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Design for effective implementation and efficient operation

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1. INTRODUCTION

The design of water supply projects in developing countries must be related to the implementation resource constraints and to the operational requirements of the user. This paper discusses the practical approach to design and implementation philosophy with particular reference to treatment plant design and the Matara Water Supply Project in Sri Lanka.

The long term operational objectives of a water supply scheme must be to operate a supply system at minimum local and foreign expenditure, within levels of technical competence and to generate sufficient revenue to meet both operational and capital repayment costs. Design and implementation philososphy should reflect these objectives.

2 DESIGN PHILOSOPHY

2.1 Feasibility and Ranking of Options

Each project has its own unique source and demand centres, supply requirements, topographical features and particular problems. Having identified feasible supply systems based on alternative sources or conjunctive use, principal components need to be sized. Capital costs in both local and foreign currency together with operating costs for each option need to be estimated.

Ranking of options is normally undertaken on a purely financial comparison, but we would suggest ranking factors be extended to include:

- finance, both in foreign and local costs
- source reliability
- operations

The relative weightings given to these factors need to be considered for each project. Where projects are internally funded a greater weighting should be given to local costs rather than foreign costs; conversely where external funding is available a different weighting would apply.

Funding Agencies, particularly bilateral ones, are keen to provide external funds but not local and this distorts the "clean" ranking. There is a tendency to limit the availability of foreign exchange for plant and equipment which may not be entirely suitable for the design; this should be avoided.

Phased development of new projects in relation to demand growth projections needs to be carefully considered; very often extra system supply capacity is provided too early and the additional capital costs are reflected in higher unit water costs. Consideration could be given to smaller augmentation phases with the system base designed to achieve this objective.

The operational factor, which is subjective will depend on the number of components in the system, the level of technology and energy and chemical consumption. The reliability factor is also subjective and is based on both source and system reliability. How will the sources react to drought conditions? Will the supply system work in a power cut? Have standby generators been included? Are there alternative supply sources/systems if one fails for any reason? The overall ranking may be determined by a summation of the weighted rankings of these defined factors.

2.2 Design Philosophy

To achieve the defined objective the following principal criteria should be considered:

- straightforward system and process design
- a level of technology appropriate to the ability of local staff to operate and maintain
- minimum dependency on imported spares
- minimum energy costs and making the best use of gravity where possible
- minimum chemical requirements

These criteria are inter-related, but the overall philosophy is for straightforward, easy-to-maintain, minimum energy systems. Means to simplify process design are discussed in the next section.

It is important to assess the level of competence of operatives and maintenance staff and the degree of complexity of plant which they operate. Feedback from existing supply systems is important and can show the drawbacks of earlier designs. Keep design simple, use basic well tried and robust pumping systems, avoid complex telemetry and hydraulic control systems, complicated pumps and mechanical plant. Use simple electrode and high pressure cut-outs for pump operation; remember labour is relatively inexpensive and provides local employment and security. Often plant breaks down and cannot be repaired because of few qualified maintenance staff.

Reliance on imported spares should be minimised through stocking of sufficient spares at initial purchase. Individual spares ordered at a later date tend to be more expensive. Local enterprise should be encouraged to manufacture spares, perhaps on licence from the supplier to meet these needs more economically.

Energy costs tend to inflate at a greater rate than normal inflation, and emphasis should be given to energy efficient designs. Operational ranking should favour minimum pumping schemes; therefore, wherever possible use should be made of gravity systems, perhaps at higher initial cost but showing long term advantages. Solar pumping may be a feasible alternative for small supplies.

Chemical requirements are dependent upon process design. In developing countries chemicals tend to be expensive and sometimes difficult to obtain. KEEP IT SIMPLE should be the "motto" by using commonly available chemicals - Alum, lime etc and avoid polyelectrolytes and similar compounds.

2.3 Water Treatment

By way of example this design philosophy is related to a typical medium-sized new water treatment plant at Matara, Sri Lanka. Here, careful thought was given in defining process and performance requirements to achieve a straightforward treatment system. Whilst process design was the responsibility of a treatment plant supplier, the performance specification was specific and detailed, applying the design philosophy to treatment units. A schematic arrangement is shown in figure 1.

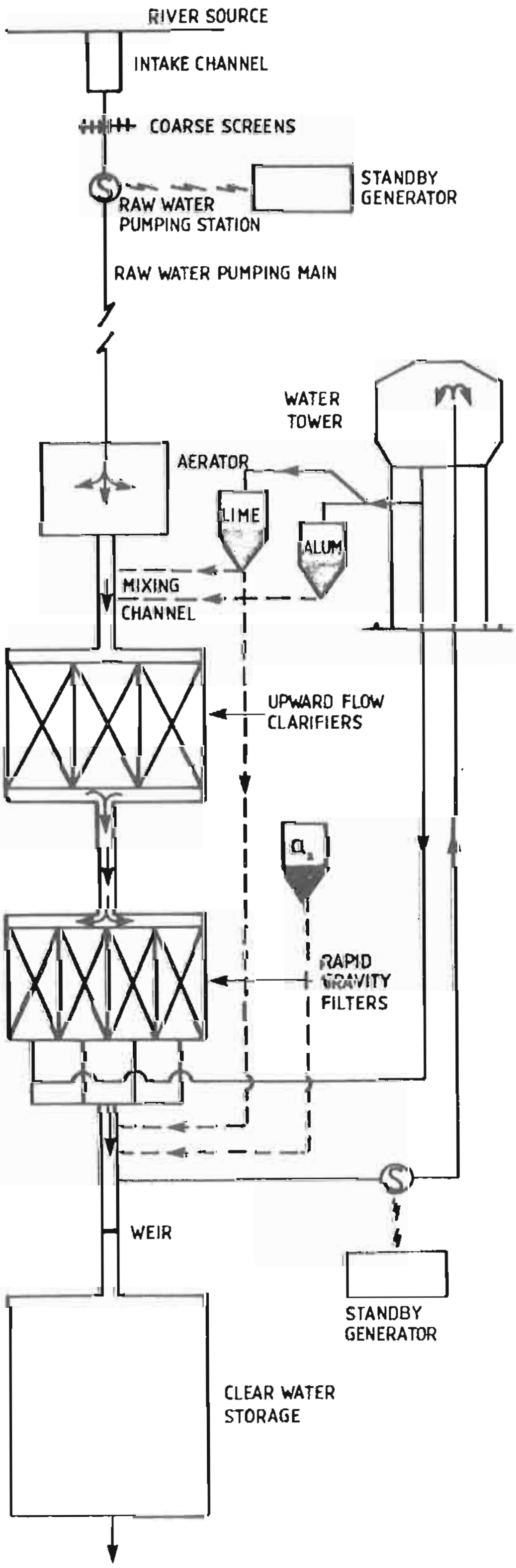

FIGURE 1 - SCHEMATIC ARRANGEMENT OF NEW WATER TREATMENT WORKS AT MATARA

Aeration

- important for removal of taste and the oxidation of iron. a simple process using side weirs and with no moving parts, using local materials.

Chemical Mixing

- Hydraulic mixing in the inlet channel using baffles; no flash mixers were required and no energy input.

Sedimentation

- Hopper-bottom upward-flow clarifers with no mechanical equipment were used and no power needs. Only pipework and sludge concentrators were required. Mechanical scrapers in horizontal or circular tanks were avoided as they are difficult to install correctly and have a relatively short life; external funds may not be available for replacement. Avoid pulsators again because of electrical and mechanical plant, design life and maintenance problems; however, fixed inclined plates may assist floculation in some instances.

Chemicals

- Low cost chemicals ie alum and lime are used. Polyelectrolytes are avoided. Gravity alum dosing is carried out after mixing in the upper floor of the chemical house. However lime needs to be kept in suspension by pumping.

Filters

- Slow sand filters were considered because of low maintenance, low technology and no power requirements. However, this was not practical because of the greater land requirements.

  Rapid gravity filtration was proposed, with the controls kept simple - removal of all hydraulic control systems - removal of all flow controllers - simplification of the control system to a butterfly outlet control valve with mechanical linkages and manual start-up and use of manual power for all valving. There is a need for airblowers but these are basic small units and should present few mechanical problems and low energy needs.

  Savings may be achieved by eliminating large capacity backwash pumps and using an elevated tank instead; this could be filled using smaller duty pumps operating over longer periods. The supply could also be made available for chemical mixing and local uses. Whilst the initial local capital costs may be higher, the savings in foreign exchange on larger pumps and associated equipment and its maintenance could be substantial.

Chlorination

- There is a need to install reliable and well tried equipment which is available. If the supply of gaseous chlorine is unreliable an alternative dosing system using chloros powder should be incorporated at the design stage and not left to improvisation by the works superintendent later. Remember this is an essential treatment process.

Flowmeters & Controls

- Avoid complex control system if you can! Pressure differential flowmeters are preferred because of minimum maintenance within the pipe system but basic maintenance of the recorder/indicator is still required.

To summarise, the philosophy on water treatment plant design is to keep all the processes and equipment straighforward and easily manageable. One should not be influenced by bilateral funding agencies wanting to make their scheme a "showpiece" for the latest technology - there may be no cost to the user at commissioning but when things go wrong, as inevitably they do, it could be expensive to rectify.

3 REHABILITATION

Rehabilitation of existing supply systems and treatment works is most cost effective as both the long term life of the plant is extended and also large capital expenditure is deferred. In the existing Nadugala treatment works at Matara, the throughput of the works was raised from 5000 cu m/day to 9000 cu m/day as a result of minor refurbishment works.

The three existing hopper-bottom type clarifiers were originally arranged on a primary/secondary basis with a maximum upward flowrate of 3.7 m/hr. The clarifiers were reconnected in parallel and the design flowrate of 2.1 m/h was able to pass the 9000 cu m/day. There was little difficulty in settling these flows.

In the rapid gravity filters, the sand was replaced and the flow controllers and instrumentation refurbished to accommodate a new loading of 5m/h. In the course of refurbishment, the opportunity was taken to simplify filter controls and ease future maintenance and spares problems. Rate of flow control is now achieved with new butterfly valves with a free outlet above sand bed level. This eliminated expensive replacement of rate-of-flow controllers and associated hydraulic systems.

Improvements to the chlorination system were undertaken and refurbishment of some items of the chemical dosing systems. A new raw water pump was installed at the inlet and because of changed pump duties, new clear water pumps were installed. Additional lime dosing was undertaken to raise the pH.

Rehabilitation may also be applied to trunk and distribution systems through

- leak detection and repair
- relining of old pipelines

The former can be cost effective in both saving treated water as well as possible deferment of future capital expenditure, however, the costs and benefits are unique to each project and an assessment of leakage, detection and repair costs against savings must be undertaken to justify the approach.

4. IMPLEMENTATION

4.1 Objectives

The overall objective of the implementation stage is to complete and commission the project within the given restraints of time, and financial, technical and human resources. To achieve this objective early consideration and planning is required at an early stage in the Project Appraisal.

4.2 Criteria

The principal criteria to be considered for effective implementation include:

- overall programme and resource balancing
- procurement of materials and equipment
- construction by contractor or direct labour
- commissioning and staff training

in addition to the establishment of a project team within the implementing authority. An efficient team of client/consultant is required for overall management from inception to commissioning; it is important to provide this continuity of staffing of both client and consultant for the efficient and timely completion of the project.

4.3 Overall programme and resource balancing

There are many factors affecting overall programme. Completion dates are sometimes determined by political needs; it is often necessary to phase completion of certain sections of the project to meet interim needs and show early financial returns. The programme will depend on financial resources, either offshore or local, being made available. Sometimes government departments/or funding agencies towards the end of the financial year have surplus money available which they cannot carry forward. Hence the need for the next phase design or document to be ready on the shelf!

In medium to large size projects, the impact of construction work on existing limited human and financial resources can be significant and market costs of labour and local materials could rise with detrimental effects on other local projects. It is therefore important to consider means of reducing this impact and balance resource requirements.

4.4 Procurement of materials and equipment

The procurement of materials and equipment requires a long lead time within the project and often takes even longer than planned. It is therefore important to:

- establish procedures and clear lines of communication with all concerned;
- identify at an early stage actual material/equipment requirements and related supply contracts
- closely co-ordinate all stages from appointment of supplier to equipment inspection, shipping and delivery to user.

Procedures need to be established at an early stage between Funding Agency, Implementing Authority and the Designers, whether they be Consultants or in-house Designers. Lines of communication need to be clearly defined and KEPT SIMPLE, something which is difficult to achieve under present procedures which tend to be lengthy, complex and can significantly delay the completion of the work and hence benefits to the users.

There may be scope for a Procurement Manager, who may indeed be the Designer or Consulting Engineer appointed by the Funding Agency (or agencies) who would:

° procure equipment under defined (and simplified) procedures;
° undertake inspection services, and organise shipping and insurance;
° arrange clearance and delivery to site; and
° manage a procurement fund under specific budget targets.

There is a need to identify, under a shopping list, specific requirements for pipes, pumps, electrical equipment, treatment plant and ancillary equipment, prepare tender "packages" and prequalify suppliers. In addition, feedback from technical resource analysis will define requirements for small tools, workshop equipment and larger plant equipment such as cranes (do not forget pipes need to be lifted!), but care is required to keep such equipment simple and easy to maintain.

As examples, ductile iron pipes may be cut just as easily, if a little longer, with a hacksaw then with a power cutter; a cable operated crane is preferable to one with hydraulic systems.

Requirements for spare parts need to be carefully considered and one should not rely completely on manufacturer's recommendations as they often leave important items out.

Some examples of problems are given here; many are commonsense, but often are overlooked:

° despatch the pipe jointing and handling equipment with the first shipment; similarly ship pipe fittings with associated straight pipes together. Invariably pipes are manufactured quicker than fittings and manufacturers are keen to be paid on delivery!

° Include sufficient spare items to make up for losses and damage.

° do not send expensive tools which are difficult and expensive to maintain.

° Ship in containers where possible, for greater security, especially for smaller items.

° Many difficulties arise from missing and incorrect Shipping Documents; careful checking and despatch is required.

° clear lines of communication at the receiver's end, through Customs, Port Officials, Government Departments and Implementing Agencies.

° give careful thought to local transport, handling, unloading and storing, particularly with delicate items - don't store PVC pipes in the sun!

4.5 Construction

Construction may be undertaken by international or local contractors or by direct labour depnding upon the size of the work, its complexity and funding arrangements.

At the design stage, careful thought needs to be given to how the structures are to be built, the type of materials to be used, the temporary works construction requirements and the complexity of the works. To keep costs down, encourage the use of local contractors, giving employment to local artisans. Detailed designs need to be carefully thought out, be kept simple and easy to construct. This does not mean that construction standards be relaxed; good concrete can be made with close inspection using volume batching, small mixer and traditional placing methods.

There is a need to develop and improve construction techniques, particularly in pipe laying and testing and the role of supervising engineer is to assist and guide as well as supervise - the conventional engineer/contractor relationship may be relaxed.

Very often local contractors have a limited financial base and delayed payments by clients have a marked effect on cash flow and hence construction progress is affected. Whilst close financial control is required for all contracts, measures should be taken to help contractors with their cash flow - it all assists in timely completion.

Direct labour works often have advantages where the work is closely related to existing supply systems, difficult to measure is disjointed or labour intensive; for example plumbing for house connections, modifications to existing treatment plants and small diameter pipe-laying; sometimes there is political motivation for direct labour works.

4.6 Commissioning and Training

Both commissioning and training are essential elements in the successful implementation of a project and consideration needs to be given at design stage to the identification of staff requirements for operation and maintenance, definition of job descriptions and training requirements. It is important here to get feedback from similar earlier projects to see where they were successful and where they were less so. Operating staff should be involved during plant installation to become acquainted with all the equipment and during commissioning to be able to effectively operate the works.

5 SUMMARY

The overall objective of a successful and timely completion to a new project should not be overlooked because of the mechanics of implementation.

To achieve this objective requires careful planning and design at an early stage in the Project to include:

- straightforward designs for ease of operation
- correct level of technology
- minimising energy requirements and chemical needs
- reducing dependancy on imported spare parts

but do not forget rehabilitation.

REFERENCE

Peiris N D and Jones J N S. Matara Water Supply Project in Sri Lanka. <u>AQUA Vol 1 1984 - Journal of the International Water Supply Association</u>