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Wrights Road Storage Pond Business Case – Further Irrigation Supply and Demand Modelling

Waimakariri Irrigation Limited

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Wrights Road Storage Pond Business Case – Further Irrigation Supply and Demand Modelling

Prepared for

Waimakariri Irrigation Ltd

October 2021

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1.0 Introduction

At the Special General Meeting in June 2021 Waimakariri Irrigation Ltd (WIL) shareholders voted in favour of finalising the business case for the Wrights Road Storage Ponds. In preparation for the final vote Pattle Delamore Partners Ltd (PDP) has been engaged by WIL to undertake further supply-demand modelling and provide further comments on several key items for the business case.

Previous work undertaken by PDP for the business case focused on modelling reliability of supply for both a long-term modelling period (48 years) as well as for a 1 in 5 dry year, 1 in 10 dry year and for the driest year. Further work undertaken and described in this report focusses on other aspects including:

1. Future anticipated changes that will affect WIL shareholders should the Wrights Road Storage Ponds not go ahead.
2. Storage refill – Further details on how the storage can be used and re-filled multiple times.
3. The benefits of storage focusing on the number of days in restriction and effect on soil moisture.
4. Water trading.

More detail on the supply-demand model developed for WIL along with a summary of the modelling results are provided in the PDP (April 2021) report 'Wrights Road Storage Pond Business Case – Irrigation Supply and Demand Modelling'.

For consistency the scenarios in the Tables and Figures in this report use the same abbreviations for each modelled scenario as those in the previous report. For clarity the four scenarios considered are:

1. The current Waimakariri River minimum flow (41 m^3/s) and no on-plains storage at Wrights Road (Scenario: Current no OPS).
2. The current Waimakariri River minimum flow with 8.2 Mm^3 of storage at Wright's Road (Scenario: Current with OPS).
3. Increased Waimakariri River minimum flow of 50 m^3/s and no on-plains storage at Wrights Road (Scenario: Increased MF no OPS).
4. Increased Waimakariri River minimum flow of 50 m^3/s with on-plains storage at Wright's Road (Scenario: Increased MF with OPS).

At the request of some of the WIL shareholders the 1999 -2021 period was chosen as the modelling period for analyses as this is the period the WIL scheme has been operational.

It is noted that the impacts of each of the scenarios that reduce or increase current reliability of supply have each been modelled or commented on as separate scenarios to demonstrate their potential impact (e.g. increase in Waimakariri River minimum flow, use of water for MAR & TSA, use of water for trading). If water is used for combinations of these activities the impact on water reliability would be modified accordingly.

2.0 Impact on WIL Shareholders if storage is not implemented

Previous work undertaken for the WIL business case (PDP, April 2021) outlines how future anticipated changes are likely to affect WIL shareholders. It is likely that the reliability of supply for WIL shareholders will reduce due to a potential future increase in minimum flow in the Waimakariri River, climate change and water requirements for environmental enhancement activities such as Managed Aquifer Recharge(MAR) and Targeted Stream Augmentation (TSA).

This section provides further details on how the scheme is likely to be affected due to an increase in minimum flow for a scenario where Wrights Road Storage is not implemented to offset these impacts. The analyses focus on adverse effects on the number of days in restriction and soil moisture. In addition, further details are provided on the required stepped reductions in nutrient leaching over time as detailed in Plan Change 7 and how this will impact on farming operations in the future. Stored water from Wrights Road can assist with reducing nutrient concentrations in groundwater and surface water through MAR and TSA which in turn is likely to assist with meeting the water quality targets with less severe impacts on farm operations.

2.1 Adverse effect on number of days in restriction due to increase in minimum flow

Table 1 provides a comparison of the total number of days in (partial and full) restriction for the current minimum flow (41 m^3/s) in the Waimakariri River and for the situation if an increased minimum flow is established (50 m^3/s), as has been proposed in some ECan reports (Meredith, 2009). Detailed outputs for each irrigation season for the full modelling period including a breakdown in the number days in partial and full restriction are provided in Appendix A. This Table assumes that no on-plains (Wrights Road) storage is available.

Table 1: Scheme Wide Model Results (Total number of days in restriction)

Scenario	No on-farm storage		With on-farm storage	
	Current no OPS	Increased MF no OPS	Current no OPS	Increased MF no OPS
Average	46	64	10	19
Median	45	65	0	10
Min	2	2	0	0
Max	114	136	57	73
1 in 5 dry year (2019 - 2020)	62	73	6	25
1 in 10 dry year (2009 - 2010)	72	90	37	49

Note: Modelling period is 1/Jun/1999 to 9/May/2021

As expected, the model results indicate that for farms with and without on-farm storage there is a significant increase in the number of days in restriction under an increased minimum flow scenario. On average farms without on-farm storage show an additional 18 days in restriction per irrigation season. For a 1 in 5 dry year and for a 1 in 10 dry year the additional number of days in restriction is 11 and 18 respectively.

For farmers with on-farm storage the average number of days almost doubles with 10 days in restriction under the current minimum flow and 19 days under an increased minimum flow scenario. For a 1 in 5 dry year and for a 1 in 10 dry year the additional number of days in restriction is 19 and 12 respectively.

2.2 Adverse effect on soil moisture due to potential increase in minimum flow

Outputs from the supply-demand model were used to create soil moisture plots for two example irrigation seasons being 2011-2012 and 2015-2016 (refer to Figure 1 and Figure 2). Daily soil moisture levels are plotted for a scenario based on the current minimum flow of 41 m^3/s as well as for a scenario based on an increased minimum flow of 50 m^3/s. These plots assume that no on-farm storage or on-plains (Wrights Road) storage is available. In other words, the soil moisture plots are based on the assumption that only run of river water is used to meet irrigation demand.

The example years in the Figures below are not extreme dry years. In terms of number of days in restriction (refer to Appendix A) they are around the average (2011-2012) or less than average (2015-2016). These irrigation seasons were chosen to demonstrate that in some seasons soil moisture levels under the current minimum flow (41 m^3/s) generally stay above 50% and only drop below 50% for short periods of time whereas under an increased minimum flow scenario they can drop below 50% for significant periods of time. The 50% trigger point shown in these Figures relates to water stress in plants which influences crop growth. Water stress is influenced by soil water content. When the soil water content is close to its full point (field capacity), water supply can meet demand and a crop can grow at its maximum rate. As the soil dries, the roots can initially get enough water from the soil for the plant to continue growing at its maximum rate. However, at a certain point, called the trigger point (at around 50% of the profile available water), the roots can no longer extract enough water, supply will fall below demand, the crop becomes water stressed and growth decreases. As the soil continues drying, growth continues to decline until eventually it stops at what is often called the permanent wilting point or lower limit (at 0% of PAW).

For the two example seasons soil moisture levels drop below 50% for significant periods of time under a scenario with increased minimum flow. The soil moisture plot for 2011 – 2012 (Figure 1) indicates that there is no difference in soil moisture prior to late December. This is due to high river flows resulting in no restrictions under either the current or increased minimum flow scenario. From late December/early January river flows drop resulting in river flow restrictions. Restrictions are much more severe under the increased minimum flow scenario resulting in soil moisture levels dropping below 50% from around 10 January through to end of February and again for 7 days in early April. Soil moisture levels are generally maintained above 50% under the current minimum flow.

The 2015-2016 season shows a similar trend with limited difference in soil moisture levels for the period with relatively high river flows (through to mid-February). Once river flows start to drop the much more severe restrictions under the increased minimum flow scenario result in soil moisture levels well below 50% from mid-February through to mid-March and again from 22 April through to the end of the irrigation season (9 May).

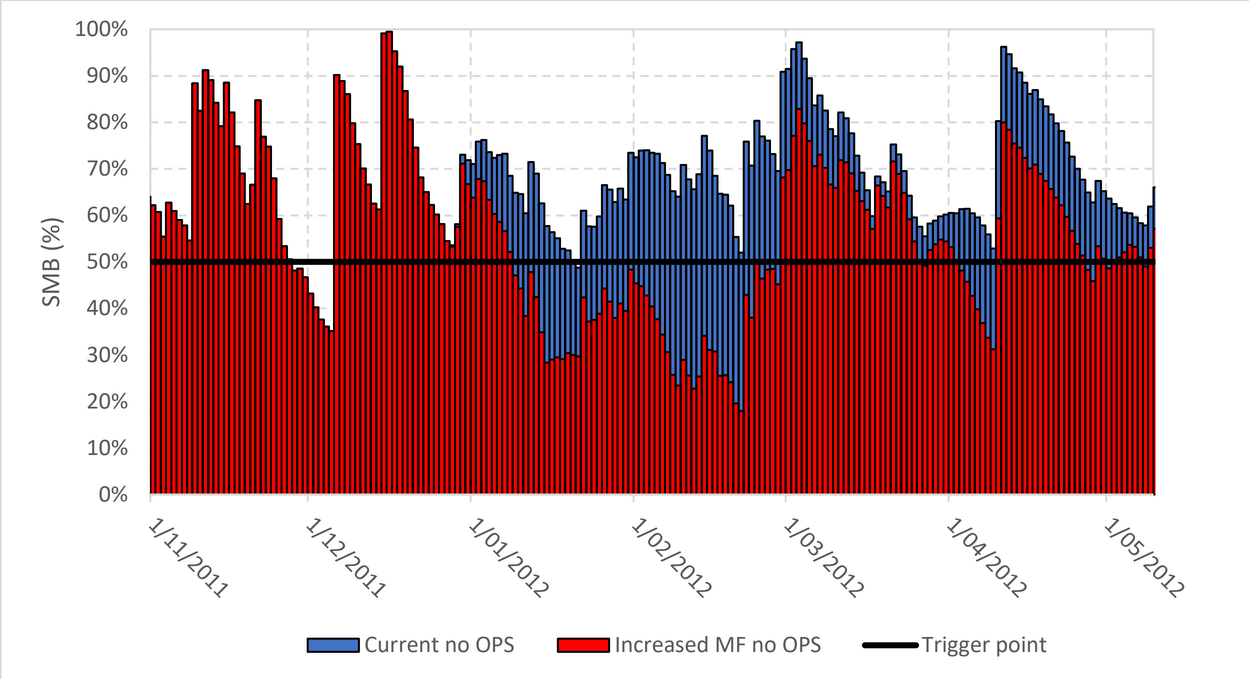

Figure 1: Daily soil moisture based on the current and potential future minimum flow for the period 1 November 2011 to 9 May 2012

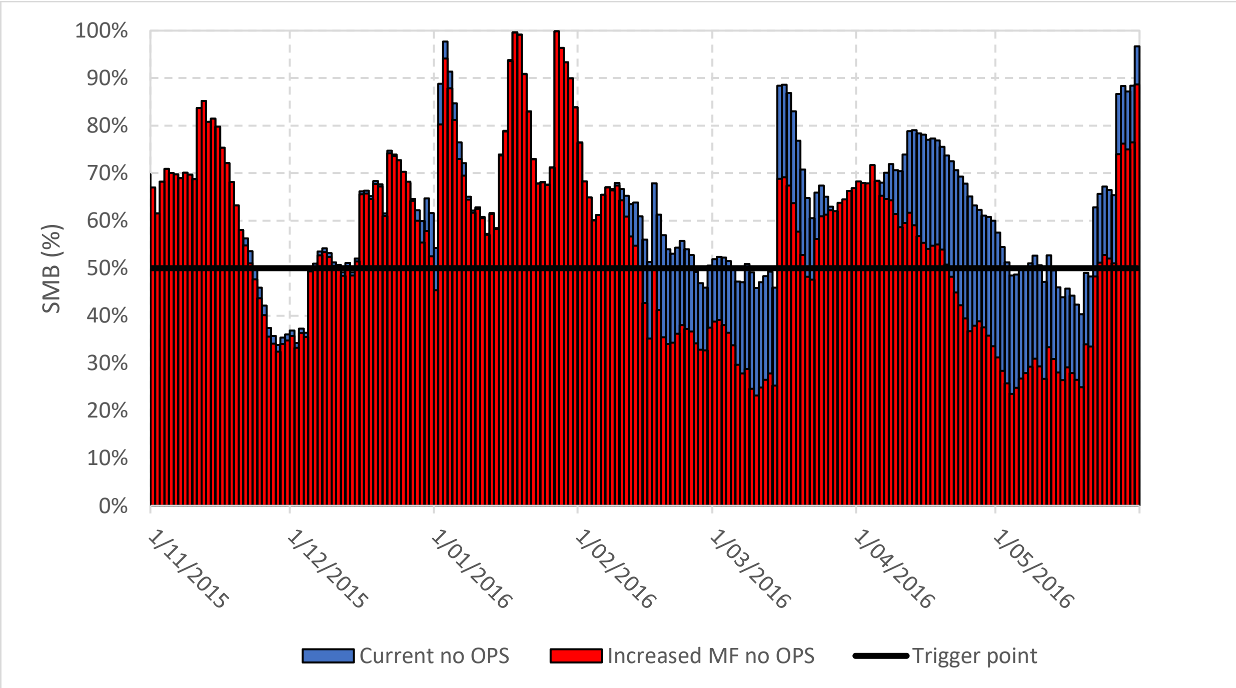

Figure 2: Daily soil moisture based on the current and potential future minimum flow for the period 1 November 2015 to 9 May 2016

In summary the soil moisture plots above demonstrate that during 'average years' shareholders without on-farm storage can generally maintain soil moisture levels close to or above 50%. With a potential future increase in minimum flow soil moisture levels will be well below the trigger point of 50% for significant periods of time, especially in the second half of the irrigation season when river flows are generally low. In other words, not implementing Wrights Road storage results in a significant reduction in soil moisture levels under an increased minimum flow scenario.

2.3 Adverse effect on farming operations as a result of PC7 water quality limits

Proposed Plan Change 7 (PC7) to the Canterbury Land and Water Regional Plan (LWRP) requires farms to further reduce nitrogen losses over time. The proposed reductions below a farm's baseline Good Management Practice (GMP) loss rate are set out in Table 8-9 of PC7, as shown below.

Table 8-9: Nitrate Priority Area Staged Reductions in Nitrogen Loss for Farming Activities, Farming Enterprises and Irrigation Schemes

Nitrate Priority Sub-area (see Planning Maps)	Farming type	Cumulative percentage reductions in nitrogen loss and dates by which these are to be achieved					
		By 1 January 2030	By 1 January 2040	By 1 January 2050	By 1 January 2060	By 1 January 2070	By 1 January 2080
Sub-area A	Dairy	15%	30%	-	-	-	-
	All other	5%	10%	-	-	-	-
Sub-area B	Dairy	15%	30%	45%	-	-	-
	All other	5%	10%	15%	-	-	-
Sub-area C	Dairy	15%	30%	45%	60%	-	-
	All other	5%	10%	15%	20%	-	-
Sub-area D	Dairy	15%	30%	45%	60%	75%	-
	All other	5%	10%	15%	20%	25%	-
Sub-area E	Dairy	15%	30%	45%	60%	75%	90%
	All other	5%	10%	15%	20%	25%	30%

1. The starting point for applying each percentage reduction in nitrogen loss in Table 8-9 is generally the Baseline GMP Loss Rate except as otherwise provided for in Policy 8.4.26 for individual farming activities and farming enterprises, and in Policy 8.4.29 for irrigation schemes

2. For the purposes of applying the nitrogen reductions in Table 8-9, 'Dairy' farming does not include 'Dairy Support' activities. 'Dairy Support' is classified under 'All other' farming activities

3. The percentage reductions required by Table 8-9 are only to be applied to farming activities that require resource consent for farming land use and only where the required reduction for each stage is greater than 3 kg nitrogen per hectare for dairy, and 1kg per hectare for all other farming activities.

WIL's PC7 evidence indicated that shareholders may be able to reduce their losses by 30% below GMP. However, any reductions beyond 30% would not be feasible. As shown in Table 8-9, the proposed *maximum* nitrogen loss reduction is Baseline GMP minus 90% by 1 January 2080.

The WIL Solutions Package put forward at the PC7 hearing enabled the desired water quality outcomes to be met through:

- Achievable nitrogen loss reduction on farm; and
- Managed aquifer recharge (MAR); and
- Targeted stream augmentation (TSA).

However, MAR and TSA can only be implemented if there is available water. Figure 3 below (adapted from Jeremy Sanson's PC7 evidence) indicates that in most years there is not enough water available during the peak irrigation period (November to February) to meet the MAR and TSA requirements needed to achieve the desired water quality outcomes.

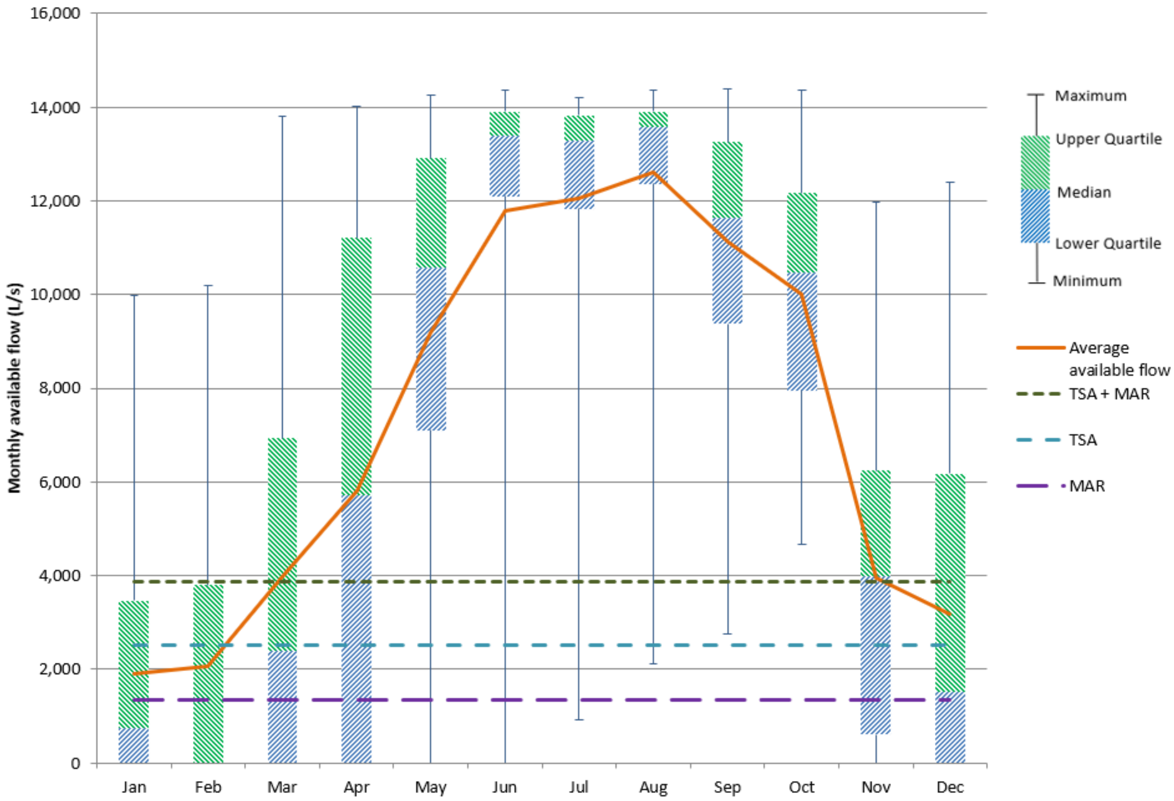

Figure 3: Monthly water availability with MAR and TSA requirements (L/s)

Wrights Road storage allows for MAR and TSA to occur when the Waimakariri River is on restrictions, or when all the run of river supply is being used for irrigation. If the Wrights Road storage is not built, it is expected that either:

- Farmers will need to give up irrigation water so that MAR and TSA can continue during peak irrigation months; or
- Farmers will need to make greater nitrogen loss reductions beyond what is considered feasible. These changes could include reducing stocking rates, or land use change.

2.4 Summary

In summary if Wrights Road storage does not proceed future anticipated changes such as an increase in minimum flow and required reductions in nutrients are likely to have significant impacts on farmer operations within the WIL scheme. Adverse effects are likely to include:

- A significant increase in the number of days in restrictions.
- Significantly lower soil moisture levels.
- Greater nitrogen loss reductions beyond what is feasible (e.g. reducing stocking rates or land use change).

3.0 Storage use and refill

3.1 Multiple refill events and use of stored water throughout the irrigation season

Table 2 shows the cumulative Wrights Road storage volume to irrigation for each irrigation season. Due to multiple storage refill events in between drawdown periods (to meet irrigation demand) the volume used for irrigation exceeds 8.2 Mm^3 for 13 out of the 22 irrigation seasons shown in the Table. The average and median seasonal storage volume used is 10.8 and 10.2 Mm^3 respectively and the minimum and maximum is 0.95 Mm^3 (2003 -2004) and 26.6 Mm^3 (2005-2006) respectively. The high variability can be explained by the seasonal differences in irrigation demand and supply which is affected by rainfall, evapotranspiration, and Waimakariri River flow.

Table 2: Cumulative storage to irrigation per irrigation season

Irrigation Season	Cumulative Storage to irrigation	Irrigation Season	Cumulative Storage to Irrigation
1999-2000	5,064,739	2010-2011	5,073,571
2000-2001	13,730,480	2011-2012	7,156,992
2001-2002	4,286,161	2012-2013	10,576,349
2002-2003	7,461,337	2013-2014	11,006,820
2003-2004	945,048	2014-2015	9,856,126
2004-2005	5,324,863	2015-2016	4,667,667
2005-2006	26,555,234	2016-2017	5,841,896
2006-2007	10,941,531	2017-2018	9,031,685
2007-2008	22,906,249	2018-2019	10,616,508
2008-2009	18,817,174	2019-2020	17,555,367
2009-2010	10,634,777	2020-2021	20,148,382
Average			**10,827,225**
Median			10,216,238
Min			945,048
Max			26,555,234

Figure 4 shows the storage volume in Wrights Road for the 2019/20 season. This season was identified in previous modelling as representative of the 1 in 5 dry year. It is noted that this season had a number of large flow events predominantly in December 2019 which resulted in closure of the intake.

In the 2019/2020 season the closure of the intake due to high river flow coincided with high irrigation demand resulting in drawdown of the reservoir to around 2 Mm^3. Following this period, the reservoir was refilled to around 7.5 Mm^3 during a period of low demand with river flows being above the restriction levels. This was subsequently followed by a period of restrictions towards the end of January emptying the storage reservoir. A few smaller refill and drawdown events occurred later in the irrigation season. Due to these storage refill events in between drawdown periods (to meet irrigation demand) the volume used for irrigation was significant at around 17.5 Mm^3; more than twice the Wrights Road storage capacity of 8.2 Mm^3.

Figure 5 shows the storage volume in Wrights Road for the 2009/2010 season. Previous modelling identified this season as representative of a 1 in 10 dry year. This season was characterised by low river flows and high evapotranspiration. The storage reservoir is empty for long consecutive periods between mid-February through to the end of April. Some refill occurs after the initial drawdown in early February. These small refill events are associated with small freshes in the Waimakariri River. The total stored volume of water used for irrigation for this season was around 10.6 Mm^3; approximately 2 Mm^3 greater than the Wrights Road storage capacity of 8.2 Mm^3.

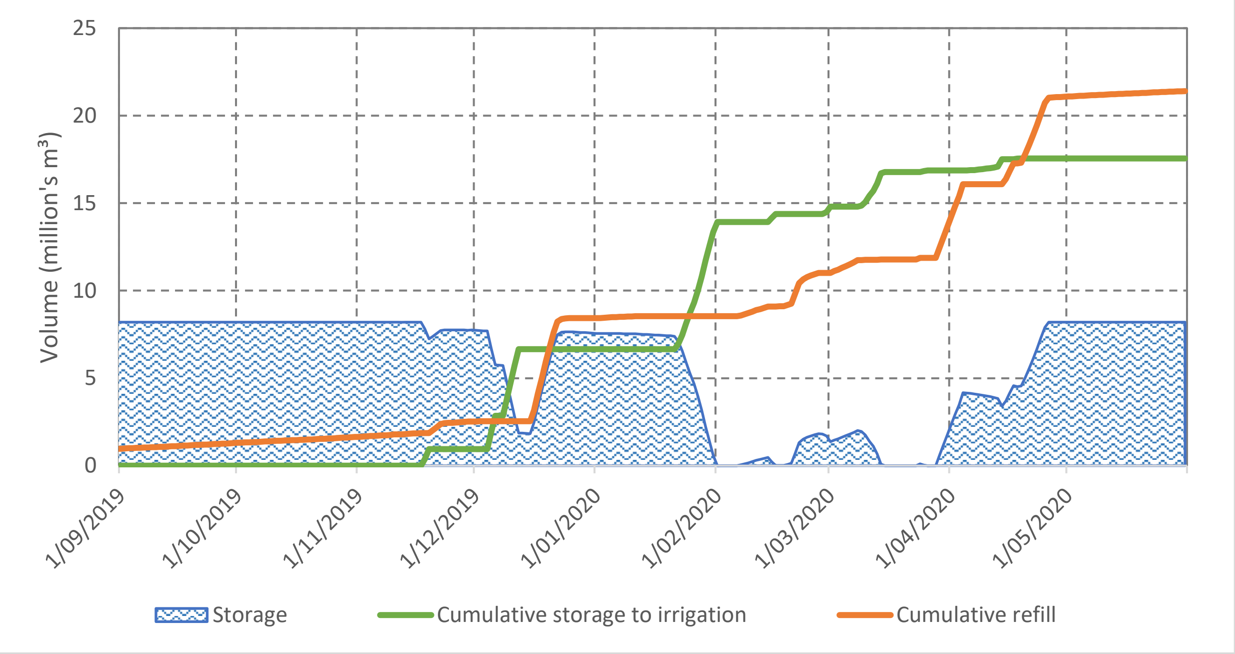

Figure 4: Active storage volume, cumulative refill and cumulative storage to irrigation for Wrights Road for a 1 in 5 dry year (2019/2020).

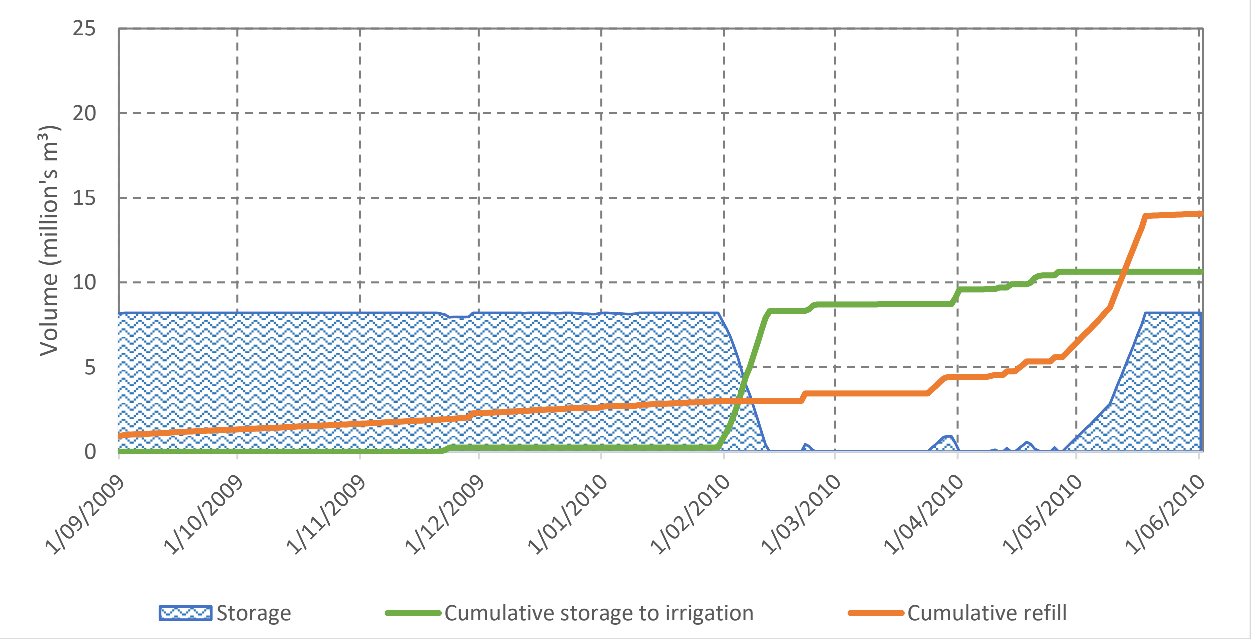

Figure 5: Active storage volume, cumulative refill and cumulative storage to irrigation for Wrights Road for a 1 in 10 dry year (2009/2010).

3.2 Summary

In summary the analyses indicates that the amount of storage used for irrigation can vary greatly from year to year. The average seasonal storage volume used is 10.8 Mm^3. Due to multiple storage refill events in between drawdown periods (to meet irrigation demand) the volume used for irrigation exceeds the Wrights Road storage volume of 8.2 Mm^3 for 13 out of the 22 irrigation seasons modelled. The volume used for irrigation can be in excess of three times the Wrights Road storage volume (26.6 Mm^3, 2015/2016 irrigation season).

4.0 Other benefits of storage

4.1 Reduction in number of days in restriction due to storage

Table 3 provides the average number of days in restriction for the modelling period and for the 1 in 5 and 1 in 10 dry year. The numbers are reported for shareholders with on-farm storage and shareholders without on-farm storage for each of the four model scenarios. Detailed outputs for each irrigation season for the 1999 – 2021 modelling period including a breakdown in the number days in partial and full restriction are provided in Appendix A.

Table 3: Scheme Wide Model Results (Total number of days in restriction)

Scenario		Average (1999-2021)	1 in 5 dry year (2019 – 2020)	1 in 10 dry year (2009-2010)
No on-farm storage	1. Current no OPS	46	62	72
	2. Current with OPS	19	21	52
	3. Increased MF no OPS	64	73	90
	4. Increased MF with OPS	31	34	65
With on-farm storage	1. Current no OPS	10	6	37
	2. Current with OPS	3	0	3
	3. Increased MF no OPS	19	25	49
	4. Increased MF with OPS	9	1	40

Note: 2009-10 is assumed to represent a 1 in 10 dry year and 2019-2020 is assumed to represent a 1 in 5 dry year.

As expected, the model results show that farms with on-farm storage have a lower number of days in restriction than those without. For farms without on-farm storage the average number of days in restriction reduces by 27 days with the addition of Wrights Rd for the current minimum flow (46 to 19 days). For the increased minimum flow scenario the number of days in restriction reduces by 33 days (64 to 31 days).

The decrease in average number of days in restriction for farms that already have access to on-farm storage decreases by 7 days (10 to 3 days) for the current minimum flow scenario and 10 days (19 to 9 days) for the increased minimum flow scenario. It is also worth noting that if a minimum flow increase is implemented, then the additional storage at Wrights Road ensures that the average number of days in restriction (9 days) for shareholders with on-farm storage is very similar to the current average number of days in restriction (10 days). For farms without on-farm storage, a small decrease in restriction days is predicted (46 to 31).

4.2 Wrights Road storage during floods and low flow

The benefits of storage in terms of providing water during times of low river flow restrictions has been discussed in the previous (April 2021) PDP report. As discussed in section 3.1 above the Browns Rock intake is closed during and immediately following large flood events due to high sediment loads in the Waimakariri River. When this coincides with high demand these flood flow cut-off periods can have significant impacts on the reliability of supply and soil moisture levels. These events occur on a regular basis as large flood events typically occur during Northwest rainfall events resulting in 'spillover' in the upper Waimakariri catchment and high river flows. During North-westerlies temperatures on the Canterbury plains are high resulting in high crop evapotranspiration. During these periods it is critical to maintain the irrigation water supply. With Wrights Road storage in place the supply of water can be maintained when the Brown's Rock intake is closed off. An example of the storage drawdown during a large flood event in December 2019 is shown in Figure 4 above and the effect of supplying stored water during this period on soil moisture levels is demonstrated in Appendix B, Figure B1. This Figure indicates that during the December 2019 floods soil moisture levels dropped to around 10% whereas with Wrights Road storage in place soil moisture levels are maintained at or above 35%.

For operational reasons WIL currently also shuts down when less than 20% of the maximum consented abstraction rate (11.041 m^3/s) can be abstracted from the river. In other words when river flows in the Waimakariri River at Old Highway Bridge are at or below 45.4 m^3/s no water is taken for irrigation purposes even though WIL is authorised to take up to 2.2 m^3/s when the river is flowing at 45.4 m^3/s. We understand from WIL that these operational constraints are lifted when Wrights Road is constructed which will allow the Scheme to take water when river flows are between 45.4 and 41 m^3/s.

4.3 Increasing application rate for farmers with on-farm storage

Due to capacity constraints in the water race network the flow entitlement for each WIL shareholder is limited by the number of shares they hold. Therefore, water stored at Wrights Road cannot be used to increase the flow rate at the farm gate. However, for WIL shareholders with on-farm storage the additional storage at Wrights Road does provide opportunities to increase the application rate on-farm by drawing down from on-farm storage to better 'keep up' with evapotranspiration during the peak irrigation season. The additional storage provided by Wrights Road allows for increased drawdown of on-farm ponds due to the increased security of supply provided by the Wrights Road Ponds.

5.0 Water Trading

Throughout the WIL scheme, there is currently approximately 12,800 ha of land irrigated without the benefit of on-farm storage. The remaining 8,000 ha or so of the scheme includes on-farm storage totalling approximately 5.7 Mm^3 (equivalent to an average storage of 710 m^3/ha). Shareholders with on-farm storage currently have a higher level of irrigation supply reliability and may want to trade some (or all) of the additional storage entitlement Wrights Road will provide them (approximately 390 m^3/ha). A trading model has been proposed whereby these shareholders may sell some (or all) of their stored water or the use of their Wrights Road storage entitlement for a duration of time.

The irrigation supply-demand model was used to quantify the irrigation reliability at different levels of storage and infer how much storage, above and beyond what will be provided by Wrights Road, will be required by WIL shareholders without on-farm storage to reach a certain target level of reliability. A target level of reliability of 95% has previously been used in the business case reporting as an acceptable reliability threshold although other reliability levels have also been considered in the analyses. It is noted that storage results are presented in terms of m^3/ha instead of total m^3 for easier comparison between different areas of the scheme.

5.1 Reliability and required storage volumes in m^3/ha

The supply-demand model was run with storage sizes ranging from 0 to 1,800 m^3/ha and irrigation reliabilities over the 1999-2021 period were calculated. These results are presented in Figure 6 for the current minimum flow alongside predicted reliabilities for the most recent season (2020-2021, solid blue line), the 1 in 5 dry year (2019-2020, solid grey line), and the 1 in 10 dry year (2009-2010, solid yellow line).

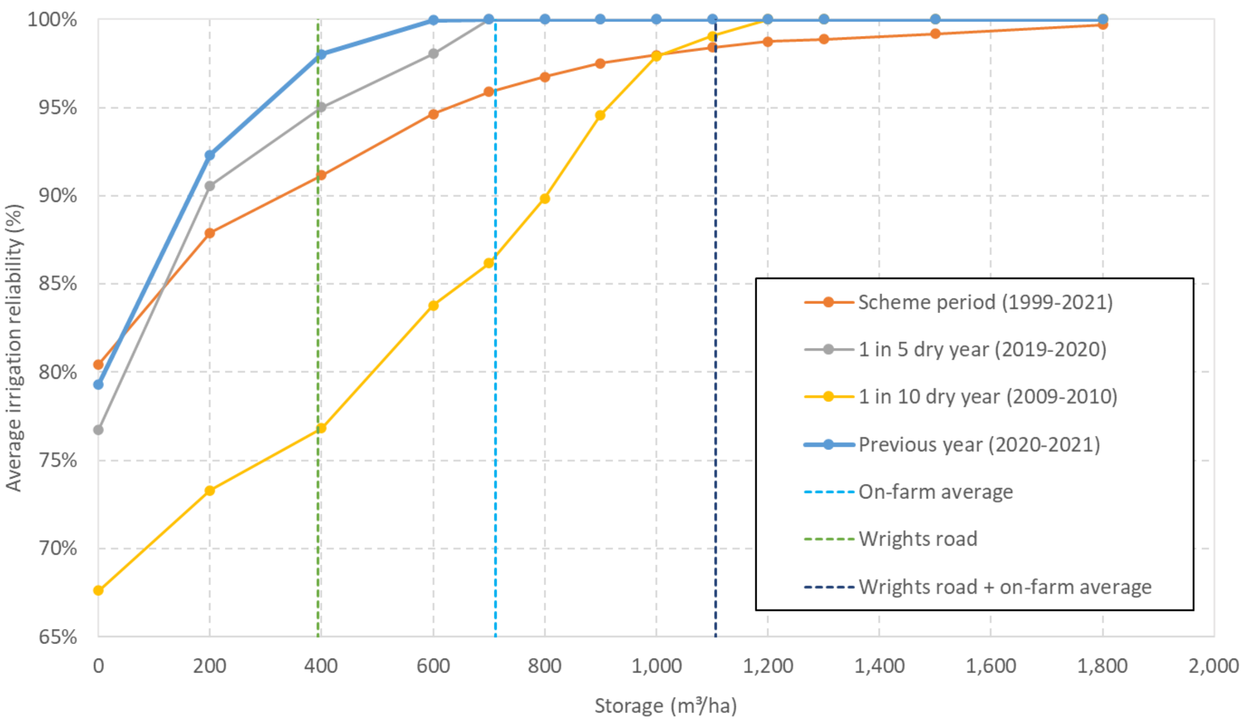

Figure 6: Modelled storage requirements to achieve different levels of irrigation reliability under an increased minimum flow scenario

In Figure 6, the dashed blue vertical line indicates the current average level of on-farm storage (710 m^3/ha) is sufficient to provide at least 95% reliability over the 1999-2021 period (solid orange line) in all but more extreme dry years such as the 2009-2010 season. This means that some of these shareholders with on-farm storage may seek to trade some (or all) of their entitlement to Wrights Road storage to those with less storage. Alternatively, if they choose to hold onto their entitlement (combined storage of approximately 1,100 m^3/ha shown by the dashed black vertical line), the results indicate they would reach approximately 98.4% reliability (1999-2021) and a similar level of reliability in the extreme dry 2009-2010 irrigation seasons. It is important to realise that the reported reliability above for farmers with on-farm storage is the **average** reliability based on the total volume of on-farm storage within the WIL scheme and the associated area irrigated from those on-farm storage ponds. However, the graph can easily be used to determine the level of reliability for individual farm storage volumes. For example, if a shareholder has an existing on-farm storage volume of 800 m^3/ha the farmer will have a reliability of around 97% over the 1999-2021 period, 100% for the most recent (2020-2021) and 1in 5 dry year (2019-2020) and around 90% in the 1 in 10 dry year.

The dashed green vertical line in Figure 6 indicates the storage entitlement WIL shareholders will receive once the reservoir is constructed (approximately 390 m^3/ha). For WIL shareholders currently without storage to reach 95% average reliability over the 1999-2021 period (indicated by WIL as an acceptable reliability threshold), the graph indicates approximately 630 m³/ha of storage would be required. This means that approximately 240 m³/ha of additional storage will be required for these farmers beyond the 390 m³/ha provided by Wrights Road. Another threshold discussed with WIL has been doubling the 390 m³/ha to 780 m³/ha. Doubling the storage volume for farmers without on-farm storage through water trading would result in a reliability of around 97% for the 1999-2021 period.

The results for the increased minimum flow scenario are presented in Figure 7 below. As expected, an increased minimum flow results in a significant reduction in reliability of supply. For example, at the average level of on-farm storage (dashed blue line, 710 m³/ha) under an increased minimum flow scenario the reliability is approximately 91% over the 1999-2021 period (solid orange line). To achieve 95% of reliability over this period around 990 m³/ha of storage is required. Under this scenario it is likely that farmers without on-farm storage have a much greater demand for stored water and farmers with on-farm storage are likely to have less water available to trade. Some shareholders with relatively large amounts of on-farm storage may still seek to trade some (or all) of their entitlement to Wrights Road storage to those with less storage.

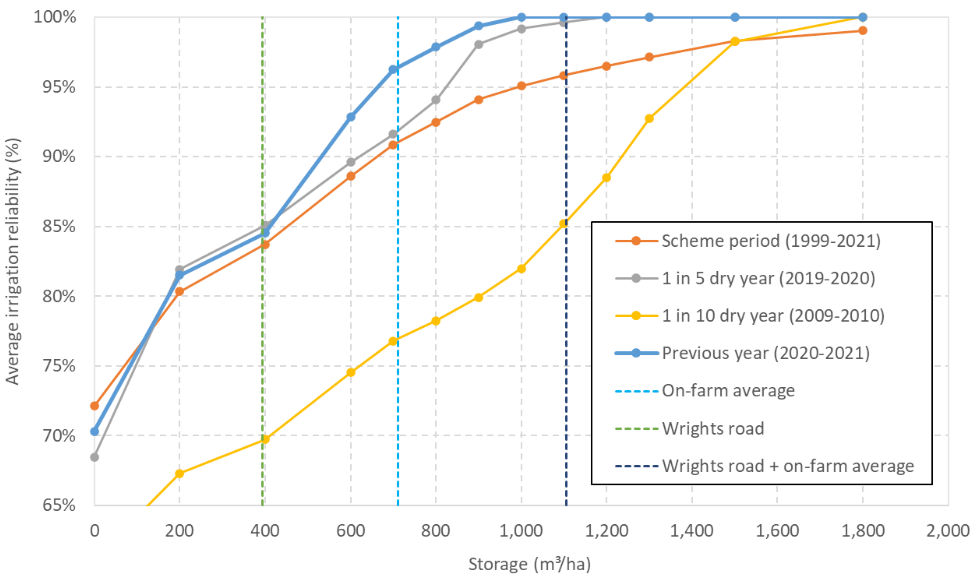

Figure 7: Modelled storage requirements to achieve different levels of irrigation reliability under an increased minimum flow scenario

Soil moisture level plots are included in Appendix B. These plots are produced for the 1 in 5 and 1 in 10 dry year based on the current and future minimum flow. The colour coding used on these graphs align with the key m³/ha storage volumes described above to demonstrate the benefit of stepped increases in storage (390 m³/ha, 630 m³/ha, 780 m³/ha and 990 m³/ha) on soil moisture levels in these two example years. The results for each individual plot are not discussed in detail here but the plots clearly demonstrate the benefit of additional storage on soil moisture levels throughout the irrigation season.

Detailed reliability outputs for two individual farms have been provided to Water Strategies to enable quantifying the change in farm economics as a result of water trading.

5.2 Demand and supply for stored water

Using the numbers in Figure 6 and Figure 7 above an indication can be provided on the likely demand and supply for trading Wrights Road stored water for the current and increased minimum flow scenario.

If all WIL shareholders currently without on-farm storage (12,800 ha) were to seek 95% reliability under the current minimum flow they will need around 630 m^3/ha. In other words, they require an additional 240 m^3/ha of storage over and above their 390 m^3/ha Wrights Road entitlement. Based on 12,800 ha of farmland without on-farm storage this equates to a total volume of approximately 3.0 Mm^3. The estimated amount of water available for trade from WIL shareholders currently with on-farm storage (8,000 ha) was estimated to be around 2.5 Mm^3. This estimate was derived from a list of on-farm storage volumes provided by Water Strategies and Ngai Tahu Farming Ltd. For farmers with on-farm storage volumes at or above 630 m^3/ha it was assumed that the full Wrights Road entitlement of 390 m^3/ha is available to trade. For farmers with less than 630 m^3/ha of on-farm storage it was assumed that the farmer wants to keep a portion of the Wrights Road entitlement to bring the reliability up to 95 % (630 m^3/ha) with the excess being available for trade. Based on the same logic the demand for water and supply of water for trading can be calculated for a range of scenarios. For example, when assuming that farmers want to achieve 97% reliability (780 m^3/ha) the demand for water is estimated to be around 5.0 Mm^3 and the supply of water is estimated at around 2.0 Mm^3. This is summarised in the table below for the two current minimum flow reliabilities (95 and 97%) as well as for 95% reliability for an increased minimum flow scenario.

Table 4: Demand and supply for stored water

Scenario	Total demand for water (Mm^3)	Available stored water (Mm^3)
Current 630 m^3/ha (95%)	3.0	2.5
Current 780 m^3/ha (97%)	5.0	2.0
Increased minimum flow 990 m^3/ha (95%)	7.7	1.2

This indicates that based on the assumptions outlined above the demand for stored water is likely to be greater than the available amount of storage. For 95% reliability under the current minimum flow there is a reasonably good balance between potential buyers and sellers of Wrights Road storage across the scheme. However, for the other two scenarios; current minimum flow 97% reliability and increased minimum flow 95% reliability, the demand for water is likely to be much greater than the supply. It is noted that the individual decisions of WIL shareholders when making decisions on buying or selling water from the Wrights Road storage pond cannot be predicted and that the calculations presented are based on a long-term average over the period 1999-2021. Demand and supply of Wrights Road storage water is likely to vary from year to year based on factors such as climate conditions, river flow, economics etc.

It is important to note the model results do not include any additional pressures on water supply or factors that may increase water demand over time beyond those described above such as climate change, Targeted Stream Augmentation (TSA) or Managed Aquifer Recharge (MAR). This means the demand for additional storage is likely to grow over time, as additional storage will be required to meet the same level of reliability modelled here.

6.0 Summary and Conclusion

Key findings of the further work undertaken for the Wrights Road Storage Pond Business Case are summarised below.

<u>Impacts on WIL Shareholders if storage is not implemented</u>

The analyses undertaken indicate that if future potential water management strategies are implemented by ECan, such as an increase in minimum flow in the Waimakariri River and required reductions in nutrient losses from farms, they will cause significant impacts on farmer operations within the WIL scheme if the Wrights Road storage is not in place. These adverse effects include:

- A significant increase in the number of days in restrictions under an increased minimum flow.

  A comparison was undertaken of the total number of days in restriction between the current minimum flow (41 m^3/s) and a future increased minimum flow scenario (50 m^3/s). The results indicate that the average number of days in restriction will increase from 46 days to 64 days per irrigation season (an increase of 18 days) for farms without on-farm storage. The average number of days in restriction for farmers with on-farm storage is estimated to almost double from 10 days to 19 days per irrigation season.

- Significantly lower soil moisture levels.

  Soil moisture plots for two example 'average' irrigation seasons indicate that during some irrigation seasons shareholders without on-farm storage can generally maintain soil moisture levels close to, or above, 50% under the current minimum flow. With a potential future increase in minimum flow soil moisture levels will be well below 50% for significant periods of time, especially in the second half of the irrigation season when river flows are generally low. In other words, not implementing Wrights Road storage results in a significant reduction in soil moisture levels under an increased minimum flow scenario.

- Greater nitrogen loss reductions beyond what is feasible (e.g. reducing stocking rates or land use change).

Proposed Plan Change 7 (PC7) to the Canterbury Land and Water Regional Plan (LWRP) requires farms to further reduce nitrogen losses over time (GMP minus 30% for may farms and potentially extending to GMP minus 90% for some farms by 1 January 2080). Managed Aquifer Recharge (MAR) and Targeted Stream Augmentation (TSA) will assist with meeting the desired water quality outcomes. However, MAR and TSA can only be implemented if water is available and water from storage (Wrights Road) allows for MAR and TSA to occur when the river is on restriction. If Wrights Road is not built farmers will either need to give up irrigation water or make nitrogen loss reductions beyond what is considered feasible without making land use changes or reducing stocking rates.

<u>Other benefits of storage</u>

The reduction in the number of days in restriction as a result of the construction of Wrights Road storage was quantified for shareholders with and without on farm storage.

Model results for shareholders without on-farm storage indicates that construction of 8.2 Mm^3 of storage at Wrights Road will result in:

- a reduction of 27 days in the average number of days in restriction (46 to 19 days) under the current minimum flow (41 m^3/s).
- a reduction of 33 days in the average number of days in restriction (64 to 31 days) under an increased minimum flow scenario (50 m^3/s).

Model results for shareholders with on-farm storage indicates that construction of 8.2 Mm^3 of storage at Wrights Road will result in:

- a reduction of 7 days in the average number of days in restriction (10 to 3 days) under the current minimum flow (41 m^3/s).
- a reduction of 10 days in the average number of days in restriction (19 to 9 days) under an increased minimum flow scenario (50 m^3/s).

In addition to a reduction in the number of days in restrictions, construction of the Wrights Road Storage Ponds provides opportunities to continue to supply water to WIL shareholders when the Brown's Rock intake currently has to shut down due to high or low river flows. The Browns Rock intake shuts down when:

- The Waimakariri River is in flood and sediment loads in the Waimakariri River are high. When this coincides with periods of high irrigation demand these flood flow cut-off periods can have significant impacts on the reliability of supply and soil moisture levels.
- When less than 20% of the maximum consented abstraction rate of 11,041 m^3/s (2.2 m^3/s) can be abstracted from the river (for operational reasons).

With Wrights Road storage in place the supply of water can be maintained at times of high river flow and we understand from WIL that the operational constraints on low flow can be lifted resulting in continued supply of water when WIL is authorised to take less than 2.2 m^3/s from the river.

<u>Water Trading</u>

Throughout the WIL scheme, there are farmers with and without on-farm storage. Shareholders with on-farm storage currently have a higher level of irrigation supply reliability and may want to trade some (or all) of the additional storage entitlement Wrights Road will provide them (approximately 390 m^3/ha). The irrigation supply-demand model was used to quantify the irrigation reliability at different levels of storage and infer how much storage, above and beyond what will be provided by Wrights Road, will be required by WIL shareholders without on-farm storage to reach a certain target level of reliability. A target level of reliability of 95% has previously been used in the business case reporting as an acceptable reliability threshold although other reliability levels have also been considered in the analyses. The supply-demand model was run with storage sizes ranging from 0 to 1,800 m^3/ha and irrigation reliabilities over the 1999-2021 period were calculated. Storage results were presented in terms of m^3/ha instead of total m^3 for easier comparison between different areas of the scheme.

The results of the modelling for the current minimum flow indicate that:

- The 390 m^3/ha of storage provided by Wrights Road is insufficient for farmers without on-farm storage to reach a target reliability of 95%.
- Around 630 m^3/ha of storage is required to reach a target reliability of around 95% for the period 1999-2021. This indicates that farmers without on-farm storage are likely to have further demand for water from storage.
- The average level of on-farm storage within the WIL scheme is 710 m^3/ha which is sufficient to provide at least 95% reliability over the 1999-2021 period. This indicates that some of the shareholders with on-farm storage may seek to trade some (or all) of their (390 m^3/ha) entitlement to Wrights Road storage to those with less storage.
- Doubling the Wrights Road storage entitlement of 390 m^3/ha to 780 m^3/ha will result in a reliability of approximately 97%.

The results of the modelling for a future increased minimum flow indicate that:

- Around 990 m^3/ha of storage is required to reach a target reliability of around 95% for the period 1999-2021. This indicates that farmers without on-farm storage under this scenario are likely to have a much greater demand for stored water compared to the current minimum flow scenario.
- The average level of on-farm storage of 710 m^3/ha is no longer sufficient to provide 95% reliability over the 1999-2021 period. This indicates that farmers with on-farm storage are likely to have less water available to trade.

Based on the results of the modelling described above an indication can be provided on the likely demand and supply for trading Wrights Road stored water for the current and increased minimum flow scenario. Using the area of WIL farms currently without on-farm storage and the individual on-farm storage volumes an estimate can be made for the total demand and available supply of stored water as shown in the Table below.

Table 5: Demand and supply for stored water

Scenario	Total demand for water (Mm^3)	Available stored water (Mm^3)
Current 630 m^3/ha (95%)	3.0	2.5
Current 780 m^3/ha (97%)	5.0	2.0
Increased minimum flow 990 m^3/ha (95%)	7.7	1.2

The results indicate that the demand for stored water is likely to be greater than the available amount of storage for the current minimum flow assuming a target reliability of 95%. The demand for water will increase further under a current minimum flow scenario assuming a target reliability of 97 % or under a scenario with an increased minimum flow. This will coincide with a decrease in the available amount of stored water.

It is noted that the individual decisions of WIL shareholders when making decisions on buying or selling water from the Wrights Road storage pond cannot be predicted and that the calculations presented are based on a long-term average over the period 1999-2021. Demand and supply of Wrights Road storage water is likely to vary from year to year based on factors such as climate conditions, river flow and economics.

The impacts of each of the scenarios that reduce or increase current reliability of supply have each been modelled or commented on as separate scenarios to demonstrate their potential impact (e.g. increase in Waimakariri River minimum flow, use of water for MAR & TSA, use of water for trading). If water is used for combinations of these activities the impact on water reliability would be modified accordingly.

7.0 References

Pattle Delamore Partners Ltd (April 2021), Wrights Road Storage Pond Business Case – Irrigation Supply and Demand Modelling.

Meredith, A. (2009). Waimakariri River B Block allocation / Plan Change. Memorandum from Adrian Meredith to Anna Veltman, Matthew McCullum – Clark.

Appendix A

Days in Restriction

NO WRIGHTS ROAD STORAGE												
	No farm storage						With on farm storage					
	Current minimum flow			Increased minimum flow			Current minimum flow			Increased minimum flow		
	Partial	Full	Total	Partial	Full	Total	Partial	Full	Total	Partial	Full	Total
1999-2000	9	4	13	28	13	41	0	0	0	0	0	0
2000-2001	13	84	97	17	95	112	6	51	57	4	64	68
2001-2002	14	4	18	23	17	40	0	0	0	0	0	0
2002-2003	10	10	20	18	17	35	0	0	0	0	0	0
2003-2004	0	2	2	0	2	2	0	0	0	0	0	0
2004-2005	18	0	18	24	12	36	0	0	0	0	0	0
2005-2006	60	27	87	45	74	119	0	0	0	8	31	39
2006-2007	13	55	68	2	76	78	3	2	5	5	20	25
2007-2008	22	92	114	25	111	136	12	36	48	13	60	73
2008-2009	18	44	62	14	59	73	0	0	0	3	6	9
2009-2010	16	56	72	21	69	90	12	25	37	14	35	49
2010-2011	12	5	17	26	18	44	0	0	0	0	0	0
2011-2012	33	13	46	33	51	84	0	0	0	2	1	3
2012-2013	11	52	63	12	61	73	10	20	30	9	28	37
2013-2014	16	17	33	18	29	47	0	0	0	3	7	10
2014-2015	23	35	58	21	54	75	4	22	26	4	36	40
2015-2016	18	5	23	35	24	59	0	0	0	0	0	0
2016-2017	6	15	21	6	29	35	0	0	0	0	0	0
2017-2018	15	6	21	17	16	33	0	0	0	1	0	1
2018-2019	24	19	43	20	40	60	0	0	0	10	8	18
2019-2020	22	40	62	18	55	73	3	3	6	7	18	25
2020-2021	26	29	55	23	46	69	0	0	0	3	8	11
Total	399	614	1013	446	968	1414	50	159	209	86	322	408
Average	18	28	46	20	44	64	2	7	10	4	15	19
Median	16	18	45	21	43	65	0	0	0	3	7	10
Min	0	0	2	0	2	2	0	0	0	0	0	0
Max	60	92	114	45	111	136	12	51	57	14	64	73
1 in 5 YR (2019-20)	22	40	62	18	55	73	3	3	6	7	18	25
1 in 10 YR (2009-10)	16	56	72	21	69	90	12	25	37	14	35	49

TABLE A1: DAYS OF RESTRICTIONS FROM 1999 TO 2021 WITHOUT WRIGHTS ROAD STORAGE

WRIGHTS ROAD STORAGE												
	No farm storage						With on farm storage					
	Current minimum flow			Increased minimum flow			Current minimum flow			Increased minimum flow		
	Partial	Full	Total	Partial	Full	Total	Partial	Full	Total	Partial	Full	Total
1999-2000	0	0	0	0	0	0	0	0	0	0	0	0
2000-2001	11	61	72	6	77	83	4	38	42	5	50	55
2001-2002	0	0	0	1	0	1	0	0	0	0	0	0
2002-2003	0	0	0	1	7	8	0	0	0	0	0	0
2003-2004	0	0	0	0	0	0	0	0	0	0	0	0
2004-2005	0	0	0	6	5	11	0	0	0	0	0	0
2005-2006	8	11	19	30	48	78	0	0	0	3	9	12
2006-2007	12	26	38	10	37	47	0	0	0	0	0	0
2007-2008	22	55	77	17	76	93	2	12	14	7	29	36
2008-2009	5	18	23	11	28	39	0	0	0	0	0	0
2009-2010	23	29	52	14	51	65	3	0	3	15	25	40
2010-2011	0	0	0	6	1	7	0	0	0	0	0	0
2011-2012	0	0	0	22	8	30	0	0	0	0	0	0
2012-2013	15	27	42	9	40	49	4	3	7	6	13	19
2013-2014	11	0	11	4	14	18	0	0	0	0	0	0
2014-2015	15	21	36	7	44	51	2	1	3	5	26	31
2015-2016	0	0	0	2	0	2	0	0	0	0	0	0
2016-2017	0	0	0	0	0	0	0	0	0	0	0	0
2017-2018	1	0	1	5	5	10	0	0	0	0	0	0
2018-2019	12	6	18	10	20	30	0	0	0	0	0	0
2019-2020	11	10	21	11	23	34	0	0	0	1	0	1
2020-2021	4	5	9	8	26	34	0	0	0	0	0	0
Total	150	269	419	180	510	690	15	54	69	42	152	194
Average	7	12	19	8	23	31	1	2	3	2	7	9
Median	5	3	10	7	17	30	0	0	0	0	0	0
Min	0	0	0	0	0	0	0	0	0	0	0	0
Max	23	61	77	30	77	93	4	38	42	15	50	55
1 in 5 YR (2019-20)	11	10	21	11	23	34	0	0	0	1	0	1
1 in 10 YR (2009-10)	23	29	52	14	51	65	3	0	3	15	25	40

TABLE A2: DAYS OF RESTRICTIONS FROM 1999 TO 2021 WITH WRIGHTS ROAD STORAGE

Appendix B

Soil Moisture Plots

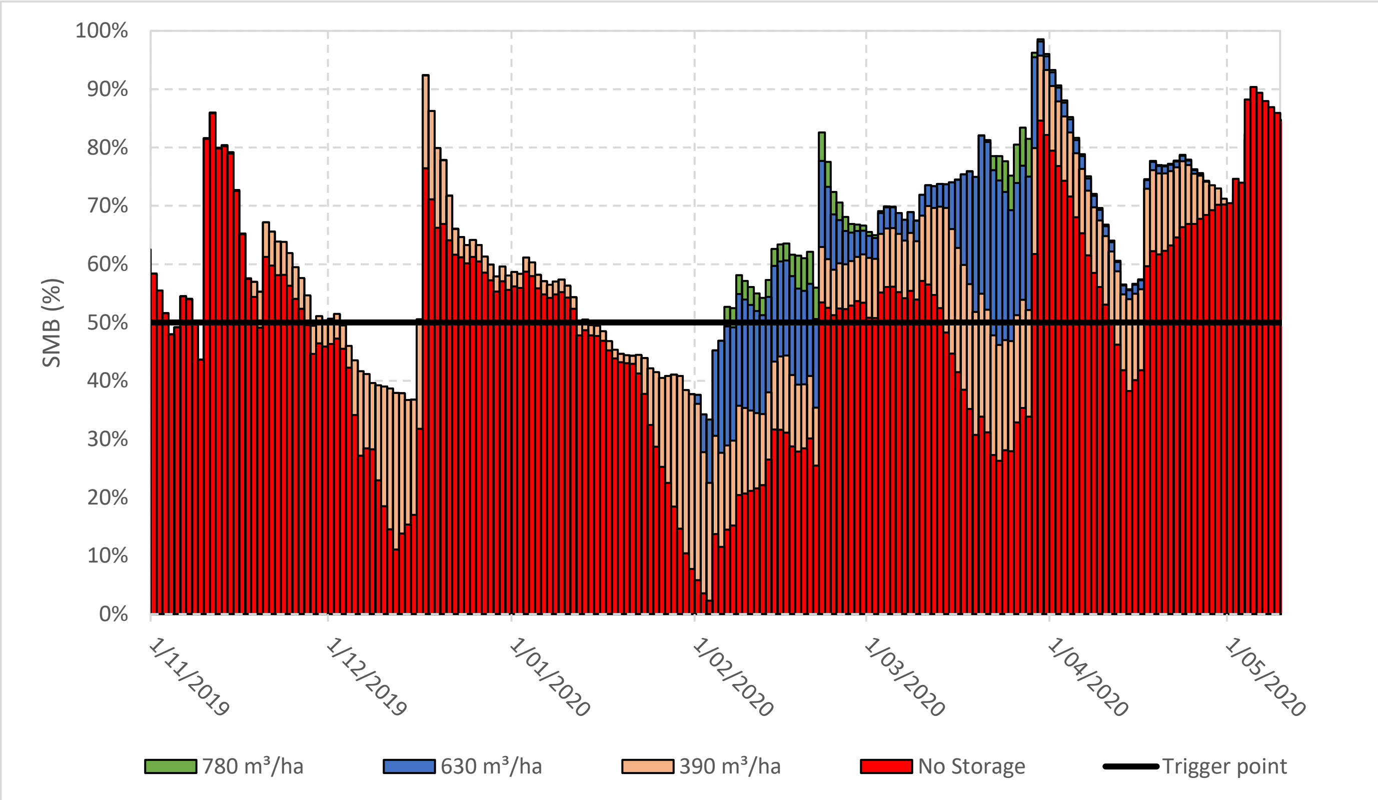

Figure B1: Benefits of water trading on soil moisture levels for a 1 in 5 dry year (2019-20) based on the current minimum flow

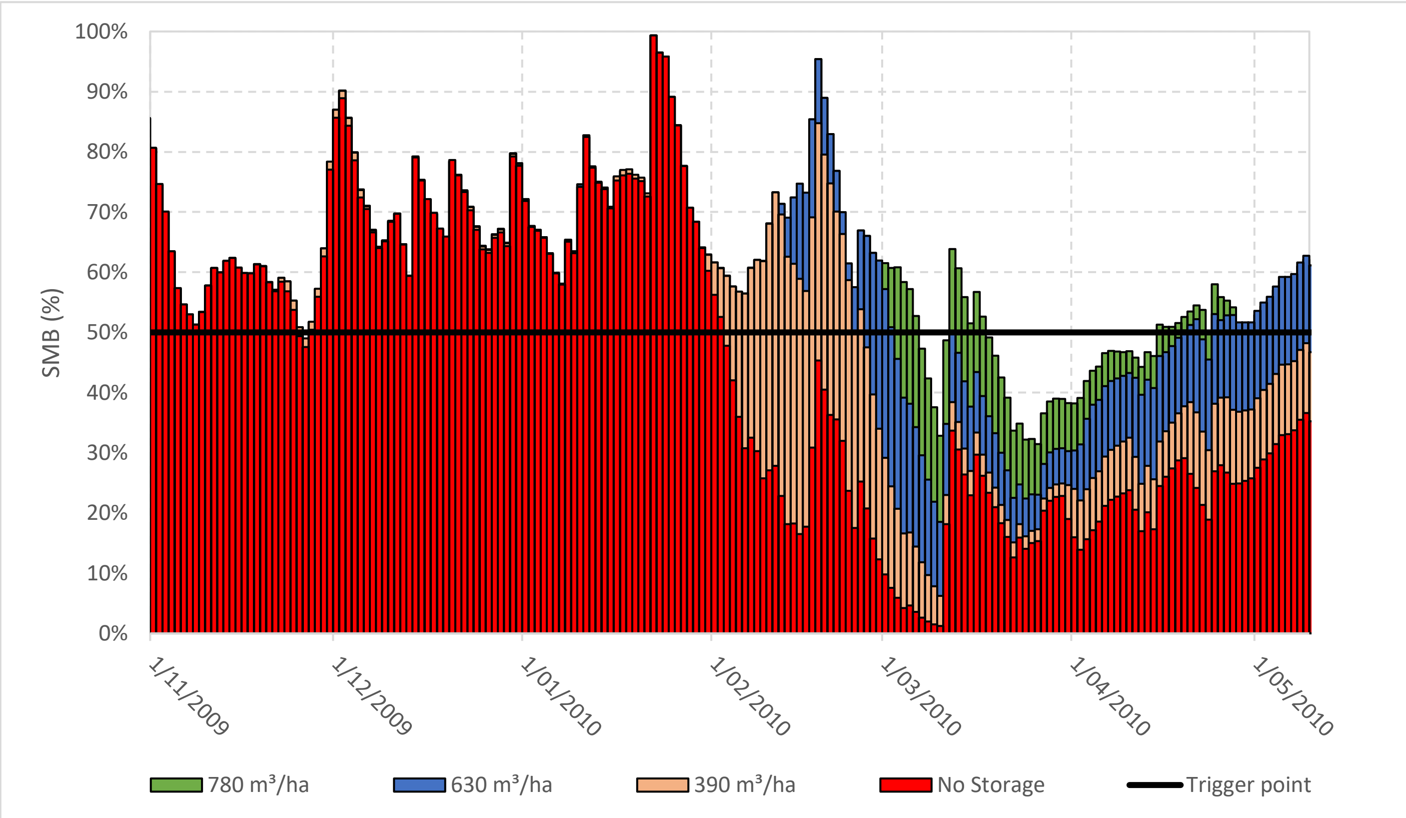

Figure B2: Benefits of water trading on soil moisture levels for a 1 in 10 dry year (2009-2010) based on the current minimum flow

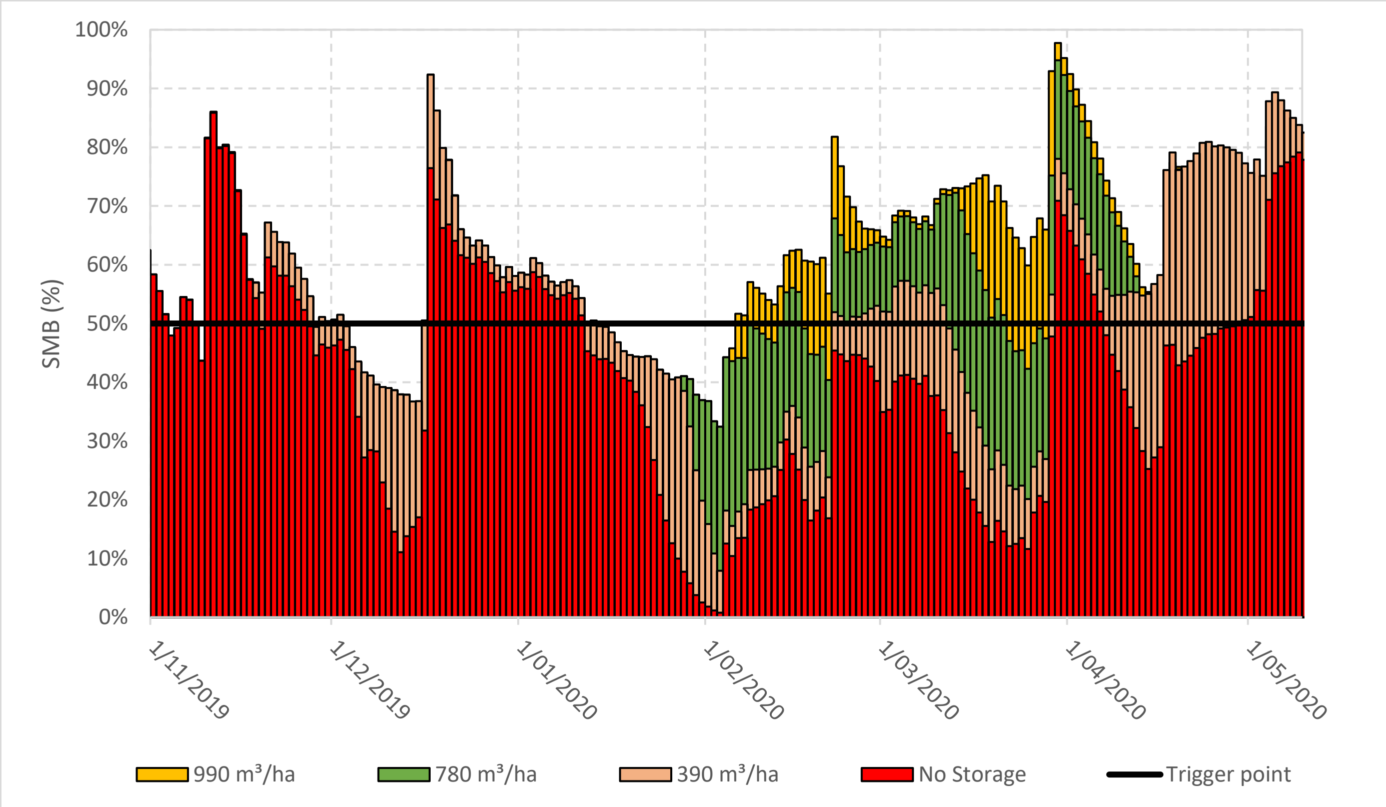

Figure B3: Benefits of water trading on soil moisture levels for a 1 in 5 dry year (2019-20) based on future increased minimum flow

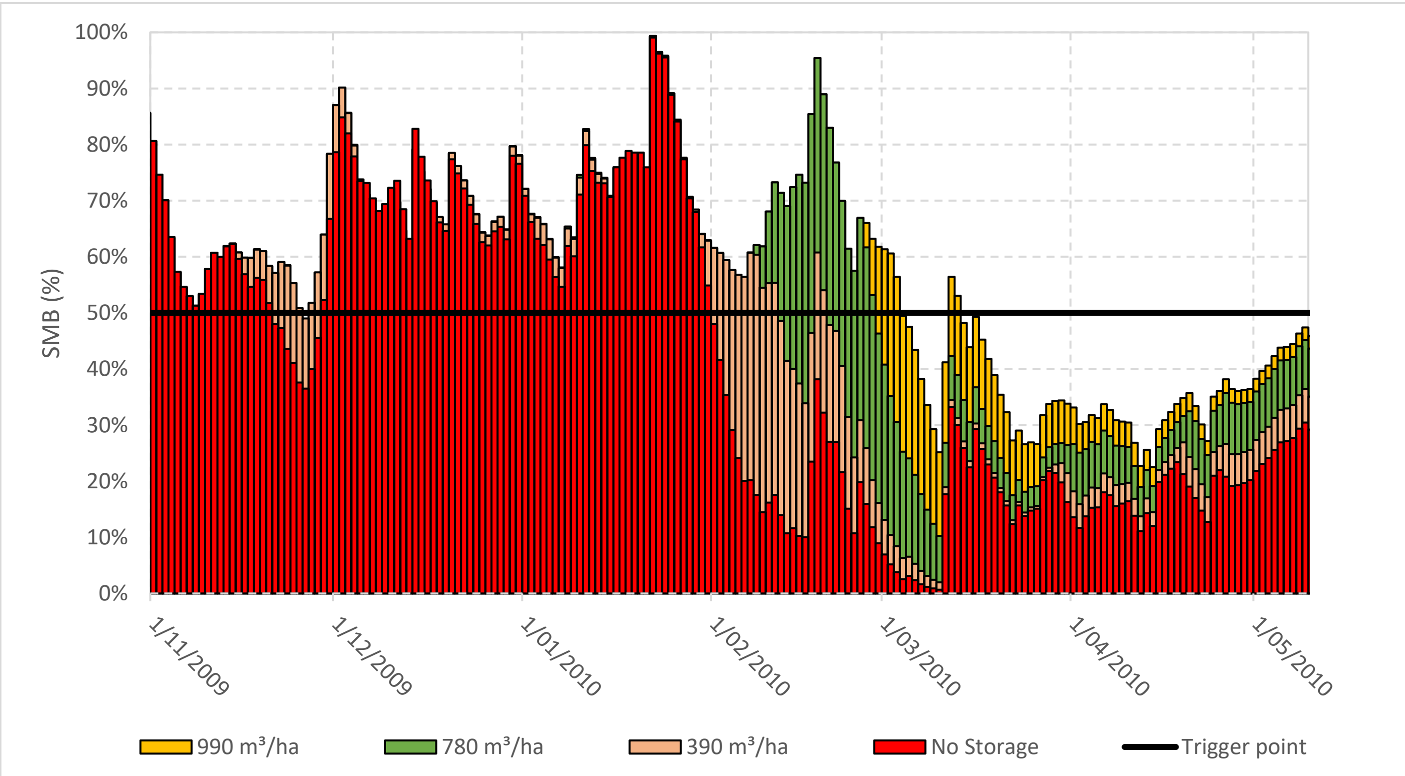

Figure B4: Benefits of water trading on soil moisture levels for a 1 in 10 dry year (2009-2010) based on future increased minimum flow