HYDRAULIC STRUCTURES, EQUIPMENT, AND WATER DATA ACQUISITION SYSTEMS

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Contents

Summary

In this theme the historical origins, modern developments, and future perspectives in the field of water supply engineering are discussed. Various types of hydraulic structures, their associated equipment, and the various systems for collecting data are described. The main topic categories are then dealt with, with particular reference to the individual articles elaborating each topic area.

1. Introduction

Hydraulic structures occupied a vital role in the development of civilization from the earliest recorded history up to the present, and undoubtedly will do so in the future.

Humanity in ancient times settled mostly near perennial rivers, nomadic people frequented oases and springs, and to augment these natural ephemeral supplies, established societies built primitive dams and dug wells (see "Uses and impacts of water from streams and rivers," EOLSS on-line, 2002).

Hydraulic equipment in early times was primitive, but there were some breakthroughs. For example, the use of a rope and leather bucket to extract water from wells and the like was replaced by a hand-operated lever and bucket (*shaduf*) or wooden capstan and winch. Wooden water wheels were developed to increase the efficiency with which humans or animals hauled water, and wooden sluices in embankment dams were developed to replace manual methods of water extraction.

Water data acquisition may perhaps initially have consisted only of noting the dry and wet seasons and making crude records of good and bad crop years. Only after calendars and writing implements became established in the Asian and Egyptian cultures were any systematic records kept, by scribes employed by monarchs and priesthoods in what later became civilized communities.

1.1. Historical Review

From these early beginnings, of which some elementary records are in existence, more rapid and definite developments in the above three fields resulted after the silk and jade trade routes became established in the East, and the Roman conquest, followed by the Crusades in the Middle Ages, opened up global cultural horizons to humanity.

Hydraulic structures such as groundwater extraction tunnels and wells (*qanats* in Persia), aqueducts (in Europe during the Roman Empire), ducted water and urban domestic supplies (Rome), and the first masonry dams (Iran and Iberia) were constructed, some dating back 2,000 to 3,000 years. A water tunnel, the Hezekiah Tunnel, conducted water into the ancient walled city of Jerusalem in what was formerly known as Palestine.

Hydraulic equipment advanced from the level of human and animal operated treadmills to extract water for irrigation from wells and springs, to wind-powered wooden pumps (windmills) to raise groundwater or to lower water levels in flooded areas for crop production; and improved wooden water-driven wheels for grinding grain and later for operating the first primitive factories.

Water data acquisition became well established during these times, with rainfall records dating back several centuries in the most developed areas. Groundwater levels have been recorded for several thousand years on the River Nile (*nilometers*) and annual flooding data was kept relating to crop raising in the Nile Delta area. Such stream flow stage records were of interest to establish safe levels for planting and living, and were also flood alerts for low-lying regions such as in the Dutch Province of Zeeland in Europe.

The Jin-Jiang reach of the Yangtze River in Asia and the Indus River of the Indian subcontinent have become noted for the construction and maintenance of *levees*. Only much later were flow rates recorded, in the past couple of centuries, when hydraulics became an established science in the era after Leonardo da Vinci. With the Industrial Revolution and the advent of steel construction, the invention of equipment such as sluices and valves, pumps and turbines became possible, and this heralded the rapid development of agriculture and industry, as water and waterpower became more readily available.

1.2. Present State of the Art

Up to the present day, the worldwide development of water resources and population growth seem to have kept pace with each other. Hydraulic structures include the tens of thousands of high dams and their voluminous water storage reservoirs. The hydraulic equipment associated with them comprises pipelines, valves, sluices, pumps, turbines, motors and power generating plants, operated by water power or fossil fuel power. By these means water can be intercepted or extracted, conserved and recovered, conveyed over long distances, and distributed over large areas. Water energy can be harnessed, along with wind, thermal, and tidal energy, for industrial and urban needs.

The conveyance systems for water developed mainly in the twentieth century include tunnels, canals and pipelines of proportions far exceeding the early *qanats*, aqueducts and conduits of medieval times. Sewer and drainage systems commensurate in size with the supply conduits became necessary and were developed. These developments also gave rise to heavy effluent loads on rivers, which came to have a double function as supply sources and drainage conduits.

More recently we have seen an over-extraction of water which has led to the lowering of groundwater tables, so that groundwater can only be extracted from an increasing depth. This has necessitated the development of short-term as well as long-term techniques to ensure that supply and demand remain in some balance. These again gave rise to supplemental developments such as bigger dams and reservoirs, longer conveyance routes, and the replacement of inadequate distribution networks.

More sophisticated hydraulic technology continued to be developed, resulting in better and more versatile pumps, turbines, prime movers, and energy generation systems. Water and wind power has been supplemented by fossil fuel power and nuclear power in the last few decades. Water treatment works for potable supplies and for disposal of used water developed rapidly over the last century, from the early slow and rapid filtration tanks to pressure filters, from settling tanks to clarifiers, from lime dosing to chlorination and ozonation, to the highly sophisticated physico-chemical processing of raw water as well as effluent.

Water data acquisition developed from mechanical discharge measurements by means of flumes (Parshall) and weirs (broad crested and Crump), flow meters (Venturi and orifice plate) to electronic-digital recording, data processing by computer. Magnetic and acoustic flow meters enable highly accurate data to be collected and analyzed, enabling an adequate quantity and quality of water to be distributed economically to users.

1.3. Future Perspectives

A look into the future shows that information databanks are being established for surface and groundwater resources worldwide. This is being achieved through the satellite surveillance of crops, rainfall, and runoff; the integration of water quality and quantity data, on a micro, meso, and macro scale; and through numerical modeling techniques which have generated the sub-science of *hydro-informatics*. Equipment is progressively replaced, updated, improved, and developed in the water supply, control, and monitoring fields, as better technology is developed. This applies to unit processes, pumps, turbines, flow meters, automatic controls, sluice gates and valves, other mechanical and electrical service equipment, and data transmission.

Hydraulic structures such as dams still benefit from greater economics due to improved construction techniques and materials such as roller-compacted concrete and high-tensile steels; designs such as multiple-arch dams and concrete-faced rock-fill dams; equipment such as fuse-gates, bulb-turbines, and submersible pump motor units; energy generation such as wind power, tidal and wave power; tunneling techniques such as tunnel-boring machines (TBMs), concrete segment-lined and plastic-lined water tunnels; and pipeline materials and canal linings of higher strength and tenacity. Unit processes, such as water and effluent treatment and conditioning, desalination, cooling, thermal energy extraction, and chemical industries, have developed into a great complexity of applied hydraulics.

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Biographical Sketch

Jan Malan Jordaan was born in 1932 in Cape Town, and raised in Bloemfontein and Pretoria, South Africa. He obtained his B.Sc. Eng. Civil at the University of the Witwatersrand, Johannesburg in 1952, and joined the Irrigation Department of South Africa, now known as the Department of Water Affairs and Forestry. While on study leave from 1953 to 1958, he obtained the SM Degree at the University of Wisconsin, USA and the CE and Sc.D. Degrees at the Massachusetts Institute of Technology, USA. He then returned to South Africa, resuming work with the Department of Water Affairs in Pretoria until 1959. He joined the South African Council for Scientific and Industrial Research as a Research Officer until 1963, involved with mainly coastal engineering research and its applications.

He was a Hydraulic Research Engineer on ocean wave research at the US Naval Civil Engineering Laboratory, Port Hueneme, California, until mid-1965, Associate Professor in coastal engineering and tsunami research, University of Hawaii from 1965 to 1968, and Associate Professor, University of Delaware, from 1968 to 1969. He then resumed employment with the Department of Water Affairs, Pretoria, where he was active in hydraulic engineering design for almost twenty-eight years until his retirement in 1997 as Chief Engineer Design Services. During this period he was assigned to the P. K. le Roux Dam and the Van der Kloof Canals Construction Project for two years; and for seven years in Namibia (then South West Africa) in the branch of the same department, as Chief Engineer, Investigations, dealt with aspects of water resources, hydrology and construction.

In 1985 and 1987 he was temporarily seconded to the Department of Foreign Affairs, and acted as Technical Assessor in Bolivia for the Misicuni Hydroelectric and Water Supply Project for Cochabamba Department. He was also sent as observer to Grenoble, France in connection with the model studies done by SOGREAH for the Lesotho Highlands Water and Power Project. He also visited Britain, Spain, Portugal, Germany, Norway, the Netherlands, Hungary, Egypt and the Sudan, China, and Taiwan in connection with official duties.

He is a registered Professional Engineer in South Africa, retired Fellow Member of the South African Institution of Civil Engineers (SAICE), Member of the American Society of Civil Engineers (ASCE), Fellow Member of the Indian Association of Hydrologists, Roorkee, and was Member of the International Association for Hydraulic Engineering and Research (IAHR). From 1989 until 1998 he was part-time Professor of Hydraulic Engineering in the Department of Civil Engineering at the University of Pretoria, and until the end of 2000 was a part-time guest professor of the Water Utilisation Division at the same University.

His major publications include a chapter in *Advances in Hydroscience* (1970, Academic Press, USA) on laboratory experiments with impulsively generated water waves; a chapter co-authored with Prof. J. A. Williams in *Tsunamis in the Pacific Ocean* (ed. Prof. W.M. Adams; East-West Center Press, Honolulu, Hawaii, USA); co-authorship of “Water in our Common Future” (1993, COWAR, UNESCO); editorship of the SANCOLD volume, *Large Dams and Water Systems in South Africa* (1994); and co-authorship with Dr Dan Batuca of Romania of *Silting and Desilting of Reservoirs* (2000, Balkema, Rotterdam, the Netherlands).