UNIVERSITÀ DEGLI STUDI FIRENZE

Corso di Laurea in: SCIENZE E TECNOLOGIE DEI SISTEMI FORESTALI
Curriculum: PRODUZIONI LEGNOSE

Pianificazione ed organizzazione tecnologica

Elementi costruttivi

UNIVERSITÀ DEGLI STUDI FIRENZE
DAGRI
DIPARTIMENTO DI SCIENZE E TECNOLOGIE AGRARIE, ALIMENTARI, AMBIENTALI E FORESTALI

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Principali elementi costruttivi delle strade forestali

- **Massicciata**
  - Sollecitazioni verticali e orizzontali – Scarsa portanza del terreno naturale
  - pressione specifica delle ruote pneumatiche

    trattori 1-2,5 kg/cm2, rimorchi per trattori di 2,5-4 kg/cm2,

    autocarri 8 kg/cm2 piede ca. 0,5 kg/cm2

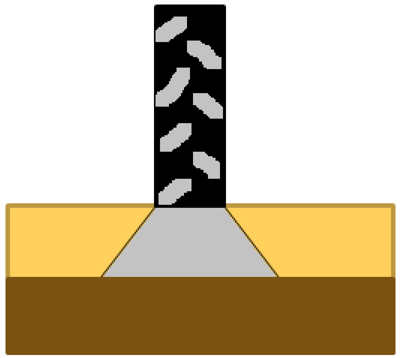
- Gli scopi della massicciata sono:
- distribuire il peso dei veicoli, su una superficie del sottofondo (naturale) maggiore, in modo da ridurre la pressione che vi grava;
- evitare o almeno contenere la penetrazione dell'acqua nel sottofondo, cosa che ne riduce la portanza;
- presentare alle ruote una superficie di rotolamento poco deformabile, per ridurre la resistenza all'avanzamento.

Principali elementi costruttivi delle strade forestali

Massicciata

Si suppone che le componenti del peso si trasmettano nella massicciata

con un angolo di 45°: spessori della massicciata di 10-20-30 cm - riduzione della pressione specifica sul sottofondo a circa 1/2-1/4-1/8, a condizione che la massicciata stessa sia indeformabile.



Spessore massicciata variabile tra 10 e 40 cm.

- La massicciata è formata da più strati:
  - uno o due strati profondi, impegnando inerti con granulometria crescente verso il basso
  - uno strato superficiale di copertura per compattare, pareggiare e sigillare la carreggiata.

Principali elementi costruttivi delle strade forestali

- **Massicciata**

- Attualmente le massicciate di strade forestali vengono formate normalmente da:
  - un primo strato di ghiaione (40-71 mm), o "tout venant", dello spessore di 10-20 cm. Su tratti di sottofondo a scarsa portanza 30-40 cm impiegando nella parte più profonda anche sassi e pezzature di maggiori dimensioni, o posare sul sottofondo una stuoia geotessile ("tessuto non tessuto") + ghiaione;
  - un secondo strato di ghiaia o breccia (10-40 mm) dello spessore di 5-10 cm per intasare e compattare quello sottostante;
  - un ultimo strato, di copertura, di ghiaietto o brecciolino calcareo (4-15 mm) con funzione di sigillante, dello spessore di 2-5 cm
  - Tutti gli strati vanno compattati rullandoli.
- Nel calcolare la quantità di inerti necessaria per formare la massicciata, bisogna tenere presente che la rullatura, compattandoli, riduce lo spessore degli strati del 20- 30%.

Principali elementi costruttivi delle strade forestali

Principali elementi costruttivi delle strade forestali

- **Banchine e piazzole:**

La carreggiata deve essere affiancata da una banchina lungo il lato a valle per la sicurezza dei veicoli e per contenere la massicciata.

- larghezza minima banchina è di 50 cm; su strade camionabili anche 1 m; in zone a rischio di incendio 2 m e più
- Se lungo il lato a monte della carreggiata viene realizzata una cunetta a sezione trapezoidale, anche questa va separata dalla carreggiata con una banchina larga 50 cm

Principali elementi costruttivi delle strade forestali

- **Banchine e piazzole:**
- Piazzole di scambio per l'incrocio di veicoli - consistono nel raddoppio della larghezza della carreggiata per una lunghezza di:
  - almeno 25 m sulle camionabili principali
  - 15-20 m sulle camionabili secondarie.
  - 10-12 m su strade trattorabili
- vanno previste alla fine della strada e ogni 1-2 km

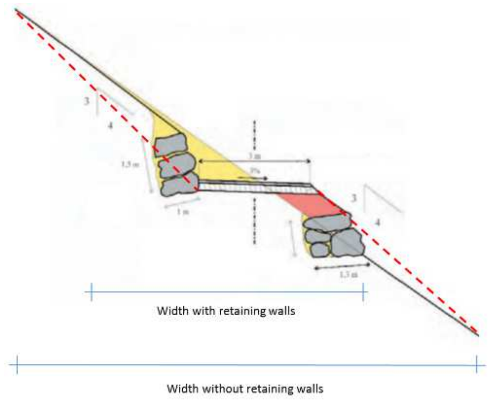
Principali elementi costruttivi delle strade forestali

- **Scarpate monte/valle:**

Principali elementi costruttivi delle strade forestali

Muri di sostegno

- I muri di sostegno sono necessari su versanti ripidi per garantire la stabilità dell'opera
- Permettono di contenere la lunghezza e pendenza delle scarpate:
  - Riduzione della larghezza totale del tracciato
  - Aumentare la stabilità delle scarpate
  - Ridurre I costi di manutenzione
- Permettono di risolvere problemi legati al cedimento di scarpate su strade esistenti.



Principali elementi costruttivi delle strade forestali

Muri di sostegno

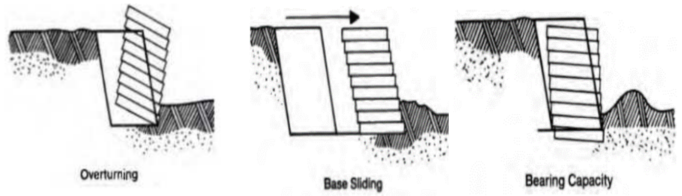
- opere devono resistere alla spinta della terra retrostante, che tende a spostarle verso valle e a ribaltarle
- resistono per gravità, perciò devono essere pesanti, saldamente fondate e va data loro scarpa, normalmente con pendenza da 3:1 a 5:1

Principali elementi costitutivi della viabilità

Muri di sostegno

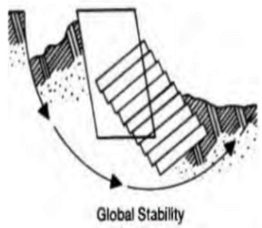
Stabilità: Esterna, globale e interna

- Tre criteri per la stabilità esterna:
  1) resistenza al ribaltamento
  2) resistenza allo slittamento
  3) adeguatezza alla capacità portante del terreno sottostante.

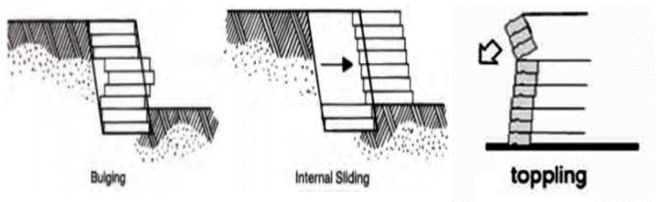


External Stability

- Stabilità globale



- Stabilità interna



Internal Stability – Poor connection/friction

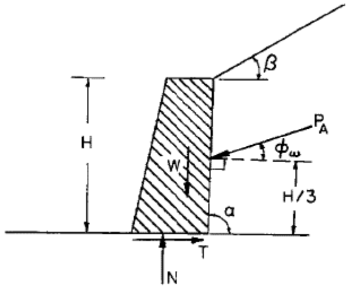
- Diversi metodi possono essere applicati: Metodi semiempirici, teorici e grafici
- Coefficiente di sicureza

Nota: i prodotti commercializzati per muri di sostegno hanno una guida per la progettazione- o per progetti più grandi utilizzare l'esperienza di ingegneri!

Principali elementi costitutivi della viabilità

Esempio - Formula di Coulomb.
Presupposti: la coesione del suolo viene ignorata, l'altezza del muro non deve superare i 6 m, il muro deve essere permeabile all'acqua, β <10 °
Si presume che le forze che agiscono sul muro di sostegno siano concentrate ad un'altezza pari a un terzo dell'altezza del muro con una forza pari a:

$$P_a = \frac{1}{2}\gamma H^2 K_a$$



P_a = spinta delle terre per unità di lunghezza del muro
γ = unità di peso del muro
H = altezza del muro
K_a = coefficient di pressione del muro, dato da:

$$K_a = \left[\frac{\dfrac{sin(\alpha - \Phi)}{\sin\alpha}}{sin(\alpha + \Phi_w)^{\frac{1}{2}} + \left(\dfrac{sin(\Phi + \Phi_w)sin\,(\Phi - \beta)}{\sin(\alpha - \beta)}\right)^{\frac{1}{2}}}\right]^2$$

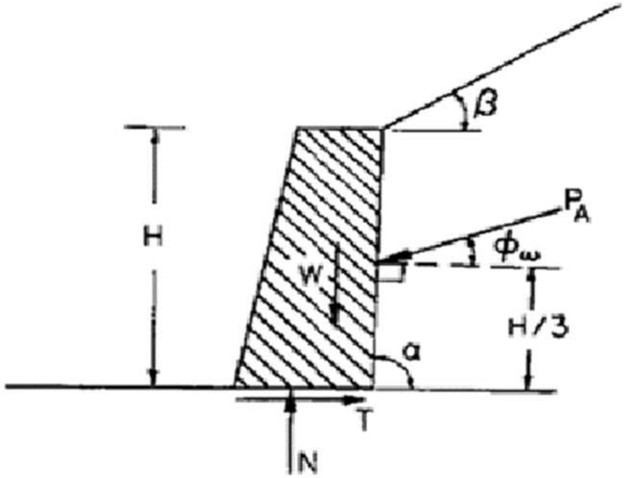
- Where:
- *β* = angolo di inclinazione della scarpata
- *α* = angolo interno del muro,
- *Φ* = angolo di frizione interna del muro,
- *Φ* w = angolo di frizione del muro

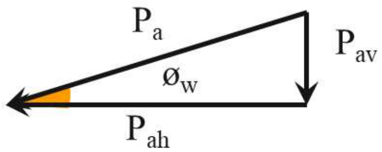
Principali elementi costitutivi della viabilità

- Componenti orizzontale e vertical di *P*a:

$$P_{av}=P_a \sin \Phi_w$$

$$P_{ah}=P_a \cos \Phi_w$$





Principali elementi costitutivi della viabilità

Somma dei momenti stabilizzanti in relazione al piede del muro:

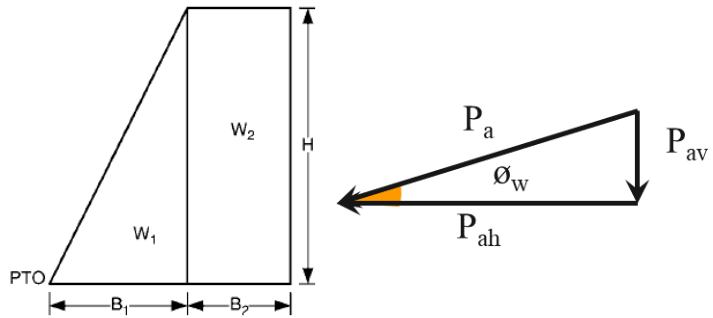
$$M_r = W_1\,(2/3\;B_1) + W_2\;\;(B_1 + B_2/2) + P_{av}\,(B_1 + B_2)$$

Momento ribaltante Mo,:

$$M_o = P_{ah}\,(\mathrm{H}/3)$$

Forza vertical sulla base del muro:

$$N = W_1 + W_2 + P_{av}$$



Retaining wall – Design

Check the three conditions for stability; the resistance to **overturning**, **sliding**, and **bearing failure** for adequate Risk factor:

1. First criteria - To have an adequate resistance to overturning requires that **Mr/Mo >RF** (risk factor), for example, 1.5.

2. Second criteria - To have an adequate resistance to sliding requires that **N tan Φ /P_{ah}>RF,** for example, 1.5.

3. Third criteria - To spread the bearing load and keep the entire base under compression requires the resultant of the normal force, N, is in the middle third of the base. This requires that **0.33(B1+B2)<x<0.67(B1+B2)**. For the check on bearing capacity, we require the ratio **bearing capacity/N** to be greater than RF, for example, 2.5.

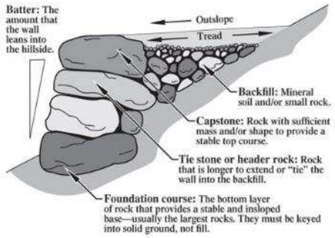
Retaining wall – Design

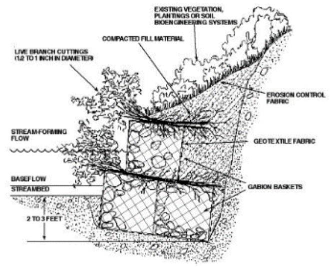
Many possible situations!!!

Soil, rock layer and soil, groundwater, ……….

Fill slope - traffic load

Support by expert, i.e. geologist





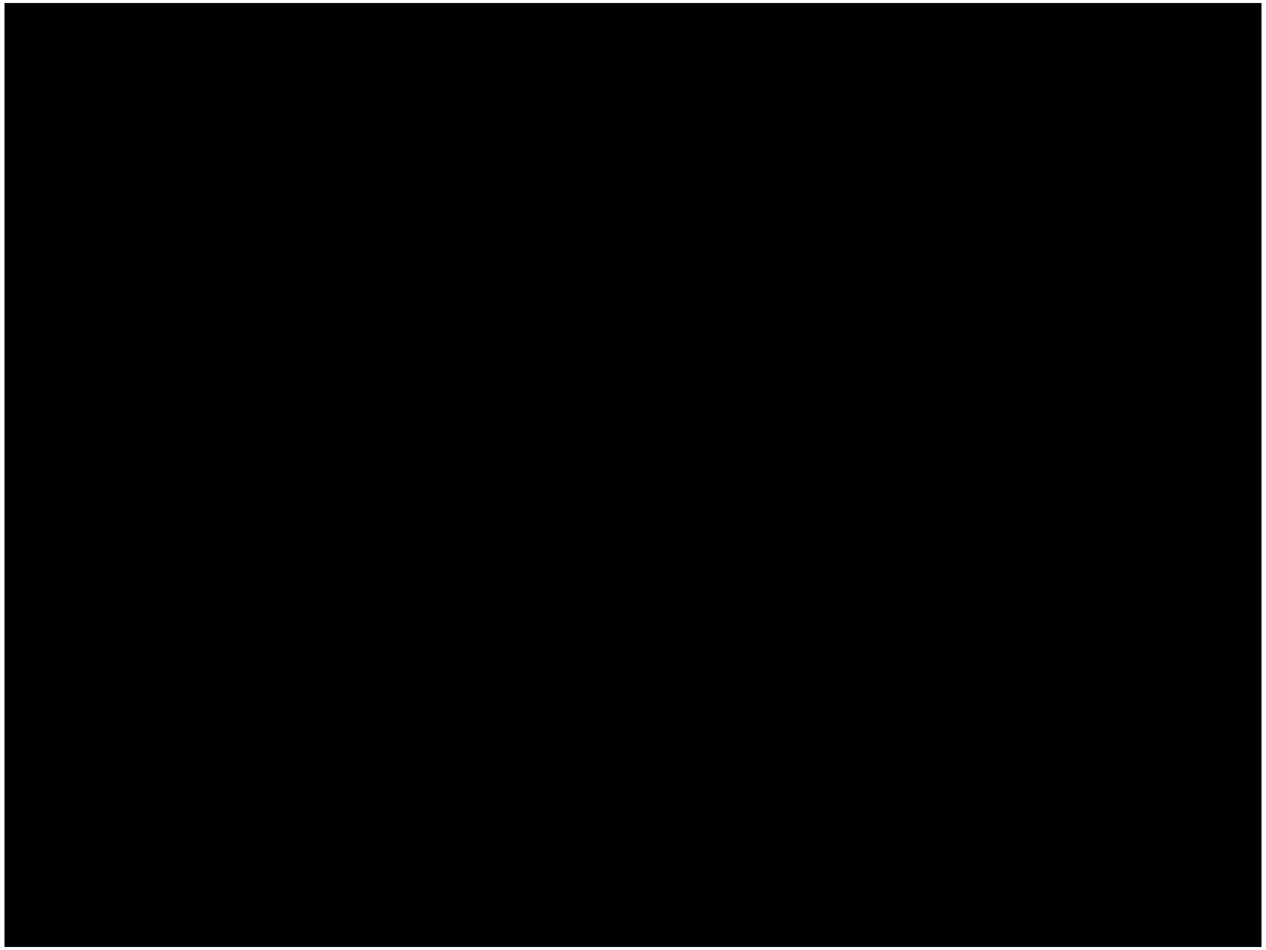
Retaining wall – Types

- Based upon the mechanics of retaining wall performance, the basic wall used on forest road are classified as:
  - Mechanically Stablllzed Backfill (Reinforced Soil)
    - Various types of mechanically stabilized earth structures
  - Gravity
    - Boulder retaining walls
    - Gabions
    - Timber cribs
  - Cantilever Piles

Retaining wall – Types

Mechanically stabilized earth structures

- Earth reinforcement is simple concept to use for both the design and construction of retaining walls.
- Ease of use and low cost of construction and materials are its major strength points.
- Mechanically stabilized embankments require minimal foundation preparation and can sustain large loads without serious damage.
- E.g. Compacted soil, appropriately shaped welded wire mesh and geosyntetic and overlaid layers.



Retaining wall – Types

Boulder retaining walls

- Boulders make an phenomenal building material.
- Never suffers from weathering or erosion,
- Weight of boulders allows them to tolerate earth movement without transmitting that through the wall.
- The resulting wall is very well drained
- Cost-effective option if boulders onsite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Retaining wall – Types

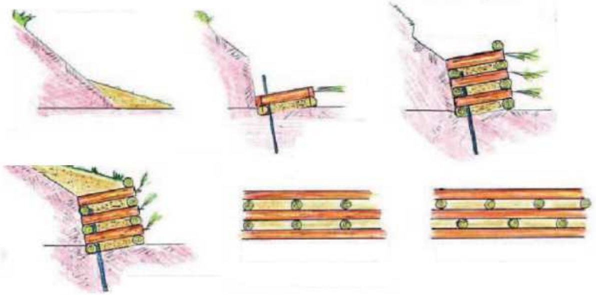
Gabions

- Gabion structures are designed to support slopes and to provide erosion protection. Also called gravity retaining walls
- Wire mesh baskets are filled with stones or rocks and are laced together to form a continuous structure.
- Gabion wall design is flexible – adaptation capacity – however flexibility may result in wall failure
- High permeability provides free drainage through the structure
- Often a very cost-effective option
- Range of sizes from 2 m in length, 1 m in width, and 0.5 m in height up to 4 m in length, 1 m in width and 1 m in height.

Retaining wall – Types

Timber cribs

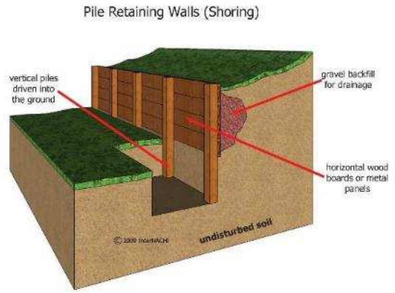
- Designed to support slopes and to provide erosion protection.
- Aesthetically more pleasing and possibly less expensive compared to conventional gabion baskets.
- Log (natural durability), stones, spikes or rebar 20-30cm (10-12mm dia). Geotextile and drainage pipes may also be needed.
- Live Cribwalls – include live branch cuttings, such as willow or dogwood, which root inside the crib structure



Retaining wall – Types

Cantilever pile wall

- Eliminating or greatly reducing the amount of excavation required.
- Pile walls may be economical solutions to retaining wall design in very steep ground.
- There is virtually no disturbance to the downslope hillside
  - If hard bedrock occurs at shallow depths and it may be difficult to drive piles to the necessary depth



Retaining wall – Design

- A well-planned geotechnical investigation is essential to the economical and safe design of a retaining structure.

- Preliminary analysis:

1. Scope of project
    - Locations, size, risk and budget

2. Project objectives - will the proposed wall be designed to retain:
    - Fill slopes
    - Cut slopes
    - Landslide forces
    - Presently failed cut or fill slope conditions
    - Road width

Retaining wall – Design

- Preliminary analysis (cont):

3. Project constraints:
    - Right-of-way (for construction or tiebacks)
    - Environmental impact
    - Visual impact
    - If the design requires a retained cut slope, will tieback or staged excavation be necessary?

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Water Control on Roads and Landings

- Critical to maintain cost-effective and long-lasting surfaces.

- Benefits of well-drained roads and landings:
  - Ability to withstand higher axle loads and traffic volumes
  - Lower maintenance
  - Increased access (all-year access?)
  - Decreased environmental impact

- Uncontrolled water can cause enormous damage in a short period of time, including:
  - Destruction of road pavement
  - Culvert washout
  - Scouring of water table drains
  - Gully formation below road drainage outlets
  - Debris flows

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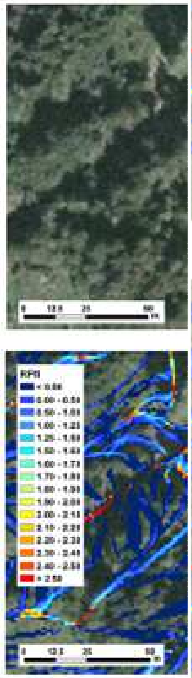
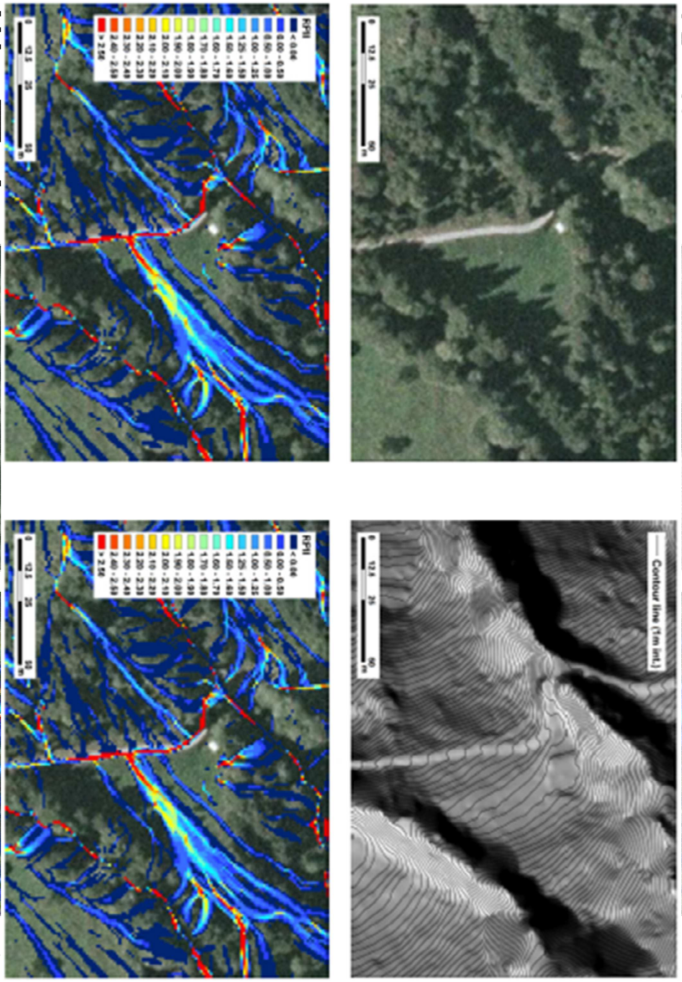
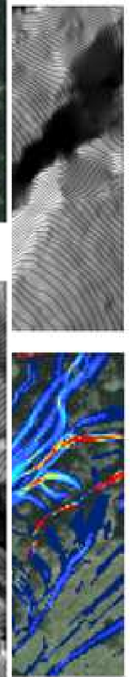
water







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Erosion and Sedimentation

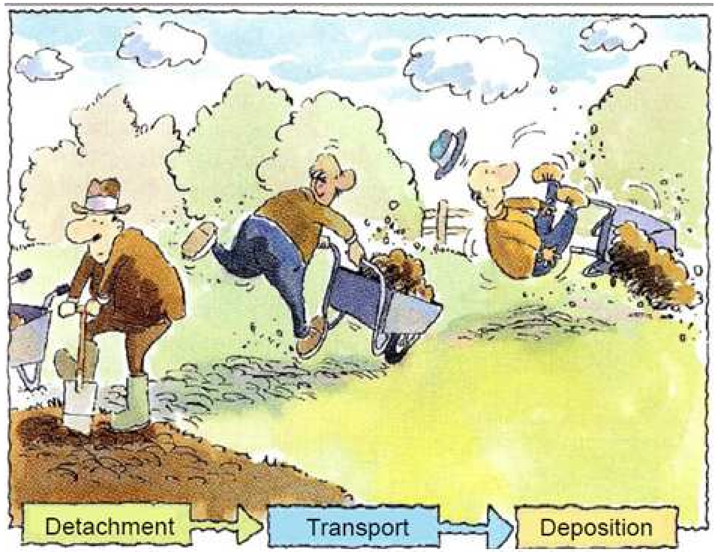
- Many processes contribute to erosion. Wind, water, ice and gravity are known as agents of erosion.



- but water is the most aggressive in the short term.

Erosion and Sedimentation

- Erosion is the wearing away of soil.



Erosion and Sedimentation

- Sediment is transported by water into waterways and deposited downstream. This is the process of sedimentation - soil particles fall to the bottom of a liquid and form a layer.

- Both erosion and sedimentation are natural processes that occur all of the time.

- Forestry-related earthworks modify the catchment and expose soil so that erosion (and subsequent sedimentation) is accelerated.

Erosion and forest roads

Understanding water erosion processes

Rain splash

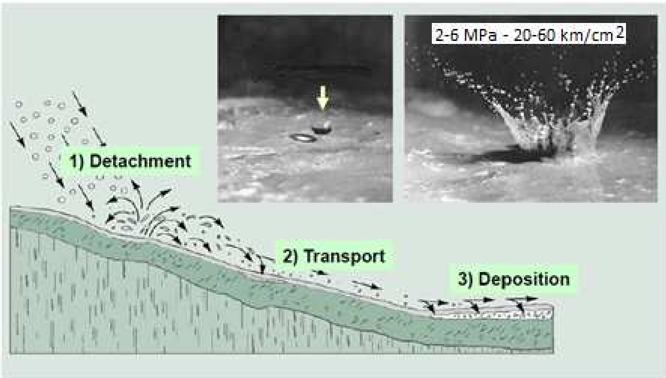
Sheetflow

Rill erosion

Rain Splash

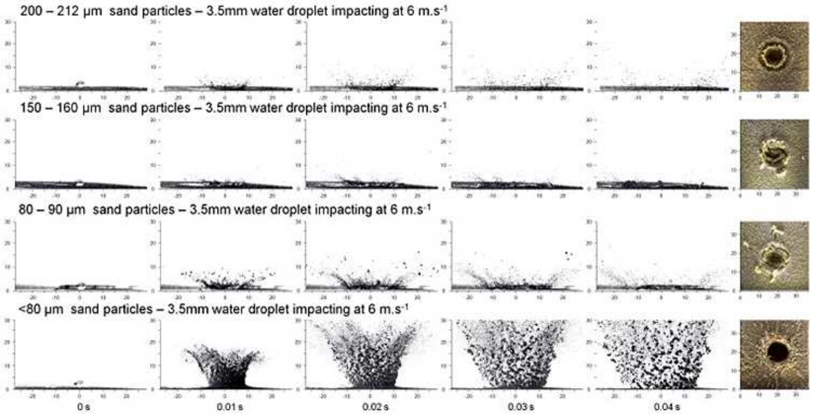
- Raindrop speed and impact

Diameter (µm)	Terminal velocity (m/s)	Type of raindrop
1000	4	Small
2000	6.5	Typical
5000	9	Large



Brady and Weil (2002)

- Particle size and aggregation, relative to the raindrop diameter, has a dramatic effect on the number of ejected particles, their trajectory, velocity and overall displacement.



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Rain Splash

- The impact of the raindrop breaks apart the soil aggregate.

- Particles of clay, silt and sand fill the soil pores and reduce infiltration and increases the runoff.

- Overland flow of water begins due to the lowering of infiltration rates.

- Once the rate of falling rain is faster than infiltration, runoff takes place (Sheetflow).

- Raod pavement – low infiltration capacity.

Sheetflow and Rill

- Sheetflow – when water move downhill in thin sheets.
- Sheetflow erosion uniformly remove soil from a planar area and it cause relatively low rates of erosion, especially in compacted soils.
- Sheetflow collects in micro-depression (usually ruts) and forms rill.
- Rill erosion remove soil from relatively small area but with an higher rate. They may become gullies.

Concerns about erosion and sedimentation

– Environmental damage by loss of topsoil and associated nutrients, degradation of water quality and aquatic habitat.

– Economic damage by loss of access, damage to infrastructure, downstream damage and cost of clean up.

Environmental impact of erosion and sedimentation

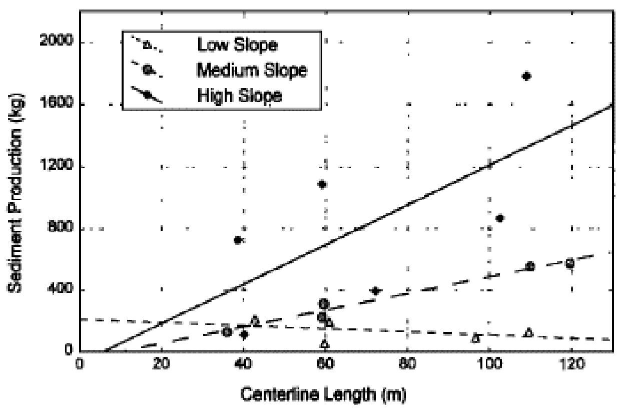
– Alteration of physical and chemical property of water (changes in temperature and pH) - traffic intensity and weather conditions

– Impact on aquatic fauna (fishes, anphibians, ……) (Megahan, 1984)
  - Fishes mortality by gill abrasion increased (Megahan, 1984)
  - Reduction of fish abundance and diversity (Richardson and Jowett, 2002)

Erosion and road design

- Road design is the main aspect to consider for mitigating erosion:
  - Road gradient and road segments length (Optimal gradient 3-8%)
  - Cut and fill slope gradient and length (soil type)
  - Water control structures

Slope classes 4-6% 6-11% 11-13% Length classes 40, 60 and 110m



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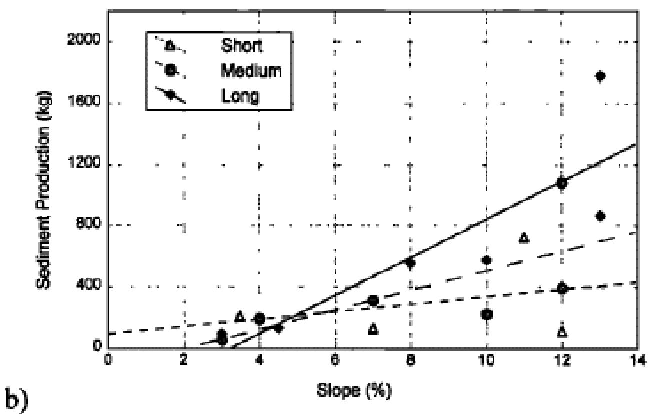

b)

Luce and Black, 1999

Water Control Structures

- The purpose of water control structures is to:
  - Efficiently remove water from road and landing surfaces back into “natural” drainage systems
  - Control the velocity and volume of water flow

- Types of water control structures include:
  - Road template
  - Water table drains
  - Ditch dikes
  - Catch drains
  - Cross culverts
  - Water bars
  - Rolling dips
  - Cut-outs
  - Drainage culverts

Road template (profile)

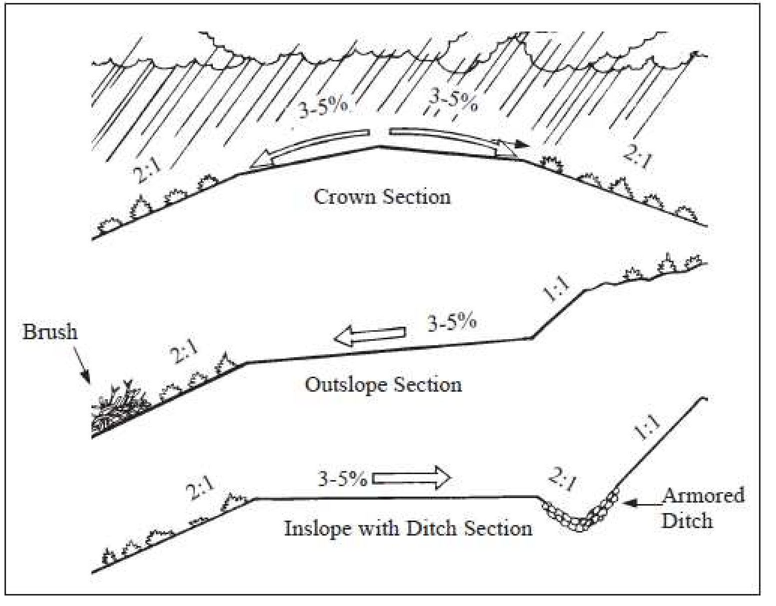

Figure 7.1 Typical road surface drainage options.

Keller and Sherar, 2003. Low-Volume Roads Engineering BMP Field Guide

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Wheel ruts

- Ruts increase the erosion more than 2 times

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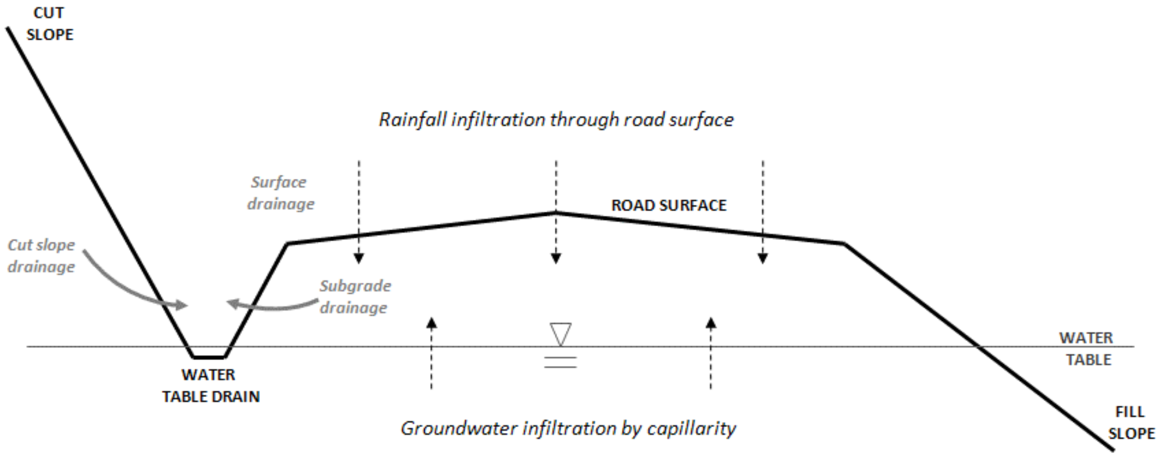
Water Table Drains

- Run inside and parallel to the roadway to capture water runoff from the road surface and adjoining slopes.
- Usually designed with flat bottoms to avoid scouring.
- Can be armoured with rock or gravel on slopes to prevent scouring
- Water table drains on sloping terrain must be coupled with other drainage features (such as culvert cross-drains or ditch dikes) to control water volume and

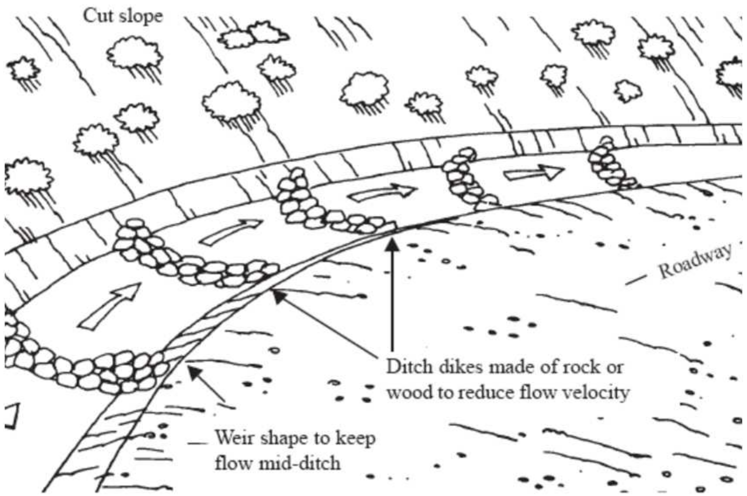


Principali elementi costitutivi della viabilità

- **Cunetta longitudinale**

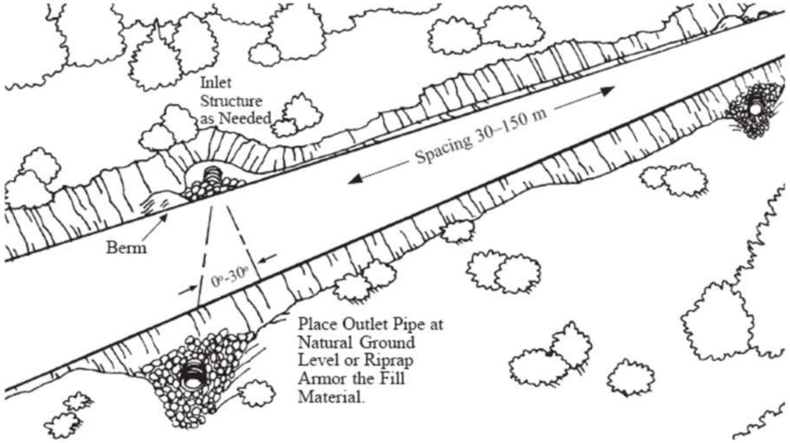

Ditch Dikes

- Used to prevent ditch erosion. Water flow is disrupted and course sediments deposit
- Must be regularly cleaned to prevent sediment build-up.
- Must be constructed with a weir shape to keep flow mid-ditch



Culvert Cross-drain

- Used for insloped or crowned roads
- Cross-drains are used to drain water from one side of the roadway to the other and are usually used together with a water-table drain to slow and disperse water in a controlled manner
- Cross-drains are best used for roads that require a smooth grade (higher speed roads)
- Generally slope a culvert using about a 3% grade, to help prevent soil and other debris from accumulating



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Principali elementi costitutivi della viabilità

- **Tombini con chiavica**



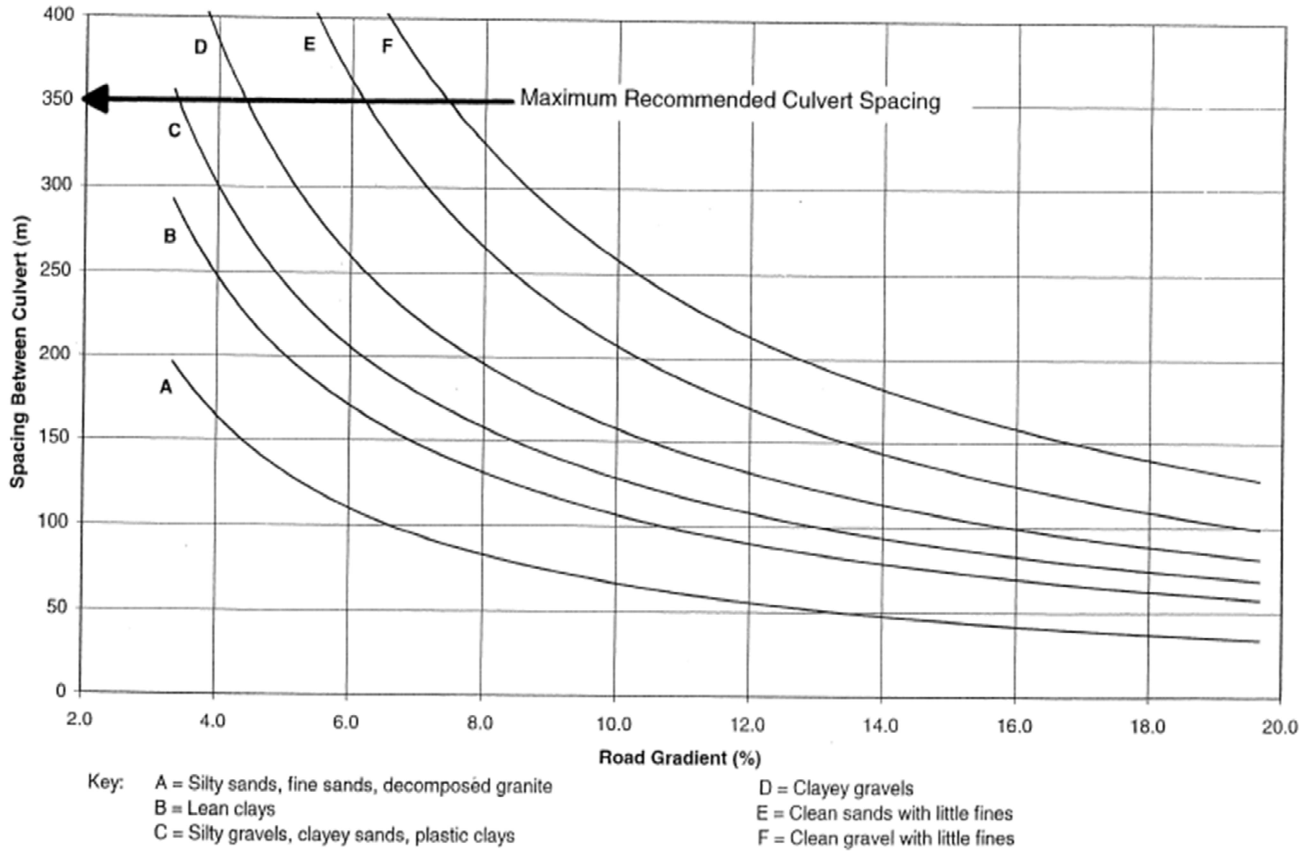


Culvert Frequency

- The frequency of culvert cross-drains is dependent on the road grade and the soil type within the water table drain.

- Steep grades and fine-grained soils require more regular cross drains.

- Culvert frequency on a given road grade can be reduced by increasing the particle size used in the water table drain (armouring).



Larcombe, G. (1999). LIRO Forest Roading Manual

Table 7.1

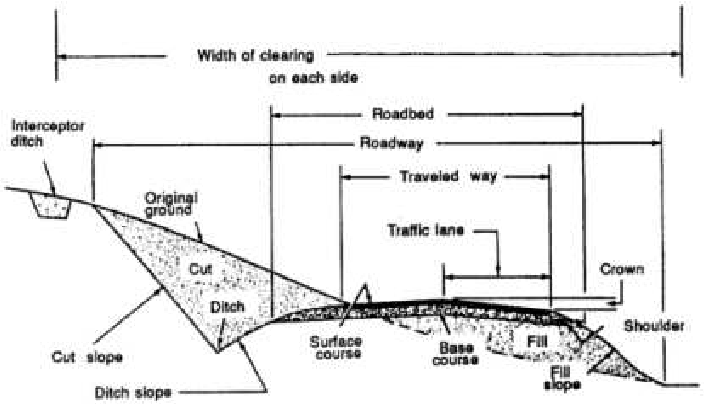
Recommended Maximum Distance Between Rolling Dip or Culvert Cross-Drains (meters)		
Road Grade %	Low to Non-Erosive soils (1)	Erosive Soils (2)
0-3	120	75
4-6	90	50
7-9	75	40
10-12	60	35
12+	50	30

Keller and Sherar, 2003. Low-Volume Roads Engineering BMP Field Guide

Canali di guardia

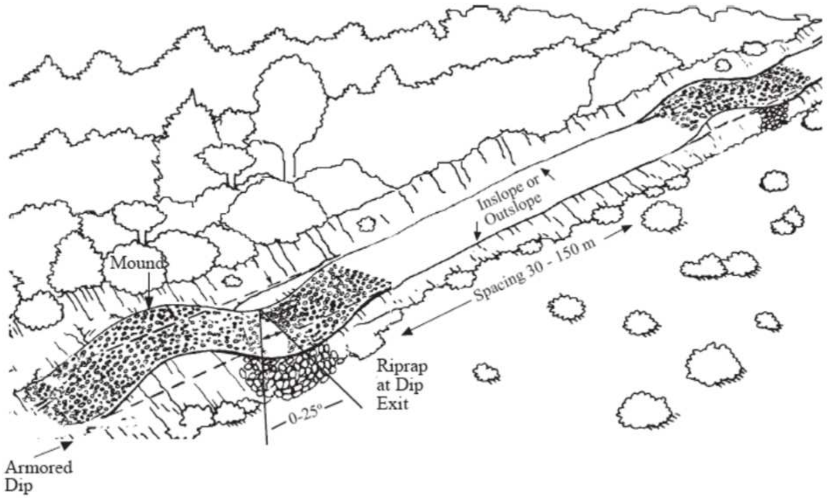
- Catch drains are located at the top of cut slopes to capture water flow before it can erode and destabilise the cut slope.

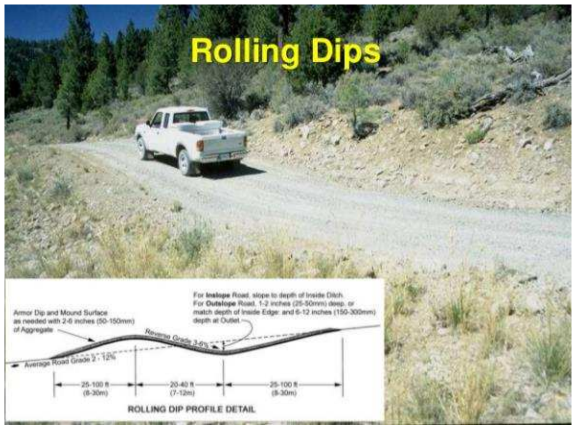
- These drains must be regularly maintained, else they can become a counter-productive pool of water above the slope – increasing the probability of slope failure.



Rolling Dips

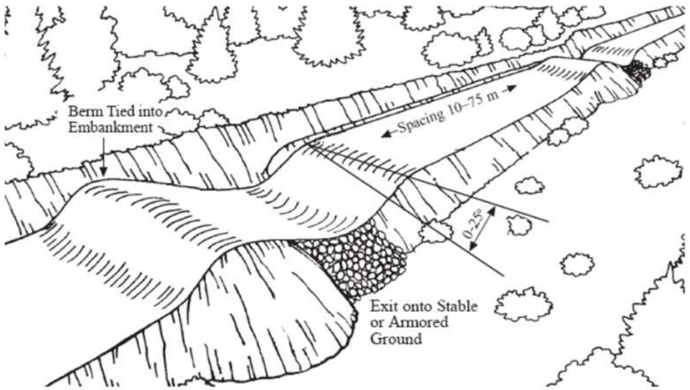
- Used for outsloped road segments; can be used in place of culvert cross-drains, but result in a road surface that has an irregular slope.
- The rolling dips reduce water velocity and allow water take-off in a controlled manner.
- Like culvert cross-drains, distance between dips depends on soil type and road slope.





Water Bars

- Water bars are used in place of cross-drains and rolling dips when roads are infrequently used or have been closed.
- Water bars are only used on lightly travelled roads (e.g. old skid trails) because they are easily damaged by vehicular traffic.
- Frequent spacing for maximum erosion control. Can be used as a traffic deterrent.



Principali elementi costitutivi della viabilità

- **Cunette o canalette trasversali (doppie)**

Principali elementi costitutivi della viabilità

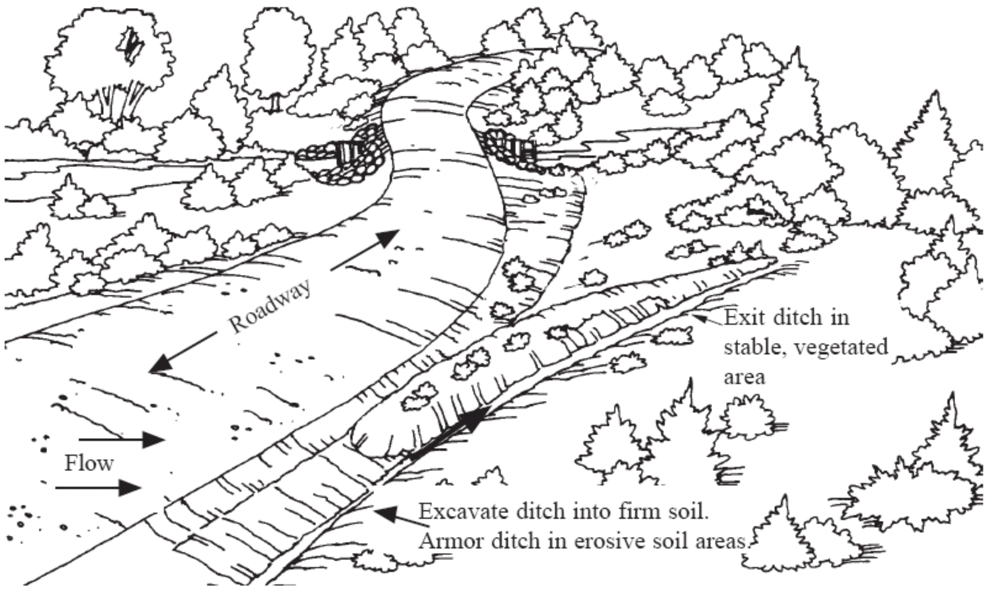
- **Cunette o canalette trasversali**

Pendenza della strada (%)	Spaziatura canalette (m)	
	Condizioni favorevoli	Condizioni sfavorevoli
8	40	30
10	36	26
12	32	22
14	28	18
16	25	15
18	22	12
20	20	10

Cut-outs (Leadoff)

- Cut-outs perform the same task as culvert cross drains, rolling dips and water bars. They are preferred in less steep terrain, as they are much less expensive to construct.

- The cut-out enables water to exit from the water table drain and filter through the forest floor before reaching the stream

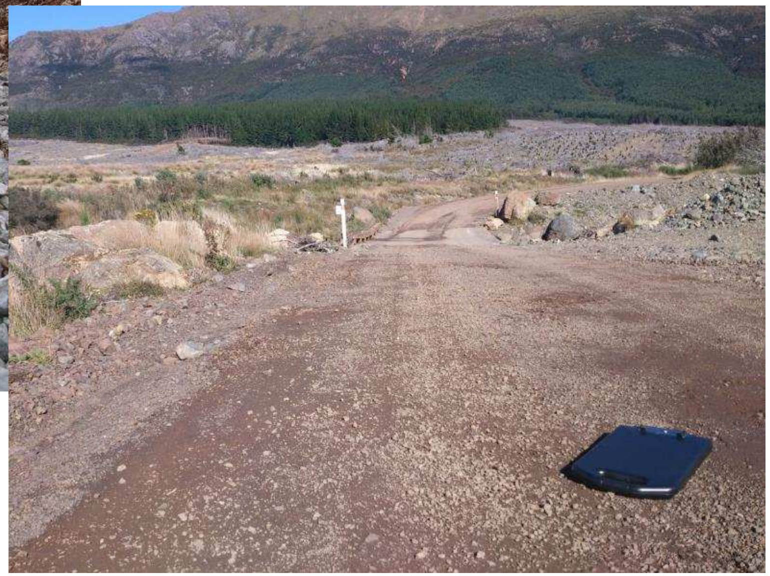


Sediment Control Structures

- The purpose of sediment control structures is to limit sediment production (erosion) and to limit sediment entering waterways.

- Types of sediment control structures:
  - Gravel surface
  - Armoured drains
  - Silt fences
  - Sediment traps
  - Roadside and riparian vegetation
  - Geotextiles, grass seeding, slash

Gravel surface



Armoured Drains

- Armoured drains provide a protective layer of large granular material with mass that is too large for water to dislodge.

- The granular material also impedes water flow and reduces the energy in flowing water (by inducing collisions).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Silt Fences

- Silt fences are installed to collect sediment from small areas during construction. They are not designed as long-term features.
- The silt fence can trap sediment and let water pass through.
- The silt fence provides an additional benefit of reducing water flow velocity

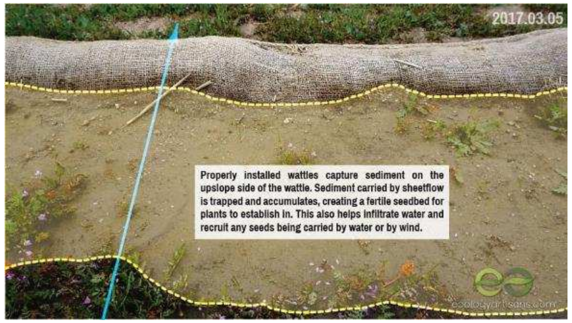
Straw wattles

- Can be used as silt fences substitute

- Enviromentally friendly (biodegradable)

- Diameter 20-30 cm
- Length 6-7 m
- Weight 15-20 kg

- Stakes can be replaced by cuttings of tree species – higher soil stability



Sediment Traps

- Sediment traps work by slowing water velocity, enabling coarser sediments to deposit. The clarified water is then allowed to flow away via a weir structure or drop pipe.

- Sediment traps can be used to monitor the quantity of sediment being produced from a site.

- The sediment trap can be used to prevent sediment from entering into waterways; however, it is difficult to build a trap of suitable size to be effective.

Trapped sediment must be excavated (maintained) to maintain storage capacity!

Roadside and Riparian Vegetation

- Roadside and riparian vegetation provide protection from scouring, slipping and erosion.
- Achieved by reducing water flow and holding soil in place via root networks.
- Riparian planting is also useful in filtering water to reduce the amount of water and sediment that will enter the waterway.

Geotextiles, Grass seeding, Slash

- These approaches all work to provide a covering over exposed soil, thus reducing erosion.

- The ground cover also works to reduce water velocity

Principali elementi costitutivi della viabilità

- **Ponti e tomboni**
  - **normalmente calcolati e progettati da specialisti**

- ALTERNATIVE


Water quality
in Otago
GOOD WATER IN OTAGO
FORESTRY

Principali elementi costitutivi della viabilità

- **Guadi**