Rural hydraulic engineering

Contents

1. Scope

Hydraulic engineering can be **divided** into the following areas:

- large-scale hydraulic engineering
- (small-scale) rural hydraulic engineering and
- river and canal engineering.

In brief, **"rural hydraulic engineering"** can be said to cover the following **water management works** carried out **in rural areas**:

- **weirs and bottom sills** for retaining water for use in small hydroelectric power stations, for irrigation and water supply, and for regulating watercourses;
- **head races** (receiving bodies and drainage systems) for receiving discharged water;
- **detention basins** for flood protection in smaller watersheds;
- **small earth dams**, low in height, for the storage of water and for flood protection;
- **bank and bed stabilisation work,** erosion protection measures;
- **channelisation** (embanking) of watercourses.

These works are generally carried out for **economic reasons**, either for improved **utilisation of water resources** for humans, animals, production (agriculture, industry) or services, or to **prevent damage** being done by the water itself (floods, erosion; this also includes consequential damage caused by poorly executed construction work).

Most rural hydraulic engineering work may produce **structures serving both productive and protective purposes**. For example, a small reservoir may be used not only for water supply but also for retaining rainwater and hence for flood protection and also for fish production.

2. Environmental impacts and protective measures

2.1 Overview

Hydraulic engineering work in rural areas exerts an influence on the environment, and constitutes **interference with nature and the landscape**; changes in the natural conditions and hence in living conditions may be **brought about** by:

- **construction work** on water and land, and the associated interference with the natural discharge regime, groundwater balance and regional water cycle and
- the resulting **use** of water resources by man and animals, for production (agriculture, industry) and for services.

Prerequisites for environmentally and socially orientated rural hydraulic engineering work are that:

- the **planning** must take account **of all the defining conditions** and of their **consequences** (including long-term consequences) and the works must be sized in the light of reliable estimates of demand and **growth in demand** and of the beneficiaries' **ability to pay**,
- **interference** must be **minimised**, adverse effects must be reduced by taking **corrective measures**, and **irreversible processes** must **not be allowed to occur**.

As far as economic use is concerned it is important to alert the responsible workers and participants, through **increased awareness/training**, **to environmental impacts** and ways of avoiding or reducing them, and to ensure that the works will be usable in the long term **(operation/maintenance)**; these factors must be taken into consideration as early as the planning stage.

The possible **environmental impacts and environmental protection measures** resulting from construction work relate to the **following spheres:**

(A) THE NATURAL ENVIRONMENT:

(a) the physico-geographical sphere and
(b) the biosphere

(B) THE HUMAN SPHERE: with all its social, socio-economic and socio-cultural aspects (including the use made of water resources) and the effects on human life and quality of life.

The impact of rural hydraulic engineering works tends to be **localised**, and because of this, **less serious interference** and less severe environmental damage can be expected than from large-scale hydraulic engineering and river and canal engineering.

2.2 Weirs and bottom sills

2.2.1 Objective

Weirs and bottom sills are constructed mainly with the intention of **impounding water** so that it can then be **abstracted from the impounded body of water** for various purposes. In most cases the water is extracted in **free fall** by means of a discharge channel (see also 2.3: Headraces) or pipe but abstraction by means of **syphons** or pumps (manually, animal or motor-operated) is also possible.

Weirs generally constitute **a greater interference** with the natural watercourse than **lower bed sills**, but both structures **alter the discharge conditions**, such as channel cross-section, gradient, and bed roughness and hence volume and velocity of discharge. Because they reduce the flow gradient most **bottom sills** merely perform the tasks of **stabilising the river or stream bed** and **reducing bed and bank erosion.** From the hydraulic point of view **small weirs** operate on the same principle as large impounding weirs, but the **intensity of the impacts** on the environment is generally much **smaller.**

2.2.2 Natural environment

(a) Physico-geographical sphere:

There will be impacts on the water balance, and particularly on the **groundwater conditions**, downstream of a small weir only if the quantity of water abstracted is a relatively high proportion of the undisturbed discharge of the watercourse (e.g. only if the weir brings the discharge below the mean low water discharge (MLQ). However, if the **total discharge** is abstracted, which rarely happens, the **watercourse** will **run dry** and the **groundwater level** will **drop.** It much be checked in each particular case, and an estimate made from the results, of whether and how the quantity of water abstracted (less the losses, e.g. as a result of utilisation) can be returned to the watercourse or groundwater aquifer concerned. In doing so it must be **considered** very carefully whether 100% abstraction **is justified** in the light of the serious impacts on the water balance downstream.

If the **quantity of water abstracted** is **returned** to the river a short distance downstream of the weir (as in the case of small hydroelectric power stations, for example), an impact occurs in the **intervening section**, e.g. due to interruption in the transport of sediment and bed load caused by their trapping in sand.

If the water abstracted is used in the area close to the banks for **irrigation,** it can generally be expected that a high proportion will return to the watercourse above and below ground as **drained and percolating water**. However, use of the water for irrigation agriculture, which must be regarded as beneficial, has accompanying adverse effects such as **salination** or other **changes in quality** of the water used (due to fertiliser and pesticide incursion etc.), which may lead to a considerable deterioration in the **quality of the watercourse** over long sections.

Depending on the suspended matter and bed load carried (i.e. depending on the soil type and plant cover in the watershed), the **river bed** will **silt up** particularly heavily in front of the weir (more rarely in front of the bottom sill), thereby causing the channel cross-section and the water level to vary. This may result in **waterlogging of the riparian areas**, which may even extend to **flooding**, so that as in the case of large river structures, embankments may be necessary upstream to act as **protective structures**, which in turn constitute an interference with the environment and landscape. Their consequences must also be considered.

Variations in the watercourse level may also affect the **groundwater level**, depending on the hydrogeological conditions. Thus a stabilising effect, which in some cases even raises the groundwater level, extends upstream from the area of the weir impoundment, whereas downstream there may be a **lowering of the groundwater level**. However, the effects of minor, isolated measures, are only of **local** significance, although a **string** of small weirs may have a **more far-reaching effect.**

Erosion resulting from sediment retention at the weir may occur downstream, depending on the nature of the watercourse bed.

(b) Biosphere:

Plants can react extremely **sensitively** to variations in groundwater level, and among other factors, the **quantity of available water** affects **species diversity**.

For example, if the **river bed runs dry** for a prolonged period downstream from a small weir, due to relatively heavy abstraction in the dry season, this will cause **damage to the variety of species of fish, insects, birds** and other **local species.** Furthermore consideration should be given to the division into upstream and downstream regions caused even by small weirs, in terms of their impacts on **living and migration conditions of fish** (fish ladders may be needed).

Upstream from weirs **dormant water areas** may be formed due to the change in flow regime, and in these areas the oxygen intake is greatly reduced. The consequences of this may be either **disturbances to the fauna** in the water or the **growth of pathogens**, which are in turn transmitted to man and animals through the water.

Further negative impacts on the environment may arise due to the clearing of forests and the construction of access roads required to **erect the structure**.

2.2.3 Human sphere

Hardly any negative effects may be expected if there is **expert planning** and if at the same time the **interests of the population, the area directly adjacent to the river** and existing **water rights** are considered (no measure must do harm to the downstream area).

The possible formation of **dormant water areas** upstream from weirs, with reduced oxygen intake and the growth of waterborne pathogens, poses a potential **health risk.**

However, it must be determined in each case what effect the project measures have on the **work load on women** given the sex-specific division of labour in the traditional areas of water collection, agriculture, etc. and on their economic situation.

2.3 Headraces/receiving bodies

2.3.1 Objective

Headraces are set up to **discharge water from weirs** and other river abstraction points. When in the form of **artificial receiving bodies** they also absorb the **seepage and drainage water** from adjacent (in some cases agriculturally used) areas flowing into them by force of gravity, and are therefore used to **avoid waterlogging**.

2.3.2 Natural environment

(a) Physico-geographical sphere

The construction of headraces/receiving bodies constitutes **interference** with the **slope** or **terrain**. It must be ensured, through the **choice of suitable parameters**, and depending on the soil material, the construction method and the size of the canal (width, depth, water supply):

- that the stability of the slope is not impaired by the cutting in the slope to the extent that landslips occur;
- that **seepage flows**, extending to escapes of water, do not cause landslips and erosion at the foot of the slope or embankment where they are too steep and/or are leaking. Subsequent rainfalls may considerably increase the damage, giving rise to additional damage due to the **erosion** of unplanted outer embankments. Moreover, gust of winds may erode inner embankments.

(b) Biosphere

Negative impacts are caused by the above sources of **erosion** and **landslip.** Otherwise the headrace/receiving body may have a positive effect, as a **small biotope**, on the flora/fauna along its route, as many examples show (e.g. in the Peruvian Andes: vegetation along the old Inca canal routes in otherwise desert-line areas).

2.3.3 Human sphere

Direct negative effects are not expected. However, they may occur as **secondary effects** with injuries to man resulting from landslips (including flooding).

2.4 Detention basins

2.4.1 Objective

Detention basins serving as **protective structures** for **averting the risk of flooding** in small, rural catchment areas, affect all spheres; negative effects may therefore be expected from inexpert planning/execution of the work (failure of the structure) and due to incorrect operation of the plant. The determination of the highest high water level, required for **dimensioning** both the detention basin and the barrier structure, is often extremely difficult in many countries because of the **lack of basic water resource data**. However, it is not always possible to plan on the safe side for reasons of cost.

2.4.2 Natural environment

(a) Physico-geographical sphere

The installation of the barrier structure and the operating outlets, which are normally open, do not constitute an **impairment of the runoff behaviour.**

In the **case of high water (flooding) a portion of the high water level** is **stored** in the outlets by partial closing of the locking mechanisms, and the **emission** downstream is **reduced** correspondingly; this can have the following **effects:**

- the **runoff** downstream is **stabilised** by capping the high water peak (intermediate storage);
- **erosion and sedimentation** are **reduced** in the downstream area because high runoff peaks no longer occur. However, this positive effect is offset by the **mineral undersupply** of the banks and watercourse beds due to reduced underwater sedimentation (this may have consequences for the flora/fauna);
- if there is **no sealing of the soils** due to depositions of fine sediments (depending on the soil material in the catchment area), the infiltration area in the dam area (or river bed) is increased on the one hand, and the infiltration times may be extended on the other due to the intermediate storage with subsequent more uniform runoff, which has a **positive** effect on **groundwater renewal;**
- the **deposition** of clayey-silty material in the dam area (often laterite) results in sealing of the sill, the **positive effect** of which is the **sealing of the reservoir** and hence longer availability of water. However, this may have a **negative** effect on the groundwater conditions in the reservoir area, and as the material penetration continues, the **reservoir capacity** and hence the efficiency of the detention basin, will ultimately be **reduced** (for effects due to damage to the barrier or dam structure of the detention basin see 2.5).

(b) Biosphere

In the **reservoir area** the flora is **not substantially damaged** by the overdamming times and intervals during the period of rain, which are normally only very short.

Sediment penetration and depositions on forelands and in the actual core area of the detention basin may both **impair** and **promote plant growth**, depending on the nature of the sediment (humus proportion).

The **fauna** is **greatly affected** by damming in the detention basin; animals must **escape very quickly** from the rising water due to rapid filling following heavy rain in the mostly small catchment areas; for many animals this may be problematic and may even lead to destruction.

For the fauna (particularly birds) living in **flood areas**, and water-bound flora, reductions in runoff due to intermediate storage may have **considerably negative effects** which would have to be investigated in the individual case. **Habitats** may be **dried out.**

2.4.3 Human sphere

With expert planning, construction and operation, **overwhelmingly positive effects** may be assumed in the human sphere. However, if there are **incorrect planning estimates** of the expected high water level, which is increasingly observed due to a lack of basic data, or if the detention basin is incorrectly operated, **flooding**, an **intensification of the high waters** and damage both up- and downstream may occur.

Explaining to the population the logic, purpose and mode of operation is necessary at the initial planning stage, and this may allay fears and uncertainties. **Flood and utilisation plans** must be drawn up for the detention basin, agreed with the local residents and implemented by a member of the village trained for this task and competent to operate the plant.

2.5 Smaller earth dams/installation of reservoirs

2.5.1 Objective

Low-level earth dams (only a few metres high) are often erected on or in the river/watercourse or in the associated catchment area at the foot of suitable valley troughs or cuttings in the land for **storing surface water** for different purposes (e.g. water supply, irrigation), and for making it **available** for the longest possible periods, or all year round.

Environmental effects are caused by the small dams and by the reservoirs formed by them.

In some cases small dams are not **planned** with the same **care** as large barrages. This is because non-experts also venture into the field of dam construction and fail to observe simple rules. Although the **damaging effects** in the event of the failure of a large dam are considerably more serious, the small earth dam is equivalent to the large dam in terms of basic hydraulic engineering data.

Numerous examples of destroyed smaller earth dams point to causes of damage which are attributable both to **planning and construction errors** and **defective maintenance**, and are responsible for damage as well as environmental impacts. In most cases **slope inclinations which are too steep, flood overflows which are dimensioned too small** and which are inadequately **secured** against the flowing water, **unsuitable installation material** and little or **insufficient compaction** are the main reasons. **Newly erected earth dams** should be kept **free from grazing animals** for a sufficient length of time to allow consolidation and growth of soil covering grasses/plants (fencing).

2.5.2 Natural environment

(a) Physico-geographical sphere

The artificial/storage lake or reservoir has a similar effect on the environment, taking into consideration the various interrelationships, as the large barrages (see the environmental brief Large-scale Hydraulic Engineering).

In the case of **relativey shallow lakes** deterioration in **water quality** resulting from the permeation of light as far as the bottom of the reservoir, **algae and plant growth** and considerable **heating of the water** may be expected. If there is an abundant supply of nutrients with only a small water exchange, **eutrophication processes** may be triggered. **Sedimentation** dependent on soil type and soil cover in the catchment area and -where fertilisation takes place - **phosphate penetration** (or the penetration of other agrochemicals), directly or via the sediments, promote these negative changes in water quality and the warping of the reservoir.

If cattle use the reservoir for **drinking** and also remain in the reservoir for a long time (depending on the water depth), this effect is greatly intensified and the water quality is impaired to such a degree that **use of the reservoir water as drinking water is called into question.**

The **groundwater horizon** in the more immediate reservoir area may be **lowered** as a result of extraction from otherwise seeping surface water.

Dam fracture may result from defective construction or maintenance of the earth dam, with considerable damage downstream, and **total loss of water** into the subsoil.

(b) Biosphere

In the **shallow and stagnant water zones** of the reservoir area, particularly in tropical regions, there may be a multiplication of **insects**. Moreover, if the reservoir is used by cattle for drinking, and if animal excrement occurs in the bank areas or throughout the lake (depending on water depth), the risk of the transmission of **water-induced diseases** increases substantially.

The **flora** which originally existed before the construction of the earth dam in the reservoir area is **destroyed** by the damming of the water. It is replaced by an **aquatic flora**, and **algae growth** is particularly promoted. The development of the **fish population** depends on the type and quantity of vegetation existing in the reservoir area. **Water hyacinths** may **propagate** to such an extent in a tropical climate that they will cover the entire surface of the lake in a short time, thereby substantially impairing the fauna.

2.5.3 Human sphere

Waterborne diseases, such as bilharziosis and malaria etc., may occur **more frequently** under tropical conditions prevailing in water reservoirs unless adequate precautions are taken in terms of **local separation** of washing, collection of water and animal drinking (if possible below the dam), together with suitable **water treatment measures** (e.g. sand filters) and **disposal of water** (e.g. VIP[1)] latrines) as part of the **comprehensive hygiene education** of the consumers.

[1)] VIP latrine = Ventilated improved pit latrine

Positive socio-economic effects may be expected from a reservoir assuming **population-orientated planning and implementation** in terms of self-help, including women in particular, for the purpose of selecting suitable **standpipe sites** (social integration), point out **cash crop growing areas** (improvement in income situation) and proper **use and care**.

The erection of smaller reservoirs may require the **relocation** of resident populations; a dam fracture may endanger human life.

2.6 Bank and bed stabilisation

Bank and sill defences, as **erosion protection measures** in limited areas of small flowing watercourses or on coastal structures in hydraulic engineering in rural areas have **hardly any negative effects** on the different spheres if environmentally friendly **materials** and **materials adapted** to the local conditions are used, and if such defences are properly constructed. However, this **must be determined in the individual case** according to the scope of the measure taken.

2.7 Channelisation (embanking)

Generally speaking negative effects on the different spheres, as already described in the Environmental Brief River and Canal Construction, may also be found in minor channelisation and embanking works.

However, if such works, **limited locally as protective structures,** are only erected in the area of the village for averting seasonally restricted high water (flood) risks to man, animals and material (e.g. harvest yields), and if a transition to the natural water course, adapted to the conditions, is guaranteed up- and downstream, **hardly any negative effects** may be expected.

3. Notes on the analysis and evaluation of environmental impacts

As the general representation of the possible effects on rural hydraulic engineering works on the environment shows, the **relationships** may be **complex** and **difficult to record and demonstrate** because of the **small-scale measures** taken in most cases.

Interactions are not as **clearly** recognisable as in other major hydraulic engineering subsectors.

In order to conduct any analysis and evaluation of the effects on nature and the environment an **examination of the natural conditions**, not only from the **technical and engineering point of view** (hydraulic engineer), but also, in particular, **the socio-economic and socio-cultural points of view** (socio-economy, ethnology), must therefore be carried out at the beginning of each project.

In this case the **consumers** (men and women/executing organisation) must be **involved** as early and as comprehensively as possible, with emphasis placed on the **integration of women**. The analysis and evaluation of the environmental impacts includes:

- as complete a **description** as possible of the prevailing **actual situation**, and of the interactions;
- the **establishment** of adequate, protected **basic data** for the **technical planning** and **construction work** (precipitation-runoff ratios, useful water supply, building land, consumption and cost/benefit analysis), **involvement of the population** and guarantee of readiness for subsequent **management** (staff, costs, fees);
- the surveying of the social behaviour of the consumers relating to the **management** of the very often sensibly handled **resource water** (marketing, cost structures, traditional way of life, self-administration, agricultural cultivation and marketing methods, cattle and forest management);
- the development of **alternative project concepts** for arriving at the most environmentally friendly solution and the best solution from the socio-economic and socio-cultural points of view, taking into consideration the original project objectives and their maximum attainability (including, for example, supplementary measures for minimising undesirable side-effects).

Difficulties are often encountered in analysis and evaluation arising from a **weak database**, so that although the effects of measures and interference with nature and the socio-economic environment can be described qualitatively, they **cannot be quantified very accurately.** Here **comparisons** of existing rural hydraulic engineering projects with similarly structured peripheral and general conditions (population, climate, landscape etc.) may be helpful in arriving at better supported statements and solutions. So far **no universally applicable standards** have been established for quantifying effects.

However, each project should try, by suitable **sensitisation and explanation,** to meet the **most stringent requirements possible** for protecting the environment, according to the socio-economic conditions, during planning, construction and operation.

4. Interaction with other sectors

Hydraulic engineering in rural areas may have **points of contact** with all plans/measures whose direct or indirect objective is the **use of water** in the following subsectors:

- water framework planning
- rural water supply
- solid waste disposal
- river and canal engineering
- erosion control
- large-scale hydraulic engineering
- spatial and regional planning

and from the agricultural sector, the areas of:

- plant production,
- plant protection,
- forestry,
- fisheries and aquaculture and
- irrigation.

The **superimposition** of negative effects of rural hydraulic engineering on **effects** of the above-mentioned projects (compare the applicable briefs) with negative effects can result in **major damage.**

5. Summary assessment of environmental relevance

The **environmentally oriented planning** and **implementation** of rural hydraulic engineering projects is possible, and **technical solutions** are available, but they must be **supplemented by the general socio-economic and socio-cultural conditions**. The **opinion,** still **widely held,** that rural (i.e. small-scale) hydraulic engineering projects only involved a low planning cost, and had **little or no environmentally relevant effects**, because in most cases they were on such a small scale, thereby rendering their examination generally superfluous, is **incorrect.**

With **careful planning and implementation** of rural hydraulic engineering work by experts, **less marked** (negative) environmental **impacts** may be expected than in **large-scale hydraulic engineering** work or **river and canal engineering** work. Regular **inspection** and **maintenance** of the plant must be guaranteed.

Possible damage to the natural environment and in the human sphere must, in particular, necessitate an **examination** of the **environmental and social relevance** of the work, even in the case of small-scale hydraulic engineering works, to achieve a **maximum level of safety,** if necessary by providing alternatives.

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