

IN THE MATTER OF the Resource Management Act 1991
AND
IN THE MATTER OF resource consent applications to take and use
 water for irrigation in the Upper Waitaki

EVIDENCE OF DAVID J PAINTER

Qualifications and Experience

- 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 experience and expertise in [*inter alia*] surface hydrology, soil erosion by water and wind and irrigation water engineering. I 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.
- 3 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.
- 4 In the 1970s I carried out and supervised research into wind erosion of agricultural soils, funded by the National Water and Soil Conservation Authority. This involved field measurement of background and event wind erosion rates at mainly arable sites in various parts of Canterbury, evaluation of wind erosiveness for all of New Zealand, literature study of wind erosion control internationally and contact with relevant soil scientists and agricultural engineers in Australia, Europe and the United States of America.
- 5 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.

Purpose of this Statement

- 6 I have been engaged by Mackenzie Water Research Limited to provide a summary of existing information on soils and wind erosion in the Upper Waitaki Basin.

Documents Relied On

- 7 Documents referred to in this statement are listed at the end. In preparing the statement I have also considered the evidence to this Hearing of: Mr Simon Harris, for Meridian Energy; Mr Rob Potts, for Meridian Energy; Dr Matt Ryan, for Meridian Energy; and Dr David Scott. I have also briefly examined S42A Officers' Reports: 4A; 4B; 4F; and 5.

Summary of Existing Information: Soils and Wind Erosion in the Upper Waitaki Basin

Soils

- 8 This evidence will refer in places to: the Upper Waitaki Catchment, comprising the Tekapo, Pukaki, Ohau and Ahuriri/Omarama catchments above Lake Benmore; the Mackenzie Country, comprising the Tekapo and Pukaki catchments; and the Upper Waitaki Basin [henceforth 'the Basin'], the middle part of the Upper Waitaki Catchment south of Lake Tekapo, approximately north of Lake Benmore, and excluding the mountain lands. These are shown in Figure 1.
- 9 A comprehensive description of the soils of the Upper Waitaki Basin is contained in DSIR Land Resources Scientific Report No. 3 (Webb 1992). The report covers all except the mountain lands in a survey covering 155 150 hectares of the approximately 976 000 hectares of the whole Upper Waitaki catchment, above the Waitaki Dam. It not only provides a description of the soil resources, but relates the soils to geology, geomorphology, climate, vegetation and land use.
- 10 The report highlights that there were 77 500 hectares [50%] of stony soils in the survey area "which have low water-holding capacity and low productive potential." But there were also 37 000 hectares [24%] "of moderately deep and deep soils that were very suitable for more intensive development, particularly with irrigation." The remaining 40 650 hectares [26%] of soils [not specified] would have had various limitations such as impeded drainage.
- 11 The general pattern of soil occurrence in the Upper Waitaki Basin can be understood by considering variations within the Basin of: soil parent material and development; landscape elements [physiography]; and climate. The mountain bedrock parent material is mainly 'greywacke' with some 'argillite', so variation of soils in the Basin is largely due to climate and the nature and age of the deposits on landscape elements. These deposits include glacial till on moraines; river/glacier outwash on floodplains and terraces; detritus on stream fans; and

deposits re-worked from these by water and wind. In simplified geomorphic terms, the Basin has: moraines in the North and North-west; terraces and floodplains in the centre; fans on the eastern, southern and western margins and some small wetland areas (Webb 1992).

- 12 The Basin is “dry in the South and East and moist in the North and West, with hot summers and cold winters.” (Webb 1992) Snow, frost and high sunshine hours are part of the climate, but rain is the most important climatic element related to soils. [See paragraphs 15 to 26 below about wind and soil erosion.] Soil series have been separated into three rainfall regions: dry subhumid [< 550 mm p.a.] in the South-East; a small humid region [> 800 mm p.a.] in the West; and the largest region, moist subhumid, in between. These regions are marked on Figure 1. Some soil series span two regions.

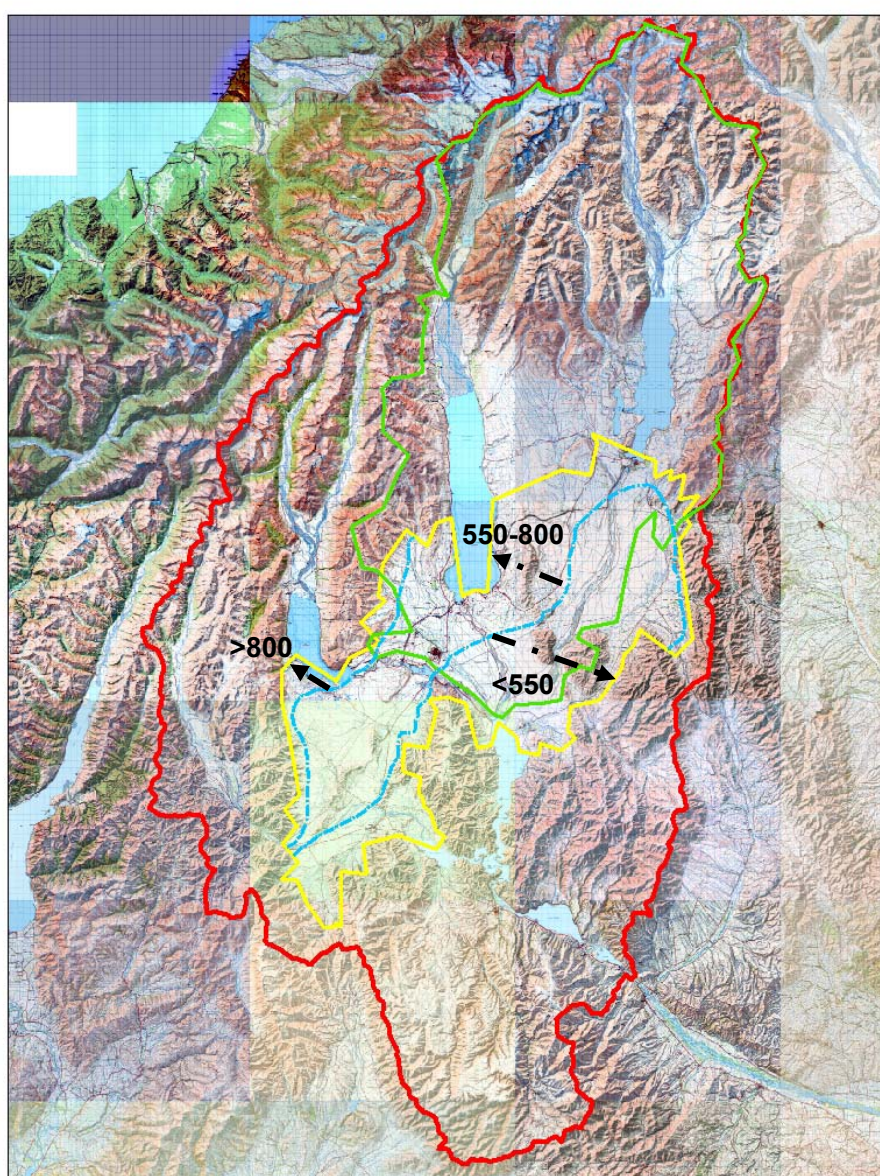


Figure 1. The Upper Waitaki Catchment **—**; the Mackenzie Country **—**; the approximate boundary of the soil survey **—**; and rainfall regions **—**.

- 13 Wind erosion and deposition of soil [loess] occurring over geologic time has been a feature of landscape development. Moraines, in particular, “are mantled with loess of variable thickness derived mainly from Godley, Tasman and Hopkins river flats.” (Webb 1992) Areas exposed to north-west winds often have little or no loess cover, as the strong winds have either not allowed soil to deposit or have removed it again. Lee slopes and areas at moraine toes can have loess up to 2 metres thick. Old river terraces and old fans often have 0.4 to 0.8 metres of loess cover, sometimes moulded into distinctive geometries by wind. Younger terraces and fans, and any areas with severe wind exposure, have little or no loess cover.
- 14 Because it is an aspect of importance in classifying soils, some soil series are clearly ‘loessial’ in nature [e.g. Grampians, Simons, Tekapo, Ohau, Pukaki, Bendhu, Cass]. In terms of texture, these soils are mainly silt loams, fine sandy loams or loamy fine sands. However, these are not the only soils in the Basin susceptible to wind erosion; other soils of similar texture, and loamy sands or sandy loams like Mackenzie and Fork on the intermediate terraces and fans, are also very susceptible when other factors allow.

Wind Erosion – General

- 15 Wind erosion of soil takes place when a sufficiently erosive wind makes contact with sufficiently erodible soil. That contact can be reduced by the vegetative cover on the soil. The soil erodibility is affected by its physical state, including the size distribution of aggregates [clods] and the soil moisture content. The location, magnitude and timing of wind erosion events is complex because of the interplay between the many factors involved in its three necessary parts: sufficient wind; insufficient cover; and high erodibility.
- 16 It is convenient to distinguish contemporary ‘event’ wind erosion, which can involve very high localised rates of erosion over hours and days, from the ‘background’ wind erosion which takes place over years and has taken place over centuries and millennia.
- 17 Surface wind ‘erosiveness’ at a particular location depends on climate wind erosiveness, estimated using data from nearby climate stations (Painter 1978a), and any local ‘speed-up’ effects due to topography. Field soil ‘erodibility’ (Chepil 1950) depends on the basic erodibility of the soil when dry [a function of the size distribution of its ‘clods’] and on surface soil water content. Then the rate of soil erosion due to wind is determined by the following seven factors: surface wind erosiveness; field soil erodibility; surface geometry and roughness [e.g. due to cultivation]; the field length in the ‘preponderant’ wind erosiveness direction; surface vegetation cover; any tall shelter effects [e.g. tree shelter belts]; or any short shelter effects [e.g. wind ‘barrier’ crops].
- 18 The adverse effects of wind erosion [i.e. excluding beneficial soil formation over geologic time] are conveniently divided into those due to soil movement along and near to the surface and those due to soil [dust] movement well above the ground.

Surface effects include:

- loss of topsoil, organic matter, nutrients [especially phosphorus], seeds and fertilisers
- deposits and water quality impacts in open drains, waterways and other surface water
- deposits on roads and farm tracks
- deposits under shelter belts and against buildings, hedges and fences
- abrasion and impact damage to plants, crops and farm infrastructure

Suspended particle effects include:

- respiratory illness effects on humans and animals
- obscuring transport visibility
- deposits on laundry on clotheslines, on painted surfaces and on animals [e.g. wool]
- deposits and water quality impacts in open drains, waterways and other surface water

Wind Erosion – Upper Waitaki Basin

- 19 Wind erosion of soil has taken place in the Upper Waitaki Basin over geologic time and is still occurring today. Since the development of the Upper Waitaki Catchment for hydro-electric purposes, with consequent increases in level variation of the three major lakes, there has been an additional source of glacial silt for wind erosion around the lake margins (Kirk 1992).
- 20 There are many references in books, technical reports, scientific journals and news publications to both background and event wind erosion in the Basin. (von Haast 1879; Hardcastle 1889; Wild 1919; O'Connor 1976; Kirk 1992; Innes 1996). Those which refer to background erosion mainly describe either deposition as loess, or degradation of the landscape in association with stock and pest grazing, tussock land depletion and surface vegetation deterioration [weed invasion and bare ground]. Those which refer to event erosion mainly describe 'dust storms' and transport visibility effects, or agricultural land erosion (Martin *et al.* 1994; Brown & Harris 2005).
- 21 Evidence to this Hearing (Painter 2009a) provides estimates of the annual losses of soil due to background and event wind erosion on susceptible areas of Simons Hill and Simons Pass Stations. Those estimates are based in part on measurements of the activity of radioactive ¹³⁷Caesium at six wind-eroded transects in the Basin compared to its activity at a site considered to be 'non-eroded' since addition of ¹³⁷Caesium to soil [from atmospheric nuclear testing] peaked in 1953 (Basher and Webb 1997). An intermediate terrace area of Simons Hill and Simons Pass Stations known as the 'Pukaki Flats' is estimated to be losing an average of

5.5 to 11.0 tonnes of soil per hectare per year. Because the areas involved are large, the soil losses are also significant: tens of thousands of tonnes of topsoil per year from the 'Pukaki Flats' areas of Simons Hill and Simons Pass Stations. [More detail in Painter (2009a,b.)

- 22 There have been no direct measurements of wind erosion soil loss in the Basin, such as have been made elsewhere in New Zealand (e.g. Basher and Painter 1997; Painter 1978b). For this reason, the indirect measurements of soil loss made in the 1990s using the radioactive ¹³⁷Caesium technique (Basher and Webb 1997) [mentioned in paragraph 21, above] are significant. An estimate of 2.2 tonnes/hectare per year has come to be "in general use" (Personal communication from Denis Fastier, Simons Hill Station). This figure was included in a Ministry for the Environment report prepared for the Waitaki Allocation Board (Brown and Harris 2005) and in other reports and evidence related to the Mackenzie Country and the Upper Waitaki Basin.
- 23 A summary of data from two Landcare Research reports and a science journal paper (Basher and Webb 1995; Basher 1996; Basher and Webb 1997) is provided here to clarify the context and appropriate consideration of data from the ¹³⁷Caesium technique results. Wind erosion depths were estimated from ¹³⁷Caesium radioisotope measurements at three "undisturbed" sites and at three "eroded" sites for the 1995 report. Estimates were made at three different "uneroded [input]" sites and at four "eroded" sites for the 1996 report. The 1997 journal paper included input site results and "eroded" site results from the three 1995 sites and three of the four 1996 sites. Sites are identified in Table 1 and Figure 2. The ¹³⁷Caesium radioisotope measurement technique allows an estimate to be made of the depth of soil lost from whatever cause; the sites selected in 1995 and 1996 made wind erosion the likely predominant cause. This depth change is deemed to have occurred over an approximate period from the peak of ¹³⁷Caesium radioisotope deposits in about 1953 until the measurement date.

Table 1. Site Identification and Location: Wind-eroded Sites

1995 Report	NZMS 260	NZMS 250	Latitude	Longitude	
T2	I38 9785 6980	BZ16 879 082	44 08.937	170 20.863	
T3	I38 9045 5950	BZ16 805 979	44 14.366	170 15.061	
T6	H38 7435 5130	BZ15 644 896	44 18.493	170 02.756	
1996 Report					
T1	I37 0144 9216	BY16 915 305	43 56.928	170 24.079	
T2	I37 9818 9177	BY16 882 301	43 57.084	170 21.634	
T3	I37 9814 9184	BY16 882 302	43 57.046	170 21.606	
T4	I37 0061 8732	BY16 906 257	43 59.528	170 23.346	
1997 Paper					
T1	Same as 1996 T1	I37 0144 9216	BY16 915 305	43 56.928	170 24.079
T2	Same as 1996 T2	I37 9818 9177	BY16 882 301	43 57.084	170 21.634
T3	Same as 1996 T4	I37 0061 8732	BY16 906 257	43 59.528	170 23.346
T4	Same as 1995 T2	I38 9785 6980	BZ16 879 082	44 08.937	170 20.863
T5	Same as 1995 T3	I38 9045 5950	BZ16 805 979	44 14.366	170 15.061
T6	Same as 1995 T6	H38 7435 5130	BZ15 644 896	44 18.493	170 02.756

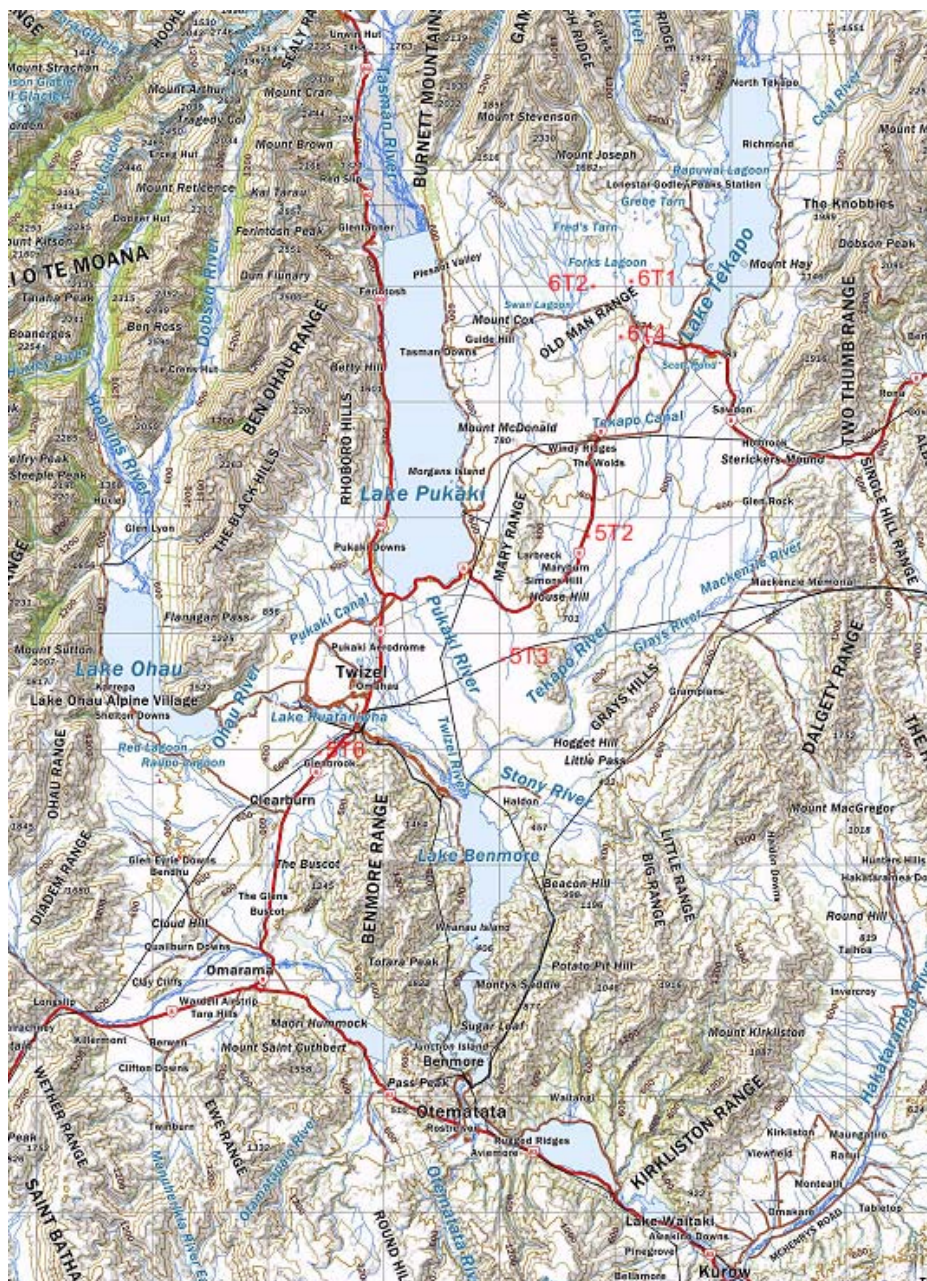


Figure 2. Upper Waitaki Basin sites of Basher *et al.* wind-eroded transects in the 1995 [5Tn] and 1996 [6Tn] reports. [6T3 is adjacent to 6T2.]

24 It is important to note the different soil types, vegetation cover, geographic locations and exposure to winds of the transects. There is no *a priori* reason to believe that the individual transect measurements, or statistical parameters derived from them, are ‘representative’ of the whole Upper Waitaki Basin. For detailed information, the original sources should be consulted. The summary in Table 2 is presented to show the variability and to highlight the context of the 2.2 tonnes/hectare per year figure which has come to be “in general use”.

Table 2. Mean Soil Losses from ¹³⁷Caesium Technique: Wind-eroded Sites

	Depth mm	Depth/year* mm/year	Mass Erosion* t/(ha yr)	Comment [this writer]
1995 Report				
All sites	33	0.8	8.0	Superseded by modified below
0-25% cover	47	1.1	11.5	Superseded by modified below
1995 Report Results Modified in 1996 Report				
All sites	16	0.4	3.9	OK
0-25% cover	21	0.5	5.1	OK
1996 Report				
All sites	9	0.2	2.2	Low due to under-sampling bare sites
All sites except T3	10	0.2	2.4	Low due to under-sampling bare sites
Bare soil	25	0.6	6.1	OK
1997 Paper				
All sites	22	0.5	5.4	Uses high 1995 and low 1996 results
Bare soil	39	1.0	9.5	Uses high 1995 and low 1996 results
1996 except T3 and Modified 1995				
All sites	13	0.3	3.2	Best estimate from best data; low due to under-sampling bare sites
0-25% cover	23	0.6	5.6	Best estimate from best data

25 Transect 3 1996 was dropped by Basher and Webb from their 1997 journal paper. Dr Les Basher's recent comment (personal communication) about the three sets of results is: "I would assume that we critically reviewed all our data in writing the 1997 paper and I'd regard this as our best estimate of erosion rates. The reality is all these erosion rates are quite low and when you consider the likely errors in converting Cs-137 to erosion rate they are probably indistinguishable." Noting the warning in paragraph 24 above, a figure could be used as 'representative' of sites similar to the measurement transects: in location, exposure to wind, surface cover and soil type. But the '2.2 tonnes/hectare per year' could be 30% [3.2] to 60% [5.4] too low for the purpose.

26 Modelling wind erosion is a complementary approach to direct measurement (Woodruff and Siddoway 1965; WEPS 2004). The seven factors listed in paragraph 17 above, or similar variants, can be used as parameters with empirically derived values in a wind erosion prediction system [whence WEPS – the best-known internationally, from the USDA Agricultural Research Service]. Preliminary values of climate wind erosiveness (Painter 1978a) for climate stations in or near the Basin have been provided in other evidence to this Hearing (Painter 2009a). Values of basic soil erodibility could be readily provided by standardised wind erosion aggregate size measurement of appropriate soil samples. Values of some of the other factors could be adapted from WEPS (2004) and of the rest by direct measurement or chosen representative values. A significant factor among the latter group is surface soil water content.

Wind Erosion and Irrigation

- 27 This Hearing is concerned with water consents for irrigation. The occurrence and magnitude of wind erosion in the Upper Waitaki Basin will potentially be reduced by increased areas of irrigated land. In other evidence to this Hearing (Painter 2009a) I present information including the potential effects of irrigation on wind erosion on Simons Hill and Simons Pass Stations. That evidence is based on a report: **Irrigation Effects on Wind Erosion: Simons Hill and Simons Pass Stations** (Painter 2009b) which discusses the interactions of irrigation and wind erosion, in general, before focussing on site-specific effects on the two Stations.
- 28 The focus of this evidence has been on 'soils' and 'wind erosion'. It should be noted that what is lost, when wind removes 'soil' from a property, is not just the structural particles of the 'soil', but material that moves with those particles. That can include: organic matter; solid fertiliser and lime; soil micro-fauna; seeds; and nutrients. In particular, some forms of phosphorus attach to soil particles and move with them. And what is 'lost' from a property can be 'deposited' downwind. For an area of the 'Pukaki Flats' forming part of Simons Hill and Simons Pass Stations, the estimated soil loss of 5.5 to 11 tonnes/hectare per year [see paragraph 21, above] could be carrying with it 2.2 to 11 kg/ha of phosphorus per year. [Based on 40-100 mg per 100 g soil (Webb 1992)]. "This is phosphorus which **is** needed in the soil for plant growth, **is** expensive to replace and is **not** needed in the Tekapo River or Lake Benmore, downwind" (Painter 2009b).
- 29 One conclusion from the report specific to Simons Hill and Simons Pass Stations (Painter 2009b) is that soil loss due to wind erosion from the areas potentially irrigated "could be substantially reduced, or eliminated." That conclusion might apply, with provisos, to much of the land potentially irrigated under the resource consents which are the subject of this Hearing.

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