# Application of Groyne as a Sustainable Solution to Agulu-Nanka Erosion Problem

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**Abstract**
The paper aims at highlights the natural and anthropogenic impact in gully-erosion geo-structural failures. The application of groyne model-placement as sustainable solution which minimizes the control cost and guaranttees bed load as well as suspended load sediment transport.
**Keywords:** Erosion model sediment, groyne, sustainable-solution, control

## Introduction

soil erosion is the process of weathering and transporting of solid, sediment, soil, rock and other particle in the natural environment, Punmia and Jain (2005). It also occurs due to transport by wind, water or ice, by down-slope creep of soil and other mineral under the force of growth Egboka and Nwankor (1985) in their hydrogelogical parameters as agent for gully-type erosion stated that most serious threat erosion however comes from storm water erosion on land surface and it occurs when heavy rain,falls on the land surface, sheet erosion appears as the rainfall, loosens and washes away soil particles down a slop surface to form rill erosion which eventually develops to gully-erosion

Podani in 1988 opined that erosion-induced soil degradation has been a vicious cycles that has devastated entire soil in the south-east and some part of south-south region, resulting in decline of crops productivity also caused intensification of agricultural activities, which increases the risk of erosion and its consequences. Nigeria Meteorological Agency (2007) with evident of data advised the communities in the south-eastern state especially Agulu-Nanka that flooding causing erosion has become now an annual occurring event, after heaving rain storm. This further worsened by the nature of topography and soil texture of the area which caused by poor/inadequate drainage net-work, leading to 53% evacuation of the people from their houses and farm lands to erosion as associated with loss of properties depending on the intensity of flood.

Gully and soil erosion are very severe in this part of Nigeria because of high amount of rainfall in the region, unfavourable geology and rapid increase in construction of building and roads with poor or inadequate drainage system, Okeke and Akaolisa (2004). In 2012, the average annual rainfall in some south eastern state was 2025mm with prominent peak period in the late and early September-October. Under heavy rainfall, the area usually extensively recharged, resulting in significant reduction of average intergrannular friction and shear resistance, therefore causing the particles disaggregation rate of soil zone to increase in the sandy formation Ogbonna (1990).

Okogbue and Ezechi (1998) confirmed that erosion menace is viewed from two main perspective, firstly as a natural phenomena which is a fundamental process for the formation and modification of land forms on earth surface according to their geotechnical characteristics of soils susceptible to severe gullying. The second perspective is the human mismanagement of the entire biophysical environment and both are caused by inducement. Consequently, construction of groyne is viewed as a model for sustainable solution to erosion devastation in the area. Groyne is a hydraulic structure designed for gully erosion which has been proved efficient in the control of erosion menace in the advanced countries. It serves to main channel for the purpose of flood control and protection, Duan and Nanda (2006).

The groyne placement model uses a set of mathematical equations of hydrodynamics which includes the sedimentation, momentum and continuity equations..

## Aims and Objective

Water erosion in several different forms with various causes impacted by humans both negatively and positively. Therefore the aims and objectives of this research modeling is to:

- Ascertain the community's perception of erosion devastation in the study area.
- Ascertain responses of the communities to risk of erosion menace.
- Ascertain government response to the problem of erosion in the area.
- Find solution to be adopted in solving the problem of erosion.
- Using construction of groynes as solution in modeling and simulation.

**Study Area**

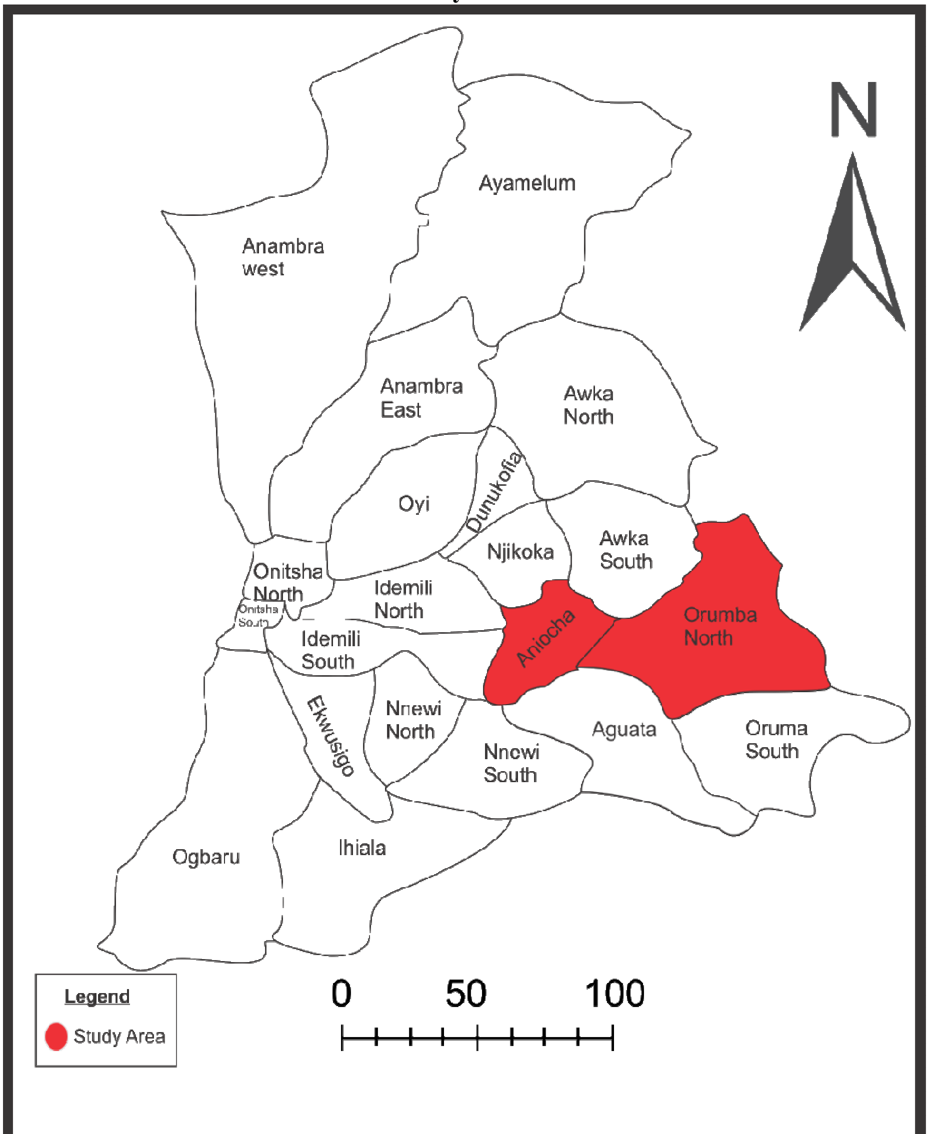


Fig. 1: Map of Anambra State showing the study area

Agulu and Nanka are two close neighbouring communities which are in Aniocha and Orumba North Local Government Areas respectively. Agulu is located between latitude 6.1100 and longitude 7.0224 ($6^0 6' 36$ N, $7^0 4' 21$ E) while Nanka is between latitude 6.0606 and longitude 7.0875 ($6^0 3' 38$ N, $7^0 5' 15$ E).

Agulu/Nanka study area falls within Anambra/Imo basin meteological zone characterized by warm temperature day and moderately cool nights.. the rainy and dry season representing two broad periods of significant, but contrasting variations in weather parameters, and hence geopedologic stability. The rainy season which lasts for nine months while dry season which is a short period of three months.

**Methodology**

Recognition of Agulu-Nanka drainage basin in terms of erosion occurrence and its severity has always been one of the most important issues the federal government of Nigeria via the government of Anambra State is battling in the post civil war, Egboka and Nwankwor (1985).

In achieving the goal the government invited some experts for discusion and decision which has reached for the construction of groyne as a model at the instant of the professionals, using dimensional and non dimensional parameters.

The study is designed to identify the problem of erosion and proffering the solution by applying the placement of groyne as a hydraulic structure. More so the research is done according to Suhajoka (2001) in his numerical modeling of two dimensional horizontal flow, directly on groyne field is placed perpendicular to flow at angle $90^0$

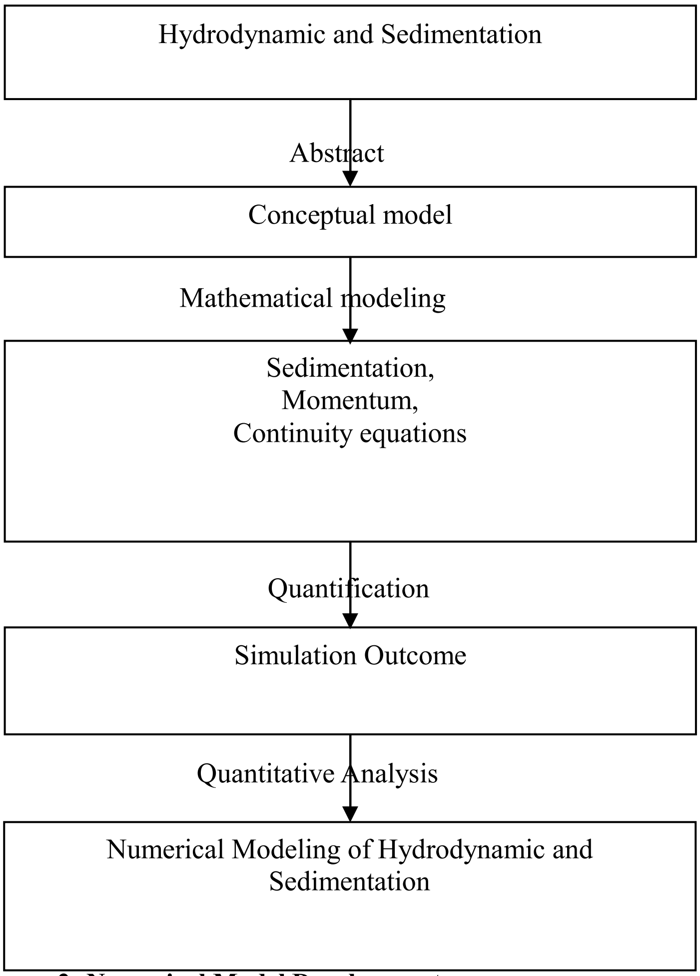


**Figure 2: Numerical Model Development**

The Objective of the conceptual model involves identification of problem, sedimentation analysis, good placement of groyne, sedimentation accumulation volume of groyne field, numerical simulation two dimensional difference flow.

- The two dimensional horizontal continuity equation.

**Conservation Equation**

$$\frac{\partial \eta}{\partial t} + \frac{\partial (hu)}{\partial x} + \frac{\partial )hv)}{\partial y} = 0 \qquad (1)$$

Where, $\eta$ = water level fluctuations
$h$ = water depth,
$d$ = still water depth (constant),
$u$ = mean velocity in the x direction
$v$ = mean velocity in the y direction

- The two dimensional diffusion equation, involving diffusion equation, velocity profile, unit depth constant diffusion coefficient.

**Equation of suspended sediment dispersed**

$$\frac{\partial C}{\partial t} - U\frac{\partial C}{dv} - k,\left[\frac{\partial^2 C}{\partial x^2}\right] - \left[\frac{\partial^2 C}{dx^2}\right] - \left[\frac{\partial^2 C}{\partial x^2}\right] - \lambda C \qquad (2)$$

*$C - C_0\, x - 0$ and $yt<y<y_2$*
*$C = 0.\ X\ 0$ and $y<yt$ or $y>y_2$*

$$\frac{\partial C}{dv} = 0. \ \ y = 0$$
$$\frac{\partial C}{\partial v} = 0. \ \ y = W$$
$$\frac{\partial C}{\partial y} = 0. \ \ X = L$$

**Setting velocity**

$$w_s = \frac{1}{2.8}\sqrt{\left(\frac{36v}{d_n}\right)^2 + 7.5(p-1)gd_n - \frac{36v}{d_n}} \tag{3}$$

Where, $d_n$ is Normal diameter. $P$ is sediment concentration and $g$ is sediment concentration
The Maginot (1989) on Signh 2005 [13] formula is used to calculate the cohesive sediment setting velocity:

$$w_{sc} = \frac{250}{d^2} w_s$$

Where: $w_{sc}$ = setting velocity of cohesive sediment flocs
$w_s$ = setting velocitys of single cohesive sediment Stoke Law is used to calculate the single cohesive sediment particle

$$w_s = \frac{gd^2}{18\mu}(\rho_s - \rho)$$

The two dimensional horizontal, momentum equation
**Momentum Equations**

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{dx} + v\frac{\partial u}{\partial y} = -g\frac{\partial \eta}{\partial x} + \frac{g}{C^2{}_z}u\sqrt{u^2+v^2} + \upsilon\nabla^2 u \tag{4}$$
$$\frac{\partial v}{\partial t} + u\frac{\partial v}{dx} + v\frac{\partial v}{\partial y} = -g\frac{\partial \eta}{\partial y} + \frac{g}{C^2{}_z}v\sqrt{u^2+v^2} + \upsilon\nabla^2 v$$

Where, $V^2\left(\frac{\partial^2}{dx^2} + \frac{\partial^2}{\partial Y^2}\right)$.

Cz = Chezy Coefficient
g = gravitation

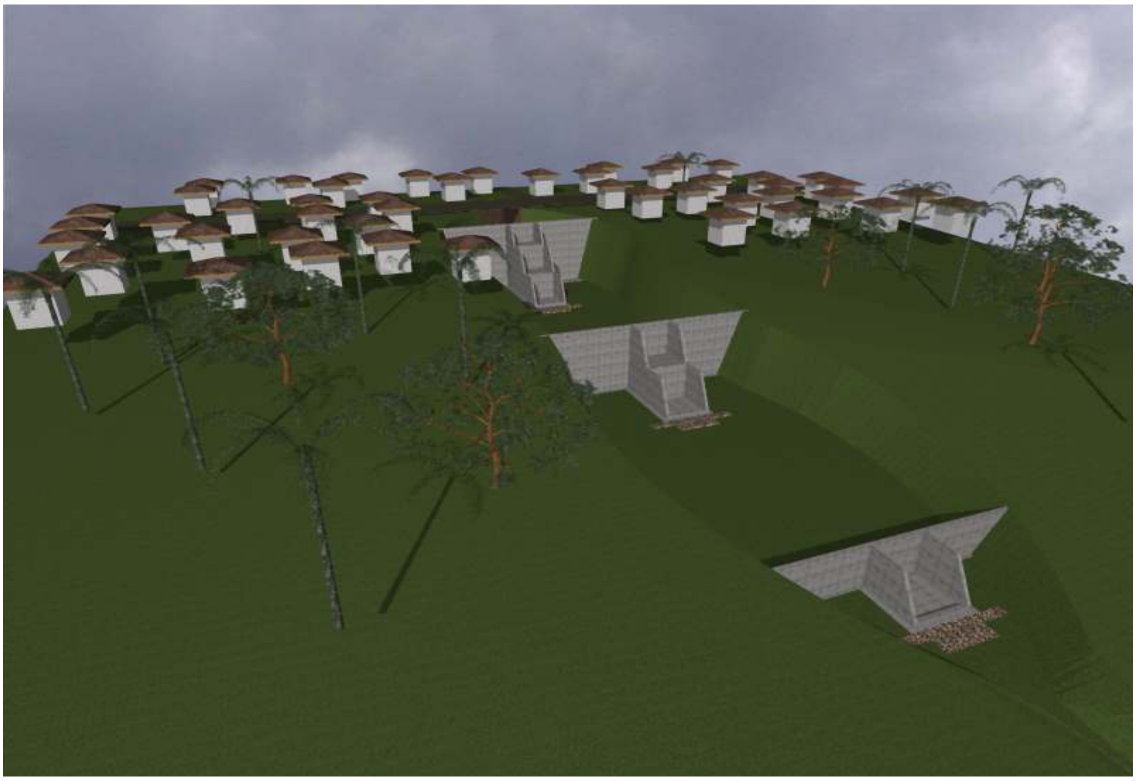

**Figure 3: Schematic Perspective**

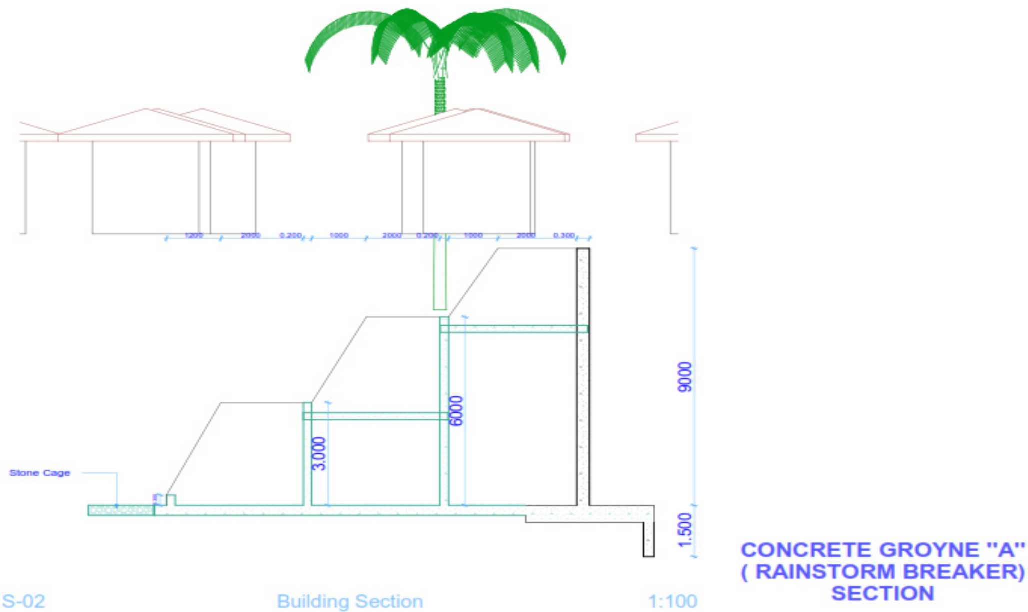


**Figure 5: Elevation View**

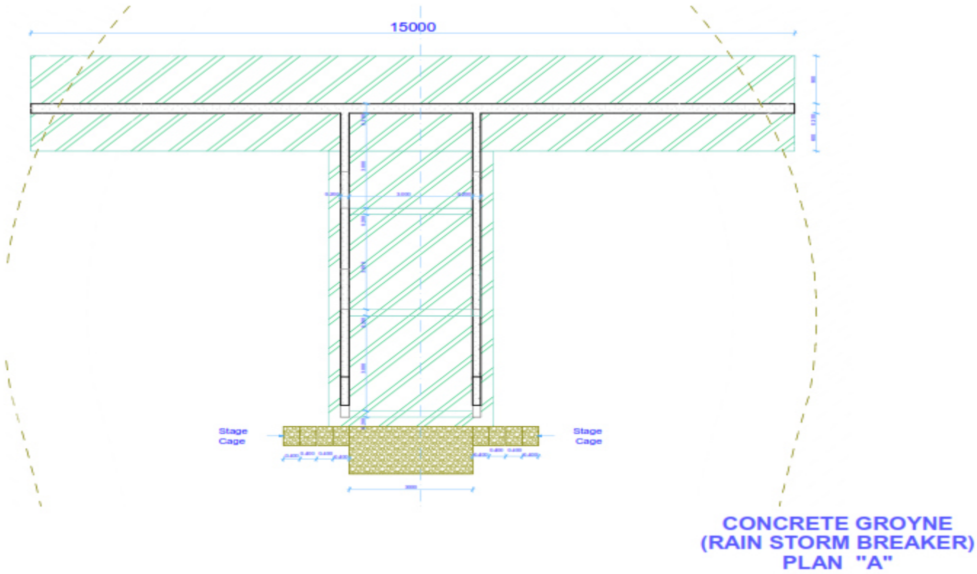


**Figure 6: Plan View**

The groyne is placed perpendicular to the flow direction on the straight channel at angle 90°. Moreso, in the non-dimensional practice, the parameters relationship of sedimentation accumulation on the groyne field is generally formulated to solve non dimensional analysis by stepwise method. The relationship becomes non-dimensional by eliminating dimensional stages. Therefore, it is meant for changes in sedimentation, deposition accumulation on groyne field.

The parameters are
B = channel breadth
u = flow velocity
η = flood depth
υ = viscosity
P = sediment concentration
do = diameter of soil grain size
r = specific gravity of soil sediment
vol = sedimentation accumulation
L = breadth of groyne
α = angle of groyne placement α=90°

**Sedimentation accumulations**

$$Vol = f(B, R, \alpha, u, h, v, p, d_0, \gamma, \rho, L, t)_{\text{various of rroyne placement}}$$

**Non-Dimensional Parameters**

$$\theta = \left( \frac{Vol}{h^3}, \frac{B}{h}, \frac{D}{h}, \frac{d_0}{h}, \frac{v}{\rho u}, \frac{h\gamma}{\rho}, \frac{gh}{u^2}, p, \frac{ut}{h} \right)$$

$$\frac{Vol}{BRL} \approx p \frac{h}{d} \frac{v}{\rho u} \frac{\rho}{h\gamma} \frac{ut}{h} Fr, can\ be\ simplified \frac{Vol}{t} \approx (BRL) \frac{p}{d} \frac{h\gamma}{u} Fr$$

Where:

(Vol) sedimentation accumulation
P is the suspended load concentration
Fr. Is Froude Number that's equal

$$Fr = u / \sqrt{gh}$$

$\frac{Vol}{t} = C_{vol}(BRL)\frac{P\gamma}{d_0}\frac{h}{v}Fr\left(m^3/dt\right)$, if to be considered in the different time, so this equation became the differential equation as follow,

$$\frac{d(Vol)}{dt} = C_{vol}(BRL)\frac{p\gamma}{d_0}\frac{h}{v}Fr\left(m^3/dt\right)$$

**Table 1: Non-dimensional analysis**

| | **Vol** | **B** | **R** | **D** | **ρ** | **u** | **h** | **υ** | **$d_0$** | **γ** | **g** | **t** | **P** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\rho(M/L^2)$ | $L^3$ | L | L | L | $M/L^2$ | L/T | L | M/LT | L | M/L3 | $L/T^2$ | T | I |
| | $vol$ | $B$ | $R$ | $D$ | $\rho/\rho$ | $u$ | $h$ | $\upsilon/\rho$ | $d_0$ | $\gamma/\rho$ | $g$ | $t$ | $p$ |
| $u(L/T)$ | $L^3$ | L | L | L | I | L/T | L | L/T | L | $L^{-1}$ | $L/T^2$ | L | I |
| | $vol$ | $B$ | $R$ | $D$ | | $u/u$ | $h$ | $\upsilon/\rho u$ | $d_0$ | $\gamma/\rho$ | $g/u^2$ | $ut$ | $p$ |
| $H(L)$ | $L^3$ | L | L | L | | I | L | I | L | $L^{-1}$ | $L^{-1}$ | I | I |
| | $vol/h^3$ | $B/h$ | $R/h$ | $D/h$ | | | | $\upsilon/\rho u$ | $d_0/h$ | $h\gamma/\rho$ | $gh/u^2$ | $t/h$ | $p$ |

**Discussion** observation shows that the modeling analyses the changes conduct of flood pattern and the best distance between impermeable groynes using hydrodynamic simulation on a straight eroded channel using Froude Number (Fr) Zhany et al (2007).

Suharjoko (2001) in his numerical model improves the eroded bed flow by using two dimensional horizontal flowing on groynes field, considering the current vertical velocity on vertical sediment concentration distribution. Placement of groynes other wise improves the eroded bed flow sediment transport model in determining erosion and controlling erosion at Agulu-Nanka erosion site.

According by Abbot and Price (1979), it gives effective value of the critical erosion shear stress to be smaller than the average values of the assert shear stress. The analysis simulates the currents flow pattern around up stream of groyne and distribution of sedimentation concentration around the groyne. The simulation gives good placement of groyne that results in sedimentation accumulation volume on groyne field in two dimensional fined difference flow model, Duan and Nanda (2006). It is also the combination of various groynes position, length, flow velocities and suspended load concentration.

**Conclusion:** In the field of engineering, observation shows that the most effective way of reducing the risk to people and property of erosion menace, is through the construction of hydraulic structure as stated by singh (2005) in his master thesis, using his numerical modeling of two dimensional horizontal flow on groyne field. Moreso erosion control involves the managing and controlling of flood run-off through the construction of groynes, rather than trying flood prevention.
There are many effective ways of putting check to erosion menace which are

- Production of flood risk map, showing areas prone to flooding event which reduces the risk of people and property
- Channeling of canals and river running through urban and rural development.
- By growing plants and colonizing to create deep rooted plant not systems protecting the soil from water, in its various forms
- Construction of concrete hydraulic structure (impermeable groynes)
- Involving management of people through evacuation

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