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| **IN THE MATTER OF** | the Resource Management Act 1991 |
| **AND** | |
| **IN THE MATTER OF** | Hearing Stage 14 concerned with Variations 1 and 2 of Chapter 5 and Schedules WQN8 and WQN9 of Environment Canterbury's Proposed Natural Resources Regional Plan. |

# Evidence of David Painter Related to Schedule WQN9

## A. INTRODUCTION

1. My full name is David John PAINTER. I am a Water Resources Engineer with 39 years' experience. I hold BE(Hons)(Mechanical) and PhD (Civil Engineering) degrees conferred by the University of Canterbury. I am a Fellow of the Institution of Professional Engineers New Zealand and a Member of the Royal Society of New Zealand. I am a self-employed consulting engineer trading as David Painter Consulting [DPC] Ltd.

2. I have previously been employed for 13 years as a research and extension Soil and Water Engineer at the New Zealand Agricultural Engineering Institute [now Lincoln Ventures Ltd]; for 15 years as a university academic in Natural Resources Engineering at Lincoln University; for 5 years as Associate Professor of Natural Resources Engineering at the University of Canterbury; and for 7 years as a self-employed consulting engineer.

3. I have experience and expertise in [*inter alia*] surface hydrology and irrigation water engineering and am a long-term member of the NZ Hydrological Society, the NZ Institute of Agricultural and Horticultural Science and the NZ Water and Wastes Association.

4. I acknowledge that I have read the code of conduct for expert witnesses contained in the Environment Court's Practice Note dated 31 March 2005. I have complied with it when preparing my written statement of evidence and agree to comply with it when giving oral evidence.

## B. PURPOSE OF THIS STATEMENT

5. The statement introduces and summarises a report: "A Comparative Review of Two Methods for Estimating Seasonal Irrigation Demand" ['the report']. I wrote this report following a 21 January 2009 request from Holland Beckett, Lawyers, acting

for Rangitata Diversion Race Management Limited [RDRML] and provided it to them on 18 March 2009.

6. Also on 18 March 2009, with the approval of Holland Beckett and RDRML, I provided an electronic copy of the confidential client report to: Environment Canterbury Officers, Anna Veltman and Malcolm Miller; Consultants Dr Tony Davoren, Dr John Bright and Ian McIndoe; and Irrigation New Zealand Chief Executive, Dr Terry Heiler.

7. On 1 May 2009 the report was printed and made available by Environment Canterbury, with Holland Beckett and RDRML approval, to, and at the request of, participants at the pre-Hearing meeting for this present Hearing.

8. On 21 May 2009, I was requested by the present Hearing Committee, via Environment Canterbury Officers, to present the report at this reconvened Hearing. The report now presented [CP5R-09, 21 May 2009] is identical to the 17 March 2009 version [CP5-09] except for the updated disclaimer on front pages p. ii and the omission of Appendix 9.3, the detailed brief of Work from the client.

# C. FACTS RELIED UPON

9. The report considered and compared: the methodology underlying 'Version 2' of Schedule WQN9 for Chapter 5, as proposed for Variation 2 of the Proposed Natural Resources Regional Plan [PNRRP]; and the alternative methodology put forward by Dr John Bright in evidence dated 2 November 2007 to this Hearing. These were the only versions having any 'formal' status at the time the report was being prepared. However, developments taking place during 2008 and at that time, as a result of discussions and workshops involving Environment Canterbury and proponents of the two methodologies, were also taken into account as far as possible.

### Reliance on Other Submitters and Officers

10. In addition to documents listed in an appendix to the report, I have relied in part on information requested and supplied from: Environment Canterbury Officers, Anna Veltman and Malcolm Miller; Consultant to Environment Canterbury, Dr Tony Davoren; and Aqualinc Consultant, Dr John Bright. Except as briefly noted in §28 and §29 herein, this evidence has not considered new information such as the Officers' Report for this reconvened Hearing, in preparation at the time this evidence was submitted.

## D. BRIEF SUMMARY OF REPORT AND CONCLUSIONS

11. A brief, tabular summary of the report and conclusions follows:

**D. Key Points**

i. Both methods are intended to provide estimates of seasonal irrigation demand which can be used to set standards to guide allocation and management of water resources.
ii. A method for this purpose must be reasonable, scientifically defensible and as fair as possible to all interested parties. It needs to be understandable to those who must use it, require data of reasonable availability for its use and be cost-effective to use.
iii. In line with objectives and policies in the PNRRP, 'efficient' use requires that wastage be minimized i.e. water extracted for a purpose should not be 'lost' in 'non-useful' ways. 'Reasonable' use implies that amounts used are appropriate for the purpose and not prejudicial to the rights of other actual or potential water users.
iv. There are no problems with the simple procedures involved. It is the methodologies underlying the two procedures, and the actual tabulated and mapped values obtained by each one, which differ markedly between them.
v. The Aqualinc methodology is the more robust relative to scientific defensibility and the appropriateness of data and use requirements. It can be criticised for requiring data for calibration and validation that are not widely or locally available, such as lysimeter data for arable crops.
vi. The Schedule WQN9 method more closely matches policy in the PNNRP than does the Aqualinc method but it has too many approximations, adjustments and corrections to allow confidence in the values it provides.
vii. The Aqualinc methodology is readily adaptable for use in estimating seasonal irrigation demands for different circumstances, including different statistical percentiles and different irrigation technologies and management.
viii. The Schedule WQN9 methodology is not readily adaptable for use in estimating seasonal irrigation demands for different circumstances, including different statistical percentiles and different irrigation technologies and management.

## E. SUMMARY OF THE REPORT

12. Both methods are intended to provide estimates of seasonal irrigation demand which can be used to set standards to guide allocation and management of water resources. A method for this purpose must be reasonable, scientifically defensible and as fair as possible to all interested parties. It needs to be understandable to those who must use it, require data of reasonable availability for its use and be cost-effective to use.

13. The emphasis in the report is on: scientific defensibility; appropriateness of data and use requirements; fitness for purpose; and applicability in various resource, irrigation system and management contexts.

14. In line with objectives and policies in the PNRRP, 'efficient' use requires that wastage be minimized i.e. water extracted for a purpose should not be 'lost' in 'non-useful' ways. 'Reasonable' use implies that amounts used are appropriate for the purpose and not prejudicial to the rights of other actual or potential water users.

15. The basic scientific principle invoked by both methods is "Conservation of Volume". The two methods reviewed differ in the ways they cater for Actual Evapotranspiration and Drainage [from the effective root zone] to be taken into account in model calibration and use; they also make different assumptions about Irrigation and Rainfall values used for calibration of model parameters.

**Schedule WQN9 Variation 2 and 'Aqualinc' Procedures**

16. The procedure in Schedule WQN9 Variation 2 for making use of Seasonal Irrigation Demand Standards involves 5 steps; two significant steps are to select 'Total Seasonal Demand' from Table WQN24, and 'Effective Irrigation Season Rainfall' from Figure WQN12. The alternative ['Aqualinc'] procedure for making use of Seasonal Irrigation Demand Standards involves 2 steps; a significant step is to select Seasonal Irrigation Demand Standard from a table [directly, as effective rainfall is already taken into account].

17. There are no problems with either of these simple procedures. It is the methodologies underlying the two procedures, and the actual tabulated and mapped values obtained by each one, which differ markedly between them.

**Schedule WQN9 Variation 2 Methodology**

18. Schedule WQN9 methodology derived values of "Total seasonal demand to meet plant water requirements" in Table WQN24 from 1998/99 irrigation season field measurements for soil types and crop/pasture distributed across the Canterbury Plains. Measurements of rainfall, irrigation and soil moisture were used to determine effective rainfall, effective irrigation and "freely available water, FAW", and to determine soil moisture at the beginning and end of the monitoring period.

19. Adjustments were made to AET for monitoring period difference from nominal and to effective irrigation to "allow for a uniform irrigation application efficiency of 80%". Profile Available Water, PAW, was estimated from Freely Available Water, FAW, by further adjustments. Corrections increasing 1998/1999 demand values by between 5% and 37% were made, based on a water budget model applied at the monitoring sites, to estimate 80%ile high demand values. Finally, the Table WQN24 values of Total Seasonal Demand for pasture are taken from a stepped line which 'envelopes' the calculated values in three categories of Profile Available Water. A similar, lower, stepped line is used to derive Total Seasonal Demand for crops, although justification for its position is unclear.

20. Adjustments were made to NIWA values of 1972-2003 daily rainfall on a 0.05 degree latitude/longitude grid to allow for 10% under-catching by standard raingauges and rainfall considered to be excess to Profile Available Water values because rainfall on two consecutive days was greater than 50 mm. The 6$^{th}$-lowest of the 31 ranked seasonal values at each grid point was mapped as 80%ile "effective irrigation season rainfall" contours in Figure WQN12.

21. The overall effect of the various corrections and adjustments is to introduce unknown amounts of error in relation to a complete water balance and to introduce doubts about whether the particular envelope lines do represent appropriate 80%ile total seasonal demand standards.

22. The methodology is not readily adaptable for use in estimating seasonal irrigation demands for different circumstances, including different statistical percentiles and different irrigation technologies and management.

**'Aqualinc' Methodology**

23. The Aqualinc methodology derived values of "total seasonal irrigation demand standard" equivalent to those from a combination of Table WQN24 and Figure WQN12. It is based on a daily time step water balance computer model ['Irricalc'] and validated against 1999/2000 data measured at an Environment Canterbury lysimeter site near Dunsandel. It requires Potential Evapotranspiration and Irrigation Application Uniformity as additional inputs. Actual Evapotranspiration is derived from Potential Evapotranspiration using lysimeter-calibrated Crop Factors.

24. No adjustments were required other than to 'simplify' Crop Factors to 8 values for pasture over the 12 months July to June. Crop Factors were provided only for pasture. The methodology does not require effective rainfall as an input; it is built in by the way the 80%ile Seasonal Irrigation Demand Standard is calculated.

25. Although the methodology is robust, the actual numerical values of derived Seasonal Irrigation Demand Standards suffered at the time considered for the report from having been derived from only one site and for only one 'crop' – well-watered pasture.

26. The methodology is readily adaptable for use in estimating seasonal irrigation demands for different circumstances, including different statistical percentiles and different irrigation technologies and management.

**Example Numerical Values of Seasonal Irrigation Demand Standards**

27. It has not previously been straightforward to compare example numerical values of Seasonal Irrigation Demand Standards derived using the two methodologies as the required inputs and provided outputs have been different. In addition, there have been variations and corrections since the Standards derived using the two

methodologies were first made available. Dr John Bright provided a table of values from the Aqualinc procedure for approximately 80% Application Efficiency, 80%ile reliability and PAW = 60, 80, 120 mm to a June 2008 Environment Canterbury workshop. For the report, I estimated Effective Rainfall from Figure WQN12 to allow the comparison in the following table, Table 4 from the report.

28. **Table 4: Seasonal Irrigation Demand Standards for 80% Application Efficiency and Intensive Pasture.**

| Site | PAW WQN9 | PAW Aqualinc | $R\text{-}D_R$ WQN9 | SIDS WQN9 | SIDS Aqualinc | Aqualinc % greater |
|---|---|---|---|---|---|---|
| Lincoln | < 75 | 60 | 190 | 625 | 729 | 17 |
| | 75 - 110 | 80 | 190 | 560 | 689 | 23 |
| | > 110 | 120 | 190 | 480 | 702 | 46 |
| Te Pirita | < 75 | 60 | 250 | 565 | 680 | 20 |
| | 75 - 110 | 80 | 250 | 500 | 683 | 37 |
| | > 110 | 120 | 250 | 420 | 678 | 61 |
| Hororata | < 75 | 60 | 300 | 515 | 592 | 15 |
| | 75 - 110 | 80 | 300 | 450 | 572 | 27 |
| | > 110 | 120 | 300 | 370 | 539 | 46 |

The WQN9 values of Seasonal Irrigation Demand Standard differ for the two higher Profile Available Water classes from higher values ['Version 3'] suggested at the June 2008 Environment Canterbury workshop. The higher values remain less than Aqualinc values. I understand that further comparison of values of Seasonal Irrigation Demand Standard will be provided in the Officers' Report to this reconvened Hearing.

## F. OTHER USE OF THE METHODOLOGIES

29. Passing references have been made in §13, 22 and 26 to applicability of the methodologies in circumstances other than to provide seasonal irrigation demand standards, as in Schedule WQN9, for 80%ile high irrigation demand [low effective rainfall] and 80% 'application efficiency'. This was significant under Variation 2 because there was provision under Rule WQN26 for discretionary activities for a seasonal irrigation volume which exceeded the standard to be sought when circumstances were such as to make the Schedule WQN9 standards inappropriate. The Officers' Report to this reconvened Hearing might recommend changes but it seems there would still be consideration of the use of 'other methodologies' under the recommended changes.

30. The way in which effective rainfall has been calculated in the Schedule WQN9 methodology for Figure WQN12 means that it is independent of irrigation application method and efficiency, but tied to a particular reliability [80%]. The way in which

the seasonal irrigation volumes have been calculated [before being converted to an enveloped maximum] means that a similar method could be used with ‘adjustment’ [but see §19-22] to application efficiency other than 80%.

31. The ‘Aqualinc’ methodology used to derive Seasonal Irrigation Demand Standards can be used in the same way for different irrigation management and application efficiencies. It is not dependent on having a separately specified effective rainfall, as drainage is estimated during the procedure. As part of the model outside the computation routine, application efficiency is calculated as $\frac{I - D}{I}$.

32. There needs to be equity between consent holders obtaining consents under the two different activity categories: permitted, as in Schedule WQN9; and discretionary, as under Rule WQN26. It would be undesirable to use one methodology to set scheduled standards and a different methodology [or methodologies], giving different numerical values of seasonal irrigation demand, for slightly differing circumstances.

# G. SUMMARY OF THE CONCLUSIONS

33. The report lists these conclusions to the comparative review of the two methodologies:

1. Both methods are based on forms of ‘conservation of volume’ equations which are appropriate to the purpose.
2. Both methods make use of appropriate field measurements of water balance components.
3. The two methods differ markedly in the assumptions and approximations incorporated, the computational procedures employed and the seasonal irrigation demands they arrive at.
4. The Aqualinc method has the more robust methodology relative to scientific defensibility and the appropriateness of data and use requirements.
5. The Aqualinc method can be criticised for requiring data for calibration and validation that are not widely or locally available, such as lysimeter data for arable crops.
6. The Schedule WQN9 method more closely matches policy in the PNNRP than does the Aqualinc method.
7. The Schedule WQN9 method has too many approximations, adjustments and corrections to allow confidence in the values it provides.
8. The Aqualinc method is more appropriate for use in relation to the Rangitata Diversion Race schemes.

# H. A NOTE ON EFFICIENCIES

34. The report includes a section [3.4] on 'application efficiency'. This was not directly part of the comparative review of the two methodologies, but was indirectly important as it is enshrined in Policy WQN17 (2) (b) with a specified numerical value of 80%. The section was intended as constructive criticism of references to efficiencies in Variation 2, Chapter 5 of the PNNRP.

35. Chapter 5 of the PNRRP refers to "application efficiency" in Policy WQN17 and the following "Explanation and Principal Reasons", in notes following Table WQN24 of Schedule WQN9 and in other places. It is defined in the "Definition of Terms for Chapters 4 to 8 Only" at the end of the revised Chapter 5: "**Irrigation application efficiency** is a measure of the amount of applied water that is stored in the crop root zone, as a proportion of the average depth of the water applied to the crop."

36. The alternative Aqualinc method for deriving "Total Seasonal Demand" calculates "actual" "application efficiency" and provides it as an output.

37. A complete and consistent set of volumetric efficiencies which allows for losses at various levels of any irrigation system can be based on the set developed by Painter and Carran (1978):

$$Extraction\ Efficiency = \frac{volume\ delivered\ to\ the\ reticulation\ system}{volume\ extracted\ from\ the\ supply}$$

$$Reticulation\ Efficiency = \frac{volume\ delivered\ to\ the\ application\ devices}{volume\ delivered\ to\ the\ reticulation\ system}$$

$$Application\ Efficiency = \frac{volume\ delivered\ to\ the\ application\ surface}{volume\ delivered\ to\ the\ application\ devices}$$

$$Distribution\ Pattern\ Efficiency = \frac{volume\ retained\ in\ the\ crop\ root\ zone}{volume\ delivered\ to\ the\ application\ surface}$$

38. It is important to note that the volume of water temporarily "stored" in the crop root zone is not necessarily the same as the volume "retained" in the crop root zone long enough for the crop to make use of it. This can be understood by considering the concepts of 'effective rainfall' and 'effective irrigation'.

39. If the wording in the Chapter 5 definition, as in §35, is changed to 'retained in' instead of 'stored in', then the definition is better. But that definition is then the product of the 3rd and 4th definitions in §37 [one of which is 'application efficiency'!]. It does not provide separately for losses between delivery to the application devices and delivery to the application surface [such as evaporation and windblow losses from 'Rotorainer' or centre pivot irrigators] and losses between delivery to the

application surface and retention in the crop root zone [such as losses beyond the root zone due to overwatering or inopportune rainfall].

40. The ‘application efficiency’ in McIndoe (2002), and implied in Dr John Bright’s evidence to this Hearing in November 2007, is equivalent to the “Distribution Pattern Efficiency” in §37, with the same important proviso that “stored” means “retained”. It therefore does not include any loss of water which is delivered to the application devices but does not reach the application surface, as allowed for in the ‘Application Efficiency’ of §37. In later work, Dr Bright recognised this and estimated an allowance for such losses to make his numerical ‘application efficiency’ values equivalent to those considered in Schedule WQN9.

41. The report also contains comment on ‘Irrigation System Efficiency’. This product of all four definitions in §37 includes all losses between the volume extracted from the supply and the volume retained in the root zone. With the same qualification and word change as in §38,39, the identically named definition in McIndoe (2002) is the same as that derived from the product of the four definitions in §37.

42. Policy WQN17 in Variation 2 Chapter 5 also contains a textual reference stating: “Irrigation application efficiency is to be calculated as the amount of water reaching the crop root zone as a proportion of the total amount of water taken.” This is contradictory to the definition at the end of the chapter. It is actually equivalent to the ‘Irrigation System Efficiency’ in §41. The latter efficiency is correctly defined in the definitions at the end of Chapter 5, subject to the qualification and word change as in §38,39. However, later information from Environment Canterbury Hearing Offices indicates that this definition is to be removed, “as it is not referred to”.

43. These aspects of efficiency terminology are not just semantics; there are risks of misunderstanding and miscalculation apparent in Variation 2 Chapter 5, as there was in the methodologies reviewed here. A draft of the report Section 3.4 was provided to Environment Canterbury Hearing 14 Officers on 30 January 2009.

<u>Report Erratum</u>

44. This evidence and the report refer to Bright (2008), which was inadvertently omitted from the list in the report, appearing instead in the appendix of Documents Consulted.

<u>References</u>

Bright JC (2008) Notes Prepared for Workshop on Technical methods for estimating seasonal allocations for irrigation. Environment Canterbury, 18 June.

McIndoe I (2002) Efficient and Reasonable Use of Water for Irrigation, Report U01/69, Environment Canterbury.

Painter D; Carran P (1978) What is Irrigation Efficiency?, Soil and Water 14(5):15-17, 22.

David Painter, 27 May 2009