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The New Irrigation Era

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THE NEW IRRIGATION ERA

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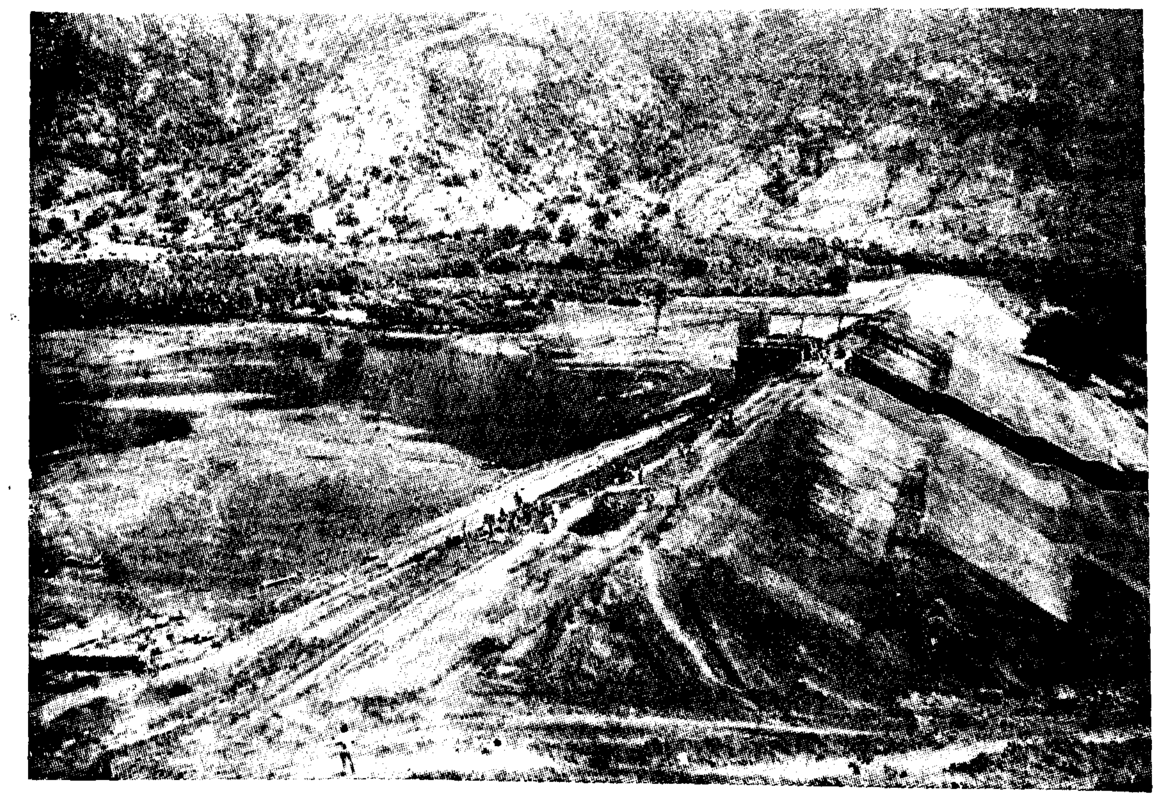
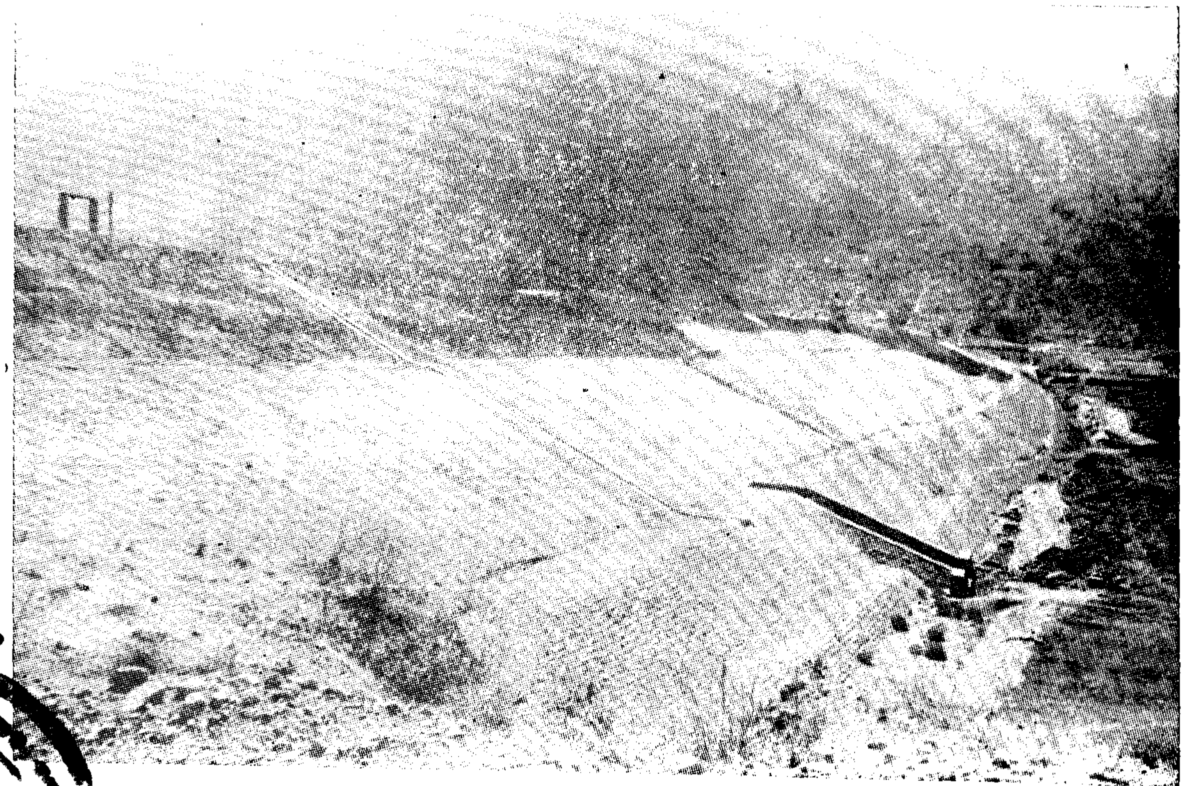
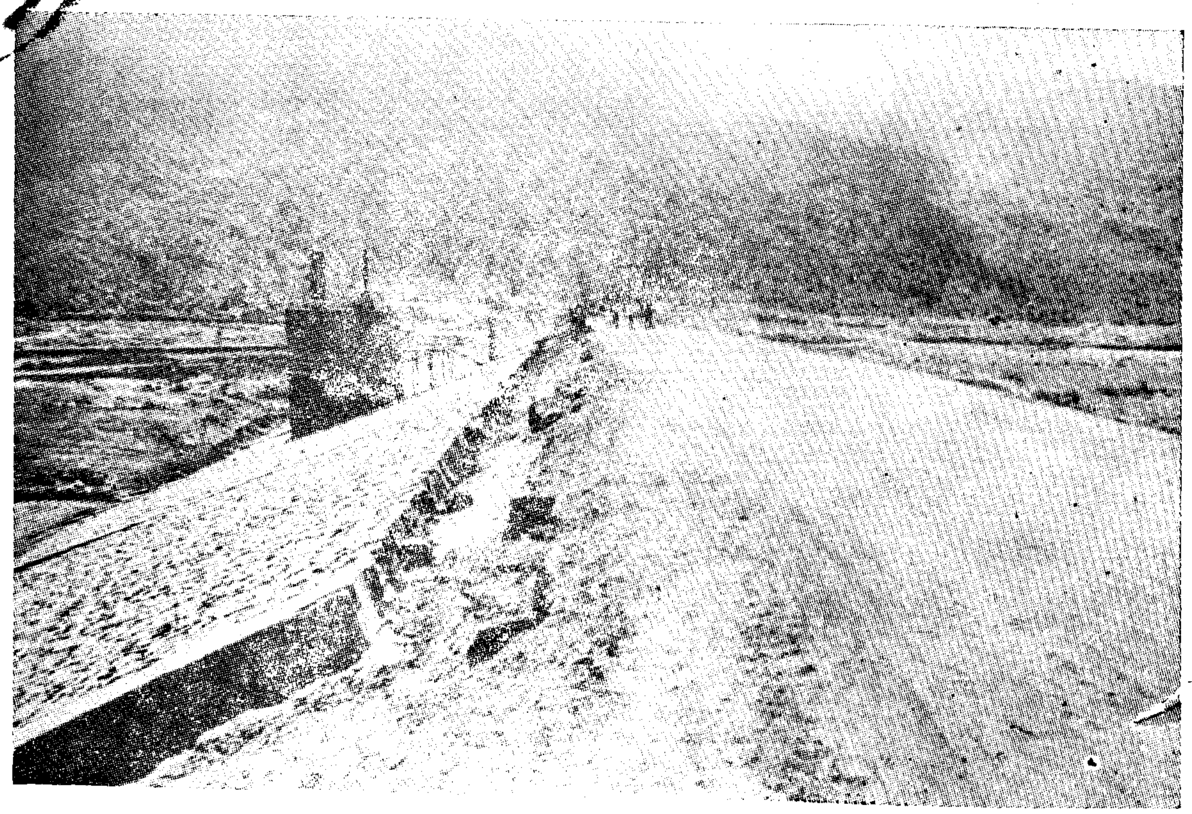


View of the Marudhanadhi Reservoir.



Rear View of Gunderipallam Reservoir Project [In progress].



Top View of Right Flank of Gunderipallam Reservoir Project.

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THE NEW IRRIGATION ERA

Vol. XV **October 1977** **No. 4**

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EDITORIAL.

In the first article of this issue Thiru K. Ramalingam, Superintending Engineer, P.W.D. gives an idea on suitability of dewatering by filter point technique in the island of Sri Harikotta which is located on the sea coast and made up of sandy soil in cases of laying foundation for the block house for satellite launching vehicle project and laying of fewer lines at depths of 3 to 4 metres. He also lists the precautions that should be taken before the centrifugal pump was put on, and details the design of the filter plant system, the procedure for laying deep fewer lines and foundation for block house.

A resume of the lecture deliverd byEr. E. C. Saldanha, Member (P & P) Central Water Commission, Government of India on 14th September 1977 on the eve of Dr. M. Visweswarayya Memorial Sixth endowment lecture is included as the second article in this issue. Er. E. C. Saldanha gives an account of the multi-purpose development of water resources in Northern India over the last 30 years and the significant success that has been achieved with regard to the provision of irrigation facilities and power benefits through adoption of bold and modern concepts and use of appropriate technology and judicious exploitation.

In the third article by Er. K. Ethirajan, the author suggests that any hydraulic engineer needs a thorough knowledge over the remote sensing systems in these days of well advanced science and technology to adopt the same for studying river mechanics for better, accurate and quick results. He also narrates in this article the principles of electromagnetic radiation, its important features and the main object of the study of the remote sensing methods.

Lastly the paper " Aerial Photo Interpretation " presented by Er. R. Jayaprakasam, Research Engineer, Theni attached to the Institute of Hydraulics and Hydrology, Poondi has explained the aerial photography, its utility, photogrammetry and photo-interpretation in detail.

EDITOR.

Dewatering by Filter Point Technique.

By

Er. K. RAMALINGAM, B.E., Superintending Engineer, P.W.D.

1.0. General.

1.1. Dewatering in foundations is generally carried out by direct pumping from sumps through centrifugal pumps. This is quite effective in cases where ground water level is low and soil consists of loam. In cases of sandy soil and on locations on the sea coast, this method is not effective. This method becomes still more ineffective in cases where we want to do some important work in dry state. The most suitable method is only the filter-point. This has been adopted in a few works in this Island of Sriharikota where we have quite a few very unique and interesting works. This article deals with two cases of (*a*) foundation for the Block-house for Satellite Launching vehicle project and (*b*) laying of sewer lines at depths of 3 to 4 metres.

1.2. Sriharikota is an Island bounded by Buckingham canal on the west and the Bay of Bengal on the east, the Veppancheri Canal on the North and the Araniar on the South. The Island is about 7 km. from the sea coast at its widest part and only about 500 m. at its narrowest place. The soil consists of medium to fine sand. The ground is covered over with shrub jungle and plantations of Casurina, Eucalyptus and Cashew. The ground water is at the ground level during the winter months and it goes down to 3 m. depth during summer months.

1.3. There are several ready-made units patented, manufactured, and sold in the market by many companies in India. Some of them make use of PVC pipes, headers, etc., and the cost of even a small unit dealing with 200 m³ of earth excavation may exceed one lakh of rupees. Purchasing such units may be worthwhile in large works involving major dewatering operations. In smaller works like those we did in this Space Project, it was not considered economical to invest in an elaborate unit and the contractors having slender resources could not be persuaded to purchase them. Hence the standard filter-points of 40 mm. diameter with brass screens generally used for tube-wells in village were purchased. G.I. pipe, 75 mm. diameter of C class was devised into a manifold by welding about 20 numbers of G.I. couplings 40 mm. diameter as shown in the sketch. To these couplings hose nipples 40 mm. were screwed In one of the 20 couplings one gate valve 40 mm. was fixed along with a bend and short pipe for priming purposes. All the connected equipments required for the work are given in the sketch. Ordinary centrifugal pumps of 5 to 10 horse-power were used as they were readily available. The filter-points were attached with a non-return valve and a riser pipe 40 mm. diameter 3 m. long. The entire assembly was jetted down into the soil by sending a water-jet 20 mm. diameter operated by a 20 H.P. high pressure pump. The jetting of each pipe assembly took only a minute The riser pipe was connected to the manifold by means of rubber hoses of 40 mm. diameter of braided heavy-class and tightly screwed by hose clips.

1.4. The manifold was plugged at one end and its other end was connected to the suction side of centrifugal pump. To prime this pump, water was let into the manifold through a suitable inlet by pumping water using another pump. As soon as the centrifugal pump was ascertained to be properly primed, it was put on, setting the filter points to work. The following precautions should be however taken.

1.4.1. All the joints must be properly tightened and rendered absolutely water tight.

1.4.2. The manifold and the pipes connecting them with the filter-points should be below the level of delivery point of the delivery pipe of the dewatering pump.

1.4.3. The rubber-hose pipes are likely to collapse in the course of pumping, hence coiled wire may be introduced inside the hose for reinforcing it.

2.0. Design of the filter plant system.

2.1. The permeability of the sand strata to be dewatered was determined prior to designing a dewatering system. Various methods may be used to determine the permeability. The simplest is a visual examination and classification of the sands by some one familiar with soils and by comparison with sand of known permeability. A rough approximation of the permeability may be obtained from the following table.

Type of sand (U.S. army Engineer classification).	*Coeff of permeability: 10 x 10 cm/sec*
(1)	(2)
Very fine sand	50
Fine sand	200
Fine to medium sand	500
Medium sand	1,000
Medium to coarse sand	1,500
Gravel to coarse sand	3,000

2.2. A better estimate of the permeability can be obtained from a comparison of grain size curves or the D10 of the sand samples with certain empirical relationship between D10 and K such as Hazen's formula of K (cm per sec) $= C_1 D^2_{10}$ where 10 per cent of the soil by weight consists of particles smaller than D 10. After determining the grain size, the total flow-volume rate per unit of total cross-section perpendicular to the direction of macroscopic flow commonly called the discharge velocity can be calculated from the formula $V = Ki$. In this formula K represents the permeability co-efficient and 'i' the total head lost per unit length of macroscopic flow path called hydraulic gradient. The value of 'i' can be determined by conducting a small field test in a glass tube packed with the sand in question and finding out the loss in piezometric pressure between the two ends of the sand medium.

2.3. The sand samples at a depth of 3 to 4.5. m Keepakam were analsed and graded as medium to fine sand. It gave a N value of 40 in standard penetrometer tests. Its fineness moudlus was given between 1.6 and 1.5. Its bulk density in compact state was about 101 to 92 lbs. per cubic foot in loose state. The specific gravity of sand was found to be 2.68. For this particle size, the permeability coefficient was deduced to be 400 × 10. The discharge velocity was found to be in the order of 1/2500 cusecs per square foot or 1/250 cusecs per running foot of area tackled assuming a water depth of 10 feet to be tackled. This gave a discharge flow of 1.6 gallons per running foot or 5 gallons per running meter of the length tackled. We proposed to place filter-points at 90 centimeter centres (3 feet) and they roughly came to 4.88 gallons per minute. 10 numbers of filter-points were connected to a 5 H.P. centrifugal pump which was tried and found to discharge actually 40 to 50 g.p.m. As a thumb rule each filter-point was assumed to need ½ H.P. of pumping and filter-points were suitably grouped under each pump on this basis.

3.0. Laying deep sewer lines:—

3.1. The work of laying cast-iron sewage pipe line (250. dia) had to be taken up in the month of June 1976 as a link in the sewer system. The work was programmed in this month as the ground water was expected to be low enough to permit quick execution. On excavation, the ground-water level was found to be at 2.5 m. below ground (at about 1.5 m. above MSL). We had to lay the pipe line at depths ranging from 3.00 to 3.80 meters (0.70 m. above MSL to 0.20 m. below MSL). The conventional method of digging a sump and pumping from there, was not possible as sand was flowing into the sump and filling it up. Hence. this technique of filter-point was adopted and a length of 240 meters was laid at the correct grade and the lead joints were done in dry state satisfactorily within one month.

3.2. The pipe lines were in six lengths of about 40 m. each. Each length was done in 2 operations of 20 m. each, using two sets of filter-points, manifolds and pumps. Excavation for the full length was done up to the ground water level. The centre line was marked on the ground. Filter-points were sunk along two lines at a distance of 30 cm. of either sides of the centre line. The filter-points were all spaced at 90 cm and they were taken down to 2 m. below the final grade of the pipes. The filter-points on one row were staggered between those on the other line. The excavation for the final grade was done in dry state and the cast iron pipes were rolled down and introduced. The water could be controlled very easily. Extra depths near the joints were excavated and the water from the pits were initially baled out manually and thereafter the filter-points preserved their dryness. A photograph of the filter-points and a sketch given in this article will give an idea of the actual procedure.

4.0. Foundation for Block house:—

4.1. Block-house building of the Satellite Launching Vehicle Complex lying at a distance of 1 km from the sea is a cylindrical reinforced-cement concrete building at 24 m. in diametre and 6.7 m. high It has a conical inverted dome as foundation and a conical dome as roof. The entire building floats on the concrete inverted dome 600 mm. thick laid over two 150 mm. thick layers of lean concrete interlaid with 3 courses of heavy duty hessian based tarfelt with suitable bitumen coatings. The bottom level of the pit for laying the lower larger of concrete was 6.1 m. (at about the mean sea level). The ground level was about + 10.00 and the ground water level was at + 8.00 (+ 4 m. and + 2 m.) above mean sea level respectively.

4.2. The area of foundation extending over 26 m in diameter was unwieldy and it was calculated to demand large number of pumps, pipes, etc. Hence, it was split into 2 stages. As a first stage, the inner central area 16 m in diameter was taken up. The initial excavation was done upto + 8.00 level where we touched the ground water. It was estimated that 120 numbers of filter-points and pumps aggregating to about 50 H.P. would be required. We collected the following pumps.

		Nos.
(a) 5 H.P. pumps	... ...	4
(b) 7.5 H.P. pumps	... .	1
(c) 20 H.P. pumps	....	1

4.3 Seven manifolds each 8 m. long (M1, M2, M3, M4, M5, M6 and M7) and of 7.5 mm diameter were installed around the circle as chords at 8.50 M level over temporary supports for being above submersion level. Filter-points were sunk in a circular line at 50 cms.. Outside the first stage limit. Another rows of filter-points were spaced at 90 cms on each row and were also staggered between the two rows. These are shown in the enclosed drawings. The top of filters was kept at 4.50 metres level. At the centre, a large filter-point 80 mm. diameter was also installed, for effecting better draw-down. But this filter-point and connected pipes lying at the centre, posed problems in concreting of the first stage and hence they were removed. When the 7 pumps were connected to the manifolds and run, the water level got lowered to the required level. The pumps had to be kept running over a period of 2 weeks to enable the lower concrete-mat to be laid and then the water proofing course with 3 layers of tarfelt was also laid. Soon after this, another 15 cm. thick concrete layer was laid for throwing weight on the water-proofing course and for preventing demages to it while tying the reinforcements for the raft. The raft concrete was laid for the first stage and the second stage taken up.

4.4. The manifold M2 was dismantled and shifted and re-erected at the outside edge of the outer circle. Similarly M5 and M7 were dismantled and re-erected outside the outer circle. The manifold M3 was altogether removed. The pumping was kept continuously going and the sets were commissioned as soon as erection was completed. When this system started working water started gushing out from the old holes from where the filter-points were removed under

manifolds M2, M3, M5 and M7. Pieces of gunny were rammed under manifolds M2, M3, M5 and M7. Pieces of gunny were rammed into each hole and then grouted with neat cement mixed with water proofing compound of CICO. The water seepage was controlled by entinuous pumping and water proofing was got done and they were weighted by placing sand bags closely. They were later released after laying one layer of cement concrete 15 cms thick as a protective layer. In this way the entire raft slab was concreted within about 6 weeks.

The success of the work depended upon the uninterrupted power supply which was available and due to very hard work of continuous pumping operations and checking and removal of air leaks. The entire operation cost us only Rs. 30,000 and this should be considered as very worthwhile, considering the impossibility of adopting any other method of dewatering. The sketches 4, 5 and 6 give the layouts of the pumps in the two operations.

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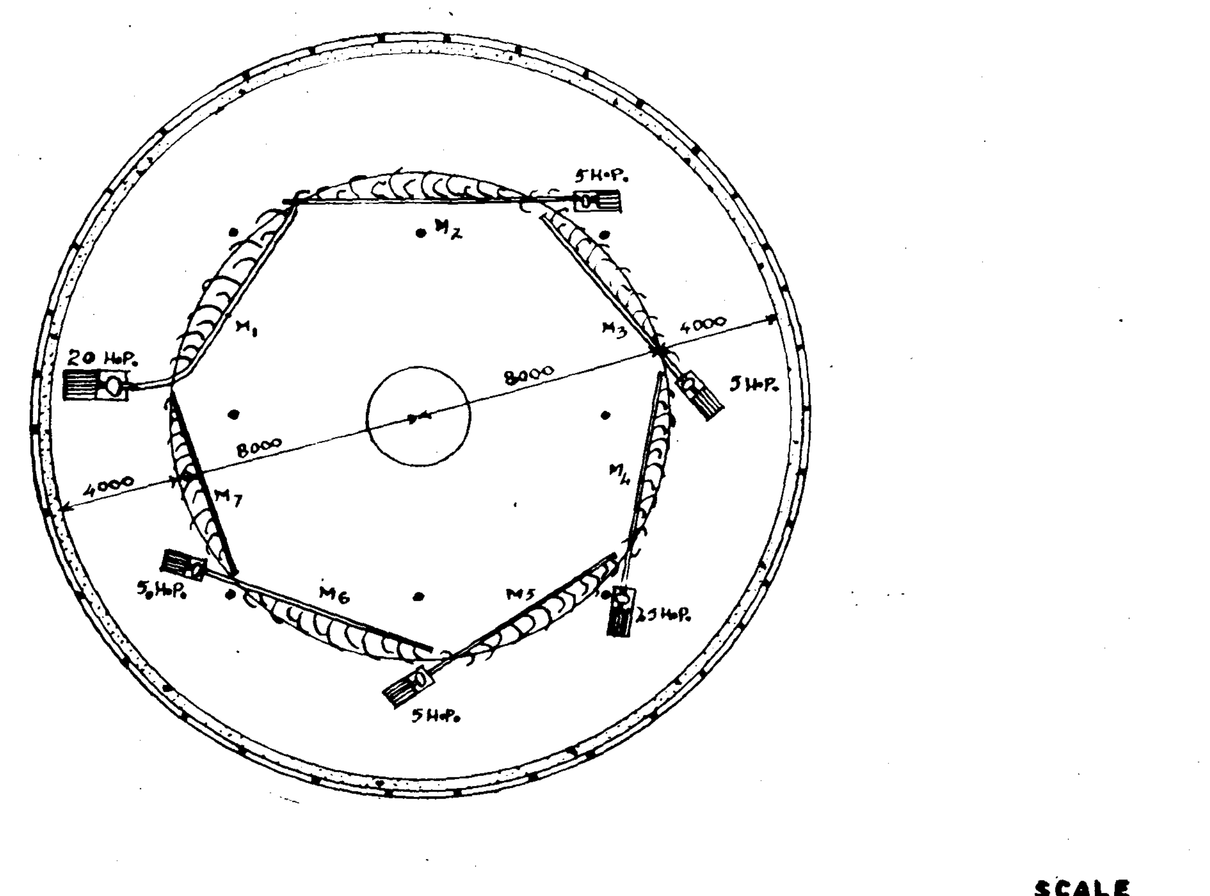
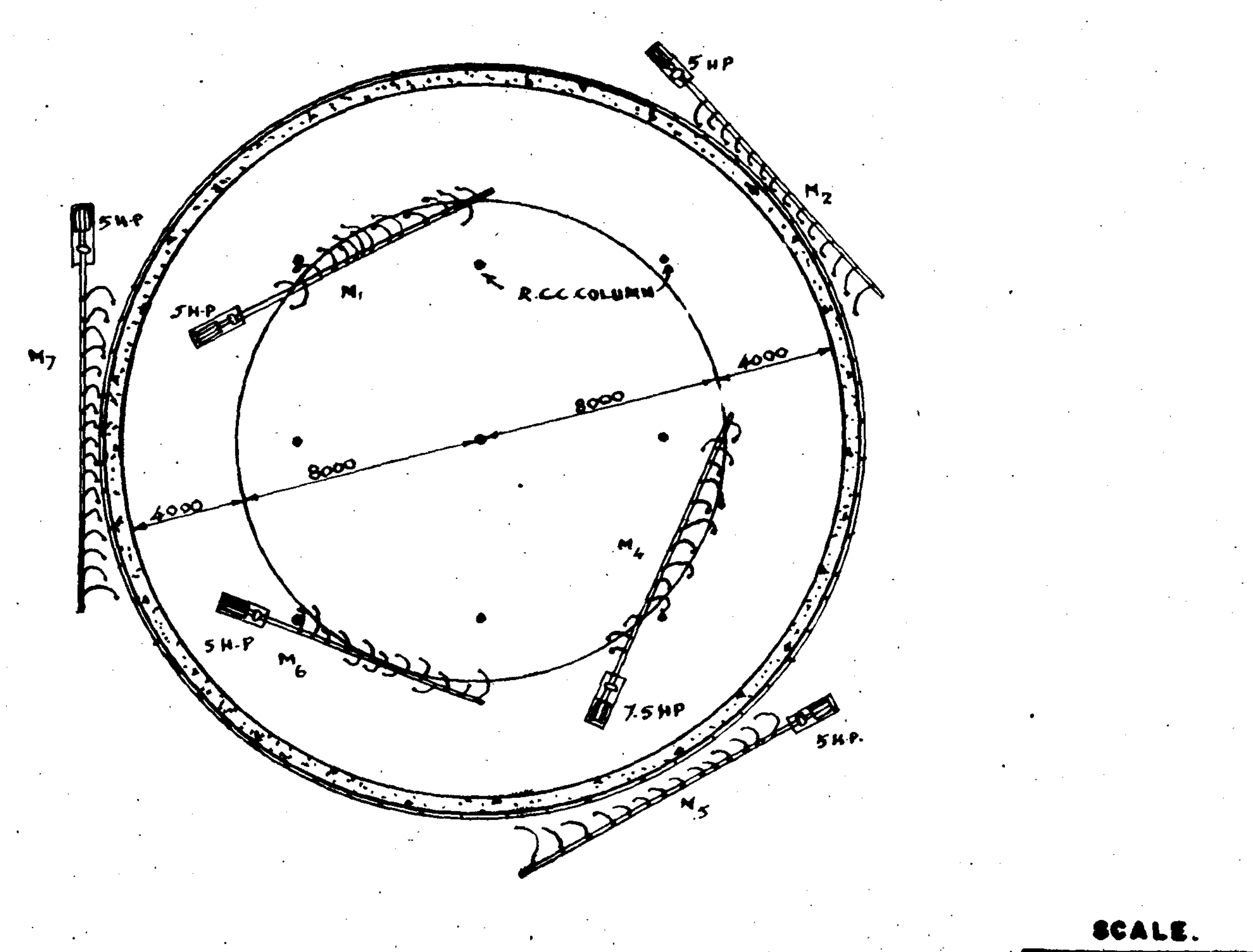


DEPARTMENT OF SPACE
CIVIL ENGINEERING DIVISION
SRI HARIKOTA RANGE.

BASEMENT PLAN OF BLOCK HOUSE
SHOWING I STAGE OF PUMPING



DEPARTMENT OF SPACE
CIVIL ENGINEERING DIVISION
SRINARIKOTA RANGE.

BASEMENT PLAN OF BLOCK HOUSE
SHOWING II STAGE OF PUMPING.

Multi-Purpose Development of Water Resources in Northern India.

By

Er. E. C. SALDANHA, B.E., M.I.C., Member (P & P) Central Water Commission, Government of India.

The endless varieties of landforms, changing landscapes and climates in the vast Indian sub-continent have, over the ages, exercised a tremendous influence in shaping the destinies of its people and have been largely instrumental in evolution of the mosaic of cultures, which characterise the rich and colourful diversity that India is. It makes a facinating study as to how people in various parts of our country, by making ingenicus use of locally available natural resources, have, in course of time developed distinct traditions and social values.

Although every part of the country has contributed to the rich heritage of India, yet the region, which has, perhaps, made the greatest impact is the area covered by the vast alluvial plains in the north. With the lofty Himalayas, providing shelter from the north, these plains extend over a length of over 2,000 kms, and have a width varying from 240 kms. to 370 kms. These plains, which constitute one of the world's greatest stretches of flat alluviam, are watered by three great river systems, originating in the Himalayas—Indus, the Ganga and the Brahmaputra. How deeply the history of these rivers is inter-twined with the history of this area is to well-known and need no elaboration. The mighty Indus from which India gets its name, has nurtured and seeded many great civilisations and cultures in its area, whose riches have attracted countless millions from Central Asia and West. The awe and majectic vastness of the Brahmaputra have inspired many a legend and myth. It is, however, the Ganga, which has been identified as the 'River of India' and, in the words of Jawaharlal Nehru, 'it has held India's heart captive and drawn unaccounted millions to her banks since the dawn of history. The story of Ganga from her sources to Sea, from old times to new, is the story of India's civilisation and culture, of the rise and fall of empires, of great and proud cities, of the great adventure of men and quest of mind.

Why this unbelievable reverence for Ganga and other rivers ? The reasons are not far to seek. Mythology apart, these rivers, provide life giving waters, which enable the people of the area, with its excellent climate and fertile soils, to produce plentiful from agriculture and thus, sustain themselves. The magic and spell of these rivers is due to their role as sustainers of life. In modern times, this dependence on water has become all the more predominant, due to population, explosion. The region is one of the most thickly populated areas on Earth. Water being the main resources of this region, its development has become a matter of crucial importance for the existence and prosperity of vast majority of people, which inhabit this area.

Since the attainment of Independence, significant progress has been achieved with regard to tapping of huge water potential of the region for providing irrigation, power and other benefits. In the process of multipurpose development of water resources, many new and significant trend are evident which should be of interest to the Engineering Community. I, therefore propose to devote my talk to this subject, which will be benefiting the memory of the great Engineering and Visionary, whose exploits in the field of water resources development. are a source of inspiration to all of us.

Northern India—Physiography.

Northern India, comprising the States of Jammu and Kashmir, Himachal Pradesh, Punjab, Hariyana, Rajasthan, Uttar Pradesh and Bihar, lies almost entirely in the two great river basins, namely, Indus and Ganga. In the nothern part of this area are the great Himalayas, which comprise almost three parallel ranges interspersed with large plateaus and valleys, some of which like Kashmir and Kulu are very extensive and fertile. The western part lies in the Indus basin, while the rest of the area lies in the Ganga basin. The Indus, which rises near Manosarovar Lake in Tibet, traverses the mountain ranges in Northern Kashmir and, thereafter, enters Pakistan and finally flows into the Arabian Sea near Karachi. It has five eastern tributaries—the Sutlej, the Beas, the Ravi, the Chenab and the Jhelum, which (except Sutlej), originate in India. Four of these, except the Beas, after traversing areas in Indian territory flow into Pakistan. The Beas river joins the river Sutlej at Harike in India. Of the total catchment area of Indus, which is 11.65 lakhs square miles, 3.21 lakhs square miles lie in India.

The Ganga has its source in the Gangotri Glacier in Northern Utter Pradesh. It is formed by the joining of two streams—the Alakananda and the Bhagirathi. After emerging from the hills into the plains at Rishikesh, it traverses the plains first in a southernly direction and then turns east. After traversing the plains of Uttar Pradesh, Bihar and West Bengal, it bifurcates into two branches—one branch flows into Bangladesh and the other, Bhagirathi, which is known as Hooghly in the lower reaches, flows through West Bengal into the Bay of Bengal. The important tributaries of the Ganga are Yamuna, Ramganga, Ghaghra, Gandak, Bagmati, Kosi and Sone. Important subtributaries like Chambal and Betwa join the Yamuna before it joins the Ganga. The total length of the Ganga (measured along the Hooghly) is 2,525 Kms. and the area of the river basin in India is 8.61 lakhs square kilometres, which is one-fourth of India's geographical area.

* *From the Sixth Bharat Ratna Dr. M. Viswesvaraya memorial lecture delivered on 14th September 1977 at Madras*

Climate and Rainfall.

The Indus basin has extremes of climate. The climate of the region varies from arctic cold in Ladakh and perpetually snow-clad peaks in Himachal Pradesh to the tropical heat of the sub-montane and plain tracts of Punjab and Rajasthan. Major portion of the basin receives a rainfall of over 600 mm. The south-west monsoon brings rain in summer months, while the winer rains are caused by storms in Jammu and Kashmir. The winter is followed by the summer when there is extensive melting of snows and the glaciers which brings in large flows into the rivers.

The Ganga basin is so vast that physiography, climate, rainfall, etc., are different in different regions. Most of the rainfall in the region, however, occurs during the south-west monsoon. Winter is generally cold and summer very hot except in the head reaches and in some sub-basins like Chambal, where summer is mild. The rainfall in the basin varies. In the west in the Yamuna sub-basin, it varies from 1,500 mm. in the hilly regions to 400 mm. on the right bank towards Rajasthan. In the Chambal sub-basin, the maximum and minimum annual precipitation vary from 1,270 mm. to 356 mm. In the Sone sub-basin, rainfall varies from 1,620 mm. in the Vindhyan Plateau to about 990 mm. in the plains where the river joins the Ganga. In the Gandak sub-basin, which experiences very hot summer and severe winter, the average rainfall varies from 1,000 mm. to about 1,300 mm.

Surface Water Resources.

The Indus has large water potential. However, under the Indus Waters Treaty with Pakistan, India has been allowed the use of Indus waters to the extent of 41,955 million cubic meters. India has been allowed full use of the waters of the rivers Sutlej, Beas and Ravi plus the use of Chenab and Jhelum water to specified extent in Jammu and Kashmir.

The total surface water run-off in the Ganga basin is roughly assessed at 432,000 million cubic meters. of which 368,000 million cubic meters pass through Uttar Pradesh.

The ultimate irrigation potential of States in the Northern India from surface water resources is at present assessed as under:

	Lakhs ha.
Jammu and Kashmir	5·50
Himachal Pradesh	N. A.
Punjab and Haryana	50·20
Rajasthan (Indus Basin only)..	11·00 (Approx.)
Uttar Pradesh	160·00
Bihar	111·30 (Approx.)
Total ..	338·00
Say ..	340·00

This estimate of utilisable surface water resources is based on present assessment. The figure may increase with advancement of technology.

STATUS OF WATER RESOURCES DEVELOPMENT IN 1947.

Irrigation.

At the time of gaining Independence in 1947, in the northern region, considerable use was being made of river waters in the Indus basin in the undivided India for irrigation as a result of large number of perunnial, non-perennial and inundation canals constructed in the 19th and early part of the 20th century. At that time, there were 32 perennial and non-perennial canals and about 120 inundation canals taking off from the Indus System. As a result of partition, the bulk of this system fell to the lot of Pakistan and only three perennial canals (one of which was divided between India and Pakistan), two non-perennial canals and nine inundation canals remained in India. Before Independence, the Indus canals irrigated annually an area of 9.6 m.ha., of which 8 m.ha. lay in Pakistan and only 1.6 m.ha. remained in India. The three important perennial irrigation systems, which remained in India were Upper Bari Doab Canal taking off from Ravi, the Sirhind Canal and the Eastern Canal, taking off from River Sutlej.

In the areas served by the Ganga and its tributaries, there were a number of systems existing at that time. The major systems, which existed at that time, were Eastern and Western Jammu Canals, taking off from the Tajewala Barrage on Yamuna. Agra canal taking off from the Okhla Barrage on Yamuna, upper and lower Ganga canals taking up from the Harward Narora Barrages on the Ganga, Sarda Canals taking off from Barrbassa Barrageon Sarda. sone canals taking up near Dehri-on-Sone, Betwa Canals taking off from Parischa Weir on Betwa. Some of these systems taking off from the Ganga rank among the classical irrigation systems of the modern era. Besides the perennial canals, there were a number of inundation canals existing at that time. Among these were the Naraini and Triveni Canals taking off from the river Gandak in Uttar Pradesh and Bihar.

The total irrigation potential from major and medium projects existing in 1947 in the States of Jammu and Kashmir, Punjab, Haryana, Himachal Pradesh, Rajasthan (Indus system only), Uttar Pradesh and Bihar, fed by the Indus and the Ganga river systems was 5.0 m.ha. Table below gives the details.

Irrigation potential created through major and medium project in 1947.

	Lakhs ha.
Jammu and Kashmir	0·43
Haryana	4·36
Punjab	12·20
Rajasthan (through Ganga and Indus waters only)	3·20
Uttar Pradesh	25·53
Bihar	4·04
Total ..	49·76
Say	50·00
or	5·00 m·ha.

Power Generation.

There was hardly any use being made of waters for power generation in 1947. The hydel power availability was mainly through 3—4 schemes, i.e., Jogindernagar Mandi Hydro-electric Works on Uhl river, a tributory of the Beas river in Punjab and through utilisation of canal falls on Upper Ganga and Sarda Canals in Uttar Pradesh. and through utilisation of Jhelum water in Jammu and Kashmir. The total installed capacity of Hydel power in the region was 79 MW only.

Water Resources Development since Independence.

After the start of planned development in 1951, a systematic programme for development of water resources was undertaken in the various States of this region. As a result, there has been phonomenal increase in the development of irrigation facilities as well as in hydel power generation. This was possible through undertaking of large number of river valley projects, some of which are unique and rank among the most outstanding water resources projects executed for human good any time anywhere in the world. The irrigation potential created in the region from all sources. which was 12.5 m.ha. at the time of Independence has increased to 24.4 m.ha. by the end of the Fourth Plan. Similarly, the hydel generation capacity, which was only 79 MW in 1947 has increased to 2,216 MW during the same period. In the current Plan, there would be a further increase of irrigation potential to the extent of 6.20 m.ha. bringing the total to 30.60 m.ha and the hydel generation capacity of the region would increase to 3,955 MW. Besides multi-purpose and single purpose schemes executed for providing irrigation and power, a number of schemes have been executed during the last 30 years for providing flood protection to a large area and facilities for drinking water-supply.

Outstanding Water Resources Projects.

A feature of the development during the last quarter century of development has been significant advances made with regard to planning, design and execution of water resources projects and the qualitative change regarding concepts and trends in water development. Some of the projects executed are unique in scope and character and would have been unthinkable half a century ago. To illustrate the main features of the developments, which have taken place. I would mention some of the outstanding projects in the region, which are either complete or presently under execution.

Bhakra-Nangal.

Of all the projects executed so far. the pride of place must go to this gigantic project, which has been executed to tap the huge potential of river Sutlej, which is one of the main tributaries of River Indus. As most of you are aware, under this project a 740 feet high dam has been constructed across River Sutlej for providing 6.3 m.a.ft. of live storage for irrigation and power generation. The dam is constructed at Bhakra at the foot of the Shivalik hills in Himachal Pradesh. It has two powerhouses, one on either flank located at the toe of the dam. About 13 k.m. downstream of the dam, a pick-up barrage known as Nangal dam has been constructed across the river for diverting water into a hydel channel known as the Nangal Hydel Channel on the left bank of the river. This channel, which is entirely lined, has a length of 64 Kms. and is designed to carry a discharge of 354 cumecs (12,500 cusecs) and serves as a feeder for the Bhakra main canal, which is 174 Kms. long and which provides irrigation to arid tracts of Punjab, Haryana and Rajasthan. The Nangal Hydel Channel has two powerhouses located on it at Ganguwal and Kotla. The project provides irrigation benefits to an area of 1.46 m.ha. in Haryana, Punjab and Rajasthan, besides generating power. The total installed capacity of the Bhakra Power-houses including those on the Nangal Hydel Channel is 1,204 MW. The construction of Bhakra Dam has reduced the occurrence of floods in the river downstream and made it possible to reclaim some valuable riverine lands on both sides of the river Sutlej.

How this Project has changed the entire face of the Punjab and Haryana States and Ganganagar district of Rajasthan by ushering an era of prosperity is something which has to be seen to be believed. The region had a large-scale influx of millions of refugees from West Pakistan after Independence who had left the highly developed tracts in West Punjab having excellent irrigation facilities. On the other hand, at the time of Independence this region had very few sources of irrigation and was deficit in food production. With the execution of huge irrigation network and availability of power as a result of construction of Bhakra Nangal Project and with the unprecedented hard work put in by the refugee farmers, the region, as it is known to all of us, has not only become surplus in food production but has become a granary of the country within a span of two decades.

Kosi Project.

In the Eastern part of this region in the State of Bihar, River Kosi has been causing havoc and misery for generations on generations of people on account of the recurring floods and high amount of silt brought down by it during floods. Due to heavy silt charge, which is one of the highest in the world, the river-bed has been rising and the river has been shifting its course over a wide area so much so that its course has shifted by over 50-60 miles in a span of 40-50 years. It had come to acquire the reputation of Bihar's River of Sorrow. As a result, a major part of North Bihar, north of the Ganga has been chronically backward and one of the poorest in the country. After 1947, serious consideration was given to contain this river in order to provide relief to the people of the area. After number of detailed studies, it was decided to jacket this river by constructing flood embankments along both the banks for a length of over 250 kms. and to construct a barrage across the river and take off canals for providing irrigation to areas on either flnak made flood-free due to the construction of embankments. This solution led to the conception of the Kosi Barrage and the Eastern Kosi Canal project in the year 1955 envisaging both flood control and Irrigation benefits. Subsequently two separate projects, one for irrigation of the area lying between the present and old course of river Kosi on the eastern flnak (Rajpur Canal) and the other for a canal taking off on the western flank (Western Kosi Canal) were sanctioned. The Barrage, the Eastern Kosi Canal system and the Rajpur Canal have been completed barring some balance works on the distribution system. Work on the Western Kosi Canal. which has its initial reach in the Nepal territory has been taken up recently. The barrage is located at Hanumannagar on the Indo-Nepal border.

The Eastern Kosi and Rajpur canals are designed to irrigate an area of 5.6 lakh hectares. The Western Kosi Canal on the other hand would irrigate an area of 3.14 lakh hectares. After taking up of the project, power benefits were subsequently added by construction of a power-house with an installed capacity of 20 MW on the Eastern Main Canal.

Rajasthan Canal:

This project, which aims at turning a large part of the great Thar desert into blooming green fields has aroused the admiration of many an observer. The northern part of Rajasthan is in the thick of the desert and in this area, for miles around, there is not only no vegetation but also no source of even drinking water. The area is very sparsely populated. This region has light soils which are potentially fertile and given water the entire countryside can be transformed into a veritable farmland. The first step in reclaiming this desert was taken in the Pre-Independence period when, as a result of the construction of the Sutlej Valley Canals in 1930, the northern-most district of the State, Ganganagar was provided with irrigation facilities. Subsequently, with the construction of the Bakra Project, the irrigation facilities in the district were further extended. As a result the Ganganagar district, along with Punjab, is considered to be the granary of the country today. The Rajasthan Canal Project is, in a way, a further extension of this programme for reclaiming the desert south of Ganganagar district.

Under the project, a huge canal of discharge capacity of 524 cumecs (18,500 cusecs) has been taken off from a barrage across the river Sutlej at Harike in Punjab and after traversing areas in Punjab and Haryana it crosses over to Rajasthan and thereafter, runs, almost parallel up to the Indo-Pakistan border at a distance of 25 to 30 miles from it. The first reach of 204 kms. of the canal is known as Rajasthan Feeder. Thereafter, Rajasthan canal has a length of 445 kms. The execution has been planned in two stages. Under the first stage, the construction of Rajasthan Feeder and Rajasthan main canal in the first 189 kms. length along with distribution system is planned. The remaining 256 kms. of the main canal and distribution system are to be constructed in the second stage. Irrigation benefits to the extent of 11.9 lakh hectares were to be provided as per the original scheme—5.9 lakh hectares from stage I and 6.0 lakh hectare from stage II. Construction of this project was started in 1958 and the First Stage of the project has been nearly completed. Work has been taken up on Stage II of the Project. The Canal which has been designed as a contour canal, was originally planned to irrigate areas through gravity flow. Only one branch, namely Lunkaransar-Bikaner Lift Channel was to provide irrigation to areas around Bikaner by lifting of water in four stages under Stage I of the project. However, there has been re-thinking about the scope of this scheme recently, so far as stage II is concerned. In order to provide irrigation facilities to affected desert district of Churu, Bikaner, Jodhpur and Jaisalmar it has been decided to provide five lift channels from the main canal to provide irrigation to 2.6 lakh hectares of land in these areas, commandable up to 60 metre lift. Besides, 5 lakh hectares would be provided Irrigation through gravity flow under this stage.

Construction of a canal of such dimentions has posed a tremendous problem in its execution. For providing drinking water to the labour and for other construction activities, a pilot water supply channel had to be executed first. Sometimes, instead of open channel, pilot water supply through pipelines had to be resorted to in order to obviate difficulties due to covering up of the open channels during sand-storms. The working conditions have been extremely tough. Availability of construction labour has posed problems. In view of the sandy soils, the entire main canal and distribution system is being lined. The construction methods employed on this project constitute a fine example of judicious blending of technology, *i.e.* combination of manual and animal labour with mechanised equipment. For earth-work excavation and transport in the desert terrain, large-scale use of camel-carts with specially-wide tyres is a good example of how appropriate construction methods can be employed to suit local conditions. Along with the camel-carts, use of heavy earthmoving equipment, donkey labour and manual labour has been resorted to get optimum results. There is hardly any other example of this type where a great desert like Thar is sought to be reclaimed through a scheme, which is very bold in concept.

Ramganga Project:

In Uttar Pradesh, there is great demand for water on the existing irrigation systems in the Ganga-Yamuna Doab. The Irrigation intensity on these canals is hardly of the order of 40 to 50 per cent. In order to supplement the waters in the Lower Ganga and the Upper Ganga Canals as well as in the Agra Canal, a multi-purpose project was conceived to augment supplies to these canals by diverting the water of the River Ramganga, which is tributary of river Ganga to the main Ganga and using it on the Lower Ganga Canal system through the existing Narora barrage. Water which was presently being released in the Ganga from the upper reaches for the Lower Ganga system is to be utilised for extension of irrigation in the Upper Ganga system as well as on the Agra Canal. Under this scheme, a 127.5 metre high earth and rock-fill dam has been constructed at Kalagarh in district Garhwal, Uttar Pradesh. Other components of the Project are:—

(i) a 74 metre high saddle dam.

(ii) a diversion barrage at Hareoli, 26 km. downstream of the Ramganga Dam.

(iii) a 82 km. long Feeder Channel, with a capacity of 44.4 cumecs taking off from the barrage at Hareoli and discharging into the river Ganga at Brij Ghat near Garhmukteswar, to be picked up further downstream at Narora for being utilised in the Lower Ganga Canal system; and

(iv) remodelling and extension of Lower Ganga Canal system and part distribution system of Upper Ganga Canal and Agra Canal.

Irrigation benefits to the extent of 5.75 lakh hectares would be provided to three canal systems by redistribution of waters. The project as been practically completed. Apart from Irrigation benefits, the project is to provide power benefits to the extent of 450 million units of electricity annually by means of a power

station located at the toe of the Ramganga Dam, which has an installed capacity of 198 MW. The project would also cater for augmentation of Delhi water supply by providing 5.6 cumecs of water to the Yamuna river through Jani escape and Hindon cut.

Gandak:

Gandak, which is a major tributary of the Ganga, has a very large water potential. This river, which forms the boundary between Bihar and Uttar Pradesh, along a part of its length, has been causing floods to areas in these States frequently. In the Pre-Independence period, inundation canals were taken off on either side of this river. Naraini canal was irrigating areas in Gorakhpur district of Uttar Pradesh, whereas the Tribeni Canal was serving areas in the Tirhut Division of Bihar. Gandak project was taken up in 1961, jointly by the Governments of Bihar, Uttar Pradesh and the Government of India for providing benefits to areas in Nepal, Bihar and Uttar Pradesh. Under this scheme, a barrage has been constructed across the River Gandak at Valmikinagar with two canals taking off from its own on either side. The Eastern Main Canal, which is known as Tirhut Canal is to irrigate areas in Bihar. The main Western Canal after irrigating areas in Uttar Pradesh crosses over to Bihar, where it is known as Saran Canal. For Irrigating areas in Nepal, two smaller canals, the Nepal Western Canal and Nepal Eastern Canal also take off on either flank of the barrage. The project, on completion, would irrigate 11.5 lakh hectares in Bihar, 3.08 lakh hectares in Uttar Pradesh and 0.56 lakh hectare in Nepal. Apart from irrigation benefits, navigation and power benefits are envisaged for Nepal. The main Western Canal is to have a power-house of 7,500 KW capacity for use by Nepal.

Beas Project.

This is by far the largest single water and power development project so far undertaken in the country and is being executed to harness the vast potential of the Beas river. The project proposes to tap the total run-off of the river, which is about 13.0 m.a.ft. for irrigation and power generation. The project comprises two units—Beas Dam at Pong and the Beas-Sutlej Link, both of which are multi-purpose schemes for irrigation and power.

Beas Dam at pong:

Under this project, a 132.6 metre high earth and rock-fill dam has been constructed across the river Beas at Pong in Kangra District of Himachal Pradesh for storing 5.6 m.a.ft. of water (Live storage) for irrigation and power generation: this would enable irrigation of large tracts of land on Rajasthan Canal through Harike Barrage as well as areas in Punjab and Haryana. The dam is to have a power-house located at its tow with an installed capacity of 240 MW in its final phase, with prospect of further increase to 360 MW later on. The work on the dam has been completed two years back. This dam together with the one constructed at Kalagarh under the Ramganga project are the highest earth dams built in the country to-date. Their construction posed a number of complex technical and geological problems, which have been tackled successfully. Construction of these dams involved boring of large diameter tunnels in seismically active terrain. Also, for design of various components of these projects, many novel engineering solutions were evolved and executed.

Beas-Sutlej Link:

This project, which is about to be commissioned, is a marvel of engineering. It envisages diversion of Beas waters into River Sutlej, upstream of Bhakra reservoir through a long water-conductor system. At the end of the water-conductor system, a fall of 320 metres at the tail-end would be utilised for generation of 267 MW of firm power and another head of about 120 metres at Bhakra for augmenting the power output by 140 MW at 100 per cent load factor. The Beas water would also enable extension of irrigation to the arid areas of Punjab, Haryana and Rajasthan, besides improving irrigation facilities in the areas served by the Bhakra system. The various components of the project are:

(i) Pandoh Dam across Beas, about 20 Kms. upstream of Mandi Town for diverting Beas Waters;

(ii) Water-Conductor system consisting of 7.62 m. diameter Pandoh-Baggi tunnel—13—17 kms. long, 11.8 kms long Sundarnagar Hydel Channel and Sundernagar-Sutlej tunnel. 8.53 metres diameters and 12.3 kms. long.

Construction of this project has posed numerous challanges to the engineers, particularly with regard to the construction of huge tunnels running many kms. in length through the Shiwalik mountains. Therewere many set-backs and problems encountered in tunnelling. These have been successfully overcome. The completion of this Link along with the storage created at Pong would enable further massive extension of irrigation and power facilities in the three States of Punjab, Haryana and Rajasthan.

Sarda Sahayak Project:

For irrigating tracts in Central and Eastern Uttar Pradesh in Ganga-Chagra Doab, Sarda Canal Project was constructed in 1978. Due to inadequate supplies in the river, the intensity of irrigation of this system was very low, varying from 33 per cent in Upper reaches to 19 per cent in the lower reaches. With the increase in the tempo of developmental activities, the clamour for water has increased. For extending irrigation facilities in the area, this project has been conceived, which is a landmark because of its huge size and scope. A solution has been found by tapping the hitherto untapped waters of river Ghagra, which is a major tributary of Ganga and utilising these for stabilising and extending the irrigation on the Sarda Canal System.

Under the Sarda-Sahayak Project, it is proposed to divert waters of Ghaghra into Sarda river by construction of a barrage and a 29 km. long Link Channel, with a capacity of 480 cumecs and, thereafter, divert water from Sarda river by constructing a barrage across that river into a Feeder Channel 260 km. long with a discharge capacity of 650 cumecs (22.750 cusecs) for feeding the various branches of the Sarda Canal System. The canal system would be further extended and remodelled extensively so much so that the capacity of the existing branches in some cases will have to be increased to as much as eleven times. This is proposed to be done by constructing parallel channels as well as by remodelling the existing ones. The project, on full completion, would irrigate 1.6 million hectare of land and would be the biggest single irrigation project in the country.

The commissioning of the project is planned in phases. Two phases of the project have been commissioned so far—first stage by completion of a barrage across Sarda and the initial 105 km length of the Feeder Channel, for feeding Daryabad Branch and stage II by completion of a barrage across Ghagra, Link Channel and Feeder Channel up to km. 119 for feeding Barabanki branch During the current plan, this project is to create about one million hectare of additional potential against the target of 5.8 million hectare for the country as a whole. Noteworthy features of this project are the barrage across Ghaghra, which posed a great difficulty in diversion during construction, feeder channel with very large cross-drainage works, particularly the crossings on major rivers like Gomti and Sai for which aqueducts are being constructed. The aqueduct across Gomti is particularly a unique structure in respect of design, consisting of 10 metre deep prestressed beams spanning 31.8 metres. This aqueduct will carry a discharge of 357 cumecs (12600 cusecs) and will cost Rs. 16 crores.

Jawaharlal Nehru Lift Canal and Sutlej-Yamuna Link.

The State of Haryana has attracted much notice in recent years on account of progress made by it with regard to extension of irrigation and power facilities in the state. The South Western part of this State, which lies along the Rajasthan border, is arid and has very meagre water resources. The slope of the land is from south-west to north-east and the area is not commendable by gravity from irrigation systems taking off from Yamuna and Sutlej. In this area, which consists of districts of Bhiwani,, Hissar and Gurgaon, Mohindergarh, even drinking water is scarce. For providing irrigation facilities to this area, the State took up during the Fourth Plan, a number of medium lift schemes in Hissar and Bhiwani districts, which envisaged lifting of water from the tail reaches of Western Jamuna Canal system. With a view to covering all such areas, the State have now taken up a major project —Jawaharlal Nehru Lift Irrigation Scheme, which envisages a total lift of 1.408 feet, for providing irrigation to chronically drought affected areas of Mohindergarh, Gurgaon and Rohtak districts by providing waters through western Jamuna Canal, which is proposed to be remodelled. In all. 104 pump-houses are proposed to be constructed on the entire canal sustem and the whole system is proposed to be lined. The project will provide irrigation benefits to 1.44 lakh ha. of land.

Further, in order that Haryana can utilise the waters of Ravi and Beas allocated to it as its share of Indus waters. for providing irrigation through J. L. Nehru Canal and other Lift Irrigation Schemes. water would need to be diverted from the Sutlej to the Yamuna basin. For this, Haryana has now taken up work on construction of the Sutlej-Yamuna Link Canal. Under this project, water from the river Sutlej is proposed to be diverted through a link canal with a capacity of 7,500 cusecs at the head, to be constructed to inject water into irrigation systems of the State. The total length of the Link Canal is to be 214 kms. out of which 122 kms. would be in Punjab.

Hydel Power Development:

Apart from the multi-purpose projects about which I have mentioned earlier during this period, a number of hydel power projects have been executed in the region, Among the notable schemes are Gandhi Sagar (which has irrigation component also), Ranapratapsagar and Jawahar Sagar Hydel Stations on Chembal river, Rihand and Obra Stations on Rihand river, which is a tributory of Sone and a series of Power Stations to tap the power potential of river Yamuna and its tributaries in Uttar Pradesh. The Rihand reservoir created by construction of a 91 metre high concrete dam is the second biggest man-made reservoir in the country. The power potential of Yamuna valley is being tapped through a series of cascade developments and four power stations—Chibro, Dhakrani, Dhalipur and Kulhal have already been commissioned. Chibro Station is an underground power house. It involved construction of a 6.2 km. long power tunnel through complex geological strata for utilising a head of 124 metres. Tail-race waters of this power-house are proposed to be taken across the Tons river by a syphon tunnel and thereafter through another tunnel to utilise a further head of 62 metres for power generation at a surface power house near Dakpathar. This project is at present in an advanced stage of execution. The second power-house when completed would operate in tandem with the first power-house at Chibro, which is unique.

Outstanding concepts in the development:

From some outstanding examples of water development, which I have referred to earlier, it would be noted that in the region for ensuring equitable distribution of available water resources, resort has been made to large scale intra-basin and inter-basin transfer of waters. Particularly, in the case of Punjab, Haryana and Rajasthan, through the inter-linking of the four rivers—Ravi, Beas, Sutlej and Yamuna, it has been possible to cover a large area of these States and to provide irrigation facilities to wider areas on an optimum basis. Here, I may mention that apart from Beas-Sutlej and Sutlej-Yamuna Links to which I have referred earlier, a link has also been constructed to divert Ravi water to Beas (Madhopur-Beas Link), which diverts 10,000 cusecs of Ravi waters upstream of existing Madhopur Headworks to Beas. Another objective of the intra-basin water transfers has been to augment the supplies in the existing systems for increasing the intensity of irrigation and bringing new areas under irrigation. Sarda Sahayak and Ramganga Projects are outstanding examples of this kind. In the construction of links for intra-basin and inter-basin transfer of waters in this region, execution of big engineering works like long tunnels, large cross-drainage works, big aqueducts, etc., had to be done. which, at times, posed major technical and construction problems, which were successfully tackled.

In the pre-Plan period, the approach was entirely to utilise the run-of-the river supplies only. However, due to dwindling down of the supplies in the rivers

during the summer months, the scope for extension of rabi irrigation in the area was rather limited. There has been a break-through in this regard as a result of execution of major storages at Bhakra on Sutlej, Kalagarh on Ramganga and Pong on Beas. Recently, some more storage projects have been approved, which on completion, would lead to further extension of perennial irrigation in this area.

Most of the rivers in the region have their source in the Himalayas, which have a substantial hydel power potential. The execution of multi-purpose storage projects has enabled generation of cheap power along with irrigation benefits. This has given a tremendous boost to development of industry in Northern India, which has no other natural sources of energy such as coal or petroleum.

Problems in development:

With run-of-the-river flows in rivers getting tapped, further expansion of irrigation facilities in the area would be possible only by creating storages in Himalayas. Because of the steep slopes, for provision of even small sized storage, dams of relatively big heights are required to be constructed. The region, being geologically very active, construction of high dams invariably involves tackling a host of difficult technical problems resulting in high project costs. Also, for water resources development in the region, construction of large diameter long tunnels for water conductor systems is invariably necessary. The strata through which these tunnels are required to be bored generally consists of soft rock. As the experience in the last 20 years has shown, tunneling in such terrain is extremely difficult and full of geological surprises. Unlike tunnels, tunnels in the southern part of our country, where these are generally required to be bored in hard rock, without needing any support, tunnels in Himalayas invariably require provision of supports during execution, as well as extensive protective measures such as rock-bolting, grouting, etc., for restraining the rock loads and stresses. The execution of practically all the tunnel projects in the Himalayan region has been hampered due to various difficulties, which cropped up during tunnel boring. Although a lot of experience has been gained on the excavation of these tunnels, yet tunnel excavation is likely to pose a major problem in the future projects, particularly with regard to construction of long tunnels for water conductor system for power generation. In order to cut down the construction time, resort has to be made to faster methods of tunnel excavation and lining. In this context, suggestions have been made to excavate tunnel through the use of moles and point excavators.

Another problem to which I have already referred to in my talk earlier, is the problem of flooding by rivers in North Bihar which bring large amount of silt due to inadequate river slopes. To tackle this problem, a start was made by provision of flood protection embankments along Kosi and other rivers in North Bihar, but this has not provided complete relief and areas still continue to be submerged because of floods in one or the other rivers, though comparatively the areas east of Kosi between this river and river Mahananda have been made relatively flood-free. A permanent solution of the flooding problem in North Bihar, with the resources at present available, is not foreseen in the near future. For providing flood protection, extensive measures by way of detention reservoirs and soil conservation are needed to be carried out in the upper reaches of these rivers, which lie in Nepal and for which full understanding would be necessary with that country. Through construction of embankments, only temporary relief is afforded from floods. At the same time, it must be appreciated that problems of River Kosi is rather unique. This river, along with River Bhang Ho of China has the highest silt charge among the rivers of the world. We will have to struggle with its problems and make further efforts till these can be completely over come. Along with North Bihar, eastern part of Uttar Pradesh in the Rapti-Ghagra Doab is also subjected to recurring floods. Flood proofing of this area as well is still far from being achieved

Outlook for Future Development:

In the Indus basin in the States of Punjab, Jammu and Kashmir and Haryana, the waters allocated to India under the Indus Waters Treaty are expected to be fully utilised after the storage on the river Ravi is created by constructing a dam across it. For this purposes, The dam project has been conveived and is expected to be taken up shortly.

In Uttar Pradesh, which is in the Ganga basin, there are a number of old canal systems, which were designed on the earlier concept of providing protective irrigation with irrigation intensity ranging from 30 to 40 per cent mostly for Rabi irrigation. These are totally inadequate for the requirement of modern-day agriculture with a view to improving these systems, some projects for their re-modelling, have already been executed or are under execution. Recently, a number of projects have been approved for providing Kharif irrigation on these systems. For meeting the requirement of water during Kharif, the capacity of the main canals is sought to be increased by providing parallel channels along the existing canals. Such major schemes, which have already been sanctioned and taken up for execution are the Madhya Ganga Canal and the Parallel Lower Ganga Canal. In addition, a number of similar schemes for supplementing Kharif irrigation on Ganga and Yamuna Canals have been proposed.

There is to be further expansion of storage capacity through creation of new reservoirs. Amongst the new storage projects already taken up for execution is the 246 M high dam across Bhagirathi (Ganga) near Tehri, which would be multipurpose scheme having both irrigation and power benefits. The dam, when completed, would be one of the highest in the world. A still bigger storage on the main Ganga is proposed at Kotli Behl, which will be created through construction of a 217 M high dam across the river near Risikesh. The project is expceted to generate 1,040 mw of power besides providing additional irrigation facilities to 8.2 lakh ha. Storages are also proposed to be created along the Yamuna river, first of which would be through the dams at Lakhwar-Vyasi, which would be 190 metres and 81 metres high respectively. This scheme is also to be multi-purpose project having both irrigation as well as power benefits.

There were number of storages proposed on Sarda river, tributary of Ganga, which has large power potential. Among these are the Pancheshwar dam, 232 Metres high and Purnagiri Dam, 145 Metres high, besides a number of other dam schemes on Eastern Ramganga river and Sarju river. All these schemes are being conceived with both irrigation as well as power benefits. There is also a proposal by Nepal to construct a dam across Ghagra in its territory, for which Karnali, dam project has been formulated for generation of power. India has already agreed, in principle, to buy the huge quantity of power, which would be generated by this project. The creation of storage on this river would further result in tremendous increase in irrigation on the system to be irrigated by Sarda Sahayak Project.

Besides these multi-purpose schemes, a number of power projects are on the anvil for tapping the potential of Sutlej in Himachal Pradesh and Yamuna, Ganga and Sarda rivers in Uttar Pradesh.

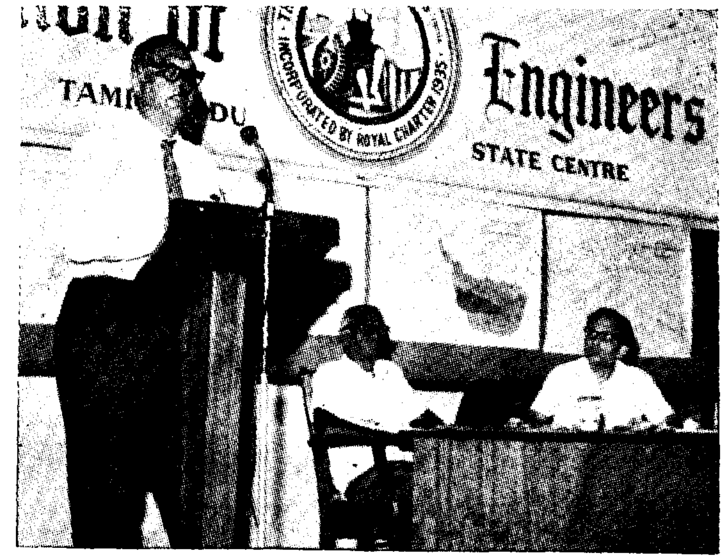
To tackle the flooding problem in Bihar and Uttar Pradesh, proposals have been framed for construction of dams in upper reaches of river Rapti and Kosi. For this, some dialogue has already been initiated with Nepal.

New Trends in Development

Faced with problems of meeting the food and fibre needs of increasing population and effecting improvements in standard of living, States in the region are now paying greater attention to water resources development. In the States of Punjab and Haryana, which have practically utilised the available water resources, further extension of irrigation facilities is sought to be made through economising in the existing water uses. For this purpose, large-scale Programme for lining of distribution systems in both Haryana as well as Punjab has been undertaken. In the next Plan, the major thrust of the programme in these States would be on lining and modernisation of existing systems.

A review of the water resources development of the region over the last 30 years would indicate that significant success has been achieved with regard to provision of irrigation facilities and power benefits through adoption of bold and modern concepts and use of appropriate technology for water resources development. Given the resourcefulness, there is no cause for any despair with regard to solution of our immense problem of removal of poverty. The message of the story of water resources development in Northern India is clear. Through judicious exploitation of our water wealth, we can remove to a very large extent, the many ills which afflict our land today.

(Photographs taken during the Sixth Bharat Ratna Dr. M. Visweswaraya Memorial lecture day at Madras).



(Photographs taken during the Sixth Bharat Ratna Dr. M Viswesvaraya Memorial ecture day at Madras.)

Study of River Mechanics by Remote Sensing.

By

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Scope.—The flow mechanism of natural rivers and its after effects on the geometry of the rivers, etc., are practically very difficult and cumbersome to be understood and determined for practical purposes, even with the application of advanced methods of hydraulics. Further, it also becomes necessary to any hydraulics Engineer to introduce a new, accurate, quick and practically feasible method for studying the flow mechanism and for determining the after-effects on the river behaviour, for purposes of River training, flood control, Diversion and storage works, etc., of the rivers. This paper is initiated to explain briefly, the method called "*Remote Sensing*" by adopting or applying the fundamentals of Electromagnetic radiation; it is presumed that this method of studying River mechanics is quick, accurate and practically feasible in these days of advanced sciences. Though, a thorough knowledge on the subject of Electromagnetic radiation and "*Remote Sensing*", as it is called, is possible to be acquired and applied here for bringing the practical application of those subjects, the scope of this paper is restricted to the understanding of the study of river mechanics by the method of "*Remote Sensing*". The actual scheme of study on the topic will be on the practical or execution part of it, adopting the methods of Aerial surveying and stereography, etc.

Introduction.—The flow characteristics or mechanism of a river or channel is a complicated phenomenon. A clear understanding of this phenomenon is possible by a study with certain Remote sensing principles. These Remote sensing principles are based on the electromagnetic radiation, i.e., the intensity of electromagnetic energy that is being reflected or emitted from an object or scene, by applying the methods of "Multiband photography, precision mapping Camera photography and thermal infrared imagery" with a line scanner, etc. For this purpose, there are various combinations of Films and filters available for this photographic study for different wave lengths of electromagnetic waves. Certain optical and Mechanical line scanners with detectors can be adopted for obtaining the imagery in different bands of wave length. On the whole, this remote sensing study mainly consists of different types of photographic works on the river or channel flow and their after-effects and similating the features of those photos to the variables of river flow and understanding the flow or river mechanism. The main principle that is applied here is that the radiation obeys the laws of "Optics" on the presence of matter with different mass, density, shape, size, colour and surface area characteristics. Optical Transmission, reflection, refraction, diffraction, absorption, Interference, Dispersion and polarisation effects are all encountered in the similation of the features of the photos to the variables and components of any flow.

Principles of Electromagnetic Radiation.—Our environmental atmosphere consists of "Electromagnetic field" of varying intensity. "Radiation" is one form of energy transfer. Light from the sun, heat from a fire, radio waves from the ionoscope, etc., are all a few examples of electromagnetic radiation that is, forms of electromagnetic energy transfer. These forms of energy transfer are similar in their nature which may be grouped and ordered on an electromagnetic spectrum with reference to their wavelength or frequency of occurrence. For instance, it is possible to indicate that any "Audio waves" of sound have lesser frequency of occurrence, than "Radio Waves, the Micro Waves" have higher frequency than the radio waves and the "Infrared Waves" from the radiated light have higher frequency than the micro waves, etc.

The ordinary "Visible light" has got more frequency of occurrence than all the above waves; then come the "ultraviolet", "X-Rays" and "Gamms rays" in the increasing order of the their frequency from the visible light range. Regarding the wave lengths of the different waves of the electromagnetic radiation, the "Solar radiation" that is radiation of heat and light from the sun to the earth ranging between 0.1 micron and 4.0 micron are called "Short wave lengths" and the *Emitted radiation* from the surface of earth which is in the infrared range, that is between wave lengths 4.0 microns and 100 microns are called "Long wave lengths". To be more elaborate, the white sun light received from the solar radiation may be allowed to disperse through a glass prism and the emergent beam of light be seen on a screen. It may be found that the incident white beam of light, after passing through the denser medium of glass prism from the lighter medium of atmospheric air, is dispersed in seven regions of different colours, viz., violet, indigo, blue, green, yellow. Orange, and red, arranged and ordered in their increasing wavelength. It may also be noted that these dispersed coloured light waves have different angles of "deviation", the violet being deviated more than others while the red being the least deviated, the Yellow lies in the via. media (mean) of these two extremities. The wave length of these seven coloured light waves, will be of the ranges given below:

Violet	..	—3800· A to 4400·A,
Blue	..	—4800· A to 5000·A,
Yellow	..	—5500· A to 5900·A,
Red	..	—6400· A to 7800·A,
Indigo	..	—4400· A to 5500·A,
Green	..	—5000· A to 5500·A,
Orange	..	—5900· A to 6400·A.

Where I is 10·8 cms.

The coloured band of these seven ranges is called the "*Electromagnetic Spectrum*". There are also certain region of the coloured band, both beyond and below the **two extremities viz., red and violet which are called** "Infrared radiation" and "Ultra Violet radiation" respectively. The Infrared radiation which cannot be seen on the Spectrum by the naked eye as it does not produce light, but can be felt as "heat wave", has the wave length of more than 7800.A, that is between 8000.A and 0.04 cm. so also with the ultra violet radiation, which has the wave length of less than 3800.A that is between 3000.A and 150.A.

Through any visible spectral photography, with precision, taken at the objects or matter, the very presence of those objects in their shape, colour, size and the nature of surface, etc., can be determined. This fact is the primary basics for the whole study of Remote sensing process with the said methods. That is to say that the ordinary visible white light of wave. length varying between (4,000 A and 7,000 A) 0.4 micron and 0.7 micron will enable us to observe the presence of any object, when it is photographed, the colour, size, shape etc., being understood and determined by the intensity and quantum of the primary colours of the spectrum, viz., blue, green and red, which are reflected and transmitted from the object. These reflected and transmitted electromagnetic radiation energies, both within as well as outside the visible light region can be carefully detected and imaged with certain electromechanical scanners and detectors. For this purpose, there are specially sensitized photo films available to record the scenes or objects with reflected energy, even outside the visible region in the ultraviolet range of (3,000 A to 4,000 A) 0.3 micron to 0.4 micron and in the photographic infrared range of (7,000 A to 9,000 A) 0.7 micron to 0.9 micron wave lengths. There are also specially devised precision "Cameras" for taking the 'Multi band photos" and for the precision mapping of scenes and objects and "Line scanners" for imaging the emission of thermal infrared radiation.

Important features of Electromagnetic Radiations.—The total quantum of Radiation energy reaching the earths surface through atmosphere from the sun or any light source will be partly "Reflected" from any objects or surface, partly "Absorbed" by the objects or surfaces and the rest "Transmitted". This process is called "Extinction" which is due to the attenuation of the energy. Certain amount of energy will also be transferred by "Emission".

The Radiant Reflectance from a particular object surface is a function of (1) the wave length of the incident radiation, (2) the character of the reflecting surface and the material itself and (3) the incident and reflecting angles. However, purely opaque materials and black bodies are least reflectors and perfect absorbers of light. The reflectance can also be described and defined for all wave radiations like any "Monochromatic radiation" which is a narrow band width on a spectrum and visible light and solar radiations which have wide or continuous band width. There are two main types of reflectance in detecting and imaging the terrestrial environment. viz., (1) *"Specular"* and (2) *"Lambertain"*. The 'Specular reflection" or mirror reflection is the simplest, where the angle of incidence is equal to angle of reflection. All smooth surfaces and clear water will produce this type.

The "*Lambertain reflection*" is one in which the reflectance is uniformly diffused, that is, the reflected radiant flux is uniform and same in all directions. Most of the terrain features are detected and imaged only by this type, as they reflect the diffused light-mainly due to their surface conditions, colour and their absorbing capacities of the incident light. The general law of the incident angle being equal to the reflected angle does not hold good and instead "Lamberts cosine law" which states that the intensity of reflectance varies as the cosine of the reflecting angle is adopted here.

The "*Radiant Emission*" is a function of temperature of the materials or surface. All materials and objects having their temperature more than the absolute Zero (-273°C) emit electromagnetic energy proportional to their emissivity and absolute temperature to the 4th power This electromagnetic energy emitted can be recorded indirectly with a radiometer or transduced with a special detector and imaged through the use of an electro-mechanical scanner. Any terrestrial object or material can be mapped with infrared imaging system even in a total visual darkness, by this method. Any black body is a good absorbant but withincreasing temperature, it emits electromagnetic energy at all wave lengths; the wave length is inversely proportional to the temperature. As per stefan-Botzmann law. the total radiant emittence W -o-1[4] where W' is the radiant emittance in watt/cm. + [2] 0·1 is the stofan Bolzmann constant (5.6697 + 0.0029) 10^{-12} watts Cm^{-2} K^{-4} and 'T' is the temperature in Kelvin. The ratio between the radiant emittance of a particular material and that of a black body at a particular temperature is known as the "Radiant Absorptance of that material That is Ww='x' where 'W' is the radiant emittance of the materials, W is the radiant emittance of a black body and 'x' is the constant. This is called the kirchhoff's relation. From this, and from the Bolzmann law, it is shown that the Emissivity of any material at a given temperature is equal to its absorptance at the temperature. From all the above relations and laws, it is possible to determine the Emissivity of any opaque material by measuring its reflectivity. Also from the Botzmann law and others, selection of proper detectors, for imaging and mapping of a scene or object depending on, or in accordance with the detector sensitivity characteristics and the temperature of the scene or object is possible.

The *radiant energy transmission* is an important energy transfer with special reference to the topic as it relates to the optimum transmission of light in water of different specific gravity and density and also the transmission of ultraviolet, visible and infrared waves through the atmosphere. The transmission of the atmosphere is strongly dependent on the wave length of the radiant energy, particularly for the visible light (0.4 to 0.7 micron) photographic infrared waves (0.7 to 0.9 micron) and thermal infrared waves (3.5 to 5.5 micron). The transmittance is expressed as '=eox where 'T' is the transmittance, 'O' is the extinction co-efficient and 'x' is the length of travel by the transmitted wave. 'O' can be equated to the sum of the absorption and

scattering co-efficient, which also vary with the wave length. The attenuation of visible light in a distilled water is minimum for the blue-green region and any longer wave length energy in the red region of a spectrum will suffer severe attenuation. The graph below indicated the change in the relative illumination, with reference to the distance length of path, of the different coloured waves from a monochromatic source in distilled water with the barest minimum attenuation.

Graph:

In the usual photographic processes, scattering of light will be attributed to the size of the suspended particles in three ways viz., (1) particles smaller than wave length of light (2) particles ranging from 1/10 wave length to 10 wave lengths and (3) particles larger than 10 wave lengths. Air molecules are the predominant particle size in the first case where the scattering of light is inversely proportional to the 4th power of the wave length and hence this type of scattering makes the sky appear blue since the blue light is scattered about six times as strongly as the red light. This will be very clear during bright days. The second case is predominant when the particles in the atmosphere increase in size and the visibility decreases. Here, the scattered light tends to be in the blue range of the spectrum which will be well defined through any blue and particle size. The third case is a non-selective filters. This is due to the wide range of wave lengths and scattering of light of all wave lengths beyond the above two ranges. Due to this type of scattering, the clouds appear white, as the range of variation of wave lengths is still wider. Water vapour in the atmospheric air is the common cause for this scattering and there may be smoke and dust particles present in the air which will give more attenuation to the incident light. However, we can produce good and sharp photographs through colour infra red or black and white infarred photo films with the help of minus blue filters, even in dull or hazy conditions of the sky.

Certain photo films and Scanners.—Here, it is tried to enumerate some of the useful photo films and scanners which may be used in the multi band and precision mapping photographs and in the thermal imaging that are adopted as the remote sensing methods for the study of the river mechanics. (1) The kodak aero colour negative film 2445 (estar base) with aerial exposure index of 32, which is a colour film having three layers of emulsion sensitized to respond to the wave lengths corresponding to the blue, green and red ranges. and which can be processed to a colour or black infra red film 2443 (estar base) with serial exposure index 10, which also has three layers of emulsion, but sensitized to respond to the wave lengths corresponding to green, red and photographic infra red. This can be processed to a transparency for direct viewing and for direct contact print process. This colour infra red film processed to a transparency and viewed on a light table with a magnifying glass provides most useful data for river studies. As there may be a "false colour image" of the scene photographed, during the colour process, it is necessary that a minus blue filter, kodak wratten 12 is adopted for better and accurate outcome of the process (3) Minus-blue film, which is similar to the regular colour films, but it has got no emulsion layer of blue sensitiveness. This has more advantage over the cunvensional colour or colour infra red sarial firms; for clear water penetration, the time of exposure may be increased 2 to 3 times over that for the terrain, as the depth of water that will be penetrated and recorded will be more than 150', while the shutter speed for the exposure of film is about four times than that for the others This needs no filter, gives improved image and its processing and drying times are about 20 per cent less than any conventional three layer film. (4) the kodak Tri-x aerographic film 2403 (estar base) which is a black and white-ve film with aerial exposure index 250, is very much useful for mapping and other phtogrammetric applications under minimum light levels. (5) The Kodak infra red aerographic film 2424 (estar base) with an aerial exposure index 100, with a yellow or red filter is also a black and white infra red film which can be adopted for river studies instead of the colour infra red film. This film being sensitive over a broad range wave lengths from 0.4 to 0.9 micron, this can be adopted for producing photos in discrete bands of blue, green, red and photographic infra red with different interference filters in conjunction with the infra red blocking filters.

In general, all the above films can be processed to prints and viewed in stereo pairs with a mirror stereoscope, to derive sufficient informations of a river system with the help of magnifying glass like a large size reading glass. The stereo effect produced in the prints helps in justifying the relative depths of clear water stretches and the study of intricate details of the submerged bars and other bed forms.

The line scanners are electro-mechanical devices with reflective optical principles, used in the thermal infra red imagery for imaging the emitted infra-red radiation. These devices over come the practical difficulties of keeping the photo cameras with the emulsion films in the absolute zero (-273 cc) to a void emission of thermal infra red energy by the cameras themselves, if they are used for the study. The output from these scanners will be in the form of black and white film or magnetic tape. A simple scanner operation diagram is shown below.

Proper interpretation of the therma infra red line scanner imagery may be done with the black and white film prints, or by enhancing the colours to show the discrete film-density stages corresponding to the temperature differences in the scene, or any digital or Anologue computer processes may be employed to print out an iso-thermal map, which will be more accurate.

Identification and Interpretation of the results.—The main object of the study by the above said remote sensing methods is to identify and determine the flow dimensions or variables and the very characteristics of the river flow very accurately and quickly without adopting the conventional methods, which will be laborious and voluminous. Various informations may be obtained by the multiband photography, precision mapping camera photography and the thermal, infra red imagery methods either by any one of these systems or by any combination. Generally the photographic processes need good light conditions, without clouds and the thermal infra red imagery can be collected either day or night. In practice, the precision mapping camera with colour infra red film may be very useful for the river studies; but the thermal properties of the surface of the water, ground and the ground cover, etc. can only be determined by the thermal infra red line scanner. Any how, an operation of these two systems simultaneously will be an outstanding accurate process even in a wave-length range of 8 microns to 14 microns.

The different variable of any river system that can be identified and interpreted are, the breadth, depth, meander pattern, sediment nature and concentration, undulations in the river bed, mixing processes of two rivers or channels, presence of foam and debris at the water surface, temperature variation of the water surface, for purposes of coolant water-supply, wakes and vortices, river pollutions, nature of ground cover of river banks for its stability study, flood damages, ground water table and see-pages from any impoundments, etc. The proper identification and interpretation of some of these variables are as below. The operation of the remote sensing systems from an Aircraft platform gives a record of the total operation or working system of any river or water-supply complex after the usual processes and developments by the method of photography. Operation of spillways, Intake structures, Canals, etc. Can be effectively monitored by suing the appropriately selected high resolution films and imagery and with frequent sequential flights over the scene, by which even water management and maintenance of an irrigation system may be determined. The depth of any flowing river or stream may be achieved by using colour infra red and minus-blue photography and processing them to a + Ve transparency (that is viewed on a light table with a reading glass.) Here, the whole L.S. and C.S. had formation pools and crossings in a flow path may be plotted the accuracy being dependent on the scale of the photographs. If necessary appropriate measuring device such as a "Comparator" may be used to measure the variables from the photographs. The demarcation of the different layers of undulations in the bed of o river or any changes in the density of the path travelled by the radiant waves in general will be indicated by the tone change on the colour infra red film, which will vary as dark blue for clear waters to very light blue for any turbid water according to the concentration of suspended materials. Sometimes, due to the false colour image of the scene, green will appear blue, red will appear green and infra red will appear red, which shall be carefully identified. Thus, any distinctive tone change in the photo prints may be used to monitor and measure the required results, viz. the source of sediment, transport process, deposition location, etc., of a river system and the mixing proceeds of a tributory with a main river. The colour infra red film can also enhance presence of foam and floating debris by which the discreate flow path and directions may be identified. The vegetal cover type and extent on and along a river bank or bed, islands and soil moisture, etc., can also be identified by the same tone differences and colour identification. Any land classification over a flood plain, water table fluctuations under water plains and weeds can be identified and interpreted with the colour infra red film. When more defined and clear prints are necessary the appropriate film filters and detectors are to be used with the film.

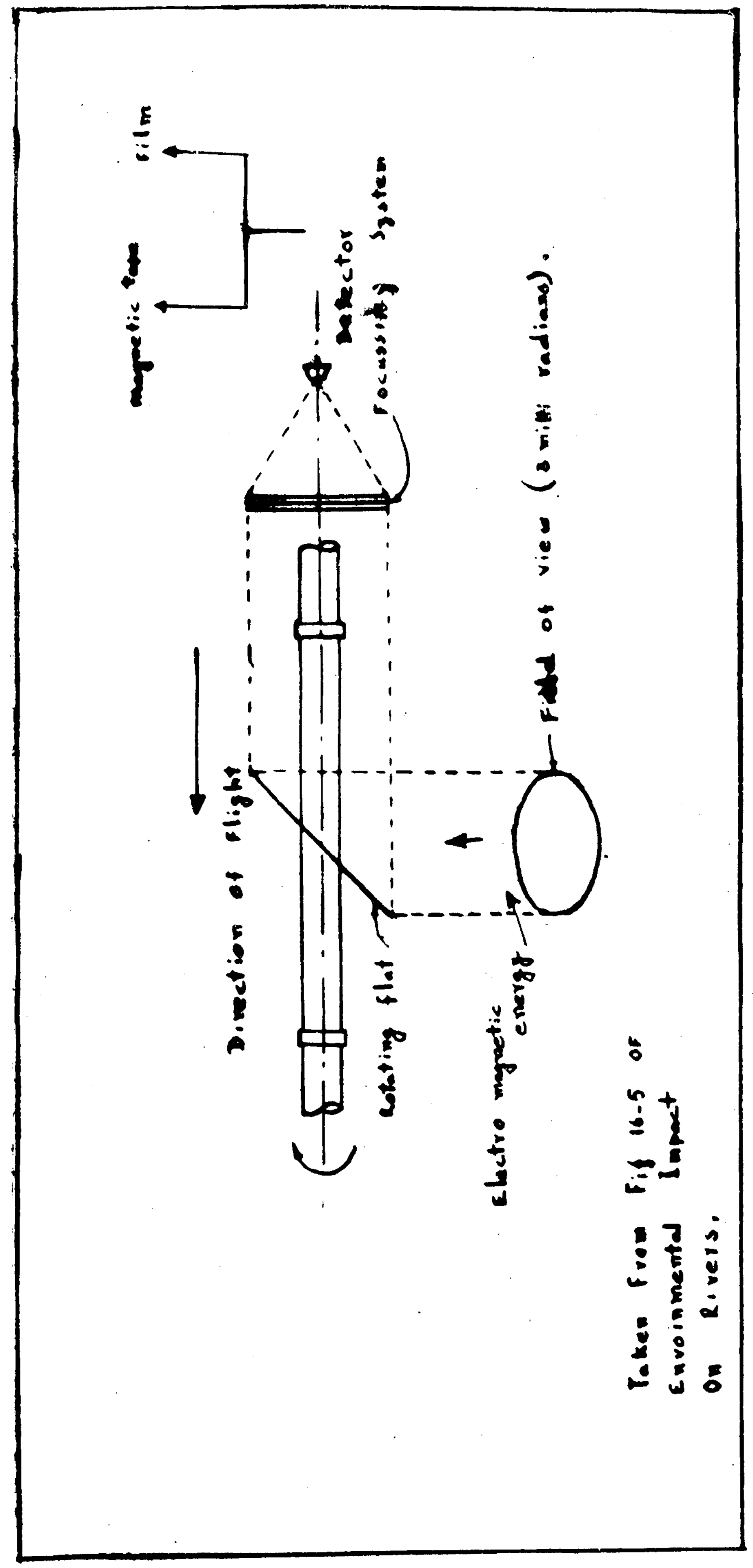
Like-wise, a thermal infra red line scanner can be operated in a range of 3.5 micron to 5.5 micron in which both the sun's reflected energy as well as the objects emitted energy may occur, but due to the specular reflection of sun light during the day time, there may be certain undesirable hot spots in the imagery and hence, during day time flights, only the range of 8 to 14 micron wave length band should be used. However, the reflected and emitted portions of the spectrum in the 3.5 to 5.5 micron band is quite useful, if careful interpretation is made. As regards to the emitted energy through the line scanner it is to be reminded that the thermal infra red scanner records the emitted energy only from the top layer of the water surface or ground and hence no appreciable penetration occurs. Hence, this system can well be adopted for studying the relative temperature gradients between different stages of flow which, is related to the study of coolant water and thermal effluents mixing into a river flow.

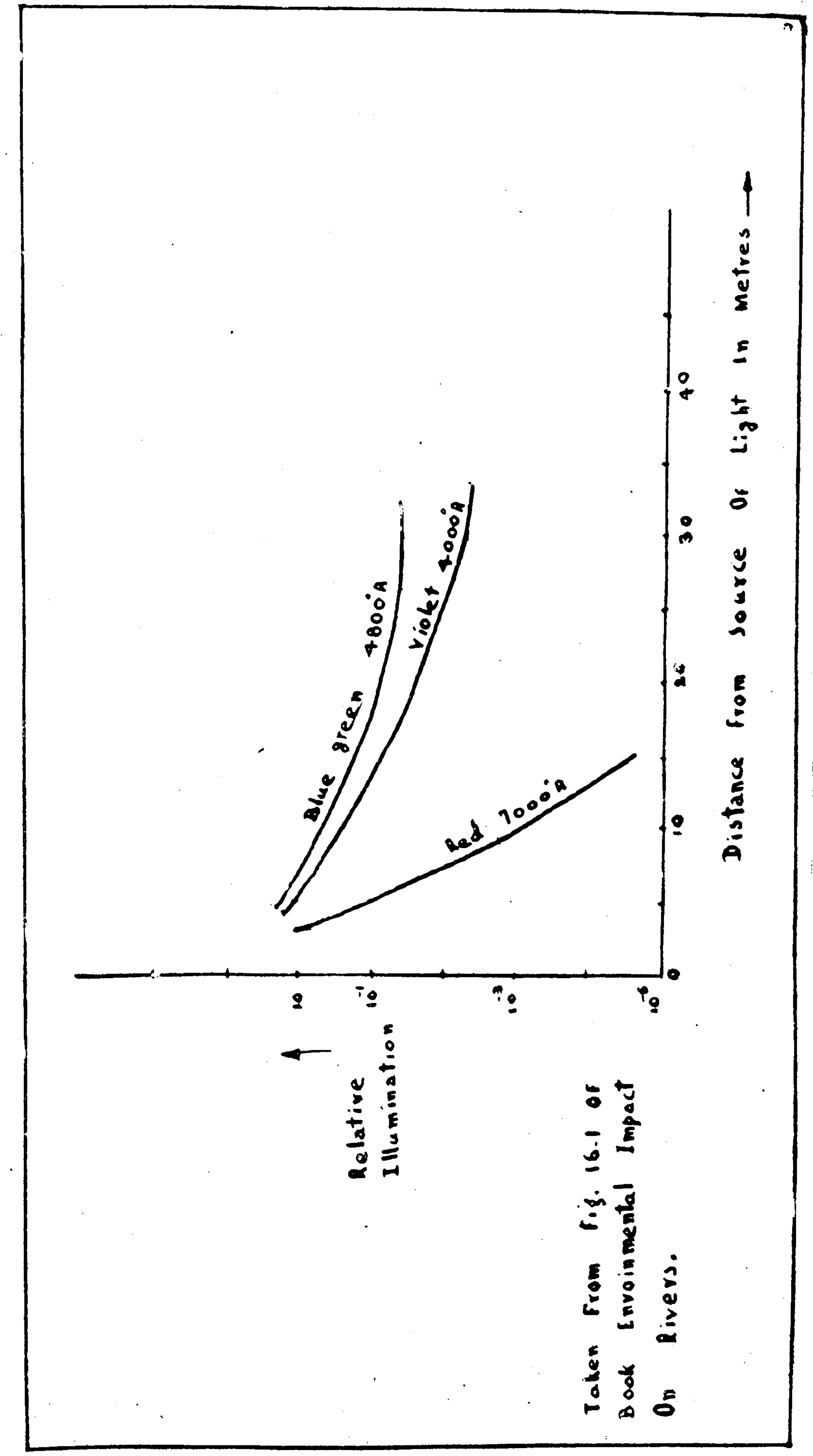
Finally, to end with, it is suggested that any hydraulices Engineer needs a through knowledge over these remote sensing systems in these days of well advanced science and technology, to adopt the same in his doings for better, accurate and quick results. Such of these implementations shall serve as a set of precision tools to Engineer even for exhibiting his talency, advancements and achievements.

Reference books—

1. A text book of Engineering physics—by R.C. Handa.

2. Environmental impact on Rivers by H.W. Shen.





Taken From Fig. 16.1 of Book Envoirnmental Impact On Rivers.

Aerial Photo Interpretation.

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1. AERIAL PHOTOGRAPHY.

1.1. *Definition.*—Aerial photography is defined as the science of making photographs from air for studying the surface of the earth. The main advantage of Aerial photography is the pictorial and faithful representation of the terrain at the time of photography.

1.2. *Utility.*—All studies of natural resources basically involve qualitative examination of the terrain, the correct correlation of the observed data and finally the evaluation of the data. The orthodox methods involve detailed study of the terrain with its attendant handicaps but modern techniques of investigation make full use of the immense wealth of information which is recorded in an Aerial photograph and thus not only economise and expedite the investigation but also offer more reliable results. The Aerial photograph offers possibilities of detailed study of the terrain and its culture suited to the needs of the investigator—i.e. Engineer, Geologist, Soil Scientist, Forester, etc. The only stipulation is that the specialist must know what he is looking for and how the information which he is seeking appears in the Aerial photograph.

1.3. *Basic Information and Specifications.*—The basic considerations for Aerial photography are as given below:

1. Area to be photographed.
2. Purpose of photography.
3. Scale of photography.
4. Aerial Camera and lens.
5. Flight direction.
6. Time and season of photography.

1.4. *Types of Photographs.*—Photographs can be grouped into different types depending upon the various factors.

1.4.1. *Depending upon the Type of Lens.*—The lens used in the camera can be classified into four groups based on the angle of convergence (angle of coverage) of the lens.

1. Narrow angle — Angle of coverage. $<60°$
2. Normal angle — Angle of coverage $>60°$ $<75°$
3. Wide angle — Angle of coverage. $>75°$ $<100°$
4. Super wide angle — Angle of coverage. $>100°$

The photographs taken using the above lenses are also classified accordingly.

1.4.2. *Depending upon the Camera Axis.*—Photographs which are used for mapping and photo interpretation can be divided into the following main classes according to the direction of Camera axis (*vide* figure-1).

1. Vertical photographs (Nearly vertical).
2. Horizontal photographs.
3. Oblique photographs—
   (*a*) Low oblique (*b*) High oblique.

1.4.3. *Depending upon the Colour of Photography.*—

1. Panchromatic (Black and White) photographs.
2. Colour photographs.
3. Infra red photographs.

1.4.3.1. *Panchromatic Photograph.*—Panchromatic photograph is the normal black and white photograph and it is widely used. Other photographs like colour photograph or infra red photograph are used only on special occasions.

1.4.3.2. *Infra red Photograph.*—For infra red photography, the aerial film emulsion should have infra red sensitivity. In this photography, the vegetation will appear brighter (due to the chlorophyll effect) whereas water and soil will appear as black. The haze penetration of infra red film is superior to that of Panchromatic film. Infra red photograph is particularly good for detection of springs and seeps. It has the following disadvantages:—

(i) Completely different terrain impression.

(ii) Special training is required to identify the objects.

(iii) The photographs are less durable and have storage problems.

1.4.3.3. *Colour Photographs.*—Colour photographs convey no more information than a good black and white photograph and sometimes even less. The aim of the colour photography is to get a faithful reproduction of the colours of the scene. There are special applications where colour photographs are very valuable to interpretation.

1. The geological mapping confined to localised areas.

2. In geochemical and geobotanical studies, where the probability of colour significance is high.

3. In forestry studies, to decide the location of disease striken areas.

4. In detailed land use studies, to study the difference in growth pattern.

5. In river, harbour and coastal studies.

6. In certain military studies.

2. PHOTOGRAMMETRY.

Photogrammetry is a complex Science with many Sub-divisions that utilise the principles of geometry, mathematics, optics and physics to obtain reliable details concerning the confirmation of the earth. It is concerned with the quantitative characteristics of the terrain, such as elevations, distances and contours.

2.1. *Scale of Photography.*—The scale of photograph is a ratio of distance on a photograph to its corresponding distance on the ground. The scale of photograph varies from point to point due to displacements caused by relief and tilt but is usually taken as f/H where f = principal distance of the camera and H = height of the camera above mean ground elevation.

$$\text{Photo Scale} = \frac{a'\ b'}{ab} = \frac{f}{H} \ (\textit{vide}\ \text{Figure-2}).$$

The scale of photograph is not constant due to the following two major factors.

(i) Scale variation caused by relief.

(ii) Scale variation due to Tip and tilt.

2.2. *Scale Variations due to Relief.*—Let 'S' be the camera station from which a truely vertical photograph is taken (vide Figure-3). If the point P 1 has no elevation, it will appear in photograph at P 1. If it has an elevation 'h', then its top P 2 appear at P'' i.e. the image will appear displaced by P' P''. This is known as Relief displacement. It can be shown that its magnitude is equal to N' P'' H/h. The images of the ground points with greater elevations will be displaced outward from the centre point N' of photograph. Conversely, ground points lying below a selected datum plane are displaced radially inward. The relief displacement can be eliminated by the equipment namely Orthophotoscope.

2.3. *Scale Variation Due to Tip and Tilt.*—Tilt is defined as the inclination of the camera axis with reference to the normal to the direction of flight. Tip is the inclination of the camera with reference to the wings of the Airplane. The Figure 4 shows the variations that occur in scale and in the shape of the land area due to Tip and Tilt.

2.4. *Stereoscopic Vision.*—A pair of photographs taken from the two camera stations but covering some common area, constitutes a stereoscopic pair which when viewed in a certain manner given an impression as a three dimensional model of the common area is being seen (*vide* Figure-5).

In order to obtain the stereoscopic effect, it is necessary to regulate the frequency at which aerial exposures are made so that each picture over laps the previous one by 60 per cent. Thus each object on the ground will appear on atleast two consecutive photographs and will be seen in three dimensions when the two pictures are viewed stereoscopically. In order to view the photographs stereoscopically, the consecutive photographs should be superimposed and at the same time, the images of photograph should be seperated such that left eye sees the left hand photograph and the right eye sees the right hand photograph. If the left eye sees the right side photograph and the right eye sees the left side photograph then the elevation will be seen as depression and vise versa. This is konwn as 'PSEUDOSCOPY'.

2.5. *Requirements for Stereoscopic Photographs.*—

1. The camera axis should be approximately in one plane

2. The base height ratio $\frac{B}{H}$ (B = Air Base; H = Height of the camera above mean ground elevation) must be an appropriate value i.e. between 0.02 to 2.00.

3. The scale of photography must be the same.

4. Each photograph should be viewed by one eye only.

5. The brightness of both the photographs must be the same.

2.6. *Equipments used for Steroscope Vision:*— 2.6.1. *Pocket Stereoscope.*—The pocket stereoscope has two piano convex lenses with upper side flat and with a focal length of 100 mm. While viewing through the pocket stereoscope the rays entering the eyes are parallel and converge at infinity and have been accomodated at (focussed at) 100mm. distance (vide Figure-6). Since the normal viewing distance is 250 mm. a closer viewi.e. at 100 mm result in magnification. The magnification is then $\frac{250}{100}$ 2.5. The pocket stero scope is cheap, transportable and has a large field of view. The image quality is also good.

2.6.2. *Mirror Stereoscope.*—Mirror stereoscopes are designed so that the images of the photographs being studied are reflected into the mirror and prism system (*vide* Figure-7). After reflected upto the body of the instrument, the images are brought into position so that they can be studied through binocular like eye pieces which are adjustable both for focus and for varying the eye base.

The main advantage of mirror stereoscope is the field of view is more. By attaching the lenses. the magnification also can be obtained. The photographs can be seperated wide apart i.e. 240 mm. Hence marking can be done easily while viewing stereoscopically.

2.7. *Measurement of Height Difference from Photographs.*—The feasibility of finding height differences of objects from aerial photographs is the most important quality of photograph. This is achieved by measuring parallaxes on the photographs.

2.7.1. *Parallax.*—The term parallax is applied to the apparent change in position of an object caused by change in position of the observer.

It is equal to the algebric difference of the projection, on the base line of intercepts joining the principal points on each of the two photographs forming a stereoscopic pair, to the corresponding images of the point under consideration. From refering to Figure-8,

$$\text{x Parallax for } A = P_{Ax} = x_1 + x_2 = \frac{Bf}{Z_A} = \frac{Bf}{H-h_a}$$

$$\text{y Parallax for } A = P_{Ay} = y_1 - y_2$$

Normally if photographs are without tilt and if flying heights has also not changed between two consecutive exposures, the resulting stereoscopic pair does not have any parallax.

The parallax difference between the two points A and B can be worked out as follows:—

$$\text{Parallax difference} = \Delta P = P_B - P_A$$

$$= \frac{Bf}{Z_B} - \frac{Bf}{Z_A};$$

Assuming the point A is located at mean ground level i.e.

ZA = H and ZA—ZB = Δh (Eleation difference between points A and B).

This Can be simplified as

$$\Delta P = \frac{Bf}{H} \left\{ \frac{\Delta h}{H - \Delta h} \right\} = b \left\{ \frac{\Delta h}{H - \Delta h} \right\}$$

H

b = photo bas i.e., distance between principal points in photograph.

$$\Delta h = \frac{H}{b - \Delta P} \Delta P$$

2.7.2. *Floating Marks.*—If the two marks are on the corresponding points on a stereopair of photographs, they are seen as one mark on the ground. If one mark is then shifted inwards or outwards it is seen to float over or under the ground respectively. Such marke are named as floating marks. Human eyes are very sensitive in assessing whether the mark is on the ground or not. The above principle is used for the measurement of parallax diffence. The instrument used to the measure the relative heights using the above principle is named as parallax bar.

2.7.3. *Parallax Bar.*—A parallax bar consists of two glasses engraved with measuring marks connected by a bar whose length can be changed by a micrometer screw (vide Figure-9).

The micrometer is numbered increasingly as distance between the corresponding points is decreasing.

Parallax for A = P_A = $a_1 + a$

Parallax bar measurement for A = P'_A = $x - P_A$ = A' A''

Similarly P'_B = $x - P_B$ = B' B''

$$\therefore \Delta P = P'_A - P'_B = (x - P_A) - (x - P_B) = P'_B - P'_A = -\Delta P$$

$$\Delta h = \frac{H.(\Delta p)}{b - \Delta p} = \frac{H(-\Delta P)}{b - (-\Delta P)} = \frac{-H.\Delta P}{b + \Delta P}$$

Where H Height of photography

b photo base ie distance between principal points.

2.8. *Steroscopic Exaggeration.*—The three dimensional model obtained by the stereoscopic study of the Aerial photographs is seldom an accurate reproduction of the terrain. In most cases, the relief appears more severee than it actually is in nature. This is produced when the vertical scale of the model exceeds the horizontal scale and this is named as VERTICAL EXAGGERATION (vide Figure-10).

2.8.1. *Factors Affecting Vertical Exaggeration.*—When a ground feature is photographed from two any stations as in figure 10, there is a fixed ratio between camera height H and air base B. It it is possible to view the two photographs in such a way that the same ratio is maintained, a true geometrically similar three diamentional model of the terrain would be seen. But in practice, this could not be achieved due to limitation in eye base, and the viewing distance.

Vertical exaggeration is not constant in all cases but it varies.

(1) Directly with air base 'B' (inversely with overlap).

(2) Inversely with Camera focal length 'f'.

(3) Inversely with Camera height H.

(4) Directly with viewing distanced.

(5) Directly with photographic Seperation S.

(6) Inversely with eye base E.

$$\textbf{Vertical Exaggeration factor} \sim \frac{Bds}{fHE}$$

Vertical exaggeration is extremely important when one must estimate slopes, dips, strata thickness, fault displacement, etc. At the present time, numerous individuals, companies and Government agencies are conducting exhaustive tests and experiments in the study of vertical exaggeration; unfortunately many valuable findings are still confidential and therefore not available.

2.8.2. *Estimation of Slopes.*—As the stereoscopic exaggeration is a difficult quantity to determine, the estimation of slope is also very difficult to ascertain from the visual observation of stereopair. However, the slopes can be correctly determined graphically or using 'Stereo slope Comparator' or 'I T.C. slope finder'.

2.9. *Model Deformation.*—The model deformation is generally used to designate an unnatural and apparent change of shape while viewing through the stereoscope. We are able to see a deformed model due to following reasons:—

1. Theoretically, the photographs are central projection. In actual practice, the lens system introduces distortion.

2. The air base B is not exactly horizontal.

3. The camera axis is not exactly vertical at the time of exposures.

4. The paper on which prints are taken is not generally stable.

5. The two photographs of a stereo model are seldom in their relative position with respect to each other.

Under the above circumstances, a model of flat ground would appear warped depending upon the degree of deformation. The model deformation will not affect the stereoscopic view, but, while preparation of scaled maps from photographs, this deformation should be eliminated. There are certain instruments for eliminating the deformation and for the preparation of scaled maps.

2.10. *Preparation of Mosaics.*—Maps showing the results of natural resources surveys belong to a group of thematic maps or special maps. The data represented on such maps are generally more of a qualitative nature than of a geometrical, quantitative nature. Hence to prepare such maps from photographs, first, we have to prepare mosaic—an assembly of aerial photographs so as to form a continuous photographic representation of a portion of the earth's surface. Three different types of mosaics can be prepared.

2.10.1. *Uncontrolled Mosaics.*—Uncontrolled mosaic is a compilation of photographs without regard to any horizontal control. The alternate photographs are oriented in position by matching corresponding images on adjacent photographs. It is a photo assembly without any strict scale or size relation and it cannot be used for measurements. Relief displacement which is inevitable with photographs of mountainous terrain make this procedure very difficult. Hence this is recommended for flat terrain only.

2.10.2. *Semi-Controlled Mosaics.*—If the terrain is not flat, it will be desirable to make some kind of semi controlled mosaic when no control is available and there is urgent requirement of mosaic or where the accuracy requirements do not demand a more precise control. In semi-controlled mosaic, the principal point and the line joining the principal points of each individual photograph against its neighbour is used for fixing the position of photographs.

2.10.3. *Controlled Mosaics.*—Controlled mosaic is a compilation of scale and rectified photographs which have been assembled to fit in the plotted control points. It is the most accurate form of mosaics. The fully controlled mosiac is obtained when it is possible to carry out a normal slotted templet layout with photographs of reasonally flat terrain.

2.11 *Preparation of Maps.*—2.11.1 *Line Maps.*—As soon as a mosaic is prepared, it is anotated, i.e., special features such as roads, railway lines, boundaries, etc., are marked. The *line maps* can be prepared, by simply tracing these details from the mosaic. The accuracy of the traced map will be that of Mosaic.

2.11.2. *Planimetric Maps.*—Planimetric maps can be compiled from aerial photographs by 'Arundel method' or by Radial line plotter. Sketch master, (vide Figure 11) Stereosketch Master and Radial line plotter are some of the instrument used for the preparation of planimetric maps.

2.11.3. *Standard Topographic maps.*—Standard topographic maps can be prepared from aerial photographs using Stereopret, Stereotope, Stereomicrometer, Stereo plaingraph, etc.

3. PHOTO-INTERPRETATION.

3.1. *Introduction.*—Photo-Interpretation has been defined as the act of identifying objects in photography and determining their significance. As soon as a problem is selected for analysis by photo interpretation, it is helpful to think ahead to determine what Critical images will be helpful in the analysis of the problem and what these critical images might look like.

3.2. *Image Identification Criteria.*—1. *Size.*—How large (considering photo scale) should critical images be and how large are the images that have been detected?

2. *Shape.*—What shape should critical i mages have viewed from the above and what is the shape of the images that have been detected?

3. *Shadow.*—What is the profile shape of the critical images? Whether the shadows of the detected images have the proper shape?

4. *Tone.*—In black and white photography used, if the objects reflected more light, they would appear lighter than their back ground. If they reflected less light they would appear darker.

5. *Texture.*—The appearance of the image in photograph whether mottled tonal appearance or rough surface appearance?

6. *Location.*—The location of the image with reference to the topography.

7. *Relationship with the Surrounding Object.*—Images often can be identified and their significance determined by the company they keep.

3.3 *Elements of Air Photo Pattern.*—The complete air photo pattern comprises of the total arrangement of all natural and man made features appearing on the photograph of the area being analysed. The elements of pattern are individual land scape features and collection of such features that compose the complete picture. They are:

1. Origin, Land form and rock type.

2. Surface drainage pattern.

3. Erosion features.

4. Photographic grey tones.

5. Vegetative Features.

6. Cultural features.

7. Natural slope.

8. Characteristic boundaries.

9. Covergence of evidence.

3.3.1. ***Origin Land Form and Rock Type.***—The various origin, rock types and land form directly reflect the characteristics of the materials with which they are associated. In case of geologists, once the origin, land-form and rock type of a given area has been established a large proportion of the interpretation is completed and remainder will follow with comparative ease.

3.3.2. *Drainage Pattern.*—Analysis of drainage pattern helps one to understand the dip and strike of the basic bed rock structure, and of the fault and fracture pattern that exist in it. They also show the resistance of the soil to weathering and erosion.

Six basic drainage patterns are the following:—

(i) Dendritic (branching like a tree).

(ii) Trellis.

(iii) Radial.

(iv) Parallel.

(v) Annular.

(vi) Rectangular.

3.3.2.1. ***Dendritic Form.*—The dendritic form (vide Figure 12) is by far most common. Note that tributory branches join the next lower order systems at approximately the same angle. There are few, if any, abrubt bends in stream channels. Dendritic stream forms are so universal that if the basic form in any area is not dentritic, earth structure or land form conditions are unusual and probably warrant further study.**

3.3.2.2. *Trellis form.*—**The trellis form (vide Figure 13) resembles a vine on a garden Trellis. Primary tributories are long and straight. They are often parallel to the main channel and to each other. Many short tributories may join the longer channel at approximately right angles. The trellis form evolves in areas where the bed rock is sharply folded. The long parallel tributories follow the less resistance layers in the bedding. The short stubby tributories flow down the sides of the more resistant upturned beds. The trellis form is controlled by the structure of the rock.**

3.3.2.3. *Radial Form.*—**Radial drainage pattern (vide Figure 14) will develop primarily under topographic influence. The radial form can be either centrifugal or centripetal. Centrifugal (outward flowing) drainage indicate doming isolated hill, volcano, and similar land forms. Centripetal (inward flowing) drainage indicates subsidence and basin formation.**

3.3.2.4. *Parallel Form.*—**Parallel drainige pattern (vide Figure 15) consist of higher order streams whose lower order tributories flow parallel with them. They can form in tilted rocks with parallel faults or as a result of pronounced regional slope.**

3.3.2.5. ***Annular Form.*—Annular draiage pattern (vide Figure 16) are ring-like tributories that intercept radial streams. They indicate doming especially where intruded bodies have broken through bedded sedimentary rock. This form is controlled by the shape of the topography and the altitude of the bed rock.**

3.3.2.6. *Rectangular Form.*—Rectangular drainage pattern (vide Figure 17) forms are influenced by joint patterns. Streams join together at right angles. Rectanguar patterns are affected locally by the differences in composition of horizontal bedding.

3.3.3. *Erosion Features.*—**There are numerous types of erosion features. Most of these can not only be discerned on aerial photographs but also have a greater or lesser significance to the accumulation of accurate qualitative terrain data. Erosion features may be divided according to the process in which they are formed.**

(1) By water action (rills, gullies).

(2) By wind action (blow outs, yardangs).

(3) By glacial action (grooves).

(4) By mass wastage (land slides).

(5) By thermal action (polygons).

Of all the above features, gullies are considered as the most indicative, the most widely distributed and the most important to the interpreter. Gullies often reveal that significant bit of information which allows a correct interpretation to be made of soil texture, depth satisfication and profile. By analysing the dimensions of the gullies[length, width and depth and the shape of the gullies (cross section and plan)] the age of the gully, the hydrological details responsible for its formation and the characteristics of the materials in which it is formed can be determined.

3.3.4. *Grey Tones.*—**Grey tones may be defined as any density or shade between and including absolute white and absolute black that is registered by the terrain on an exposed aerial photo. Grey tones are of great value in corrcborating the interpretative conculsions reached through an examination of land form, drainage and erosion. They are of particular value in estimating variation in soil moisture content, differnces in surficial soil organic content, general soil texture, general soil porosity and boundaries between areas of different soil and rock bodies.**

3.3.5. *Vegetative Features.*—**Vegetative features and pattern refer to the complete vegetative complex as it is developed upon the land. Vegetation is frequently a clear indicator of the hydrological environment. From the composition and distribution of plant species it is possible to determine the depth of occurance of ground water, degree of mineralisation,** place of charging and discharge of water bearing horisons and the directions of their movement. Tugai, Licorice, Haloxylon plants are some of the plants which will indicate the ground water conditions. A general knowledge of Botany, Ecology and Forestry is desirable for the effective interpretation.

3.3.6. *Cultural Features.*—A proper interpretations of cultural features and pattern will provide selective and general qualitative terrain information of a practical nature and will also give a better understanding of those portions which are reflections of tradition, ingenity or climate rather than terrain condition.

3.3.7. *Natural Slope.*—The slopes of materials in their natural angle of repose or their temporary state of stability often have great significance in interpreting predominal textures, extent and type of satification, etc. Particularly in the case of gully cross section, the natural slope of sides will give the type of soil and their characteristics.

3.3.8. *Characteristic Boundaries.—Characteristic* boundaries may be defined as one having the habitual typical aspect that is intimately related to the physical characteristics or formation of the natural materials on one or both sides of the boundary—Characteristic boundaries may be of a topographic nature or a tonal nature or a combination of both.

3.3.9. *Convergence of Evidence.*—The pattern displayed by each of the elements, land form, rock type, surface drainage pattern, erosion features, grey tones, vegetation, culture, etc., was evaluvated individually. Finally the indicative weight of each element was compared with that of all others and a conclusion was formed upon the basis of convergence of evidence.

3.4. *Qualifications for an Interpretor*—3.4.1. *Knowledge.*—An interpretor must have knowledge in Geological Sciences, Petrology, Structural Geology, Geomorphology, Sedimentation, Soil Sciences. Soil Mechanics, Hydrology and Meteorological Science, Enginnering, Geography, etc., along with Aerial photo interpretation.

3.4.2. *Photo Experience.*—An interpretor must have enough photo experience to evaluate air photo patterns of similar land forms as they develop in different climatic regions and its response to variation in local factors.

3.4.3. *Field experience.*—An interpretor must have filed experience also in order to correlate the repetitive photo details with actual significant field details.

3.4.4. *Professional experience.*—A certain amount of practical or working knowledge in the field of Engineering, geology, forestry or soils as the case may be, for which interpretation is conducted is also necessary.

3.5. *Photo Interpretation Process.*—(1) Scanning the photographs and collection of data.

(2) Preinterpretation of data.

(3) Field check.

(4) Post interpretation.

(5) Preparation of maps and report.

3.6. *Application to engineering.*—Aerial photo interpretation technique provides a means for the rapid, economical and dependable evaluation of ground conditions that are usually completely investigated by field survey. As a result, optimum conditions may be selected early in an engineering problem, while difficulties can be avaluated in advance of actual planning and field work. The various applications of Aerial photographic techniques to Engineering are as given below:—

1. Route location (highways, railways, conduits, canals communication lines).

2. Site location (Airports, Towns, Industries, Dams, Military installation).

3. Materials location (gravel, sand boulders, clay, rock, etc.).

4. Water resources studies (Ground water, infiltration run off, etc.).

5. Water utilisation and water regulation studies (Water supply, hydro-electricity, navigation, flood control drainage, etc).

6. Coastal and Harbour studies.

7. Special studies (land slide studies, planning of field investigation, Town Planning, etc.).

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By Victor C. Miller.	80
2. 'Aerial Discovery Manual'	46
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7. 'Air photography applied to surveying'	46
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'Earth satalites and their application in hydrometry and hydrology'	
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11. Report on—	
(a) 'Preliminary Engineering Soil Classification by Photo Interpretaton Techniques'.	64
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By R. Jayapragasam.	
12. 'Hand Book of Aerial mapping and Photogrammetry'	46
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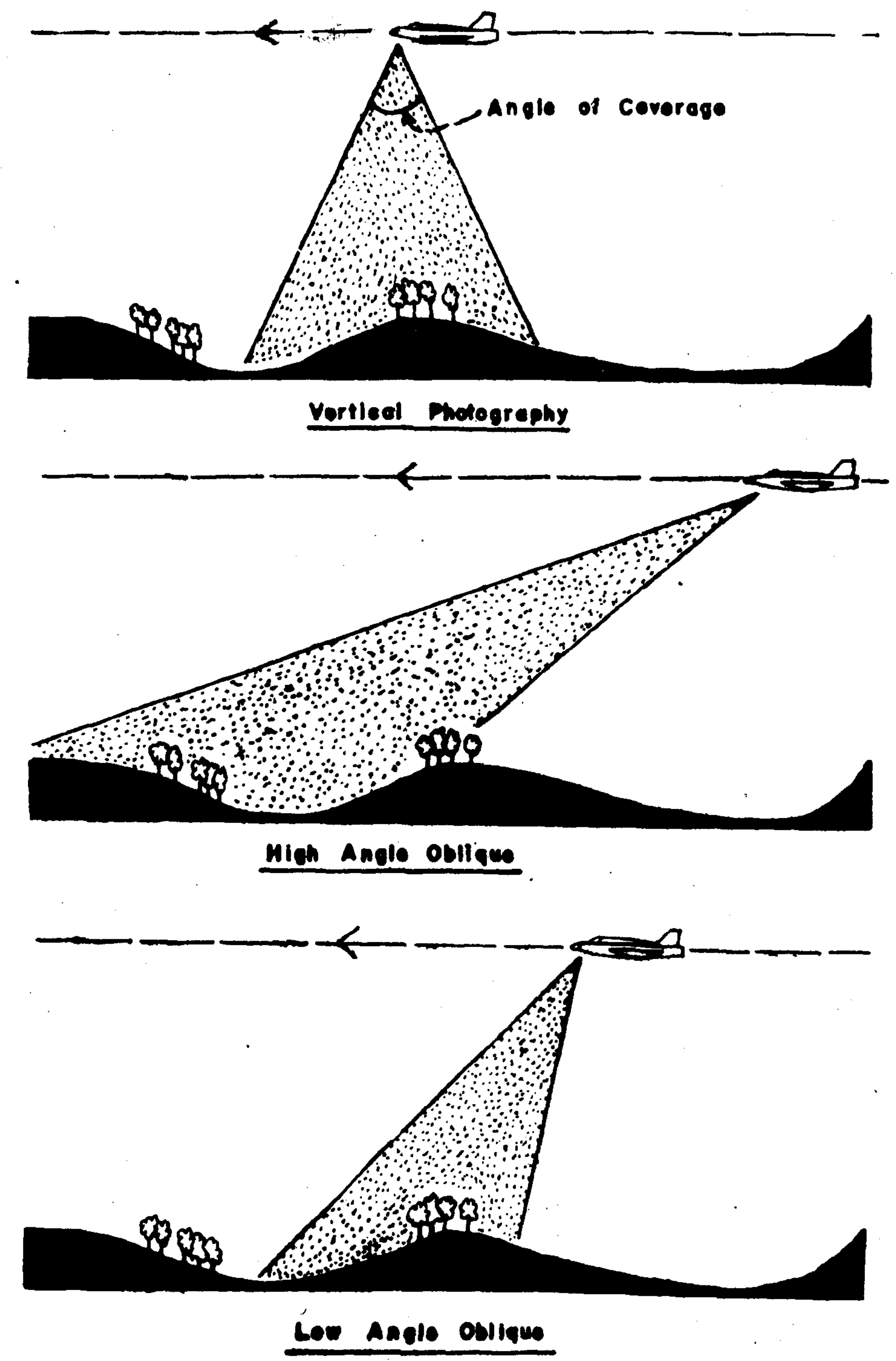


Fig. 1. Types of Photographs based on Camera Axis

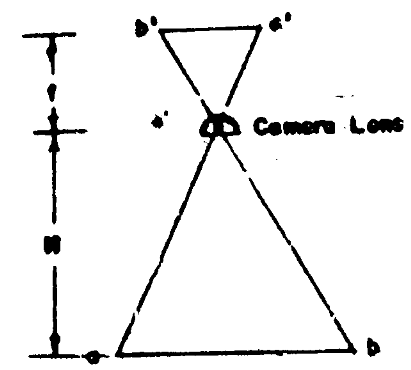
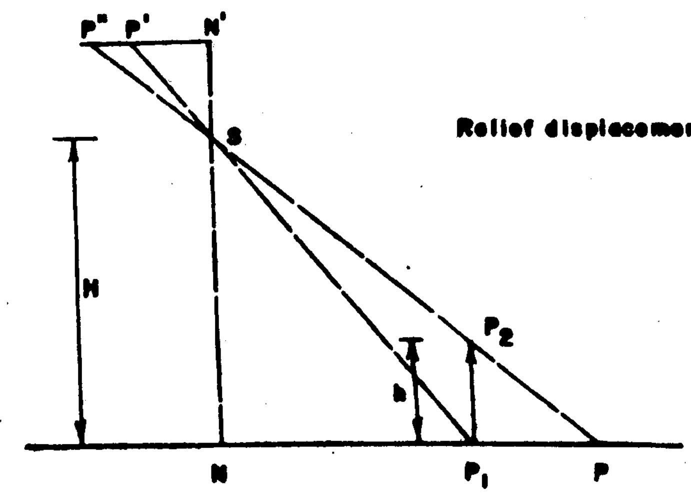


Photo Scale $= \frac{a'b'}{ab} = \frac{f}{H}$

f = Principal distance of Camera.

H = Flying height above mean ground elevation.

Fig. 2. Scale of Photograph



Relief displacement $= P'P'' = N'P'' \times \frac{h}{H}$

Fig. 3. Relief Displacement

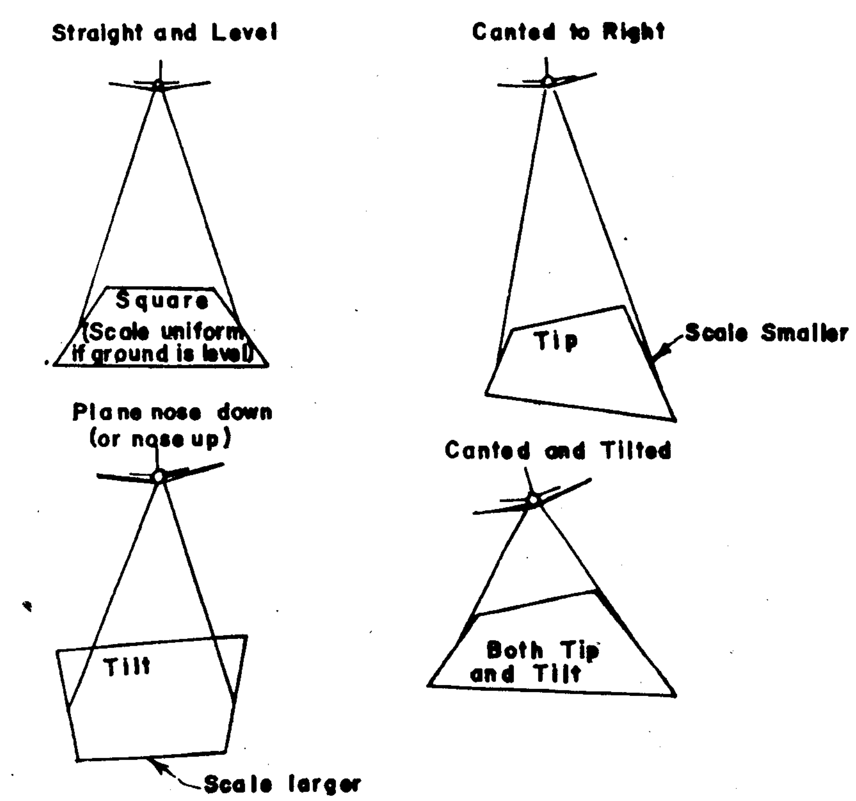


Fig. 4. Scale Variation due to Tip and Tilt

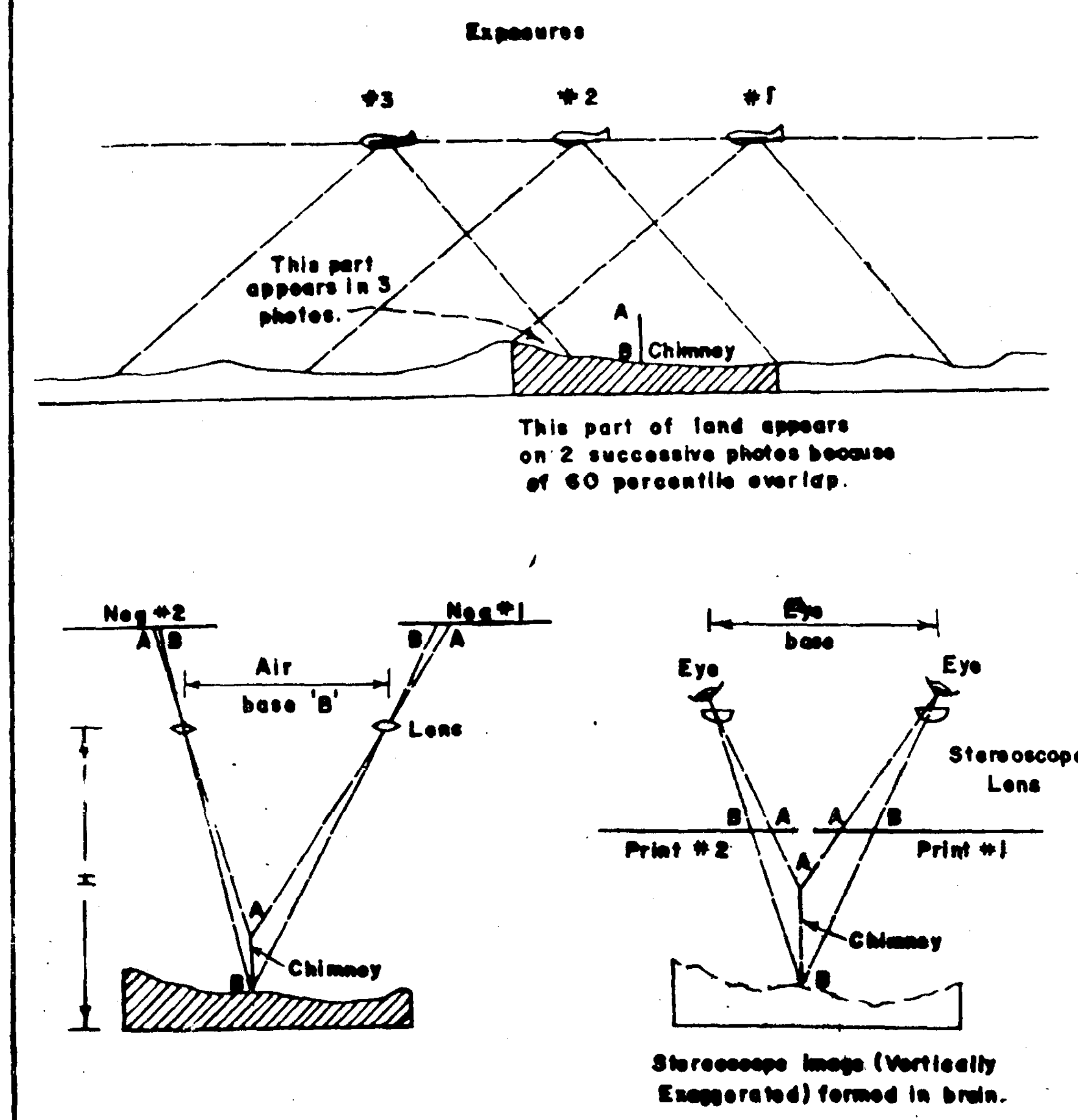


Fig. 5. The Process of Stereophotography and Stereoviewing.

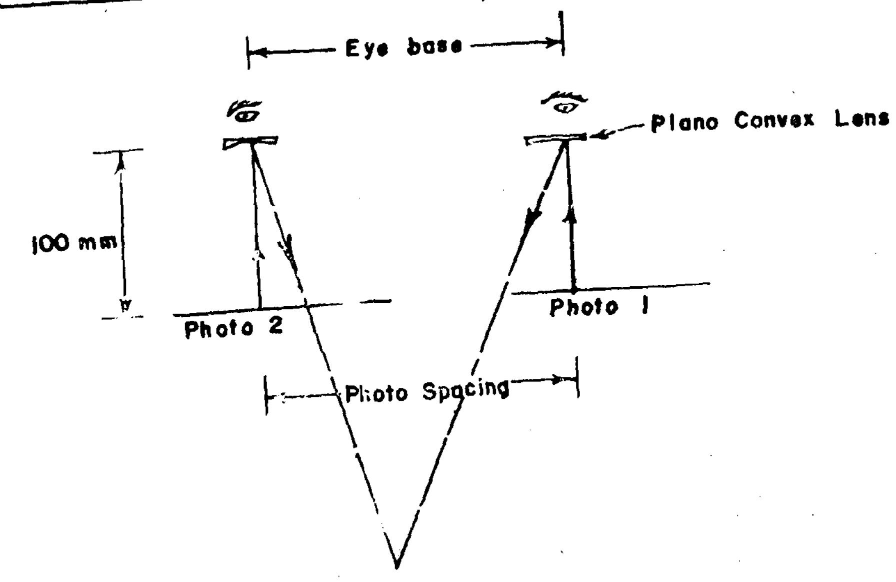


Fig. 6. Working Principle of Pocket Stereoscope

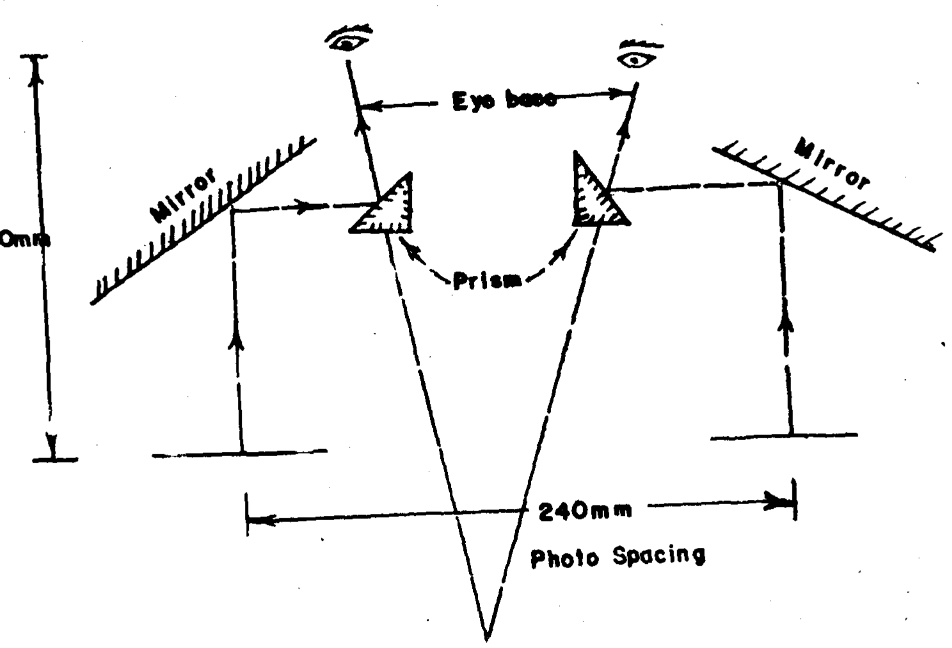
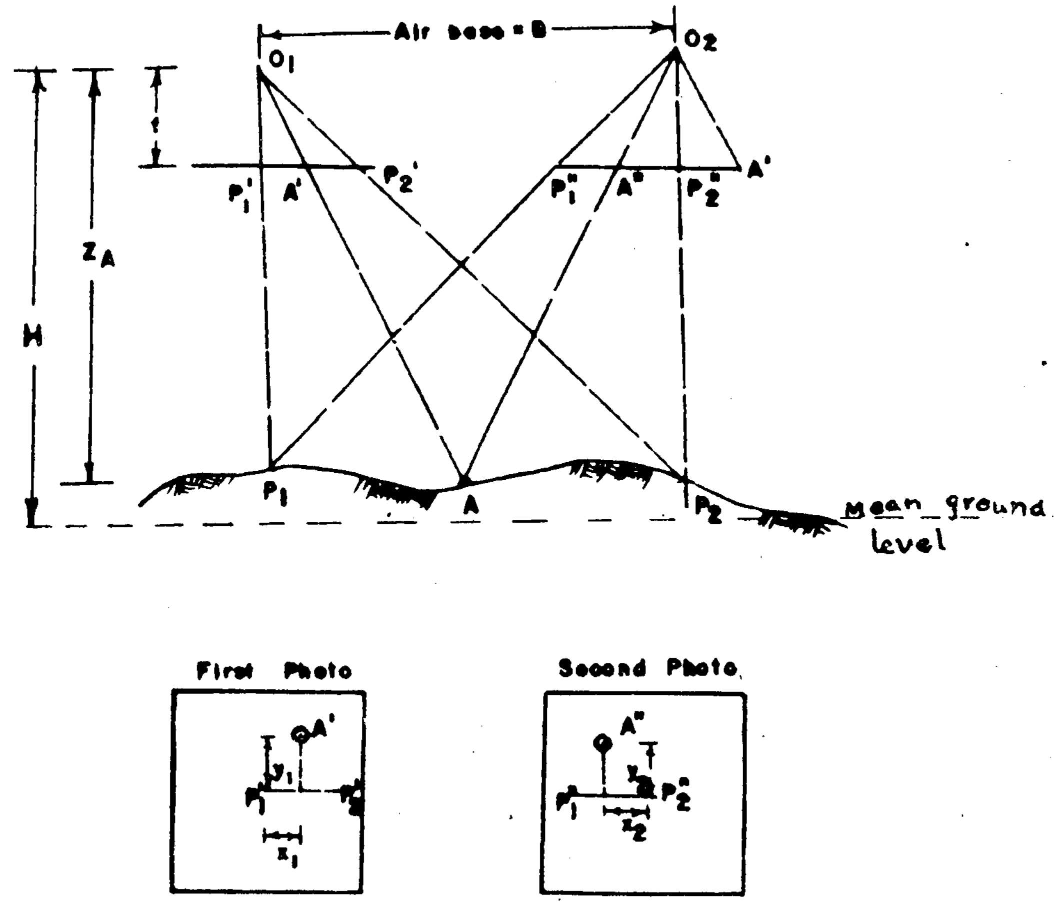
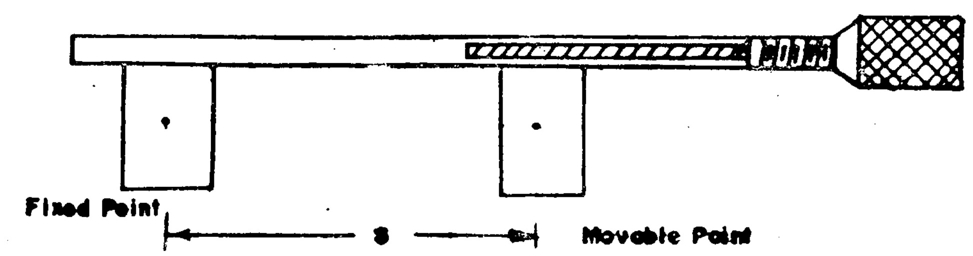


Fig. 7. Working Principle of Mirror Stereoscope

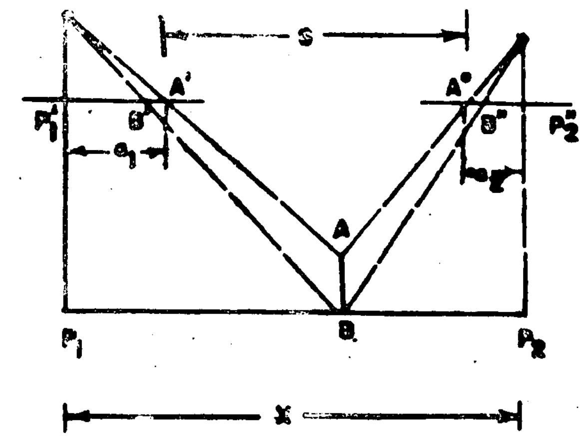


x Parallax for Point A $= x_1 + x_2$; $P_1'P_2'$ = Photo base = b
y Parallax for Point A $= y_1 - y_2$

Fig. 8. Parallax



Parallax Bar



Parallax for Point $A = a_1 + a_2$

Parallax measurement for $A = S = A'A" = x - (a_1 + a_2)$

Fig.S. Parallax Measurement

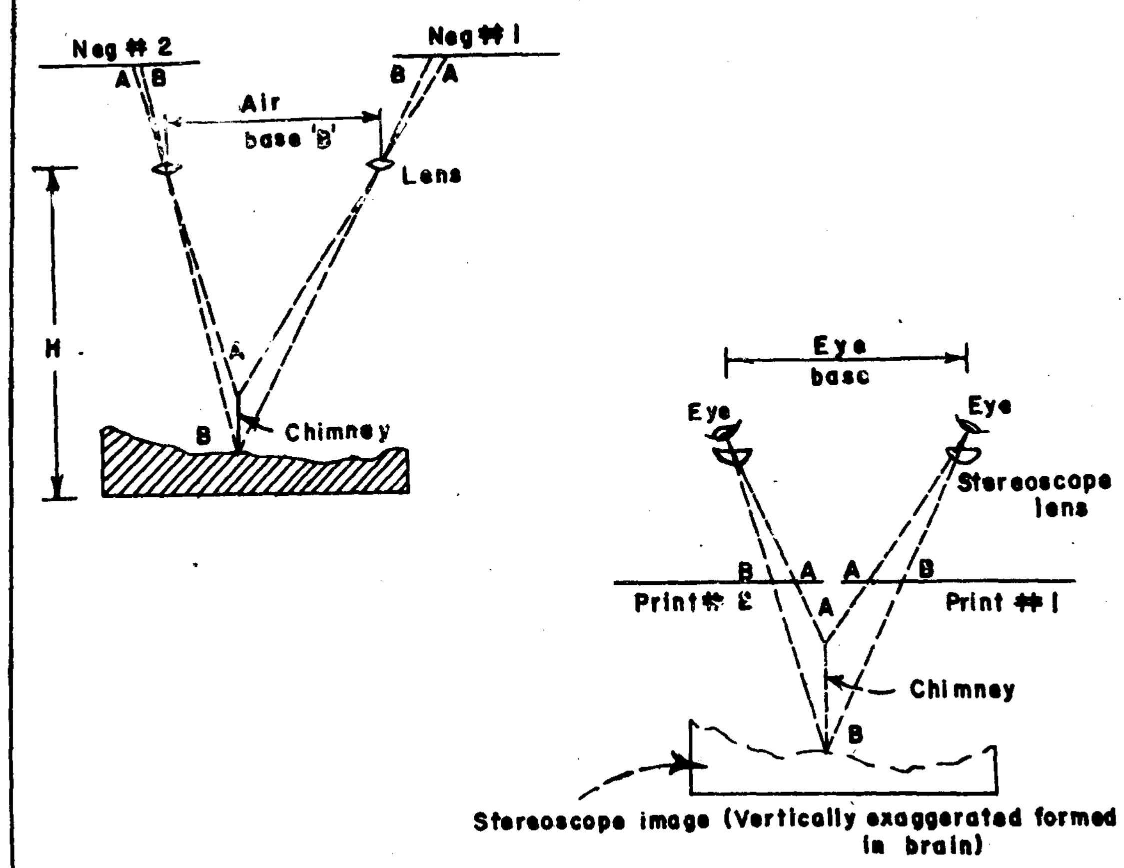


Fig. 10. Vertical Exaggeration

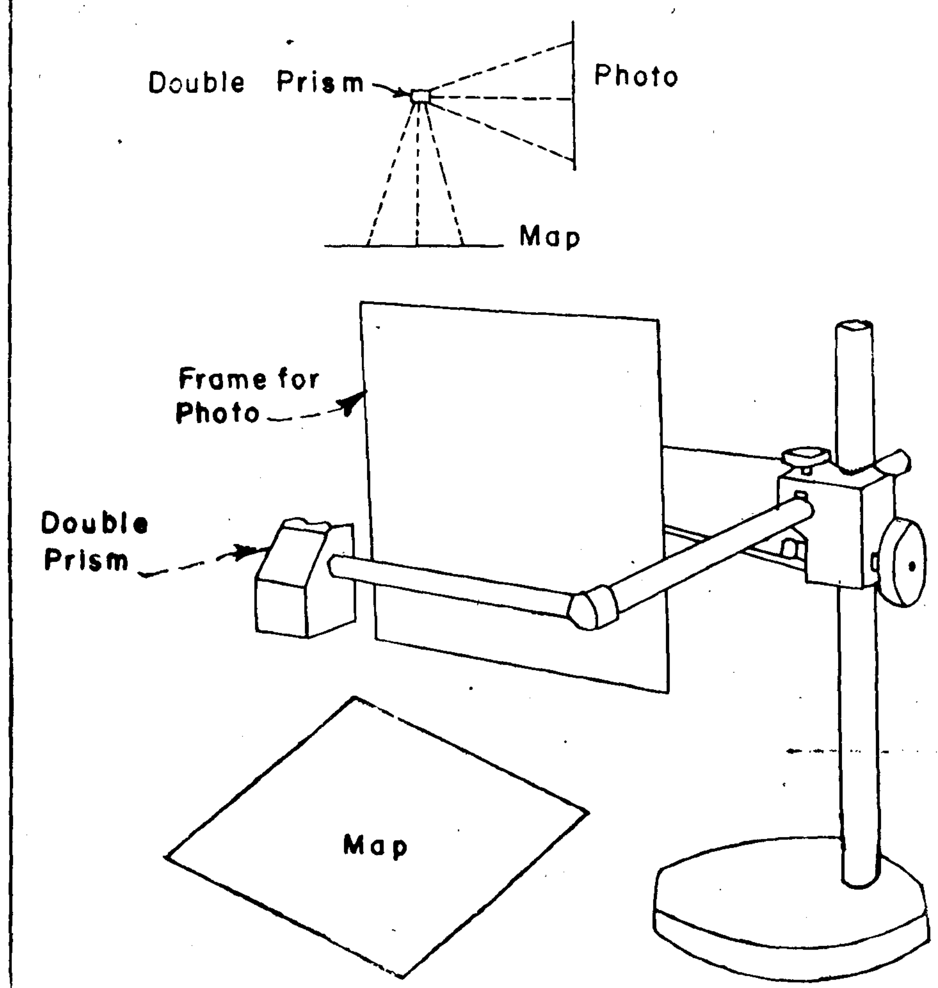


Fig. 11. The Working Principle of Sketch Master

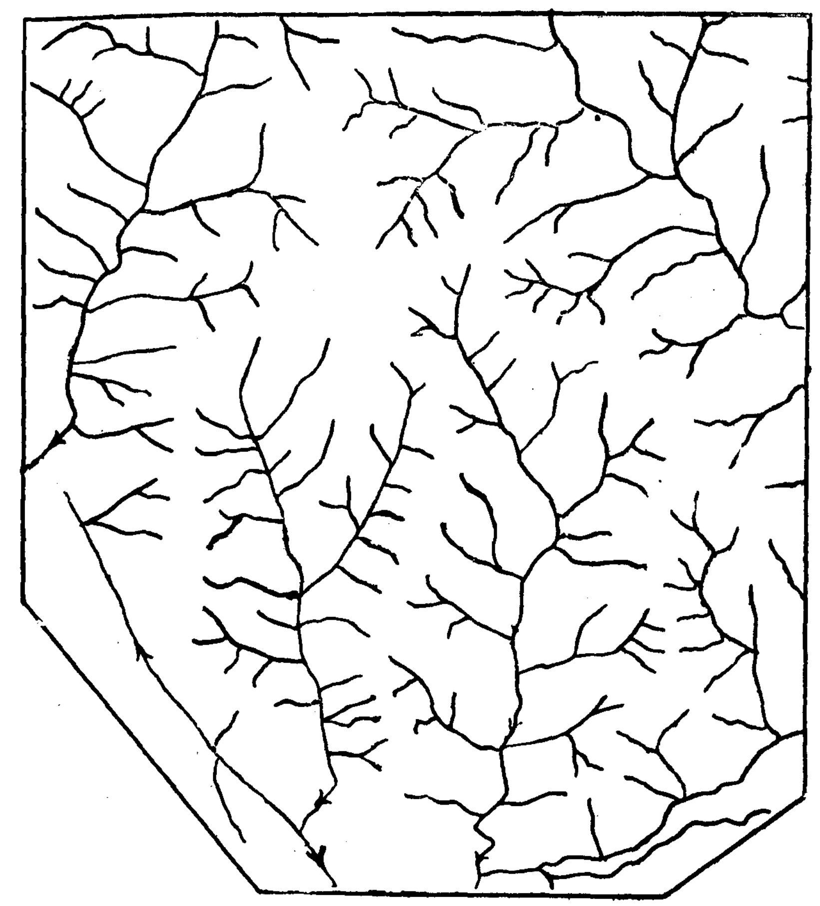


Fig. 12. Dendritic Drainage Pattern

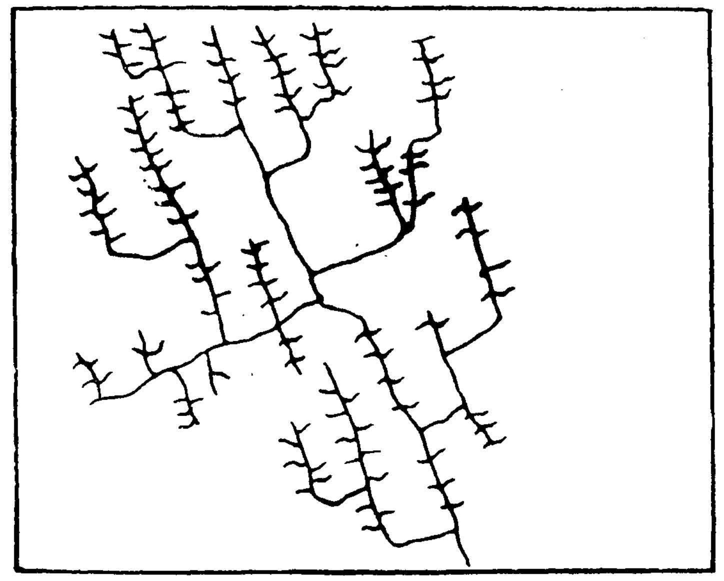


Fig. 13. Trellis Drainage Pattern

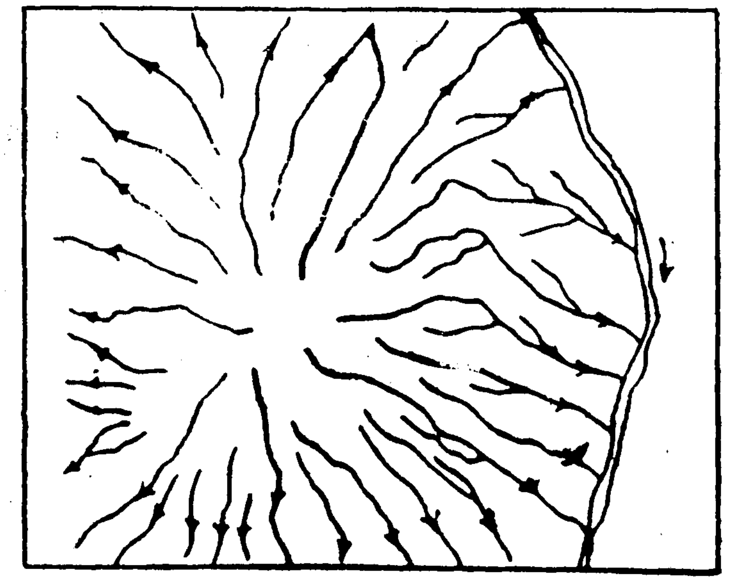


Fig. 14. Radial Drainage Pattern

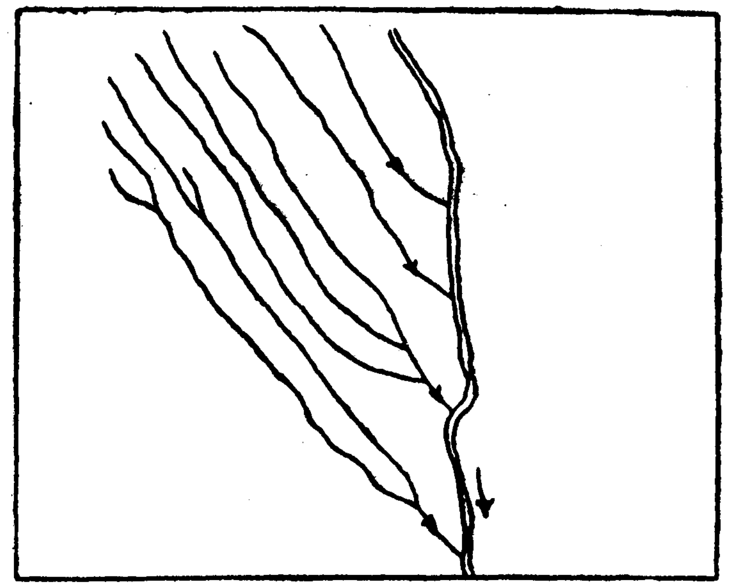


Fig. 15. Parallel Drainage Pattern.

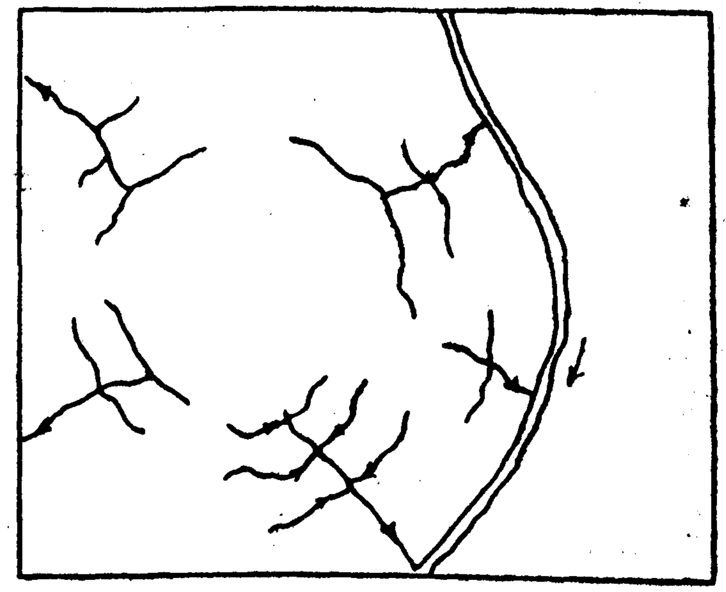


Fig. 16. Annular Form

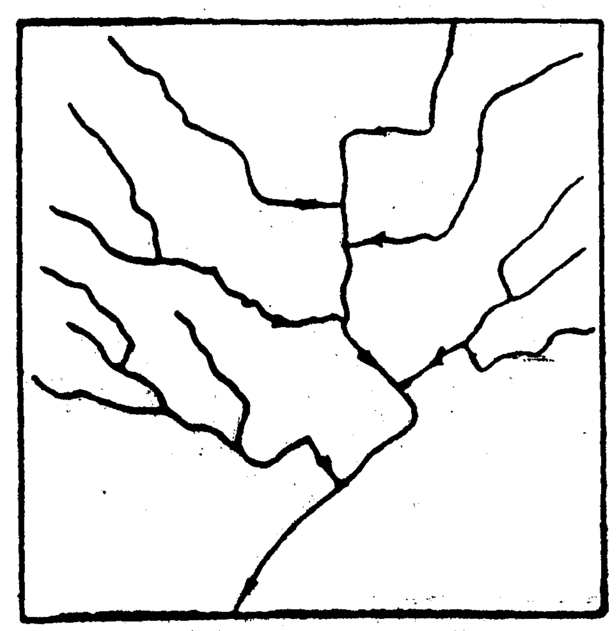


Fig. 17. Rectangular Drainage Pattern.

The Cyclone and its Aftermath

The severity of the cyclonic storm that hit Thanjavur district on 12th November 1977 and the fury of the floods that ravaged the area the next day are beyond measure. There had been such severe cyclones in this area previously in the years 1681, 1871, 1899 and 1952. Historical records reveal that in the year 1681, the death toll at Nagapattinam alone was in the order of 14,000. Even though the loss of human life during the recent cyclone is much less considering the year 1681, the present cyclone is considered to be the severest in the living memory. The storm hit the coasts with its centre at Nagapattinam, passed through Thiruvarur and Thiruthuraipundi and travelled west through Thanjavur, Tiruchirappalli and hit the Ayyalur hill ranges before proceeding further west, causing heavy rains in the area of its influence. A severe cloud burst in the Ayyalur hill ranges caused heavy floods in rivers like Kodaganar, Ariyar and Korayar flooding vast areas in Tiruchirappalli and Thanjavur districts on the 13th November. The floods of Varattar breached the earth dam portions of Kodaganar dam and joined Amaravathi which in turn joined the Cauvery washing away the Railway Bridge near Karur. On the other side, the Ariyar and Korayar breached Uyyakkondan channel in 22 places. These two rivers join and take the name of Kodamurutti before joining Cauvery near Tiruchirappalli Town. The banks of Korayar and Kodamurutti breached in many places and lowlying portions of Tiruchirappalli Town were flooded. The Tiruchi–Karur Road was also breached by the flood waters joining Cauvery. This resulted in three breaches on the opposite bank of the Cauvery in Srirangam near Ammamandapam and flooded Srirangam and Thiruvaorai kovil areas. These flows joined coleroon after crossing the National Highways. The heavy flood in Cauvery caused by Amaravathi and kodamurutti caused a big breach in the left bank of Cauvery near kilikudu about a kilometre upstream of Grand Anicut through which a portion of the floods flowed to the coleroon. The floods reaching Grand Anicut were diverted to Coleroon through the vents of the Grand Anicut and scour sluice. A small portion was sent through Cauvery, Vennar and Grand Anicut Canal also. Due to the cyclonic storm and heavy rains breaches occurred in 467 places and there were overwashes in 850 places in the delta rivers, channels and tanks in Thanjavur district.

This flood is unique because floods normally occur in Cauvery in the months of July and August due to rains in Mercara area, when there will be no rain in Thanjavur district and the sea also will be calm. Such floods occurred in the years 1924 and 1961. But during this November, there were heavy floods in Cauvery in Tamil Nadu without much flow above from Mettur. This is the first time such an occurrence takes place. Also previously there was either a cyclone or a flood, both did not occur together. This time floods followed the cyclonic storm. The tidal waves in the sea were also high and the flood water could not easily drain into the sea. When the floods in Cauvery come from Mettur and above we will have 2 or 3 days of prior notice. But this time unexpectedly and all of a sudden several streams and drains near Tiruchirappalli brought heavy floods to the Cauvery and that too at a time when everybody was immobilised by the breakdowns in communication caused by the cyclonic storm.

Thousands of trees were uprooted by the storm and were lying across the roads and the canal banks. Telephone connections were disrupted. Wireless communication was also immobilised. This was the situation immediately after the storm. But even under this trying circumstances all the staff of P.W.D. engaged themselves on rectification of damages on a warfooting. They rushed to the various sites by jeep wherever jeeps could go. They cycled where cycles could reach. They walked to the sites which could be reached only by walking and arranged for arresting floods by sand bags to save villages and crops from inundation. They arranged for safeguarding the banks against erosion wherever possible by brushwood, etc., and raised the banks by placing earth. They arranged for removal of trees from the roads to facilitate traffic. Mitigation of floods by proper regulation at all control points was attended to, day and night. Because of these measures river banks, for several hundreds of miles, were saved from breaches. Crops in thousands of acres were saved from submersion. In several tanks, to avert breaches in the deep portions in the middle, they arranged for breaches in the flanks. Arrangements were also done to drain the flooded fields. The tank breaches were closed within ten days so as to conserve water for irrigation. The rivers and channels were also repaired expeditiously to the extent of carrying the designed discharges. Temporary sheds were provided where Government school buildings were damaged. Action is also being taken to repair the damaged buildings and to reconstruct the dilapidated buildings. The breach closing works were entrusted to the local villagers except in cases which needed special expertise. The educated unemployed persons in the locality were also employed on the breach closing works. All these were achieved with the excellent co-operation of the public, the Revenue Department, the Police and other Government Departments. I would like to give just two examples to explain the contribution of the P.W.D.

The first example is in the two breaches at Kilikudu in the left bank of Cauvery. The first breach is 150 feet wide. A big tree of 30 feet girth was uprooted and had fallen in the breach site. The breach closing could be attempted only after cutting and removing the tree. A number of sawyers and wood-cutters had to be engaged day and night for 5 days.

The second breach site 1 kilometre away could be reached only after crossing the first breach. The second breach was 450 feet wide and 30 feet deep. More than 30,000 cusecs. of water was gushing out through the breach with a velocity as high as 15 feet per second

Radio talk by Thiru K. T. Guruswamy, B. E. Suprintending Engineer P.W.D., Thanjavur Circle recorded on 6th December 1977.

and with a depth of 18 feet. The velocity of flow in an irrigation channel will normally range between 1.5 feet to 2 feet per second. The velocity of the water flowing through the breach was about 6 to 10 times of such normal velocities. The flow was swift and dangerous. Naturally nobody could approach the rushing water or enter into the breach site. The Chief Engineer (Irrigation) rushed to the site and had discussions with the Engineers at site to decide the strategy to be adopted to close the breach. It was decided to provide a ring bund about 1 furlong upstream of the breach site. Big casurina piles of 1½ feet girth and 18 feet in length were driven into the river bed for 6 feet at close intervals. These were tied with walings. About 4 lakhs of empty cement bags were filled with sand and placed to support the pile ring. Bulldozers were used to move earth and dump it in the rear of the ring bund. The ring bund is about 1,000 feet long. The depth of water at the ring bund site was 7 feet and the velocity of flow about 10 feet per second. Pile driving experts were brought from places near Karur, Koviladi, etc., to rise temporary scaffolds and drive the piles with wooden mallets. The pile driving was done from both ends approaching the centre so as to expedite the closing. The casurina piles, sand bags and men had to be ferried in boats to the other side. Even on the accessible side conveyance of the materials had to be done by headload for ½ a mile length. The work of filling the bags with sand and stitching them was entrusted to the local villagers. Thus employment was provided to the flood affected people. The work of dumping the sand bags was commenced on 7th December 1977. 30 Engineers camping at site carried out the works day and night. The breach closing and strengthening of the bank in rear is expected to cost about Rs. 25 lakhs.

It is assessed that repairs to flood damages to irrigation works in Thanjavur District will cost about Rs. 230 lakhs and the repairs to the cyclone havoc on buildings will be about Rs. 48 lakhs. The P.W.D. has the heavy responsibility of closing the breaches to restore flows to irrigation even under the constraints of flowing floods and non-availability of earth.

Another example is the Government Hospital at Nagapattinam where the roof has been blown off by the cyclone and the patients in the wards were exposed to the vagaries of the weather. The cyclone was severe at that spot and has blown off most of the tiles. The operation theatre was also in an exposed condition. The reroofing and renewal of tiles were done in just two days and the inpatients were given protection. The operation theatre could also start functioning. It is proposed to provide concrete roof to avert such calamities in future.

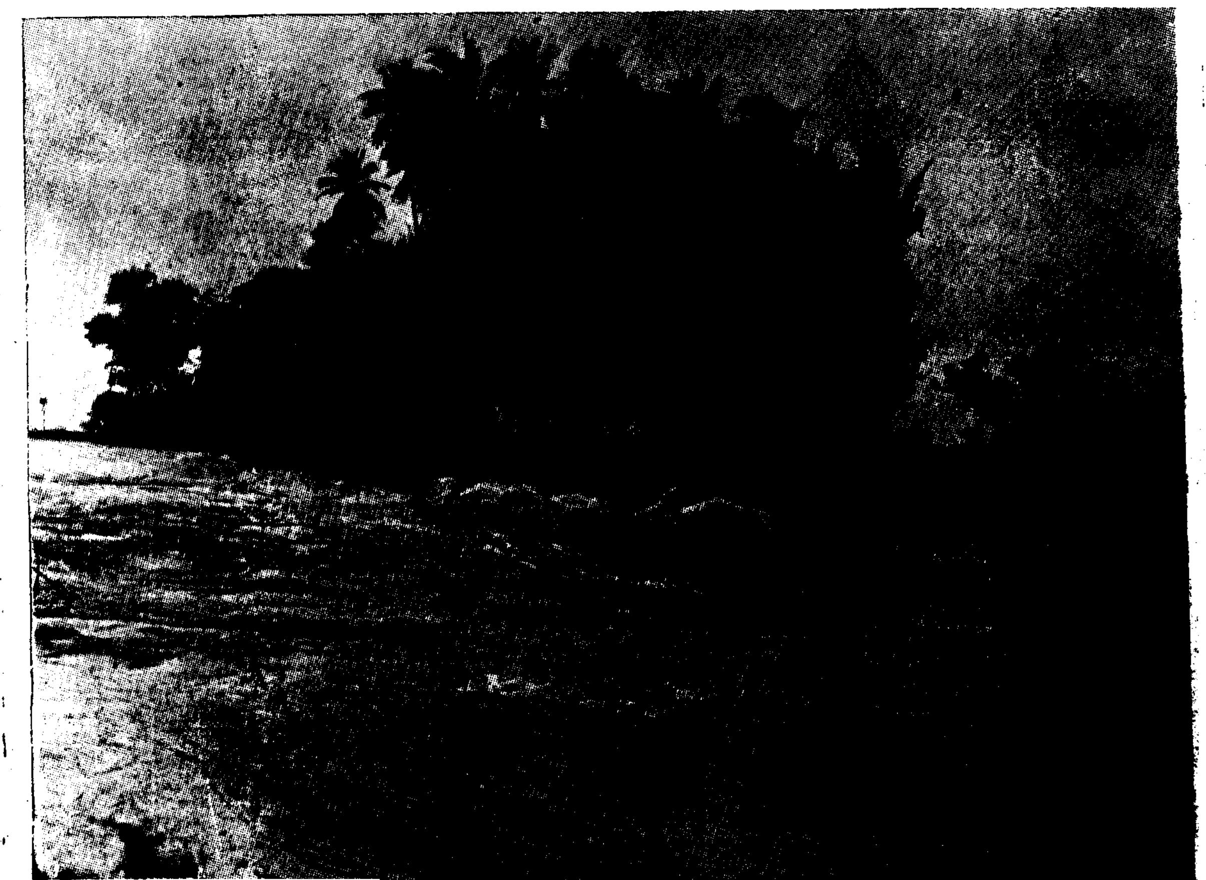
The P.W.D. has the onerous responsibility to avert such extensive calamities and damages in future cyclones and floods. Necessary planning in this direction has been taken on hand.

[The above is an English version of the script of the Radio talk in Tamil.]

[The breach closing work at Killikoodu mentioned above was almost closed on 8th December 1977 but for the central gap of about 15 metres which gave way due to the high velocity of water. A second ring bund aligned in front was formed with great difficulty in the swift currents and completed on 14th December 1977 but it developed trouble again. The breach could be finally closed on 17th December 1977 and flow restored to the delta from 18th December 1977. The forming of earthern bank in rear of the ring bund was done by earth moving machinery and by 21st December 1977 the breach was closed and strengthened to withstand high flows in the river. The releases from Mettur Dam were also stepped up from 21st December 1977 to ensure copious supplies to the delta.

The peak strength of labour engaged was about 3,000. On many occasions the Engineers themselves had to wade through the deep waters to sustain the morale of the workers when they got discouraged by what seemed to be unsurmountable difficulties.]

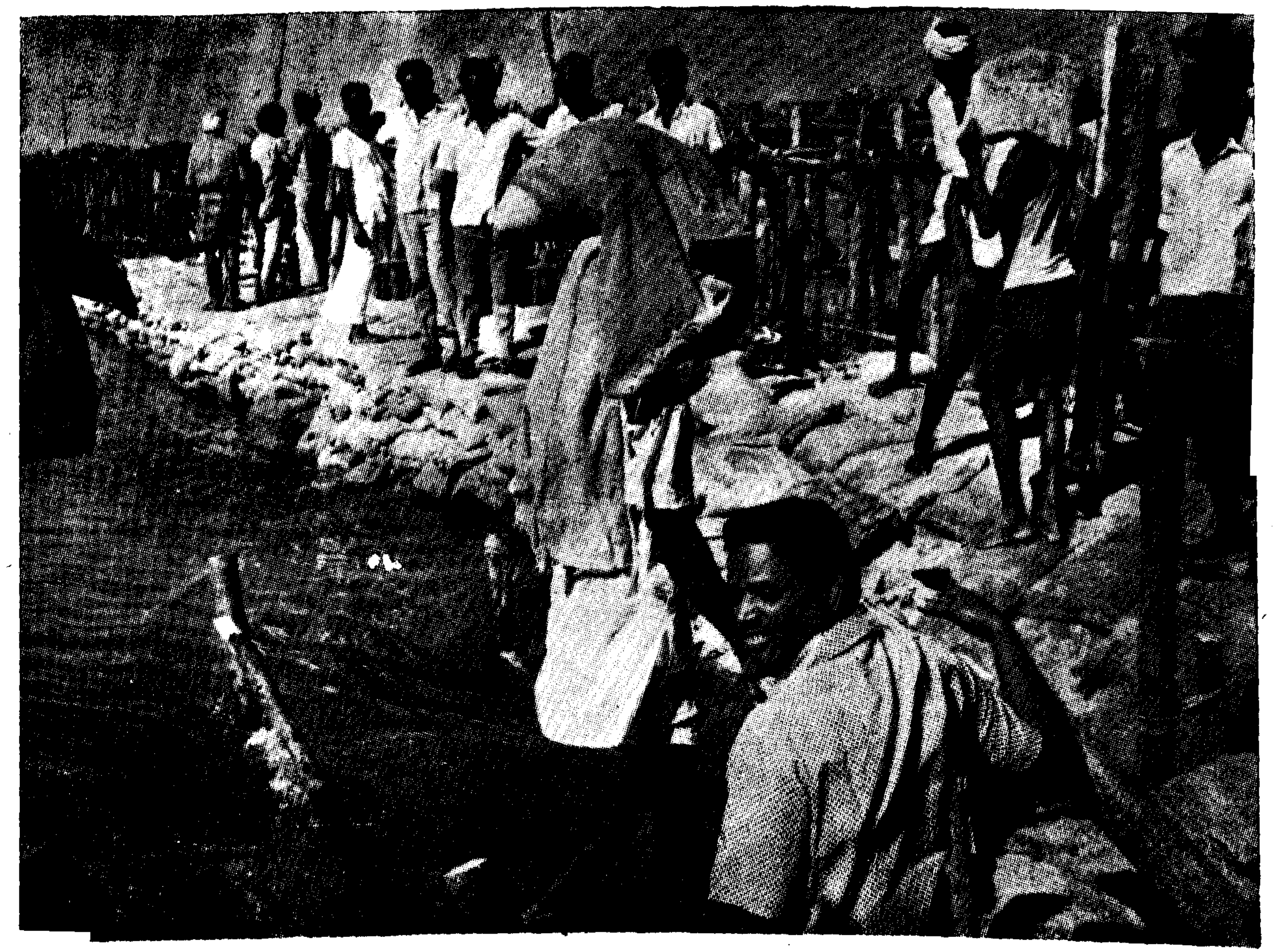
Breach No. 1 at Killikkoodu.



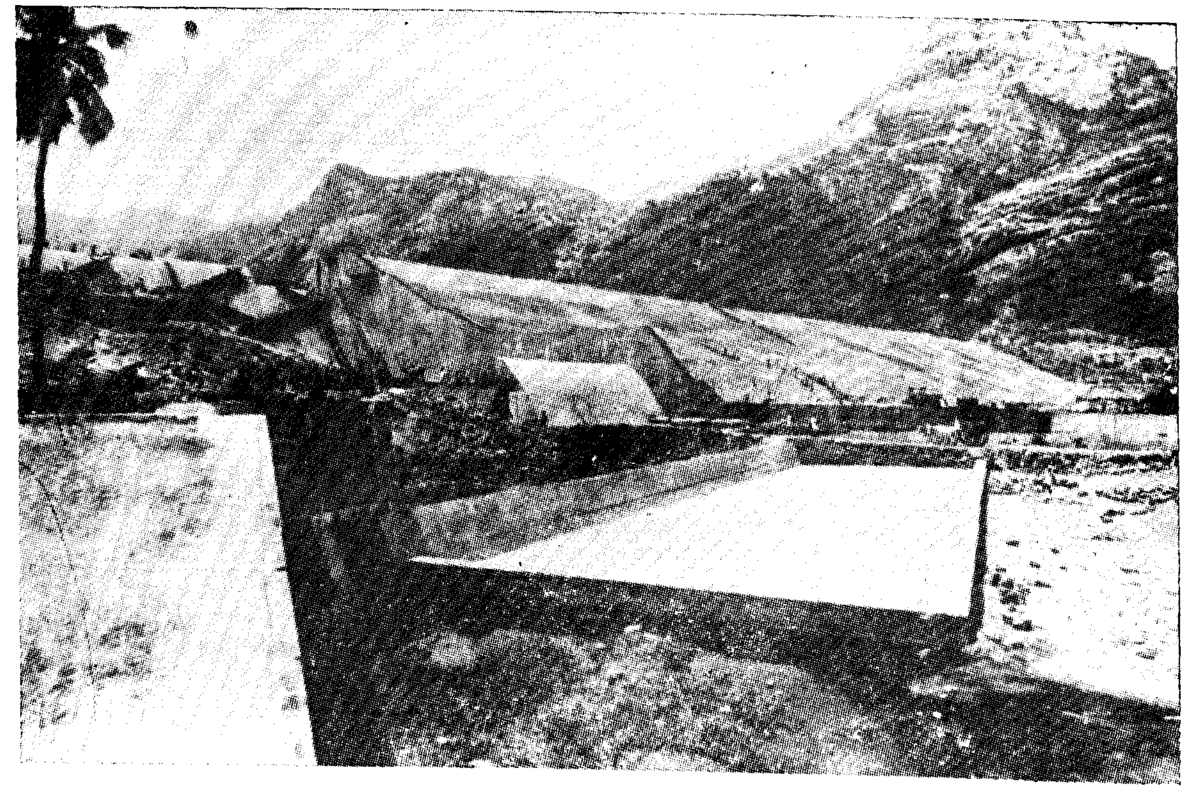
Breach No. 2 at Killikkoodu.

Rear View of a portion of the ring bund at Killikodu.

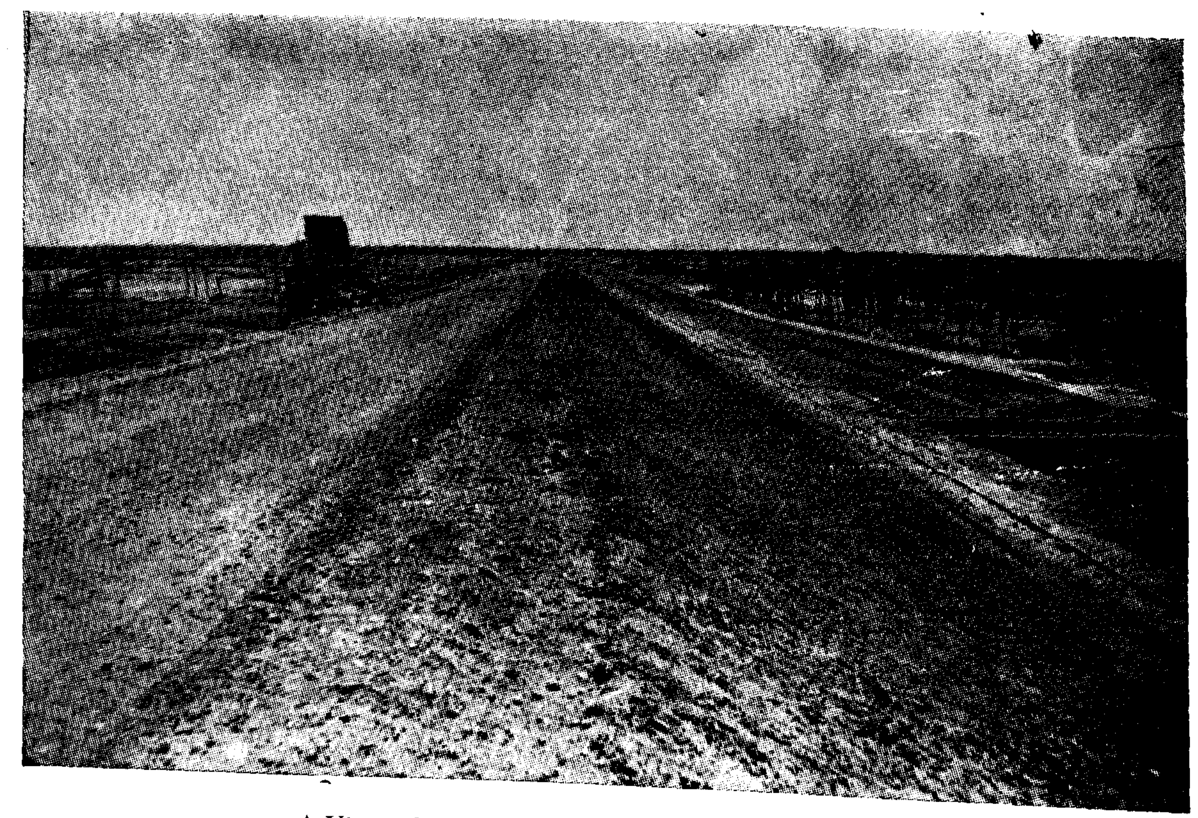
Photo showing the upstream side of the ring bund at Kilikodu.



·Assistant Engineer supervising the breach closing operation at Killikodu.

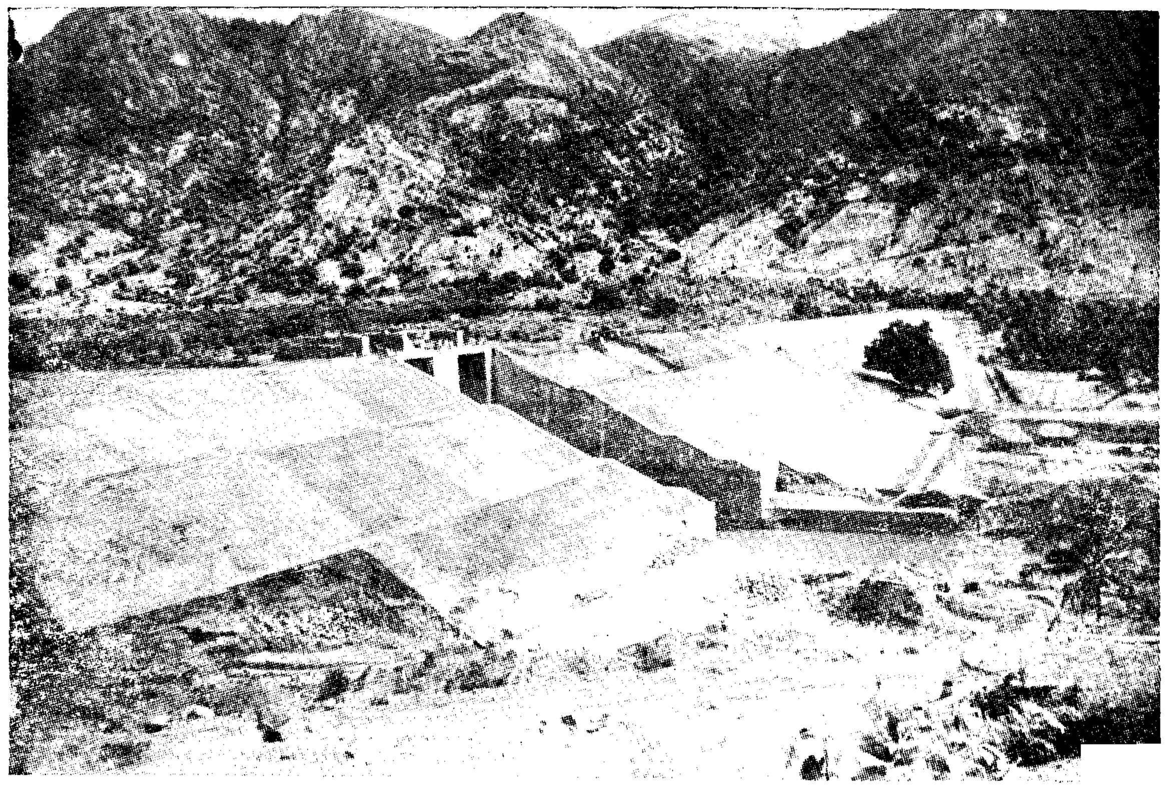


A View of Varadamanadhi Reservoir.



A View of Vattamalai Karai Dam (Right Flank).

(1)	(2)	(1)	(2)



A View of Marudhanadhi Reservoir (Right Flank).