Erosion control

Contents

1. Scope

Erosion is the **carrying away of solid matter** and its **subsequent deposition**. These are part of the cycle through which matter passes and are thus **natural processes** observable as action and reaction everywhere in the ecosystem's intrinsically balanced operation. It is only major **interference** with this system coming from outside that may so **change the state of equilibrium** that corrective measures, even including direct protection for structures, may become necessary. Such **external interference** may take the form of:

- land use (depending on its nature and extent),
- damage to the vegetative cover, due in particular to deforestation and grazing,
- interference with the structure of the terrain, e.g. by road building and human settlements,

- interference with the watercourse system by straightening, channelisation, shortening or impoundment of flowing waters.

The term **"erosion control"** means any measures taken to control erosion by **physical**, **biological**, or **biotechnical** means. Its **goal** is to **reduce soil erosion**, i.e. the weathering away and carrying off of soil by wind, water or natural mass movement that may occur as a result of human action or natural factors (terrain, vegetative cover, climate). Erosion control measures are normally carried out to **counter threats** to the human habitat and thus to preserve the basic necessities of life. Hence, their primary function is as **protective measures** (often intended to protect infrastructural and farming facilities and structures) but secondarily and in the medium to long term they also help to benefit human beings and to **improve environmental conditions**.

With regard to the **forms and impacts** of soil erosion resulting from disturbance or destruction of the natural vegetative cover, a **distinction** can be made between:

- **sheet erosion**, or the carrying off of soil from the surface of an area, particularly by heavy precipitation or strong winds, leading to losses of or damage to the natural flora and fauna or soil used for crop growing,
- **rill erosion**, or the cutting by runoff water of anything from rills through trenches to gulleys that occurs when the surface runoff is higher, resulting in fissuring and fragmenting of the terrain in a more pronounced form of sheet erosion,
- **gulley erosion**, or erosion caused by streams of flowing runoff water producing deep cuts, deepening of the stream beds, erosion of the stream sides or banks, and shifts in the position of the stream beds, with all the consequences this may have for runoff, groundwater, vegetation, crop cultivation and the human infrastructure,
- **landslides and land slips**, these being erosion-related phenomena caused by gravity acting in combination with natural or anthropogenic triggering factors that may cause damage to the environment and infrastructure,
- **sedimentation and alluvion**, these being the deposit and build-up of solids eroded elsewhere that have been transported by wind or water, with all the undesirable consequences this may have such as the silting up of dams, canals and watercourses, the encroachment of sand dunes and the burying by sand of villages and areas of vegetation.

By making the widest possible use of biological measures, endeavours should be made wherever possible to employ **natural erosion control suited to the landscape**. Control of this type will be orientated towards **restoring the natural balance of solid matter** in the given ecosystem (soil loss tolerance level) and constitutes positive environmental action. However, physical erosion control too, aimed at directly **safeguarding/protecting the existing infrastructure**, may allow beneficial environmental impacts to be obtained by a feedback process (e.g. protecting a village by terracing a hillside in danger of slipping will cause a reduction in slope erosion and will also protect the vegetation).

Although in most projects it will be a question of providing **aftercare**, wherever possible it should not be simply the localised effects (damage and destruction) that are dealt with. **Attention should also be given**

to the causes situated elsewhere in the watershed which, in the final analysis, constitute the **triggering factors** (watershed management): for example, upstream erosion control to improve retention capability will reduce the high water discharge responsible for bank collapse downstream. **Integral erosion control programmes** are seldom feasible,

the reasons for this being not simply economic and technical reasons but social or political too. Restricting human activity over a large area for the benefit of nature (creating a reserve), even to the extent of stopping settlement, infrastructural development and agriculture, is something that is felt to present considerable problems.

The objective of any steps taken to control erosion is to reduce the **human- accelerated rate of erosion** to the **natural level specific to the site**. Erosion control therefore consists of measures to **control the symptoms** of an imbalance not peculiar to the site and the **causes** of those symptoms, remembering that the **triggering factors**, such as human beings, wind, water and mass movement, can be **totally eliminated only in exceptional cases**. **Measures** of this kind are generally of a **physical and biotechnical nature** and they **include**:

- **keeping in place of areas of soil threatened by erosion** (biotechnical erosion control by afforestation, planting of vegetation, construction of wind-breaks and embankments to restore vegetative cover),
- **landshaping techniques** to retain erosive surface runoff and discharge it in such a way that no damage is done,
- **changes to the structure of the terrain**, e.g. by terracing and embankment building,
- **stabilisation of slopes at risk of slipping**, e.g. by planting of vegetation and erection of retaining walls,
- **stabilisation and lining of eroded trenches**,
- **river engineering operations in watercourse beds** to stabilise bed and banks and alter bed roughness and cross-section
- **changing of flow velocities** in watercourses by impeding flow (deceleration by in-stream structures) or by contraction/shortening length (acceleration of flow by transverse dykes, reductions in cross-section, cutoffs and straightening),
- **constructional activities** carried out to provide direct protection for infrastructural facilities of general public utility.

2. Environmental impacts and protective measures

2.1 Overview

The primary distinction that has to be made in the field of erosion control is between measures to **protect**, **preserve** or **support parts of an anthropogenically disturbed ecosystem**, though in particular cases these parts may also be parts of the **infrastructure**. Just as with biotechnical erosion control, so too may making physical changes to the existing conditions produce **environmental impacts**, and these impacts can be divided up as follows by path of impact and duration into:

- (adverse) environmental impacts that are **direct** but **of limited duration** and that occur during the implementation phase when physical erosion control measures are being implemented, and
- **indirect** impacts **of unlimited duration** that occur once the measures have been completed and that have to do with:

- changes to

(A) the natural environment in the

(a) physical-geographical sphere, and
(b) the biological sphere, and

- improvements or deterioration in

(B) the sphere of uses and
(C) the human sphere.

The impacts on **spheres (B) and (C)** are closely connected. Often they are not simply side-effects (especially not in the case of protection for infrastructural facilities) but **consciously planned parts** of an erosion control programme where the programme is of the type that may lead to restrictions on settlement and use of land and water and to infrastructural operations (e.g. road and footway building).

2.2 Control of sheet erosion

2.2.1 Objectives

Control of the erosion of areas of land should be achieved principally by **biotechnical measures** - afforestation, vegetative cover, choice of suitable cultivated crops and farming methods, which measures may be accompanied where necessary by **minor physical measures** (e.g. sand arresting fences, embankments following contour lines). **Collaboration with farmers and foresters and their industries** is vital in this case.

However, in the present case **physical erosion control** may also be deployed in preparation for, as a back-up to, or a contributory measure to **slope stabilisation**. When this is the case, preference should be given to using **natural materials** and **materials** and **building methods suited** as far as possible to local conditions (e.g. wood, dry masonry, or gabions rather than concrete). **Measures** that can be employed for this purpose are ones such as:

- terracing, correction of relief (levelling), rock anchoring, structures for protection against rockfalls, incorporation of berms, slope drainage, intercept channels, drainage ditches, geomeshes, retaining walls, reinforced earth.

2.2.2 The natural environment

(a) The physical-geographical sphere

Adverse changes to **terrain structures** and **soil quality** and **re-ordering of layers** in existing soils are all possibilities. While measures to control sheet erosion are being carried out, there may for a time be quite considerable **soil losses** due to the loosening of the soil caused by the earth-moving operations.

(b) The biological sphere

Damage (generally only **temporary)** may be done to the existing flora and fauna as a result of the measures carried out and due to changes to the local conditions caused by changes to the surface configuration and soil quality, thus affecting species diversity. Such **changes** are often **planned and desired** with a view to agricultural use.

2.2.3 The use sphere

Particularly where erosion control measures to improve retention (e.g. by afforestation) are aimed at reducing the entry of sediments into watercourses/reservoirs, an attempt must also be made to **restrict land use in the watershed at risk from erosion**: a ban or restrictions on grazing, logging, farming and settlement.

Not only do **measures to control sheet erosion** lay **positive foundations** for ensuring that **agricultural use** will in fact become possible again, in the majority of cases they are also **vital** for the **long-term preservation of soil resources** for agricultural use.

2.2.4 The human sphere

Impacts in the human sphere are directly related to those in the sphere of land use. These impacts are adverse for the population, herders and farmers affected due to the **restrictions on settlement and use**, but they have to be viewed as unavoidable for the purpose of **preserving the environment** or **infrastructural items** (e.g. earth dams) of general benefit. **Corrective measures**, and **programmes to prevent social impacts** aimed specifically at women in their frequent role as farmers/subsistence producers, must be designed and executed with the full participation of those affected.

However, erosion control measures on existing agricultural land may cause increases in production and hence an **improvement in existing living conditions.** They do however have **cost implications** and management repercussions because it is very often the land users who have to carry them out and maintain them.

The **alternative** is **total loss of the soil by erosion**.

2.3 Erosion control in water runoff channels and watercourse beds

2.3.1 Objectives

With the aim of ensuring **safe discharge of water** and preventing bank collapses, scour, etc., preference should be given in the present case, as with land erosion control, to biotechnical or combined controlling measures wherever possible. Endeavours should be made to employ **biotechnical stabilisation** in the form of a combination of natural building materials, building methods and plant cover. It should also be

borne in mind that changes in the **sediment charge**, due for example to erosion control in the watershed, will also affect the **erosion and sedimentation regime in the receiving waters**.

2.3.2 The natural environment

(a) The physical-geographical sphere:

Stabilisation and lining of eroded channels and stream and river channels may amount to **severe interference with the landscape**. The control measures will mean that the flowing water will contain less solids and although this may raise its carrying capacity and thus its potential erosive power, bed sills will normally be constructed at the same time to **decrease the gradient** and hence the **flow velocity**, which is a cause of erosive damage to beds and banks.

Despite this, unprotected reaches lying further **downstream** may become exposed to **more severe attack** as a result of control measures upstream, the possible consequences of which should be considered in each particular case; broadly speaking, the downstream area should always be preserved from any damage.

The environmental briefs Rural Hydraulic Engineering, River and Canal Engineering, and Large-scale Hydraulic Engineering should be consulted for **other impacts** caused by erosion control measures applied to surface waters.

(b) The biological sphere

Deleterious effects may occur in watercourses that carry water at all times. However, **stabilising the bed of the watercourse** will have **hardly any impact** on the aquatic flora and fauna, providing steps are taken to ensure the **use of natural materials** and particularly if biotechnical stabilisation is employed, something which should always be striven for (plants soon grow through and over rubble and broken stone). The **slowing-down of discharge** by bed sills however, though planned as a corrective measure, will have impacts on living and migratory conditions and hence on the **spawning and feeding opportunities for fish** (which is why fish ladders should be built) and on the surrounding vegetation (beneficial effect on the groundwater level).

Due to the change in flow regime upstream of sills, weirs and similar structures, **areas of dead water** may be created in which **oxygen intake** is **severely reduced**. The consequences may be both **disruption of the fauna in the water** and **invasion by disease bacteria**, and the latter may be transmitted in turn from the water to humans and animals. To prevent this from happening, thought should be given to fencing off the areas in question.

2.3.3 The use sphere

Generally speaking, **erosion control measures in water runoff channels and watercourse beds** have a **beneficial** impact in the sphere of land use, provided they are carried out with the aim of **stopping land losses** and **protecting infrastructure** along, in and on the bed of watercourses.

However, the possibility of **detrimental effects on fishing** cannot be ruled out in watercourses that carry water at all times (see above). It is while erosion control measures are being carried out that such effects are particularly likely.

Where measures are implemented with a view to retaining material that could become sediment and bed load, for example by **shoring watercourses or eroded channels** (which is often done in the higher and steeper parts of a watershed which are more susceptible to erosion), then detrimental effects need only be anticipated in the event of **failure of the shoring**. If this happens, it is likely to cause landslips, earth flows, and major erosive and sedimentation damage on and about land and structures devoted to human use. At the same time however, the measures will also reduce the opportunities for obtaining gravel and aggregates for building purposes downstream.

2.3.4 The human sphere

The **impacts** in this case are the same as in the use sphere but despite the potential risks described above (the improbability of whose occurrence makes them exceptional risks), they are wholly **beneficial**. It is however **essential** that the **planning** of erosion control measures for flowing watercourses should be **properly** carried out, that the **population** (the riverside inhabitants) **are involved in good time**, and that they are **informed** of the purpose and utility of the measures.

3. Notes on the analysis and evaluation of environmental impacts

In the majority of cases, extensive **erosive and sedimentation damage** is an **indirect consequence** of **population pressure**, **uncontrolled settlement** and **heavy use of resources**, all of which lead to a reduction in the retention capability of a region.

By calling on the widest possible armoury of biotechnical measures, an attempt should be made to obtain erosion control that is as natural and as well suited to the landscape as possible and whose object is to **restore a natural solids balance** in the ecosystem in question. If at all possible, it should be not just the localised **effects** (damage and destruction) that should be dealt with but, **above all**, the causes situated in the rest of the watershed which, in the final analysis, constitute the **triggering factors**.

If it is to be possible for the impacts on nature and the environment to be analysed and evaluated, then a specific **study of the natural conditions** will need to be made at the start of any project and due consideration will need to be given in this study not just to **technical and scientific questions** but to **socio-economic aspects** too. The **population** and the **organisation in charge** should be **involved** as **early** and as **fully** as possible, and great importance should be attached to the **involvement of women**.

To be specific, what **the analysis and evaluation of environmental impacts** involves is:

- as full as possible a **description** of the **actual situation** and of the existing interactions,
- the collection of an adequate volume of reliable **basic data** for **technical planning** and **construction work** (precipitation/runoff ratios, winds, foundation soils, studies of demand and cost-benefit, estimates

of secondary costs, and means of ensuring ongoing maintenance),
- the development of alternative **project schemes** with the aim of obtaining an environment-friendly solution that cannot be bettered in socio-economic or socio-cultural terms and that allows for the aims of the original project and ensures they are achieved to the maximum possible degree (e.g. that includes complementary measures to minimise undesirable side-effects that may arise as a result of conflicts of interest).

Universally applicable **standards** to allow the impacts of erosion control to be quantified **do not exist as yet**. In each **individual case**, it is both feasible and to the point for **comparative surveys** of the existing soils (and vegetation), of dimensions (areas/volumes) and of long-term groundwater measurements to be made before and after the erosion control measures are implemented for the purpose of quantifying and thus evaluating the environmental impacts. **Potential detrimental effects** (areas of dead water, invasion by pathogens) should be included. There are however two **key questions** that always require critical analysis and evaluation given that even erosion control constitutes interference with nature and the landscape and these are:

- Physical erosion control measures (including ones working in combination with biotechnical measures) may be beneficial to the environment and may be intended to correct the impacts of other actions or changes, but are they really necessary or are they simply providing **technical support for wholesale exploitation of and changes to the landscape**?
- Do erosion control measures (irrespective of whether they are physical and/or biotechnical, as in the case of river straightening for example) merely **shift problems** downstream, without there being any solutions ready for them?

Comprehensive erosion control programmes in the form of integrated programmes covering large watersheds require suitably **wide-ranging planning** that must include sex-specific and group-specific analyses of the **socio-economic and socio-cultural needs of the resident population** and an examination of **policy-based constraints** in the region concerned. **Collaboration**, e.g. with structural and regional planners, with farmers and foresters and their industries and with fishing interests, is **essential**.

4. Interaction with other sectors

It can be expected that there will be **two-way influences** between physical erosion control and **all the sectors** that interfere with the existing **balance of nature and the landscape**.

Although **physical erosion control measures** are **preventative in nature**, or in other words are devoted to directly protective purposes, they are often carried out as a **result of adverse (external) environmental impacts** (caused by action in other sectors) and are aimed at the prevention of further stresses. The impacts in question may be **caused by activities** in a wide variety of sectors such as agriculture, infrastructure, energy/mining, and trade and industry.

Where there are **closer points of contact** is particularly with planning and activities in the following sub-sectors aimed directly or indirectly at **making use of soil and water resources**:

- Water Framework Planning
- Rural Water Supply
- Rural Hydraulic Engineering
- Solid Waste Disposal
- River and Canal Engineering
- Large-scale Hydraulic Engineering
- Spatial and Regional Planning
- Transport and Traffic Planning
- Road Building and Maintenance
- Provision and Rehabilitation of Housing

and in the agricultural sector, the areas of:

- Plant Production, Plant Protection, Forestry, Fisheries and Aquaculture and Irrigation.

5. Summary assessment of environmental relevance

Erosion control measures should always be planned and executed to be beneficial to the environment and to **support and improve the threatened or damaged ecosystem**. Hence their role is to **correct** the consequences of other measures that interfere with nature and the landscape.

A **significant place** must be accorded in the planning to the presence and activities of **human beings** and their socio-economic and socio-cultural needs. This being the case, the measures may be devoted directly to protecting infrastructure and may thus, by feedback, have beneficial impacts on the ecology.

It is **possible in principle** for erosion control measures to have **impacts damaging to the environment** though if they do it runs contrary to the intention of projects in this sector. Such impacts are only likely if **the aims being pursued in the planning are too narrow** or if there have been **errors in planning or execution**; what are possible as a result of erosion control measures on the other hand are conflicts of interest resulting in restrictions on use (e.g. in the areas of settlement, farming and forestry).

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