archived. In Egypt, for example, this is being done by the Field Investigation and Design Directorate of EPADP.

In the feasibility study, the major drainage works are designed to that degree of detail needed to allow the quantity of engineering work to be estimated to an accuracy of some 10%. It should be in sufficient detail to allow cost estimates to be made.

All project activities should be described in detail, starting with the field investigations, and progressing, via design and tendering, to construction and project implementation.

A further important aspect to be dealt with is how the project should be executed and operated, and what organization will handle this task.

18.4 The Post-Authorization Study

After the feasibility study has been completed and the most appropriate drainage system has been selected, a post-authorization (or design) study should be made. This study should start with the preparation of a basic map, making use of existing topographic maps with relevant field characteristics and boundaries. If necessary, the maps can be checked and updated from recent aerial photographs. Next, the working map should be checked in the field, especially the widths of roads, open drains, canals, and bridges, and perhaps the exact location of trees and buildings. For the basic map, a scale of 1:10 000 or 1:5000 is recommended.

The definitive project design is made on this basic map. It may happen that, apart from the data collected in previous surveys, additional data will be required before the construction design and detailed cost estimates can be made. If, for example, there is any doubt about the applicable drain spacing, additional measurements of the hydraulic conductivity should be made.

The post-authorization study encompasses the following components:

- The preparation, on the topographic map, of the alignment of the main drains, collectors, laterals, interceptor drains, relief drains, and pipelines. The spacing of the collectors is often determined by the standard length of the laterals. The collector alignments are further fixed by the field boundaries. The length of a collector is restricted either by a field boundary or by the available slope. The available slope is fixed by the shallowest permissible drain depth, the maximum water level in the main drain, and the slope of the land surface. It is customary to draw up various alternatives for the collector layout, from which the best solution is selected. Next, the collector alignments, and more specifically the levels, are checked in the field.
  The use of sub-collectors involves a greater collector length, a more complicated system, and higher costs. The advantages of using sub-collectors, however, are that the laterals can be designed parallel to the minor infrastructure, thereby avoiding an excessive number of crossings. The length of the laterals is determined either by fixed boundaries or by a fixed length, whereas the lateral spacing and depth are indicated on the maps.

It is often decided to place the laterals perpendicular to the collectors. If so, it may happen that the laterals do not run parallel to the minor infrastructure. In such a case, it is advised to install the laterals at such an angle with the collector that the number of crossings with the minor infrastructure is minimized (Other aspects of layout will be discussed in Chapter 21);
- Surveying and plotting the length profiles and cross-sections needed for the design and for estimating quantities. The cross-sections of the main drains are drawn at a scale of about 1:200, whereas the longitudinal sections are drawn at scales of about 1:10 000 for the horizontal profile and 1:100 for the vertical profile;
- Investigating the geological features and the groundwater characteristics and any necessary testing to determine the channel stability;
- Determining all other structures and appurtenant facilities to complete the design (e.g. bridges, culverts, inlet structures to open or close drains, floodgates, pumping facilities, dikes). The necessary information for the hydraulic foundation and structural design of each facility should be collected;
- Drafting the construction specifications for the various work items;
- Estimating the needs and costs of additional necessary improvements (e.g. land grading, land smoothing, extra field drains, and other drainage structures not yet incorporated in the project design);
- Estimating the quantities and costs of all project features.

The post-authorization or detailed design study is generally done by a special department of the authority responsible for the execution of drainage projects. In Egypt, for example, the Field Investigation and Design Directorate under the Research and Design Department of EPADP is responsible for all pre-drainage investigations and the design of field drainage works. In Pakistan, specially-created project directorates within WAPDA are responsible for these activities.

For more details on the design of subsurface drainage systems, see Chapter 21.

The design of drainage networks in Egypt, which changed from a manual system to a computer-aided one, is described in detail by Camel et al.(1991). They have shown that the complete computerization of drainage design, with digitized inputs and outputs, is technically possible in Egypt, but not yet realistic or economically feasible for daily use. Fully computerized procedures require not only very accurate input data, but also expensive digitized maps. Therefore, the Egyptian authorities have chosen an intermediate solution of computer-aided design. Its main characteristics are:
- Processing and storing field data in the computer;
- Drawing the layout of the drainage system by hand;
- Calculating the drain spacings with the computer;
- Calculating the collectors and subcollectors with the computer;
- Calculating the list of quantities with the computer.

The advantages of the computer-aided design over the manual design are, among others, the reduced costs of excavation and construction as a result of a more exact design level of the collectors and the use of smaller diameter collector pipes.

18.5 Implementation and Operation of Drainage Systems

18.5.1 Execution of Drainage Works

Drainage works are generally executed by a contractor under the supervision of the public drainage authority. A contractor is selected by tendering, usually from a list of contractors drawn up by the authority in a pre-qualification process. It is customary to award the contract to the lowest bidder.

In the execution of drainage projects, four phases can be distinguished: preparation, execution, inspection, and registration of data. This has been extensively described by RIJP/EPADP (1985) and summarized by Abdel Fatah Salman et al. (1991).

During the construction of the drainage system, the work should be inspected. This inspection should cover both the total output (quantity control) and technical factors (quality control). Both types of inspection should be done regularly during execution because this enables any faults to be corrected immediately.

In Egypt, the contractor keeps records of the progress in the schedule of drainage execution in his office. Figures are prepared on the designed schedule, the estimated schedule, and the actual schedule, on the stages of execution for the main collectors, on the progress of laying lateral and main collectors, on the production of cement pipes, and on payments made to the contractor by EPADP. This gives a good insight into the progress of drainage construction.

Also in Egypt, time-and-motion studies on the capacity and productivity of drainage machines have been conducted since 1982. These studies have revealed the worsening condition of the older machines, which can be avoided by efficient management and good maintenance, repair, and driving. In-service training has improved these factors to such an extent that the organizational losses have been reduced by 20% and the net operating time of drainage machines has been increased by 25% (Abdel Fatah Salman et al. 1991).

18.5.2 Operation and Maintenance of Drainage Systems

A subject that is often overlooked is the operation and maintenance of drainage projects after they have been implemented. The institutions charged with this task are often inadequately equipped for the job. This could either be the result of inadequate financial resources, or because of institutional, technical, and managerial weaknesses.

During the construction phase of a drainage project, an operation and maintenance unit should be established in the field, and its staff should be trained. This unit will have to undertake a considerable amount of preparatory work in formulating a plan to operate and maintain the project.

Apart from routine operation and maintenance work, major problems in maintaining open drains may include erosion, settlement, sloughing, silting, vegetation, and seepage. For the maintenance of pipe drains, the problems may be physical blockages, organic and biological blockages, chemical or mineral sealing, and outlet restrictions.

In Egypt, a department within EPADP has been charged with this task. In Pakistan, after completion of the Project and a bridging period of 18 months, WAPDA will hand over the Project and its operation and maintenance to the Provincial Irrigation Department.

For more details about the management, operation, and maintenance of drainage systems, see ICID (1989) and Johnston and Robertson (1992).

18.5.3 Monitoring and Evaluating Performance

A government needs to make a quantitative assessment of the effectiveness of its investment in drainage. This will ensure that the best possible use is made of the funds to be spent on future drainage works. A monitoring and evaluation (M & E) program could make such an assessment and could contribute to the development of suitable planning criteria.

It is recommended that a drainage project be regularly monitored and evaluated, in terms of both its physical and its economic aspects. This will show whether the project is functioning properly. Monitoring and evaluation should usually be considered from a long-term viewpoint and should be based on parameters that are relatively easy to evaluate.

Consideration should be given to proper collection, storage, and retrieval of data. This is of the utmost importance for the subsequent physical and economic analysis of the project.

In a drainage monitoring program, the items to be considered are:
- Crop production;
- Drainage water quantity and quality;
- Groundwater quality and level;
- Soil salinity.

In Pakistan, within WAPDA, the SCARP Monitoring Organisation (SMO) has been entrusted with the monitoring and evaluation of the impact of drainage. In Egypt, within EPADP, a specially designated Monitoring and Evaluation Directorate fulfils this function. Currently, a program is being pursued with the following objectives:
- To continue the monitoring of soil and water characteristics that was initiated in the eighties, and to add to that the collection of crop-yield data;
- To evaluate the impact of drainage on crop yields;
- To develop planning criteria for the priority-ranking of areas still to be drained or to be rehabilitated.

To meet these objectives, the Directorate plans to collect data on watertable depths, soil salinity, crop yields, and to observe the presence or absence of discharge in manholes and collector outlets.

This information is expected to provide quantitative relationships between crop yields and the physically constraining factors of soil and water, and to gain an insight into how greatly drainage works can influence these factors.

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