BEFORE THE HEARING COMMISSIONERS
AT CENTRAL OTAGO

IN THE MATTER	of the Resource Management Act 1991 ("**the Act**")
AND	
IN THE MATTER	of the Proposed Plan Change 14 to the Central Otago District Plan

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STATEMENT OF EVIDENCE BY ROGER GIBSON
FOR HORTICULTURE NEW ZEALAND
20 MAY 2020

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1. QUALIFICATIONS AND EXPERIENCE

1.1 My name is Roger Gibson. I hold a B.Sc in Botany from the University of Canterbury granted in 1985, a Master of Applied Science (1st class hons) in Plant and Soil science from Lincoln College of the University of Canterbury granted 1988 and a Level 7 Graduate Diploma in Tertiary Education from the Otago Polytechnic 2015.

1.2 Prior to the year 2000 I worked in a variety roles applying my plant and soil science knowledge which included Plant ecologist/conservation officer with the Department of Conservation 1987-1994, and Landscape Ecologist with Landcare Research (based Alexandra) 1994-2000.

1.3 As a Landscape Ecologist with Landcare Research in Alexandra I researched the relationships between plants and soils in Central Otago and have published both as principal author and co-author peer-reviewed scientific papers on this subject as well giving presentations to related conferences such as the annual NZ Ecological Society Conference.

1.4 During 2000 to 2019 I have worked part time as a senior lecturer with the Otago Polytechnic Cromwell campus teaching plant science, soil science, climate, site evaluation and a range of other relevant subjects for horticulture and viticulture enterprises, to students undertaking Certificate and Diploma studies.

1.5 I have been the owner of land in the Lowburn Valley near Cromwell from 1990-2017 and during the period 2000-2017 I developed a vineyard on this land which became known as Lowburn Ferry. Lowburn Ferry has won many trophies (both national and international) for its outstanding wines.

1.6 I have undertaken consultancy as a private consultant from time to time to assess soil suitability for viticulture and horticulture around the Cromwell basin.

1.7 I have been called upon a number of times to give presentations to growers (e.g Central Otago Wine Growers Association) to explain the pattern of soils found around Central Otago and to elucidate the parameters that affect their suitability for horticulture/viticulture.

1.8 I have read the Environment Court's Code of Conduct for Expert Witnesses, and I agree to comply with it. My qualifications as an expert are set out above. I confirm that the issues addressed in this brief of evidence are within my area of expertise, except where I state I am relying on what I have been told by another person. I

have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

2. SCOPE OF EVIDENCE

2.1 This evidence provides an assessment of the soils within Plan Change 14 with emphasis on their value in a local context and for crops and uses which are suited to the environment and climate of the local area - the Cromwell basin.

2.2 In undertaking this assessment I have considered:

(a) The Request Documents as lodged by the Proponent;

(b) The soil investigation evidence lodged by Ian Lynn for the Proponent

3. MY UNDERSTANDING OF HORTICULTURE NEW ZEALAND'S SUBMISSIONS

3.1 HortNZ made a submission and further submission on Proposed PC14 opposing Plan Change 14 in its entirety because of the potential impacts on horticulture in the district.

3.2 The submission also identified that PC14 is inconsistent with the proposed Otago Regional Policy Statement, in particular as it relates to recognition and providing for significant soils (Policy 3.2.17, 3.2.18) and the need to ensure that soils are retained in the district for horticultural use.

4. PC14 APPLICATION

4.1 NZ Cherry Corp seek a plan change to amend the zoning of the site from Rural to Rural Resource Area (5) and develop up to 160 new lots.

4.2 The land in questions is located within the rural area adjacent to existing horticulture operations.

5. MATTERS THIS EVIDENCE WILL ADDRESS

5.1 This evidence will address the planning matters as they relate to HortNZ's interests in PC14:

(a) Soil information sources

(b) Description of soil resources

(c) Definitions of soils value

(d) Other considerations

(e) Evaluation of the soils of PC14

(f) Allotment size and practical use for production

6. SOIL INFORMATION RESOURCES

6.1 The description of the soils used in this evidence relies on published resources, such as maps and typical profile descriptions, as well as my personal knowledge of the pattern of soils and their profiles in the Cromwell basin. I have not entered the property or undertaken any soil pit analyses or inspections on site.

6.2 A number of published relevant soil map resources exist covering the area in question. These include; Leamy and Saunders 1967– NZ Soil Bureau Bulletin 28 -Soils and Land use in the Upper Clutha Valley, Otago. GrowOtago web site hosted by the Otago Regional Council created in 2001-2003 and the current Landcare Research SMAP Web based system

6.3 The Leamy and Saunders 1967 report was a comprehensive report based on extensive field work and contains soils descriptions, soil use suitability assessments, and detailed soil maps of the Upper Clutha area from the Kawarau River to Wanaka. Although some aspects have changed in that time such as new crops not considered by Leamy being introduced to the area, the landscape is mostly unchanged and the maps remain the best and most detailed spatial resource for soils of the area.

6.4 The growOTAGO project comprehensively maps the Otago region's climate and soils and has made this information available on a web site and through a CDrom. The growOtago project utilised existing resources such as the Leamy and Saunders 1967 report to correlate and compare information on a regional basis and used some limited ground work to fill the gaps. The web site states “During the compilation a number of previous soil series have been merged to provide a uniform coverage of soil series. Some simplification and loss of detail were necessary where very detailed soil maps were available.”

6.5 S-map Online is a web site developed and maintained by Landcare Research where you can view detailed soils information using an interactive map viewer and obtain soil factsheets for specific locations. It uses data from existing soils surveys such as Leamy and Saunders 1967 when available and seeks to correlate and standardise soil names and descriptions using computer modelling. SMAP uses what is termed Probability Distribution Functions

(PDFs) to correlate similar soils and profiles to provide a standardised national system for obtaining soils information. Sibling soil descriptions can be obtained for the map polygons. The maps are not as detailed and the descriptions not as site specific as studies such Leamy and Saunders 1967 which have provided much of the base data for this area.

6.6 I will therefor refer mostly to Leamy's 1967 work as it is the most detailed work and is the source of the base data for the later web based systems.

7. DESCRIPTION OF SOIL RESOURCES

7.1 Appendix 1 contains the relevant portion of the soil map from Leamy and Saunders 1967 covering PC14. Leamy identifies the following soils contained within the area PC14

- W5 Waenga fine sandy loam
- W3 Waenga shallow sandy loam
- L2 Lowburn very shallow sandy Loam
- L4 Lowburn shallow sandy Loam
- L5 Lowburn Sandy Loam
- R2 Ripponvale very shallow sandy Loam
- R3 Ripponvale shallow sandy Loam
- CL Clare Hill Soils

7.2 It should be noted that soil maps focus on mapping soils in their natural or unmodified state and then describing their potential. When considering the soils of PC14 we should also consider modifications to those soils and the increased/decreased value these modifications have had. Appendix 6 shows a photo taken from Ripponvale road and a photo from Google Earth. Both clearly show the area of W5 soils. On the surface are borders for border dyke irrigation and it is clear the majority of The Waenga soils in particular the W5 soils have had irrigation for some time. Irrigation has a very significant effect on soils in dry areas. It increases weathering and release of nutrients but of greatest benefit is the increase in organic matter. Typically dry Central Otago soils can have very low Organic Matter (OM) values (as low as 1%) The addition of water allows increased plant growth and increased deposition of fresh organic matter. Over time this can lead to soils which have Organic Matter contents well over 4% and I have seen them over 6%. Increased OM has huge benefits for soil – improved cation exchange capacity, water holding, structure, microbiology and is a store of nutrients in particular Nitrogen a nutrient lacking in most of the dryland soils in their natural state in Central Otago. Soils

with high OM levels are ideally suited to undertaking "Organic" certified production. It would appear that much of the W3 and W5 soils have been improved with irrigation and this will be considered.

8. DEFINITIONS OF SOIL VALUE

8.1 Various definitions of high value, or high class soils exist which take slightly different viewpoints. In my opinion we must view high class soils in a local relevant context that recognises the opportunities and industries of the local area, in this case the Cromwell Basin. It could be argued it is largely irrelevant that better pasture soils or arable soils exist elsewhere when what we are seeking to protect is the productive capacity and future of the crops and industry that make Cromwell and Central Otago great. I will comment on the definitions currently in circulation.

8.2 The "high class" definitions used by Leamy and Saunders 1967(see appendix 5) revolve around soils being capable of sustaining production of a wide range of crops including fruit, nuts. Emphasis on wide range and high sustained production. Leamy has used a 1 to 5 scale to class the soils (1 being best) for their relative suitability for agriculture (which includes fruit growing).

8.3 The operative district plan describes "High class soils" as "soils that are capable of being used intensively to produce a wide variety of plants including horticultural crops".

8.4 Peter McIntosh in his report titled "High Class Soils of Central Otago" produced for the ORC in 1993 defined high class soils as "Soils that are capable of being used intensively to produce a wide variety of plants including horticultural crops."

8.5 Ian Lynn in his report on the soils for the applicant has stated the soils cannot be considered "high class" unless if they are not suitable for "intensive arable cropping". This is simplistic and highly restrictive and is at odds with other classifications and does not recognise that soils can be extremely valuable and of high class to particular industry and yet still not ideally "arable". It assumes arable farming is the ultimate use a soil can be put to. For our much more sustainable horticultural and viticultural systems the soils we value the most might be the soils with just the right moisture release characteristics, soil chemistry, physics and biology to grow the highest quality fruit or make the best wines to be found in the world. Try going to France and informing the French wine industry that the soils of Clos de Vougeot or Domaine Romanée Conti aren't high class because they aren't ideal for cultivating.

8.6 A common theme in all the above definitions is that a high class soil has to be capable of supporting a wide range of crops and utilisation methods or in other words be a “jack of all trades”. My own view point is that there are situations where soils can be indeed “high class” but may not support a range of crops but may be highly suited to a mainstream crop of an area.

8.7 Consider the analogy if we go down the road to the Highlands race track and we observe a Ferrari going at speed comfortably around the track – very few people would suggest that a Ferrari is not high class and yet it is not suited to a range of uses. It is very high class at going fast on a smooth surface and can be used for racing. Not so if we go say to the backblocks of Southland and gravel roads . Some may argue the Ferrari is specialised but if smooth roads and race tracks are the norm then I would beg to differ and consider that within the smooth road context it is not speciality but it is the norm in that context and the Ferrari is undeniably high class.

8.8 Consider then that premium Pinot Noir grape production is a mainstream and common place industry in the Cromwell Basin. To make the best Pinot Noir you need a soil with all the right attributes, and such a soil containing all the right attributes will be of the highest class for Pinot Noir production – it is not specialist as it is a mainstream crop within the context of the Cromwell Basin. The soil that is just right for producing the highest quality grapes for this mainstream use may not be suited to a wide range of uses but will undoubtedly be considered high class by anyone in the industry operating in the Cromwell basin. Just like the Ferrari on the smooth road. The Ferrari is within the context of smooth roads “high class”. A soil perfectly suited to Pinot Noir production in an area where Pinot noir is common place is also “high class”. It is irrelevant that it can’t suddenly be turned to arable production when arable production is not desired or suited to the region.

9. OTHER CONSIDERATIONS

9.1 In assessing the potential of the soil to support crop production other relevant parameters should be considered.

9.2 Heat: Sufficient heat must be present to grow and ripen the crop - there is ample published and anecdotal information as well as successful surrounding horticultural enterprises to show that the heat (e.g. Growing degree days) of the Cromwell Basin is well suited to a wide range of horticultural crops. The district plan identifies the area as part of its “Special Land Resource” (page 2:15, figure 2.4 page 2:16) for having Growing degree days in excess of 800. GrowOtago climate maps show the area to have 900-1000 growing

degree days (base 10) making it ideal for grapes, cherries and other fruit crops. As this land is only gently sloping, I would not expect heat accumulation to be significantly affected either positively or negatively.

9.3 Frost: Frost is an ever present issue throughout the Cromwell basin. Most sites require some sort of protection from frost. Sloping sites assist drainage of cold air. Wind machines are the preferred method and the location is highly suitable for use of wind machines with no adjacent residential areas to be affected by noise. Other wind machines already exist closer to Cromwell town. As wind machines would be sited near the top end of the gently sloping ground they are more likely to be more effective than if located lower down the slope.

9.4 Irrigation: Water for irrigation is needed for most horticultural crops. Water has been historically available on PC14. Much of the area of the W5, W3 and R3 soils appears to have been border dyked irrigated. Modern micro sprinkler/drip irrigation systems used with horticulture and viticulture are much more efficient and water use goes down with these applications. My personal experience of growing vines on W5 soils has shown me that once established irrigation use of grapes on W5 soils can decline to almost nothing meaning there should be a surplus of available water if grapes were planted especially if additional storage is created. A detailed water budget showing how the existing water is to be utilised along with ALL sources of water would be helpful.

9.5 Processing facilities: Cromwell already has a thriving grape/pipfruit/stonefruit industry. The required infrastructures and facilities needed to support these industries already exist.

10. EVALUATION OF THE SOILS OF PC14

10.1 Of all the soils found within PC14 the W5 soil stands out as the best and fits the category “high class”. I have measured that there is approx. 32 Ha of W5 soils outside of the planned cherry orchard expansion. The R2,W3, and L soils whilst not being of as high a class as the W5 are never the less suitable for fruit and vine growing and there are many orchards found growing on them along Ripponvale road. The Clare soils, Letts soils, and other hill country soils at the back of PC14 do not merit further discussion as “high class”.

10.2 Leamy and Saunders 1967 describe the W5 Waenga fine sandy loam as “*consisting of more than 18 inches (approx. 460mm) of fine sandy loam”.* The typical profile description shows a layer of fine

gravels underneath the layer of fine sandy loam. A photo taken from Leamy and Saunders is shown in Appendix 8.

10.3 On the SMAPS the polygon labelled Ranf_4 includes the area mapped as W5 by Leamy and Saunders. However within the SMAP polygon labelled Ranf_4 Leamy and Saunders also identified, L4,L5 and L2 (Lowburn Soils). Elsewhere in the Cromwell basin W5 soils have sometimes been placed in the SMAP Annan Sibling and sometimes in the Ranf_4 Sibling without any reason being immediately apparent for the difference. This immediately leads one to question the detail of the SMAP information. Please note the following is stated on the SMAP web site, "The accuracy of S-map data varies from one location to another, and even for one location the information for some soil properties will be more accurate than for other soil properties. Accuracy depends on many factors, including the complexity of the landscape and its predictability, the quality of other useful information like a digital elevation model, aerial photos, past soil surveys, how many measured soil profiles are available, and how familiar the pedologist is with the area. We collect uncertainty information in the database but this is not available on S-map Online".

10.4 On Leamy and Saunders' 1 to 5 scale (1 being best) for classing the relative suitability for agriculture (which includes fruit growing). The W5 soil is ranked a "2" with the availability of water. A "2" is described as "*Soil with a high suitability for agriculture capable of producing good to high yields from most crops including grain, seed, fodder and fruit crops and pasture*." Cleary Leamy's classification of the W5 soil meets the requirement of the operative district plan, as well as McIntosh's report for the soil to be considered "high class".

10.5 Leamy's report found Class 1 and 2 soils only accounted for 15% of the soils in the entire area surveyed. That puts the W5 in the top 15%. It should be noted that there are no class 1 soils in the Cromwell Basin part of the survey area where the climate is most suitable for fruit and viticulture. It could therefore be argued the W5 is a representative of the best soil class to be found around Cromwell for Orcharding and Viticulture.

10.6 Peter McIntosh in his report to the Otago Regional Council (1993) has also identified the W5 (as described by Leamy and Saunders) Waenga fine sandy loam (Appendix 9) as a high class soil. He has ranked it as a "1" for non- arable Horticulture (eg. trees and vines) and a "2" for arable horticulture.

10.7 In Peter McIntosh's book "Soils for Horticulture – Central Otago" in his description of the soils of the low terraces and fans around Cromwell on page 58 he describes the W5 Waenga fine sandy loam as described by Leamy and Saunders as "*the most valuable of the Waenga soil types for horticulture and highly suitable for irrigation and a wide range of crops*".

10.8 I also have personal experience of growing crops on W5 soils. The property I owned in the Lowburn Valley for 27 years had an extensive area of W5 soils, some also had a history of irrigation. These soils had accumulated Organic Matter to levels in excess of 5% and had a layer of top soil that was easily cultivated with depths of 500-600mm to the first gravels. We grew sweetcorn and, pumpkins to sell to the local markets as well as herbs for essential oils for the first few years see Appendix 11 before establishing Pinot Noir vines as part of our Lowburn Ferry brand. Grapes from these vines contributed to wines that went on to win a string of national and international trophies for best in class and best in show. I considered these soils to be of the highest class and they certainly demonstrated the ability to be able to grow a wide range of crops

Ian Lynn has suggested the SMAP system listed some potential water movement issues based on the W5 area being mapped as a Ranf_4 Sibling in the SMAP soil preventing it from being "high class". Whilst it is known water movement can be moderate to slow in some of the W5 profiles based on A horizon permeability in my experience mottling (consequence of oxidation/reduction due to periodic inundation) is rare and is only likely to occur around the lower parts of slopes where excessive amounts of water are applied through flood irrigation. Leamy and Saunders agree, and in their description of W5 soils state

> *"In the Ripponvale district there is weak mottling in the topsoil under irrigation. The soil is suitable for border-dyke irrigation with the provision that drainage will probably be necessary on the lower parts of fans".*

10.9 The mottling in these W5 soils is induced by inappropriate or poor irrigation management and is not inherently found in these soils in their natural or carefully irrigated state. The mottling in the W5 soils will only occur with poor irrigation practice. Border-dyke irrigation is no longer encouraged or widely used – it is very wasteful of water and can lead to excessive amounts of water applied to areas of soils which causes mottles to form. It is mostly used for pasture. Modern methods used in horticulture and viticulture avoid these issues especially when combined with modern soil moisture monitoring techniques.

In my 28 years of farming W5 soils 98% of the soils have never shown mottling and were aerobic soils with adequate permeability. The remaining 2% were located at the lower end of slopes and suffered from excess water in part through use of flood irrigation leading to the mottling. The description given by Leamy and Saunders very closely matches my own experience of W5 soils.

10.10 Ironically in the W5 soils the horizon with the slowest permeability is usually the A horizon (topsoil). Cultivation (a practice used regularly in arable systems) would improve any slow permeability issues paritcularly if the discontinuity between the A and lower horizons is reduced. Cultivation and deep ripping is normally used to prepare the soil for planting with tree or vine crops

10.11 Ian Lynn's report provided suggests the slow drainage makes the soil not "high class". An alternative viewpoint is that this depends very much on how the soil is being managed, for what crop and in what climate remembering the Cromwell basin is semi-arid with average annual rainfall under 400mm.

10.12 When "arability" is thought of as the ultimate landuse and it is to be undertaken in a higher rainfall environment then reduced drainage can be an issue as the soils may remain saturated and anaerobic on a regular basis. This would be harmful to plants and difficult for machinery to operate and for cultivation to occur

10.13 Reduced drainage can also be a problem in areas which may have a dry climate but have poor irrigation practices leading to regular saturation of soils. Flood irrigation is such a practice and is far from an ideal way to apply water and is no longer supported by organisations such as the Otago Regional Council.

10.14 However, slower permeability and drainage, in a semi-arid environment where saturation from rain is very rare and evapo-transpiration exceeds inputs over most of growing season, and with modern irrigation systems where applications are carefully applied and managed, means, reduced permeability is not necessarily an impediment. Central Otago is already seeing modern covered plastic structures with retractable roofs for growing cherries being utilised. Such setups like these can easily control excess rain and moisture but what they need is high class soils such as the W5 to be established on. The W5 soil of PC14 would be ideal for such a setup.

10.15 Within the context of tree crops or viticulture in a semi-arid climate reduced drainage can mean better water retention and less leaching. As long as irrigation is managed carefully it can lead to less water being applied. In such circumstances the soil physics and

micro-pore sizes can control the release of the water to plants, enabling appropriate irrigation practices that can lead to slow sustained moisture release and allow the manager to use irrigation practice such as RDI (Regulated Deficit Irrigation). This is an example of where a soil may not meet criteria that would make it high class elsewhere in NZ but in the context of Fruit/Grape growing around Cromwell in a Semi–arid climate a different set of properties may make the soils "high class" in the local context.

10.16 I know this from first hand experience as I have grown grapes that have made trophy winning wines from exactly these W5 soils and have been able to manage the vines so that irrigation water use was minimal –see appendix 10. In my context the parameters of the W5 soil were certainly "high class". They provided opportunities for high class management of the grapes that could not be obtained on other soil types. Grapes are not a specialist crop in the Cromwell basin context, they are a common and mainstream crop.

10.17 "Jacksons" is another example of an outstanding orchard that is established on W5 soils near Cromwell see Appendix 12. Even with the use of overhead sprinklers for frost control, drainage must be adequate, as crops are ripened and harvested successfully every year. Along the Cromwell-Wanaka highway in the Pisa Flats area there are many other vineyards and orchards established on W5 soils

10.18 So far I have argued the W5 soils are "high class" soils mostly on their described potential based on how they have been mapped. Remembering that soil maps, map and describe soils in their natural un-modified state. To fully appreciate the value of the W5 soils in PC14 we need to consider that these soils have had irrigation over a long period of time. Irrigation allows for increased plant growth and accumulation of organic matter as mentioned earlier.

10.19 Leamy and Saunders don't have Organic Carbon test results for W5 soils but do report levels of only 0.9 percent in the topsoil of W3 soils. This equates (using standard conversion factor) to roughly 1.5% Organic Matter. It is likely that the W5 soils of PC14 after decades of irrigation now have figures between 4-6% - at 3-4 times increase just on concentration alone. Along with an increase in organic matter also come an increase in the depth of the A horizon where most of the organic matter is concentrated. I have observed these soils with increase of 2-3x depth (volume) when compared with their un–irrigated counter parts. Overall this mean an increase in total organic matter resources of 6-12x. This in my opinion raises the value of these soils very significantly. An increase in organic matter improves all of the following – water holding and release properties, structure, drainage, macro-porosity, aeration, and

Cation Exchange Capacity and greatly improves nutrient reserves and supply in particular Nitrogen. These factors all greatly improve the suitability of the soil for all kinds of horticulture. In particular I would consider these soils an ideal choice for conducting horticulture or viticulture using "Organic production practices" such as those certified by "Biogro". Organic production may once have been considered speciality but is also becoming mainstream and adding extra value to all types of horticultural crops. I am of the opinion that this consideration lifts the W5 soils from "high class" to "outstanding".

10.20 **ALLOTMENT SIZE AND PRACTICAL USE FOR PRODUCTION**

10.21 My last consideration is around block size. With every block there is usually a house, a driveway a garden and garages/workshop. I can easily see 2000m2 lost to these with every block created. Even with block sizes created of 4000m2 on the W5 soils means roughy 50% of the "high class " soils productive capacity will be lost. Smaller blocks mean greater concentration of houses which can cause conflicts with horticultural practices, especially noise such as, gas guns, wind machines, helicopters, irrigation pumps, tractors, sprayers etc. To enable blocks which can allow meaningful utilisation of these outstanding soils I would see 4-8Ha as a more reasonable size.

11. CONCLUSION

11.1 Peter McIntosh lists the W5 soils of PC14 as "high class"

11.2 Leamy and Saunders 1967 rank the W5 soils on a 1-5 scale as "2" with water which is the best ranking for a soil in the Cromwell basin and puts in the top 15% in their survey area.

11.3 The Leamy and Saunders description of the suitability of the W5 soil for productive uses clearly fits the Operative plan and Peter McIntosh's definition as a "high class soil"

11.4 My personal experience of managing the W5 soils is in agreement with both of the above and I also find the W5 soils are "high class soils".

11.5 I believe the previous irrigation management may have improved the W5 soils (organic matter content) to what I believe could be an "outstanding category"

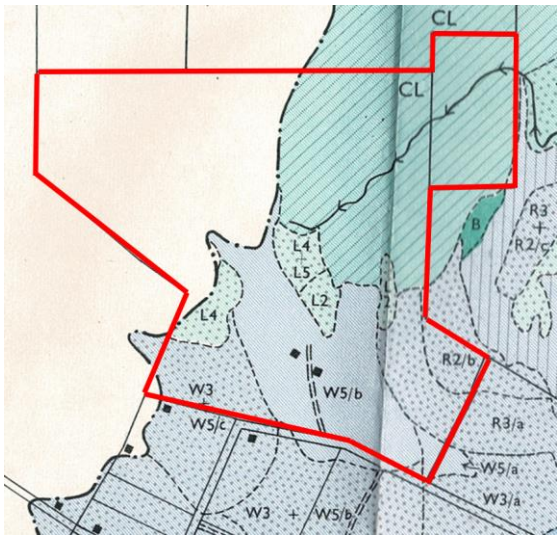
11.6 Slow permeability in W5 soils and possible issues with drainage under border-dyke irrigation may in fact be an advantage in modern horticulture and viticulture and in the context of the climate and crops of the Cromwell Basin.

11.7 The W5 soils exist within the Operative plan “special land resource area” due to the recognition that the heat accumulation (in excess of 800 GDD) for this area is well suited to fruit production and this should be recognised.

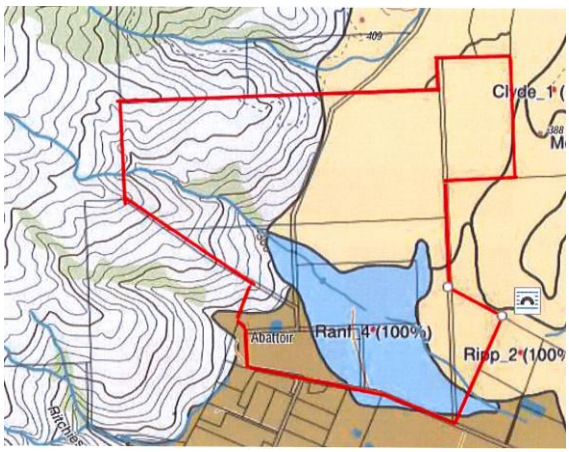
11.8 I believe the “high class” nature of the W5 soils should be recognised and subdivision limited to block sizes which optimise utilisation. I believe in the 4-8Ha category would be more reasonable.

APPENDIX 1: Soil Maps cover PC14

Leamy and Saunders 1967 – original detailed survey



SMAP – soil map (from Ian Lynn's report) showing aggregated/correlated polygons with less detail



Appendix 2: Soils descriptions from Leamy 1967

Waenga fine sandy loam (*W5*) occurs on the middle and lower parts of fans. This soil occurs on near level, very gently and gently sloping surfaces. It consists of more than 18 in. of fine sandy loam which may in places include some gravel lenses overlying schist gravels. A profile is:

6 in. greyish brown loose to friable fine sandy loam; with a weakly developed medium platy structure;
13 in. pale olive brown fine sandy loam; massive, moderately compact;
12 in. small stones intermingled with fine sandy loam; on 40 in.+ pale olive brown fine sand.

A few bare patches exist, probably caused by high concentrations of soluble salts, on soil of this type on the Keogh Creek fan. Patches of loamy sand in the Lowburn Valley and on the fan of the Park Burn were also included with this type and in some places on the toes of fans silt loam textures are common. In the Ripponvale district there is weak mottling in the topsoil under irrigation. This soil is suitable for border dyke irrigation, with the provision that drainage will probably be necessary particularly on the lower parts of fans. The calculated benefit of irrigation is very high.

Waenga shallow sandy loam (*W3*) occurs on near level, very gently and gently sloping surfaces on the middle parts of fans and consists of from 9 to 18 in. of sandy loam over schist gravel. A typical profile is:

8 in. greyish brown friable to firm sandy loam; with a weakly developed coarse platy structure;
7 in. yellowish brown slightly gritty firm sandy loam; with a moderately developed fine and medium nutty structure; moderately compact;
on schist gravels.

Appreciable amounts of shallow fine sandy loam and shallow loamy sand are included with this type and in the Ardgour Valley stony patches are to be found in some areas. There is some danger of down-fan seepage but these areas are suitable for border dyke irrigation, provided care is taken to avoid over-irrigation. Calculated irrigation benefit is high.

Ripponvale very shallow sandy loam (*R2*) was mapped on near level and very gently sloping surfaces in the Lowburn Valley; between the Lowburn and Keogh Creek; and in the Ripponvale district. It occurs on the higher parts of fans and consists of less than 9 in. of sandy loam over gravel. It includes some small areas of very shallow loamy sand. Irrigation of this very shallow, porous soil would be likely to cause pronounced seepage further down the fan. Because of its very shallow depth and the attendant disadvantages of coarse texture and high porosity, this soil is only of limited suitability for irrigation. The calculated irrigation benefit is moderate.

Ripponvale shallow sandy loam (*R3*) occurs on near level, very gently, gently and moderately sloping surfaces between Keogh Creek and Ripponvale; between the Lowburn and Keogh Creek in the Lowburn Valley; between the Lowburn and Five Mile Creek; between the Tinwald Burn and Gravelly Gully; in the Ardgour Valley; between Tarras and the Lindis River; east of Tarras; and west of Long Gully. It is the most extensive of the Ripponvale soils, consisting of from 9 in. to 18 in. of sandy loam over gravel and also includes some small areas of shallow loamy sand. A profile is as follows:

4 in. greyish brown sandy loam; with a weakly developed fine nutty and crumb structure;
3 in. transition zone of worm mixing;
6 in. pale brownish grey to pale brown coarse sandy loam; with a moderately developed fine nutty structure;
on greywacke, quartz and schist stones and gravels.

This profile was recorded from a soil under irrigation. On near level, very gently and gently sloping surfaces, this soil is suitable for border dyke irrigation and on moderately sloping topography, irrigation by contour ditches would be feasible. There is some slight danger of down-fan seepage if excess water is used, but the overall calculated irrigation benefit is high.

Lowburn very shallow sandy loam, rolling phase (*L2*) was mapped in the Ripponvale district where this soil occurs on rolling topography. Because these soils are stony, porous and of low fertility they are of limited suitability for irrigation. The calculated irrigation benefit is also low.

Lowburn shallow sandy loam, rolling phase (*L4*) was mapped in the Ardgour Valley and north-east of Tarras, as well as in the Ripponvale district, where the Lowburn shallow sandy loam occurs on easy rolling and rolling topography.

Lowburn shallow sandy loam is well suited to border dyke irrigation and the rolling phase is suitable for contour ditching. In both cases, care will be needed to prevent waterlogging, caused by the perching of water on the claypan. The calculated irrigation benefit is moderate.

Lowburn sandy loam (*L5*) was mapped on flat and easy rolling topography in the Ardgour Valley; and in the Ripponvale district where it is the subdominant member of a complex with Lowburn shallow sandy loam, rolling phase; and north of Maori Point, where it is the dominant member of a complex with Lowburn shallow sandy loam. It consists of more than 18 in. of sandy loam over gravel in which a claypan is developed. It is well suited to border dyke or contour ditch irrigation. The calculated irrigation benefit is high.

CLARE SOILS

Clare Hill Soils (CL)

These soils cover only 650 acres and are formed on greywacke gravels referred to as Maori Bottom gravels (Park, 1908, p. 42) which are now usually regarded as being early Pleistocene in age. According to Park (loc. cit.) they "consist of yellowish brown sandstone gravels, well rounded, and fairly uniform in size. The material seldom exceeds 6 in. in diameter, and is generally much decomposed". The gravels actually contain some quartz and a few lenses of sand and clay, and occur north-east of Ripponvale along the flanks of the Pisa Range. Maori Bottom deposits occur at a higher altitude than any of the younger terraces in the southern part of the valley and strong dissection in the past has almost completely obliterated the original terrace form. The resulting close pattern of dry, shallow gullies imparts a topography which contrasts quite strongly with the younger, weakly dissected terraces. Near the headwaters of Keogh Creek scattered schist, basalt and greywacke stones occur on the surface.

Clare hill soils are shallow and stony particularly on northerly slopes. A massive claypan occurs from 12 to 24 in. below the surface and in some places there is carbonate deposition below the pan. Efflorescences of soluble salts were observed in cuttings and a few bare patches, possibly caused by high soluble salt concentrations, occur on the surface. A profile of Clare hill soils is:

3 in. dark greyish brown stony sand to stony sandy loam;
9 in. pale yellowish brown stony sand;
12 in. yellowish brown stony sandy clay; (claypan);
on weathered greywacke gravel.

On slopes other than those facing north, loess accumulation has produced soils which, on southerly slopes for example, may be up to 30 in. deep.

Chemical analyses of the Clare hill soils (Lab. No. 5616, see table 8) were similar to those for the Conroy hill soils, except that the base saturation is a little lower.

Clare hill soils are subjected to severe sheet and wind erosion with a certain amount of gullying on slopes having sunny aspects, but they are only moderately eroded in protected shady aspects. They are used for very extensive sheep farming. The predominance of stony shallow profiles and the presence of a massive claypan and soluble salts combine with the moderately steep topography to make Clare hill soils of very limited suitability for irrigation. Under irrigation soluble salts may be carried to more fertile soils at lower levels by

Appendix 3 – part of the "Table of Soil factors" – Leamy and Saunders 1967 for the soils relevant to PC14

(1) Soil	(2) Native Vegetation	(3) Topography and Land form	(4) Parent Material	(5) Nutrient Status	(6) Relative Suitability for Agriculture			(7) Irrigation Suitability Class	(8) Present Land Use	(9) Area in Acres (approx.) of Major Soil Series	(10) Remarks
					Rating under Dryland Farming	Rating under Irrigation Farming					
					Class	Class	Benefit of Irrigation				
WAENGA											
stony sand (W1) ..	Silver and hard tussock	Gently and moderately sloping. Fans	Schist alluvium ..	Very low	6	6	Very low	VII ..	Not used	8,600	Bouldery in some places. Vegetation very sparse.
very shallow sandy loam (W2)	,,	Very gently, gently and moderately sloping	,,	Low to medium	5	4	Moderate	IV ..	5S		Danger of down-fan seepage under irrigation.
shallow sandy loam (W3)	,,	Near level, very gently and gently sloping	,,	Medium to high	4	3	High ..	I	7BAS		
shallow sandy loam, bouldery phase (W4)	,,	,,	,,	Medium	5	4	Low ..	IV ..	2S		
fine sandy loam (W5) ..	,,	Near level, very gently, gently sloping	,,	Very high	4	2	Very high	III, some I ..	7BAS		
mottled fine sandy loam (W6)	,,	Near level ..	,,	Medium to high	Not applicable	3	Nil ..	VI ..	7BAS		
CLARE											
hill soils (CL) ..	Scabweed ..	Moderately steep to steep, few narrow rolling ridges. Hills	Maori Bottom gravels and loess ..	Medium to high	6	5	Very low	V	2S	600	Slipping.
LOWBURN											
very shallow sandy loam (L1)	Scabweed and scattered tussock	Flat, gently undulating. Terraces	Loess and Clutha alluvium	Low to medium	5	4	Low ..	IV ..	2S	3,500	Strongly developed clay-pan and soluble salts.
very shallow sandy loam, rolling phase (L2)	,,	Rolling	,,	Low to medium	5	4	Low ..	IV ..	2S		
shallow sandy loam (L3)	,,	Flat and gently undulating	,,	Medium	4	3	Moderate	I	2S		
shallow sandy loam, rolling phase (L4)	,,	Rolling	,,	Medium	4	4	Moderate	II ..	2S		
sandy loam (L5) ..	,,	Flat and easy rolling	,,	High to medium	4	3	High ..	I and II ..	2S		
RIPPONVALE											
stony sand (R1) ..	Hard tussock and scabweed	Gently sloping. Fans	Clutha alluvium ..	Very low	6	6	Very low	VII ..	Not used	1,100	Danger of down-fan seepage if irrigated.
very shallow sandy loam (R2)	,,	Near level and very gently sloping	,,	Low ..	5	4	Moderate	IV ..	5S		
shallow sandy loam (R3)	,,	Near level, very gently, gentlyandmoderately sloping	,,	Medium	4	3	High ..	I and II ..	5SF 7B		
sandy loam (R4) ..	,,	Near level, very gently and gently sloping	,,	Medium to high	4	2	Very high	I	5SF 7B		

Appendix 4 – Table of Soil areas and percentages of relative suitability for agriculture – Leamy and Saunders 1967

II. Relative Suitability for Agriculture under Irrigation

	Area (in Acres)	Percentage of Total Area
Class 1	6,590	4·4
Class 2	15,020	10·2
Class 3	55,590	37·4
Class 4	34,090	22·9
Class 5	19,840	13·3
Class 6	14,750	9·9
Not irrigable ..	3,010	1·9

Appendix 5 – Soil suitability descriptions (1and 2) – Leamy 1967

Class 1

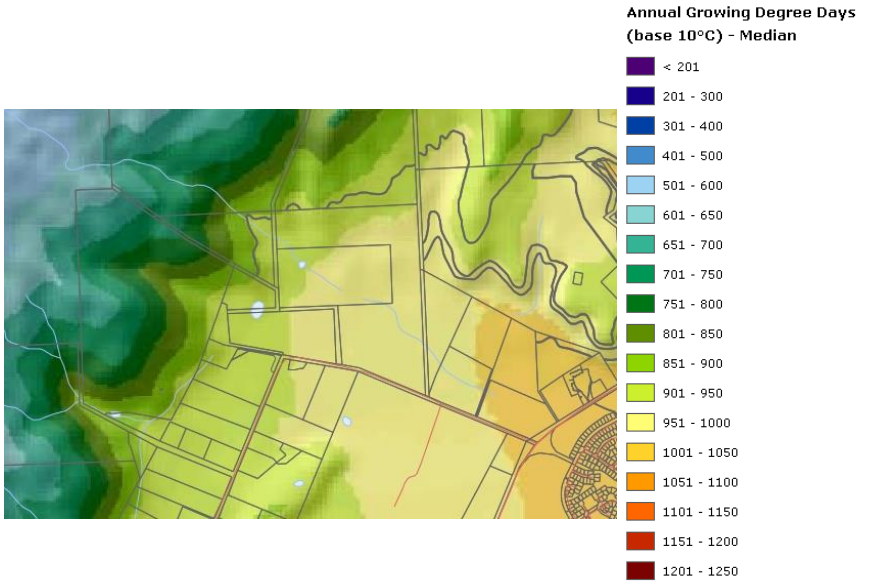
Soils with a very high suitability for agriculture which are capable of sustained excellent yields of a wide range of crops, including grain crops, seed crops, fodder crops, fruit and pasture.

Class 2

Soils with a high suitability for agriculture capable of producing sustained good to high yields from most crops including grain, seed, fodder and fruit crops, and pasture.

Appendix 6 – Photo of the approximate area of W5 Waenga Fine Sandy Loam (shaded light green) on PC14

Appendix 7: GrowOtago Growing degree map – base 10 degrees



Appendix 8: Waenga Fine Sandy Loam from Leamy and Saunders 1967

Appendix 9: Portion of table 4 from Landcare Research report "High Class Soils of Otago 1993" by Peter McIntosh

Table 4. List of high class soils in Otago

Soil[1]	Code	Survey	LUC class	Estimated OSLUI classes		Area (ha)
				Arable Hort.	Non-arable Hort.	
Pigburn sl	PB			2	1	210.49
Pigburn sh sl	PB2			3	2	988.36
Pigburn fsl	PB4			2	1	94.55
Pigburn zl	PB5			3	1	980.24
Queensberry sl	Q4			2	1	573.78
Queensberry sh sl	Q3			3	2	630.79
Ripponvale sl	R3			2	1	278.40
Speargrass sl	S			2	1	102.42
Speargrass sl	S2			2	1	64.39
Speargrass sl	S3			2	1	184.51
Speargrass zl	S4			2	1	1203.11
Waenga fsl	W5			2	1	1983.11
Waenga sh sl	W3			3	2	432.03

Appendix:10 Healthy vines being harvested growing on W5 Waenga fine sandy loam soils in Lowburn Valley

Appendix 11. W5 Waenga fine sandy loam soils in Lowburn Valley being cultivated and planted for arable

Appendix 12: W5 Waenga fine sandy loam soils – "Jacksons orchard"

References:

Leamy and Saunders 1967, Soils and Landuse in the Upper Clutha Valley, Soil Bureau Bulletin 28. Department of Scientific and Industrial Research

McIntosh 1993. High Class Soils of Otago. Landcare Research Contract Report LC9293/85

McIntosh 1998, Soils for Horticulture in Central Otago, Landuser Guide Number 2, Landcare Research NZ Ltd.

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20 May 2020