

On-Orchard Implementation of Land Shaping for Surface Drainage

GUIDELINES FOR OPERATORS



Dan Bloomer, Luke Posthuma,
Georgia O'Brien and Pip McVeagh

Page Bloomer Associates Ltd.

March 2020



PAGEBLOOMER

Table of Contents

1	Introduction	5
1.1	Case Study T & G, Evenden Road and Red Barn, Bostocks NZ.....	5
2	The Process	6
3	The Equipment.....	7
3.1	Software.....	7
3.2	Equipment Requirements.....	7
3.2.1	Machinery	7
3.2.2	GPS and Software.....	7
4	Preliminary Proof of Concept.....	8
5	Ground Preparation	9
6	Survey.....	10
6.1	Set up Equipment.....	10
6.1.1	Land Shaping Equipment	10
6.1.2	Levelling-Blade GPS Control Equipment	11
6.1.3	RTK-GPS base station	12
6.2	Benchmark Equipment.....	13
6.3	Survey the Interrow	13
7	Analyse	14
8	Design.....	15
9	Install.....	16
9.1	On-Screen Guidance	16
9.2	Reshaping the Interrow	17
10	Verify.....	18
10.1	Completion Survey	18
10.2	Post-treatment observations	18
10.3	Rut Measurement	19
11	Reflection	20

Table of Figures

Figure 1. Trial Layout, T & G - Evenden.....	5
Figure 2 Ponding map of T&G Evenden created in ArcGIS and Optisurface from LiDAR elevation data	8
Figure 3 Ground profile on interrow generated from LiDAR data and from an RTK-GPS ground survey. Blue dots show identified puddles after rain, blue arrows show main soil movement required.	8
Figure 4 Interrow cultivated prior to land shaping.....	9
Figure 5. Rotary hoed inter-rows ready for shaping. Rows for the surface shaping trial are marked by yellow triangles.....	9
Figure 6. Gene Williams' Land Shaper connected to three-point linkage raw-bar.....	10
Figure 7 Connect hydraulic hoses to tractor remote hydraulic couplers	10
Figure 8. Screenshot of Section Survey to establish existing and planned ground profiles	14
Figure 9. Screenshot of Section Survey showing existing and planned ground profiles and the constraint fields available for editing	15
Figure 10. FMX screen post survey showing surveyed sections (lines) and the resolved profile after design selection.	16
Figure 11. Section profile shown in FMX screen showing optimal profile as green line and current blade location indicated by thin white vertical line at right of the profile	17
Figure 12. Completed inter-row shows flat section with minor soil ridging at sides.	17
Figure 13: Inter-row surface after rut filling and re-grading by the land shaping machine and drilling with grass.	18
Figure 14: Sled design to measure rut depth, measuring the difference in height between the bottom of the wheel tracks and the centre of the inter-row.	19
Figure 15: Example of matching rut depth measurements (a) and elevation profile (b).	19

On-Orchard Implementation of Land Shaping for Surface Drainage in Orchards

Guidelines for Operators

This report describes a process for land shaping orchard inter-rows to facilitate surface drainage. It provides detail on the steps and lessons learnt from trials in existing orchards where persistent wetness and ponding has caused water logging and serious wheel track rutting issues. This water logging has been shown to contribute to tree health decline, development of ruts, reduced machinery and labour access and increased operations and safety problems.

These guidelines were developed and amended during trials at orchards owned and operated by T&G Global, Bostock New Zealand, MrApple and Illawarra Orchard. These guidelines apply to physical on-orchard land levelling. Lessons learned from practical application are incorporated but we anticipate further amendment as experience grows and other equipment options are adopted.

A companion report discusses processes used to assess orchard blocks for suitability, drawing on publicly available LiDAR elevation data from regional councils and other organisations, and using GIS tools including ArcGIS and Optisurface Drainage.

The work was completed with funding from the Ministry for Primary Industries through the Sustainable Farming Fund and New Zealand Apples and Pears Inc. We are grateful the support of orchardists, farmers and contractors that enabled us to access equipment to conduct our investigations and trials.

We particularly note the support of:

Orchardists

Courtney St George, Andy Jones, Mark Fry and Duncan Park at T&G, Fulton Gillies and Graeme Hodges at Bostocks, Tim and Natalia Egan at Illawarra Orchards, Robbie McCormick, Stella McLeod and Tony Waites at Mr Apple.

Industry

Rachel Kilmister at New Zealand Apples and Pears Inc., Hugh Ritchie at Drumpeel Farms, Patrick Nicolle at Nicolle Contracting, John Ahearn and Wade Riley at GPS Control Systems, and Gene Williams at G Williams Engineering.

Companion Report

Luke Posthuma, Dan Bloomer, Georgia O'Brien and Pip McVeagh (2020) Feasibility Study for Land Shaping for Surface Drainage in Orchards

1 Introduction

Inadequate orchard drainage, often highlighted during harvest and winter spraying periods, is an extreme expression of a common year round problem. Soil softness and constant traffic creates wheel track ruts and muddy conditions increase disease, increase labour costs and hazards and increase storage fruit rots. Despite numerous attempts to rectify surface water issues, mud and ruts, the problem remains.

Research conducted for New Zealand Apples and Pears Inc. with funding from the Ministry for Primary Industries showed new precision agriculture technologies can address surface drainage in established orchards. It is not always possible: the technique is suited to relatively flat orchards where minor undulation causes localized ponding and soil saturation. Excessive soil movement will create hazards and access difficulties and there must be an exit point for the excess surface water to leave the rows.

This guideline describes the equipment and processes adopted to survey, design and implement surface drainage plans that minimise ponding risk and reduce these negative impacts. A complementary report describes processes used in preliminary assessment of block suitability drawing on publicly available LiDAR elevation data to create drainage and soil movement estimates.

1.1 Case Study T & G, Evenden Road and Red Barn, Bostocks NZ

The information presented in this guide is based on trials at T&G Global’s Evenden, Bostocks NZ Red Barn and Mr Apple Blyth in Hastings, on Tim and Natalia Egan’s Illawarra orchard in Gisborne and at the T&G Global’s Riwaka Orchard near Nelson. The inter-rows were levelled using Gene Williams’ levelling blade brought from Gisborne. Standard orchard tractors were supplied by T&G and Bostocks, Mr Apple and Illiawarra. Positioning used Trimble equipment; Hugh Ritchie’s Trimble AgGPS base station and radio, powered by a petrol generator, GPS Control Systems’ rover antenna and radio, and Patrick Nicolle’s Trimble FMX unit with the Trimble WM-Drain software unlocked.

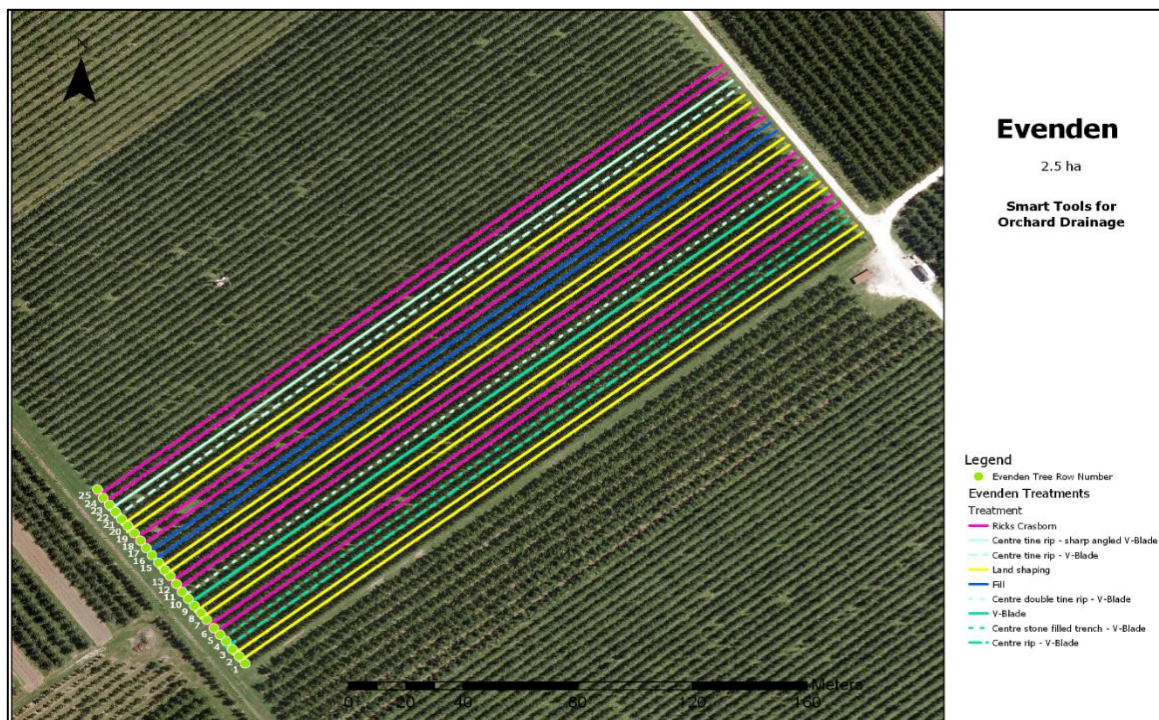


Figure 1. Trial Layout, T & G - Evenden

2 The Process

These guidelines generally follow the Trimble WM-Drain process:



Having determined a block's suitability (see Companion Report "Feasibility Study for Land Shaping for Surface Drainage in Orchards"), the on-orchard process involves ground preparation, a row-by-row elevation survey of the inter-rows, selection of a preferred final inter-row profile, land shaping with cut-and-fill including consolidation, re-grassing and monitoring.

The elevation can be measured in real-time with high accuracy using RTK-GPS and suitable commercial drainage software. Such products automatically calculate possible profiles within user prescribed slope and cut and fill limits.

With suitable machinery, the profile can be prepared using automatic height control of levelling blade. Because capacity is limited by the space unoccupied by orchard trees, multiple passes are required. This does mean any fill is consolidated each time the tractor and leveller pass across the ground, minimising later subsidence. Trial results suggest surface levelling to ensure excess surface water can flow from the block is more long-lasting than other rut fixing options.

3 The Equipment

3.1 Software

Several specialised software products are available for GPS guided land levelling operation and for drainage implementation. We note, for example, Optisurface™, Trimble FieldLevel II™ and T3RRA Cutta™ which are used locally to level whole paddocks. These are not suited to “fixing” the inter-rows in existing orchards because each row is in effect a separate field.

We co-opted Trimble’s WM-Drain software which is designed for laying tile drainage. By setting the desired level to zero metres above ground, a virtual tile could be laid along the surface. This required some minor adjustment to balance the apparent cut-and-fill volumes, but generally worked well.

Note that the highest possible accuracy RTK-GPS is required, especially for the vertical height axis. This means a base station within 1km is highly desirable which in most cases will be an on-site portable system.

3.2 Equipment Requirements

3.2.1 Machinery

- Orchard Tractor with adequate traction and hydraulic capacity. We have found that a standard orchard tractor has sufficient traction. The key requirement is around the Hydraulics which control the height of the levelling blade. Where the hydraulics have a low flow rate or do not shut off, the blade can drop and cut more dirt than desired.
- Levelling scoop or blade with hydraulic depth control
- Hydraulic control valves and electronic connection kit

3.2.2 GPS and Software

- Trimble FMX Screen and RTK-Radio
- WM-Drain software (unlocked)
- Trimble AgGPS base station and radio
- Base station electricity supply (shed or generator)

3.2.3 Digital Radio

Set to tractor Channel 9 for the Base Station used.

4 Preliminary Proof of Concept

A companion report covers the pre-treatment survey and suitability assessment process. This block is a suitable candidate for land shaping as only very shallow cuts and fills are required to ensure water flow to the north-east end to reduce surface water ponding.

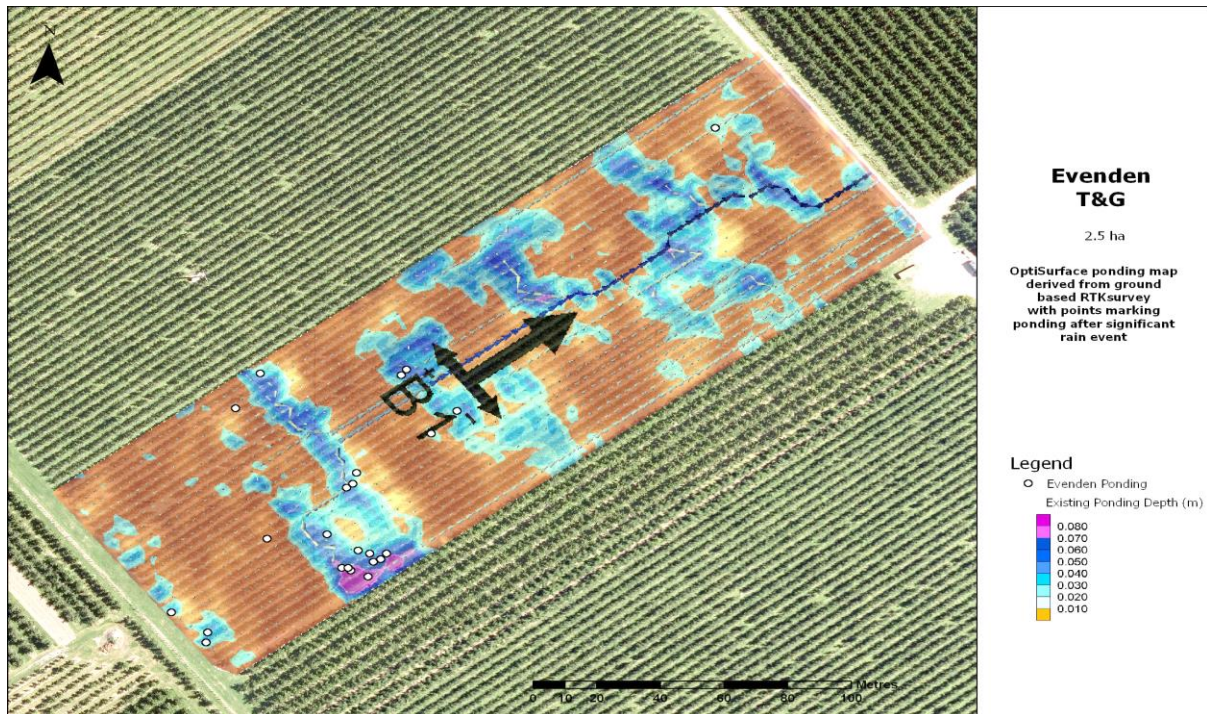


Figure 2 Ponding map of T&G Evenden created in ArcGIS and Optisurface from LiDAR elevation data

Ground profiles show there is a relatively constant fall from one end to the other, but a couple of slight ridges within the block that cause areas of ponding as shown by the blue dots in Figure 3.

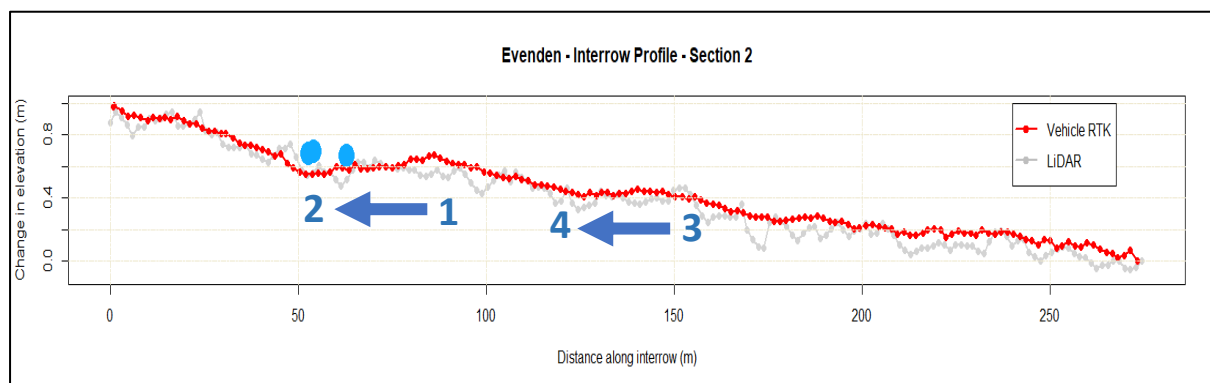


Figure 3 Ground profile on interrow generated from LiDAR data and from an RTK-GPS ground survey. Blue dots show identified puddles after rain, blue arrows show main soil movement required.

The profile shows about 1m fall in 270m of row length, an average grade of 0.37%. Setting a grader to 0.37% slope would create a perfectly constant fall but would move more soil and create larger steps between the interrow and underrow than is necessary.

Most benefit will be gained by moving some of the soil from points 1 to 2 and from points 3 to 4 to ensure that there is a slope for the water to flow to the end of the orchard row.

5 Ground Preparation

The land shaping is often moving only a one to five centimetres of soil scraped from one position and re-laid in an adjacent one. For this the soil must be well cultivated without large clods that would block up the small gap between the levelling blade and the soil.

- Spray out the inter-row sward and fallow to allow the grass roots to break down.
- Remove branches and other significant litter from the inter-row surface
- Cultivate (rotary hoe) to gain a good tilth.



Figure 4 Interrow cultivated prior to land shaping



Figure 5. Rotary hoed inter-rows ready for shaping. Rows for the surface shaping trial are marked by yellow triangles

6 Survey

6.1 Set up Equipment

6.1.1 Land Shaping Equipment

Connect the levelling system (Land Shaper) to the tractor



Figure 6. Gene Williams' Land Shaper connected to three-point linkage raw-bar

- Connect Land Shaper to three-point linkage or draw-bar
- Mount GPS antenna above blade – keep high to reduce GPS signal occlusion by trees
- Connect Hydraulic hoses to tractor – keep clean

NOTES

- Open and Closed hydraulic systems have different requirements
- Ensure the hydraulic hoses are the correct way around
- If slow operation is noted, try swapping them over or increasing the oil flow if available. Inadequate hydraulics leading to difficulty controlling the blade height will result in a suboptimal land shaping job and reduce the likelihood of achieving the desired outcome.



Figure 7 Connect hydraulic hoses to tractor remote hydraulic couplers

6.1.2 Levelling-Blade GPS Control Equipment

Mount and connect GPS control systems

1. Mount the FMX on the tractor
2. Mount the RTK radio and aerial on the tractor
3. Mount the GPS antenna on the Land Shaper
4. Connect the FMX output to the hydraulic control valve (our system did not have this feature so manual control was required)

NOTES

- Mount equipment centrally, if possible, to minimise tree interference
- The system needs to be well protected from overhanging branches
- Take precautions to protect the cables and plug connections: use lots of shields and tape as branches will catch and pull cables and plugs apart.



Figure 5. Tractor with mounted FMX protected by Shield, RTK digital radio mounted with aerial behind driver's seat



Figure 6. Antenna pole mounted above leveller blade



Figure 7. Keep equipment mounted centrally and protected from branches. Keep antenna high to minimise GPS signal blocking

6.1.3 RTK-GPS base station

High accuracy is needed so a local base station within a kilometre or so is highly desirable.

If multi-day work is envisaged a semi-permanent position is ideal. However, as each row is surveyed and graded independently, minor changes are not critical. The user will need to ensure that the GPS does not drift while completing a single row as will be experienced with a low accuracy GPS antenna.

1. Set tripod and ensure stability
2. Ensure a stable power-supply
3. Mount GPS antenna
4. Connect antenna, radio and power cables
5. Turn on and allow to stabilise position

In our system

Set tractor GPS Radio to Channel 9 to use Base Station correction



6.2 Benchmark Equipment

TIP: For WM-Drain user resources, see

- <https://www.trimble.com/Agriculture/WM-Drain.aspx?tab=Features>
- <http://trl.trimble.com/docushare/dsweb/Get/Document-579561/>
- <https://slideplayer.com/slide/10032864/>

NOTE: For surveying usual practice elevates the levelling blade to full height – a known and repeatable position. This would rip branches off trees, so we set the blade on a 150-200mm block and hold it there for bench marking.

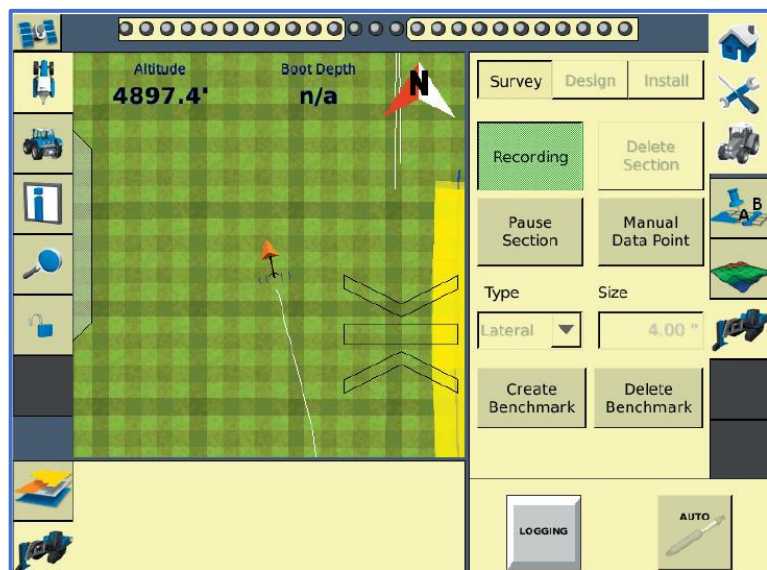
1. Turn on the tractor FmX and other GPS systems
2. Park the levelling blade at a suitable Master (permanent) Benchmark position
3. Set the blade on a block (about 200mm high)
4. Enter this height value into the FmX WM-Drain set-up screen as the *Survey Height Offset*

Create the Master Benchmark

NOTE: You can create additional benchmarks at other points such as on the track at the end of the orchard row being shaped. We set these on the same block as for the Master Benchmark

6.3 Survey the Interrow

1. Drive to the start of the row
2. Start WM-Drain and survey
3. Raise the blade to the *Survey Height Offset* level (set on block)
4. Tap record and drive along the interrow
5. Tap record to finish



7 Analyse

The completed survey is displayed on the FmX screen as a profile chart. This allows quick assessment and determination of any design settings that should be adjusted. The survey start is at the left of the profile displayed on the screen

The current profile is seen in Figure 8 as the boundary between grey and blue areas (land and sky). The desired profile is shown as the solid green line, and the minimum and maximum depth envelope by the red and blue lines respectively. Here the envelope is set 50mm either side of the current profile. If a solution for the desired profile cannot be resolved within the set parameters, work cannot proceed.

The cut-and-fill is the difference between the green line and the boundary between the blue and grey zones. These need to be balanced so the approximately same AREA is above and below.

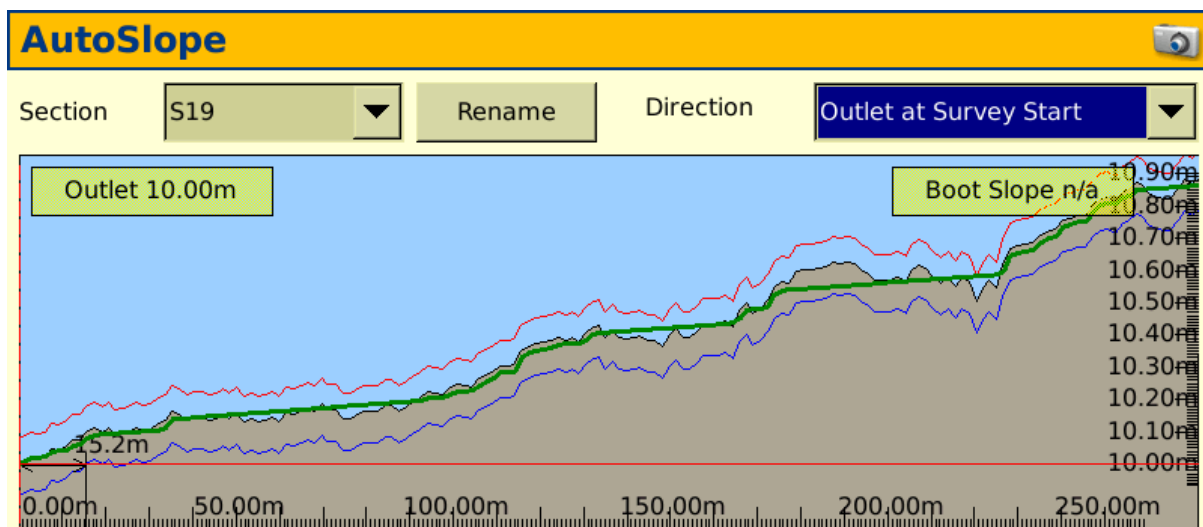


Figure 8. Screenshot of Section Survey to establish existing and planned ground profiles

8 Design

Each interrow or *Section* is an individual land shaping task. Optimising may involve slightly different setting in nearby interrows, depending mainly of the existing profile and overall average slope.

In the **AutoSlope** screen (Figure 9), edit the constraint fields.

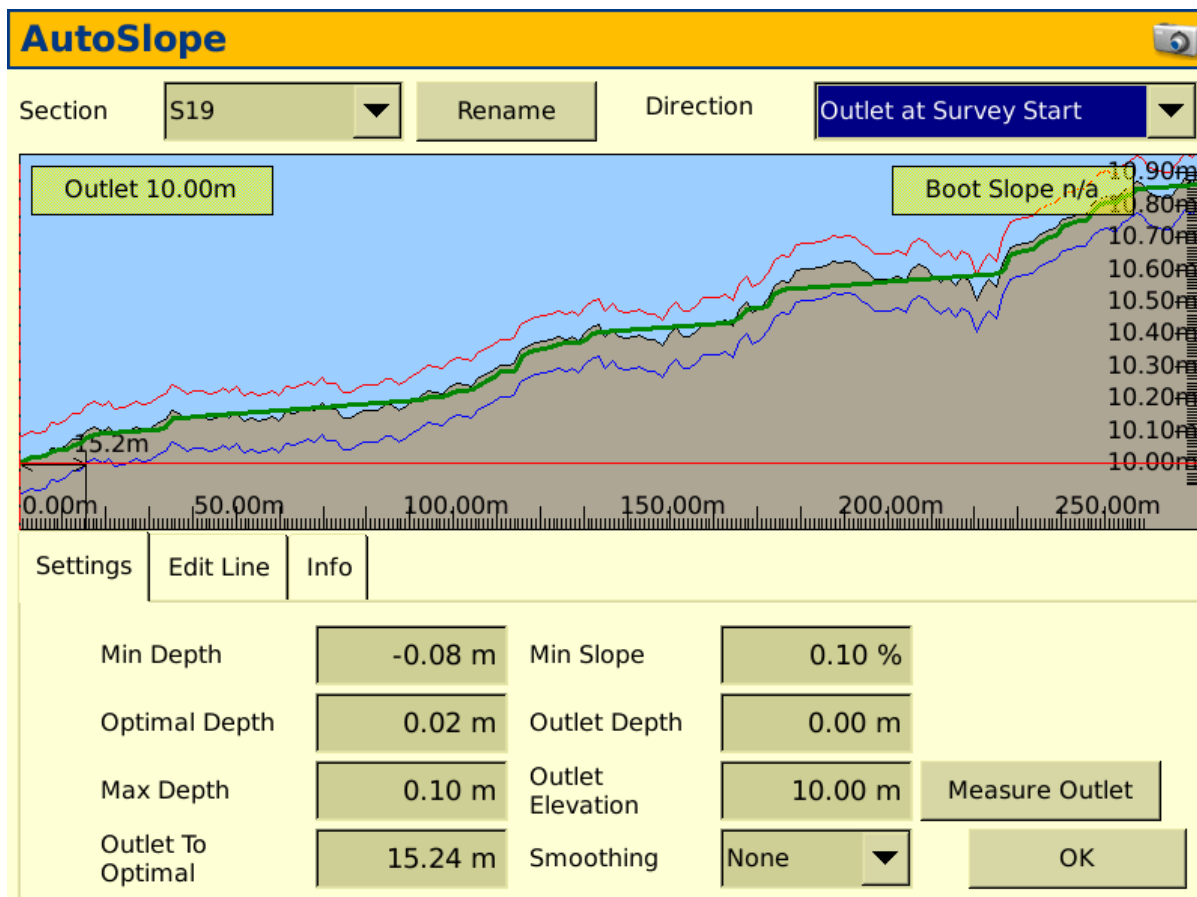


Figure 9. Screenshot of Section Survey showing existing and planned ground profiles and the constraint fields available for editing

1. Check the *Direction* is set correctly to *Outlet at Survey Start* or *Outlet at Survey End*.

2. Set the Minimum Slope

We suggest a minimum slope *Min Slope* of 0.10%.

Use a higher minimum if possible, but note the amount of soil cut and fill depth required

3. Set Minimum and Maximum Depths

NOTE: A negative number is higher (above ground), a positive number is lower (below ground)

NOTE: Minimising cuts and fills minimises the difference between the new interrow profile and the existing under tree profile. Deep cuts create steps that may affect orchard operations and could be a Health and Safety hazard.

9 Install

9.1 On-Screen Guidance

An example screen is shown in Figure 10. The surveyed rows (“sections”) are shown as white lines on the hatched green background.

The profile of the selected section (marked by the orange line and tag “S25” on the green hatched area) is shown at the bottom left of the screen (shown in more detail in Figure 11). Within this, the current location of the blade is shown as a thin white vertical line at the right high end of the profile.

The orange chevron at the bottom right of the green hatched area is indicating the blade should be lowered. The amount of lowering required is shown at the top right, in this example by 0.21 m.



Figure 10. FMX screen post survey showing surveyed sections (lines) and the resolved profile after design selection.

The profile shown in Figure 11 allows the operator to see current blade location and if the optimal profile is higher or lower than the current ground profile. In this trial implementation, the operator ensured the blade was cutting when the grey was above the green line (a hump) and allowed fill to be deposited when the green line was above the grey (a hollow).

NOTE: Blade height is normally controlled automatically by an auto-control valve using the GPS height and resolved profile solution. For our trial blade height was controlled manually as the tractor hydraulics were not compatible with the available auto-valve.

9.2 Reshaping the Interrow

NOTE: Ideally, reshaping follows immediately after the survey and design. If there are delays, ensure the blade is re-benched to get the correct elevation offsets.

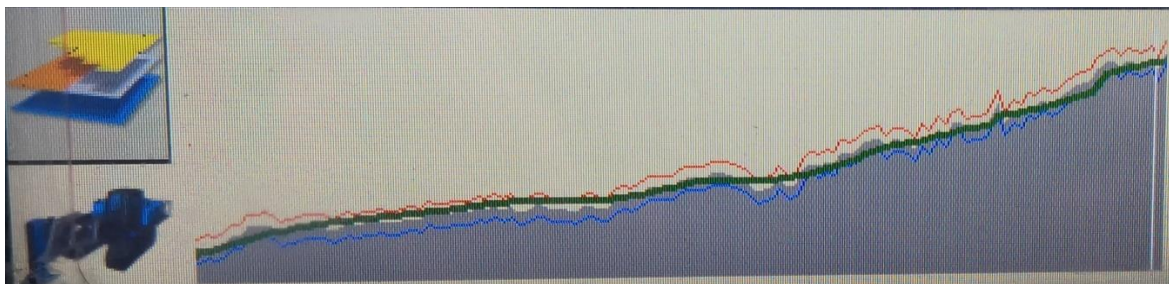


Figure 11. Section profile shown in FMX screen showing optimal profile as green line and current blade location indicated by thin white vertical line at right of the profile

1. Check blade height is benched
2. Drive into the interrow and set the blade low to avoid tree damage
3. Proceed along the row cutting off high points and releasing into low points

NOTE: Set the blade too high for the first pass if deep cuts are needed. This will minimise excessive loading in the land shaper. The first pass can be manually controlled to avoid overloading the machine

4. If the land shaper fills, raise it to allow some soil to pass underneath then carry on
5. Continue passes progressively lowering the blade as the final profile is approached

NOTE: Multiple passes with shallow fills creates better consolidation and minimises later subsidence

Multiple passes were needed to move soil from high to low areas as the blade only carries about 1.5 m³ at a time. This meant several opportunities to fill and compact wheel track ruts which were apparent even after rotary hoeing. The completed inter-rows were generally flat across the wheel tracks with fall along the entire length of the row (Figure 12).



Figure 12. Completed inter-row shows flat section with minor soil ridging at sides.

10 Verify

10.1 Completion Survey

The aim was to get the grey boundary (profile) as close to the green line as possible. To check, rows were resurveyed after several passes and the process restarted. Final profiles can be recorded and retained for reference and as evidence.

10.2 Post-treatment observations

Observations after significant rain events will show areas where ponding remains. If adequate minimum slope has been applied, there should be very little ponding except in unusual circumstances such as very heavy intense rain.



Figure 13: Inter-row surface after rut filling and re-grading by the land shaping machine and drilling with grass.

10.3 Rut Measurement

A sled was designed to measure and record the depth of ruts and their location within the orchard blocks, see Figure 14.

The location is recorded using the SBAS positioning system with an EOS Arrow 100 GPS with a horizontal accuracy of approximately 0.3-0.4m. A linear transducer measures the difference in height between the bottom of the wheel ruts and the ground surface between the wheel tracks.

The data was recorded on a smartphone using an app, Rut-O-Meter. Points are recorded approximately every 0.2m depending on travel speed as the sled was towed by a quadbike along orchard rows.



Figure 14: Sled design to measure rut depth, measuring the difference in height between the bottom of the wheel tracks and the centre of the inter-row.

The average rut depth (of the left and right wheel tracks) throughout the Evenden trial block was measured prior to the soil being cultivated. An example of the rut depth along an orchard row and the corresponding elevation profile are presented in

Figure 15. The raw data from the rut measuring sled is presented in Figure 15a. “Evenden – Rut Depth – Section 9” and the measured rut depths appear to correspond to the drainage analysis (Figure 15b. “Evenden – Interrow Profile – Section 9”) completed in OptiSurface.

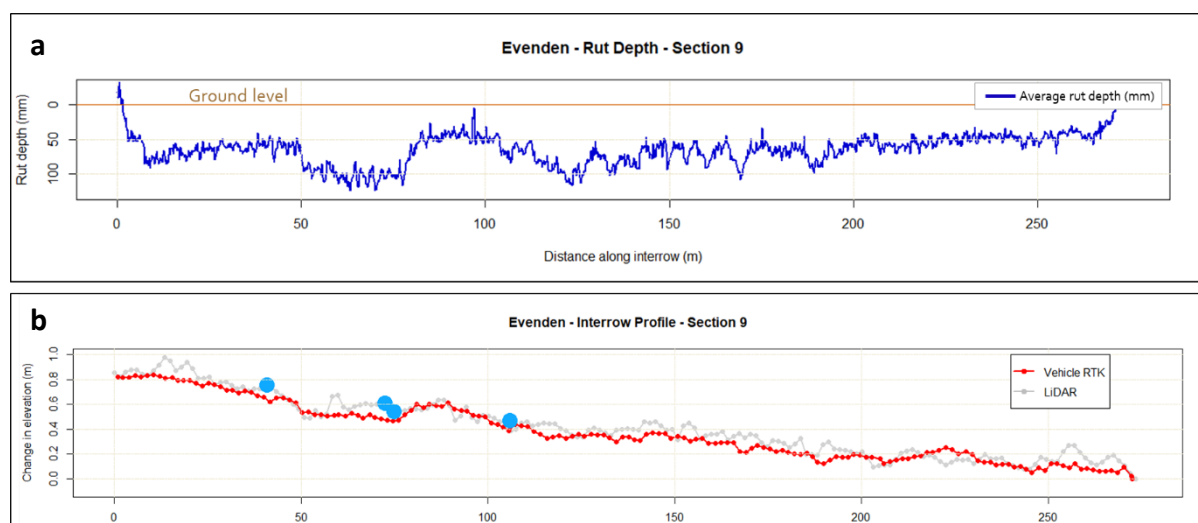


Figure 15: Example of matching rut depth measurements (a) and elevation profile (b).

11 Reflection

The primary purpose of land shaping is to ensure excess surface water can flow out of an orchard block quickly after a rain event to minimise the issues of wetness, which leads to soft mud and wheel track rutting and other associated issues.

In addition, using a blade or other option that created a camber across the orchard interrow would create a drainage flow towards the intra-row under the trees, further avoiding wetness in wheel tracks.

Being unable to survey with the blade fully raised and being unable to easily control blade height are issues that must be resolved. The work-around implemented is largely satisfactory for the purposes of a trial, but inefficient with a sub-optimal profile result.

It is not feasible to steer the tractor along the row, maintain a check on the leveller and constantly adjust the depth by hand according to the controller chevrons. Observing the profile on the screen and identifying cut and fill zones does give the operator reasonable guidance.

Compatible tractor hydraulics and an established routine for benchmarking and blade height setting for surveying are essential for efficient correct application.

If possible, use a fully automated system including auto-valve height adjustment. Automation would be desirable for contract work on whole orchards as manual control is very demanding. Driving narrow rows, looking backwards to check performance and forwards to check correct height positioning on the FMX screen was tricky in the narrow orchard rows with many mid-row branches.

Avoid design profiles with areas that have zero slope. It increases the chance of water ponding, especially where slight surface fluctuations leave higher points. If there are any areas that where the water cannot be drained to the ends of the row due to large depressions and significant rutting is an issue through the Orchard block, consider land shaping to the depression and installing a sump to drain water from the low point.

A minimum of six passes were completed on each inter-row. The blade has limited capacity both for cut and for transport of fill. The benefit of multiple shallow soil movements is good wheel track consolidation as only a small depth required packing each time. This should reduce post-operation soil subsidence and better carry traffic in wet conditions.

Particularly when using manual control, after several passes it can be helpful to to resurvey the line to check where cuts and fills are required.

Protecting the GPS equipment and cabling is essential. Tree branches extend across rows and snag and damage cables. Taping the antenna cable down the rear of the antenna mounting pole and fully taping around the cable and connections at the top of the pole seems to provide sufficient protection.

Similarly, the FMX GPS receiver cabling needs protection. The cables and plugs are exposed in open air tractors and must be shielded. We used a cut out from a 10 L plastic drum taped to the machine and receiver which provided adequate protection in the orchards where we trialed.



PAGEBLOOMER