1.3 HISTORY OF HYDRAULICS IN INDIA

"ONE WHO SOLVES THE PROBLEM OF WATER IS WORTH OF TWO NOBEL PRIZES,ONE FOR PEACE AND ONE FOR SCIENCE" - JOHN.F. KENNEDY.

1.3.1 Growth of Hydraulics and Irrigation Research In India- Introduction (CBI&P 1979)

During the nineteenth and early part of twentieth century, hydraulic and irrigation problems were being tackled mostly by engineering judgement based on experience. However, many engineers, with intuitive insight and initiative gave deep thought to various problems and arrived at valuable conclusions. They were the pioneers of of individual research exploring virgin ground in advance of the era of organised research with the aid of models and other experimental facilities and techniques. Roorkee professional papers on Indian Engineering (1863-1886) contain many original and useful ideas on the theory of flow in artificial earthen channels, measures for efficient distribution of irrigation waters and the design of hydraulic structures justifying high tribute to these pioneer researchers. In 1864, fundamental ideas on the causes of silting and scouring were initiated. At about the same time, tables of mean velocities and depths were evolved for North Indian Canals. The Ogee type fall was originated on the Ganga Canal (by 1870). Between 1874-79, Cunningham made a valuable contribution in the techniques of the measurements of discharges and determination of velocities. By about 1880, training of rivers with embankments combined with a system of groynes was experimented in the field. During 1881 - 82, Kennedy made important estimations of the losses by evaporation and absorption in the Bari Doab Canal. Cotton in the south and Cauteley in the north produced some of the most imaginative river conservation schemes over a hundred years ahead of the time they were realized to be essential and taken up for implementation.

Cottonreddypalem, Andhra Pradesh, several other villages rooted in the Cotton name and several generations of males with variations of Cotton name, all celebrated Sir Arthur Cotton's bicentenary in the Godavari District, David Abbott of the British Deputy High Commission, was present at the Rajahmundry celebrations. Cottons contribution to making the Krishna- Godavari area the granary of South India.

"Father of Irrigation", "Sculptor of Deltas". It is to be noted that the 3.685 km long Dowleswaram Barrage across the Godavari, built at a cost of £120,000 over five years, turned a flood and drought prone area into million acres of flourishing paddy and sugarcane, where the rent of an acre of paddy land today is Rs.1 lakh. "When the farmer tills his land (here) or receives the money for his produce, he thinks one man Sir Arthur Cotton".

A Sir Arthur Cotton Museum is to be set up at the dam site at a cost of Rs. 1 crore and, more significantly, a Sir Arthur Cotton Memorial Agricultural Service Centre is being set up over 15 acres, at Bobbarlanka, 20 km from Rajahmundry and near Dowleswaram, at a cost of Rs. 1 1/4 crore.

He was the beloved of the Ryots (farmers).

General Sir Arthur Cotton: His life and work, is described as "a classic on India's development". "India had taken hold of him. Not the India of Romance, but the India of need". The 500 page book was reprinted by the Institution of Engineers (India, in 1964).

Cotton had spent two years in Vishakhapatnam before moving on to Rajahmundry and his greatest work. While at Vizag, he had built the St. John's Church in Waltair, and groynes to protect the beach. He also predicted that Vizag would one day be a great port. Truly was he a farsighted engineer.

The reports of the select committee admitted the success of all the irrigation works in the Madras delta with which Sir Arthur Cotton's name is so honourably associated, namely the Cauvery, Kistna and Godavari, and indicated that if there was any financial

failure in other case in the past, the main cause appears to be the want of ability or energy on the part of the officers of the Public Works Department and their reliance on hasty generalisation.

Cotton use to use to tell his daughter, "Do something, my girl, do something. Never be idle for a single moment. Remember Time is short, Eternity is near."

He was 96 and had not suffered any major illness. On the night of July 14th, 1899 he became feverish and restless and began slowly sinking. The end when it came was 'perfect peace'.

"His life, judged by any test was one of the true greatness, such as is only given to vary few to attain in the world. He has left behind him a fame and a name which must endure to all times". Sir Richard Sankey, R.E., K.C.B., wrote in a letter to Lady Arthur on hearing of her husband's death.

Reference

Madras Musings, October 1 - 15, 1999.

During 18th and 19th centuries, the irrigation works in India were neglected by East India Company so much so that Arthur Cotton, Royal Engineer working with Madras Presidency complained bitterly in 1821 against the policy of apathy of the government. In the history of India, 18th and 19th centuries saw some of the worst famines in the north as well as south. As a result, efforts were made for saving agriculture. In the field of irrigation, these included reopening of Western and Eastern Yamuna canals, renovating Hissar branch canal and repairing Grand Anicut on Kaveri during 1810 - 1836 period.

Col. Proby T. Cautley of the Royal Artillery (1802 - 1871), was the superintendent of the canals in the North-Western Province and director of the proposed Ganga Canal. In 1838, Cautley submitted to the government the first proposal to take a canal from

Ganga at Haridwar.

Governor General Lord Hardinge visited the site personally and authorized the construction of canal in 1842.

James Thomason (1804 - 1853) who was then Lt. Governor of Northern Province fully supported the proposal of Ganga canal.

The excavation of the canal was started in 1842 and water entered the canal in 1854. It is interesting to note that when the canal was designed, the only hydraulic principles known were continuity equation and resistance law. And yet the unlined canal designed to carry discharge of approximately 300 cumecs as well as the cross drainage works such as Solani aqueduct, siphons and level crossings which are still intact and functioning well and have stood the test of time.

It is worth mentioning that Cautley became involved in public controversy over the design of Ganga canal against Arthur Cotton in 1863 - 65 and was publicly censured in the columns of the Times. However, he was officially exonerated by the Governor General in 1865.

LOOKING BACK

If we have done our duty at least to this part of India, and have founded a system which will be a source of strength and wealth and credit to us as a nation, it is due to ONE MASTER MIND Which, with admirable industry and perseverance, inspite of every discouragement, has worked out this great result. Other able and devoted officers have caught Colonel Cot-ton's spirit and have rendered invaluable aid under his advice and direction, but for this first creation of genius we are indebted to him alone.

"Colonel Cotton's name will be venerated by millions yet unborn, when many, who now occupy a much larger place in the public view, will be forgotten; but, although it concerns not him, it would be, for our own sake, a matter of regret if Colonel Cotton were not to receive due acknowledgement during his lifetime." - Minute by the

Government of Madras. Sir Charles Trevelyan, Governor, in his review of the Public Works Department on May 15th, 1858.

General Sir Arthur Cotton, R.E., K.C.S.I., was born in Cheshire, England on May 15, 1803, the tenth son of Henry Calveley Cotton. Lt. Arthur Cotton arrived in Madras in September 1821 and was attached to the office of the Chief Engineer for the presidency. In May 1822, he was posted as an Assistant to the Superintending Engineer of the Tank department, Southern Division.

Survey of the Pamban Pass to propose an enlargement of the pass for the passage of oceangoing steamers from the West Coast to the East Coast ports. This was the beginning of the Sethusamudram Project we have been talking of for a century ! .

In 1829, he was promoted as Captain and given separate charge of the Cauvery irrigation. He soon saw the need for saving the district from the ruin that was staring it with barely any flow in the cauvery due to heavy silting at the Grand Anicut. He soon evolved the scheme for erecting a control structure on the Coleroon at the Upper Anicut and the opening up of scour vents in the old Grand Anicut. On January 1, 1830 the great work of seven sluices was started. In 1832, got the project reports both for Upper Anicut and the Lower Coleroon Anicut on the Coleroon ready. They were sanctioned by the Government in time to get the preliminary work started before the freshes arrived in June.The first bold step taken by Cotton was the construction of the Upper Coleroom Dam at Mukkombu.

Mr. W.N. Kindersley, the Collector of the district, wrote “there was not one individual in the province who did not consider the Upper Anicut the greatest blessings that had ever been conferred upon it. The name of the projector would, in Tanjore, survive those of all the Europeans who had ever been connected with it”.

At this distant date we fail to realize the great truth in these statements made and the valuable contributions of this pioneer, Sir, Arthur Cotton. He always insisted on saying

that the value of irrigation works was not to be measured simply by the additional revenue yielded to the Government treasury, but that a much truer criterion would be found in the enhancement of the income of the people and in the consequent saleable value of the land itself. Irrigation brings with it prosperity to the region, some perceptible and much more imperceptible and intangible.

The work that made a magical change in the hinterland of the delta of the River Godavari, the masterpiece of the great thinker, the planner, the designer and the maker, Major Arthur Cotton, was to come soon after.

Cotton, after a careful study of the sufferings of the people in the delta, while huge volumes of floodwaters were being carried out to the sea day in and day out by the mighty Godavari, reported to the Board of Revenue in May 1844 that the only way to turn the Godavari district from being the poorest to nearly the richest in the presidency was bringing in irrigation-cum-navigation facilities in the Delta by building an anicut across the wide river.

Reference

Madras Musings-September 16-30, 1999.

Outstanding contributions to sub-surface and surface flow research came from Col. Clibborn and Kennedy during 1890's. Col. Clibborn carried out the historic experiments (1895-97) with Khanki sand to investigate the laws of flow of water through sand in relation to weir design. Col.Clibborn's other contribution was on investigations on the replenishment and velocity of flow of ground water in the Gangetic plains. In 1895, after field experiments on the Upper Bari Doab Canal, Kennedy propounded his classical relations between the critical velocity and channel depth as influencing channel design.

The early twentieth century has been notable for the rapid extension of irrigation in the country and with it for the rigorous efforts on the investigations on the economic and

reliable design of hydraulic structures, design of stable channels, efficient distribution devices, weed control, anti-water logging measures and land reclamation.

Kennedy's classical equations for the design of channels were followed by Lindley's relations in 1919 indeed the very concept of the regime theory itself. Between 1929-39, Lacey's sustained and pioneering work led to the development of comprehensive formulae for designing stable channels in alluvium. The thread was picked up by various workers- principally, Inglis, Bose, Malhotra, Blench, et al. and this subject has continued to be a subject of sustained interest in India.

Investigations for the control of sand entering channels attracted the attention of many engineers also, Inglis, the father of hydraulic model research in India, demonstrated that curvature of flow- or nature's way- was the dominant factor affecting surface and bed flow and, therefore, the most effective way of controlling sand. In 1922, Eldsen initiated the idea of the tunnel type of excluders, and in 1934 Nicholson built the first excluder at the head of the Lower Chenab Canal at Khanki. King's investigations for exclusion of heavy silt from canal by vaned pitching (1918) and with silt vanes (1920) were earlier notable investigations in the same field.

India's contribution of the development of subsoil flow hydraulics in relation to the design of weirs has indeed been unsurpassed. After Col. Clibborn's historic experiments (1895-97) with Khanki sand, Khosla propounded (1929-36) the very valuable theory of subsoil flow in relation to the design of weirs on permeable foundations. The first full size experiments in the world was conducted during 1929-36 on the Panjnad Weir. This was followed by laboratory research on models of Rasul Weir (1930-34) and Panjnad Weir (1934-35) by Taylor and Uppal, and on electrical analogy models by Vaidyanathan (1936) and others.

Efficient distribution of water from canals was another subject which attracted the attention of engineers from early times. Up to the end of the nineteenth century, ordinary canal outlets in the form of open cuts, pipe or barrel outlets were in vogue. In

1882, Beresford introduced a general type of outlet with a 15.2 cm pipe with flap and face walls. Since the beginning of this century, a number of investigators have studied the various aspects of canal outlets and several types have been developed. The earliest semi-modular type was in 1902 by Kennedy-the sill outlet. Kennedy's gauge outlet was introduced in 1906which was further improved in 1915. By 1922 Kirkpatrick on the Jamras (Sind) and Crump in Punjab developed semi-modules of the open flume and the orifice types. Among the modules with moving parts, Visvesvarya's self acting module (1904), Kennedy's outlet module (1906), Wilkins type (1913), Joshi's module (1919) and Kenti's 'O' type module (1923) were the important developments. A module without any moving parts had been developed by Gibb as far back as 1906 and it was greatly improved later by experiments in Poona. Many silt extracting outlets were also developed, the outstanding one being the Haigh's type in 1937. Valuable experiments conducted on broad-crested weirs were utilised by Burkitt in developing the 'Head-less meter'.

Bharat Rathna Dr. Sir. Dr. Mokshagundam Visvesvaraya (1861 - 1962)

September 15 is a memorable day in the annals of the engineering community in particular in this country. On this day 135 years ago, one of the greatest sons of India, Dr. Sir. Mokshagundam Visvesvaraya, the towering personality in the history of Indian engineering - was born at Muddenhalli in the Kolar district of Karnataka. Graduated from the college of science, Poona in 1883, Visvesvaraya joined the Bombay PWD and rose to the position of Chief Engineer. He worked ceaselessly throughout his life to bring fruits of advanced science and technology to the doorsteps of the common man. On retirement, his services were requisitioned by the Maharaja of the erstwhile Mysore State, who appointed him as Dewan. The following years witnessed an era of planned development and all-round growth. A visionary who could think ahead of his time, Visvesvaraya realised that there could be no salvation for the people of the country except judicious use of the results of technological innovations. In recognition of his services to national development and for the cause of engineering, he was honoured by

presentation of the country's highest award - Bharat Ratna - in 1955.

To perpetuate the memory of this great engineer-statesman, the Council of Institution of Engineers India decided to observe September 15 each year as Engineer's Day and evolved guidelines for celebrating the Day.

The State of Mysore has been well known for its engineers. Modern research as such in engineering started about 1870's. The first claimant for leadership in engineering research was Sri Adil Shah Dabe who constructed in the first decade of the 20 th Century the Mari Kanave Dam with masonry in Surki mortar. It was easily the highest dam at that time in the world constructed with a matrix other than cement.

The second decade of the 20th Century started with the advent of the world famous Engineer Bharat Ratna Dr. Sir. M. Visvesvaraya at the helm of affairs in Engineering and Administration. His pioneering works in the block system of Irrigation, Invention of the automatic gates are well known. Under his leadership considerable progress in research in the use of surki mortar for construction of hydraulic structures, gauging of rivers, evaporation and seepage losses, etc,.

Ganesh Iyer during 1930's initiated research and experimentation on Volute siphons.

In the development of canal falls, the Ogee type was in use as early as 1870. The trapezoidal notch fall was developed by 1894. With the mechanism of the energy of flowing water and the formation of the standing wave becoming known better, the standing wave flume type of fall was developed by Inglis by 1930.

Numerous investigators worked on the theory of the hydraulic jump which has helped immensely in tackling various hydraulic problems. Important investigators on this problem were Inglis and Joglekar (1924 - 1940), Coyler (1926), Lindley (1927), Montagu (1929) and Crump (1930). Energy dissipation works below river and canal structures by means of a cistern with baffles, deflectors and blocks were evolved with the help of

model experiments by Bhandari and Uppal (1938) in the Punjab and by Inglis in Poona (1935).

The control of rivers flowing through bridges and other structures by a system of guide banks, first introduced by Bell in 1888, has subsequently been investigated extensively, both on the model and in the field, and the system is now widely in use.

Losses by evaporation and percolation in canals were investigated by Kennedy on the Bari Doab Canal as early as 1882 and further work was carried out by various engineers.

The special Irrigation Research Division, created in the Bombay P.W.D. in 1916, through efforts of Inglis, contributed a great deal in the field of organised irrigation research. During 1916-1928, valuable investigations were made on the problems of land drainage and reclamation, canal losses, canal lining, weed growth and improved irrigation methods. In the field of hydrodynamic research with the aid of hydraulic models, experiments on standing wave flumes, energy dissipation devices below falls, cutwater and ease-water experiments for the best design of Sukkur Barrage piers are few examples of early organised research.

With the realisation of the importance of model investigations, research centres at Poona and Lahore were developed and new Research station started in United Provinces (1938) and some other states. The attainment of Independence and formulation of plans for a number of River valley Projects posed a multiplicity of problems and it became necessary to expand the facilities at the existing research centres and to open new centres of research, today, laboratories equipped for dealing with the problems connected with River Valley Projects, including reservoir surveys, testing of soils, concrete and other construction materials have been set up in most of the states.

1.3.2 CO-ORDINATION OF RESEARCH

The creation of the Central Board of Irrigation in 1927 was a sequel to the realisation of the need for coordinating research activities at various centres. After Independence, with growing realisation of the need for development of power the Board was redesignated as the Central Board of Irrigation and Power. In addition, it co-ordinates the national activities and functions as Indian National Committee for the International Commission on Large Dams (ICOLD), International Commission on Irrigation and Drainage (ICID), International Association for Hydraulic Research (IAHR), International Water Resources Association (IWRA) and International Conference on Large High Voltage Electric System (CIGRE). The board also actively collaborates with the Bureau of Indian Standards, the Central Road Research Institute, the Council of Scientific and Industrial Research, the Indian Council of Agricultural Research, the Department of Science and Technology, the Seven Indian Institutes of Technology, the council of Technology Education, Indian Institute of Science.

On the recommendations of an expert committee appointed by the board in 1958, a scheme of research on fundamental and basic problems, relating to river valley projects and flood control works was sanctioned. To start with 12 main topics were included for study under the scheme. Till 1980's, the work under the scheme has increased to the extent that there are 44 main topics presently under study at 16 State and Central Research Stations and 12 technical institutions under the supervisory control of the Board. The Board publishes every year the Annual Review Summaries of the work done on these problems. A quarterly journal 'Irrigation and Power' brought out by the Board contains papers on both basic and applied research in water and power engineering. The papers contributed and discussed at Annual Research Sessions are brought out as proceedings of these sessions.

Besides the journal and proceedings, publication of important researches relating to specific subjects carried out by individuals or institutions are compiled as Board's publications and these form useful authentic reference manuals with the irrigation and

power engineers of the country. As part of the Research Studies the research stations have prepared Reviews with Bibliographies as well as status reports on a number of topics. These are also issued as publications of the Board. In late 70's a new periodical 'Irrigation and Power Research Digest' has been started to furnish the latest research work done at various research stations to the research community.

1.3.3 RESEARCH ACTIVITY IN INDIA TODAY

There were sixteen major research stations in India (in 1980's) which were undertaking research studies on various aspects of river valley developments and which usually participated in the Research Scheme applied to River Valley Projects. A number of technical institutions are also associated with this programme and they are mostly tackling the problems with a great academic bias. The background and the special features of some of the State and Central Government research stations are given below.

(1) Andhra Pradesh Engineering Research Laboratory, Hyderabad

The Engineering Research Department, established by then Hyderabad State Government in the year 1945 became the Research Laboratories of Andhra Pradesh when the new state was formed in November 1956.

(2) Central Soil and Materials Research Station, New Delhi

To meet the need for research wing, for soils and material testing on the pattern of the central water and Power Research Station, Pune, (Described subsequently) the Central Soil and Materials Research Station came into existence at New Delhi during the year 1953-54. The research station undertakes field and laboratory investigations for river valley and other projects in the disciplines of soil mechanics, rock mechanics, concrete technology, sediment investigation, pre-irrigation soil surveys and chemical analysis of construction materials. The station has extended its service of consultancy to a number of foreign countries including Bhutan, Nepal and Afghanistan. Highly sophisticated

testing facilities such as 1,000 tonne testing machine, have been installed and it is one of the best equipped laboratory of the country in its field.

(3) Central Water and Power Research Station, Pune

As a sequel to the need for organised research, a special Irrigation Research Division was created under the auspices of Bombay P.W.D. in 1916, by the efforts of Sir C.C. Inglis, who did pioneering work on various aspects of the irrigation problems and laid the foundation of organised research in the country. Problems concerning laid drainage and reclamation, canal losses, canal lining and improved irrigation works were taken for investigation. Soon the Research Division expanded its activities in new branches and this centre was subsequently taken over by Government of India in 1937. Irrigation and river training research were added to its scope and was renamed as 'Indian Waterways Experiment Station'. In 1946-47, the expansion and reorganisation of the station was sanctioned with seven new branches for dealing with navigation, soils, materials of construction, statistics, physics, mathematics, hydraulic machinery research problems. The station was redesignated the 'Central Water and Power Research Station' and brought under the administrative control of Central Water Commission. The quality of research work turned out by the Research Station won it acclaim not only within the country but abroad as well. In recognition of the tremendous progress made, it has been chosen as Regional Laboratory for the United Nations Economic Commission for Asia and Far east. CWPRS has extreme built up expertise in many fields during its life span of more than 85 years. Some of the notables are: hydraulic structures, earth sciences, ship model testing, coastal engineering and the application of methods from the different disciplines of physics, chemistry, mathematics, statistics, botany, geology, instrumentation and computer science.

The station extends its activities to prototype testing, digital data acquisition, field investigations, testing of turbine and pump models in cavitation tanks and developing techniques for the use of radioactive and fluorescent tracers in tidal as well as fluvial flow conditions for various purposes.

The station has been offering technical assistance and consultancy services to other countries also, which include Burma, Afghanistan, Tanzania, Iraq, Philippines, Singapore, Libya, Nepal, Sri Lanka, Egypt and Zambia. Notable engineers from these stations are Sir C.C. Inglis and Dr. D.V. Joglekar.

(4) Gujarat Engineering Research Institute, Vadodara

On the bifurication of the Bombay State, the development and Research Division at Vadodara, which was a branch of the Central Research Institute, Nasik was transferred to the Gujarat State in 1960 and was renamed as Gujarat Engineering Research Institute, with head-quarters at Vadodara. The institute's major contribution related to the study of ground water flow and its recharge, river training, sediment studies in canal and reservoirs, canal lining, soil mechanics and materials testing specially pozzolana.

(5) Hirakud Research Station, Hirakud, Orissa

During the planning of the Hirakud Dam Project in 1947, this research station was started at the dam site for observations of data on the silt load of the Mahanadi and for testing construction materials for the project. Subsequently, this station was expanded to take up the quality control work during the construction and for the fixing and observations of the instruments provided both in the earth dam and the masonry and concrete dams. With the transfer of this station, along with the Hirakud Dam Project to the Government of Orissa in April 1960, the activity of the Research Station has been extended to cover the whole of the Orissa State.

A Masonry Testing Unit for testing large size masonry and concrete blocks, has been set up about 11.3 Km away and it is one of the few such units in the country.

The Station also undertakes the sedimentation survey of the Hirakud Reservoir by echo-sounding.

(6) Institute of Hydraulics and Hydrology, Poondi (Tamil Nadu)

Abundant water and land becoming available with completion of the Poondi Reservoir Irrigation Research Station came into being at Poondi, 60 Km from Chennai, in April 1944.

This Research Station deals with all hydraulic problems of the river valley and flood control projects. T-shaped blocks have been evolved for effective and economic dissipation of energy below spillways. Implemented in Bhavani Sagar project. Similarly, lined canal chutes have been developed and considerable savings have been effected in the cost of the Lower Bhavani Project Canal System by work at this Station. A special mention may be made of the studies conducted for the improvement of the coefficient of discharge of tank weirs, which has enabled the irrigation of additional areas from the remodeling of a large number of tanks in the Tamil Nadu State.

The Irrigation Research Station was functioning as a part of the State Public Works Department and as such it concentrated on applied research having relevance to the immediate functional needs of the department. Observing the switchover from hydraulic to hydrologic research all over the world urgent need was felt to bring about a change in the outlook of this statement also.

The station was upgraded into a full fledged Institute of Hydraulics and Hydrology in the year 1973 making it possible to deal with problems in ground water and coastal hydrology and surface water management using computer simulation methods, system analysis and the like.

The need for instrumentation, especially on the electronics side had also been realised fully. As a result an electronic laboratory has been established.

The activities of the Institute are spread over area of Ground Water Hydrology, Hydrology of River Basins including Flood Prediction, Hydrological Modeling, Instrumentation and Water shed Management Schemes.

(7) Irrigation Research Directorate, Bhopal

The research station has been started in 1964. It is mainly dealing with hydraulics, soils, and concrete and model prototype conformity problems.

(8) Irrigation Research, Jaipur

With the advent of irrigation projects in the State of Rajasthan and use of local materials for the constructional purposes, the Irrigation Research has been conceived.

(9) Irrigation Research Institute, Khagaul, Patna

The research station was opened in 1956 at Khagaul, 10 km from Patna. The Institute has done considerable work on soil, use of micaceous sand in mortar and concrete, and other construction material problems. It has recently taken up studies regarding sedimentation survey of reservoirs and ground water problems including optimum spacing of tubewells in various regions of Bihar State.

(10) Kerala Engineering Research Institute, Peechi (Kerala)

On the formation of the Kerala State on 1 November 1956, the systematic and intensive development of the water resources of the state assumed great importance.

The State Government sanctioned a Research Institute in Kerala which started functioning on June 1960.

The main Research Institute is located at the foot of the Peechi Dam, about 22.5 km from Trichur.

Being a coastal State the Institute has mainly concentrated on the problem of coastal erosion and has evolved cheaper designs of sea walls which have been constructed to protect the land against sea erosion successfully. Other studies being carried out are use of laterite as pozzolana, water requirement for rice, etc.

(11) Karnataka Engineering Research Station, Krishnarajasagar

Though it started as a small section attached to Gauging Sub-Division dealing with hydraulic investigations only, with the increase in demand for the testing of soils and various engineering materials, the Soil Mechanics Branch and the Material testing Branch were added during 1940.

The Hydraulic Research Station was later strengthened in 1945 and made a seperate wing of Public Works Department under the direct administrative control of the chief Engineer and redesignated 'Mysore Engineering Research Station'. During 1974 due to the redesignation of Mysore State to Karnataka State, the station was also redesignated 'Karnataka Engineering Research Station'.

The outdoor hydraulic laboratory and the indoor laboratories (material testing, soil mechanics, chemical, road research, etc.) are all located at Krishnarajasagar, just below the Krishanarajasagar Dam overlooking the famous Brindavan Gardens.

One of the important contributions from this Research Station has been the development of the volute siphons, initially designed and promoted by Ganesh Iyer, an eminent engineer of the Mysore State. One of the important studies carried out by this Research Station in collaboration, with other research stations was to determine the prototype behaviour of the siphons when running full under likely cavitation conditions under excessive head.

Other notable studies carried out by this Research Station are the twin surge tanks, the approach channel to the Vodenbyle twin tunnel, and the surplussing arrangements of the Linganamakki Talakalale, Kali Complex and other projects of the state. Experiments for restriction of evaporation, cheaper canal lining, model prototype conformity, sedimentation survey of reservoirs, problems of soil mechanics, materials testing and rock mechanics are some other important achievements of the station.

During 1971, an Engineering Staff Training College has been started under aegis of Karnataka Engineering Research Station, to impart training to in service engineers of P.W.D. by running short-term and long-term refresher courses.

(12) Land Reclamation, Irrigation and Power Research Institute, Punjab, Amritsar

Around the year 1925, the Government of Punjab constituted a Water logging Enquiry Committee to study and report on the extent and causes of water logging in irrigated areas and the preventive measures which should be adopted. A small farm at Chakanwali for field experiments regarding the reclamation of waterlogged areas and a laboratory at Lahore for the analysis of soil and water samples-later designated as the 'Scientifc Research Laboratory' was set up in this connection.

In 1931, the Hydraulic Section was started and, by 1932, under the redesignated name 'Irrigation Research Institute, Lahore' there were six independent Sections: Hydraulics, Physics, Chemical, Statistical, Mathematical and Land Reclamation. During the next 15 years, the Institute was able to carry out a great deal of work which gained recognition in the scientific and engineering circles.

The Hydraulic Section initiated (1932) small-scale model experiments for tracing subsoil flow under structures on permeable foundations, by treating the sand in the model with a chemical and allowing another chemical to flow from one side of the work to the other through the sand. Arrangements were made to measure the pressures under the work at different points. The comparisons of the results with theoretical expectations pointed to the need for a mathematical technique to give more exact results and standard cases were successfully tackled from 1936 to 1940 to obtain the effects of various components of a structure on the pressure distribution under it. The physics section developed, at the same time, the electric analogy model for a rapid determination of the pressure distribution comparable with those given by theory and the hydraulic model.

In 1936, Khosla put forward his 'method of independent variables' for determining the pressure distribution based on the concept that each component had an individual effect and the superposing of these individual effects have the overall effect. The theoretical results and the laboratory experiments were used to verify and, where necessary, modify Khosla's method, which ultimately became the standard method, which ultimately became the standard method for the design of works on permeable foundations. This was indeed a signal contribution by a co-operative group of Indian workers to a difficult engineering problem.

Dr. A.N. Khosla made a name in the the field of Research through his work on seepage theory and design of weirs on permeable foundations. He was appointed the first chairmen of the newly constituted Central Waterways, Irrigation and Navigation Commission in 1945 and developed it into a front rank organisation. When Bhakra control of board was set up in 1950, Dr Khosla was appointed its Vice Chairman and Chairman of the board of Consultants. He remained associated with the project till its commissioning in 1963.He served as the Vice Chancellor of the Roorkee University from 1954 to 1959 and virtually transformed it from a small though reputed college to a leading technical university. In 1962 he was appointed as Governor of Orissa, the first and so far the only professional engineer to have been given such a responsibility.

Another name worth noting is that of Dr Kanwar Sain. He was responsible for planning of the gigantic planning of the gigantic Rajasthan Canal project still under completion. For nine years he worked on the planning of the complex Mekong River project under the auspices of the United Nations.

Another important contribution of those years was in regard to the design of stable channels in alluvium. The Institute developed, for the first time, appropriate scientific instruments capable of collecting and analysing samples of silt from irrigation channels. The results of analysis were processed to obtain the mean size of the silt and to correlate it with the other hydraulic elements of the channel.

Another field of study related to the engineering works connected with the control and training of rivers. This required comparatively large-scale methods and a field research station was opened at Malakpur in Gurdaspur District where the requisite facilities were available. This station, which was started around 1934, subsequently grew into one of the most advanced station in India and handled the model work for most of the important projects in the Punjab.

Yet another development was the large-scale work on land reclamation undertaken by Punjab Government in 1940. This ultimately led to a seperate department of Land Reclamation being formed under a 'Director, Land Reclamation'.

Immediately after partition in 1947, East Punjab set up a new Institute at Amritsar and work at the Malakpur Station was continued. Since then, the institute has grown considerably and has now been made a zonal institute for the North Zone, consisting of Himachal Pradesh, Jammu and Kashmir, Punjab and Rajasthan.

In the field of hydraulics, a substantial contribution was made in regard to the design of spillway and outlets for Bhakra and Nangal Dams and of the flood control, drainage and reclamation problems of Kashmir Valley.

The Hydraulic Research Station, Malakpur has been recognised to help and solve many complicated problems in connection with Beas Dam at Pong, Beas Sutlej Link-Part II, Sirhind, Ferozpur and Rajasthan Feeders and recently for Shah Nahar Project, Anandpur Hydel Project, Mukerian Hydel Project and the prestigious Thein Dam and its appurtenant works. The station specializes in developing sediment excluding devices from rivers and channels.

A Field Lining Research Station has been set up at Doburji (Near Amritsar) for Investigations relating to the economical specifications of lining material for reducing seepage from the earthen channels and water courses. Research for development of pressure release values behind canal lining is also being undertaken at this station. Excellent work regarding vortex suppressors in the intake has been carried out.

(13) Maharashtra Engineering Research Institute, Nasik

Considering the importance of achieving efficiency, economy and progress of large development works undertaken in the Bombay State, the State Government approved the creation of a Central Engineering Research Institute, and it was set up with headquarters at Nasik in 1959. On the creation of Maharashtra State and bifurcation of research station it has been redesignated 'Maharashtra Engineering Research Institute'.

The Institute carries out investigations on soil mechanics, materials testing, hydro-dynamic problems and public health and rural engineering. The Institute specializes in Environmental Engineering with special reference to water quality and its measurement throughout Maharashtra State. Recently field studies have been conducted on breaching and dismantling of Old Waghad Dam.

The Soil Survey Division at Poona does systematic soil surveys of the areas under the command of various irrigation projects in the state.

(14) River Research Institute, West Bengal, Kolkata

Due principally to the abandonment of the Bhagirathi-Hoogly course by the Ganga, many of the rivers of West Bengal have decayed and the drainage of West Bengal during the flood Season has been seriously affected. A Research Station to study the various river problems and to evolve measures for controlling the destructive causes of the dying rivers was set up in the State in the year 1943.

Investigations for foundations of hydraulic structures for borrow materials for construction of dams and soil surveys for irrigation projects have also been taken up. Facilities are also available for conducting aggregate and concrete tests. With the passage of time the institute has acquired specialization in a number of fields such as River training for the purpose of conservancy of the river, prevention of erosion and flooding, Navigation and irrigation, Design of channels, Meandering of streams and conservation of tidal rivers, Tidal computation, closure of estuaries, tidal channel and reclamation and Engineering properties of soils.

(15) Soil Mechanics and Research Division, Chennai

The Research Station was initially formed as Physics and Soil Mechanics Office in 1946. The Concrete Laboratory was established in 1947. In 1953 the two were merged to function as "Soil Mechanics and Research Division" of the Tamil Nadu Public Works Department. The Research Station had the benefit of guidance of K.L. Rao, the noted engineer statesman in the early stages.

The laboratory has successfully evolved Ennore sand as the Indian standard sand. This sand is now supplied to engineering research institutions and cement factories all over India and has resulted in considerable saving of foreign exchange.

The laboratory, in its thirty years of useful service has made significant contributions in the various fields of engineering research. Intensive soil investigation work has been carried out for all the irrigation projects executed in the state, regular quality control work has been organised. For building works, regular foundation analysis by load tests has been carried out for almost all major buildings. The station has done notable work on Design of Weirs on permeable Foundations of Finite Depth.

(16) Uttaranchal Irrigation Research Institute, Roorkee

A small Hydraulic station was established at Lucknow in 1938 to study the problems of scour and erosion below falls and bridges on irrigation channels. To meet the needs of an increasing number of problems, an Irrigation Research Station at Bahadrabad, about 20 km from Roorkee, started functioning in 1947. This Station was further expanded in 1955. Earlier it was known as Uttar Pradesh Irrigation Research Institute, Roorkee.

The activities of this Institute cover both basic and applied problems in hydraulics, soil mechanics, ground water, mathematics, physics, instrumentation, hydrology and measurement of discharges of rivers and canals. Specific problems concerning the development projects, such as river training and protection works, soils and construction material problems, etc., constitute its main activities, but the station has been also doing remarkable basic research work in a number of fields.

Few of the important contributions of the Institute relates to the design of the 1.8 m high dentated sill for dissipating energy below Sarda Barrage sluices, which had collapsed during the floods of 1956. This was the first kind successfully tested and adopted in India under boulder river conditions.

Hydraulic design of Surge tanks for all major projects constructed / under construction in Himalayan region and its computer simulation, design of gravel pack and prepacked filter for tube wells, design of stilling basin for low Froude Number, design of stilling basin for low Froude Number, design of guide bunds at bridges and barrages, intake structures, stilling basins, design of bifurcations and trifurcations for tunnels, assortment of river training problems, prototype load test, design of channels and evolving formula for design of channels, design of structures founded on stratified soils, design of barrages and canal regulators on three-dimensional flow consideration, etc., are a few of the fields of the specialization of the Institute. The Institute offers technical assistance not only to State Irrigation Department but to other States and departments. The Institute also takes up the foundation investigations for dams, power houses and other hydraulic structures, Instrumentation in dams, in situ testing of rocks and model prototype conformity studies. Recently due to reorganisation of states, this is now in Uttraranchal.

Reference

Water Resources Research in India, Publication No. 78 (Revised) CBI&P, New Delhi, 1979.