, flood banks have been built on either side of the different arms of Godavari and these are being maintained at considerable expense year after year. The safety of these flood banks is vital not merely for the protection of the paddy crops but also for the very existence of the people in the areas.

5.3 Now coming to the improvements already carried out to the deltaic drains, mention may be made of the flood banks formed in certain reaches for the Biccavole, Tulyabhaga and Teki drains in Godavari Eastern delta. Though existence of these flood banks has certainly helped to reduce the flood problems in years when only normal floods are received, these are found to be weak and of inadequate height in years of extraordinary floods. They have got to be further raised and strengthened wherever found necessary.

5.4 The outfall sluices provided for Uppumilli drain, Injaram drain, Mandra drain, Pallikalva drain, Doddampeta drain etc. in Godavari Eastern Delta and the Gorinkala drain, Kattunga drain, Bendamurlanka North drain, Vepachettu drain etc. in Godavari Central Delta have helped to mitigate the flood problems of these drains.

5.5 It is reported that special repairs are being carried out for the following drains in Godavari Central Delta. The work generally comprises of restoration of the drain section to its designed standards.

1.	Vridha Gowtami Drain	.. Est. Rs. 54,500
2.	Kummarakalva drain	.. Est. Rs. 54,500
3.	Panchanadi drain	.. Est. Rs. 34,500
4.	Kunavaram drain, Reach M. 0/0 to M. 3/2 ..	.. Est. Rs. 67,500

Estimates are formulated for carrying out special repairs to the following drans in the Godavari Central Delta :

1.	Kunavaram drain, Reach M. 3/2 to 5/5	.. Est. Rs. 79,700
2.	Vasalatippa drain, Reach M. 9/0 to 12/4	.. Est. Rs. 33,000
3.	Outfall sluices for Sankaraguptam drain ..	.. Est. Rs. 94,000
4.	Ponnamanada No. 2 drain (falls into Sankaraguptam)	.. Est. Rs. 11,600
5.	Sompalli drain	.. Est. Rs. 11,000
6.	Gudapalli drain (falls into Kunavaram)	.. Est. Rs. 19,500
7.	Kathimanda drain (falls into Sankaraguptam drain)	.. Est. Rs. 4,200

It is reported that similar estimates are being formulated for carrying out special repairs to certain drains in Godavari Eastern Delta also.

CHAPTER VI—PRESENT CONDITION OF THE DRAINS.

6.1 In general, most of the drains in the Godavari Eastern and Central Deltas are reported to be in disrepairs, as adequate funds for their proper upkeep are not allotted. Due to paucity of the required funds, many of the drains could not even be investigated for fixation of standards. The drains are generally found to have silted up. Shoals are formed in many of them. Weed growth is widely prevalent. The banks do not either exist or where available are not found to be of adequate height and strength to confine the floods. Most of them join either the Godavari or another major drain with open head with no control for preventing flood waters from the latter backing up into them. These drains invariably require extensive repairs and improvements to enable them to cope up with the drainage water expected into them during Monsoon season. Some of the existing masonry works across the drains require to be widened as the present ventway is found to be inadequate to enable the drain waters to flow past them without undue afflux and consequent submersion. In the case of drains like Kunavaram, Lower Kowsika and Vasalatippa the Mogas where they join the sea are observed to be shifting due to littoral drift of sand and also getting choked up, causing obstructions to free flow of drainage into the sea.

CHAPTER VII—SUGGESTIONS MADE BY THE PUBLIC.

7.1 The Committee visited Lolla Lock Bridge in Godavari Central Delta, during the course of their inspection tour in December, 1964. Again, in February, 1965, the Committee paid a visit to certain areas in the Eastern as well as Central Deltas of Godavari and inspected portions of the following major drains.

Drain	Delta
Biccavole drain Tulya Bhaga Drain Teki drain	Godavari Eastern Delta.
Kunavaram drain Sankaraguptam drain	Godavari Central Delta.
Rameswaram Moga (the place of infall into the sea for Panchanadi, Lower Kowsika and Kunavaram drains)	

During the above two tours, several representations and Memoranda were presented to the Committee by individual ryots, Kisan Organisations and democratic institutions, etc., bringing forth the problems experienced due to floods in the concerned localities and the consequent losses caused to crops and other properties due to the same. While explaining the causes for the flood problems, these representations also made certain suggestions regarding the remedial measures to be adopted for prevention of the recurring damages. Some of the important and salient suggestions contained in these representations are briefly given below under two categories (A) General and (B) Specific. The specific suggestions are grouped drainwise.

7.1.1. General Suggestions

(1) A detailed survey of the existing drains and the drainage needs of the Godavari Eastern and Central Delta areas be under taken immediately. Proper standards be fixed for each drain.

(2) The section of each drain be improved by widening and deepening so as to comply with the standards fixed on detailed investigation referred to under item (1). Bunds of adequate strength and height be formed on either bank of the drain wherever found necessary to prevent spilling over of flood waters.

(3) The drains be maintained regularly. Shoals formed in the bed as also the weed growth should be removed. Removal of silt from the bed should be attended to promptly.

(4) The surface fall in the drain may be improved by straightening the kinks in the drainage course, wherever possible.

(5) Small sized dredgers of the type most suitable for operation in these deltaic drains may be procured.

(6) Out fall sluices with regulating gates be provided for such drains which are affected either by the tidal action of sea waters or by the high flood level of the main stream or river into which they have their infall. In addition, suitable flood banks be also formed to protect the tail end lands from submersion.

(7) A special drainage division with adequate staff be created immediately, to attend to proper maintenance and upkeep of the deltaic drains. Adequate funds should be made available to carry out all the required improvements and repairs to the drainage systems periodically.

(8) As the stakes erected by the fishermen are an obstruction to the drainage flow, auction of fishery rights in drainage waters may be given up.

(9) Gauge posts may be fixed at selected places along all important drains and a proper record of flood levels maintained for guidance.

7.1.2 SPECIFIC SUGGESTIONS.

7.1.2.1.1. *Godavari Eastern Delta.*

7.1.2.1.1. *Biccavole drain.*

(1) As the present section of Biccavole drain below the confluence of West Yeleru is not found adequate, the latter may be provided with a separate course dug parallel to Biccavole drain up to K.M. 22.8 (M 14/3) wherefrom it may be continued through "Yerrapaya Valu" and joined to the creek below Kovvur Old Lock. The "Yerrapaya Valu" and the said creek may be improved adequately. About 8,000 acres of paddy fields situated in Achutapuratrayam villages, Pedapudi,Domada, Kadavakuduru and Vetlapalem villages of Kakinada Tq can be saved from submersion by floods in Biccavole drain, if the above suggestion is implemented. (Three representations).

(2) The bends in the drain course may be straightened.

(3) The banks of West Yeleru and Biccavole drain may be strengthened wherever found necessary.

(4) A new drainage channel through "Dandu Punta" a Govt. Poramboke may be excavated to afford proper drainage facilities to the extent of 1,000 acres of irrigated area in Madhavapatnam, Achyutapuram, Ganganapally, Repuru and Kovvada villages of Kakinada Tq.

7.1.2.1.2. *Tulya Bhaga Drain.*

(1) The course from Km. 38.7 to 41.9 (M 24 to 26) may be straightened. Shoals may be removed from the bed and bunds may be strengthened in the reaches below K.M. 27.4 (M 17/0). Outfall sluices may be built for minor drains joining this drain, especially for the Raju and Old Tulya Bhaga drains so as to prevent high flood waters from the main drain from backing up into the minor drains. (Two representations).

(2) The lenial waterway for the highway bridge across the drain near Velangi be increased. The old road bridge across the drain near Gorripudi be dismantled. The ventway of the aqueduct built across the drain for the Kovvur-Manjeru Canal be improved so as to accommodate the volume of tidal waters, backing up the drain from the sea at high tide. Alternatively, the aqueduct itself may be dismantled since navigation in this cannal is practically negligible in recent times. (One representation).

7.1.2.1.3. *Teki Drain.*

At present during S.W. Monsoon period when the river Godavari is in high floods, the water level of Coringa into which the Teki drain falls also rises correspondingly. This results in the Coringa waters backing up into Teki drain thus causing drainage congestion under the latter.

(1) A sluice with lift shutters of screw gearing type may therefore be provided for the Coringa river just below its off take from Gowtami Godavari so as to prevent the rise of water level in Coringa river at times when the main Godavari is in high floods. If the water level in Coringa is thus kept low, the quick discharge of drainage waters from Teki drain will be greately facilitated. (Two Representations).

(2) During the North-East Monsoon period, the water level in Godavari is usually low. But the Coringa river is at high level due to tidal action. Consequently, the waters of Coringa back up into the Teki drain retarding the drainage flow. The possibility of diverting the Teki drain waters into the Godavari (*via*) Kudupuru on such occasions be explored. (Two Representations).

(3) Outfall sluices may be provided for all the feeder drains entering the Teki main drain.

(4) All the minor drains serving about 2200 acres of irrigated areas lying in Kota village limits and the leading drain connecting the same to Teki main drain to be repaired and remodelled for effective functioning. (Two Representations).

(5) There are numerous shoals in the bed of Teki drain. These are to be removed. The drain and its feeders generally require extensive repairs. (Two Representations).

7.1.2.2. *Godavari Central Delta.*

7.1.2.2.1. *Sankaraguptam drain.*

(1) Outfall sluices and connecting flood banks may be provided for Sankaraguptam drain above its infall into Vynatheyam Godavari, so as to prevent the flood waters of the latter from backing up into the drain and causing inundation over areas situated on either side of the drain. (Three Representations)..

(2) Bends in the drainage course may be straightened.

7.1.2.2.2. *Kunavaram Drain.*

(1) Outfall sluices be built for the drain above its infall into the sea near Chirrayanam and necessary connecting banks be formed to prevent saline waters from entering the tail end ayacut lands. Necessary stone groynes be constructed to arrest the tendency of Chirrayanam Moga to shift northwards.(Three Representations).

(2) The Gorganamudi and Rangarajucodu drains which join the Kunavaram drain be improved by removing the silt and the weed growth from the beds. The main drain as well as the feeder drains such as North Peekileru, South Peekileru, Samanasa etc. be also repaired extensively.

(3) The North Peekileru drain be given a separate connection into Kunavaram drain through the old poramboke of Kunavaram village.

7.1.2.2.3. *Rameswaram Moga.*

Suitable technical devices be built to prevent the Moga from shifting and to enable free discharge of drainage waters into the sea. The Moga be protected from action of sand. The old Moga may also be opened and both the Mogas be maintained to enable quick discharge of drainage waters into the sea. Outfall sluices and connecting banks be built to prevent sea-waters from backing up into the tail end lands.(Two representations).

CHAPTER VIII—RECOMMENDATIONS FOR IMPROVING THE DRAINAGE SYSTEM.

8.1 Proposals for improving the drainage system in the delta area can be categorised under (*a*) General and (*b*) specific. These are discussed below:—

8.1.1. General.

Recommendations mentioned under para 10.1 of Part III for drains of Krishna western delta-apply to the drains lying in this delta as well.

8.1.2 Specific.

8.1.2.1. *Godavari Western Delta.*

A number of drains of this section have already been restored to standard sections. The remaining ones should be improved to designed standard sections.

8.1.2.2 *Godavari Eastern Delta.*

8.1.2.2.1 *Biccavole drain.*

Improvements to Biccavole drain for about 2 miles downstream of the present confluence of west Yeleru drain are recommended to be carried out. The cost of this proposal has been worked out at about Rs. 5 lakhs.

8.1.2.2.2 *Tulyabhaga Drain.*

(*a*) This is a purely delta drain. According to general principles it should not have out-Fall sluices on the minor drains entering this drain.

(*b*) The waterway for the highway bridge across the drain nearVelangi be checked as per-general principles and if found deficient, be improved. The old bridge which was causing obstruction to flow is said to have since been removed.

(*c*) The aqueduct near Gorripudi is for providing navigation facilities between the Kakinada and Coringa Canals through the Kovvur Manjeru link Canal. This aqueduct is causing obstruction to the flow of the drain. Since at present, the transport needs are being fulfilled mostly by the existing roads, the aqueduct is recommended to be dismantled. If, however, at a later date, the navigation needs develop, then locks can be provided on either side of the canal through Tulyabhaga drain. Incidentally this will provide scope for extending navigation through the Tulyabhaga drain itself.

8.1.2.2.3 *Teki Drain.*

(*a*) The suggestion for providing a regulator on the Coringa river upstream of the canal syphon (near the bridge) may be examined in relation to the cost and benefits. The regulator be closed only when Godavari goes very high, at other times it will be kept open. This arrangement is necessary to reduce chances of silting. The regulator will have to be connected with the existing embank ments along the Gowtami Godavari. The approximate cost for the proposal as worked out by the State is Rs. 12 lakhs.

(*b*) Since the Godavari will also be subject to tidal action, no useful purpose will be served by providing a straight cut for the Teki drain to divert its waters into the former during North-East monsoon period. According to the general principles no outfall sluices be provided for minor drains entering the major drain.

8.1.2.3 *Drains in Godavari Central Delta.*

8.1.2.3.1 *Shankaraguptam Drain.*

Flood levels and tide levels be observed for a few years. The cause and extent of flooding may be found out before specific suggestion can be made.

8.1.2.3.2 *Kunavaram Drain.*

The Moga where Kunavaram drain falls into the Bay of Bengal may be maintained in regime condition as per suggestions given under general principles.

8.1.2.3.3. *Rameshwaram Moga.*

This is the place where Panchanadi, Lower Kowsika and Vasalatippa drains fall into the Bay of Bengal. It is reported that this moga is gradually shifting. Guide banks with revetment be provided as suggested under general principles so as to keep this in regime conditions.

Outfall sluices for tidal drains above their infall into the sea should not be provided as per general principles.

CHAPTER IX—PRIORITIES OF WORKS

9.1 The cost of proposed works in the drains of Godavari delta—Western, Eastern and Central, is estimated at Rs. 2 crores. Broad abstract of these is given below: —

(*i*) Restoring the drains to design standards in.

(*a*) Western section	..	.. *Rs. 26 lakhs	
(*b*) Eastern section	..	.. Rs. 40 lakhs	
(*c*) Central Section	..	.. Rs. 65 lakhs	
(*d*) Add for —			
Reclaiming certain swampy areas	..	.. Rs. 4 lakhs	Rs. 10 lakhs.
Rameshawaram Moga	..	.. Rs. 2 lakhs	
Bringing tidal banks to standards	..	.. Rs. 4 lakhs	
	Total	.. Rs. 141 lakhs	
(*ii*) Widening Biccavolu drain from mile 12/3 to 14/2		.. Rs. 5 lakhs.	
(*iii*) Providing regulator on Coringa river	..	.. Rs. 12 lakhs	
(*iv*) Miscellaneous	..	.. Rs. 30 lakhs	
	Total	.. Rs. 188 lakhs	
		Say Rs. 2 crores.	

9.2 Priority of works is recommended to be:—

As in the case of the drains of the Krishna Western delta, the excavation and maintenance of drains and mogas to design standards in the Godavari Central and Eastern deltas would require atleast two dredgers. As the drains are not very wide, 12" cutter suction type dredgers with adequate length of floating and shore pipe line along with two tugs and a few barges are suggestesd for the present. The first priority should therefore be given to the procurement of these dredgers. Simultaneously, excavation of the drains to design standards on all the sections be taken up in order of magnitude of submersion. The widening of the Biccavolu drain from mile 12/3 to 14/2 be also taken up on first priority.

*Note :—Most of the drains have already been restored to standards.

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PART V
Summary

CHAPTER I—ANDHRA PRADESH, WITH SPECIAL REFERENCE TO KRISHNA AND GODAVARI DELTAS.

1.1.1 The rich coastal deltaic areas of Andhra Pradesh in the districts of Godavari, Krishna and Guntur are subject to floods every year, principally from the rivers like Budameru, Thammileru and Yerrakalva. Therefore, the Government of India, in the Ministry of Irrigation and Power constituted an Expert Committee on Floods for suggesting a comprehensive plan for controlling the floods.

(1.1., Part I)

1.1.2 The Committee members visited the flood affected areas of delta regions and received representations from the local people. They also visited the Central Water & Power Research Station at Poona to study the model experiments conducted at the Station.

(1.3, Part I)

1.2.1 Geographically, the State can be divided into three natural regions (i) the coastal plains (ii) the Eastern ghats, and (iii) the Peneplains.

(2.1.2, Part I)

1.2.2. There are 3 seasons in Andhra Pradesh, namely, the hot summer followed by tropical monsoon and a pleasant winter.

(2.1.3, Part I)

1.2.3 The average annual rainfall of Andhra Pradesh is about 890 mm (35 inches).

(2.1.4, Part I)

1.2.4. The storms and depressions which develop in the Bay of Bengal in the monsoon season, move across the coastal areas of Andhra Pradesh causing heavy to very heavy rains. The storms are the main cause of floods in these areas and the area is most affected during the months of May to November. Between 27th September and 1st October 1964 there were very heavy rains in the districts of Guntur, Krishna, Godavari East and West due to depression formed in the Bay of Bengal.

(2.1.5, Part I)

1.2.5. The most important rivers of Andhra Pradesh are the Godavari, the Krishna and the Pennar.

(2.1.6, Part I)

1.2.5.1. The Godavari is the largest river of this State. It has its origin in the Western ghats near Nasik. The maximum recorded flood discharge at Dhowlaishwaram is 88,100 cu. metres per second (31.20 lakhs cusecs) in 1953, which is more than that of the Ganga though the latter has a catchment area more than thrice that of the Godavari.

(2.1.6.1, Part I)

1.2.5.2. The Krishna rises in the Western ghats. After traversing over a length of 1400 kms. (870 miles) it drops into the Bay of Bengal about 100 kms. (60 miles) below Vijayawada. The maximum flood discharge observed so far at Vijayawada anicut is about 33800 cu. metres per sec (11.99 lakhs cusecs) in 1903.

(2.1.6.2, Part I)

1.2.5.3. The river Pennar rises in the Western ghats. After traversing a length of 595 kms. (370 miles) it falls into the Bay of Bengal, north-east of Nellore. Its maximum observed discharge is 14700 cu. metres per sec. (5.20 lakhs cusecs.).

(2. 1.6.3, Part I

1.2.6. The districts lying in the deltas of the Krishna and Godavari are (1) East Godavari district, (2) West Godavari district, (3) Krishna district and (4) Guntur district.

(2.2, Part I)

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CHAPTER II—KOLLERU LAKE BASIN

2.1. The Kolleru lake is a natural dipression of land between two major rivers *viz.*, the Godavari on the East and the Krishna on the West. The total area of the lake at an elevation of +3.05 metres (+10′) above mean sea level is about 901 sq. kms. (348 sq. miles).

(1.1., Part II).

2.1.1. The lake receives drainage from a catchment of nearly 4760 sq. kms. (1839 sq. miles), out of which 3,400 sq. kms. (1314 sq. miles) is upland and 1,360 sq. Kms. (525 sq. miles) deltaic The main rivers are the Budameru, the Ramileru, the Thammileru and the Gunderu.

(1.2.1, Part II).

2.1.2. The deepest bed level of Kolleru lake is—0.91 metre (—3.00 ft.). The lake level goes above 1.53 metres (+5′) almost every year during monsoon season. The highest water level so far recorded is 3.26 metres (+10.7′) in the flood season of 1964.

(1.2.2, Part II)

2.1.3. On an average an area of 77.6 sq. kms. (30 sq. miles) of land gets submerged for every 0.30 metre (one ft,) rise in the lake level.

(1.2.4, Part II)

2.1.4. On the basis of Ryve's formula and on the assumption that the rainfall is on entire catchment area, the maximum discharge contributed by the rivers and drains flowing into the Kollern lake during monsoon season can be of the order of 3130 cu. metres per sec. (1,10,920 cusecs). The lake has only one outlet, the Upputeru river, which flows into the sea. The discharging capacity of Upputeru at 3.05 metres (+10′) of the lake level is only 319 cu. metres per sec. (11,250 cs.).

(1.2.6, Part II).

2.1.5. The Budameru river rises in Tiruvur taluk of Krishna district about 51.5 kms. (32 miles) north of Vijayawada town. Total length of the river is about 113 kms. (70 miles). Total catchment area of the river is 1,885 sq. kms. (729 sq. miles) out of which 1,335 sq. kms. (516 sq. miles) is upland and 550 sq. kms. (213 sq. miles) is deltaic. The maximum peak flow of the river calculated by Ryve's formula taking the value of c-oefficient as 600 for upland and 92 for deltaic catchment is 1,200 cu. metres per sec. (42,281 cs.)

(1. 3. 1, 1. 3. 2. & 1. 3. 3, Part II).

2.1.6. Thammileru is the second biggest river which falls into the Kolleru. It rises at 88.5 kms. (55 miles) north of Ellore. It branches off into two arms known as East Thammileru and West Thammileru just above the Ellore town. These two branches cross the Ellore canal and fall into Kolleru lake. The total length of the river is 109 kms. (68 miles). The total catchment is 1,354.57 sq. kms. (523 sq. miles). The maximum discharge so far recorded at Errampalli is 603 cu. metres/sec. (21,300 cs.). The maximum discharge ever recorded in East and West Thammileru are 351 cu. metres/sec. (12,395 cs.) and 307 cu. metres/sec. (10,840 cs.) respectively.

(1.4.1. and 1.4.2, Part II)

2.1.7. The river Ramileru rises near Dalagattu in Krishna district. After flowing for a length of 56.32 kms. (35 miles) in upland and deltaic regions, the river falls into the Kolleru lake. The total catchment area of the river is about 308.2 sq. Kms (119 sq. miles.). The maximum discharge as calculated by Ryve's formula with C at 500 from upland catchment and with value of C at 92 for deltaic catchment is 358.8 cu. metres/sec. (12,673 cusecs.).

(1.5.1. & 1.5.2, Part II).

2.1.8. The river Gunderu rises in Chintalapudi taluk of West Godavari district. The river drains an area of 539 sq. kms. (208 sq. miles) in the upland region and 93 sq. kms. (36 sq. miles) in the deltaic region. The calculated maximum peak flow in the river by the Ryve's formula is 474 cu. metres/sec. (16,804 cs.).

(1.6.1, Part II)

2.1.9. In addition to the above rivers there are a number of drains which join Kolleru lake (1.7, Part II).

2.1.10. The Upputeru river takes off in two arms called Perantala Kanuma and Juvvikanuma. These arms join after flowing for about 6.4 kms. (4 miles) whereafter this is known as Upputeru river. The Upputeru flows for a distance of 63 kms. (39 miles) through the plain low lying lands upto its outfall into the sea.

(1.8.1, Part II)

2.1.11. There are a number of drains originating from Krishna Eastern Delta and Godavari Western delta which fall into Upputeru directly.

(1.9, Part II).

2.1.12. The Yerrakalva river originates from Eastern ghats. During its course, it receives several tributaries, namely, the Jalleru, Byneru and Pulivagu. After flowing for 134 kms. (83 miles), it crosses the Godavari-Ellore Canal under an aqueduct near Nandamuru. On the d/s of the aqueduct this river is called Yenamadurru drain. This drain after flowing for a length of about 60.0 kms. (37 miles) falls into the Upputeru at kms. 47 (miles 29) of the Upputeru.

The catchment area of the Yerrakalva at Nandamuri aqueduct is 2,330 sq. kms. (900 sq. miles) and 2,590 sq. kms. (1000 sq. miles) at infall of Yenamadurru drain into the Upputeru. During very high floods some flow of the Yerrakalva goes into the Kolleru lake also. It frequently inundates areas lying u/s of the Nandamuru aqueduct.

(1.10.1 and 1.10.2, Part II).

2.2.1. During monsoon season, the water levels in the Budameru, Thammileru, Ramileru, Gunderu, etc. rise high and inundate large tract.

These rivers cause increase in the level of the Kolleru lake also. This rise in the lake level submerges marginal lands.

(2.1 and 2.2, Part II).

2.2.2. It has been seen that on an average, an area of about 90,000 acres were affected every year during the last 10 years. About 67,000 metric tonnes of food grains valued at Rs. 2.56 crores were lost every year due to floods.

The worst year for this area was 1964 when about 2 lakh acres were damaged. The food grains lost during that year was about 1.50 lakhs metric tonnes valued at Rs. 5.6 crores.

(2.3, Part II).

2.3.1. Rainfall is being observed at 9 stations situated within the catchment of Kolleru lake. The months of January and February are almost dry months. During March to May, though there is some rainfall, there is not much flow into the lake.

2.3.2. June to September are the four months of South-West Monsoon and majority of the rainfall in these four months varying from 432 mm(19") to 1448 mm (57") causes spilling over the banks of the rivers.

2.3.3. There are cyclonic depressions in this area during the months of September to November. During these storms which last from 1 to 7 days, rainfall of high intensity is observed,

(3.1 to 3.4, Part II).

2.4.1. In order to reduce the inflows into the Kolleru lake and flooding of fields on either side of its banks, a diversion canal for diverting 212 cu. metres/Sec. (7,500 cs.) of water of Budameru into Krishna river was completed in the year 1960.

The diversion had been effective in diverting most of the waters of the Budameru into the Krishna except some surplus water of 29.7 m. cu. metres (1,048 mcft.) in 1962, 108.5 m. cu. metres (8,815 m.cft.) in 1963 and 60.4 m. cu. metres (2,928 mcft.) in 1964, which flowed into the lake.

(4.1.1.1, Part II)

2.4.2. There are flood banks along the river from Ellore Canal crossing into Kolleru lake on both sides for a distance of 54.6 k.ms. (34 miles). These embankments breached by overtopping during floods of 1964.

(4.1.1.2, Part II).

2.4.3. There are several proposals of providing detention reservoirs on the Budameru and its tributaries under consideration with the State Government.

(4.1.2.1, Part II).

2.4.4. Forming flood banks on both banks from Mutyalampadu to Ellore canal crossing for a length of 8.25 kms. (5 miles 1 furlong) is also under contemplation.

(4.1.2.2, Part II).

2.4.5. There are no works on the river Ramileru which have been executed.

(4.2.1, Part II).

2.4.6. A reservoir across Ramileru near Mirjapuram with a storage capacity of 13.5 m. cu. metres (475 mcft.) is under consideration.

(4.2.2.1, Part II).

2.4.7. There are no works on the Gunderu river which have been executed.

(4.3.1, Part II).

2.4.8. A reservoir across Gunderu near Badarala with a storage capacity of 27.5 m. cu. metres (971 mcft.) is under consideration.

(4.3.2, Part II).

2.4.9. There are flood banks on West Thammileru from mile 0/4 to mile 7/4.

(4.4.1, Part II).

2.4.10. There are three reservoir sites across Thammileru river which are under contemplation with the State Government.

(4.4.2.1, Part II).

2.4.11. Constructing flood banks along Thammileru river from the escape across Ellore Canal to Kolleru lake for a length of 9.66 kms. (6 miles) is under contemplation.

(4.4.2.2., Part II).

2.4.12. Widening and deepening of Upputeru river for 15,000 cs. capacity at lake level of +7.00 M.S.L. from miles 6/3 to 12/2 is in progress.

(4.5.1, Part II).

2.4.13. Separating Yenamadurru Drain from Upputeru by putting a cross bund across Upputeru below mile 28/0 and widening and deepening of Upputeru river from mile 12/2 to mile 28/0 upto Lakshmipuram lock and having a straight cut from there to sea, and straightening the awkward bends in the river Upputeru are under contemplation.

(4.5.2, Part II).

2.4.14. There are more than ten reservoir schemes on the Yerrakalva which are under consideration with the State Government.

(4.6.2.1, Part II).

2.5. During the visit of the members of the Committee to the flood affected areas, several representations were submitted by the individuals as well as Panchayat bodies indicating the flood problems of the area and giving suggestions for improvement. The main suggestions are, construction of detention reservoirs and formation of flood banks for the rivers—the Budameru, the Thammileru, the Ramileru, the Gunderu and the Yerrakalva; widening and deepening of Upputeru river for increasing its discharging capacity; separating Yenamadurru drain from Upputeru, and providing extra outlet to Kolleru lake, etc.

(5.1 and 5.2, Part II).

2.6.1. The possible cause of increase in the frequency of occurrence of high levels of the Kolleru lake may be one or more of the following factors :–

1. Excessive inflows.
2. Inadequate outflow.
3. Reduction in the capacity of the lake due to silting.

The remedial measures for reducing damage from floods could, therefore comprise of :–

(*i*) Proposals for control of floods in rivers flowing into the Kolleru basin.

(*ii*) Proposals for lowering the flood levels of the Kolleru lake either by improving the outfal channel, the Upputeru, or by pumping, or by both.

(*iii*) Other measures for reducing floods. (6.2 and 6.3, Part II).

2.6.2. There are a number of drains which fall directly into the lake. On some drains which submerge large areas during floods by overflowing their banks, flow conditions can be improved by deepening and widening to suitable sections.

(6.4, Part II).

2.6.3. In the catchment area of the Budameru, there are as many as 111 tanks having a total capacity of 43 m.cu. metres (1,525 mcft.), which irrigate an area of 30,280 acres.

(6.4.1, Part II).

2.6.4. Increasing the capacity of the existing Budameru diversion channel to 15,000 cs. would cost about Rs. 90 lakhs and would require acquisition of valuable cultivated land. The benefits would not be commensurate with the expenditure involved.

Flood routing studies have shown that for absorption of flood waters, for a year like 1964 storage capacity of 1,300 m.c.ft. would be required. To accommodate this and to take care of likely reduction in capacity due to siltation etc., it would be desirable to provide reservoir or reservoirs having flood storage of about 2,000 m.c.ft. The reservoir sites should be as near to the diversion site as possible and should preferably be on the main stream.

(6.4.1.1.1, & 6.4.1.1.2, Part II)

2.6.5. The Brahmayyalingam and Suggur Amani tanks surplus a considerable amount of water. The State PWD considers that the existing capacity of 351 m.c.ft. can be increased for absorption of floods to 891 m.c.ft., at M.W.L.

(6.4.1.2.2, Part II).

2.6.6. The river near Vijayawada flows in a loop and causes lot of damage. The loop can be straightened to protect valuable areas and is recommended.

There is a proposal to form flood banks from Mutyalampadu to Ellore Canal crossing for a distance of about 8.05 kms. (5 miles) along both the banks of the Budameru. The effect of these embankments on drainage of the adjoining areas and on reduction of the valley storage of Budameru need to be examined before deciding to implement this measure.

(6.4.1.2.3, Part II).

2.6.7 Suitable proposal for strengthening and raising of the existing embankments be carried out.

(6.4.1.3.2, Part II)

2.6.8.1. Thammileru is the second biggest river of the Kolleru basin. This river contributes considerably to the rise in the level of Kolleru lake. In addition, the floods cause inundation of Ellore town.

(6.4.2.1, Part II).

2.6.8.2. No diversion of waters of the river to other basins is possible.

(6.4.2.2. Part II

2.6.8.3. Preliminary studies carried out by the State have indicated that the capacity of reservoir at Errampalli can be increased to 3,000 mcft, for flood absorption besides irrigation. This would provide some relief from floods in the lower catchment to some areas and particularly to the Ellore town. The peak inflow into the lake would also be reduced though duration will be increased.

(6.4.2.3, Part II).

2.6.8.4. For the protection of Ellore town, flood embankments along the East Thammileru as proposed by the State Government are necessary. Waterway under the Railway bridges and under the canal escape channel need to be examined in the case of East Thammileru.

(6.4.2.4, Part II).

2.6.9. A reservoir on the Ramileru river may be useful from irrigation point of view and also for reducing submersion of marginal lands along its course.

(6.4.3, Part II).

2.6.10. A reservoir on the Gunderu river may be useful from irrigation point of view and also for reducing submersion of marginal lands along its course.

(6.4.4, Part II).

2.6.11.1. By constructing a reservoir or reservoirs on the Yerrakalva river and its tributary, it would be possible to reduce flooding of marginal areas along the banks of the river and also reduce the influence of Yenamadurru drain over Upputeru.

(6.4.5.1, Part II).

2.6.11.2. The scheme of diverting water of the Yerrakalva into the adjoining valley though technically feasible is not economically justified.

(6.4.5.2, Part II).

2.6.12.1. The routing of 1964 floods with capacity of Upputeru improved from its present capacity of 188 cu. metres/sec. (6,650 cs.) to 425 cu. metres/sec. (15,000 cs.) showed that the lake level would rise to a maximum level of + 2.74 metres (9.0ft.) instead of 10.70 ft and that it would remain above + 2.19 metres (7′) for 22 days instead of 55 days with present capacity. Further studies assuming increase in the capacity of the Upputeru to 566 cu. metres/Sec. (20,000 cs.) showed that the lake level would still rise to 2.56 metres (8.4 ft.) and would remain at or above + 2.19 metres (7 ft.) for 15 days.

On account of likely difficulties and cost involved in acquisition of large areas of fertile paddy land and cost of maintaining a big section of Upputeru, improving the capacity of the Upputeru to 566 cu. metres/sec. (20,000 Cs.) has been taken as the upper limit.

(6.5.1.1., Part II).

2.6.12.2. For improving the capacity of the Upputeru it would need to be (*a*) Widened and deepened where necessary, (*b*) the severe meanders etc., would have to be straightened and (*c*) a straight cut into the sea at suitable site would have to be provided.

(6.5.1.2., Part II).

2.6.12.3. The earth obtained from excavation would be used in raising the adjoining land and also for raising and completing the bunds on both banks of this Upputeru itself.

(6.5.1.2.1, Part II).

2.6.12.4. The severe meanders in the Upputeru would also have to be removed. This would reduce the length of Upputeru by about 6.44 kms. (4 miles) and thus improve the overall slope.

(6.5.1.2.2, Part II).

2.6.12.5. A straight cut near 45 kms. or 46.7 kms (mile 28 or 29) would have the advantage that a large tidal basin would be created in the very wide part of Upputeru beyond the straight cut.

(6.5.1.2.3, Part II).

2.6.12.6. Although it would be desirable to improve the capacity of the Upputeru to 20,000 cs. but, as the work involved is very large and expensive, it would be advisable to increase the capacity to 15,000 cs. in the first instance and to watch the effects before improving the capacity further.

(6.5.1.3, Part II).

2.6.12.7. In case the tides are found to travel up beyond the road bridge, construction of a regulator with navigation lock be considered before carrying out the next phase of the programme.

(6.5.1.4, Part II).

2.6.13: The capital as well as running cost for the proposal of pumping from the Kolleru lake into the Upputeru, merely to reduce the maximum level that may be reached in a year of high rainfall like 1964, would not be economically justified. However, the studies have shown that during years of average rainfall like 1944, if pumping from the Kolleru lake for a discharge upto 8,000 cusecs is adopted, the lake will rise to a maximum level lower than +6. 2 ft. (due to Budameru diversion). This will mean reclamation of more areas and consequently more and better crop. The studies with the Budameru diversion functioning may be carried out in respect of a number of normal or nearly normal years to obtain the optimum size of Pumping Station and economics thereof.

(6.5.2, Part II).

2.6.14. Considering the serious disadvantages and high cost, construction of contour embankments around the Kolleru lake for restricting the submerged area is not recommended.

(6.5.3.1, Part II).

2.6.15. It is necessary that a fresh contour survey of the lake be carried out immediately. In order to ascertain the rate of siltation, this survey may be repeated every tenth year. It would be advisable that silt observations be made on the bigger streams like Budameru, Thammileru, Gunderu, Ramileru and Upputeru also.

(6.5.4., Part II).

2.8.1. The total approximate cost of the works as recommended comes to Rs. 15 crores. Due to limitations of funds, and equipment, the works may have to be spread over a number of years. It will therefore be necessary to take up these works in order of priority.

(8.1., Part II).

2.8.2. The first priority be given to the work of improvement of the Upputeru. In the first instance, two dredgers of 22"—24" size, cutter suction type, with about 1000 ft. of floating and shore pipe line be procured. One of the two dredgers should be sea worthy. Along with the procurement of this equipment, the land which is required for improvement of the Upputeru to 20,000 cs. capacity at the road bridge with lake level at +7 ft. should also be acquired.

Simultaneously, arrangements may be made to take up execution of work of improvement of Upputeru according to the following programme:—

(1) *Stage I :—Phase I.*

The sectional area of the Upputeru be improved in the entire length for passing 10,000 cs. at road bridge with lake level at +7.00 ft. and a straight cut of 100 ft. wide to the sea be provided. Steps for widening railway and road bridges for passing 20,000 cs. be initiated.

Phase II.

The sectional area of the Upputeru be improved for passing 12,500 cs. at road bridge with lake level at +7.00 ft. and the straight cut to be widened to 200 ft.

Phase III.

The section of the Upputeru be increased for passing 15,000 cs. at road bridge with lake level at +7.00 ft. and the cut be widened to 400 ft.

(8.2., Part II).

(2) *Stage II* :—

Section of the Upputeru be increased to pass 20,000 cs. at road bridge with lake level at+7.0 ft.

2.8.3. On the Thammileru, the first priority should be given to the construction of marginal embankments on its East Branch, improvement of waterways at escape and Railway bridge, and construction of resesservoir at Errampalli.

(8.3. Part II).

2.8.4. On the Budameru, the first priority be given to raising and strengthening of the existing embankments, and to increasing the capacity of Brahmayyalingam, and the adjoining tank. The excavation of a straight cut at Vijayawada be taken up on second priority. Third priority be given to the construction of one of the reservoirs. Fourth priority should be given to the other reservoir.

(8.4. Part II)

2.8.5. The work of improving the drains falling into the Kolleru and the Upputeru should be given priority.

(8.5. Part II)

2.8.6. On the Yerrakalva, reservoir at Anumunilanka be given priority. But it is suggested that it should have second priority interse when measures for the entire Kolleru basin are taken into account.

(3,6. Part II)

2.8.7. The following works are recommended to be taken up immediately :—

(*i*) Improvement of drains.

(*ii*) Works for protection of Ellore town.

(*iii*) Procurement of dredgers and acquisition of land and construction of Phase I of the Upputeru.

(8.7. Part II)

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CHAPTER III—DRAINS OF KRISHNA WESTERN DELTA IN GUNTUR DISTRICT.

3.1.1. Krishna Western Delta comprises the taluks of Repalle, Tenali, Bapatla and a portion of Guntur, all of which lie in Guntur district. The area is irrigated through three branch canals viz., Bank, Nizampatnam and Commamur canals which take off from the Krishna Western Main Canal.

(1.1.1, Part III).

3.1.2. The area lying in the K.W. Delta has a net work of five main drainage systems. The area lying between the Commamur canal and Nizampatnam Canal and that between Commamur Canal and the Bay of Bengal is being drained by three drainage systems viz., Romperu, Nallamada and Tungabhadra. These three drainages have both upland and deltaic catchments. The area between the Nizampatnam and Bank canals is served by two drainage systems viz., Repalle and Bhattiprolu. These drains have purely deltaic catchments.

(1.3. Part III).

3.2. The average annual rainfall in the K.W. Delta region is about 95 cms (37 inches). The area receives rainfall under the influence of both the South-West (June to September) and the North-East monsoons (October to December).

(2.1. Part III)

3.3. The drainage problemes in the Krishna Western delta are mainly due to (*i*) obstruction caused to the upland drains by theCommamur canal and consequent breaches caused to the latter, (*ii*) obstructions caused by Railway and Road embankments (*iii*) obstruction caused by sand dunes formed near the coast due to littoral drift (*iv*) inadequate water way available in the existing drainage system to afford quick relief from submersion by flood waters and (*v*) flat surface falls and due to long and tortuous courses which the drains take before finally emptying into the sea.

(3.1. Part III).

3.4. For the 10 years from 1955 to 1964 on an average an area of about 64000 acres was affected by floods every year. This meant loss of about 48,000 metric tonnes of food grains valued at Rs. 1.82 crores.

1964 was the worst affected year during these 10 years when about 1,20,000 acres were inundated by flood waters. During this year, about 90,000 metric tonnes of food grains valued at Rs. 3.42 crores were lost.

(4.2. Part III)

3.5.1. Improvements to Romperu Drainage system were carried out from 1948 to 1956. Two separate drains were excavated from below the Karamchedu under-tunnel. Though the improvements have been able to give partial relief to the lands in the region, still flood problems are frequently experienced as the drainage system has since been badly silted up.

(5.1.1. Part III).

3.5.2. Nallamada drain was initially a tributary to E.T.B. drain. A straight cut into the sea called Nallamada diversion was excavated. This diversion channel is reported to be functioning well.

(5.1.2. Part III).

3.5.3 The improvements carried out to E. T. B. drain during the years from 1958 to 1961. comprised of widening the drain and forming flood banks on either side. The drain needs further study and improvements.

(5.1.3. Part III).

3.6. In general, the sections of the drains are inadequate and have Shoals in the bed. Several of the cross drainage masonry works have in sufficient waterways. These, therefore, overflow their banks causing inundation of marginal lands.

(6.1, Part III).

3.7. During the visit of the Committee, the public submitted their representations indicating the flood problems of the area and some remedial measures. The remedial measures suggested are :—

(*i*) deepening and widening of drains ;

(*ii*) straightening of kinks ;

(*iii*) Increasing the discharge capacity of cross drainage works.

(*iv*) Providing straight cuts into sea or some other drains.

(7.1, Part III)

3.8.1. The design criteria which are being followed for deltatic area drains are explained in detail in the paper "Drainage problems in Andhra Pradesh by Shri A.R. Venkataraman". Main features of this are : —During monsoon season, paddy being the predominant crop in the delta area the runoff factor would be hundred percent. It has been laid down that the drains should cater,, without submergence, for 1" daily rainfall. This rainfall is expected normally. But, during heavy rainfall periods, rains upto 3" daily continuing for 7 days could occur. Under these conditions, the drains should be capable of draining the area in 7 days with submergence upto 1 2".

(8.1, Part III).

3.8.2. The ordinary flood levels in the case of drains draining dry land is kept 0.61 metre (2′ 0″) below the level of the adjoining lands. The discharge to be provided for at the outfall into the sea is taken as 9/7 of that assumed in non-tidal portion.

(8.4 and 8.5, Part III).

3.8.3. The standards fixed for the capacity of drains viz., submergence of area during heavy rains should be limited to one foot and period of submergence should not be more than one week at a time.

(8.7.1, Part III).

3.8.4. It is recommended that discharge observations be made for some years on representative typical drains in the various deltas. These be correlated with the rainfall intensities and quantities. Based upon these results, the value of coefficient of constants in the formulae in vogue be fixed. Till then, the design criteria and design formulae as in vogue be followed.

(8.7.3. and 8.7.4. Part III).

3.8.5. All works which envisage increasing the capacity of the drains should be carried out from tail upstream.

(8.7.6, Part III).

3.8.6. In case of deltaic drains falling into a major drain coming from uplands or into a river, outfall sluices with shutters be provided.

(8.7.7, Part III).

3.8.7. When a purely deltaic drain falls into another delta drain normally there should be no sluice. Catch water drains may however be provided wherever necessary.

(8.7.8, Part III).

3.8.8. No embankments should be provided in the tail end of drains outfalling into the sea. If in exceptional cases these have to be provided they should be sufficiently apart so that the required tidal influx for keeping the drain and the mouth stable is not adversely affected.

(8.7.9. Part III).

8.8.9. There can be no drainage congestion due to canal if the drains are maintained to the design standards.

(8.8, Part III).

8.9.1. The present condition of the drains be improved according to the design criteria already laid down.

(9.1, Part III).

8.9.2. For giving proper attention to investigations, improvements and maintenance of drains, there should be four divisions, two for Krishna delta and two for Godavari deltas.

(9.1., Part III).

8.9.3. (i) For deltaic drains having catchment area in upland also, except in the case of Upputeru river and drains of the Kolleru basin, the maintenance funds recommended annually should be on mileage and size basis. This works out to Rs. 8 lakhs annually.

(*ii*) For the maintenance of delta drains having catchment area in delta only, the funds be fixed at Rs. 1/- per acre of the area irrigated. This works out to about Rs. 22 lakhs per year. For the maintenance of the Upputeru and Kolleru basin drains there should be special estimates. Thus total maintenance cost for delta drains excluding Upputeru would be of the order of Rs. 30 lakhs per year.

(*iii*) All encroachments in drains be evicted and such cases be dealt with strictly.

(*iv*) Four cutter suction dredgers 12" size with 1000 ft each of floating and shore pipe lines-two dredgers for Krishna delta, two for Godavari deltas-are recommended in the first instance.

(*v*) The mogas must be maintained in suitable and regime conditions.(9.2. Part III).

8.9.4. Condition of every drain be reviewed every fifth year and programme made to bring it to designed standards.

(9.8.4, Part III).

8.9.5. Suitable drainage cess from the beneficiaries for proper maintenance of drains be fixed.

(9.8.5, Part III).

8.10.1. General.

To reduce damage by floods in the delta area, the following measures are considered to restric the discharge coming from uplands to delta.

8.10.1.1. Where there are complaints of flooding due to inadequate capacity of cross drainage works under the Commamur Canal, the waterway of under tunnels be improved to $Q=92\ M^3/s$

(10.1.2, and 10.1.3. Part III).

8.10.1.2. The velocity through these undertunnels be limited to 16'/sec. and afflux at the cross drainage works to 4 ft.

(10.1.4 and 10.1.5, Part III)

8.10.1.3. If the discharging capacity of any drainage work is increased, the drainage course d/s of the work should also be increased to cater for the increased capacity.

(10.1.6, Part III)

8.10.1.4. Even if the discharge coming from upland near the Commamur canal is of the order of $Q=500\ M^3/s$, the capacity of cross drainage works, however, be limited to $Q=92\ M^3/s$. Detention reservoirs should be provided for the difference of the discharges. The areas within the detention basin which are subjected to submergence of 1' for more than one week, be acquired and these areas be excluded from the ayacut of Nargarjunasagar Canal.

(10.1.8, Part III.)

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26	3.7	2	station ..	..	stations
27	4.1.1.1	6	is	..	in
29	4.3.2	2	(971 M.CV. ft. ..	..	(971 m cu ft.)
30	4.6.2.1	16	25.7 M.CU.M. ..	..	35.7 m cu m.
30	4.6.2.1	18	(832 M.CU.ft.) ..	..	(1103 m cu ft.)
32	5.3.4.1	1	laying.. ..	..	lying
35	6.4.1	2	(729 sq. mles) ..	..	(729 sq. miles)
35	6.4.1	3	irrigatng ..	..	irrigating
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36	..	22	1903	1963
39	6.4.2.4	1	Thammilleru	Thammileru
40	6.4.5.2	18	top	topo
41	..	22	Questio	Question
41	..	2 from bottom	cusecs	out-let
42	6.5.1.2.1	3	+4,88 metres	+4.88 metres
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56	1.4.4	11	an aso	drain also
56	1.4.5	11	miles).	Sq. miles).
57	2.2	4	Krishna Eastern Delta ..	for Krishna Eastern Delta

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63	7.1.1.2	1	deepending ..	.. deepening
64	7.1.3.1	6	affluent ..	.. affluent
66	7.1.6	6	tortous ..	.. tortuous
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68	8.1	18	devided ..	.. divided
69	8.6	2	effluents ..	.. affluents
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72	10.1.8	2	Comin dwn ..	.. coming down
73	10.2.1	6	fiap	.. flap
73	10.2.1	8	Same	.. some
73	10.2.1	14	providing in separate	.. providing a separate
74	10.2.4	12	extensives ..	.. extensive
76	..	7	drain of ..	.. drain off
76	..	19	to made ..	.. to make
80	Heading	..	Major drains and drainage sistem	.. Major drains and drainage system
81	1.3.3	2	Cana	.. canal
83	1.4.2	15	274.K.M. ..	.. 27.4 Km
83	1.5	7	beween ..	.. between
85	1.5.5	5	Zig-Zig ..	.. Zig-Zag
89	3.6.2	2	marginal land when	.. marginal lands. When
90	3.7.1	6	cong stion ..	.. congestion
90	3.7.1	13	crop vield ..	.. crop yield

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116	4.4.1	2	shows	showed
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