The Institute of Quarrying

Good Practice Guide for Handling Soils in Mineral Workings

GOOD PRACTICE GUIDE FOR HANDLING SOILS

In Mineral Workings

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The information in this publication is general guidance on the best practices and approaches to soils guidance.
Specialist advice should always be sought if you need more details about what action to take in your own circumstances.

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GOOD PRACTICE GUIDE FOR HANDLING SOILS

In Mineral Workings

PART TWO: Model Methodology

- Sheet O -

Soil Decompaction by
Bulldozer Drawn Tines

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Preface

The purpose of Sheet O of the guidance is to provide a model method of best practice where bulldozer drawn tines are to be used to decompact soils.

The guidance is intended for use by planning officials, statutory consultees, mineral operators and their supporting teams and specialist consultants, and earth-moving contractors, their site supervisors and machine operators.

Successful soil handling schemes are dependent on the soil resources being clearly identified and the conditions in which they are to be handled. This information should be contained in the Soil Resource & Management Plan (SRMP) and communicated to those involved in its implementation.

Key issues to be addressed are:

i) Avoiding conditions when soils are wet/plastic during handling
ii) The minimisation of soil compaction caused by trafficking and soil wetness
iii) Using appropriate remedial treatments where these are necessary
iv) Minimising soil loss, and mixing of soil layers or different soil types.

The SRMP should specify the type of earth-moving machinery and soil handling practice, and the soil wetness condition (see Part One of the Guidance) to be deployed to achieve the planned after use, soil functioning, and the environmental and ecosystem services. It is to be communicated in full to all involved and in particular to the supervisors and machine operators by appropriate means; including tool-box talks and site demonstrations. Supervision by trained supervisory staff is essential, as are monitoring and reporting.

The guidance does not specify the size or model of equipment as this is left to the mineral operator and contractor to specify and provide. The machines must be of a kind which are appropriate for the task and the outcomes required, and to be able to carry out the work safely and efficiently.

Should the agreed methodology need to be modified or changed significantly, this should be agreed in advance with the mineral planning authority. The SRMP should include a mechanism whereby unexpected less significant changes can be quickly resolved through consultation between the operator, the planning authority and statutory consultee, and soil specialist.

All persons involved in the handling of soils must comply with all relevant legislation with respect to Health and Safety, in particular the Health and Safety at work Act 1974 and in the case of mineral extraction operations, The Quarries Regulations 1999 and its relevant statutory provisions; in particular those aspects which relate to the construction and removal of tips, mounds and similar structures. These requirements take preference over any suggested practice in this Sheet and the SRMP should have taken these into account.

The users of this guidance are solely responsible for ensuring it complies with all safety legislation and good practice, including the manufacturer's specifications for the safe operation of the specific machines being used, and that all machines are in a good condition and well maintained and are suitable for the task. It is important that those involved in the operation of earth moving machines are competent and have the necessary training and certification.

Introduction

The purpose of this Guidance Sheet is to provide a model method for best practice where bulldozer drawn tines are used to decompact soils and basal/formation layers. Tines are most likely to be used for this purpose where soils are replaced by bulldozers and dump truck combinations (Sheets H, J & K), however, the methodology can be deployed in the excavator machinery combinations and practices presented (Sheet D).

Advantages & Disadvantages
The advantages of the methodology are:

i) The practice is relatively simple to deploy when there are suitable ripping tools and experience in their proper use
ii) The procedure is relatively quick to administer
iii) Significant mixing of soil horizons can be minimized
iv) It can be deployed on steep and complex landforms.

The disadvantages are:

i) The deployment adds another level of complexity needed in the soil replacement and skill and discipline in the decompaction procedures
ii) Whilst there is wide familiarity with the technique, there is little understanding of its limitations
iii) Adequate ripping tools in a good condition can be difficult to locate
iv) The method is sensitive to soil being too wet (plastic)

Suitability
Where conditions are suitable, the practice can be deployed for a wide range of after uses, soil functions, and environmental and ecosystem services, where decompaction is required. Like with the use of excavators (**Sheet N**), to be effective the soil must be dry enough to shatter. The SRMP will have specified the need and particular requirements, within the particular soil replacement procedures, site conditions and land use aims.

Many former mineral workings have been backfilled with inert waste. Remedial treatments of the infill, by digging or ripping, may not be advisable where these are not to be part of the replaced soil profile and this should be covered in the SRMP. The treatment of former silt lagoons needs careful consideration and consultation with a geotechnical specialist where there is a possibility of breaking through the dewatered and stabilised upper material into the saturated underlying lower material.

MODEL METHODOLOGY

The Decompaction Operation
O.1 Key operational points to minimize the risk of severe soil compaction and soil wetness are summarised in Boxes O.1 and O.2.

Box O.1 - To maximize the effectiveness of decompaction treatments:

- The moisture content of the soils should be at least 5% below their plastic limit, or greater if so advised
- The ripping pattern must be overlapping parallel passes and recompaction at depth must be treated in the ripping strategy
- The tines should be sufficiently closely spaced to ensure that full lateral decompaction is achieved with overlapping passes
- The use of winged straight tines is recommended
- the tine length and width must be compatible with the proposed depth of decompaction and allow for soil ‘heave’
- Tine and wings must have wear plates and be in good operating condition. Worn and deformed tools must not be used
- The towing unit must be capable of pulling the tine combination in an operationally efficient manner, without undue weaving and track slippage.

O.2 The timing of soil handling operations should only take place when the soils are in a ‘dry and friable’ condition (ie when it breaks and shatters when disturbed rather than smears and deforms) (see **Part One, Supplementary Notes 3 & 4**).

Box O.2 - To minimize re-wetting:

- The ripping should not be undertaken if significant rainfall is forecast
- Where the soil profile is partly raised to ground level, the uppermost soil layer should be left in an unripped state. Where the subsoil layer has been ripped, but the topsoil not placed, it should be sealed by blading with a bulldozer. On resumption of operations, the upper and lower layers will require decompacting

Prior to the start or recommencement of soil handling they should be tested to confirm they are in suitably dry condition (see Box O.3).

O.3 Soil handling is not to take place during rain, sleet or snow and in these conditions should be prohibited due to unsafe machine operating conditions. Prior to commencing operations, a medium/long term weather forecast should be obtained which gives reasonable confidence of soil handling being completed without significant interruptions from rainfall events. The soil based criteria set out in BOX O.4 are to be used to determine whether soil handling should cease or be interrupted with the occurrence of rain.

O.4 All machines must be in a safe and efficient working condition at all times. The machines are to only work when ground conditions enable safe and efficient operation. Otherwise the operation is to be suspended until suitable remedial measures can be put in place.

O.5 The operation should follow the detailed replacement plan set out in the SRMP showing soil units to be stripped, haul routes and the phasing of vehicle movements. Different soil units to be kept separate are to be marked out and information to distinguish types and layers, and ranges of thickness needs to be conveyed to the operational supervisor/operator. The haul routes and soil storage areas must be defined and should be stripped first in a similar manner. Detailed daily records should be kept of operations undertaken, and site and soil conditions.

Box O.3 - Test for Dry and Friable Soils

Soil tests are to be undertaken in the field. Samples shall be taken from at least five locations on the soil handling area and at each soil horizon to the full depth of the profile to be recovered/ replaced. The tests shall include visual examination of the soil and physical assessment of soil consistency.

i) Examination

- If the soil is wet, films of water are visible on the surface of soil particles or aggregates (e.g. clods or peds) and/or when a clod or ped is squeezed in the hand it readily deforms into a cohesive ‘ball’ means **no soil handling to take place**
- If the sample is moist (i.e. there is a slight dampness when squeezed in the hand) but it does not significantly change colour (darken) on further wetting, and clods break up/crumble readily when squeezed in the hand rather than forming into a ball means **soil handling can take place**
- If the sample is dry, it looks dry and changes colour (darkens) if water is added, and it is brittle means **soil handling can take place**

ii) Consistency
First Test
Attempt to mould soil sample into a ball by hand:

- Impossible because soil is too dry and hard or too loose and dry means soil handling can take place
- Impossible because the soil is too loose and wet means no soil handling to take place
- Possible - GO TO SECOND TEST

Second Test
Attempt to roll ball into a 3mm diameter thread by hand:

- Impossibe because soil crumbles or collapses means **soil handling can take place**
- Possible means **no soil handling to take place**

NB: It is impossible to roll most coarse loamy and sandy soils into a thread even when they are wet. For these soils, the Examination Test alone is to be used.

Box O.4 - Rainfall Criteria:

- In light drizzle soil handling may continue for up to four hours unless the soils are already at/near to their moisture limit
- In light rain soil handling must cease after 15 minutes
- In heavy rain and intense showers, handling shall cease immediately

In all of the above, after rain has ceased, soil tests shall be applied to determine whether handling may restart, provided that the ground is free from ponding and ground conditions are safe to do so.

Ripping Strategies

O.6 Ripping to decompact soils is a necessary part of the soil replacement procedures using bulldozer-dump truck combinations.The primary aim of the ripping strategy is to ensure that there is no significant compaction within the soil profile which might impede root growth or drainage. There are two basic ripping strategies that can be used:

i) When the soil profile is ripped sequentially as the soil layers are built up; and
ii) When it is ripped only after the full profile is complete.

O.7 Sequential ripping of each layer before next is placed has to be carried out during the replacement operations (**Figure O.1a**). The ripping of the final surface layer can be delayed until all the topsoil layer has been replaced. It is appropriate when:

i) The soil profile/horizon thickness exceeds the effective depth of the tine or capacity of the towing unit being used; a number of sequential rips are required, each layer ripped before the next is placed
ii) The depth of subsequent sequential ripping must relieve any recompaction of the lower layers following the placement of the new overlying layer or other surface operations
iii) Stones and/or damaging materials are to be released and removed from sub-surface horizons.

O.8 Single deep ripping on completion of profile (**Figure O.1b**): It is appropriate when:

i) The profile thickness is equivalent to or less than the effective depth of tine and capabilities of towing unit
ii) Large stones and/or non-soil debris are absent or need not be removed from sub-surface horizons
iii) Debris or stones need only to be removed from surface topsoil layer, where a shallower surface cultivation would be carried out prior to final ripping
iv) Sequential ripping has been undertaken and there is still recompaction at depth
v) Final ripping can be delayed until all strips and final works complete, or later in aftercare period.

O.9 Both strategies have their limitations and the selection should be compatible with the land use, soil function, environmental and ecosystem services objectives, the soil profile in question and the capability of the equipment to be used. It may not be possible to treat deep compaction or even compaction at moderate depth once the profile has been completed. Hence, it is essential that the correct strategy is adopted. In some circumstances it may be necessary to adopt a combination of both strategies to achieve satisfactory results.

Equipment

O.10 Bulldozer units of a minimum 300hp are usually required to be able to carry out the operations effectively (Box O.5).

O.11 There are two types of ripping units:

i) Frame-mounted on a bulldozer unit and often hydraulic operated
ii) Mounted on towed trailers/tool carriers and either cable or hydraulic operated.

Control mechanisms have to be compatible between the bulldozer unit and tool carriers

Box O.5

Approximately 30hp/leg or shank on multiple tine beam cultivator to 750mm depth and 100hp/tine three leg or shank to 750mm depth.

O.12 There are two types of tines: straight leg and curved leg. The former is the most commonly used and is the principal tool for decompaction. Straight tines are to be used where there are obstructions, or the soils/formation layer is excessively stony. Curved tines are typically used, in combination with straight tines, and set to operate at shallower depth for the purpose of reducing the 'drag' resistance of the following straight tines. Often the straight tine is operated in a raked mode (about 10 degrees forwards) rather than in an upright stance to promote decompaction by creating uplift and also to reduce drag.

O.13 Straight tines (leg) should have a wedge foot (**Figure O.2**) at the base to reduce drag, aid penetration and assist with the upward displacement of the soil and shattering effect.

O.14 There are two forms of straight tines: those with and those without wings (**Figure O.2**). Wings of 250-400mm total span (outer tip to outer tip) are welded either side of the tine leg or foot at angle 20-30 degrees. This is to promote upward displacement and lateral shatter, but also has the effect of significantly increasing drag. Straight tines without wings will require either more overlapping passes or closer spaced tines (the closer spacing will increase drag).

O.15 There are two critical dimensions which determine the potential effectiveness of the tines and hence the ripping operation are: i) Tine length (which determines the potential depth of decompaction); ii) Tine thickness (which determines the potential amount of heave and therefore shatter and decompaction). The achievement of the potential of the ripping tools is dependent on the moisture content of the soil/formation material (it must be dry enough to shatter otherwise the soil material simply deforms around the tool).

O.16 The length of the tine is the most common limiting dimension of the tool. The length of the tine from the heal of the foot to the base of the tool bar/carrier less 200/250mm or 30%, whichever is the lesser, is the potential maximum effective ripping depth of the tine (**Figure O.3**). This is to allow for upward displacement of the soil as the tool is drawn through the profile. Without this allowance the soil heave will rise to or above the tool bar and increase drag and reduce the decompaction achieved (**Figure O.3**), cause compaction, overheat the bulldozer hydraulics etc.

O.17 The most commonly used tines of between 300-700mm below the tool bar have maximum effective depths of about 150-500mm (Box O.6).

O.18 Longer tines can be provided but these may cause problems with mobility of the bulldozer unit. One exception is the British Coal specification SIMBA MK IV Ripper with 1.2m carrier borne tines which has a potential effective depth of 900mm.

O.19 The width of the tine (front to back) co-determines the potential effective ripping/decompaction depth, with a ratio of 5 times the width of the tine (Figure O.2). Typically, the width of the tine is 300-400mm, giving a potential effective depth of 1500-2000mm, which operationally is not usually the limiting factor. The thickness and width of the tine used is usually determined by other factors, the mechanical stresses imposed by the work undertaken (i.e. its strength) and the slot dimensions in the tool bar carrier.

Box O.6 - Allowance for Soil Heave

Length of tine below tool bar mm	Potential maximum effective length mm
200	100
300	150
400	200
500	300
600	400
700	500

O.20 The thickness of the tine (typically 40-80mm) contributes significantly to its strength but also to its drag. The tine should have a welded wear plate on the leading edge to reduce wear, as should the leading edge of the attached wings (**Figure O.2**).

O.21 The minimum number of tines must be two, each following the mid-point of the tracks of the bulldozer unit (**Figure O.4**). Generally, the most common configuration is three with a tine central to the bulldozer unit. The tines may be arranged in a straight line or as a triangle where the central tine is set further forward to reduce drag. The tines may or may not have wings, often the central tine may be without wings to reduce drag. Three winged tines are likely to be required where only single passes are made. Straight tines without wings are often more appropriate where there are significant damaging obstructions and where soils are excessively stony.

O.22 Mixed combinations of curved tines leading straight tines (as a double beam configuration) are an alternative and can potentially achieve more effective lateral shatter.

Decompaction Operations

O.23 Ripping to decompact materials must only to be undertaken when the soils are dry enough to shatter (i.e. not in a plastic condition) and must be suspended before the soil become plastic. Ripping should only be undertaken in dry weather and is to be suspended when the tractor unit loses traction/ weaves under normal operating conditions.
If the soils are inherently wet consideration should be given to deep ripping later following the establishment of a crop to dry out the upper horizons; this may require several successive years of treatment to progressively decompact the profile.

O.24 The tines are to be drawn through the basal/formation or soil layer at the required depth according to the decompaction strategy and capability of the bulldozer and towed/fixed equipment. The tines are to be drawn at sufficient and constant speed, and at their optimum angle (rake) to achieve maximum heave with the least drag, and without track slippage or the bulldozer unit ‘weaving’.

O.25 The ripping is only to be undertaken along one axis and usually at an orientation to promote down-slope drainage (see Box O.7), but never crosswise or across slope unless it is specifically in the SRMP to retain water (as is the practice in dry climates). When ripping is down slope on steep gradients, the machinery is to travel back only on unripped ground.

O.26 The ripping must achieve the required depth in the first pass without the heave rising above the base of the tool bar (Figure O.3), the tine is to enter to its full depth on the first pass and all subsequent passes. The area should not be ripped to a shallow depth first and then re-ripped to a greater depth. However, in some cases and on the basal layer this may be unavoidable in the first pass in order to ‘break’ ground and reduce resistance to be able to achieve the required penetration. Headlands are to be ripped first to enable quick and full penetration of the tines; this is essential at the base of slopes. Ripping must extend into and out of the sides of existing ditches or if installed later the ditches are to be cut across the lower rip-lines.

Box O.7 – Subsoil ‘Piping’ Caused by Ripping

Particularly with sandy soils, ripping up/down slope can facilitate the creation of subsurface ‘pipes’ through the preferential drainage. These can lead to ‘soil busts’ in wet weather and local collapses/ washouts. To minimize this, either cross slope grips or drains can be installed.

O.27 Where the final profile thickness is equivalent to or less than the effective depth of the tine, the ripping operation can be undertaken after all the horizon(s) have been laid (**Figure O.1b**), except where it is necessary for stones or non-soil debris to be removed.

O.28 Where the profile thickness exceeds the effective depth of the tine, the profile must be ripped in a sequence of successive layers. The ripping is to be undertaken sequentially following the placement of each layer and before the next layer can be laid. This usually takes place after the placement of each horizon (ie lower subsoil, upper subsoil and topsoil) (**Figure O.1b**). If the proposed horizon thickness exceeds the effective depth of the ripper tine, then the soil horizon needs to be laid in sub-layers, with each of these being ripped to the required depth before the next is laid.

O.29 In the ripping of successive replaced horizons/ layers, allowance must be given to recompaction caused in the lower layers by the laying and spreading of the soil by bulldozers, and dump trucks transporting stones and damaging materials for disposal. The allowance necessary depends on the soil type and moisture content. For dump trucks, bulldozers with narrow tracks and large excavators, recompaction to 400-600mm should be allowed for in specifying the thickness of the next layer of soil to be placed and its decompaction. A minimum of 300mm should be allowed for bulldozers with standard tracks and as a precaution the same for wide tracked machines. The recompacted soil layer must be decompacted along with the thickness of the new layer laid. This requires the depth of decompaction of the next layer to include the thickness of the recompacted soil layers. The thickness of the new layer that can be laid over the recompacted layer(s) will be governed by the potential effective depth of the tine. Hence, after the laying and decompaction of the first soil layer, subsequent soil layers will have to be laid at shallower thickness (**Figure O.3**).

O.30 The final decompaction of the topsoil layer should be to the full effective depth of the tine.

O.31 In carrying out the ripping operation, each successive pass is to overlap, with the tine on the ripped side bisecting the pass of the outer and central tine of the previous pass (**Figure O.4**). Where full depth or lateral consistency of decompaction is not achieved, the overlap should be increased.

O.32 The degree and consistency of loosened soil must be checked as the ripping is taking place, especially across the junctions between laid strips of soil (which may require inspection by pits). Routine qualitative assessment can be made with a 15mm diameter steel probe with a blunt convex end.

O.33 The probe is pressed in soils at 150mm intervals along a number of transects across the line of ripping, and the depth to penetration and feel of resistance recorded (**Figure O.5**). Alternatively, more sophisticated (recording) soil penetrometers may be used. Both methods should only be used in conjunction with a method of on-site ‘calibration’ of compactness; this is essential as soil water content and stoniness have a major influence on interpretation.

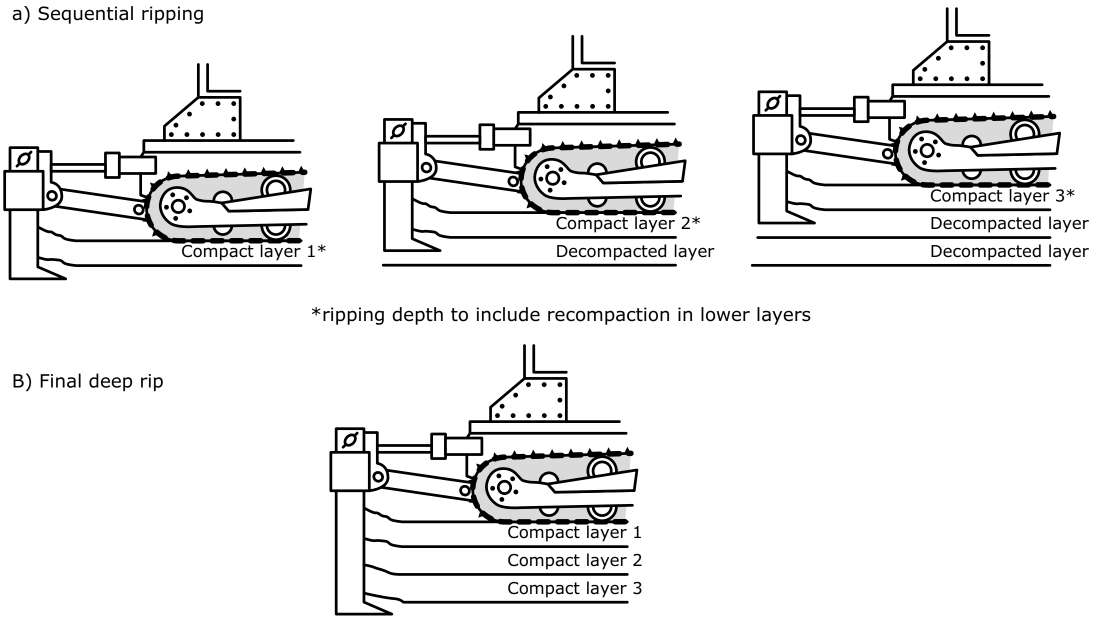


Figure O.1: Decompaction by bulldozer drawn tines.

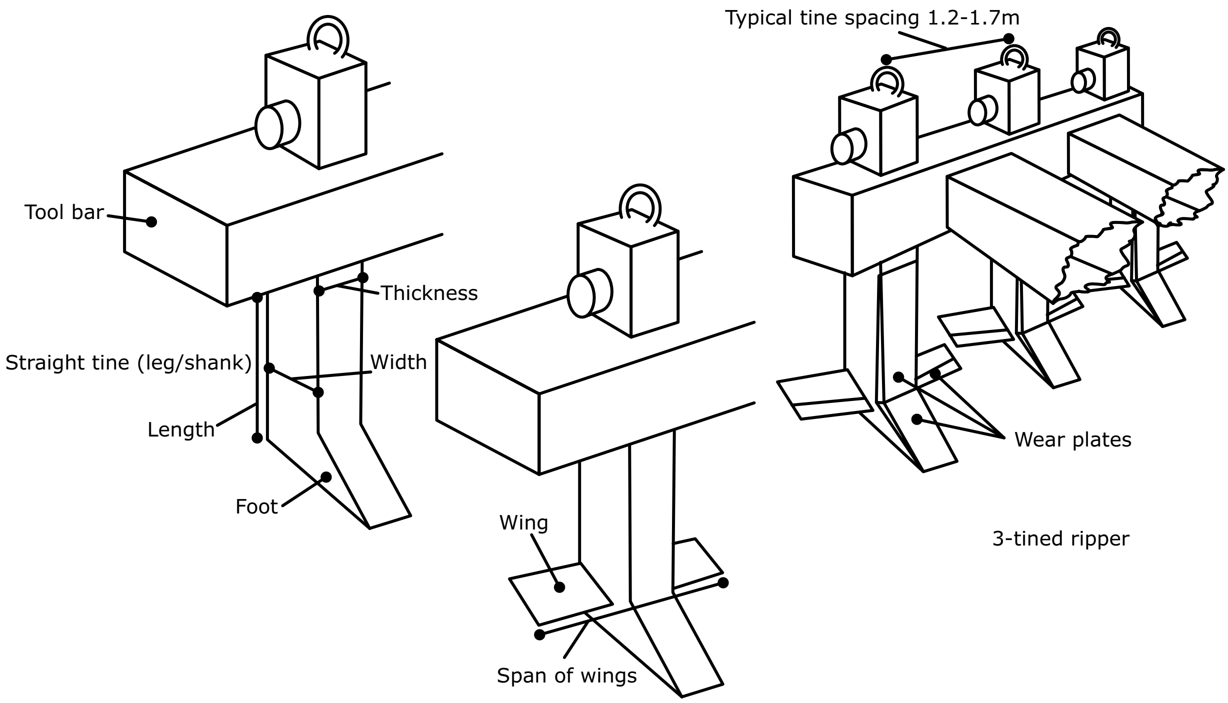
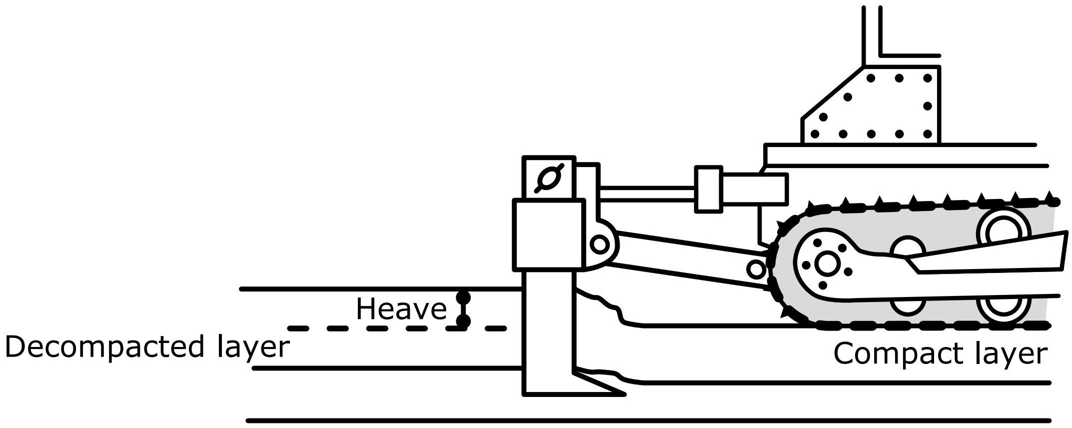
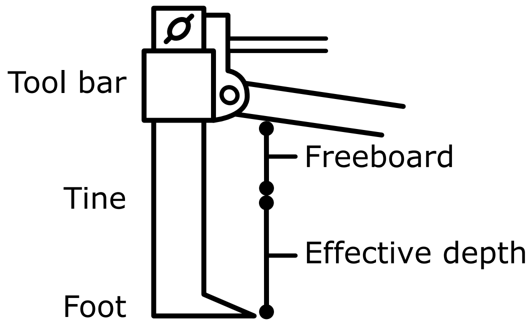


Figure O.2: Features and critical dimensions of bulldozer drawn tines.



Heave = freeboard required below tool bar



Calculation of effective depth of tine of 300mm width & 900mm in length below tool bar:

i) potential maximum depth of decompaction is 1500mm with tine of 300mm width and 900mm with tine of 900mm length

ii) potential effective operating depth for first soil layer is 900 - 200 (freeboard) = 700mm

iii) potential effective operating depth subsequent soil layer is 900 - (200 + 300 [eg depth of recompacted lower material]) = 400mm

Figure O.3: Effective decompaction depth by tines.

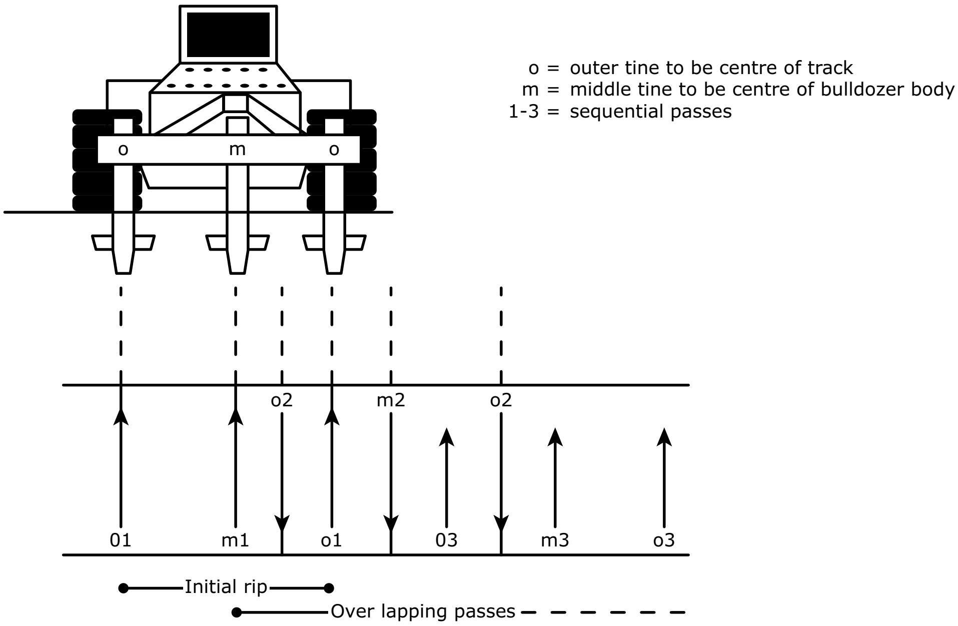


Figure O.4: Decompaction by overlapping passes of bulldozer drawn tines.

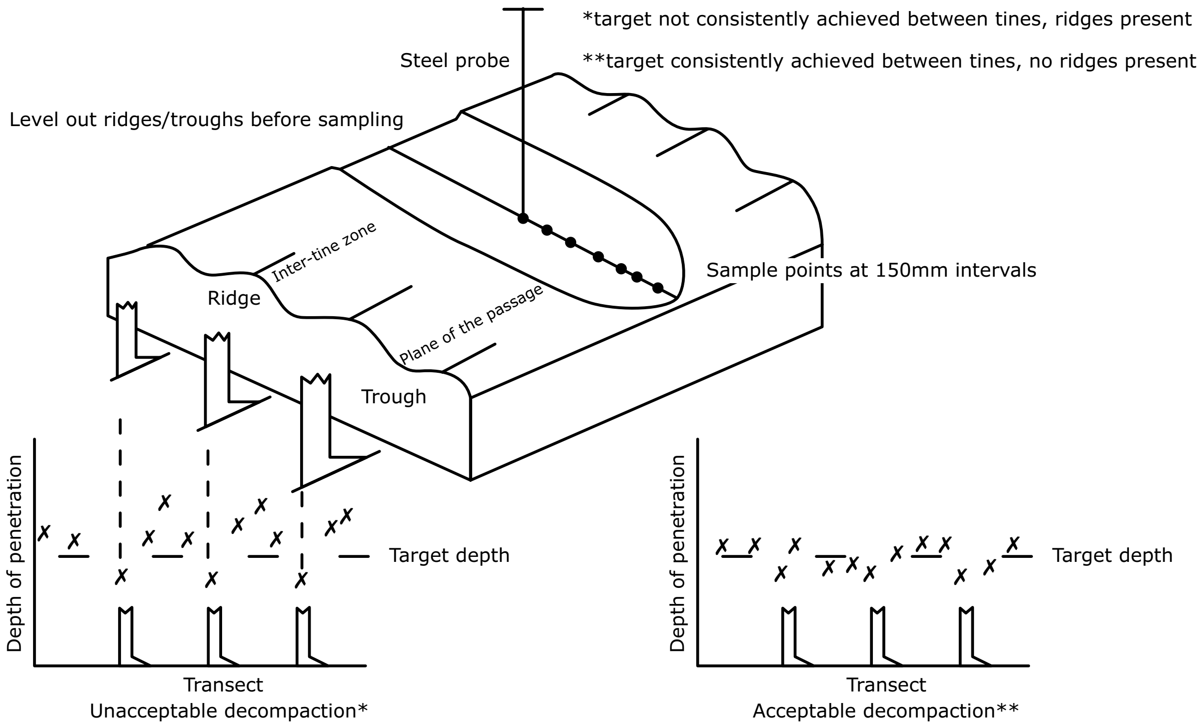


Figure O.5: Assessment of decompaction achieved.