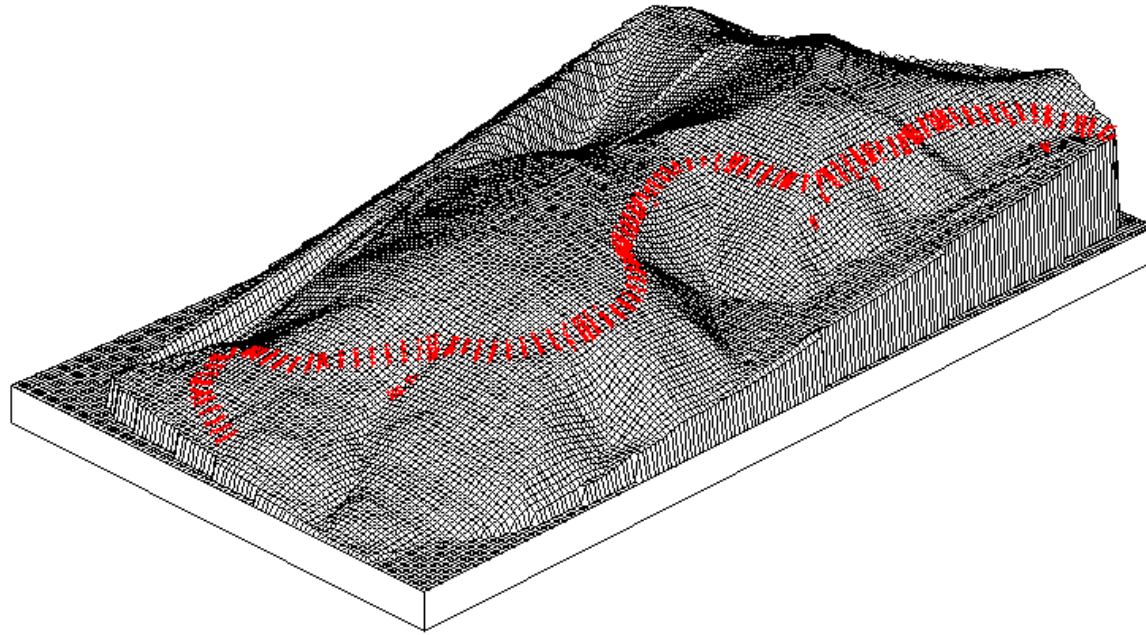


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Logging and road infrastructure in Germany

Prof. Dr. Dirk Jaeger

May 3, 2016



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Logging and road infrastructure

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1. Context and basics of forest access
2. Road standards
3. Planning process
4. Recommendations for road alignment
5. Road characteristics
6. Off-road transportation
7. Construction techniques
8. Outlook: Key messages

1. Context and basics of forest access

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Forest access:

1. Enabeling access to a forest area
2. Connection to the public road network

To fulfill two main purposes:

- a) Provide access to the stands
- b) Allow for long-distance transport (connective function)

1. Context and basics of forest access

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- Access to forests by roads is precondition for any forest management and it allows the use of forest for different purposes/functions
- Every transportation system consists of road transportation and off-road transportation
- For stand access forest roads are combined with skid trails/strip roads, tractor roads or cable lines

1. Context and basics of forest access

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- Forest cover on 32% of landbase
- Productive forest stands (AAI 11 m³ o.b. per ha and year)
- Variety of topography
- Variety of ownerships (2 million private owners with 2.4 ha in average)
- Continuous cover forestry (no clearcuts, frequent thinning/harvesting operations with 50 to 100 m³ u.b., every 5-7 years)
- Fragmented structure of forests, units of relatively small extend
- Short wood (3-6 m), long wood (max. 21 m)

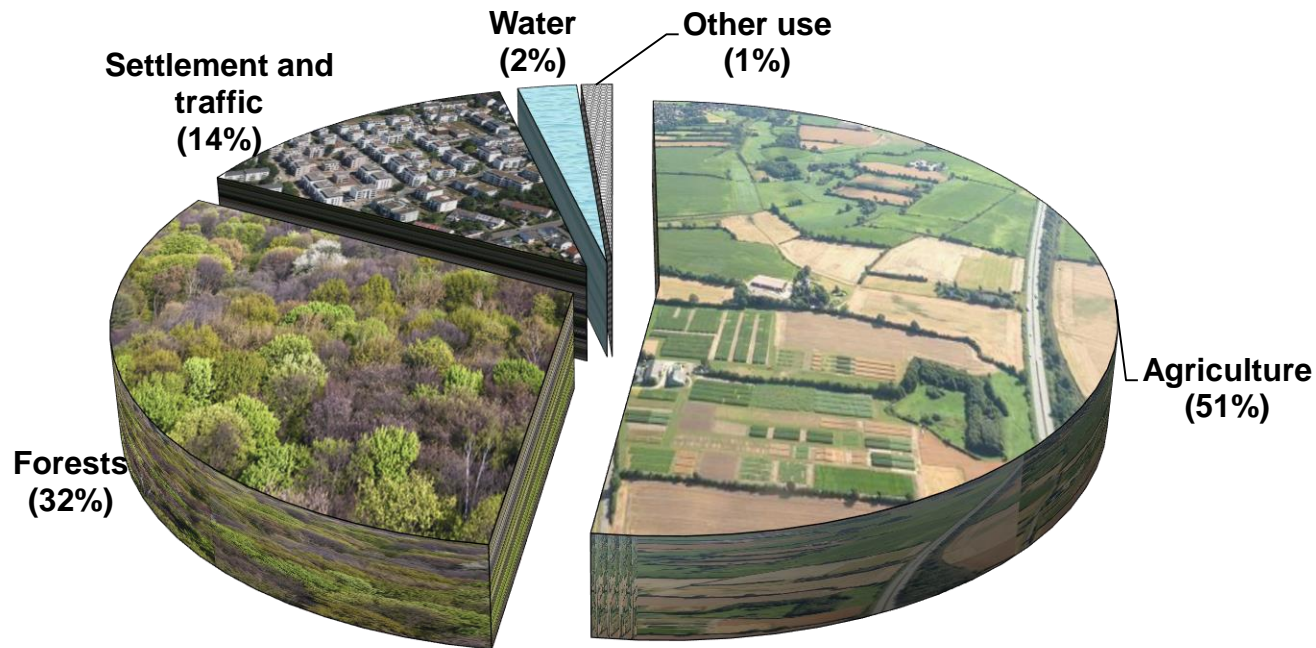
1. Context and basics of forest access

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Landuse in Germany 2013



Quelle: Destatis
verändert

1. Context and basics of forest access

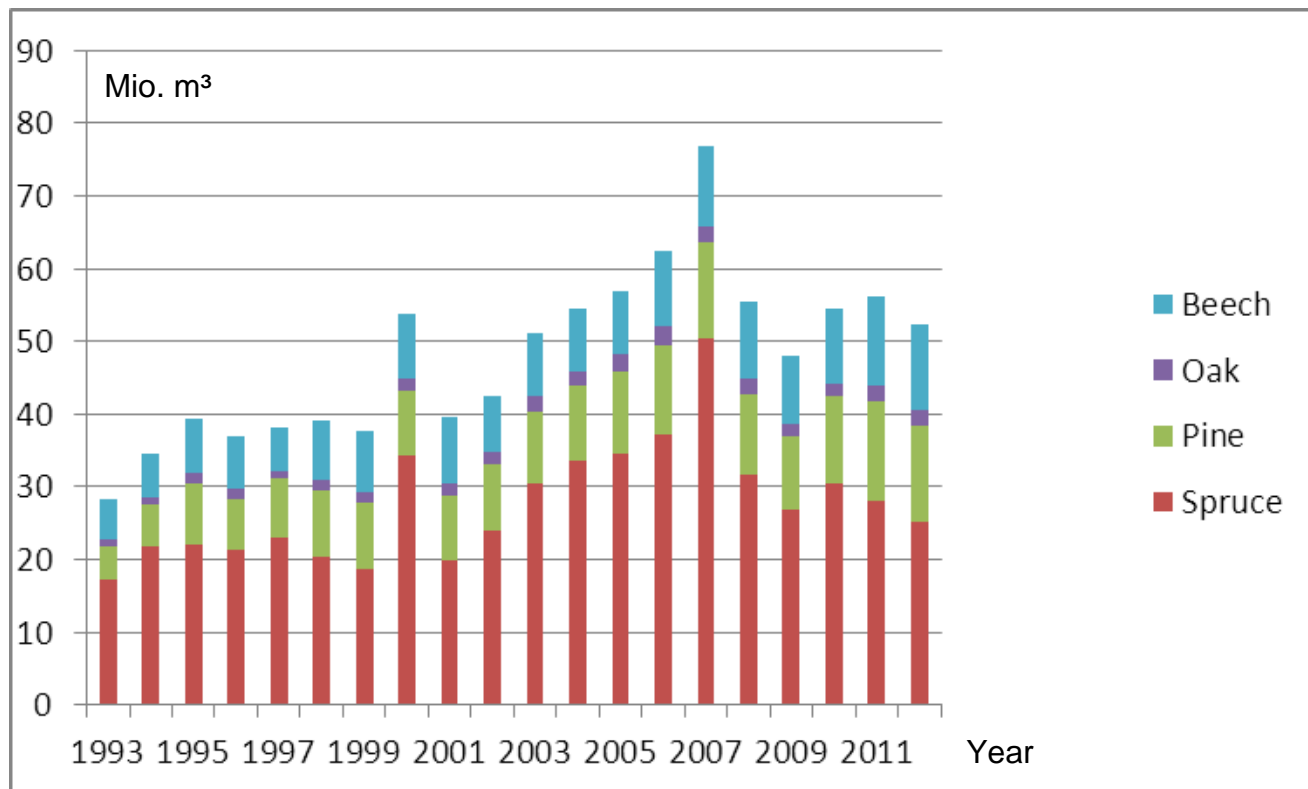
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Forest area in Germany: 11.4 Mio. hectares

Annual timber harvest volume about 76 Mio. m³



1. Context and basics of forest access

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1. Context and basics of forest access

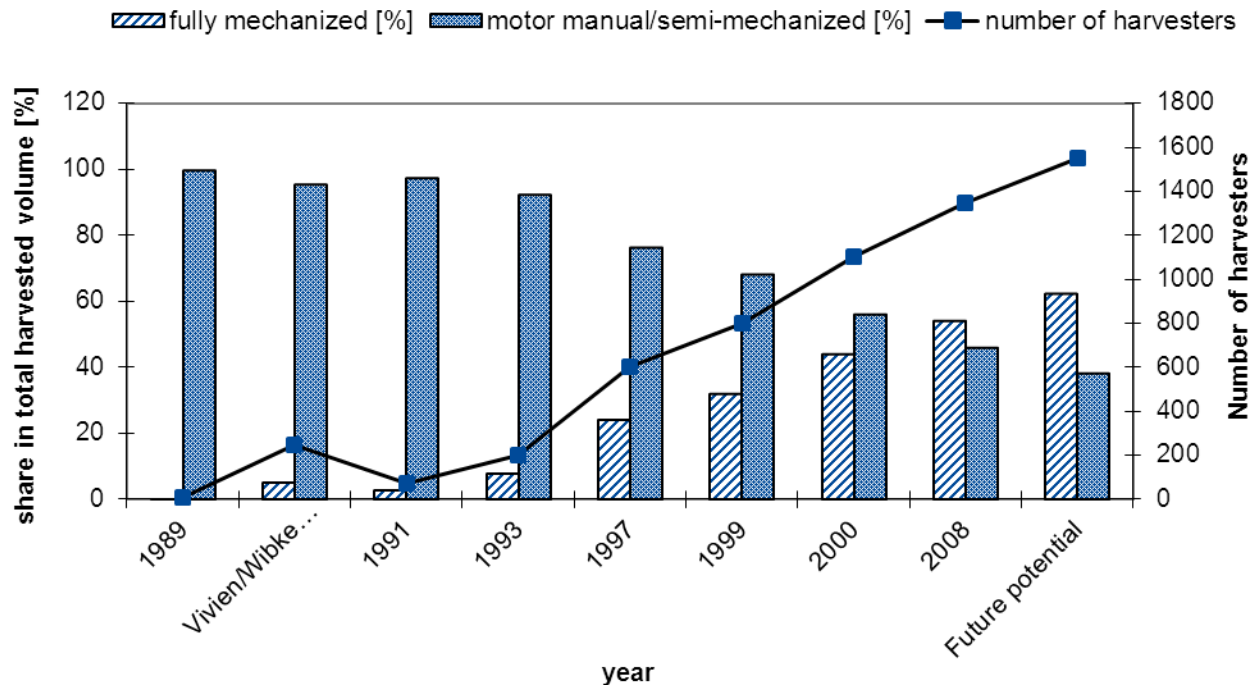
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Development of mechanized harvesting in Germany

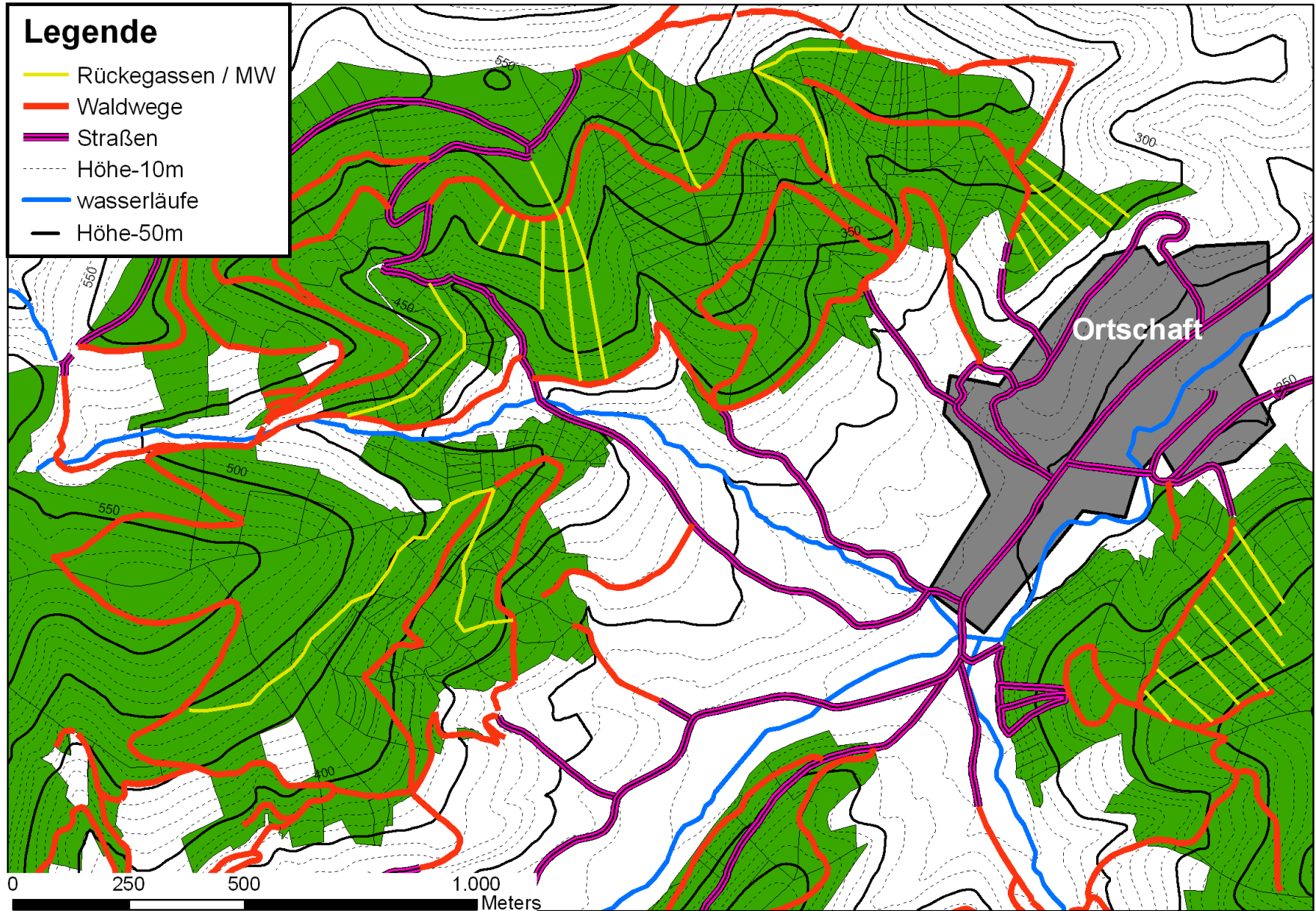
About half of the annual cut is done by mechanized harvesting



Source: KWF (estimation)

Legende

- Rückegassen / MW
- Waldwege
- Straßen
- - - - - Höhe-10m
- wasserläufe
- Höhe-50m



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Different uses of forests roads (general):

Forest management: inventory, planing, operating, supervising

Pest control/fire fighting

Game management (hunting)

Leisure and recreation

Other uses:

- Landlines, pipes
- Wells
- Antennas
- Wind mills for power generation

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Timber transport



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Timber transport



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Forest
management



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Fire
fighting



Bild: feuerwehr-landwehrhagen.de, 2013

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Recreation

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Sports



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- Low traffic frequencies: bimodal traffic of many cars and few but timely concentrated hauling trucks
- Relatively short transportation distances within the forest (until reach of public road network)
- Single lane roads with design speed of 30 km/hr
- Unpaved gravelled roads
- Restricted access to forest related vehicles
- Besides forestry many other users
- Max. gross weight of hauling trucks 40 t
- Max. axle loads: 11.5 t single axle
19.0 t tandem axle

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Short wood hauling truck

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Long wood hauling truck

2. Road standards – main roads

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2. Road standards – main roads

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Main roads: hauling roads for year round access

- Purpose: Connect to other forest road or public road (loop design, no dead end roads)
- Gravelled roads, one lane roads 3.5 m width
- Road gradient between 2 and 12%
- Radius of horizontal curves not less than 20 m
- Bridges supporting max. axle loads
- Continuous maintenance

2. Road standards – main road

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2. Road standards – main roads

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2. Road standards – main roads

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Road density of main roads in Germany

Baden-Württemberg	52 m/ha
Bayern	32 m/ha
Hessen	33 m/ha
Niedersachsen	32 m/ha

2. Road standards – secondary roads

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Secondary (seasonal) roads: hauling roads for access during favorable times (e.g., dry times or frost)

- Purpose: for shorter distance transport
- feed into main road
- sometimes designed as dead end roads
- one lane roads 3.5 m width
- sometimes gravelled
- bridges supporting max. axle loads
- maintained as needed

3. Planning process

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3. Two step process of planning forest roads

3.1 Forest road network planning

3.2 Road alignment/road design

3. Planning process

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Two step planning process

-Road network planning

- general planning of a forest transportation system
- tactical planning level
- medium-term (20-25 years) planning

-Road alignment/road design

- detailed planning of particular roads for stepwise realisation of the road network plan on the ground
- operational planning level
- short-term planning (one year)

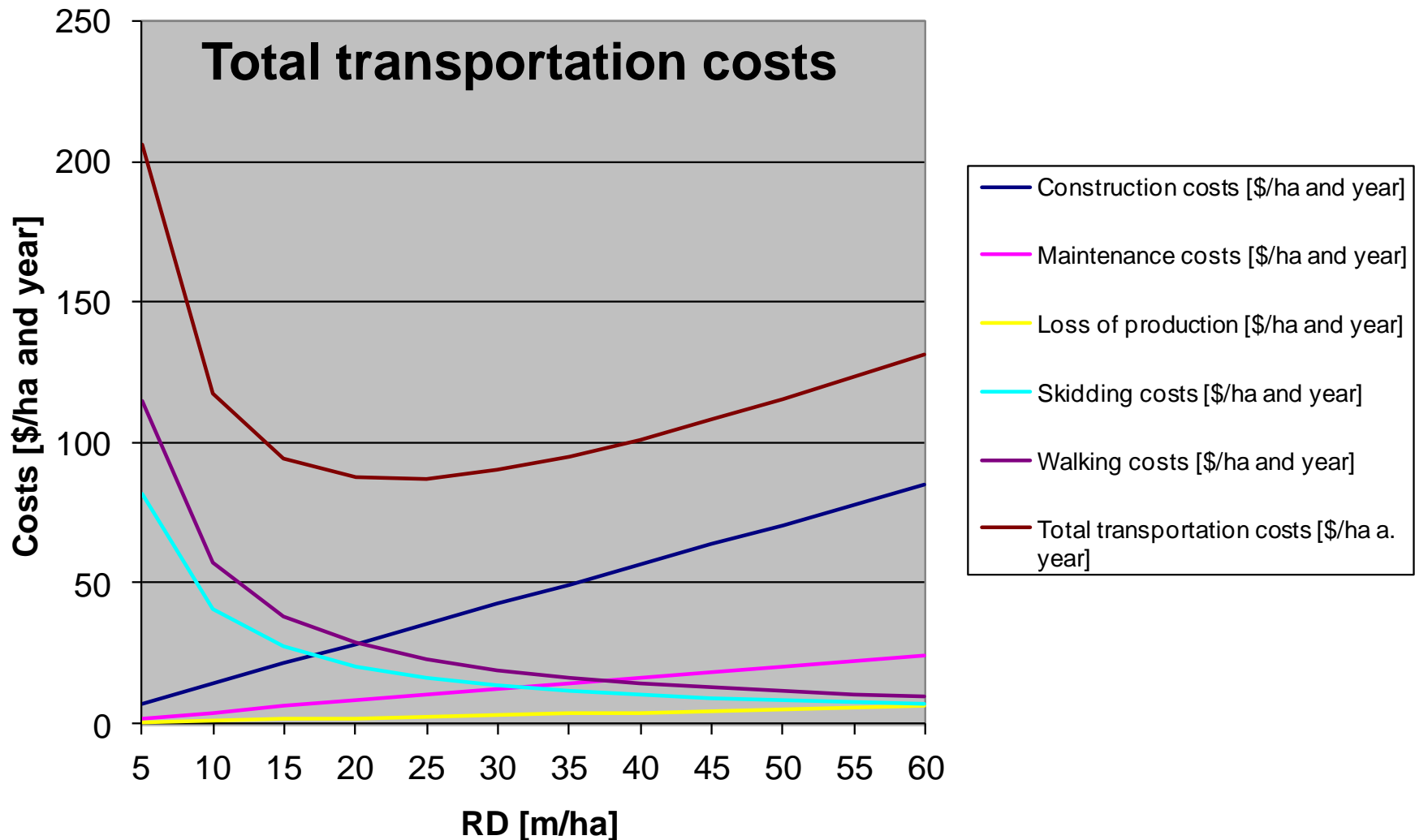
3.1 Planning process:

Forest road network planning

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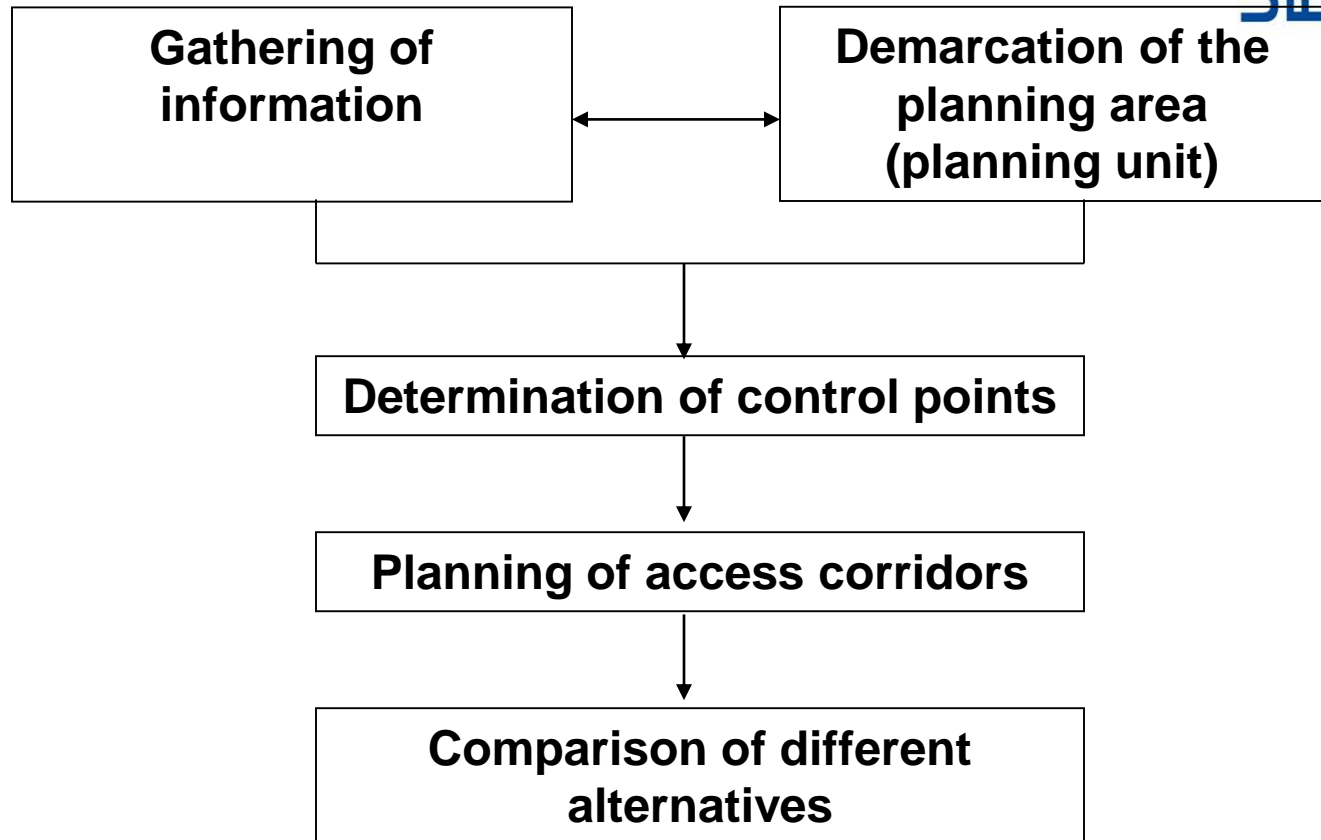
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3.1 Planning process: Forest road network planning

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Road network
planning
Empirical method



(DIETZ et al. 1984)

3.1 Planning process:

Forest road network planning

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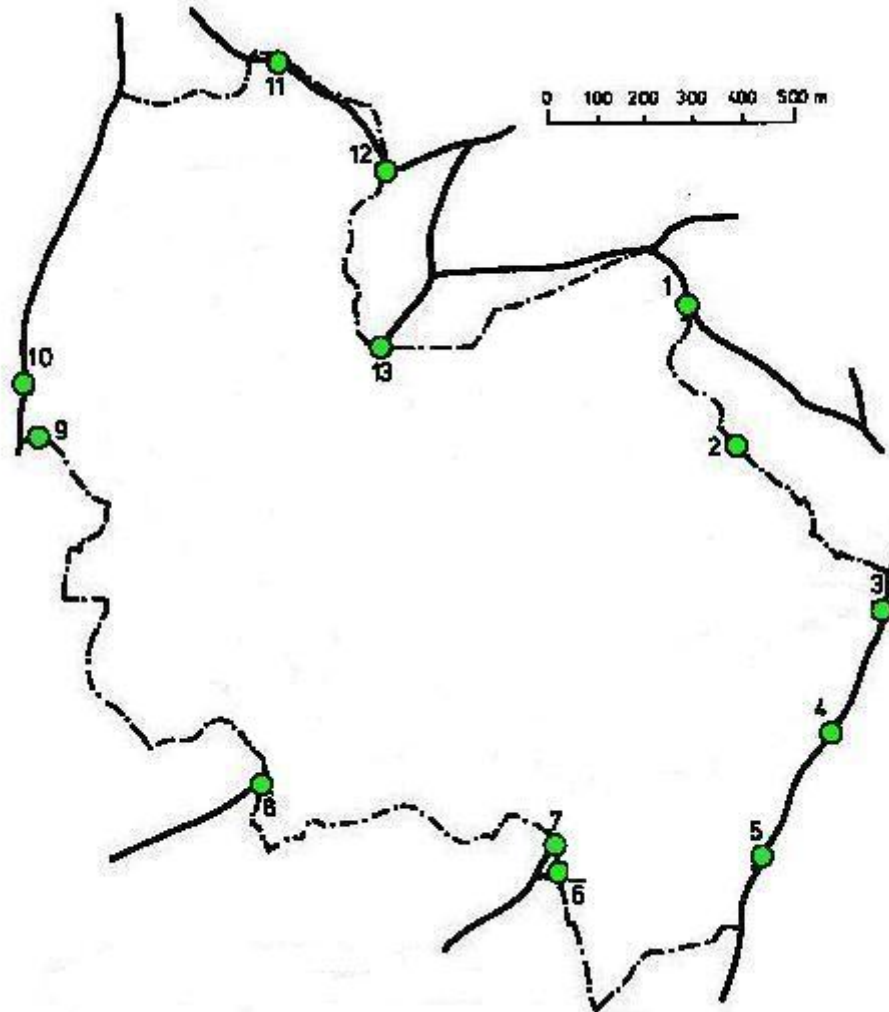


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Demarcation of
the planning area
(separate entity)

Determination
of the connection
points to existing
roads

(DIETZ et al. 1984)



3.1 Planning process:

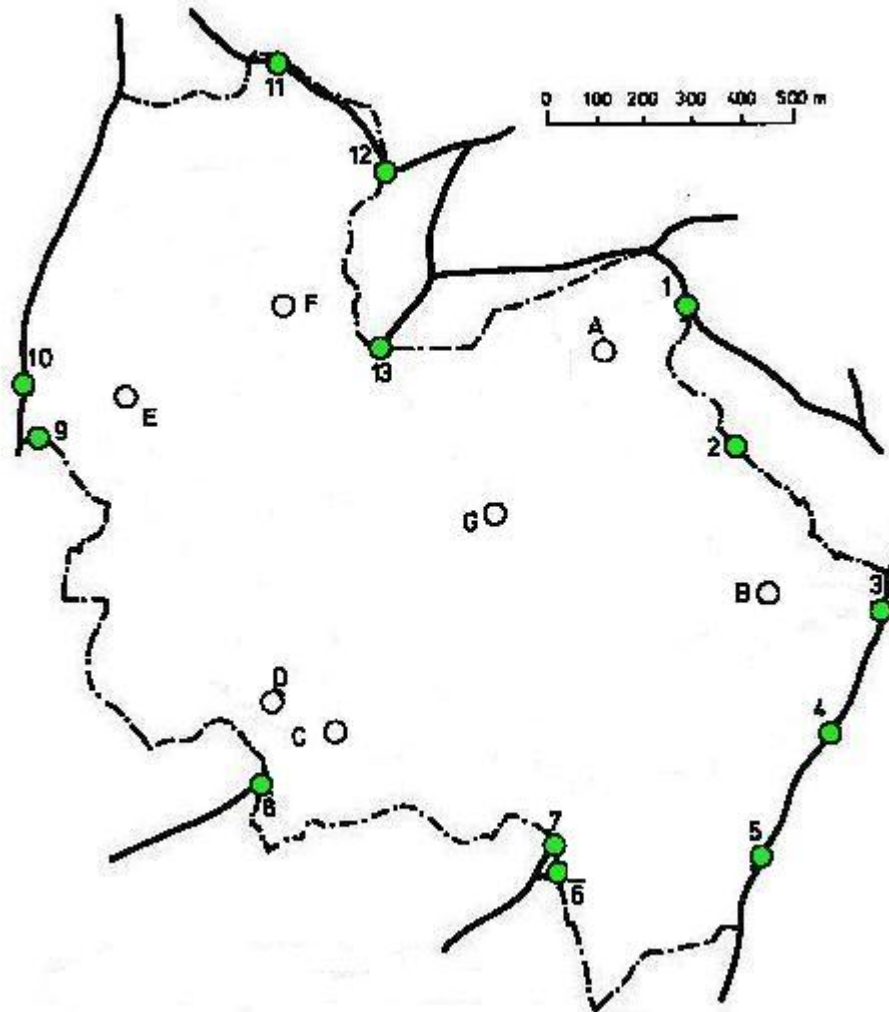
Forest road network planning

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Determination
of additional
positive control
points



3.1 Planning process:

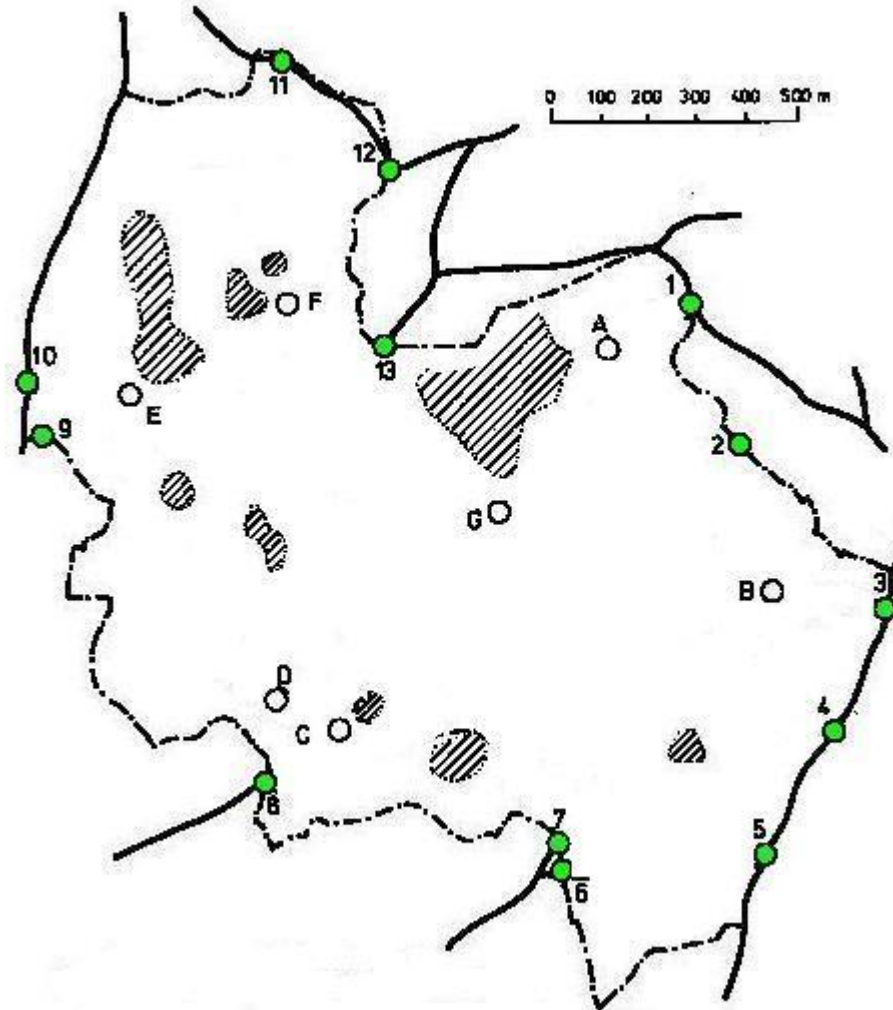
Forest road network planning

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Determination
of negative
control zones



3.1 Planning process:

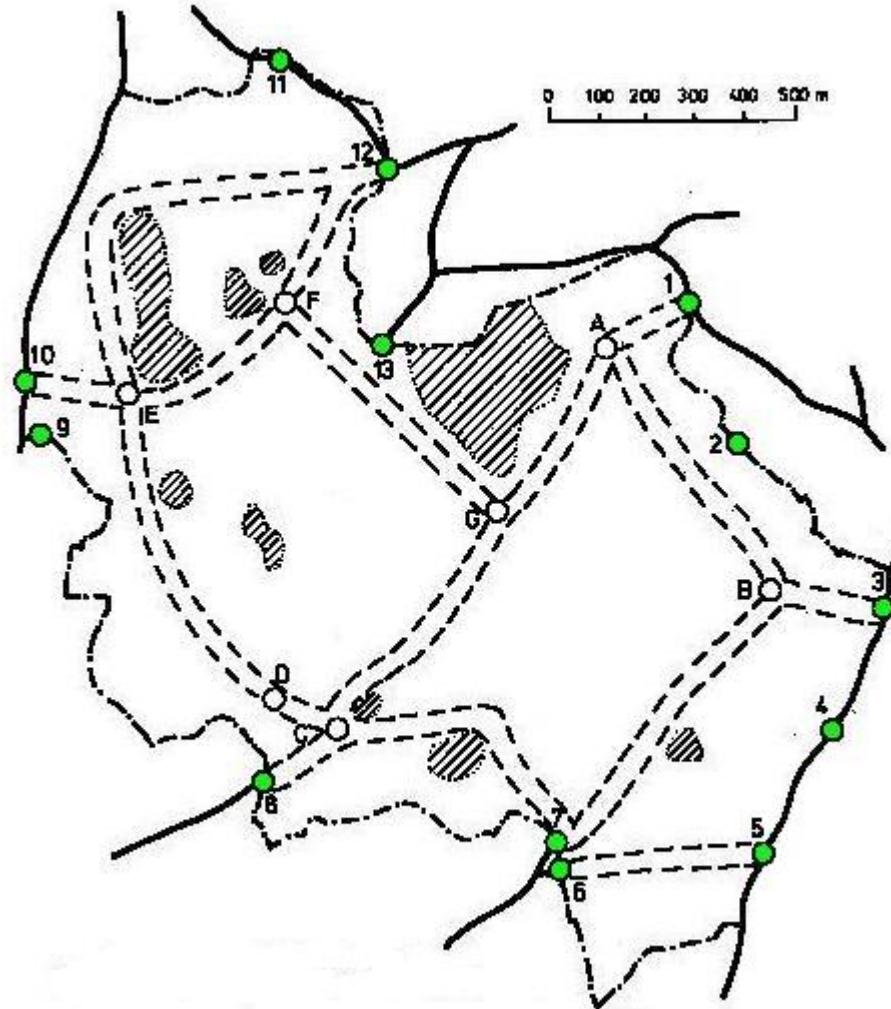
Forest road network planning

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Planning of road corridors



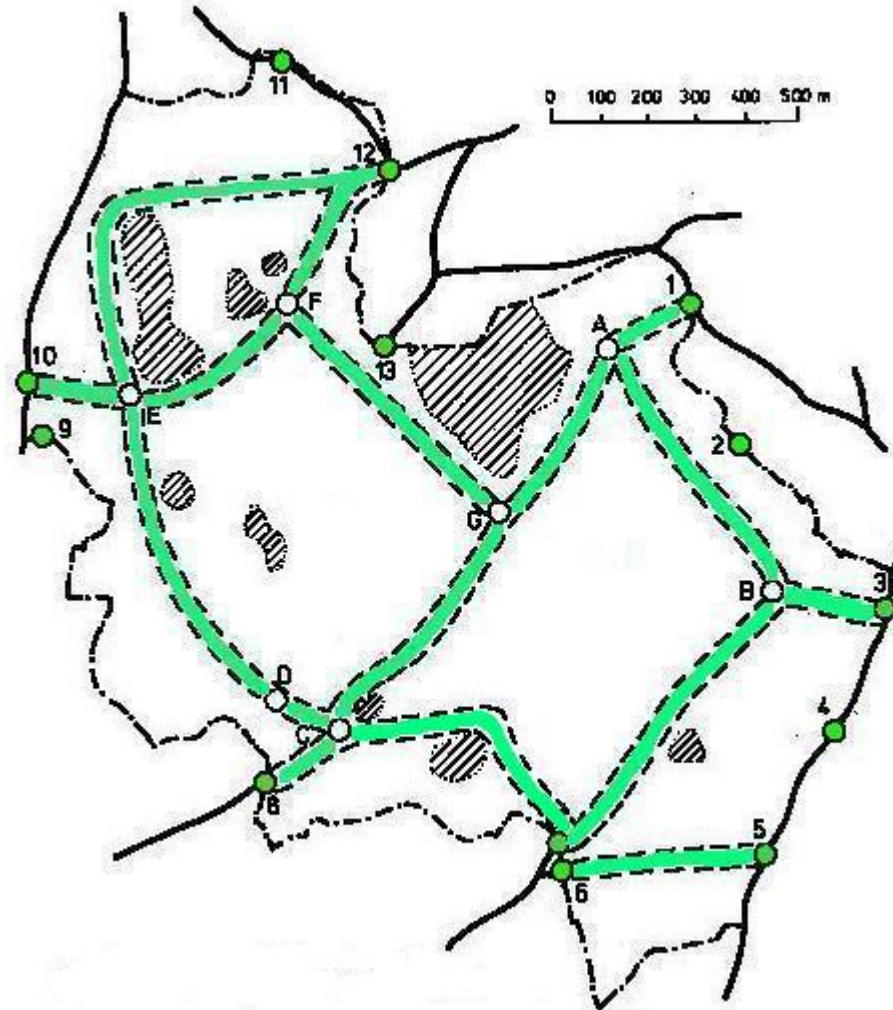
3.1 Planning process: Forest road network planning

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Road network plan



3.2 Planning process

Road alignment/road design

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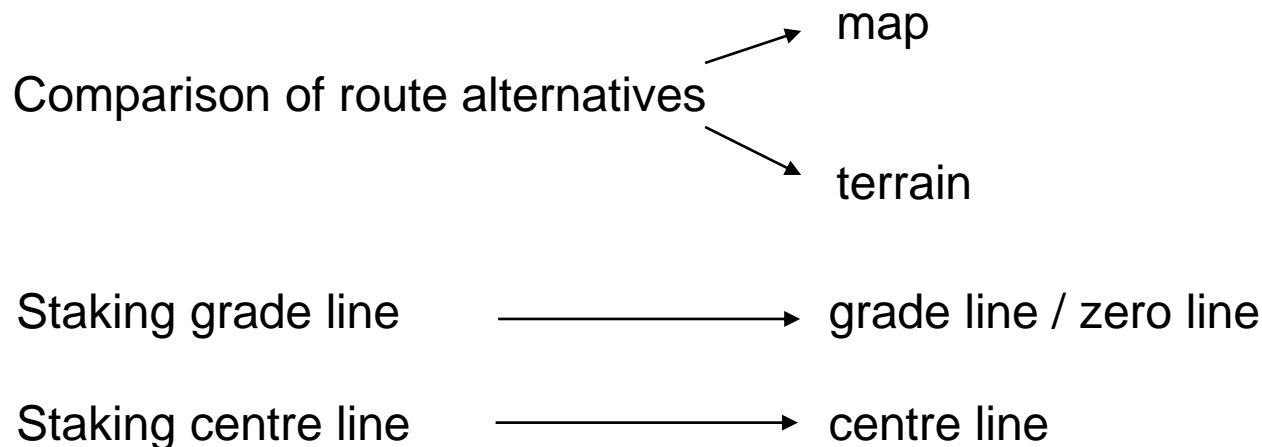


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Road Network Planning

Density, standard, rough location

Road alignment

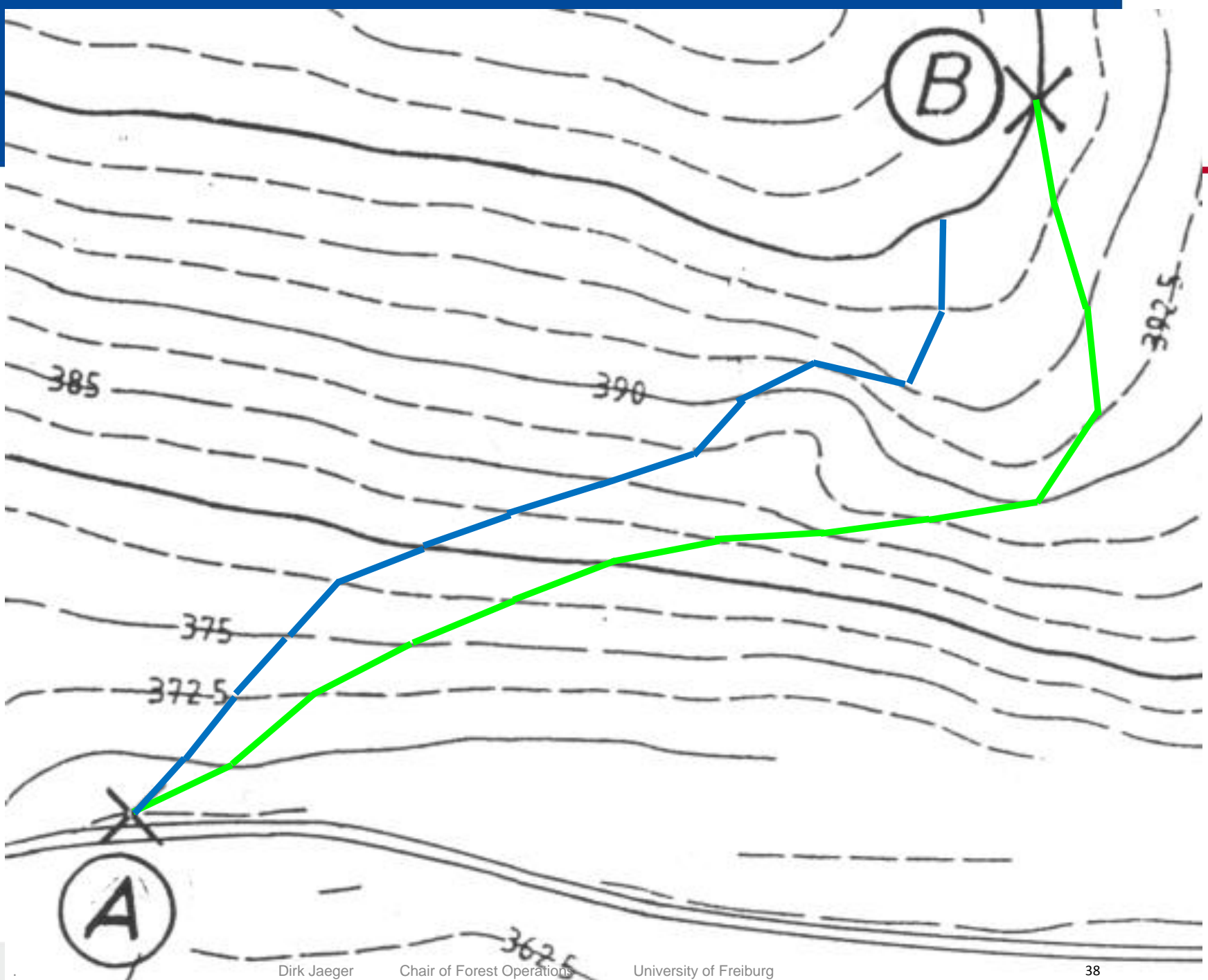


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Recorded data of the centre line:

Traverse---levelling---cross sections---miscellaneous data



3.2 Planning process

Road alignment/road design

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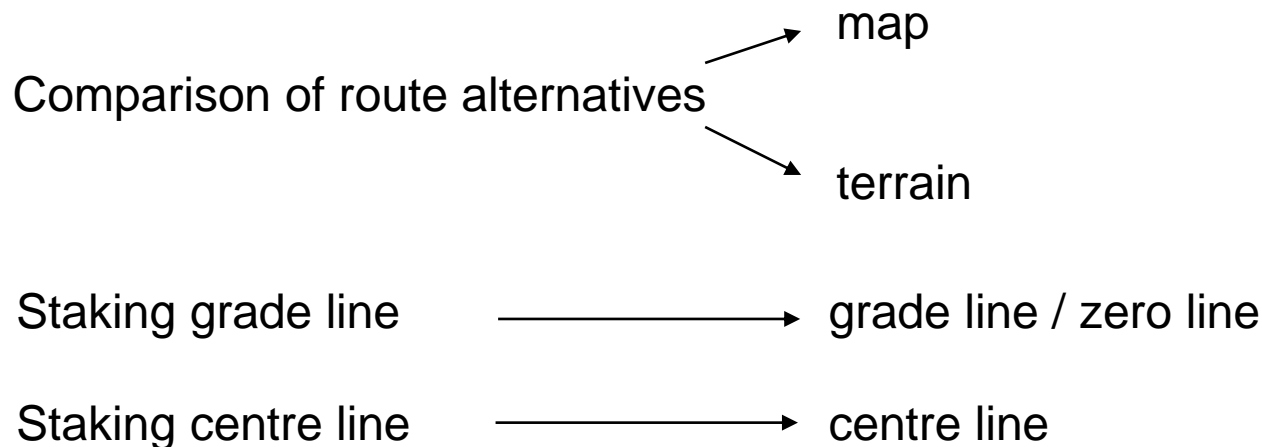


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Road Network Planning

Density, standard, rough location

Road alignment



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Recorded data of the centre line:

Traverse---levelling---cross sections---miscellaneous data

3.2 Planning process

Road alignment/road design

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URG

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Data processing

Traverse → plan

levelling → longitudinal profile, vertical alignment

cross sections → cross sections of terrain and road
calculation of earthwork (cut and fill)

miscellaneous data → other issues, e.g. design of
bearing layer

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Profiling

Construction, Control

Accounting

Dirk Jaeger

Chair of Forest Operations

Cost survey

University of Freiburg

40

4. Recommendations for road alignment

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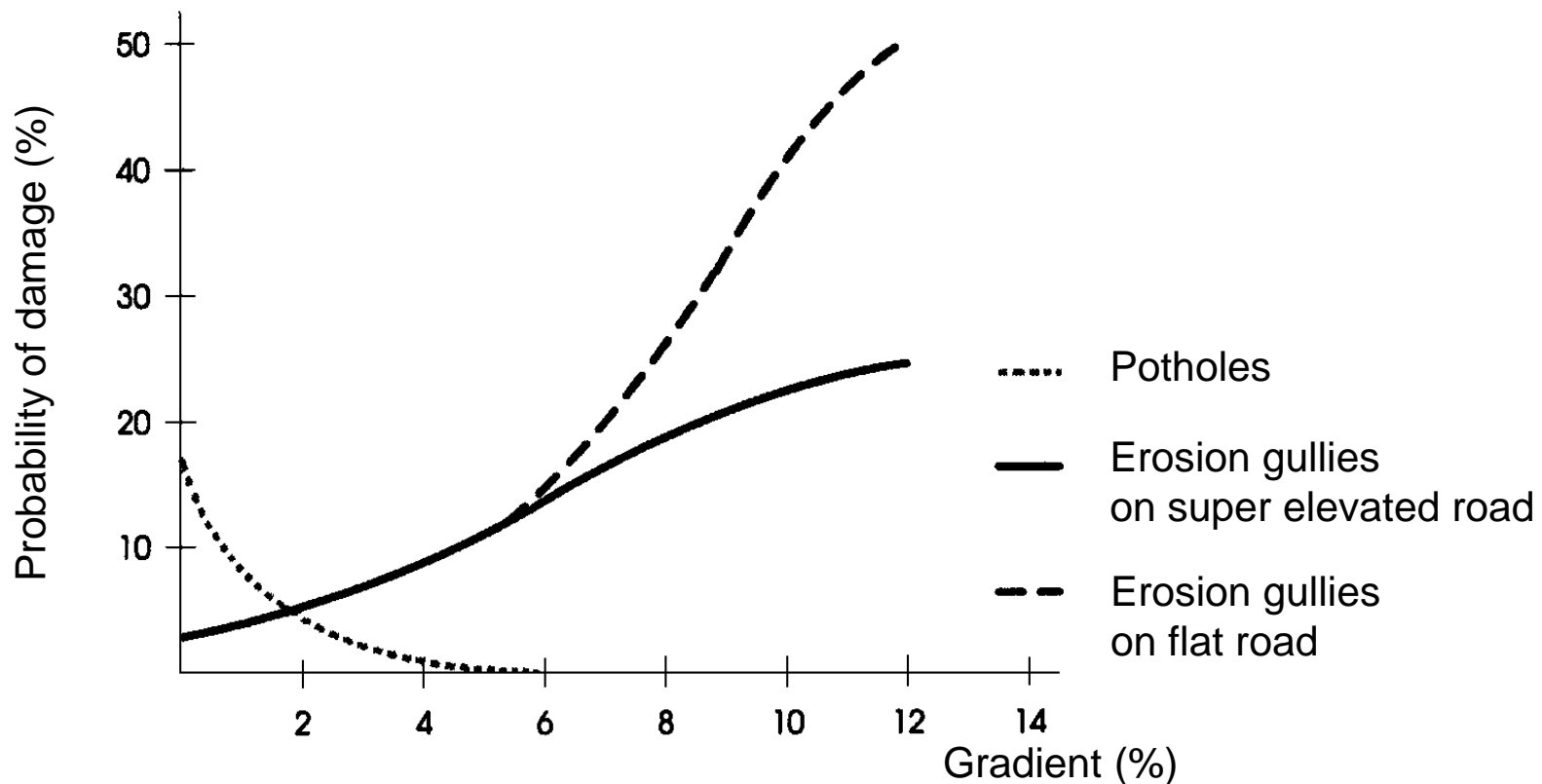
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Recommendations for road alignment:

4. Recommendations for road alignment

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Effect of gradient on road damage



(adapted from Heinimann 1997)

4. Recommendations for road alignment

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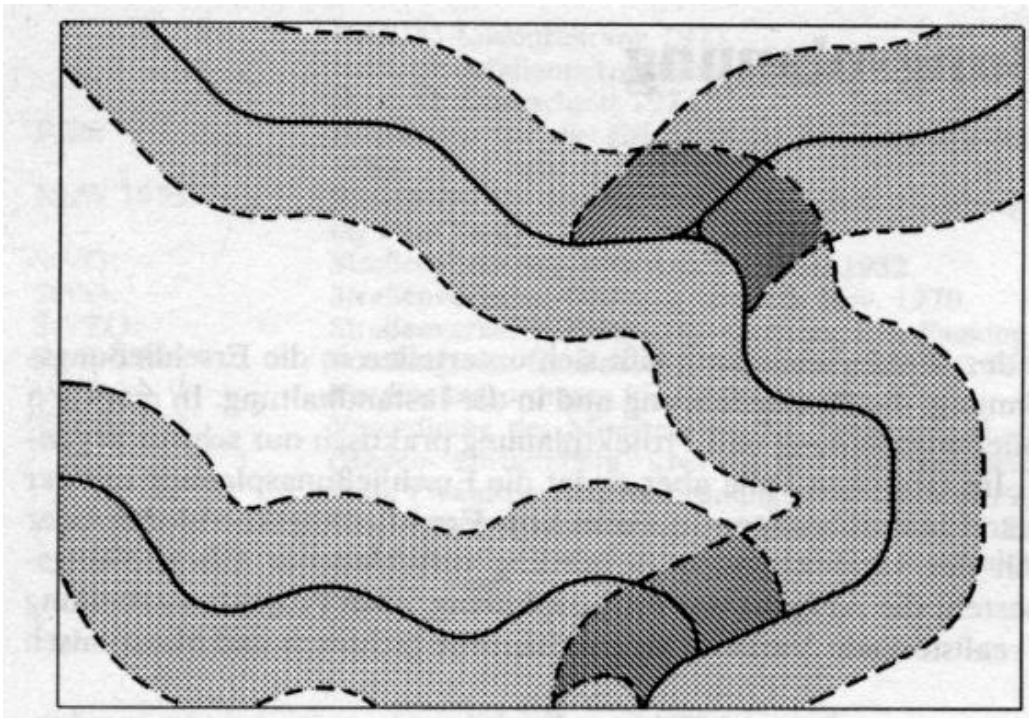
Recommendations for road alignment:

1. The higher the road gradient, the more important is the crowning (superelevation) of the road in order to avoid erosion
2. Roads should intersect at wide angles in order to avoid overlap of access corridors

4. Recommendations for road alignment

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Overlap of access corridors



Quelle: Dietz et al. 1984

4. Recommendations for road alignment

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Recommendations for road alignment:

1. The higher the road gradient, the more important is the crowning (superelevation) of the road in order to avoid erosion
2. Roads should intersect at wide angles in order to avoid overlap of access corridors
3. Align roads in the upper third of hills in order to utilize full width of access corridor
4. Avoid aligning roads next to rivers or other skidding barriers reducing effective access to one side of the road

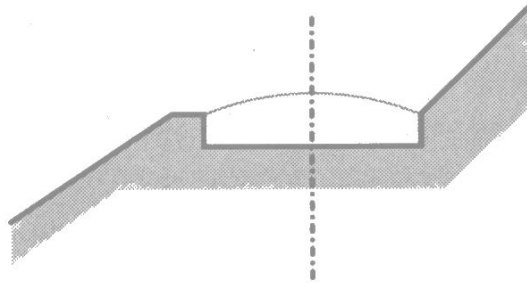
5. Road characteristics

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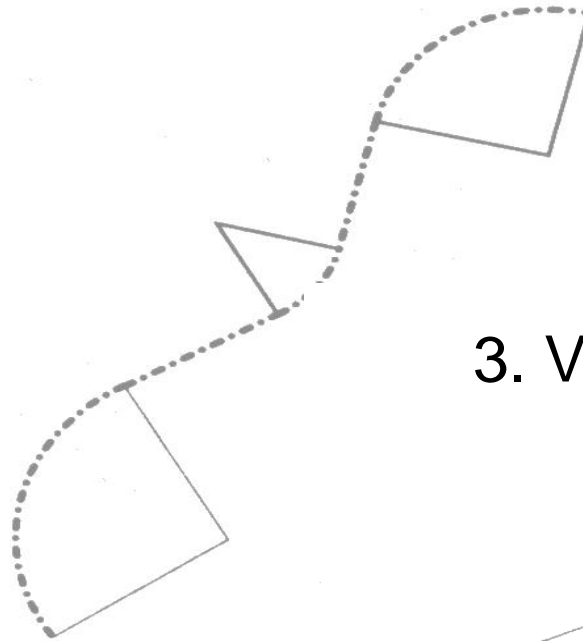
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Three perspectives to
describe a forest road

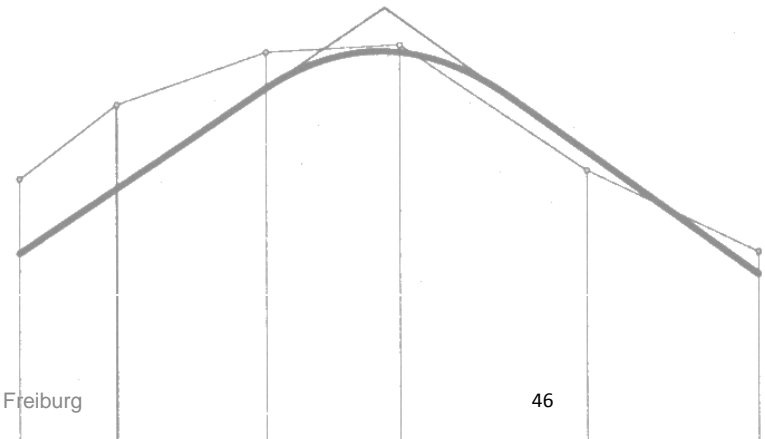


1. Cross section

2. Horizontal alignment



3. Vertical alignment



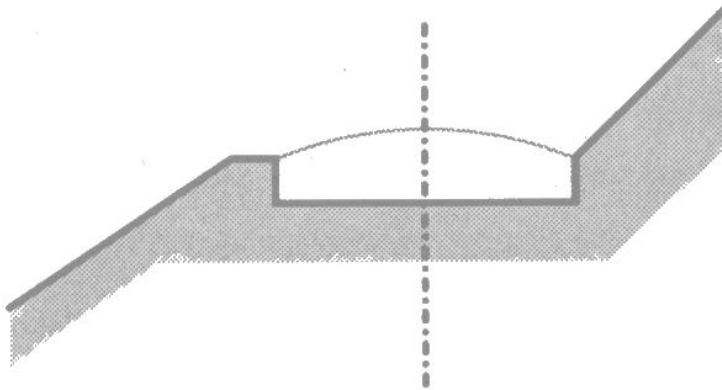
5. Road characteristics

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Cross section



Road width

Width of right-of-way

Road surface (type, shape/profile)

Verge

Ditch

Side slopes

Bearing capacity/axle loading

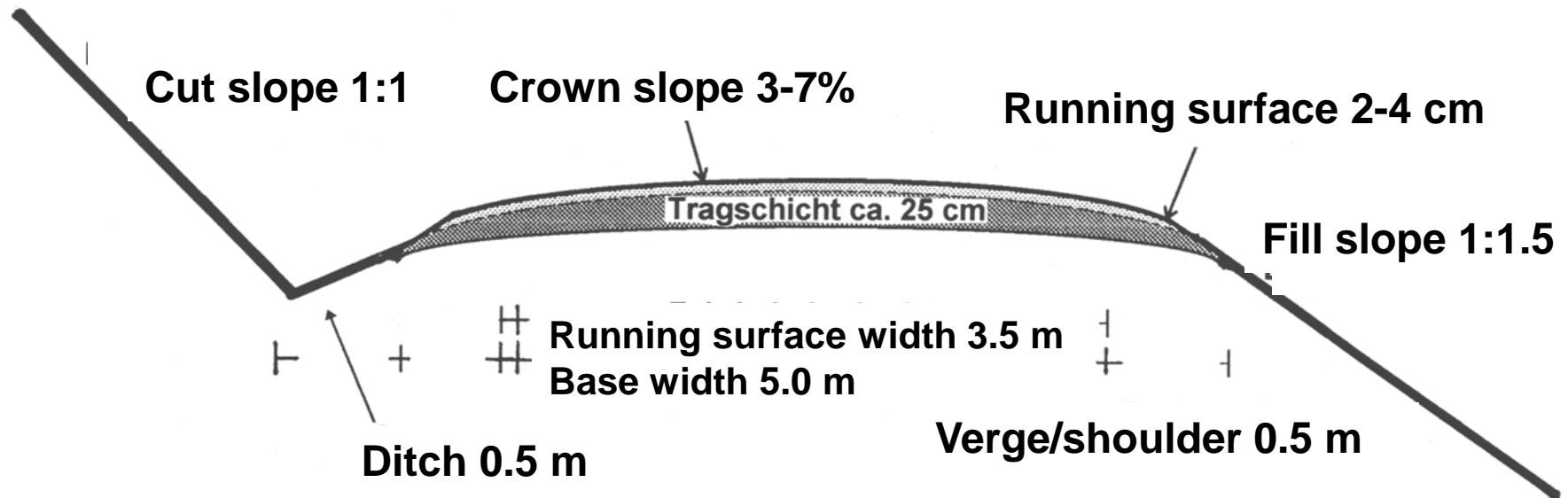
5. Road characteristics

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Forest road with crown profile



5. Road characteristics



5. Road characteristics

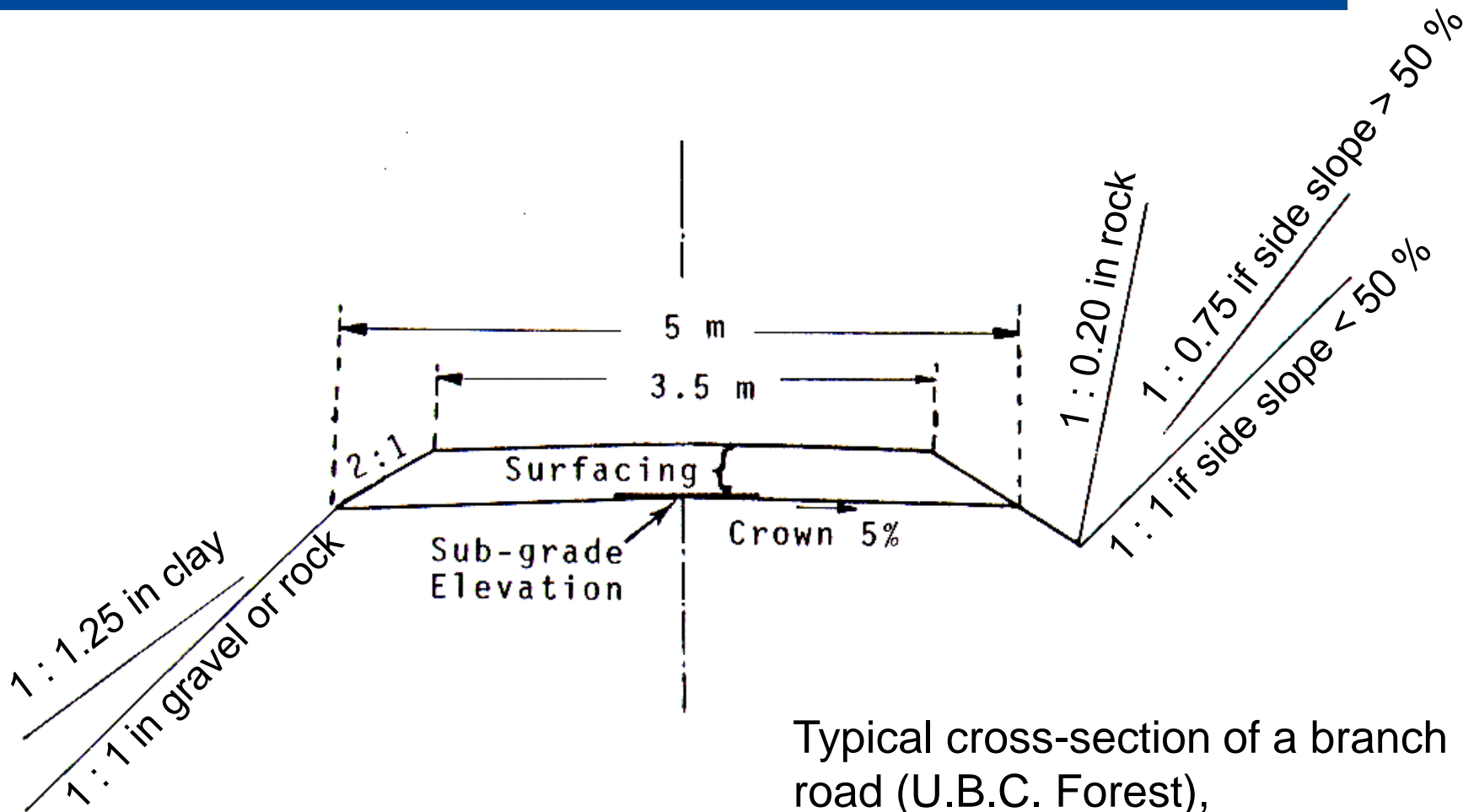
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5. Road characteristics



Typical cross-section of a branch road (U.B.C. Forest), adapted from BCIT 1989

5. Road characteristics

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Bearing capacity:

1. In Europe, especially Germany, E_{v2} is used to describe the bearing capacity

for forest roads 80 to 90 MPa/m² for E_{v2} are recommended

2. In North-America California Bearing Ratio (CBR in %) is used:

3-7	Poor to fair	Subgrade
7-20	Fair	Subbase
20-50	Good	Base or Subbase
> 50	Excellent	Base

5. Road characteristics

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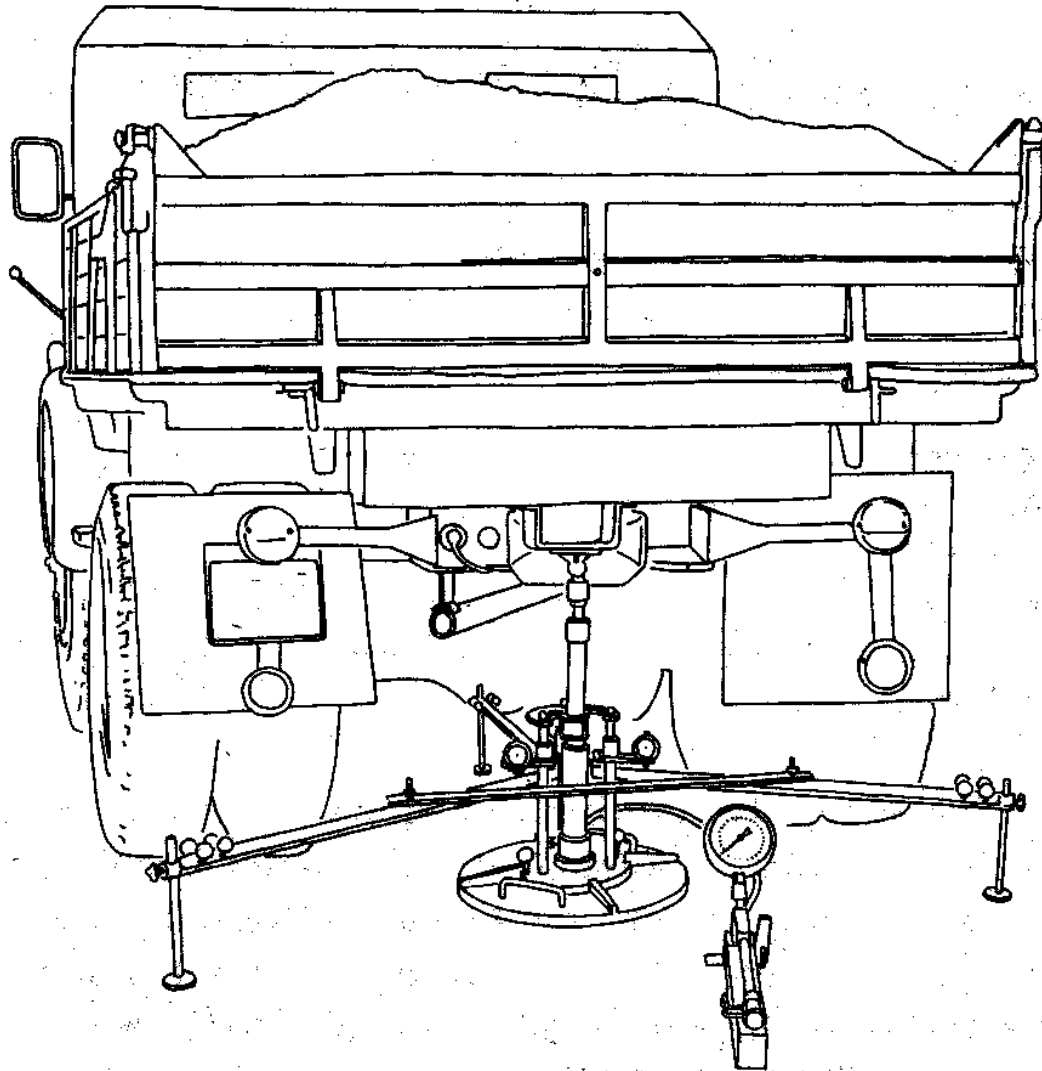


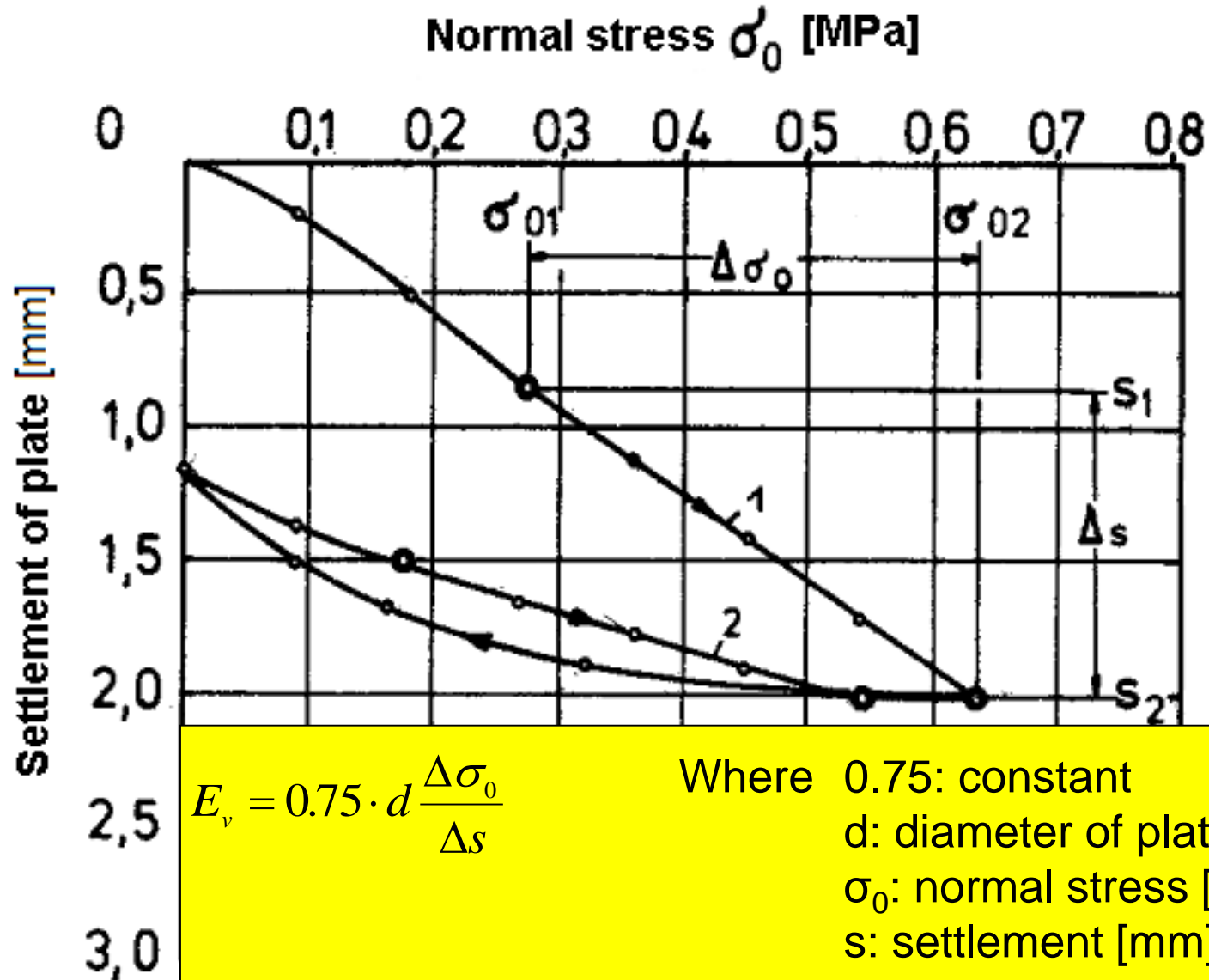
Plate load test

5. Road characteristics

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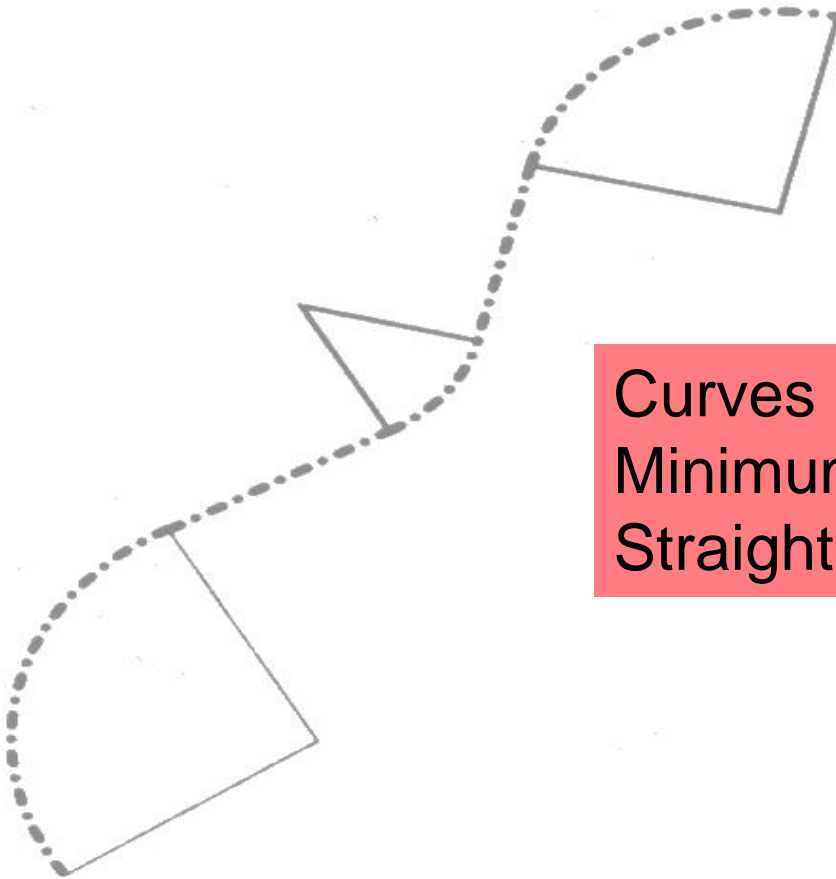
5. Road characteristics

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Horizontal alignment



Curves

Minimum curve radius

Straight segments

5. Road characteristics

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Horizontal alignment of road (plan)

arrangement of straight segments (tangents) and curves (circular arcs)

Horizontal curves

minimum radius depends on

- terrain conditions
- design speed

20 m absolute minimum radius

Straight segments

Tangent between adjacent curves in opposite direction of at least one truck length (e.g. 25 m)

5. Road characteristics

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Recommendations for
curve radius due to safety
and technical restrictions

Design speed [km/h]	Minimum curve radius [m]
20	15
30	35
40	65
50	100
60	140
70	190
80	250

(British Columbia Institute of
Technology 1989)

5. Road characteristics

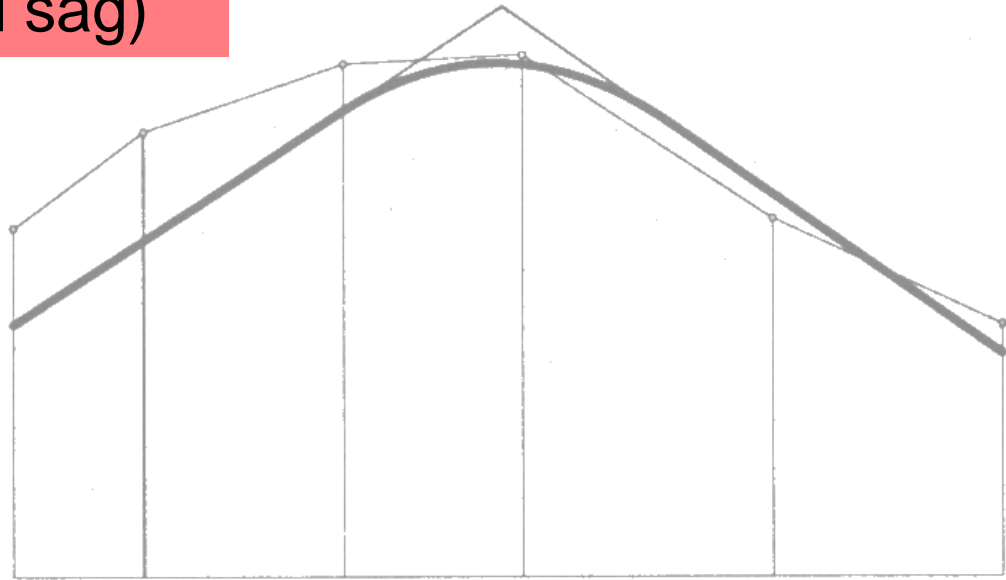
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Vertical alignment

Maximum longitudinal gradient
Vertical curves (crest and sag)



5. Road characteristics

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Vertical alignment of the road (longitudinal profile with gradient)

arrangement of favorable and adverse grades with vertical curves

Gradient between 2 and 12 %

Recommendations for minimum radius of vertical curves (Germany)

- crest: 400 m ($k=4$ m/%)
- sag: 200 m ($k=2$ m/%, no trucking at night time)

Rule of thumb: 10 m/% equals vertical radius of 1000 m

5. Road characteristics

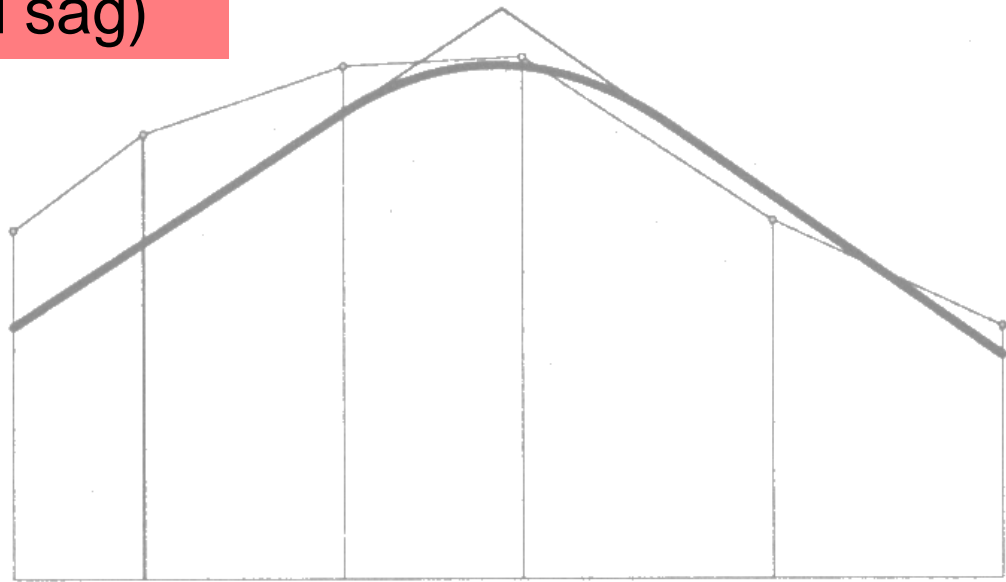
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Vertical alignment

Maximum gradient
Vertical curves (crest and sag)



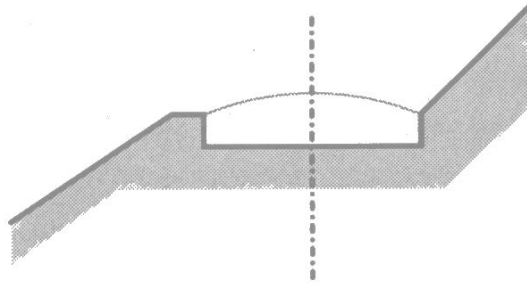
5. Road characteristics

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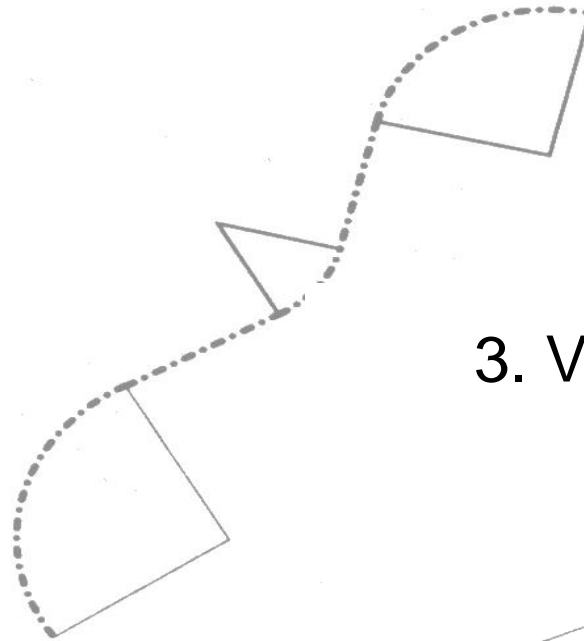
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Three perspectives to
describe a forest road

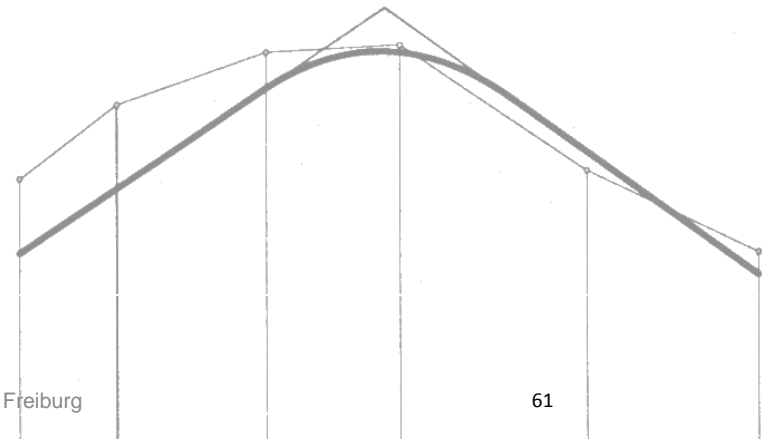


1. Cross section

2. Horizontal alignment



3. Vertical alignment



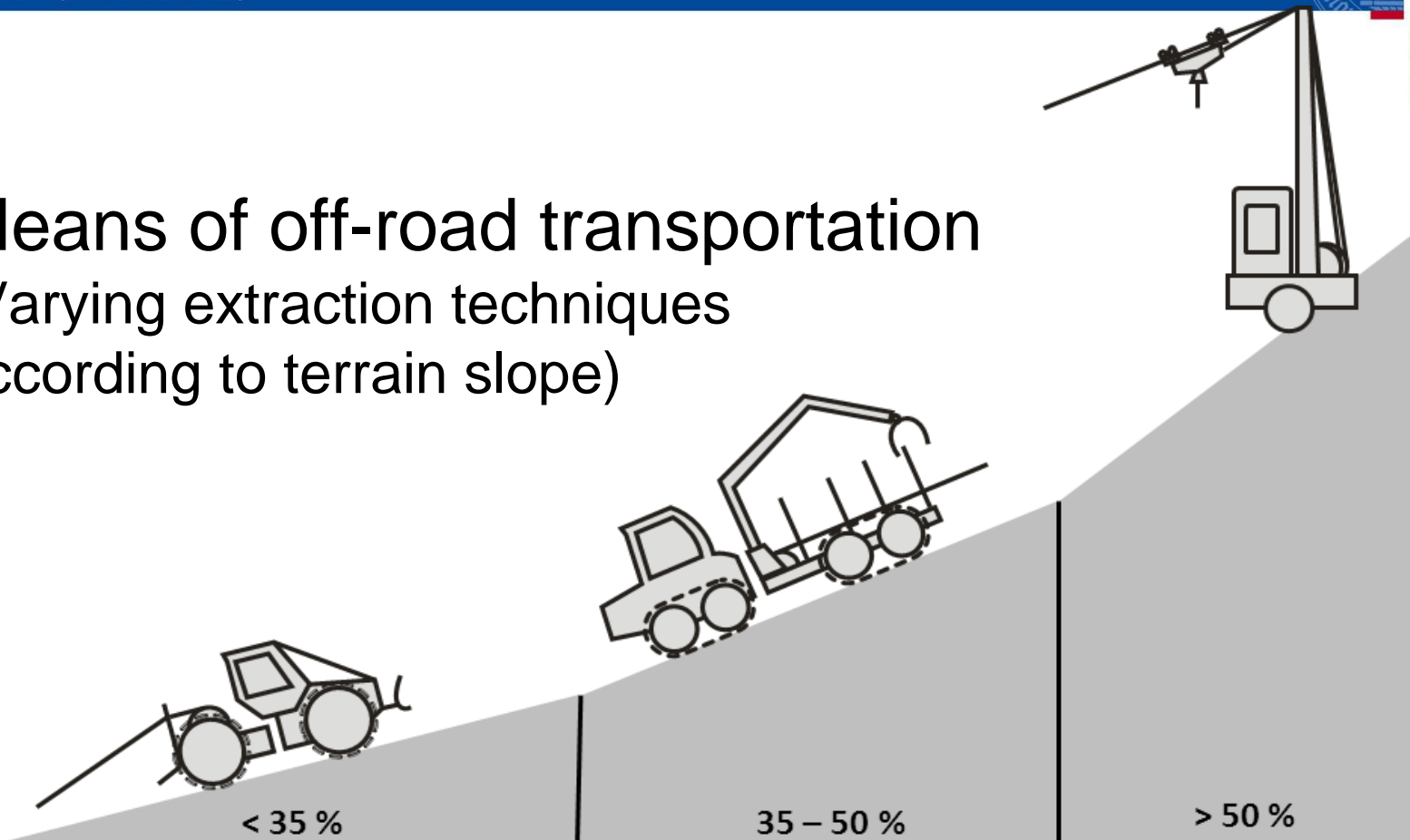
6. Off-road transportation (extraction)

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Means of off-road transportation
(Varying extraction techniques
according to terrain slope)



Skidding on skid trails
or
strip roads

Machinery equipped
with supporting
winches (tethering
winches)

Cable yarder

6. Off-road transportation (extraction)

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Skid trails for forwarding



Cleared lines in stands with drivable terrain

off-road vehicles:
forwarder, skidder

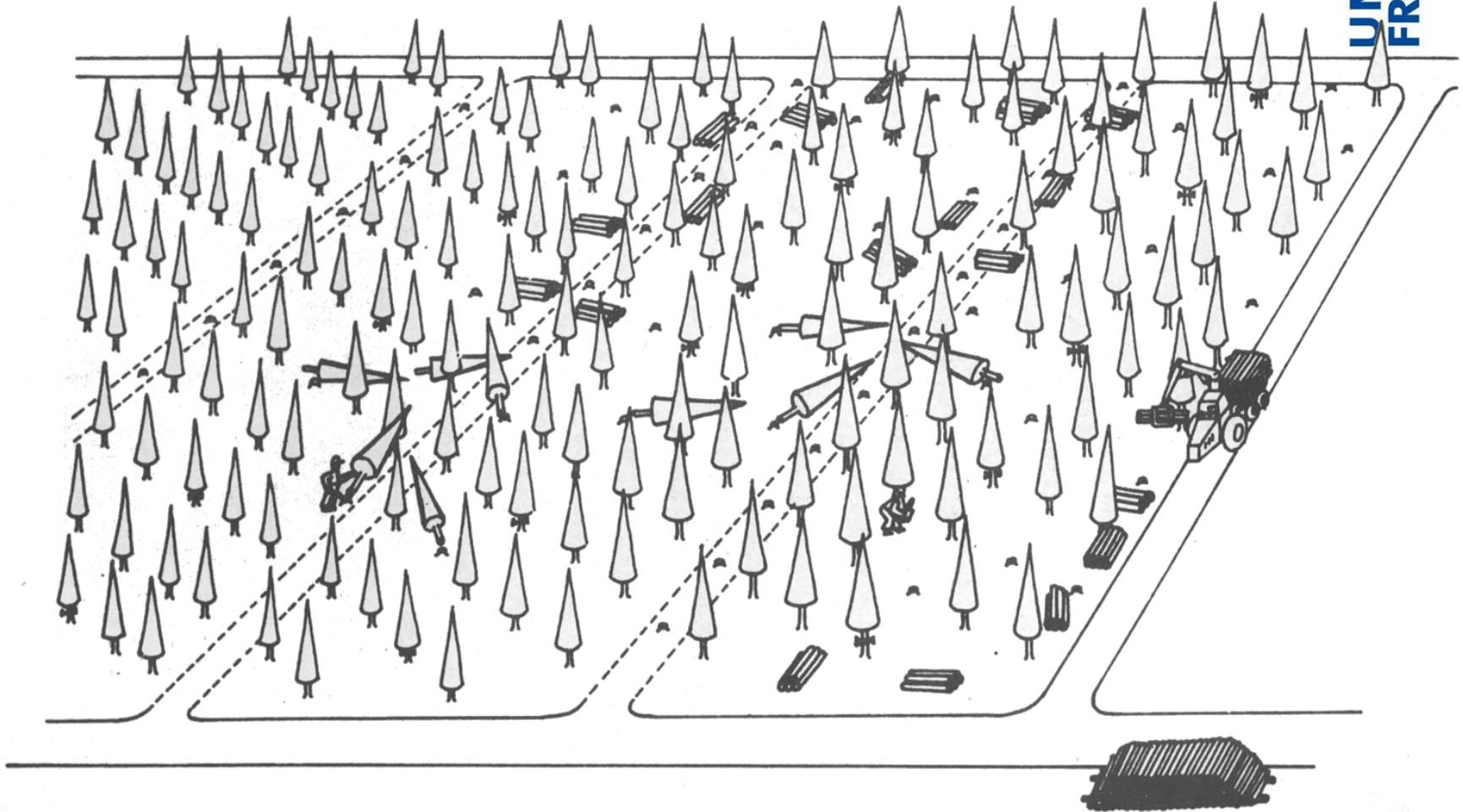
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SCHLAGORDNUNG BEIM KURZHOLZVERFAHREN



6. Off-road transportation (extraction)



6. Off-road transportation (extraction)

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6. Off-road transportation (extraction)

Skid trails for forwarding



Slope of terrain

up to 35-50%

Bearing capacity

fair

(CBR > 5 %, $\rho_d > 1.7 \text{ Mg/m}^3$)

Rocks on surface

difficult

Gradient

max. 50 % (in direction of slope, according to terrain slope)

Width

3-5 m

Spacing

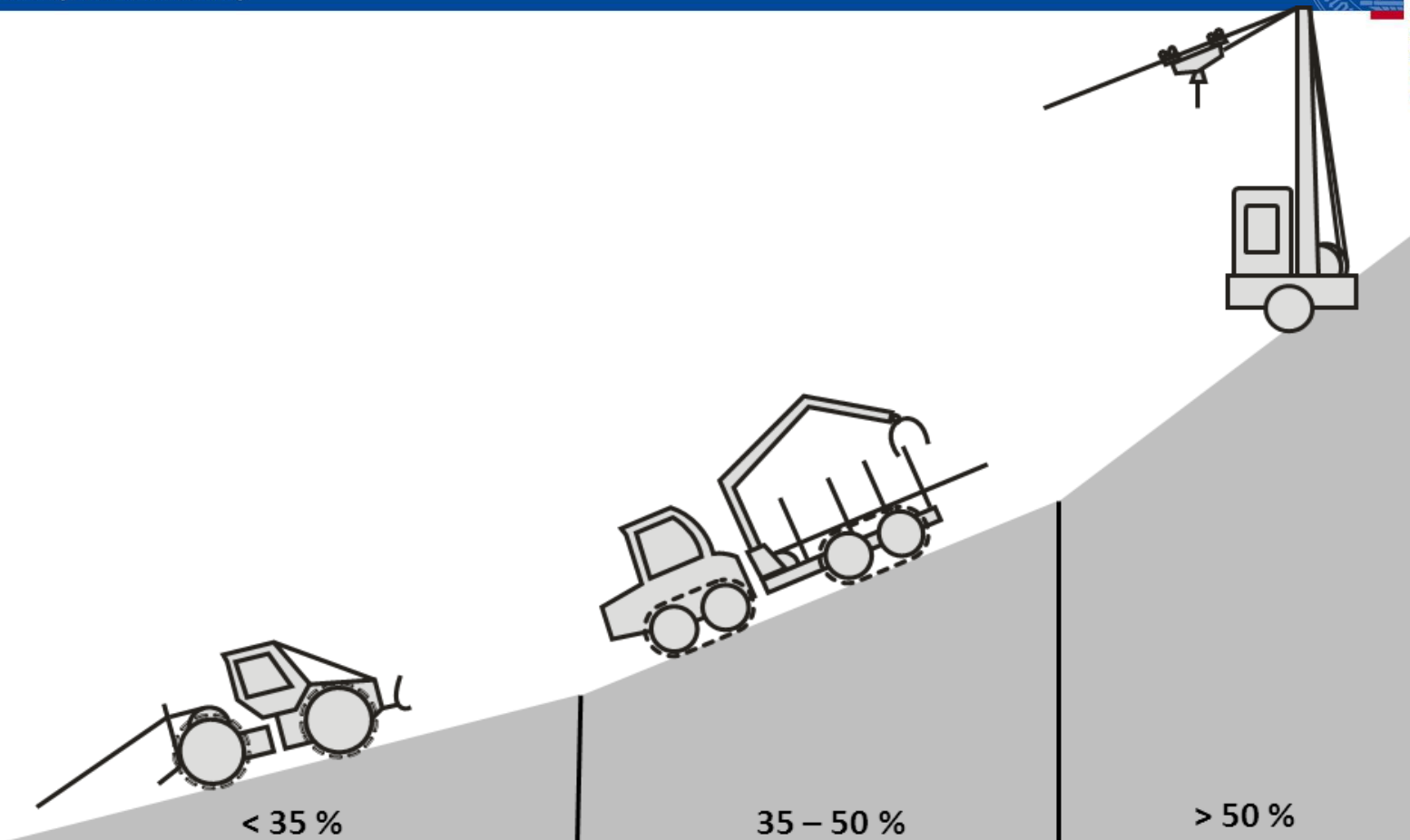
20-40 m

6. Off-road transportation (extraction)

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Skidding on skid trails
or
strip roads

Machinery equipped
with supporting
winches (tethering
winches) on skid trails

Cable yarder
on cable lines

6. Off-road transportation (extraction)

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Technical measures for steep terrain accessibility

- Increase of steep terrain operability of wheeled machines by additional equipment (e.g., chains, tracks)
- Upgrading of machinery by additional features (e.g., single grip harvester and forwarder with tethering winches)
- New developments (e.g., tracked under carriages, tiltable cabins, Highlander)
- Use of non-groundbased cable yarding systems

6. Off-road transportation (extraction)

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Use of tracks for increased traction



6. Off-road transportation (extraction)

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Supporting winch/Tethering winch (Synchro winch)

牵引绞盘机和同步绞盘机作为辅助



6. Off-road transportation (extraction)

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Specialized slope harvesters (tracked undercarriage, tilt cabins)

特殊的大坡度联合伐木机（履带式底盘，倾斜式操控舱）



6. Off-road transportation (extraction)

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Highlander: Slope adapted undercarriage systems for wheeled harvesters

可根据坡度进行调整的底盘系统，用于橡胶轮胎的联合伐木机



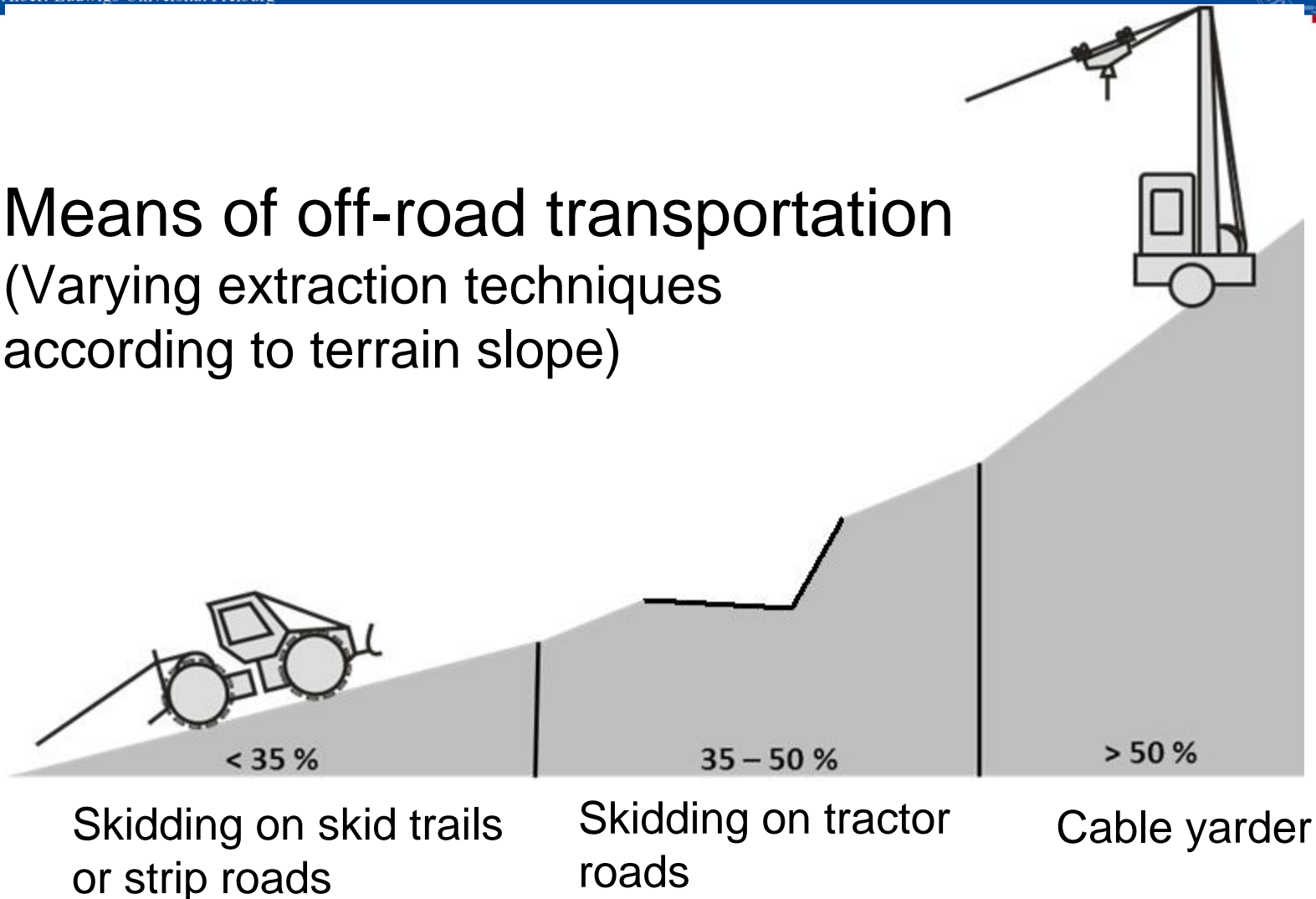
6. Off-road transportation (extraction)

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Means of off-road transportation
(Varying extraction techniques
according to terrain slope)



6. Off-road transportation (extraction)

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Tractor roads

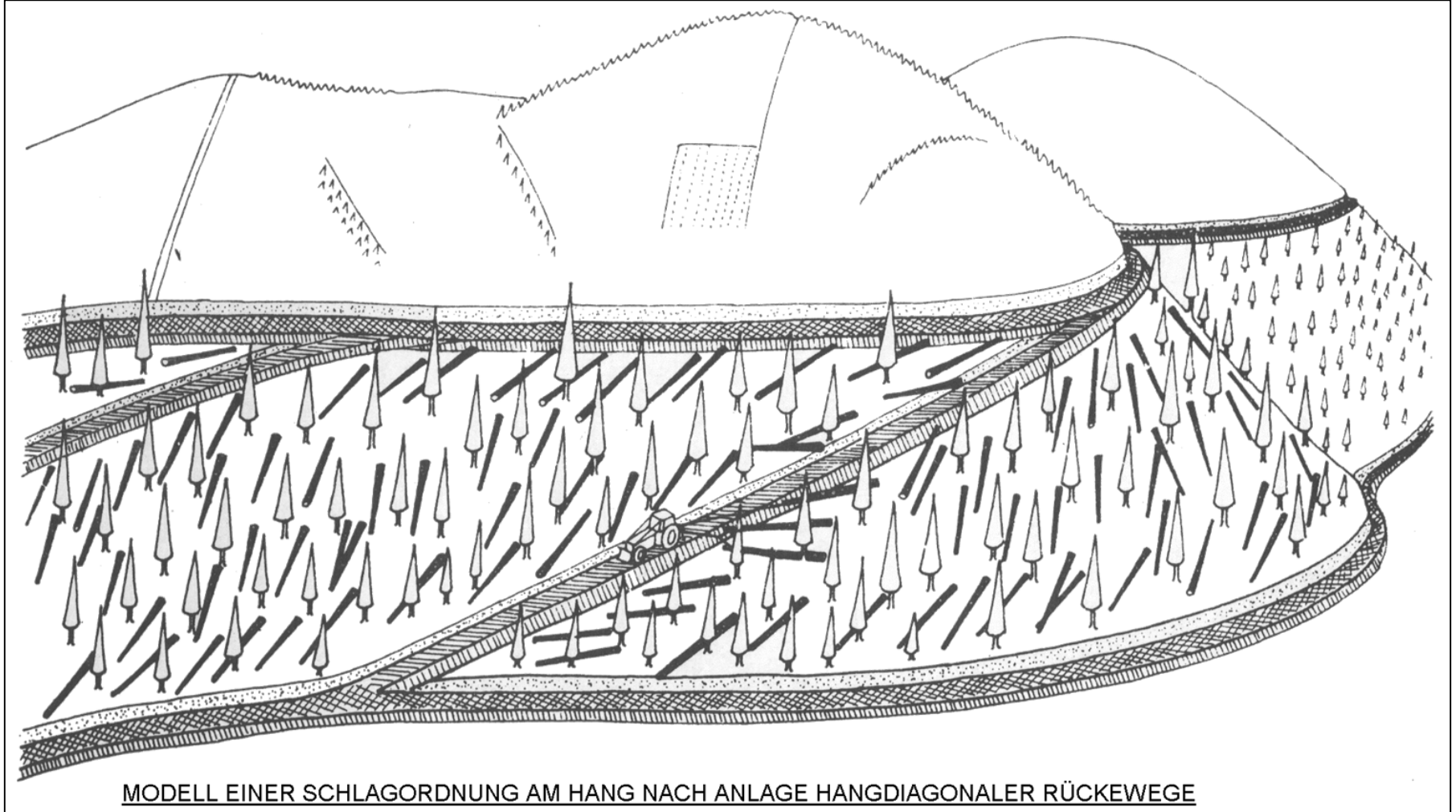


Cleared and
bulldozed lines in
steep terrain

off-road vehicles:
forwarder, skidder

6. Off-road transportation (extraction)

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MODELL EINER SCHLAGORDNUNG AM HANG NACH ANLAGE HANGDIAGONALER RÜCKEWEGE

6. Off-road transportation (extraction)



Tractor roads



Slope of terrain 35-50 %

Bearing capacity fair ($\text{CBR} > 5 \%$ $\rho_d > 1.7 \text{ Mg/m}^3$)

Rocks on surface do not matter

Gradient 5-15 %

Width 4 m

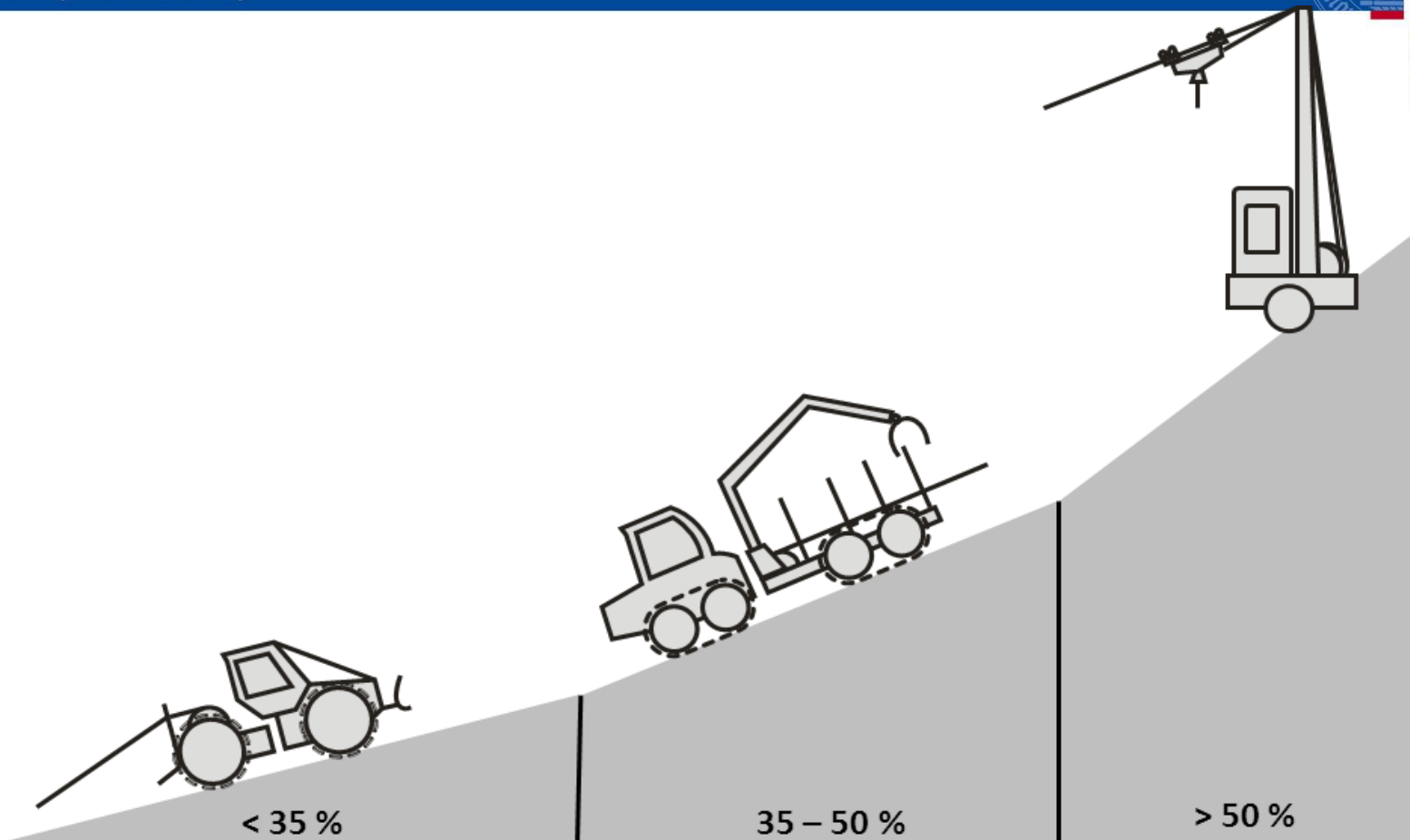
Spacing 100-150 m

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Skidding on skid trails
or
strip roads

Machinery equipped
with supporting
winches (tethering
winches)

Cable yarder

6. Off-road transportation (extraction)

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Cable lines for
cable yarding



Cleared lines in
very steep terrain
or terrain with low
bearing capacity

No ground based
transportation

6. Off-road transportation (extraction)

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6. Off-road transportation (extraction)

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Cable lines for
cable yarding



Slope of terrain

>50 % (min. 20%)

Bearing capacity

no relevance

Rocks on surface

do not matter

Gradient

according to terrain

Width

3-4 m

Spacing

40-60 m

6. Off-road transportation (extraction)

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Loiten
Riesen

Photo:
Georg Auer,
H.D. Metz



6. Off-road transportation (extraction)

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Log-line

6. Off-road transportation (extraction)

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7. Construction techniques

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7. Construction techniques

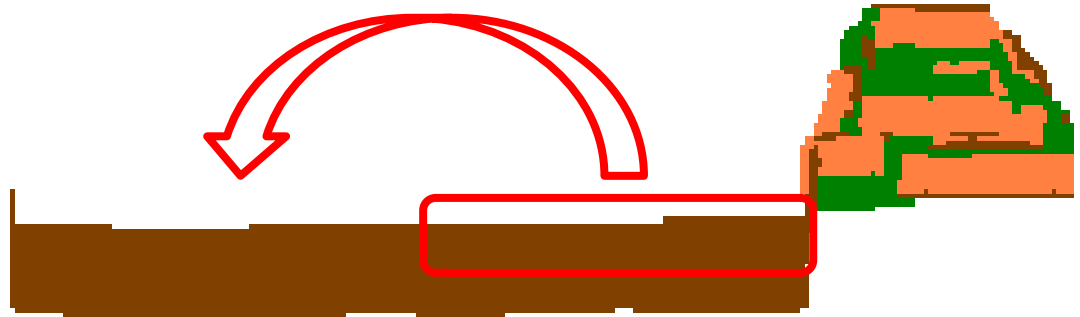
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Wide trenching

1. Clearing of right of way
2. Grubbing stumps and stripping of the organic layer, preparation for trenching
3. Trenching of gravel material in side area, refilling with organic material and fine grained soil









7. Construction techniques

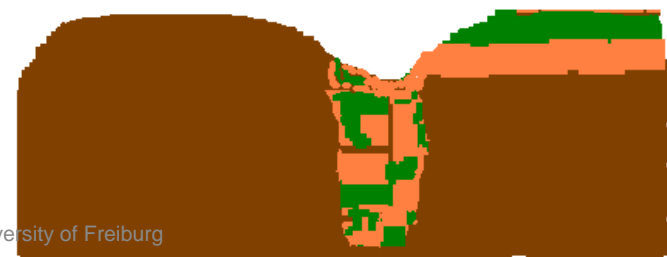
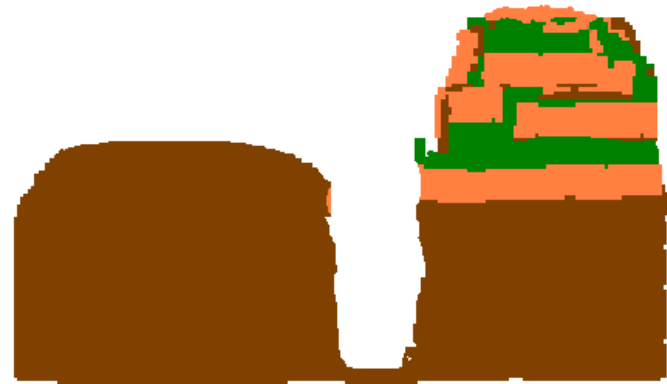
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Deep trenching

1. Clearing of right of way
2. Grubbing stumps and stripping of the organic layer, deep trenching for gravel along the road
3. Refilling of trench with organic material and fine grained soil











1. Basics of forest access
2. Road standards
3. Planning process
4. Recommendations for road alignment
5. Road characteristics
6. Off-road transportation
7. Construction techniques
8. Outlook: Key messages

8. Outlook: Key messages

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- If we talk about forest access for forest management we need to think about a transportation system and not just a road network
- Common transportation systems consist of road networks combined with off-road transportation (extraction)
- Density of forest roads is depending on the management intensity of sites: for more productive stands intensively managed a higher road density is economic reasonable



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