Fire Technology Transfer Note
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Reducing the influence of helicopter rotor wash on fire behaviour.

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Introduction

In some instances, the fanning effect of rotor wash from helicopters involved in fire suppression can negate the impact of their drops (FTTN 11). For example, some drops at the recent Whakarewarewa fire[1] and the Mohaka fire (FTTN 11) fanned rather than knocked down flames along the fire perimeter. This was most evident when drops were made from a hover and placed inside the burning zone (FTTN 11). Fanning results from helicopter rotor wash, which is a column of air forced downward by the blade rotation. When this column nears the surface, it spreads laterally along the ground, and fans the fire sideways through unburnt fuel (Teske and Kaufman 1994, Teske *et al.* 1995).

The aim of this *Fire Technology Transfer Note* (FTTN) is to use some United States Department of Agriculture (USDA) research findings to provide guidelines on how to minimise the impact of rotor wash on fire behaviour. This can be achieved by specifying helicopter speeds and heights where only minimal rotor wash will reach the surface, thus increasing effectiveness of air attack operations. Not all helicopters cause the same amount of rotor wash, and this FTTN will allow fire managers to select machines that least influence fire behaviour.

Methods

During 1994, USDA Forest Service undertook research into helicopter rotor wash. They observed 181 passes by seven different helicopter types (Bell 205H and 206B, Blackhawk, Boeing Vertol BV-107, Chinook CH-47, Sikorsky S-61, and Skycrane) (Teske and Kaufman 1994, Teske *et al.* 1995).

Each helicopter made several passes over a row of six towers fitted with propeller anemometers. The anemometers measured both horizontal wind speed (side-wash) and vertical downwash generated during each pass. The wind speed was recorded for at least thirty seconds prior to the flyover, and until all of the anemometers appeared to return to the original speed. The average wind speed for the first thirty seconds was subtracted from the wind speed during the run. This provided the effects of the helicopter alone. All trials were conducted over flat terrain and in mostly light wind conditions (Teske and Kaufman 1994, Teske *et al.* 1995).

Rotor side-wash was strongly correlated to the flight and helicopter characteristics of ground speed, height (from the rotor), rotor span and helicopter mass which could be used to explain approximately 70% of the variation recorded during their trials (Teske *et al.* 1995). The equations are shown in Appendix 1.

Figure 1 illustrates the influence of flight characteristics on rotor side-wash for a Hughes 500D and Bell 205A. The rotor span and helicopter mass values used to derive this figure

[1] Observations were made by the lead author at the Whakarewarewa fire (27/11/97). The fire burnt more than 10 ha of native scrub and an area of mature Corsican pine (Pinus nigra var. corsica). Midday weather and FWI conditions on the day of these observations were 22 km/h wind speed, FFMC 86.5, ISI 7.9, BUI 25, and FWI 13. Drops were applied to fires spreading in scrub where flame heights were 1 m to 2 m above the scrub.

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are shown in Appendix 2. These two machines were chosen to cover the approximate range of helicopter weights and rotor spans commonly available in New Zealand. The maximum rotor wash from the Bell 205A at a height of 15 m and from a near-hover is 95 km/h, compared with only 61 km/h from the Hughes 500D. The minimum height shown in Figure 1 is 15 m because the original study only recorded rotor side-wash from 20 m or greater. We decided that extending the model much below 15 m was likely to provide erroneous predictions. Similarly, extraordinarily large values are produced when a zero ground speed is used.

The peak rotor side-wash was found to move along the ground in a gust front which spreads away from the helicopter. The duration of the gust was related to the same factors which influence side-wash strength. This is important, because not only do heavier machines with shorter rotors cause more rotor wash, their effects last longer.

To help fire managers interpret the significance of rotor side-wash, an estimate of the Initial Spread Index (ISI) (Van Wagner 1987) induced by rotor wash is shown in Figure 2 for a range of wind speeds and Fine Fuel Moisture Codes (FFMC). Figure 2 shows that wind speed or in this instance, rotor side-wash, becomes more significant as FFMC increases.

Results and discussion

The general findings of the USDA Forest Service research were that rotor side-wash (adapted from Teske *et al.* 1995):

- increases as ground speed decreases;
- increases as the height of the helicopter decreases;
- increases as helicopter mass increases; and
- increases as the rotor span decreases.

The research is the first study to quantify rotor side-wash, and it provides a valuable tool for reducing its effect on fire behaviour. Fire managers can achieve this in two ways. Firstly it is possible to estimate the rotor side-wash-induced ISI and specify flight characteristics that produce an acceptable level of downwash for different conditions and helicopters. Otherwise, fire managers can derive some general *rules-of-thumb*, where rotor side-wash will be negligible in *most* instances.

Appendix 3 is a table of the values used to derive Figure 2. From this table it is possible to estimate the rotor side-wash-induced Initial Spread Index (ISI). The necessary first step is to define a maximum acceptable rotor side-wash-induced ISI that will not fan the fire so much that it will negate the effects of a drop.

(a) (b)

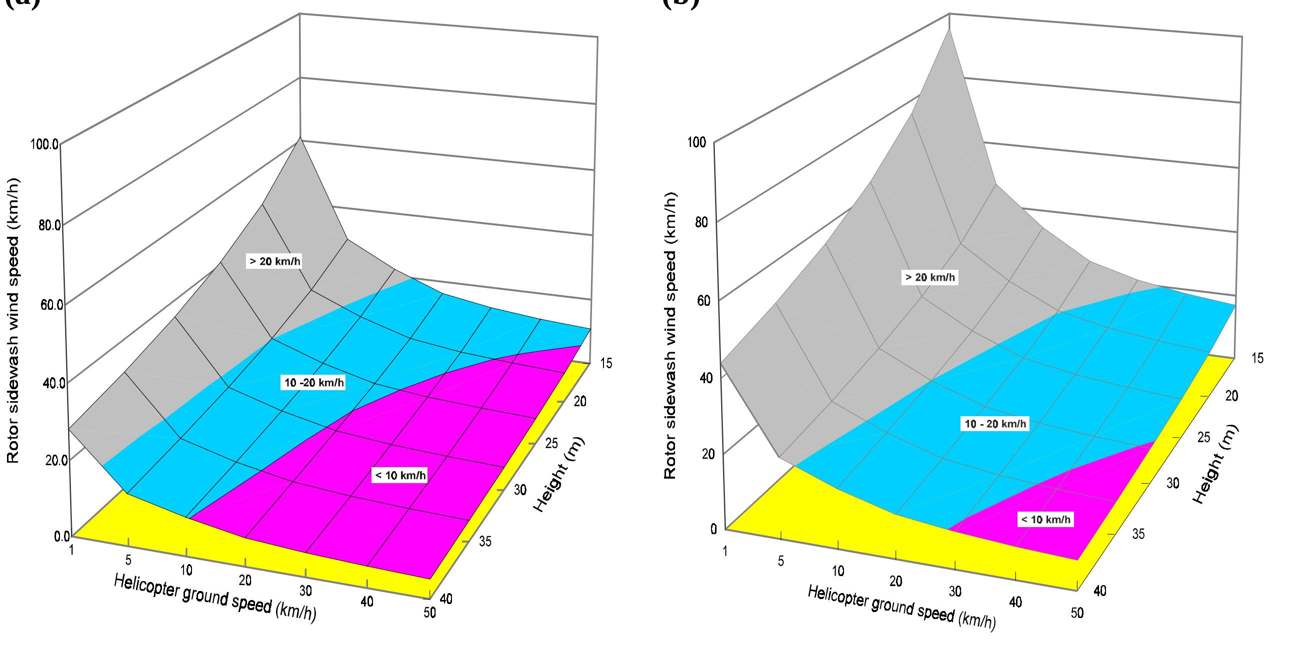

Figure 1. The influence of helicopter drop height and ground speed on rotor side-wash for (**a**) Hughes 500D and (**b**) Bell 205A.

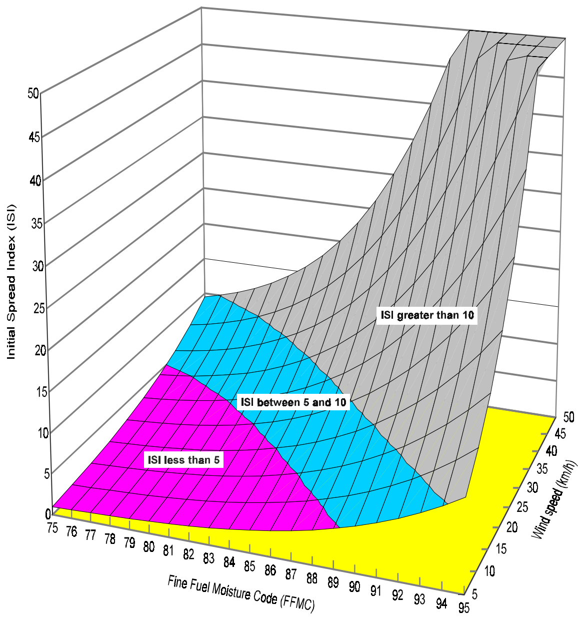

Figure 2. Influence of Fine Fuel Moisture Code (FFMC) and wind speed on Initial Spread Index (ISI).

For fires burning in open fuels, such as logging slash, pasture, gorse or tussock, that are responsive to changes in wind speed (Fogarty 1996, Rasmussen and Fogarty 1997), this may be say side-wash-induced ISI of 5 or lower. In standing forest where the canopy will buffer some of the downwash, a more appropriate side-wash-induced ISI may be 10.

The acceptable level of rotor side-wash will vary because, as Figure 2 shows:

- ISI increases as FFMC increases; and
- ISI increases as wind speed increases.

From Appendix 3, we can determine that to keep the rotor side-wash-induced ISI under 10 when the FFMC is 80, the helicopter side-wash should be less than 40 km/h, and when the FFMC is 90, it should be less than 15 km/h. If we want to keep the side-wash-induced ISI under a value of 5, the side-wash must be less than 30 km/h and 5 km/h for FFMC values of 80 and 90 respectively.

To provide an estimate of rotor side-wash, helicopter flight characteristics and rotor span have been used to produce tables for a range of helicopter weight classes (1000 - 2000 kg, 2000 - 3000 kg, 3000 - 4000 kg, 4000 - 5000 kg and 5000 - 6000 kg); these are shown in Appendices 4a to 4d. For example, if we are using a Hughes 500D[2] and we want to keep the wind speed less than 30 km/h, the drop must be carried out using a height/speed combination shown by the shaded area marked in Table 1 (which is a copy of Appendix 4a - rotor span between 8 to 9 m).

Table 1. The influence of helicopter ground speed (km/h) and rotor height (m) on rotor side-wash, for helicopters weighing between 1000 and 2000 kg with a rotor span of 8 to 9 m. The shaded area delineates the height and speed combinations that can be used to keep side-wash less than 30 km/h.

Ground	Rotor height (m)					
speed (km/h)	15	20	25	30	35	40
1	63	50	42	37	32	29
5	31	25	21	18	16	14
10	23	18	15	13	12	11
20	17	13	11	10	9	8
30	14	11	9	8	7	6
40	12	10	8	7	6	6
50	11	9	8	6	6	5

The use of Appendices 2, 3, and 4 to estimate the flight characteristics that will keep the side-wash-induced ISI below acceptable levels should provide reasonable results in most conditions. The side-wash-induced ISI values of, say, 5 for open fuels and 10 for forested fuels should provide reasonable starting levels. As with all aspects of aerial suppression in New Zealand, these need to be operationally tested and refined.

The main area for caution involves the application of this technique to scrub fires spreading in lower FFMC conditions. Even at an FFMC of 80, side wash of 30 km/h will cause vigorous fire behaviour, and speeds greater than 10 to 15 km/h are still likely to fan fire behaviour. Therefore in more heavy open fuels such as scrub, tall tussock and logging slash, the aim should be to keep the rotor side-wash-induced ISI below 5, and also keep the side-wash wind speed less than 10 km/h.

Another less precise approach is to derive some *rules-of-thumb* that can be used in most instances. These rules can be developed by determining a maximum rotor side-wash allowable for certain conditions. If we want to keep the side-wash-induced ISI below say 7.5

[2] Appendix 2 shows that a Hughes 500D has a rotor span of 8.1 m and a mass of 1361 kg.

when the FFMC is 90, then the wind speed must be less than 11 km/h (Appendix 3). To achieve this, lighter helicopters (less than 2000 kg) need to fly at a ground speed greater than 25 km/h, and drops must be delivered from a height of at least 25 m (the "25 × 25" rule). For heavier helicopters (2000 - 6000 kg), a "35 × 35" rule would achieve a similar result.

The proposed *rules-of-thumb* aim to keep the wind speed below 11 km/h and should work reasonably well in most conditions. However, they will be too conservative when the FFMC is less than 80, and when FFMC is greater than 90 excessive rotor side-wash may still occur.

At many wildfires, drops are being delivered from a near-hover (FTTN 11). This is probably necessary to overcome canopy interception which prevents drops from low volume, low drainage rate buckets from being effective. When used in forests or dense scrub fuels, these delivery systems may still be ineffective at ground speeds greater than 25 km/h.

Teske *et al.* (1995) found that side-wash moves as a gust front spreading either side of the helicopter. This information also provides some guidance on how to best place helicopter drops. In FTTN 13, we suggested that as a starting point, fire managers should follow the current New Zealand practice of flying parallel to the fireline, allowing foam drops to be placed on the leading edge of the flames, and retardants to be placed on unburnt fuel ahead of the fire. The other options discussed were placing the drop on the rear of the flame with the bucket angled over the flame or having foam drops slightly ahead of the fire. The USDA research suggests that if a drop must be delivered by helicopters flying low and slow, then they should be placed ahead of the flames so that the gust front pushes the fire away from unburnt fuels.

Conclusion

Research by the USDA Forest Service found that rotor side-wash is influenced by helicopter flight (height and speed) and physical (rotor span and mass) characteristics. The results of this research have been presented in such a way that they will allow fire managers to minimise the effects of side-wash on fire behaviour.

The most accurate way to minimise side-wash effects is to ensure that it does not surpass levels where it will negate drop impact, and then to determine desirable flight characteristics for the aircraft being used at a wildfire. The difficulty is to determine maximum acceptable levels of rotor wash because these will vary with changes in fine fuel moisture content and vegetation type. Side-wash-induced ISI values of 5 and 10 have been suggested for open and forested fuel types respectively. However, fires burning in some open fuel types (particularly scrub) are very responsive to changes in wind speed, so an upper limit of 10 km/h for side-wash has also been suggested. These thresholds need to be operationally tested and refined.

As an alternative to calculating individual flight characteristics, two general *rules-of-thumb*, have been developed for helicopters less than and greater than 2000 kg, where rotor side-wash will be negligible in *most* instances (for helicopters up to 5000 kg). If following these rules, lighter machines should fly at a height of 25 m and at a ground speed of 25 km/h (the "25 × 25" rule), whereas larger machines should follow the "35 × 35" rule. If they do nothing else, fire managers should at the very least ensure that pilots deliver drops from outside the fire perimeter and avoid drops from a near-hover.

References Cited

Fogarty, L.G. 1996. Two rural/urban interface fires in the Wellington suburb of Karori: assessment of associated burning conditions and fire control strategies. New Zealand Forest Research Institute, Rotorua, in association with the National Rural Fire Authority, Wellington. *FRI Bulletin No. 197, Forest and Rural Fire Scientific and Technical Series, Report No. 1*. 16 p.

Fogarty, L.; Robertson, K. 1997. Firebombing effectiveness - *interim* recommended foam consistencies and aerial attack guidelines. *Fire Technology Transfer Note 13* (November 1997). 6 p.

Halliday, D.; Resnick, R. 1998. Fundamentals of Physics. John Wiley & Sons, Inc., New York, United States of America. 1149 p.

Rasmussen, J.H.; Fogarty, L.G. 1997. A case study of grassland fire behaviour and suppression: The Tikokino Fire of 31 January 1991. New Zealand Forest Research Institute, Rotorua, in association with the National Rural Fire Authority, Wellington. *FRI Bulletin No. 197, Forest and Rural Fire Scientific and Technical Series, Report No. 2*. 18 p + Appendices.

Robertson, K.; Fogarty, L.; Webb, S. 1997. Firebombing effectiveness - where to from here? *Fire Technology Transfer Note 11* (April 1997). 12 p.

Teske, M.E.; Kaufman, A.E. 1994. Helicopter rotor wash effects on lateral fire spread. Continuum Dynamics Inc. Technical Note No. 94-15. Report summarising work under contract No. 53-0343-4-00009 for USDA Forest Service. 54 p.

Teske, M.E.; Kaufman, A.E.; George, C.W.; Grim, B.S.; Barry, J.W. 1995. Field measurements of helicopter rotor wash in hover and forward flight. Presented at the American Helicopter Society Northeast Region 2nd International Aeromechanics Specialists' Conference, Bridgeport, CT, pp 1-79 - 1-86.

Van Wagner, C.E. 1987. Development and structure of the Canadian Forest Fire Weather Index System. Canadian Forestry Service, Ottawa, Ontario. Forestry Technical Report 35. 37 p.

Appendix 1. Equation for estimating helicopter rotor downwash (from Teske *et al.* 1995)

Equation 1. Standardised induced surface velocity.

$$\frac{\mathbf{V}}{\mathbf{w}} = a \times \left(\frac{S^b}{w}\right) \times \left(\frac{H^c}{R}\right) \text{ ; where}$$

$\mathbf{V}$ = the maximum induced surface velocity (m/s)
w = the induced downwash velocity (m/s)
R = the helicopter rotor radius (m)
S = the helicopter ground speed[1] (m/s)
H = the rotor height[2] (m)

Equation 2. Maximum induced surface velocity.

$$\mathbf{V} = a \times S^b \times H^c \text{ ; where}$$

$\mathbf{V}$ = the maximum induced surface velocity (m/s)
S = the helicopter ground speed (m/s)
H = the rotor height (m)
a = 1.635
b = -0.442
c = -0.792

Equation 3. Induced downwash velocity (taken from actuator disk theory).

$$\mathbf{w} = \frac{1}{R} \times \left(\frac{W_n}{2 \times \Pi \times \rho}\right)^{\frac{1}{2}} \text{ ; where}$$

$\mathbf{w}$ = the induced downwash velocity (m/s)
R = the helicopter rotor radius (m)
W_n = the helicopter weight (N)
ρ = air density (approximately 1.2 kg/m^3)

Equation 4. The helicopter weight (Halliday and Resnick 1988).

$$\mathbf{W_n} = m \times g \text{ ; where}$$

$\mathbf{W_n}$ = the helicopter weight (N)
m = the helicopter mass (kg)
g = gravity (physical constant = 9.80 m/s^2)

Equation 5. The nondimensional time.

$$\mathbf{T} = 20 \text{ x } \frac{w}{R} \text{ ; where}$$

$\mathbf{T}$ = the nondimensional time
w = the induced downwash velocity (m/s)
R = the helicopter rotor radius (m)

[1] The helicopter ground speed should be in the range between 0.28 m/s (1 km/h) and 14 m/s (50 km/h).
[2] The minimum helicopter drop height should be 15 m.

Appendix 2. Helicopter characteristics.

Helicopter make/model	Mass (kg)	Rotor span (m)
Hughes 500C	1157	8.05
Bell 206 Jet Ranger III	1452	10.1
Bell 206 Jet Ranger II	1497	10.3
Hughes 500D	1361	8.1
Hughes 500E	1610	8.0
AS 350B Squirrel	1950	10.7
AS 350 BA Squirrel	2100	10.7
AS 355 F1 Squirrel	2400	10.7
MD 530F	1705	8.4
AS 350 B2 Squirrel	2250	10.7
Kawasaki BK 117	3200	11.0
AS 315B Llama	1951	11.0
Bell UH 1F	4083	14.7
Bell UH 1H	4083	14.7
Bell 205	4309	14.7

Appendix 3. Influence of different wind speeds (or rotor side-wash) and Fine Fuel Moisture Codes on the Initial Spread Index (ISI).

FFMC	Wind speed (or rotor side-wash) (km/h)									
	5	10	15	20	25	30	35	40	45	50
75	1.0	1.3	1.6	2.1	2.7	3.5	4.5	5.7	7.4	9.5
76	1.0	1.3	1.7	2.2	2.9	3.7	4.7	6.1	7.8	10.1
77	1.1	1.4	1.9	2.4	3.1	3.9	5.1	6.5	8.4	10.8
78	1.2	1.6	2.0	2.6	3.3	4.3	5.5	7.1	9.1	11.7
79	1.3	1.7	2.2	2.8	3.6	4.7	6.0	7.7	9.9	12.8
80	1.5	1.9	2.4	3.1	4.0	5.2	6.6	8.5	11.0	14.1
81	1.6	2.1	2.7	3.5	4.5	5.7	7.4	9.5	12.2	15.7
82	1.8	2.4	3.0	3.9	5.0	6.5	8.3	10.7	13.8	17.7
83	2.1	2.7	3.4	4.4	5.7	7.3	9.4	12.1	15.6	20.1
84	2.4	3.0	3.9	5.0	6.5	8.3	10.7	13.8	17.8	22.9
85	2.7	3.5	4.5	5.8	7.4	9.6	12.3	15.8	20.3	26.2
86	3.1	4.0	5.2	6.6	8.5	11.0	14.1	18.2	23.4	30.1
87	3.6	4.6	5.9	7.6	9.8	12.6	16.3	20.9	26.9	34.7
88	4.1	5.3	6.9	8.8	11.3	14.6	18.8	24.2	31.1	40.0
89	4.8	6.1	7.9	10.2	13.1	16.8	21.7	27.9	35.9	46.1
90	5.5	7.1	9.1	11.7	15.1	19.4	25.0	32.2	41.4	53.3
91	6.4	8.2	10.5	13.5	17.4	22.4	28.9	37.1	47.8	61.4
92	7.3	9.4	12.1	15.6	20.1	25.8	33.3	42.8	55.0	70.8
93	8.4	10.9	14.0	18.0	23.1	29.8	38.3	49.2	63.4	81.5
94	9.7	12.5	16.1	20.7	26.6	34.2	44.0	56.6	72.8	93.7
95	11.1	14.3	18.4	23.7	30.5	39.3	50.5	65.0	83.6	> 100.0

Appendix 4. Influence of helicopter ground speed and rotor heights on rotor side-wash.

Appendix 4a. Helicopter with mass between 1000 and 2000 kilograms.

Rotor span: **7 - 8 metres.**

Helicopter ground speed (km/h)	Rotor height (m) 15	20	25	30	35	40
1	69	55	46	40	35	32
5	34	27	23	19	17	16
10	25	20	17	14	13	11
20	18	15	12	11	9	8
30	15	12	10	9	8	7
40	13	11	9	8	7	6
50	12	10	8	7	6	6

Rotor span: **8 - 9 metres.**

Helicopter ground speed (km/h)	Rotor height (m) 15	20	25	30	35	40
1	63	50	42	37	32	29
5	31	25	21	18	16	14
10	23	18	15	13	12	11
20	17	13	11	10	9	8
30	14	11	9	8	7	6
40	12	10	8	7	6	6
50	11	9	8	6	6	5

Rotor span: **9 - 10 metres.**

Helicopter ground speed (km/h)	Rotor height (m) 15	20	25	30	35	40
1	59	47	39	34	30	27
5	29	23	19	17	15	13
10	21	17	14	12	11	10
20	16	12	10	9	8	7
30	13	10	9	8	7	6
40	12	9	8	7	6	5
50	10	8	7	6	5	5

Rotor span: **10 - 11 metres.**

Helicopter ground speed (km/h)	Rotor height (m) 15	20	25	30	35	40
1	55	44	37	32	28	25
5	27	22	18	16	14	12
10	20	16	13	12	10	9
20	15	12	10	8	8	7
30	12	10	8	7	6	6
40	11	9	7	6	6	5
50	10	8	7	6	5	5

Rotor span: **11 - 12 metres.**

Helicopter ground speed (km/h)	Rotor height (m) 15	20	25	30	35	40
1	52	41	35	30	27	24
5	26	20	17	15	13	12
10	19	15	13	11	10	9
20	14	11	9	8	7	6
30	12	9	8	7	6	5
40	10	8	7	6	5	5
50	9	7	6	5	5	4

Appendix 4. Influence of helicopter ground speed and rotor heights on rotor side-wash (continued).

Appendix 4b. Helicopter with mass between 2000 and 3000 kilograms.

Rotor span: **8 - 9 metres**.

Helicopter ground speed (km/h)	Rotor height (m)					
	15	20	25	30	35	40
1	92	73	61	53	47	42
5	45	36	30	26	23	21
10	33	26	22	19	17	15
20	24	19	16	14	12	11
30	20	16	14	12	10	9
40	18	14	12	10	9	8
50	16	13	11	9	8	7

Rotor span: **9 - 10 metres.**

Helicopter ground speed (km/h)	Rotor height (m)					
	15	20	25	30	35	40
1	85	68	57	49	44	39
5	42	33	28	24	21	19
10	31	25	21	18	16	14
20	23	18	15	13	12	10
30	19	15	13	11	10	9
40	17	13	11	10	9	8
50	15	12	10	9	8	7

Rotor span: **10 - 11 metres.**

Helicopter ground speed (km/h)	Rotor height (m)					
	15	20	25	30	35	40
1	80	64	53	46	41	37
5	39	31	26	23	20	18
10	29	23	19	17	15	13
20	21	17	14	12	11	10
30	18	14	12	10	9	8
40	16	12	10	9	8	7
50	14	11	9	8	7	7

Rotor span: **11 - 12 metres.**

Helicopter ground speed (km/h)	Rotor height (m)					
	15	20	25	30	35	40
1	75	60	50	43	38	35
5	37	29	25	21	19	17
10	27	22	18	16	14	13
20	20	16	13	12	10	9
30	17	13	11	10	9	8
40	15	12	10	9	8	7
50	13	11	9	8	7	6

Rotor span: **12 - 13 metres.**

Helicopter ground speed (km/h)	Rotor height (m)					
	15	20	25	30	35	40
1	71	57	48	41	36	33
5	35	28	23	20	18	16
10	26	21	17	15	13	12
20	19	15	13	11	10	9
30	16	13	11	9	8	7
40	14	11	9	8	7	6
50	13	10	8	7	6	6

Appendix 4. Influence of helicopter ground speed and rotor heights on rotor side-wash (continued).

Appendix 4c. Helicopter with mass between 3000 and 4000 kilograms.

Rotor span: **10 - 11 metres.**

Helicopter ground speed (km/h)	Rotor height (m) 15	20	25	30	35	40
1	102	81	68	59	52	47
5	50	40	33	29	26	23
10	37	29	25	21	19	17
20	27	22	18	16	14	12
30	23	18	15	13	12	10
40	20	16	13	12	10	9
50	18	14	12	10	9	8

Rotor span: **11 - 12 metres.**

Helicopter ground speed (km/h)	Rotor height (m) 15	20	25	30	35	40
1	96	76	64	55	49	44
5	47	38	31	27	24	22
10	35	28	23	20	18	16
20	26	20	17	15	13	12
30	21	17	14	12	11	10
40	19	15	13	11	10	9
50	17	14	11	10	9	8

Rotor span: **12 - 13 metres.**

Helicopter ground speed (km/h)	Rotor height (m) 15	20	25	30	35	40
1	91	72	61	52	46	42
5	45	36	30	26	23	21
10	33	26	22	19	17	15
20	24	19	16	14	12	11
30	20	16	13	12	10	9
40	18	14	12	10	9	8
50	16	13	11	9	8	7

Rotor span: **13 - 14 metres.**

Helicopter ground speed (km/h)	Rotor height (m) 15	20	25	30	35	40
1	86	69	58	50	44	40
5	42	34	28	25	22	20
10	31	25	21	18	16	14
20	23	18	15	13	12	11
30	19	15	13	11	10	9
40	17	13	11	10	9	8
50	15	12	10	9	8	7

Rotor span: **14 - 15 metres.**

Helicopter ground speed (km/h)	Rotor height (m) 15	20	25	30	35	40
1	83	66	55	48	42	38
5	41	32	27	23	21	19
10	30	24	20	17	15	14
20	22	17	15	13	11	10
30	18	15	12	11	9	8
40	16	13	11	9	8	7
50	15	12	10	8	7	7

Appendix 4. Influence of helicopter ground speed and rotor heights on rotor side-wash (continued).

Appendix 4d. Helicopter with mass between 4000 and 5000 kilograms.

Rotor span: **11 - 12 metres.**

Helicopter ground speed (km/h)	Rotor height (m) 15	20	25	30	35	40
1	115	92	77	66	59	53
5	56	45	38	33	29	26
10	42	33	28	24	21	19
20	31	24	20	18	16	14
30	26	20	17	15	13	12
40	23	18	15	13	12	10
50	20	16	14	12	10	9

Rotor span: **12 - 13 metres.**

Helicopter ground speed (km/h)	Rotor height (m) 15	20	25	30	35	40
1	109	87	73	63	56	50
5	53	43	36	31	27	25
10	39	31	26	23	20	18
20	29	23	19	17	15	13
30	24	19	16	14	12	11
40	21	17	14	12	11	10
50	19	15	13	11	10	9

Rotor span: **13 - 14 metres.**

Helicopter ground speed (km/h)	Rotor height (m) 15	20	25	30	35	40
1	104	82	69	60	53	48
5	51	41	34	29	26	23
10	37	30	25	22	19	17
20	28	22	18	16	14	13
30	23	18	15	13	12	11
40	20	16	14	12	10	9
50	18	15	12	11	9	8

Rotor span: **14 - 15 metres.**

Helicopter ground speed (km/h)	Rotor height (m) 15	20	25	30	35	40
1	99	79	66	57	51	45
5	49	39	32	28	25	22
10	36	28	24	21	18	16
20	26	21	18	15	13	12
30	22	18	15	13	11	10
40	19	15	13	11	10	9
50	18	14	12	10	9	8

Rotor span: **15 - 16** metres.

Helicopter ground speed (km/h)	Rotor height (m) 15	20	25	30	35	40
1	95	75	63	55	48	44
5	46	37	31	27	24	21
10	34	27	23	20	17	16
20	25	20	17	15	13	12
30	21	17	14	12	11	10
40	19	15	12	11	9	9
50	17	13	11	10	9	8

Appendix 4. Influence of helicopter ground speed and rotor heights on rotor side-wash (continued).

Appendix 4e. Helicopter with mass between 5000 and 6000 kilograms.

Rotor span: **12 - 13 metres.**

Helicopter ground speed (km/h)	Rotor height (m)					
	15	20	25	30	35	40
1	126	100	84	73	64	58
5	62	49	41	36	32	28
10	45	36	30	26	23	21
20	33	27	22	19	17	15
30	28	22	19	16	14	13
40	25	20	16	14	13	11
50	22	18	15	13	11	10

Rotor span: **13 - 14 metres.**

Helicopter ground speed (km/h)	Rotor height (m)					
	15	20	25	30	35	40
1	120	95	80	69	61	55
5	59	47	39	34	30	27
10	43	34	29	25	22	20
20	32	25	21	18	16	15
30	27	21	18	15	14	12
40	23	19	16	14	12	11
50	21	17	14	12	11	10

Rotor span: **14 - 15 metres.**

Helicopter ground speed (km/h)	Rotor height (m)					
	15	20	25	30	35	40
1	114	91	76	66	58	53
5	56	45	37	32	29	26
10	41	33	28	24	21	19
20	30	24	20	18	16	14
30	25	20	17	15	13	12
40	22	18	15	13	11	10
50	20	16	14	12	10	9

Rotor span: **15 - 16 metres.**

Helicopter ground speed (km/h)	Rotor height (m)					
	15	20	25	30	35	40
1	109	87	73	63	56	50
5	54	43	36	31	27	25
10	40	31	26	23	20	18
20	29	23	19	17	15	13
30	24	19	16	14	12	11
40	21	17	14	12	11	10
50	19	15	13	11	10	9

Rotor span: **16 - 17 metres.**

Helicopter ground speed (km/h)	Rotor height (m)					
	15	20	25	30	35	40
1	105	84	70	61	54	48
5	52	41	34	30	26	24
10	38	30	25	22	19	17
20	28	22	19	16	14	13
30	23	19	16	13	12	11
40	21	16	14	12	11	9
50	19	15	12	11	10	9