APPENDICES

APPENDIX 1.0. Symbols Used to Describe Aircraft and Watercraft Events.

*	Late reading.
^	Helicopter (by itself it means that a helicopter has come into view, otherwise it is used in combination with other symbols).
#	Seaplane (by itself it means that a seaplane has come into view, otherwise it is used in combination with other symbols).
$	Unspecified light aircraft (by itself it means that an unspecified light aircraft has come into view, otherwise it is used in combination with other symbols).
+	Watercraft (by itself it means that a watercraft has come into view, otherwise it is used in combination with other symbols).
~	Directly in front (therefore out to sea).
~~	Directly behind.
@	Directly overhead.
!	Almost overhead.
{	Entered setting.
}	Exited setting.
>	Disappeared from view.
%	Seaplane taxing.
/	Landing.
"	Take-off.
=	Wind gust.
;	People sounds.
( )	Occurred between the ten second readings.

APPENDIX 2.0. Survey Proforma

Background Sound Levels

Date: Site (2,3,4 or 5): Data collectors names: Weather:

Time	Decibel level (A-weighted / fast)	Notable Source *	Time	Decibel level (A-weighted / fast)	Notable Source
8.00			12.45		
8.15			1.00		
8.30			1.15		
8.45			1.30		
9.00			1.45	BREAK	
9.15			2.00		
9.30			2.15		
9.45			2.30		
10.00			2.45		
10.15	BREAK		3.00		
10.30			3.15		
10.45			3.30		
11.00			3.45		
11.15			4.00		
11.30			4.15		
11.45			4.30		
12.00			4.45		
12.15			5.00		
12.30			* E.g. notable source = Power boat ~ 100m off shore, bird, wind, human …		

Aircraft events.

Date: Site (2,3,4 or 5): Data collectors names: Weather Conditions:

#	Start Time (hr:min:sec)	Decibel (A-weighed / Fast) recordings every 10 seconds plus maximum.	Finish Time (hr:min:sec)	Event occurred within own zone (yes/no)	# of landing zones away from monitoring point aircraft landed (to L or R) (e.g. 2 L)	Notes: • Type of aircraft (helicopter, seaplane…); • Flyover (F), flyover and landing (FL)...

Significant Watercraft Events.

Date: Site (2,3,4 or 5): Data collectors names: Weather Conditions:

#	Start Time (hr:min:sec)	Decibel (A-weighted / fast) recordings every 10 seconds plus maximum	Finish Time (hr:min:sec)	Event occurred within own zone (yes / no)	Notes: Notable Source (e.g. Power boat ~ 100m off shore)

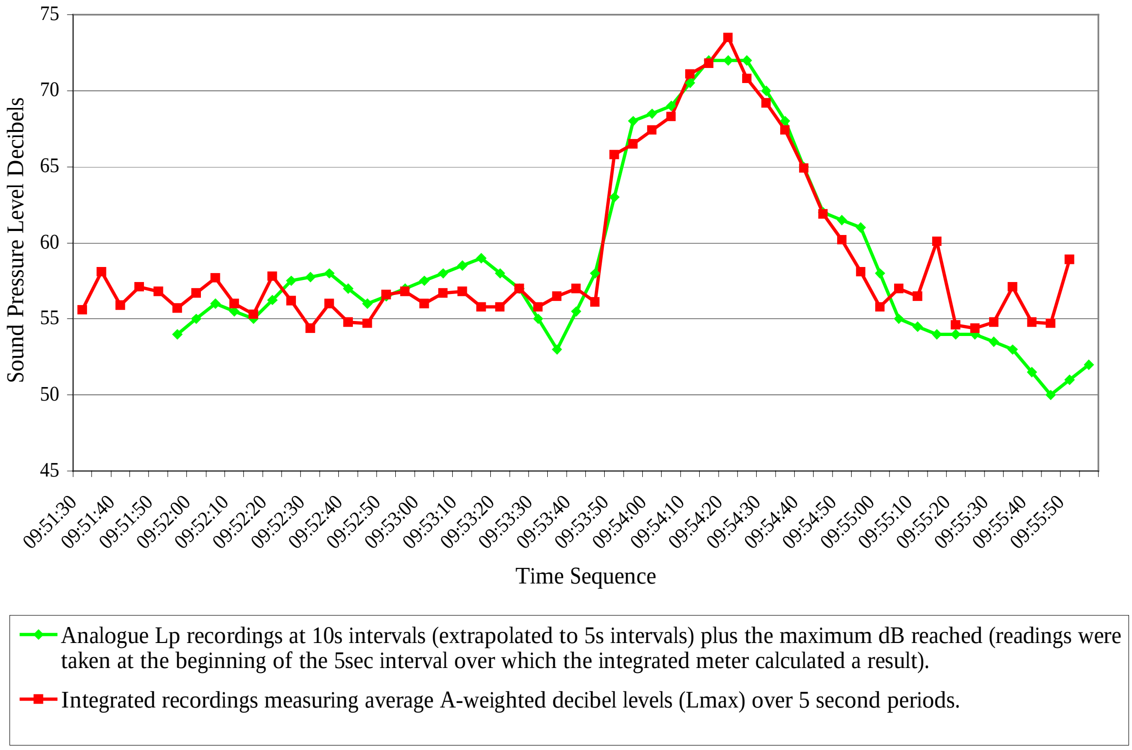
Temperature, Humidity, Wind Speed and Direction.

Date: Site: Data Recorder(s):

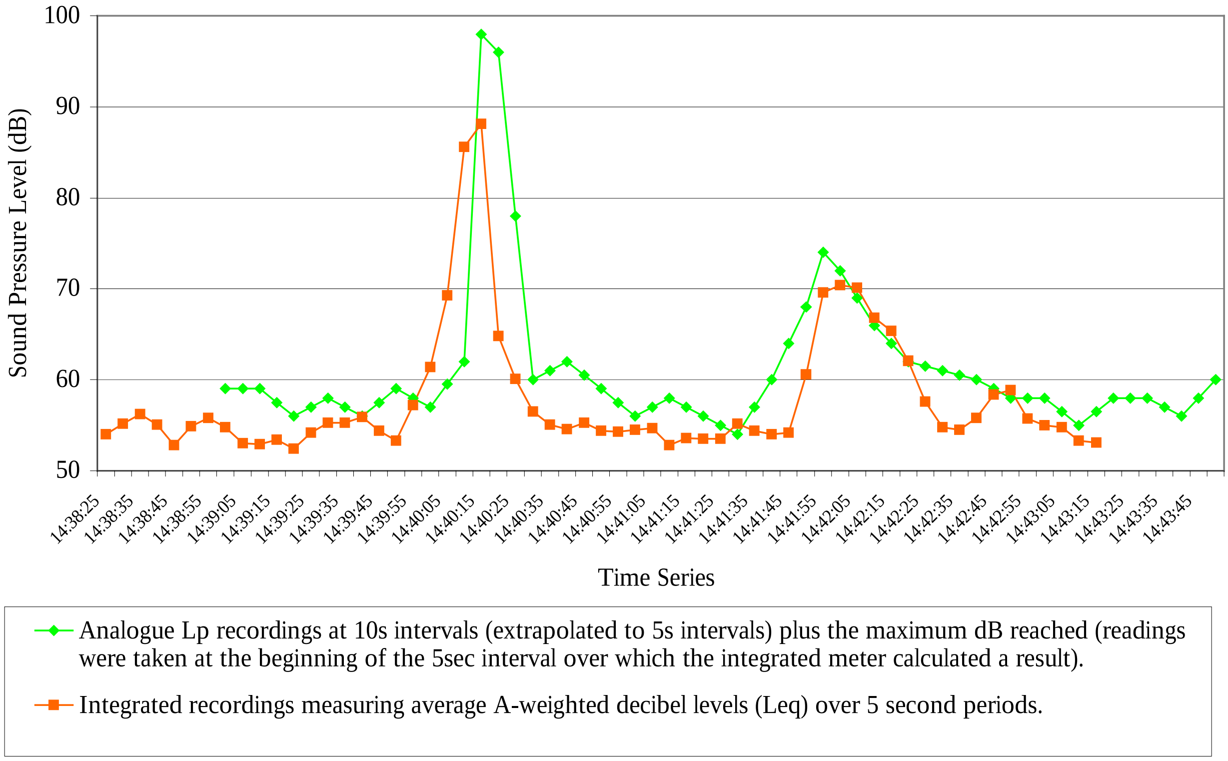
	WIND DATA			TEMP DATA	HUMIDITY DATA
START TIME	DURATION	FEET	DIRECTION	TEMP (^{o}C)	HUMIDITY (%)

APPENDIX 3.0. Instrumentation.

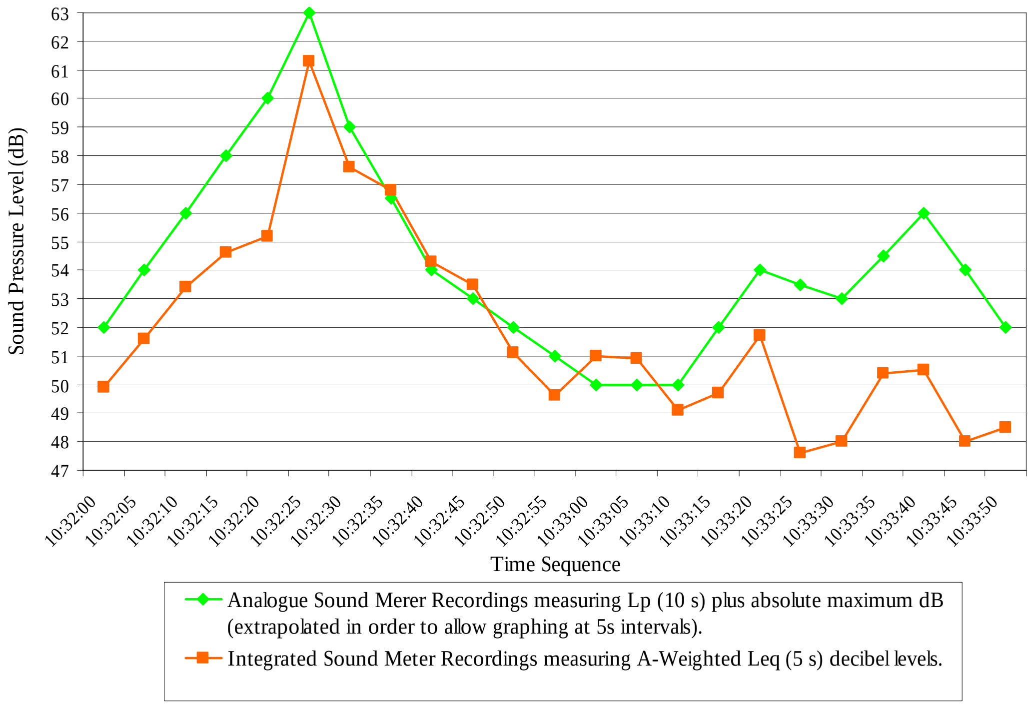
In this appendix a comparison is made between recordings made with an analogue sound meter and those made with the digital integrated type 2 sound meter for three aircraft events. The purpose being to help establish the accuracy of the analogue meters and the differences between the recording methods. The integrated meter recorded sound continuously and stored Lmax (calculated over 5 second periods) or Leq (calculated over 5 second periods) readings. Analogue meters measured Lp sound levels at ten second intervals. They also recorded the absolute maximum sound level reached during an aircraft event. Analogue recordings were extrapolated to allow plotting at 5 second intervals. Analogue meter Lp readings were taken at the beginning of every 2nd 5 second interval for which a recording was made with the integrated meter. Subsequently, the two types of recordings plotted together do not actually correlate in time precisely as is suggested by the graphs, and nor are they measuring exactly the same sound variable. Nevertheless, in all graphs, the variables plotted show similar trends.



Appendix 3.1. Comparison between analogue (measuring Lp) and integrated (measuring Lmax) sound meter recordings of aircraft event 146 at site 3.



Appendix 3.2. Comparison between analogue (measuring Lp) and integrated (measuring Leq) sound meter recordings of aircraft events 169 and 170 at site 3.



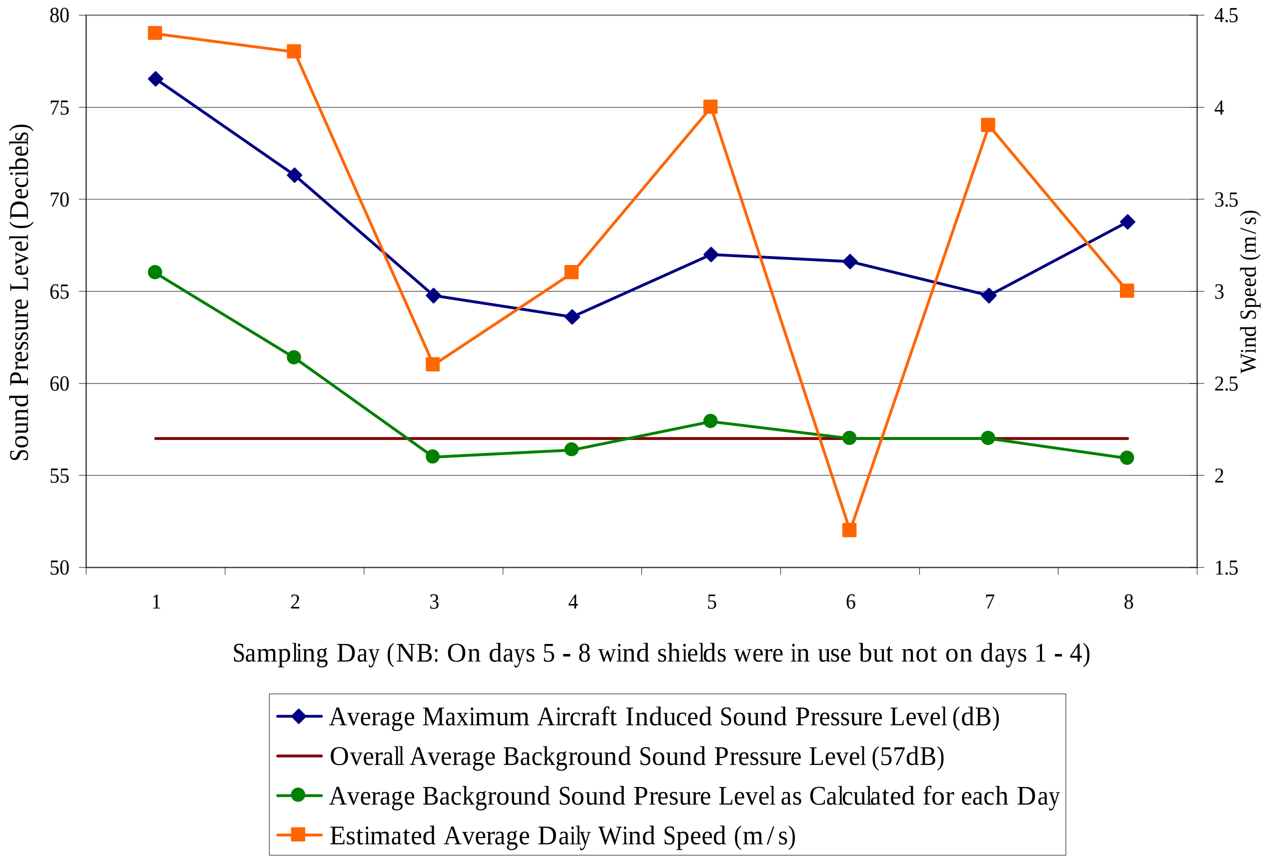
Appendix 3.3. Comparison between analogue (measuring Lp and absolute maximum) and integrated (measuring Leq) sound meter recordings at site 3 of a helicopter flyover and landing (event 181).

In appendix 3.1 both the trend of change and the peak decibel level reached by the two instruments are closely correlated. In appendix 3.2 the most notable difference between the curves is that the maximum peak reached by the analogue meter was not matched by the integrated meter suggesting that the sound level of 98dBA was maintained for an extremely short interval, resulting in an average over 5 seconds of

88.1dBA. In appendix 3.3 both the trend of change and the peak decibel level reached by the two instruments are well correlated.

Based on the assumption that the type 2 integrated sound meter used was a more accurate instrument than the analogue sound meters used, this data supports the use of Techcessories analogue sound meters for obtaining indicative results of sound levels at higher decibel levels (above 50dBA). However this analysis is complicated by the fact that the integrated meter used to give comparative and theoretically more accurate readings was itself well past its re-calibration date and when tested shown to be reading 1.8dBA lower than it should have been.

APPENDIX 4.0. Environmental Conditions.



Appendix 4.1. Relationship between wind speed and sound levels.

	Correlation Coefficients	
	Without windshields (days 1 - 4)	With windshields (days 5 - 8)
Wind Speed and Ave Max dB	0.91	-0.27
Wind Speed and Ave B/g dB	0.92	0.36

With d.f. = 2, results from days 1 - 4 are significant at $0.05 < p < 0.1$.
With d.f. = 2, results from days 5 - 8 are not significant ($p > 0.1$).

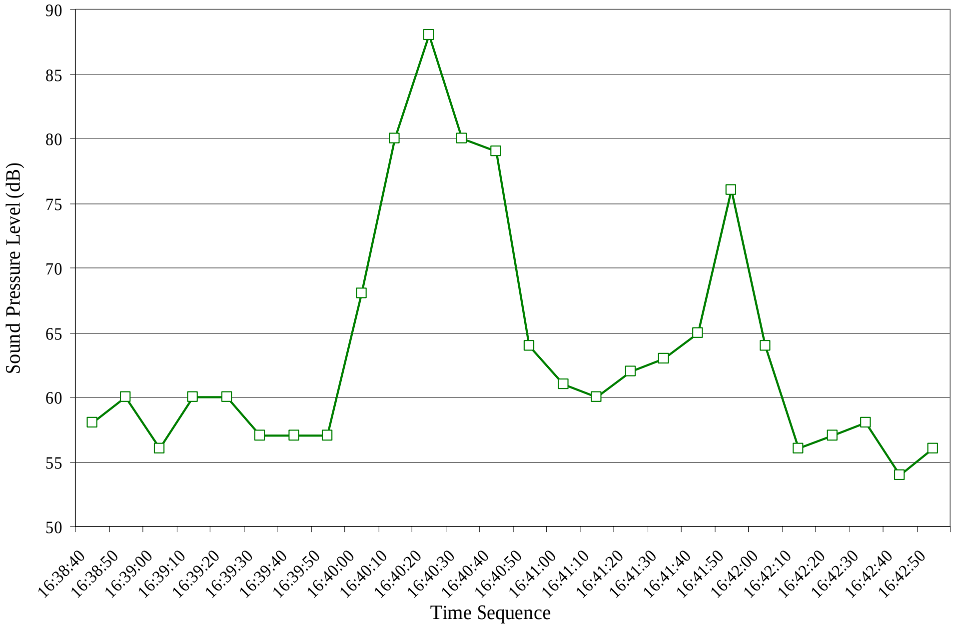
Appendix 4.2. Correlation coefficients between wind speed and sound levels. Assumes a normal distribution of x and y and a linear relationship between x and y.

Sampling Day	Average Daily Temperature (°C)	Average Daily Humidity (%)

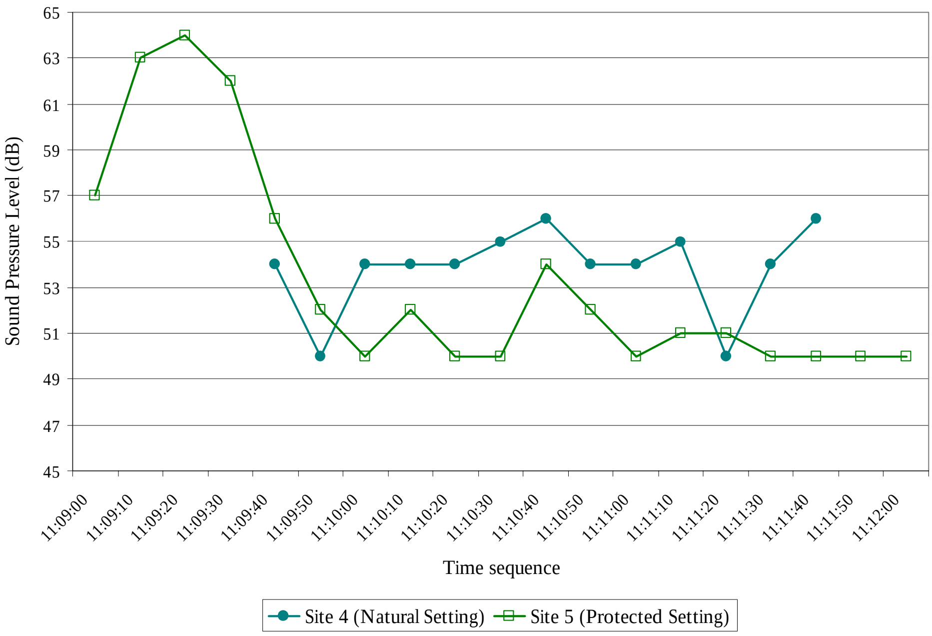
1	29.9	No measurement
2	27.1	No measurement
3	28.0	No measurement
4	No measurement	No measurement
5	26.7	81
6	27.3	77.3
7	27.7	84.1
8	26.0	89.5

Appendix 4.3. Temperature and humidity daily averages.

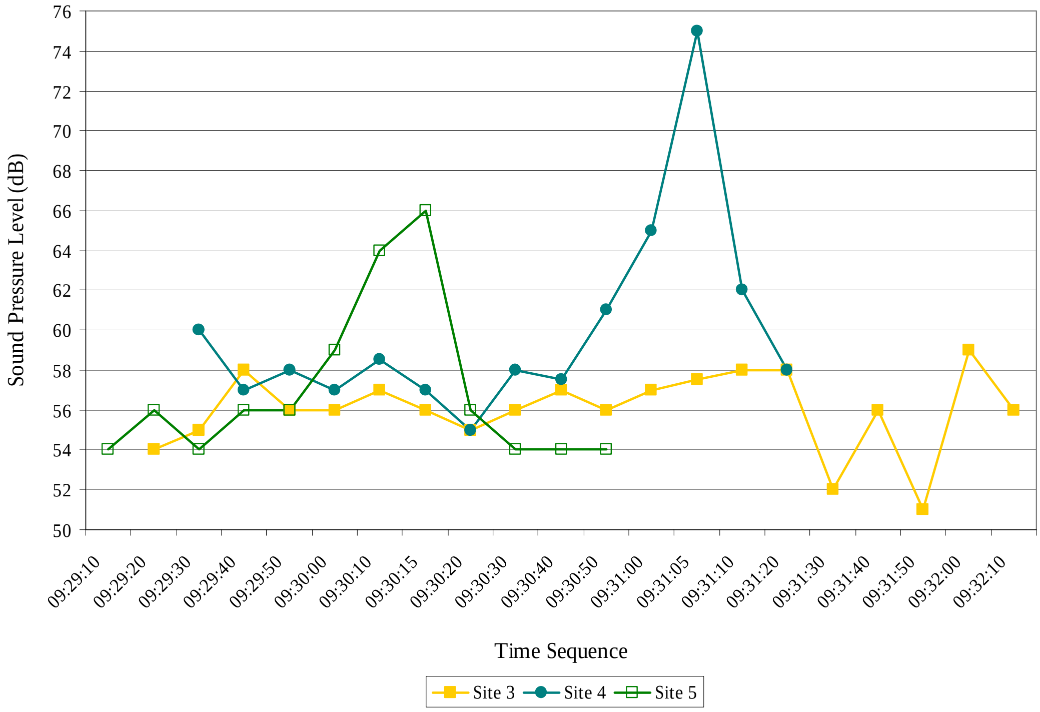
APPENDIX 5.0. Examples of Aircraft Events.



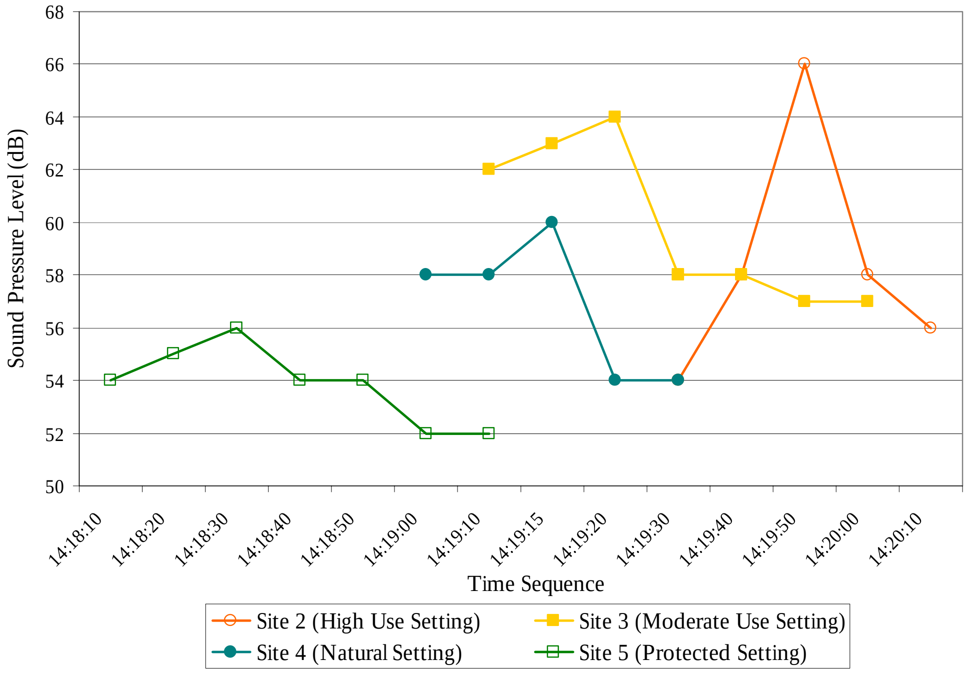
Appendix 5.1. Event 101 - Seaplane takeoff from in front of site 5. This aircraft was recorded only by site 5. It flew in a westerly direction over site 5.



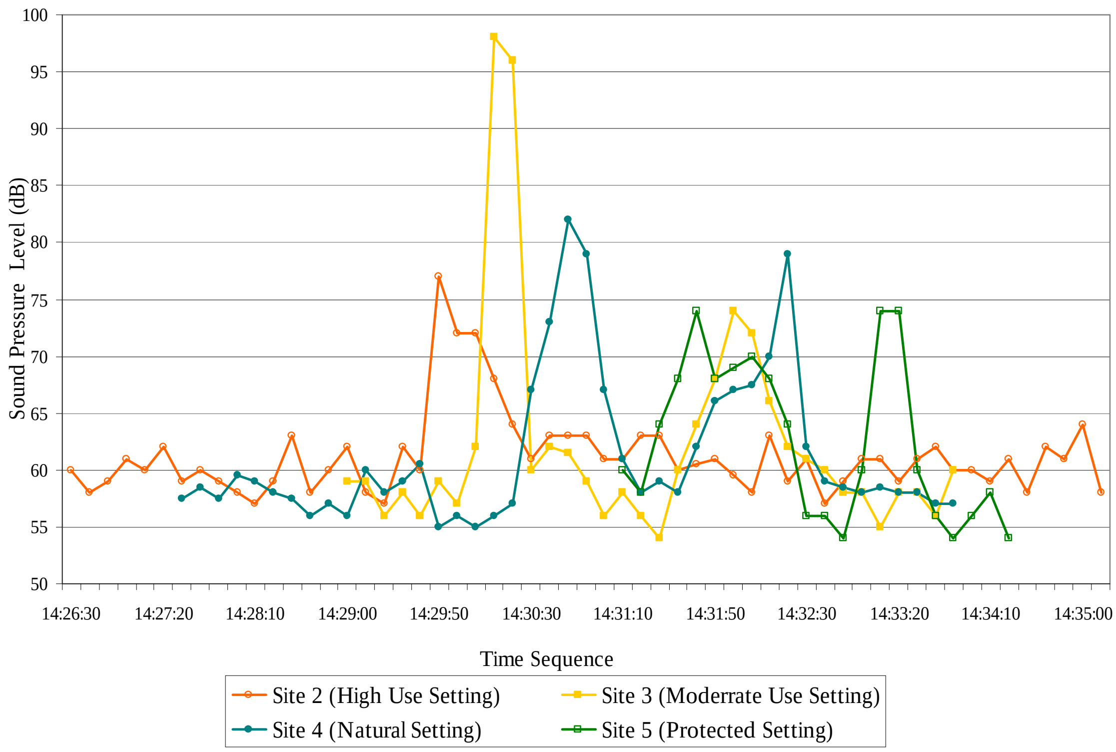
Appendix 5.2. Event 74 - Helicopter flyover at the northern end of Whitehaven beach. Event 74 registered above background sound levels at site 5 and was audible at site 4.



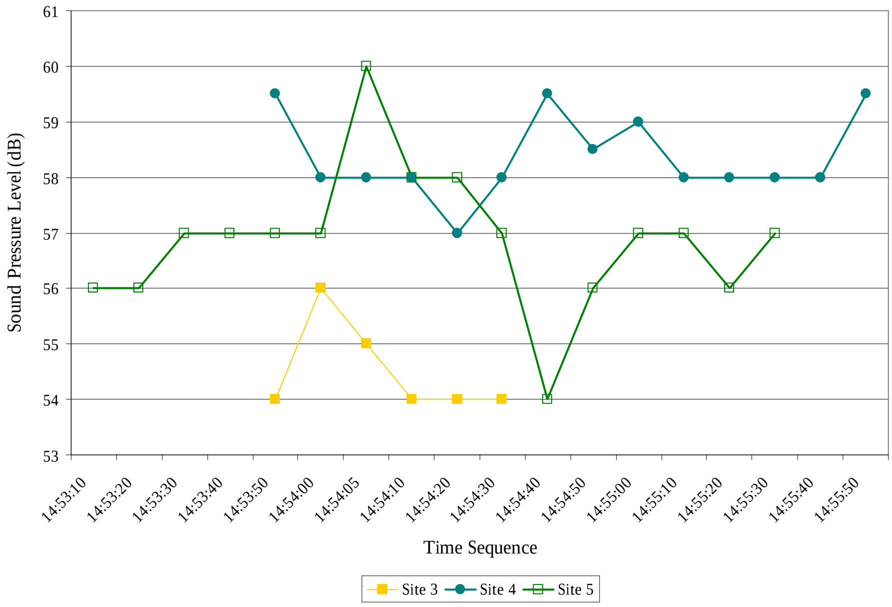
Appendix 5.3. Event 143 - Seaplane flyover from the north, landing close to site 4. This event was not noted or recorded by site 2 thus presumably site 2 was not aware of it.



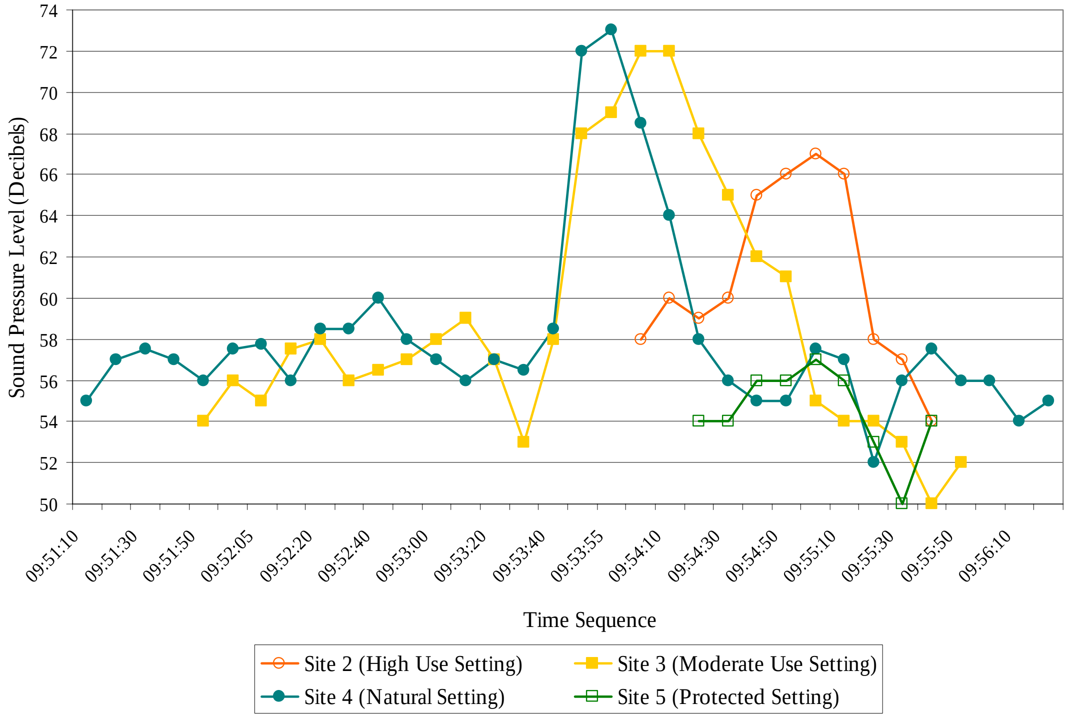
Appendix 5.4. Event 91 - Light aircraft (other than a seaplane) flyover from north to south.All sites recorded this event, registering a range of maximum sound levels for it.



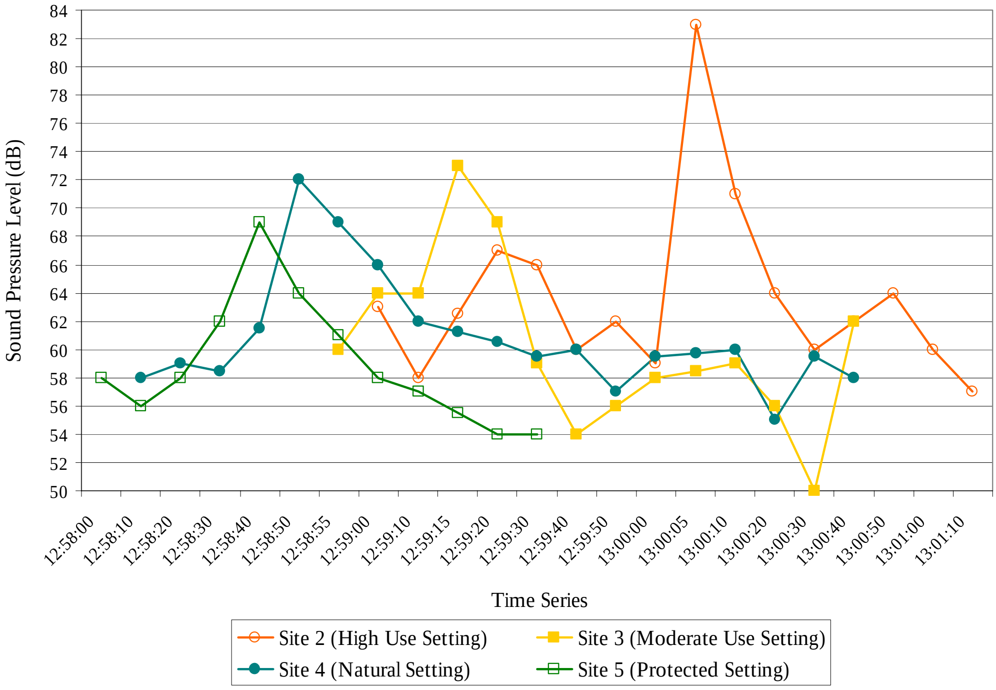
Appendix 5.5. Concurrent events 169, 170 (seaplane takeoffs) & 171 (seaplane landing). Event 169 took off from between sites 2 and 3 and flew toward the north impacting all sites. Event 170 took off from between sites 3 and 4 and also flew north. It was not noticed by site 2 at all. All sites other than 2 missed event 171 possibly partly due to the concurrent takeoff of 170 but also as it only flew over site 2 and landed close to site 2.



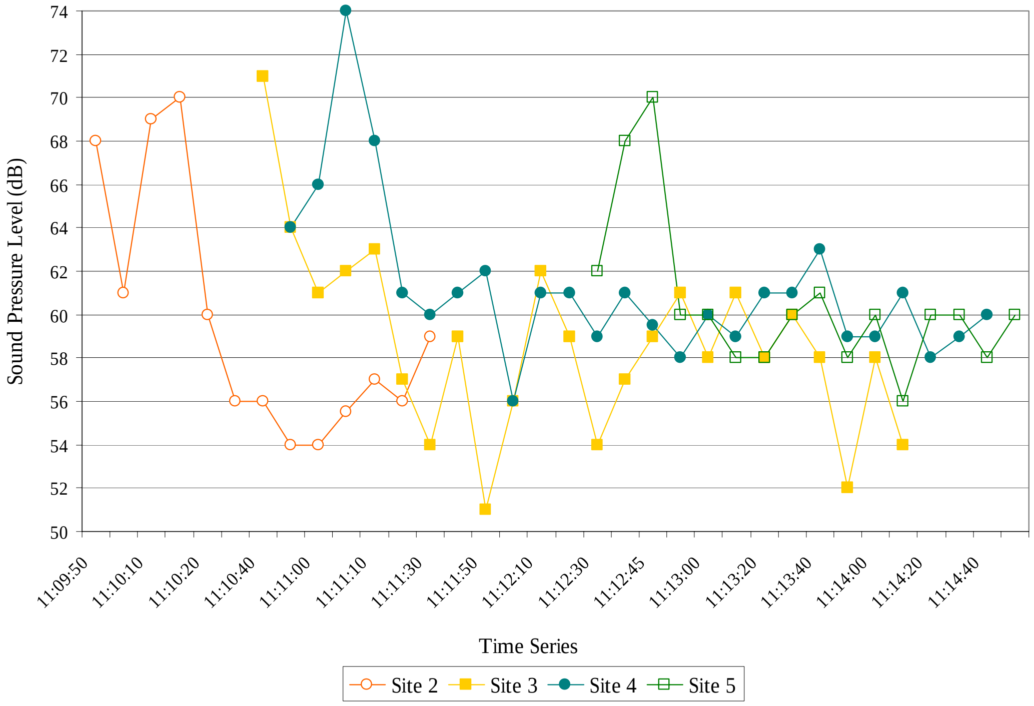
Appendix 5.6. Event 139 - Helicopter flyover in the vicinity of Hill Inlet. Event 139 registered above average background at sites 4 and 5 with a low peak of 60 dB.



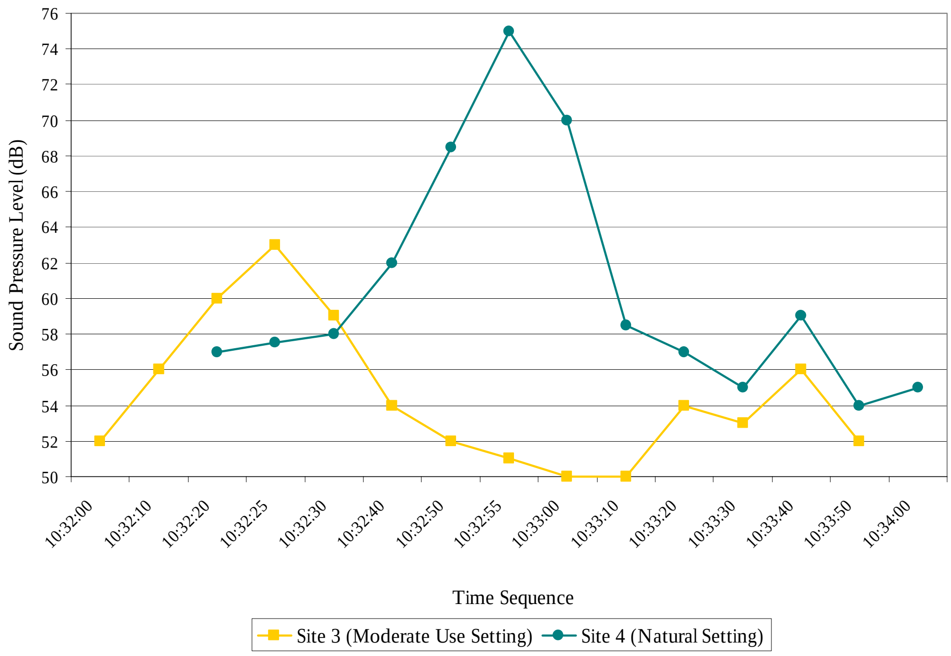
Appendix 5.7. Event 146 - Seaplane takeoff from between sites 3 and 4 and flyover toward the south. This event was first recorded by sites 3 and 4 and later by sites 2 and 5 (after takeoff).



Appendix 5.8. Event 164 - Seaplane flyover and landing close to site 2. Event 164 flew from north to south impacting all sites prior to landing close to site 2.

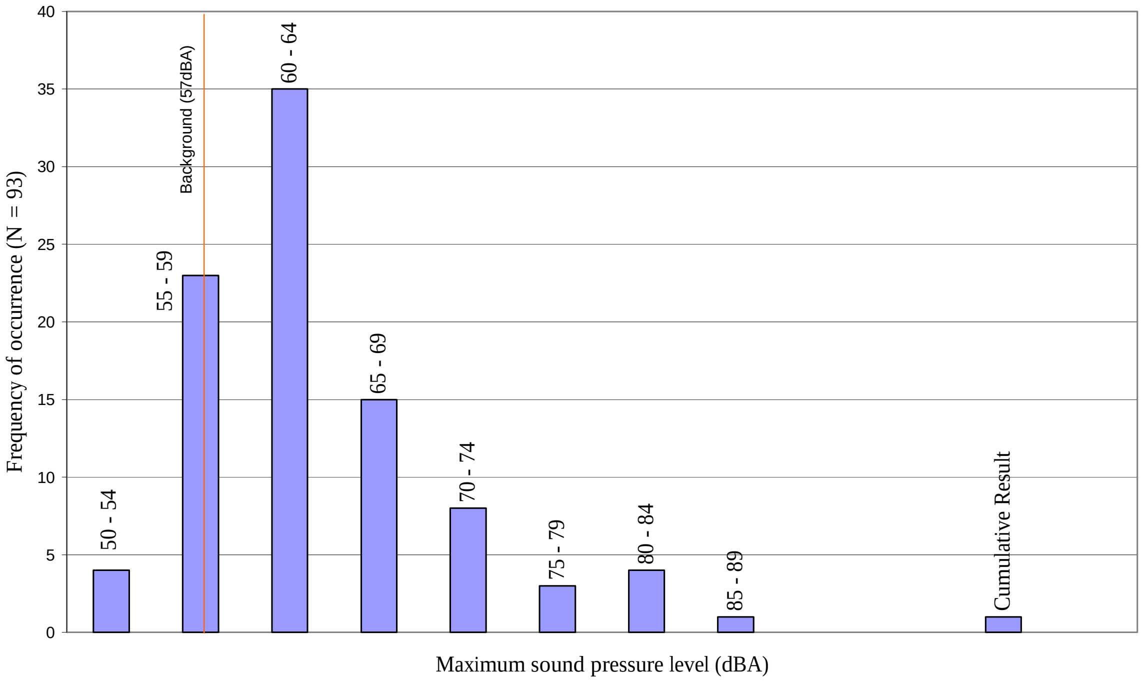


Appendix 5.9. Event 123 - Helicopter flyover from south to north. All sites started to record this event only when sound levels were well above average background levels. Thus, presumably sound levels increased suddenly.

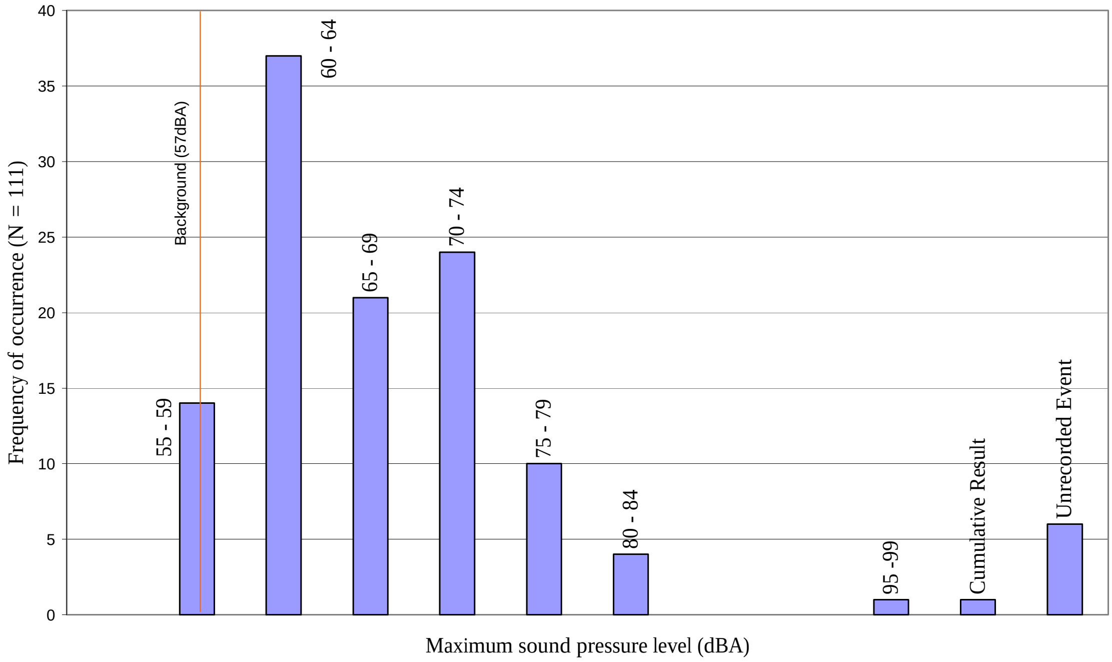


Appendix 5.10. Event 181 - Helicopter flyover / landing in the seasonal landing zone between sites 4 & 5.Event 181 probably approached from the land ward side of the beach thus impacting only the middle of the beach (sites 3 and 4).

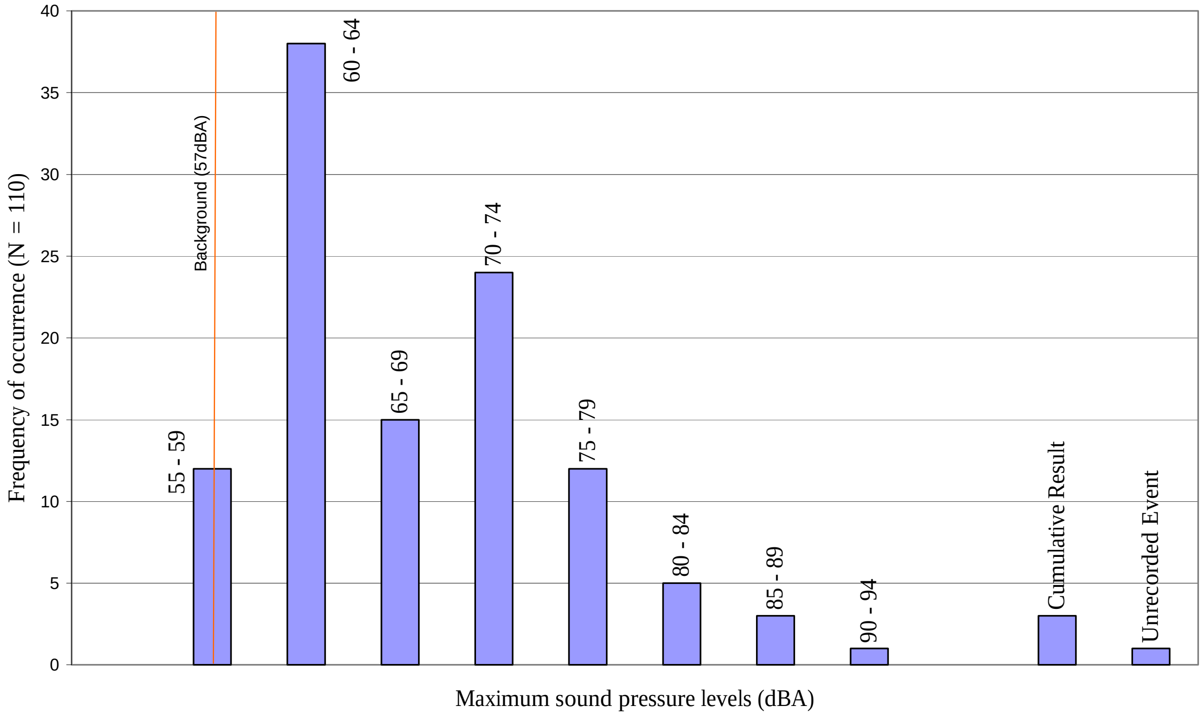
APPENDIX 6.0. Further Results – Aircraft Sound.



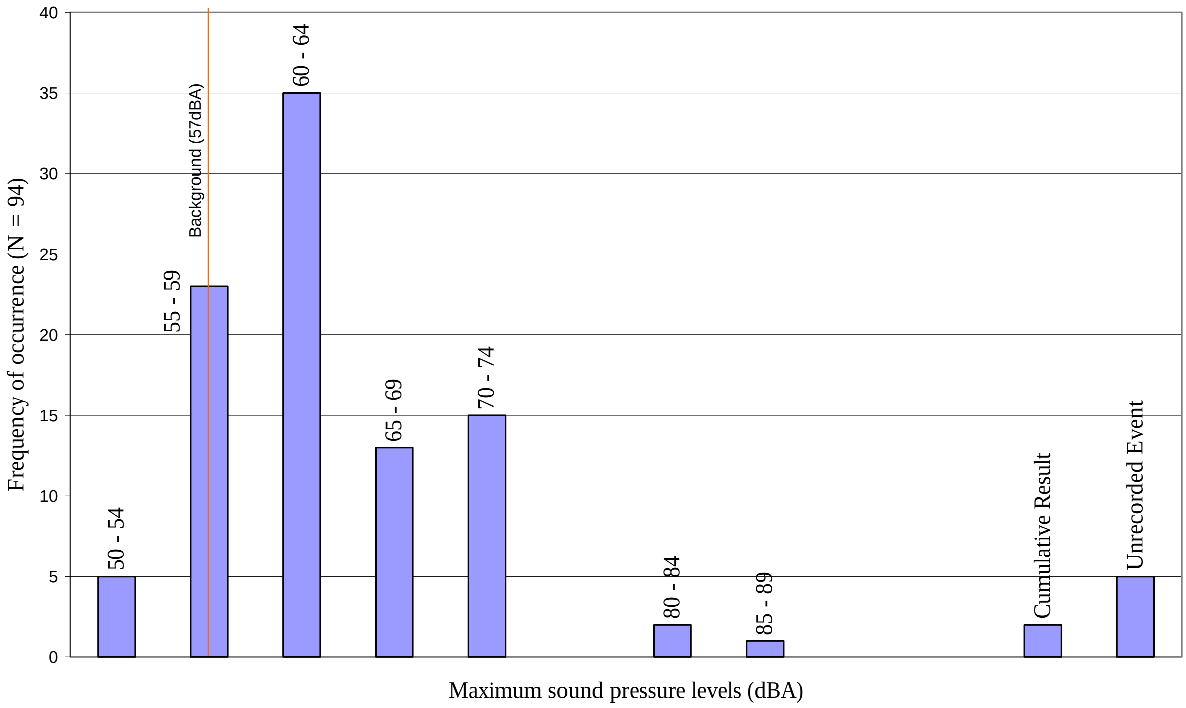
Appendix 6.1. Frequency of occurrence of Lmax aircraft induced sound levels at site 2.



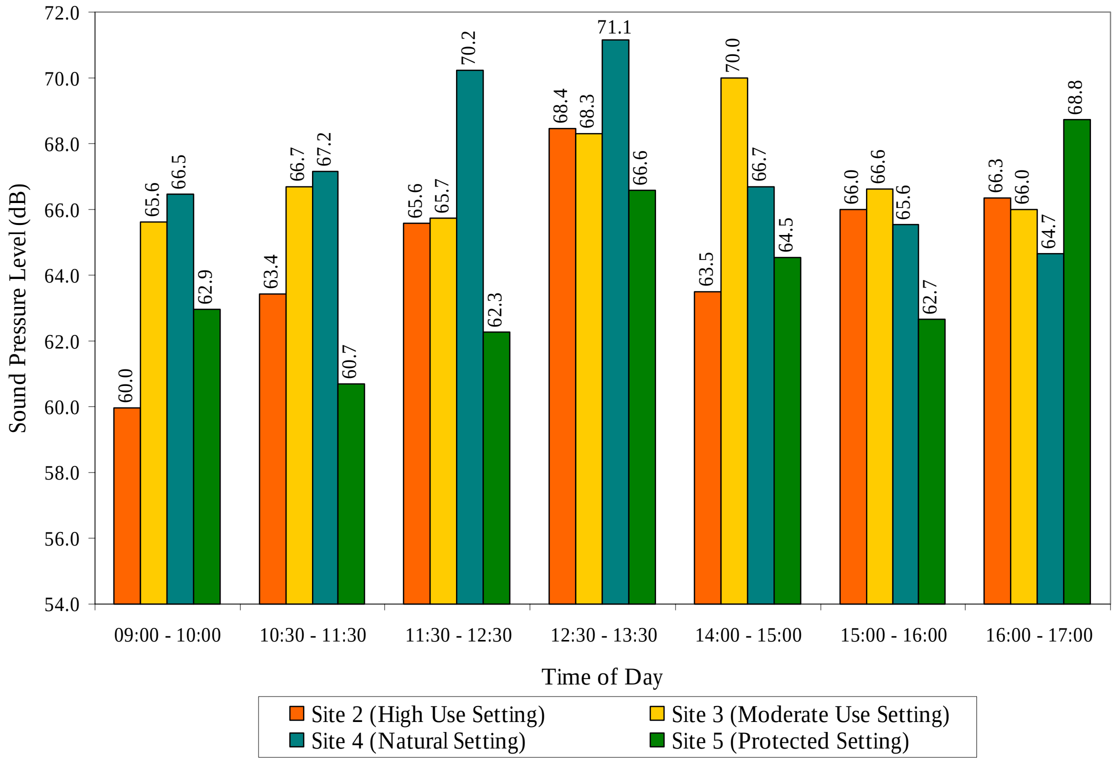
Appendix 6.2. Frequency of occurrence of aircraft induced Lmax sound levels at site 3.



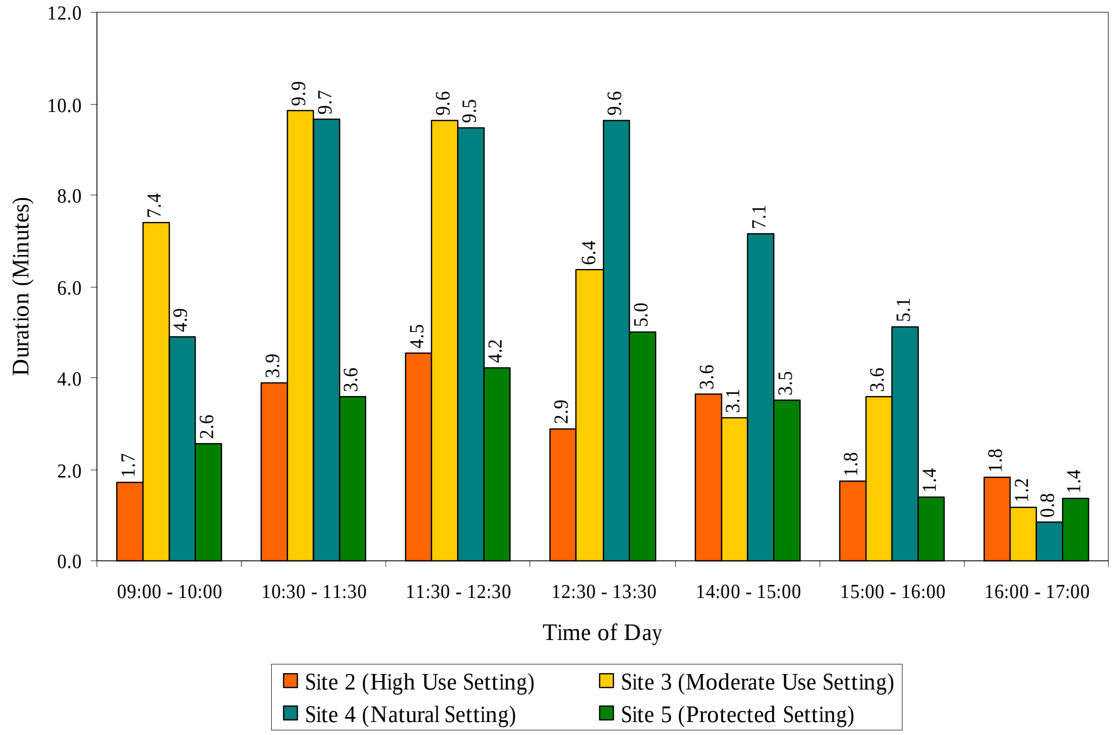
Appendix 6.3. Frequency of occurrence of Lmax aircraft induced sound levels at site 4.



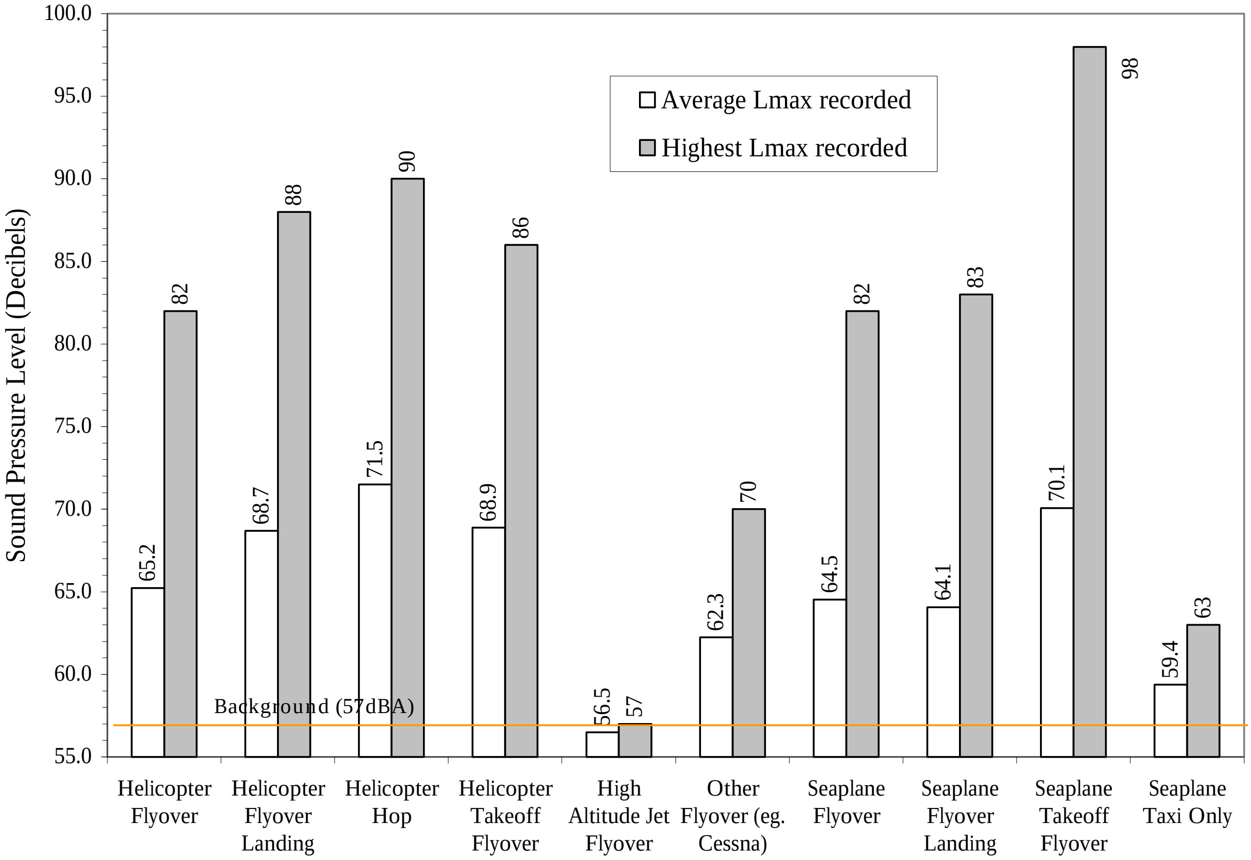
Appendix 6.4. Frequency of occurrence of maximum aircraft induced sound levels at site 5.



Appendix 6.5. Average aircraft maximum decibel levels relative to site and time of day (based on data collected on days 3 - 8).



Appendix 6.6. Average hourly duration of aircraft sound relative to site and time of day (based on data collected on days 3 - 8).



Appendix 6.7. Average and absolute Lmax relative to aircraft event type (based on data collected on days 3 - 8 of trips 1 & 2).

When results measured for helicopter and seaplane 'takeoff flyovers' recorded during break periods are included in the calculation, the overall averages for these event types increase to 70.1 and 71.1dBA respectively.

Due to the use of broader classifications of event types, and the averaging of readings based on recordings made at all sites recording the same event (therefore over distances up to 6 km), there is a less specific association between event type and sound level experienced than in figure 4.9, while averages are dampened. Data for appendix 6.7 is based on a larger data set than that for figure 4.9, however, again not all event types occurred with equal frequency. Thus for example, although seaplanes are well represented, helicopters are proportionally under represented.

APPENDIX 7.0. Factors of Sound Measurement.

When measuring sound and noise, the relevant measurement standards, the weighting network to be used, the acoustical metric(s) to be used, and the sampling period are all core factors which must be taken into consideration. When measuring aircraft sound levels an understanding of the effect of altitude is also relevant.

Appendix 7.1. Measurement Standards

Sound level meters and techniques of sound measurement must comply with international or national standards (Maekawa and Lord 1994). Australian Standards 1055, 1259 and 2659 are relevant to this study. Sound level meters meeting Australian standards are classed as either type 0, 1, 2 or 3, each being designed for slightly different purposes. Other types of sound meters are those which do not comply with the standards but which may be satisfactory for particular applications. Types 0 and 1 are typically used for technical sound studies with direct legal implications although they must meet rigorous specifications if used in the field (Standards Australia 1988).

Australian standards on noise measurement do not specifically address the measurement of aircraft noise in National Parks. Notably, standard sound level meters used in community noise studies, will not accurately measure below 20 to 25 decibels. Thus special "low-noise" instruments are required for studies where it is imperative to establish the level of extreme quiet (Horonjeff et al. 1993; US National Park Service 1994).

Appendix 7.2. Weighting Networks

The type of weighting curve used in measuring sound is important in determining the accuracy of the result as a measure of the impact of the sound on those hearing it. The frequency of sound determines the ability of the human auditory system to detect it. As a sound of constant sound pressure level decreases in frequency from about 1 kHz or increases in frequency from about 5kHz, it's loudness decreases. Therefore, in order to measure what is actually being heard by humans, measurement of sound pressure level is adjusted to account for the relative loudness of the frequency through the use of weighting networks (A, B and C) in sound level meters. Networks are based on approximate equal-loudness contours rather than the hearing threshold curve (Boeker and van Grondelle 1995; Standards Australia 1988).

The A weighted network is considered to most accurately represent human perception of noise (Maekawa and Lord 1994; Boeker and van Grondelle 1995; Berglund et al. 1996) and to date has been the most commonly used network for measuring sound levels of aircraft in National Parks. However, it underestimates the importance of low frequency sound. Therefore, noise which contains a substantial frequency component below about 100 hertz has its loudness underestimated by the equivalent of 9dB within the range of 52 - 70dB(A). Regardless of the frequency, for sounds exceeding a sound pressure level of 60dB, the reliability of the A-weighting decreases (Berglund et al. 1996). Methods of better accounting for aircraft noise, which has a significant low frequency component, are under development (Maekawa and Lord 1994; Berglund et al. 1996).

Appendix 7.3. Metrics Used

Metrics commonly used to describe aircraft overflights and background sound levels in national parks are:

- Lmax (dBA): The maximum A-weighted sound level reached;
- Leq (dBA): The equivalent A-weighted sound level (the logarithmic sum of sound exposure levels (SELs) over a specified time period);
- Ldn: The day-night average sound level. A 24 hour energy average A-weighted sound level with 10 dB added to night (20:00 - 07:00 hours) measurements.
- Onset rate (dB/second): Representing the maximum rate of increase in A-weighted sound level;
- Duration of aircraft sound levels above background sound levels;
- Percentage chance of detection by attentive listeners on the ground;
- The audibility of the aircraft (dB) (The audible portion of the total sound exposure);
- The aircraft's audible duration (seconds).
  (Brown 1986; US National Parks Service 1992; Anderson and Horonjeff 1992).

Appendix 7.4. Sampling Period

DeVor et al. (1979), Schomer and DeVor (1981) and Schomer et al. (1983) address the issue of sampling strategies for establishing the yearly Ldn close to airports. Noise levels in the vicinity of airports were found to be correlated serially in time, thus, they concluded that in order to estimate the yearly Ldn within +2 to -3 dB of the true value and with a 95% confidence level, sampling needs to be done in one of the following ways:

1. Fourteen days of totally random sampling;
2. Three to four weeks of quasi-random sampling taken one week at a time, ensuring that no periods are consecutive; or
3. At least thirty days of continuous sampling.

Bowlby et al. (1990) used the second sampling strategy for their study of aircraft noise in Grand Teton National Park in the vicinity of Jackson Hole airport. They sampled four week long periods as a function of season. To my knowledge there have not yet been any studies which specifically address the issue of establishing sampling strategies for aircraft overflights in protected areas.

Appendix 7.5. The Effect of Altitude

Anderson and Horonjeff (1992) discuss the effects of aircraft altitude upon sound levels on the ground. They discuss the causes of sound levels decreasing with distance and cite the most important of these as being: spherical divergence; atmospheric absorption; ground attenuation; shadow effects; attenuation due to topography and heavily wooded areas; and the acoustical metric being used to describe the overflight.

When the flight path is directly or nearly overhead, sound levels experienced by a listener on the ground decrease as aircraft height increases. Lmax, Leq, Ldn and Onset rate metrics experience diminishing reductions in value with increasing height. As a general rule, reductions of 4 - 10dB in sound exposure require a doubling of the distance between the aircraft and the ground. Comparatively,

'audibility' acoustical descriptors (such as percent of time audible) depend more on background sound levels. Subsequently, sound levels initially decrease following the same trend as the descriptors, Lmax, Leq, Ldn and Onset rate, but then rapidly decrease at higher altitudes due to masking of aircraft sound by background sound levels. This trend is characteristic of all aircraft overflights, however, the height at which an overflight begins its rapid reduction in audibility is highly variable and dependent on aircraft type, aircraft speed and background sound levels. Thus, the type of metric used to monitor sound levels affects the value placed on increasing altitude as a noise mitigation measure.

When flight paths are lateral to the listener, the situation becomes more complex as at low elevation angles, aircraft sound may be attenuated by acoustically soft ground, intervening hills and wooded areas. Thus, increasing aircraft height results in an increase of sound level once the aircraft gets to a height beyond the influence of the ground. Subsequently however, sound level decreases with increasing height in the same manner as when an aircraft is directly or nearly overhead.

APPENDIX 8.0. Glossary

This report contains the following technical terms:

Ambient sound: The all encompassing sound at a location (Standards Australia 1988).

Amenity: The pleasantness of a place, features and circumstances agreeable to mind, feelings and senses of the users. This definition includes not only the aesthetics but also matters such as ecological integrity, noise, the proximity of other people, their activities, vessels and structures (Adami and Jennings 1995).

Anthropogenic: Produced or caused by man (Lawrence 1995).

A-weighted network: A frequency-equalising function intended to approximate the sensitivity of human hearing to sounds of moderate sound pressure level (US Forest Service 1992).

Background sound: The ambient sound in the absence of the sound under investigation (Standards Australia 1988). In this study as all anthropogenic sound sources were under investigation, thus 'background sound' is equivalent to 'natural sound' and the terms are used interchangeably.

dBA: The A-weighted sound level measured in decibels.

Decibel (dB): The most commonly used unit of sound measurement. The decibel scale is a logarithmic scale, derived from the Pascal scale and based on sound pressure levels (the physical correlate of loudness). The threshold of human hearing is at 20 micropascals or 0dB. A change of 20dB corresponds to a ten-fold increase in micropascals. Thus, 20 dB is equivalent to 200 micropascals. However, the decibel scale gives a better approximation of the perception of loudness than the Pascal scale, 1dB indicates the same fractional change in sound pressure at all levels and is about the smallest change that the average person can reliably detect. A 6dB increase corresponds to a doubling of the sound pressure, however a 10dB increase is necessary for the sound to be perceived as being twice as loud (Standards Australia 1988; Maekawa et al. 1994; Boeker and van Grondelle 1995).

Event (applicable to aircraft and watercraft): An individual aircraft / watercraft visitation for as long as it is continuously within visual and/or audible range. Aircraft event classifications used in the main analysis are: Flyover only, flyover and landing, takeoff and flyover.

Ldn: The day-night average sound level. A 24-hour energy average A-weighted sound level with 10dB added to night (2000-0700 hours) measurements (US Forest Service 1992).

Leq: The equivalent sound level measured in decibels (the logarithmic sum of sound exposure levels over a specified time period) (US Forest Service 1992).

Lmax: The maximum sound level reached measured in decibels (Anderson et al. 1992).

Lp: The sound pressure level taken at an instant (Standards Australia 1997).

Natural quiet: The natural ambient sound condition occurring in a park unit (Lee 1994).

Natural sound: Natural ambient sound conditions. In this study natural sound is equivalent to background sound and the terms are used interchangeably.

Noise: unwanted sound (Maekawa and Lord, 1994; Bell et al. 1996; Berglund et al. 1996) or "sound having amplitude, frequency content, situational, or temporal qualities that are inappropriate to the particular setting-" (US Forest Service 1992, p2-1).

Noise is recognised as having both a physical and a psychological component. The physical component is set while, the psychological component (the degree of annoyance) depends on the listener and their physiological and psychological state as well as the frequency and time varying pattern of the sound. Low frequency (particularly anthropogenic sources) and impulse sounds are thought to result in higher levels of annoyance. Sources of low frequency sound include aircraft, wind and waves. Sources of impulse sound include artillery and sonic booms. (Berglund et al. 1975; Hall et al. 1981; Maekawa and Lord 1994; Bell et al. 1996; Berglund et al. 1996).

Onset Rate: The slope of increase in sound level with time (expressed as dB/s) (US Forest Service 1992).

Percent of time audible: The proportion of time during a period of recording that aircraft are audible to attentive listeners on the ground (Anderson et al. 1992).

Recreation opportunity: A chance for a person to participate in a specific recreational activity in a specific setting in order to realise a predictable recreational experience (Stankey and Wood, 1982).

Recreation opportunity spectrum (ROS): A method of recreation planning used to provide for a variety of recreational user tastes. It does so by combining social, managerial and environmental factors in a range of ways to produce a spectrum of recreation opportunity settings, ranging from natural, undeveloped and low-population density settings to unnatural, developed and high population dense settings. The ROS is best applied on a regional scale (Manning 1986).