WIND ENERGY and AVIATION INTERESTS

A study for

Sustainability victoria
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1 TERMS OF REFERENCE

Sustainability Victoria commissioned HART Aviation to undertake a study on wind energy and the relationships with aviation interests.

The aim of the project is to provide expert information and analysis on the interactions between wind farm developments and aviation safety.

In particular, the outputs of the project will:

• provide a clear, readable, single source of information on all aspects of the effect of wind turbines on aviation in Australia,
• identify the range of interactions between wind energy and aviation interests and the organisations involved in these processes,
• examine solutions used overseas, and
• outline possible approaches (procedural and technological) that could effectively address the issues which are likely to arise from such interactions.

The primary goal of the study is to facilitate the development of wind farms and encourage the acceptance of wind farms from local communities by helping to reduce the visual impact of obstacle lighting, whilst ensuring that the interests of civil (and military) aviation are appropriately recognised.

It has been acknowledged that it is unlikely the study will be able to provide recommendations on all of the issues relating to how aviation interests affect wind farm developments (and vice versa). Further, it has been recognised that neither the aviation industry nor the wind industry is static and both can be expected to evolve in ways which will have an effect on the other. As such, it is expected that the outcomes of the study will only be a starting point to enable balanced discussions between all stakeholders, and that the information provided would need to be revised and updated on a regular basis.

2 BACKGROUND

Sustainability Victoria is a Victorian Government statutory authority established in October 2005 under the Sustainability Victoria Act (2005). Sustainability Victoria delivers the Victorian Government’s sustainability agenda and is working together with Victorians to achieve greater environmental sustainability in the use of resources. More specifically, Sustainability Victoria (SV) is responsible for promoting a diverse and sustainable energy supply for Victoria and works with industry and other stakeholders to address the barriers that inhibit a greater uptake of renewable energy technologies. Amongst other things, SV can work towards this goal by facilitating programmes that can encourage balanced discussions between renewable energy developers and other stakeholder groups that are impacted by renewable energy developments.

It is understood that the Civil Aviation Safety Authority (CASA) currently holds the view that wind farms may have an adverse impact on the aviation domain because of the physical size and weight of wind turbine generators (WTGs). Reflecting this view, CASA, in December 2005, developed and published a draft Advisory Circular, AC139-18(0), which relates to obstacle marking and lighting of wind farms. CASA published the advisory circular to provide general information and advice to proponents of wind farms (including single wind turbines) and planning authorities with jurisdiction over the approval of such structures on the potential hazards to aviation, and advice as to measures to reduce the hazard and how to implement them. The hazard reduction methods only focussed on the means of marking or lighting wind farms.

The Advisory Circular identified two areas of concern, viz: any obstacle that might penetrate aerodrome obstacle limitation surfaces (OLS) [which is usually within 15km from an aerodrome, but may extend further] and any obstacle which is 110m or more above ground level. Under Civil Aviation Safety Regulation 1998 (CASR 1998) Part 139.370 CASA may determine that a proposed structure will be a hazardous object because of its location, height or lack of marking or lighting. The available evidence since the issue of the afore-mentioned Advisory Circular would suggest that CASA has consistently recommended the marking and lighting of wind turbines / wind farms as a means of reducing the risks to aircraft safety, regardless of whether the wind turbines / wind farms (obstacles) were within the OLS or outside of the OLS and in uncontrolled air space. The Advisory
Circular added that, if CASA’s advice was not followed, wind farm project proponents may be liable for any eventual aircraft-related incidents. As a result, up to mid 2008, a developer proposing wind turbine generators with a tip height above 110 metres would typically seek CASA endorsement and the facility would include obstacle lighting compliant to the requirements of the CASA Advisory Circular. Another influencing factor was that various planning panels in Victoria generally required developers to comply with CASA recommendations. Potential liability issues may be a motivating issue in this respect. This practice would seem to have been followed for all wind farms, including those outside the vicinity of an aerodrome.

However, obstacle marking and lighting may be an annoyance to the public residing in the areas surrounding wind farms, which could impose demands on the functioning and intensity of obstacle lighting systems. In addition to the contribution to the visual amenity impact of WTGs, the above mentioned approach has led to an increase in the cost of wind farm developments, with typical costs for low intensity aviation night lighting in the range from $900 to $9,000 per unit, and for medium/high intensity aviation night lighting in the range from $9,000 to $21,000 per unit.

In the twelve months preceding mid-2008, it is reported that a considerable number of wind farm proposals in Victoria, SA and NSW were brought forward to planning authorities. During the planning approval process for these wind farm proposals, decision-makers would strive in all cases to minimise the community impacts of obstacle lighting.

The requirements of the CASA circular did not, however, consider these impacts and related exclusively to minimising the risk for aviation. This led to conflicting priorities in some cases that have resulted in incompatible obligations arising from the planning approval and the requirements of the Advisory Circular. Among wind farm project proponents, there seems to be widespread agreement that the Advisory Circular took a “blanket rule” approach and appeared conservative in comparison with global practice.

As a result, wind farm developers have encountered difficulties at the project design and assessment stage in their dealings with CASA because of CASA’s apparent exclusive reliance on marking and lighting as the only acceptable means of risk mitigation.

Arising from the above, industry complaints considered by CASA’s Industry Complaints Commissioner identified a number of other issues with the Advisory Circular, not the least being a questionable legal grounding for the CASA Advisory Circular. As a result, in mid 2008, CASA withdrew Advisory Circular AC139-18(0) and initiated an internal review process to look at how wind farms located near aerodromes are assessed and regulated. The current status of that review is reported in Section 4 of this report.

This particular review for Sustainability Victoria will, hopefully, contribute to the above-mentioned CASA review.

3 INTERNATIONAL SITUATION

3.1 ICAO

The relevant ICAO recommendations are detailed in Annex 14 to the Convention on Civil Aviation.

The relevant parts of Annex 14, specifically dealing with obstacle lighting, are included in Appendix No 1 to this report.

Until quite recently wind turbines have been treated as any other obstacle. However, ICAO recently issued a new Section 6.4 to Annex 14 specifically dealing with the marking and lighting of wind turbines. This amendment, a copy of which is in Appendix No 1, page 38 of this report, came into effect in March 2009 and becomes applicable in November 2009.

In summary, ICAO has recommended that:

- A wind turbine shall be marked and/or lighted if it is determined to be an obstacle.
- The rotor blades, nacelle and upper 2/3 of the supporting mast of wind turbines should be painted white, unless otherwise indicated by an aeronautical study.
- When lighting is deemed necessary, medium intensity lights should be used.
- In the case of a wind farm, lights should be installed as follows:
- The perimeter of the wind farm should be identified,
- The spacing of lights should be in accordance with the recommendations of any other widely spaced obstacles, unless an assessment determines otherwise,
- Flashing lights, when used, should flash simultaneously, and
- The tallest wind turbines should be identified regardless.

- Obstacle lights should be installed on the nacelle in such a manner as to provide an unobstructed view for aircraft approaching from any direction.

In principle, the above specific requirements for wind turbines vary little from that already existing within Annex 14 for other obstacles. It is noted, however, that only medium intensity obstacle lights have been recommended.

ICAO Contracting States which are signatories to the Convention on Civil Aviation are obliged to uphold the Standards and Recommended Practices (SARPs) of ICAO, unless they lodge a formal difference. It would appear that, in principle, most Signatory States are abiding by the requirements of Annex 14, including those for obstacle lights. As will be seen later, some have imposed slightly stricter requirements.

It should be noted that a provision exists for an aeronautical study as to the need, or otherwise, for marking and/or lighting. This is a consistent provision within most national regulatory requirements as will be seen later.

Prima facie, aircraft operating en route to and from aerodromes will be unlikely to be at an altitude which would necessitate the need for obstacle lighting except, perhaps, a development beyond any OLS, but only marginally clear, laterally or vertically, of controlled airspace. Developments within or close to an aerodrome OLS are, for these reasons, discouraged. The position in respect of this will be further explained later in this report – specifically Sections 7 & 8.

3.2 UK & EUROPE

The United Kingdom policy in respect of wind turbines is detailed in the UK CAA Civil Aviation Publication CAP 764 – “CAA Policy and Guidelines on Wind Turbines”. This summarises the potential and real impact of both offshore and onshore wind turbines on aircraft radar, fixed wing aircraft and helicopter operations, both civil and military.

On obstacle lighting, the UK CAA position is summarised as:

1. Obstacle lighting is not a substitute for knowledge of the presence of such structures but is a significant and important aid to their visual acquisition and hence avoidance;
2. obstacles located close to licensed aerodromes are required to be lit;
3. structures away from the immediate vicinity of an aerodrome, which have a height of 150m or more above ground level (AGL) are required to be fitted with obstacle lights;
4. in general terms, structures less than 150m high, which are outside the immediate vicinity of an aerodrome, are not routinely lit, unless the “by virtue of its nature or location such structures could be considered a significant navigational hazard” argument holds fast;
5. if a claim for lighting was clearly outside credible limits (i.e., the proposed turbine(s) was/were many miles away from any aerodrome or was/were at a height that was unlikely to affect even military low flying), the CAA, in isolation, would be unlikely to make a case for aviation warning lighting;
6. where a wind turbine development lies (or would lay) outside any aerodrome safeguarding limits and the turbine height was less than 150m, the aviation industry, including the CAA, is not in a position to demand that turbines are lit.

The European scene:

It would seem that the European Aviation Safety Agency (EASA), which is charged, inter alia, with encouraging and establishing coordinated and common rules for the safety of aviation operations amongst its members, has not yet established a policy in respect of the wind turbines. However, individual countries have done so.
The following table is a sample of individual country requirements.

This comparative table has been sourced primarily from a 2002 report “Wind Turbines and Aviation Interests – European Experience and Practice” – see Section 12 - Reference Document No 12.

No evidence could be sourced to indicate that, with the passage of time since that report, there has been any change to the main findings listed.

### TABLE 1: SUMMARY OF MAIN FINDINGS

<table>
<thead>
<tr>
<th>Country</th>
<th>Aerodrome safeguarding</th>
<th>Technical site safeguarding</th>
<th>Planning, assessment and approval process</th>
<th>Low flying policy</th>
<th>Charting policy</th>
<th>SAR Ops policy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Civil¹</td>
<td>Other</td>
<td>Military</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Airfield radar</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UK</td>
<td>Assessed if within 17km (civil)</td>
<td>Assessed if within 30km</td>
<td>Assessed if within 34km (ILS); 30km (other systems)</td>
<td>Assessed if within 74km of AD radar; developer to prove no negative effects.</td>
<td>Voluntary; widely used Statutory via Local Planning Authority</td>
<td>Generally not below 250ft</td>
</tr>
<tr>
<td>Denmark</td>
<td>ICAO Standards</td>
<td>ICAO Standards</td>
<td>ICAO Standards; VOR stations; not within 1km</td>
<td>Nil stated</td>
<td>Wind energy incorporated into regional plans; planning authorities inform aviation authorities</td>
<td>No objections to structures &lt;100m</td>
</tr>
<tr>
<td>Germany</td>
<td>ICAO Standards</td>
<td>ICAO Standards</td>
<td>ICAO Standards</td>
<td>5km protected area; 20km “area of interest”; Military to prove negative effects</td>
<td>Construction Committees inform aviation authorities; plans assessed within two months</td>
<td>Generally not below 1000ft</td>
</tr>
<tr>
<td>Netherlands</td>
<td>ICAO Standards; not &gt;150metres within 30km</td>
<td>ICAO Standards</td>
<td>Nil stated</td>
<td>No regulated processes away from safeguarded aerodromes</td>
<td>Generally not below 1200ft</td>
<td>Archive of all structures &gt;300ft</td>
</tr>
<tr>
<td>Sweden</td>
<td>ICAO Standards</td>
<td>ICAO Standards</td>
<td>None aviation specific</td>
<td>Voluntary</td>
<td>Not below 50m</td>
<td>“FLA” data base (&gt;50m in towns, &gt;20m rural)</td>
</tr>
<tr>
<td>Norway</td>
<td>ICAO Standards</td>
<td>ICAO Standards</td>
<td>ICAO Standards, plus assessed within 10m and on OLS; (ILS; not within 20m)</td>
<td>Not known</td>
<td>Energy authorities inform aviation authorities</td>
<td>Not known</td>
</tr>
</tbody>
</table>

¹ For primary radar, ICAO Standard is a protected surface slope of gradient 1:100; for Secondary Surveillance Radar a slope of 1:200; for navaids, 1:50.

Note that in most cases, as part of the planning assessment and approval process, the provision exists for an aeronautical study to assess the need or otherwise for marking and/or lighting. Such a study may include a site specific evaluation and risk assessment considerations. See comments on each of the individual countries and the summary Table 2, Section 5.
3.3 USA

In general, the Federal Aviation Administration (FAA) requires that any temporary or permanent structure, including all appurtenances, that exceeds an overall height of 200 feet (61m) above ground level (AGL), or exceeds any obstruction standard contained in FAA Regulations 14 CFR Part 77, should normally be marked and/or lighted. However, an FAA aeronautical study may reveal that the absence of marking and/or lighting will not impair aviation safety. Conversely, the study may show that the object may present such an extraordinary hazard potential that higher standards may be recommended for increased conspicuity to ensure safety to air navigation.

Normally, outside commercial lighting is not considered a sufficient reason to omit recommended marking and/or lighting. Recommendations on marking and/or lighting structures can vary depending on terrain features, weather patterns, geographic location, and in the case of wind turbines, number of structures and overall layout of design. The FAA may also recommend marking and/or lighting a structure that does not exceed 200 (61m) feet AGL or 14 CFR Part 77 standards because of its particular location. Additional guidance is contained in the FAA Advisory Circular 70/7460-1K, Obstruction Marking and Lighting.

If the structure is on airport property, the nearest FAA Airports’ Regional/Airports District Office is tasked with assessing the situation in accordance with the FAA requirements.

If the structure is not on airport property, the Air Traffic Organization Obstruction Evaluation Specialist that services the particular area is tasked with assessing the position.

3.4 CANADA

The Transport Canada obstruction markings and lighting standards are detailed in the Civil Aviation Regulations General Operating and Flight Rules, CAR 621.19.

Summarising, the Rules state that where it is likely that a building, structure or object, including an object of natural growth, is hazardous to aviation safety because of its height and location, the owner, or other person in possession or control of the building, structure or object, may be ordered to mark it and light it in accordance with the requirements stipulated in standard.

Wind farms are not specifically mentioned.

Except in the vicinity of an airport where an airport zoning regulation has been enacted, Transport Canada has no authority to control the height or location of structures. However, all objects, regardless of their height, that have been assessed as constituting a hazard to air navigation require marking and/or lighting in accordance with the CARs and should be marked and/or lighted to meet the standards specified in CAR 621.19.

The following obstructions should be marked and/or lighted in accordance with the standards specified in CAR 621.19:

(a) Any obstruction penetrating an airport obstacle limitation surface as specified in TP 312, Aerodrome Standards and Recommended Practices;

(b) any obstruction greater than 90m (300 ft) AGL within two nautical miles of the imaginary centre-line of a recognized VFR route, including but not limited to a valley, a railroad, a transmission line, a pipeline, a river or a highway;

(c) Any permanent catenary wire crossing where any portion of the wires or supporting structures exceeds 90m (300 ft) AGL;

(d) any obstructions greater than 150m (500 ft) AGL; and

(e) any other obstruction to air navigation that is assessed as a likely hazard to aviation safety.
Because of the nature of obstructions, Transport Canada has noted that it is not possible to fully define all situations and circumstances. Thus, in certain cases, a Transport Canada aeronautical evaluation will be required to determine whether an obstruction to air navigation is a likely hazard to aviation safety or to specify alternative methods of complying with the obstacle marking and lighting standards while ensuring that the visibility requirement is met.

An aeronautical evaluation may be performed with respect to the following types of obstructions:

(a) obstructions greater than 90m (300 ft) AGL but not exceeding 150m (500 ft) AGL;

(b) catenary wire crossings, including temporary crossings, where the wires or supporting structures do not exceed 90m (300 ft) AGL;

(c) obstructions less than 90m (300 ft) AGL; and

(d) any other obstruction specified in CAR 621.19.

It should be noted that Section 601.19 of the CARs further provides that an Aeronautical Evaluation may be performed by the Minister to approve the use of equivalent methods of obstruction marking and lighting where the application of the marking and lighting requirements specified in the CAR 621.19 Standard may be impractical or present nuisance glare to the surrounding area.

Further, it should be noted that no marking or no lighting may be approved, if:

i. The object may be so located with respect to other objects or terrain, removed from the general flow of air traffic, or may be so conspicuous by its shape, size, or colour that marking or lighting would serve no useful purpose.

ii. Normally outside commercial lighting is not considered sufficient basis to omit required marking or lighting.

iii. The absence of marking and/or lighting will not impair aviation safety.

3.5 NEW ZEALAND

The CAA NZ requirements relating to the lighting of obstacles are within the Civil Aviation Regulations Part 77 – “Objects and Activities Affecting Navigable Airspace”.

In brief the objective of Part 77 is to ensure that the Director -

1. is notified of objects and activities which can affect Navigable Airspace; and

2. carries out an aeronautical study and, according to laid down standards, makes a determination as to whether -
   - marking or lighting is required; or
   - the aviation industry needs to be given prior notification of the activity.

Part 77 contains the ICAO (International Civil Aviation Organization) standard on the marking of obstructions (see Appendix No 1 to this report) except for the marking of overhead lines. Preliminary investigative work regarding the line marking issue is understood to be underway to determine a set of criteria that could be used to assess whether a line needs to be marked or not. Recommendations will then be made to all interested/affected parties by way of another NPRM (Notice of Proposed Rule Making) dealing specifically with the marking of hazardous lines. This process is likely to take some time.

The current rules require the Director of CAA NZ to determine any structure 120m or higher is a hazard in navigable airspace; allows the Director to determine, based on the circumstances of each proposal, if a structure between 60m and 120m high is a hazard in navigable airspace and allows the Director to impose conditions or limitations for the marking and lighting of structures. There is provision for a decision that marking and lighting may be omitted when an aeronautical study shows the obstacle not to be of operational significance.
The current rules do not cover the marking or lighting wind turbines specifically and, therefore, by
default they would currently be treated as obstacles as per any other structure. However, there is
some evidence of the existence of draft conditions and limitations as follows: -

"Unless the aeronautical study finds that there are specific circumstances that:

(a) Require a higher level of lighting; or
(b) In the case of wind farms with turbines between 60m and 120m, allow a lower level of marking or lighting;

the following minimum conditions and limitations are to be included in all determinations:

1. Selected individual turbines at wind farms with turbines over 60m high will be required to have lighting.
2. The highest turbines, those at the extremities of the site, and other turbines around the perimeter of the site will be lit. The spacing between lit turbines will not exceed 1NM (1850m).
3. Lighting will be medium intensity red as defined in Rule Part 77, Appendix B10, i.e., an effective intensity of not less than 1600 candela of red light, and will flash between 20 and 60 times per minute.
4. The obstruction lights shall be located on or above the top of the nacelle, shall be visible from all directions, and may be shielded below the horizontal plane.
5. Obstruction lights at intermediate levels will not be required.
6. The painting of turbines with obstruction marking will not be required.
7. All wind farms will be depicted on aeronautical charts."

The current status of these draft rules for the marking and lighting of wind turbines and wind turbine farms is unknown. However, it does give some indication of the CAA NZ thinking on these matters.

It is presumed that a provision would still exist for a decision that marking and lighting may be omitted when an aeronautical study shows the obstacle (be it a wind turbine of wind turbine farm) not to be of operational significance.

4 AUSTRALIAN REGULATORY SCENE

The Civil Aviation Safety Authority (CASA) powers in respect of the control of obstacles in and around aerodromes flow from the Civil Aviation Regulations 1988 (CAR), Part 9, and Subpart 95, which provides for the marking or removal of hazardous objects within the obstacle limitation surfaces (OLS) of any aerodrome.

Civil Aviation Safety Regulation 1998 (CASR) Subpart 139.E covers the specific definitions of hazardous objects and the reporting requirements.

In summary CASR 139.E requires: -

1. Aerodrome operators to monitor the surrounding airspace for any object that might infringe the OLS and to notify CASA;
2. Any person who proposes to construct any structure which will be 110m or more AGL to inform CASA; and
3. CASA may determine whether the proposed structure(s) will be a hazardous object because of its location, height or lack of marking or lighting.

Detailed aerodrome design requirements are within the CASA Manual of Standards 139 – Aerodromes. Chapter 7 covers the detailed requirements for Obstacle Restriction and Limitation.

In support of the above regulations, CASA issued two Advisory Circulars; viz:

- AC 139-08(0) “Reporting of Tall Structures” April 2005
- AC 139-18(0) “Obstacle Marking and Lighting of Wind Farms” December 2005.

There is no doubt that CASA has the necessary regulatory powers to control the marking and removal of hazardous objects in and around aerodromes and for the reporting of tall structures. However, as noted in Section 2 of this report, there is some question as to CASA’s powers to insist on marking and / or lighting of obstacles outside the immediate area of an aerodrome. Further, the approach by CASA raised concerns amongst the wind farm industry, particularly in those cases where independent expert aviation advice recommended that marking and lighting was not needed.
because of low risks, yet CASA recommended to the contrary and noted that failure to follow the CASA advice would mean that the proponent of the wind farm would be “responsible for creating the hazard to aircraft safety and may be liable for their actions”.

As a consequence, in mid 2008, CASA withdrew Advisory Circular AC139-18(0) and initiated an internal review process to look at how wind farms located near aerodromes are assessed and regulated. It is understood that CASA aims to undertake an appropriate safety study into the risk to aviation posed by wind farms and for the outcome of that study to be used as a basis for developing a new set of guidelines.

HART Aviation has been advised that CASA is currently in the process of selecting a consultant to undertake the afore-mentioned study and the study is expected to take some 8 weeks, i.e., this will not be completed until around early September 2009. CASA has announced that this review process will include appropriate consultation with the aviation industry and other stakeholders.

It is understood that the CASA review will look at all obstacles, including wind turbines. There are plans to include a review of the latest regulatory position amongst other authorities throughout the world, including EASA, FAA, Transport Canada and CAA NZ. The ICAO position will also be part of considerations.

HART Aviation is of the opinion that this CASA review will, inter alia, lead to a regulatory change to provide CASA with the powers to legislate for the marking and lighting of obstacles outside the boundaries of aerodromes and specifically for en route operations.

### 5 SUMMARY OF MARKING & ILLUMINATING POLICIES ACROSS VARIOUS COUNTRIES.

The following table is an abbreviated summary of various countries policies in respect of the marking and lighting of wind turbines.

The Table is designed to enable an easy comparison between countries.

It should be noted that, since wind turbines have not been specifically addressed within the ICAO Annex 14 at this stage, those countries which have accepted Annex 14 as the basic standard are considering wind turbines in the same way as any other defined obstacle.

It should further be noted that most countries have accepted the principle that an aeronautical study may show that obstacle lighting is not necessary. The extent to which this provision has been exercised is unknown.

<table>
<thead>
<tr>
<th>Country</th>
<th>Marking and Illuminating Policy re Wind Turbines outside obstacle limitation surfaces (OLS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>Required if 110m or more AGL unless a specific aeronautical study indicates otherwise.</td>
</tr>
<tr>
<td>Canada</td>
<td>Required if 90m or higher near recognised VFR routes; 150m or higher AGL elsewhere unless a specific aeronautical study indicates otherwise.</td>
</tr>
<tr>
<td>Denmark</td>
<td>Required if equal or higher than 100m AGL.</td>
</tr>
<tr>
<td>Germany</td>
<td>Required if 150m or higher within towns; 100m or higher outside towns. May be required if greater than 20m if assessed as hazardous.</td>
</tr>
<tr>
<td>Netherlands</td>
<td>As per ICAO Annex 14; i.e., if 150m or more AGL, unless a specific aeronautical study indicates otherwise.</td>
</tr>
<tr>
<td>New Zealand</td>
<td>Required if 60m or higher unless a specific aeronautical study indicates otherwise. In the case of wind farms with turbines between 60m and 120m, a lower level of marking or lighting is permitted unless a specific aeronautical study indicates otherwise.</td>
</tr>
<tr>
<td>Norway</td>
<td>Uncertain – likely to be comparable to neighbouring Scandinavian countries.</td>
</tr>
<tr>
<td>Sweden</td>
<td>As per ICAO Annex 14; i.e., if 150m or more AGL, unless a specific aeronautical study indicates otherwise.</td>
</tr>
<tr>
<td>UK</td>
<td>Required if located close to aerodromes or 150m or more AGL. Provision for review exists.</td>
</tr>
<tr>
<td>USA</td>
<td>Required if overall height exceeds 200ft (61m) AGL unless a specific aeronautical study indicates otherwise.</td>
</tr>
</tbody>
</table>
Note that the ICAO Recommendation within Annex 14 is: “in areas beyond the limits of the OLS, at least those objects which extend to a height of 150m or more above ground elevation should be regarded as obstacles, unless a specific aeronautical study indicates that they do not constitute a hazard to aeroplanes”.

6 POTENTIAL RISKS TO AVIATION

In principle, the potential risk to aviation operations due to the development of wind turbines / wind farms fall into just two areas:

1. They have the potential of generating unwanted returns on primary radar and affecting the performance and propagation of Secondary Surveillance Radar (SSR), navigation aids and communication facilities, and
2. They represent a physical hazard which creates the potential risk of aircraft collision.

The following summarises the potential risks.

Primary Radar.

A large wind turbine can reflect the radar energy pulse and create unwanted returns on the radar screen. In particular, wind turbine developments can lead to receiver saturation, constant false alarms, obscuration of moving targets, false radar returns (clutter), plot extractor / filter memory overload and obstructions of the primary radar signal leading to shadows.


SSR does not rely on reflections from objects for detection. Instead, aircraft to be detected are required to carry a transponder, which replies to radar interrogations. Wind turbines, like any other large obstacle, can cause reflections if they are sufficiently close to the SSR facility and are within the “Radar Line of Sight”. Effects similar to those mentioned for Primary Radar can also occur.

Aeronautical Navigation Aids.

A wide range of systems, including aids such as ILS and VOR/DME, together with air-ground communication facilities, could potentially be affected by wind turbine developments. The wind turbines do not emit RF interference but their physical characteristics, depending on how they are sited in relation to the specific facility, can affect the propagation of the radiated signal from the affected system.

Air Traffic Services.

The effect on radar due to the location of a wind farm development may have an adverse effect on the overall performance of the communication, navigation and surveillance infrastructure.

Physical Obstruction.

The potential hazard created by a physical obstruction is self evident.

Wind turbines can also create turbulence, but this is likely to be of more concern to those involved in light sport aviation.
7 MITIGATING MEASURES

Primary Radar.

There is no evidence to suggest that any wind turbine development in Australia has had any adverse effect on the operation of Primary Radar. Nevertheless, the potential for adverse effects cannot be ignored. The closer a wind turbine is to a radar station, the greater the likelihood it will reflect energy back to the radar receiver. It also follows that the taller a turbine is, the greater the distance from the radar that it will remain within Radar / Radio Line of Sight, depending on the terrain. Further, since the turbines rotate to follow the wind, the cross-sectional area presented to the radar will vary depending on the wind direction. This makes the effect of the wind turbines on Primary Radar more unpredictable. The best mitigating measure, therefore, is to ensure that no turbine or turbine farm is positioned in the line of sight of any Primary Radar.


The same mitigating measure as for Primary Radar applies.

Aeronautical Navigation Aids.

There is sufficient empirical evidence to suggest that existing safeguarding arrangements in respect of navigation and landing aids and communication facilities provide adequate protection.

Air Traffic Services.

Ensuring the wind turbines are not positioned in the line of sight of any Primary Radar is likely to provide the necessary mitigation measure to limit any adverse effects on the operation of Air Traffic Services.

Physical Obstruction.

Mitigating the potential risk of an aircraft collision with wind turbines can be achieved by several means; such as one or more of the following:

1. Obstacle lights,
2. Identification on aeronautical maps,
3. Establishment of a Restricted or Danger Zone on aeronautical maps.
   a. This is an option but has not been done to date for high obstacles.

It is considered that the need, or otherwise, of each or any of the above, needs to be assessed using recognised risk assessment tools.

Note: With the exception of obstacle lights on the wind turbines themselves, none of the proposed mitigating measures mentioned above are likely to have any increased negative effect on the visual amenity of wind turbines.

Possible Future Alternative Mitigating Measures.

- Operational Mitigation.

The re-routing of aircraft around an area of wind turbine radar clutter may be required for the following reasons:

a) To maintain radar identification and situational awareness of flights,
b) To provide radar separation between primary radar returns, where these returns form the basis for separation being applied.

To date, in Australia, such has not been proved to be necessary.

- Equipment Mitigation.
This is primarily necessary to be considered if there is evidence of the wind farm developments interfering with radar signals.

Equipment mitigation action includes:

a) **PSR Blanking** – a procedure which enables blanking out or masking the area over the wind farm,

b) **Data-Fusion / In-Fill Radar** – a technique that enables the inhibition of adversely affected radar returns over a wind farm development and to overlay the radar returns from alternative unaffected radar.

c) **Physical or Terrain masking** – the use of existing terrain or a man made object to prevent a radar from “seeing” the turbines.

d) **Multilateration** – this is an alternative to traditional SSR systems.

e) **Non Auto-Initiation Zones** – this enables specific programming to inhibit distracting radar tracks from being generated from within the wind turbine cluster.

f) **Advanced Tracking Algorithms** – currently being trialled as a technique to determine the most probable radar target positions and exclude, for example, distorted signals from wind farms.

g) **Use of SSR only** – it may be possible to mask the unwanted primary radar returns generated from a wind farm and use SSR in certain specified areas.

h) **Transponder Mandatory Zones** – creating a requirement for the mandatory carriage and use of transponders in the vicinity of wind farms.

i) **Mechanical Beam Tilting** – the effect of clutter generated from wind farms could be reduced by raising the radar beam so it passes over the wind farm development.

j) **Radar Absorbent Materials** – such materials are available and, if used in the construction of the wind turbine towers and nacelles, would reduce the radar cross section of wind turbines / wind farms and, consequently, the potential for interference with the radar systems.

It should be noted that many of the above-mentioned equipment mitigation measures are in the development stage at the moment. In any event, to date, none of the mitigation measures mentioned above has proved to be necessary within Australia.

- **Safeguarding Maps.**

In some cases overseas, in order to assist the consultation process with wind energy developers and Local Planning Authorities, a number of airfield operators have developed specific wind turbine safeguarding maps. These depict those areas where development would be undesirable, possible, tolerated, acceptable, and any particular issues to be considered.

It is likely that any such safeguarding maps would highlight the need to avoid any wind farm developments within the OLS for the particular airport.

In the Australian context, there may be a further possibility of associating such safeguarding maps with the Airservices Australia issued noise exposure forecast (ANEF) charts developed in consultation with the airport operators. These charts are closely linked to land use planning guidelines as detailed in the Standards Association Australia (SAA) AS 2021-2000.

The production of such maps is to be encouraged.

- **Aircraft Detection Systems.**

New technologies have been recently developed for use as an alternative to conventional obstruction markings. These systems activate white flashing strobe lights, and in some cases an audio warning, based on potential aircraft collision but remain inactive at other times. These systems use radar to detect and track aircraft; when a potential collision is determined; the strobe lights are activated, followed by an audio warning.
One such system [Obstacle Collision Avoidance System (OCAS™)] has been approved for use in Canada. It is understood that other systems have been developed and will be approved on an on-going basis.

The OCAS is an all-weather, day and night, low-voltage radar-based obstacle avoidance system. This system is independent and does not require additional installation in the aircraft (e.g. transponder). The system activates strobe lights and, in certain locations, audio signals via the aircraft’s VHF radio, to alert pilots of potential collisions with obstacles, such as power lines, wind farms, bridges and towers. The lights and audio warning are inactive when there is no air traffic in the area.

The system detects aircraft on any track that may conflict within 5NM from the surface to 200 ft above the obstacle. The system's first warning is the activation of white strobe lights 30 seconds prior to reaching the obstacle. These strobe lights are medium-intensity during the day and low-intensity at night. A second warning, 20 seconds prior to reaching the obstacle, consists of an audio message that is transmitted on pre-selected VHF frequencies, stating “POWER LINE, POWER LINE,” or whatever type of obstruction is applicable. The timing of each warning can be modified as required by the approving authority.

This OCAS has been approved for use in Canada as an alternative to conventional marking systems on a site-specific basis, and is currently being installed at cable crossings and wind farms in the Pacific Region.

HART Aviation is of the view that the installation of an aircraft detection system, as described above, as opposed to obstacle lighting, which would be “on” all the time, is an operational decision for a wind farm developer and is likely to be based on commercial considerations. If a regulatory authority (e.g., CASA) requires obstacle lighting and the wind farm developer does not want permanent obstruction lighting installed for whatever reason (cost, community resistance, etc) the developer would need to seek approval from the regulatory authority concerned to introduce this system as an equivalent means of compliance with the obstacle lighting requirement. The fact that a system has been accepted by another national regulatory authority (e.g., the OCAS, which has been accepted by Transport Canada) would be a telling point and would almost certainly facilitate acceptance.

8 THE NEED FOR OBSTACLE LIGHTING

The current Australian regulations in respect of obstacle lighting is summarised in Section 4 of this report.

There is no dispute as to the need for obstacle lighting in the vicinity of aerodromes. The matter that is in question is in respect of the need for obstacle lighting in all cases for wind turbines / wind farms outside of the immediate vicinity of aerodromes, in particular outside the OLS, and in uncontrolled airspace.

There is clear evidence that other regulatory authorities have a provision not to require obstacle lighting where there is no perceived hazard to aviation operations. See Table 2, Section 5 in particular.

HART Aviation holds the view that each wind farm development proposal should be the subject of a formal risk assessment to identify the potential risks to aviation operations. Such a risk assessment should include a full appreciation of the need to meet the CASA and Local Planning Authority regulatory requirements and also should consider the needs of all aviation-related operations that might occur in the vicinity of the development. Such aviation-related operations should include, but not be limited to, airline and military operations, general aviation operations in the vicinity, private operations, private airfields, agricultural operations, parachuting operations, hang gliding, paragliding, ultralight, and so on.

HART Aviation is of the view that there will be cases where the needs for obstacle lighting on wind turbines and within wind farms will not be justified on any rational risk assessment.

As an example, if the following conditions existed: -
1. The wind turbines are outside the OLS of any nearby aerodrome,
   a. Hence would not interfere with any operations from the aerodromes concerned, and
   b. The further away the lower the risk of any such interference.
2. There is no penetration of the prescribed airspace,
   a. Hence would not interfere with aircraft operations within such airspace.
3. The lowest safe altitude for night VMC and IFR operations is not exceeded by the highest points of the turbines (i.e., the turbine blade tips),
   a. This reduces the risk of an aircraft colliding with any wind turbine under normal aircraft operating circumstances.
4. There is no penetration of any OLS,
   a. Hence would not interfere with any operations from the aerodromes concerned.
5. There is no interference with any operational procedures due to, such as, radar interference or air navigation aids interference,
   a. Hence would not interfere with any operations.
6. The wind turbines / wind farm is, or is to be, identified on aeronautical charts,
   a. Hence all aircraft operators should know of the existence of wind turbines / wind farms and can plan to avoid them as necessary as part of standard flight planning procedures.
7. There are other higher obstacles (such as a mountain of radio tower) in close proximity,
   a. which effectively shield the effect of the wind turbines as discreet obstacles.

- then HART Aviation believes it would be reasonable to take a position that obstacle lighting would not be necessary.

The optimum position is clearly to locate wind farm developments where they avoid any conflict with aviation operational aspects. Each proposal, however, would need to be assessed on an individual basis.

This is believed to be a matter which CASA needs to consider in the context of its internal review of these issues.

9 AERONAUTICAL CHARTS

An assessment was made as to the extent to which wind turbines and / or wind farms are currently identified on aeronautical maps.

Airservices AIS

Airservices Australia provides World Aeronautical Charts (WAC) through its Aeronautical Information Service Branch.

HART Aviation is advised that there are no restrictions to placing information on the position and height(s) of wind turbines / wind farms on the WAC. However, currently there is no special identification symbol – the normal obstacle symbol is just being used, but the words “wind farm” are usually added. A sample is shown at Appendix No 2 of this report.

Since the WACs are only updated every four years, there is a need to advise as to changes in the interim. The Airservices AIS does this in two steps.

Firstly, a Notice to Airmen (NOTAM) is issued advising of any changes.
As an example, the following NOTAM is current in respect of the Capital Wind Farm development near Bungendore, NSW.

C0452/09 NOTAMR C1071/09
Q) YMMM/QXXXX/V/NBO/E/000/005/
A) YMMM
B) 0901210056 C) PERM
E) WIND FARM BEING ERECTED BTN CANBERRA-GOULBURN
A NEW 63 TURBINE WIND FARM IS BEING ERECTED BETWEEN CANBERRA AND GOULBURN ON THE HIGH TERRAIN ADJACENT TO THE EASTERN SHORES OF LAKE GEORGE APROX BETWEEN 16DME AND 20 DME CANBERRA - VTC SPOT HEIGHTS 2670, 2959, 3083 AND 3146 ARE RELEVANT. BLADES AND TOWERS UP TO 410FT AGL.
F) SFC
G) 410FT AGL

C0016/09 NOTAMN
Q) YMMM/QOBCE/IV/BO/A/000/999/
A) YRTI
B) 0904240436 C) PERM
E) AD OBST - WIND TURBINE 289FT, 303DEG M 1.25NM FROM ARP AMD ERSA

The above NOTAM alerts all pilots who might plan to operate in the area concerned as to the existence of the wind farms and the various heights of the associated wind turbines.

The NOTAM is withdrawn once the details are included in the Aeronautical Information Publication (AIP) supplement, available to all pilots.

Once the relevant WAC is amended to include an icon, or icons, to identify the wind farm and wind turbines on the chart, the AIP supplement is then withdrawn.

The above process has worked well over the years and should continue to do so. All that is necessary to ensure the appropriate advice in respect of the presence of wind turbines and wind farms is recorded on the WACs is for Airservices AIS to be advised of their existence. This is essential and should be understood to be a mandatory element of any wind farm development.

RAAF AIS

The RAAF Aeronautical Information Service has been assigned the task of maintaining a data base of tall structures, the top measurement of which is:

- 30m or more above ground level – within 30km of an aerodrome; or
- 45m above ground level elsewhere.

The database is made available for use by mapping agencies such as Australian Surveying and Land Information Group, and domestic and international aviation organisations.

The reporting requirements are detailed in the CASA Advisory Circular AC 139-08(0), April 2005.

Apart from providing the obstacle information to interested parties outside the Defence network, the RAAF AIS develops its own series of maps.

The RAAF AIS has a publication called the Chart Amendment Document (CHAD). This is issued every eight weeks to coincide with every two Aeronautical Information and Regulation Control (AIRAC) cycles. The CHAD is used to promulgate details of amendments to existing charts in the JNC (Jet Navigation Chart), ONC (Operational Navigation Chart), TPC (Tactical Pilotage Chart) and JOG (Joint Operation Graphic) Air series. It also details new editions.
Only data that meets the CHAD criteria are included. Minor differences in height, elevation, length or position of existing features are not changed. The area of coverage includes parts of South East Asia, Australia and the Western Pacific.

It is reported that some of the RAAF AIS charts are decades old. Consequently, the number of amendments for some charts is considerable. Also, some of the amendments, particularly for charts covering Asia, are understood to be questionable as to their validity. This is believed to be due mostly to their unreliable source. There is also a problem of duplicate vertical obstructions caused by different reference datums.

The above mentioned military charts do include wind turbines, if they are notified of their existence.

Currently, only the standard vertical obstruction identification is used – there is no specific icon for wind turbines. However, the wind turbines are usually identified as wind motors on the military charts and sometimes marked as individual turbines or a group of turbines.

An example is given in Appendix No 3.

The RAAF AIS reports that there is some confusion as to whether to report the wind farms at the planning stage or the building stage of the operational stage. As a result, the RAAF AIS area find there is a need for close checking as some proposals do not proceed beyond the planning stage.

The international scene.

A detailed examination of the international scene was not undertaken.

However, it has been noted that Canada does include specific advice as to wind farms on its VHF Navigation Charts. A sample is shown at Appendix 4.

It is fully expected that other countries would be taking a similar approach.

10 CONCLUDING REMARKS

Apart from the clear need for consultation with Local Planning Authorities (LPAs), environmental and other concerned authorities, there are specific considerations to be addressed from the aviation perspective.

Firstly, there are clear rules regulating obstacles in the vicinity of aerodromes, particularly when there is a possibility that any such obstacle is likely to penetrate the obstacle limitation surfaces (OLS). Any wind farm developer would be well advised to take notice of the regulatory requirements in this respect; (refer Section 4 of this report). HART Aviation is of the view that wind farm developments should always avoid the defined obstacle limitation surface (OLS) areas at any aerodrome and, preferably, keep such developments as far away from aerodromes as possible and practical. Further, no development should be proposed below any known low level flight route or within any defined general aviation entry lanes.

Any wind farm proponent should be aware of the requirement to report to CASA any obstacle which will extend 110m or more above ground level (AGL).

It should also be noted that there is a requirement to report “tall structures” over 30m AGL to the RAAF AIS - [refer CASA AC 139-08(0)].

In HART Aviation’s view, CASA needs to know of any wind farm development at the planning stage so an aeronautical study / risk assessment can be done by them and the WTG developer can then know what CASA might or might not require. Desirably, it is considered that an aeronautical study / risk assessment should be done by the WTG developer too. This will equip the developer to challenge a decision by CASA should there be a need to do so.

The view is held that a formal aeronautical study / risk assessment should be undertaken for all wind turbine / wind farm development proposals. It should not be assumed that all such developments will require obstacle lighting.
HART Aviation is convinced that there will be certain cases where specific wind farm developments will be in such a low risk area from an aviation operational perspective that an aeronautical study / risk assessment and site specific investigation will lead to the conclusion that obstacle lighting will not be necessary. Such a case would be one which was located remote from any aviation operations.

It is considered that there will also be cases where the risk is not so high as to warrant extensive high intensity obstacle lighting and, in such instances, other risk mitigation options should be considered, including a lower intensity level of obstacle lighting.

There will be cases, of course, where the aeronautical study / risk assessment might demand the use of full high intensity flashing lights, but HART Aviation is of the view that such should not be the default position and other mitigating measures should also be considered.

It is considered that it would also be in the WTG developers’ interests to alert the RAAF AIS at the planning stage as a matter of courtesy. This is particularly important for the RAAF, which has defined low level operational routes. Advance notification will enable such to be known and avoided. At this time the WTG developers should also advise that they will inform the RAAF AIS when the planned WTG has commenced construction or whether a decision has been made not to proceed. In addition, Airservices AIS should be advised along the same lines.

It is essential that every effort should be made to ensure that the WTGs will eventually be included on all aeronautical charts as this is an important element in minimising the risks. There is some evidence that this has not universally happened to date. The aviation operators must have access to this information. Without it, any argument against the need for obstruction lights will be weakened.

Apart from consultation with CASA and the RAAF, during the development stage there is a need to consult any closely located aviation related operations which might be affected by the development. This includes, but is not restricted to, the owners and operators of any nearby private airfields, local agricultural operators, nearby parachuting clubs, local ultralight operators, and such.

Available records indicate that, worldwide, there are over 75,000 wind turbines of various sizes in operation, or planned to be in operation, and the number is quickly expanding. This includes both onshore and offshore facilities. There is clear evidence that these wind turbines / wind farms can co-exist successfully with aviation operations. Indeed, no evidence could be found of any aircraft collision with a wind turbine, or any other related incident. This, of course, is not without precautions in place like obstruction lights (in cases where a particular hazard has been identified), and appropriate identification on aeronautical maps.
To repeat, it is the strongly held view that any proposed WTG development should include a formal risk assessment dealing with the possibility of a collision by an aircraft. If this assessment reveals that the absence of marking and/or lighting will not impair aviation safety, then HART Aviation believes that it would be unreasonable to require any such marking or lighting. This should not be the default position and mitigation measures other than obstacle lighting should be part of the hazard mitigation considerations.

Conversely, if the study shows that the object may present such an extraordinary hazard potential that higher standards may be recommended for increased conspicuity to ensure safety to air navigation, then such higher standards should be imposed.
## LIST OF ABBREVIATIONS

<table>
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<td>AC</td>
<td>Advisory Circular</td>
<td>NOTAM</td>
<td>Notice to Airmen</td>
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<td>AGL</td>
<td>Above Ground Level</td>
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<td>AIP</td>
<td>Aeronautical Information Publication</td>
<td>NSW</td>
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<td>AiRAC</td>
<td>Aeronautical Information Regulation and Control</td>
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<td>AIS</td>
<td>Aeronautical Information Service</td>
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<td>Obstacle Collision Avoidance System</td>
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<td>CAA</td>
<td>Civil Aviation Authority</td>
<td>OLS</td>
<td>Obstacle Limitation Surface</td>
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<td>Civil Aviation Publication</td>
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<td>CASA</td>
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<td>Royal Australian Air Force</td>
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<td>CFR</td>
<td>Code of Federal Regulations</td>
<td>RF</td>
<td>Radio Frequency</td>
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<td>CHAD</td>
<td>Chart Amendment Document</td>
<td>SA</td>
<td>South Australia</td>
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<td>DME</td>
<td>Distance Measuring Equipment</td>
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<td>Search and Rescue</td>
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<td>European Aviation Safety Agency</td>
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<td>Standards and Recommended Practices</td>
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<td>En Route Chart</td>
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<td>Secondary Surveillance Radar</td>
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<td>En Route Supplement Australia</td>
<td>TP</td>
<td>Technical Publication</td>
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<td>European Union</td>
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<td>FAA</td>
<td>Federal Aviation Administration</td>
<td>UK</td>
<td>United Kingdom</td>
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<td>ICAO</td>
<td>International Civil Aviation Organisation</td>
<td>USA</td>
<td>United States of America</td>
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<td>IEA</td>
<td>International Energy Authority</td>
<td>VFR</td>
<td>Visual Flight Rules</td>
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<td>IFR</td>
<td>Instrument Flight Rules</td>
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<td>Very High Frequency</td>
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<td>ILS</td>
<td>Instrument Landing System</td>
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<td>Local Planning Authority</td>
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<td>NM</td>
<td>Nautical Mile</td>
<td>WTG</td>
<td>Wind Turbine Generator</td>
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12 REFERENCE DOCUMENTS

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34. Wind Projects in Victoria. 22 May 2009.
APPENDICES

No 1: Excerpts from ICAO Annex 14 – Aerodromes Volume 1 – Aerodrome Design and Operations.

CHAPTER 4. OBSTACLE RESTRICTION AND REMOVAL

4.1 Obstacle limitation surfaces

Note 1.— The objectives of the specifications in this chapter are to define the airspace around aerodromes to be maintained free from obstacles so as to permit the intended aeroplane operations at the aerodromes to be conducted safely and to prevent the aerodromes from becoming unusable by the growth of obstacles around the aerodromes. This is achieved by establishing a series of obstacle limitation surfaces that define the limits to which objects may project into the airspace.

Note 2.— Objects which penetrate the obstacle limitation surfaces contained in this chapter may in certain circumstances cause an increase in the obstacle clearance altitude/height for an instrument approach procedure or any associated visual circling procedure. Criteria for evaluating obstacles are contained in Procedures for Air Navigation Services—Aircraft Operations (PANS-OPS) (Doc 8160).

Note 3.— The establishment of, and requirements for, an obstacle protection surface for visual approach slope indicator systems are specified in 5.3.5.41 to 5.3.5.45.

Inner horizontal surface

4.1.4 Description.— Inner horizontal surface. A surface located in a horizontal plane above an aerodrome and its environs.

4.1.5 Characteristics.— The radius or outer limits of the inner horizontal surface shall be measured from a reference point or points established for such purpose.

Note— The shape of the inner horizontal surface need not necessarily be circular. Guidance on determining the extent of the inner horizontal surface is contained in the Airport Services Manual, Part 6.

4.1.6 The height of the inner horizontal surface shall be measured above an elevation datum established for such purpose.

Note— Guidance on determining the elevation datum is contained in the Airport Services Manual, Part 6.

Approach surface

4.1.7 Description.— Approach surface. An inclined plane or combination of planes preceding the threshold.

4.1.8 Characteristics.— The limits of the approach surface shall comprise:

a) an inner edge of specified length, horizontal and perpendicular to the extended centre line of the runway and located at a specified distance before the threshold;

b) two sides originating at the ends of the inner edge and diverging uniformly at a specified rate from the extended centre line of the runway;

c) an outer edge parallel to the inner edge; and

d) The above surfaces shall be varied when lateral offset, offset or curved approaches are utilized, specifically, two sides originating at the ends of the inner edge and diverging uniformly at a specified rate from the extended centre line of the lateral offset, offset or curved ground track.

4.1.9 The elevation of the inner edge shall be equal to the elevation of the mid-point of the threshold.

4.1.10 The slope(s) of the approach surface shall be measured in the vertical plane containing the centre line of the runway and shall continue containing the centre line of any lateral offset or curved ground track.
Figure 4.1. Obstacle limitation surfaces

See Figure 4.2 for inner transitional and balked landing obstacle limitation surfaces and Attachment B for a three-dimensional view.
**Chapter 4**

**Annex 1d — Aerodromes**

![Diagram of inner approach, inner transitional, and balked landing obstacle limitation surfaces](image)

Figure 4.2. Inner approach, inner transitional, and balked landing obstacle limitation surfaces

**Inner approach surface**

4.1.11 Description — Inner approach surface. A rectangular portion of the approach surface immediately preceding the threshold.

4.1.12 Characteristics — The limits of the inner approach surface shall comprise:

a) an inner edge coincident with the location of the inner edge of the approach surface but of its own specified length;

b) two sides originating at the ends of the inner edge and extending parallel to the vertical plane containing the centre line of the runway, and

c) an outer edge parallel to the inner edge.

**Transitional surface**

4.1.13 Description — Transitional surface. A complex surface along the side of the strip and part of the side of the approach surface, that slopes upwards and outwards to the inner horizontal surface.

4.1.14 Characteristics — The limits of a transitional surface shall comprise:

a) a lower edge beginning at the intersection of the side of the approach surface with the inner horizontal surface and
Annex 14 — Aerodromes

extending down the side of the approach surface to the inner edge of the approach surface and from there along the length of the strip parallel to the runway centre line; and

b) an upper edge located in the plane of the inner horizontal surface.

4.1.15 The elevation of a point on the lower edge shall be:

a) along the side of the approach surface — equal to the elevation of the approach surface at that point; and

b) along the strip — equal to the elevation of the nearest point on the centre line of the runway or its extension.

Note — As a result of b) the transitional surface along the strip will be curved if the runway profile is curved or a plane if the runway profile is a straight line. The intersection of the transitional surface with the inner horizontal surface will also be a curved or straight line depending on the runway profile.

4.1.16 The slope of the transitional surface shall be measured in a vertical plane at right angles to the centre line of the runway.

Inner transitional surface

Note — It is intended that the inner transitional surface be the controlling obstacle limitation surface for navigation aids, aircraft and other vehicles that must be near the runway and which is not to be penetrated except for floatable objects. The transitional surface described in 4.1.13 is intended to remain as the controlling obstacle limitation surface for buildings, etc.

4.1.17 Description — Inner transitional surface. A surface similar to the transitional surface but closer to the runway.

4.1.18 Characteristics — The limits of an inner transitional surface shall comprise:

a) a lower edge beginning at the end of the inner approach surface and extending down the side of the inner approach surface to the inner edge of that surface, from there along the strip parallel to the runway centre line to the inner edge of the balked landing surface and from there up the side of the balked landing surface to the point where the side intersects the inner horizontal surface; and

b) an upper edge located in the plane of the inner horizontal surface.

4.1.19 The elevation of a point on the lower edge shall be:

a) along the side of the inner approach surface and balked landing surface — equal to the elevation of the particular surface at that point; and

b) along the strip — equal to the elevation of the nearest point on the centre line of the runway or its extension.

Note — As a result of b) the inner transitional surface along the strip will be curved if the runway profile is curved or a plane if the runway profile is a straight line. The intersection of the inner transitional surface with the inner horizontal surface will also be a curved or straight line depending on the runway profile.

4.1.20 The slope of the inner transitional surface shall be measured in a vertical plane at right angles to the centre line of the runway.

Balked landing surface

4.1.21 Description — Balked landing surface. An inclined plane located at a specified distance after the threshold, extending between the inner transitional surface.

4.1.22 Characteristics — The limits of the balked landing surface shall comprise:

a) an inner edge horizontal and perpendicular to the centre line of the runway and located at a specified distance after the threshold;

b) two sides originating at the ends of the inner edge and diverging uniformly at a specified rate from the vertical plane containing the centre line of the runway, and

c) an outer edge parallel to the inner edge and located in the plane of the inner horizontal surface.

4.1.23 The elevation of the inner edge shall be equal to the elevation of the runway centre line at the location of the inner edge.

4.1.24 The slope of the balked landing surface shall be measured in the vertical plane containing the centre line of the runway.

Take-off climb surface

4.1.25 Description — Take-off climb surface. An inclined plane or other specified surface beyond the end of a runway or clearway.

4.1.26 Characteristics — The limits of the take-off climb surface shall comprise:

a) an inner edge horizontal and perpendicular to the centre line of the runway and located either at a specified distance beyond the end of the runway or at the end of the clearway when such is provided and its length exceeds the specified distance;

b) two sides originating at the ends of the inner edge, diverging uniformly at a specified rate from the take-off
track to a specified final width and continuing thereafter at that width for the remainder of the length of the take-off climb surface; and

c) an outer edge horizontal and perpendicular to the specified take-off track.

4.1.27 The elevation of the inner edge shall be equal to the highest point on the extended runway centre line between the end of the runway and the inner edge, except that when a clearway is provided the elevation shall be equal to the highest point on the ground on the centre line of the clearway.

4.1.28 In the case of a straight take-off flight path, the slope of the take-off climb surface shall be measured in the vertical plane containing the centre line of the runway.

4.1.29 In the case of a take-off flight path involving a turn, the take-off climb surface shall be a complex surface containing the horizontal normals to its centre line, and the slope of the centre line shall be the same as that for a straight take-off flight path.

4.2 Obstacle limitation requirements

Note.—The requirements for obstacle limitation surfaces are specified on the basis of the intended use of a runway, i.e. take-off or landing and type of approach, and are intended to be applied when such use is made of the runway. In cases where operations are conducted to or from both directions of a runway, then the function of certain surfaces may be nullified because of more stringent requirements of another lower surface.

Non-instrument runways

4.2.1 The following obstacle limitation surfaces shall be established for a non-instrument runway:

— conical surface;
— inner horizontal surface;
— approach surface; and
— transitional surfaces.

4.2.2 The heights and slopes of the surfaces shall not be greater than, and their other dimensions not less than, those specified in Table 4.1.

4.2.3 New objects or extensions of existing objects shall not be permitted above an approach or transitional surface except when, in the opinion of the appropriate authority, the new object or extension would be shielded by an existing immovable object.

Note.—Circumstances in which the shielding principle may reasonably be applied are described in the Airport Services Manual, Part 6.

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4.2.4 Recommendation.—New objects or extensions of existing objects should not be permitted above the conical surface or inner horizontal surface except when, in the opinion of the appropriate authority, the object would be shielded by an existing immovable object, or after aeronautical study it is determined that the object would not adversely affect the safety or significantly affect the regularity of operations of aeroplanes.

4.2.5 Recommendation.—Existing objects above any of the surfaces required by 4.2.1 should as far as practicable be removed except when, in the opinion of the appropriate authority, the object is shielded by an existing immovable object, or after aeronautical study it is determined that the object would not adversely affect the safety or significantly affect the regularity of operations of aeroplanes.

Note.—Because of transverse or longitudinal slopes on a strip, in certain cases the inner edge or portions of the inner edge of the approach surface may be below the corresponding elevation of the strip. It is not intended that the strip be graded to conform with the inner edge of the approach surface, nor is it intended that terrain or objects which are above the approach surface beyond the end of the strip, but below the level of the strip, be removed unless it is considered they may endanger aeroplanes.

4.2.6 Recommendation.—In considering proposed construction account should be taken of the possible future development of an instrument runway and consequent requirement for more stringent obstacle limitation surfaces.

Non-precision approach runways

4.2.7 The following obstacle limitation surfaces shall be established for a non-precision approach runway:

— conical surface;
— inner horizontal surface;
— approach surface; and
— transitional surfaces.

4.2.8 The heights and slopes of the surfaces shall not be greater than, and their other dimensions not less than, those specified in Table 4.1, except in the case of the horizontal section of the approach surface (see 4.2.9).

4.2.9 The approach surface shall be horizontal beyond the point at which the 2.5 per cent slope intersects:

a) a horizontal plane 150 m above the threshold elevation; or
b) the horizontal plane passing through the top of any object that governs the obstacle clearance altitude/height (OCA/H);

whichever is the higher.
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**Volume I**

#### Table 4.1. Dimensions and slopes of obstacle limitation surfaces — Approach runways

**APPROACH RUNWAYS**

<table>
<thead>
<tr>
<th>Surface and dimensions</th>
<th>L</th>
<th>Non-instrument</th>
<th>Non-precision approach</th>
<th>Precision approach category</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>Code number 3</td>
<td>Code number 4</td>
<td>Code number 1</td>
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<td></td>
<td>Code number 2</td>
</tr>
<tr>
<td></td>
<td>(3)</td>
<td></td>
<td></td>
<td>Code number 3</td>
</tr>
<tr>
<td></td>
<td>(4)</td>
<td></td>
<td></td>
<td>Code number 4</td>
</tr>
<tr>
<td></td>
<td>(5)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(6)</td>
<td></td>
<td></td>
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<tr>
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<td>(7)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(11)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**CONICAL**

- **Slope:** 5% 5% 5% 5% 5% 5% 5% 5% 5% 5%
- **Height:** 35 m 55 m 75 m 100 m 60 m 75 m 100 m 60 m 100 m 100 m

**INNER HORIZONTAL**

- **Height:** 45 m 45 m 45 m 45 m 45 m 45 m 45 m 45 m 45 m 45 m
- **Radius:** 3 060 m 2 500 m 2 000 m 4 000 m 4 000 m 4 000 m 4 000 m 3 500 m 4 000 m 4 000 m

**INNER APPROACH**

- **Width:** — — — — — — — — 90 m 120 m 120 m²
- **Distance from threshold:** — — — — — — — — 60 m 60 m 60 m
- **Length:** — — — — — — — — 900 m 900 m 900 m

**APPROACH**

- **Length of inner edge:** 60 m 60 m 60 m 60 m 60 m 60 m 60 m 60 m 60 m 60 m
- **Distance from threshold:** 30 m 30 m 30 m 30 m 30 m 30 m 30 m 30 m 30 m 30 m
- **Divergence (each side):** 10% 10% 10% 10% 10% 10% 10% 10% 10% 10%

**FIRST SECTION**

- **Length:** 990 m 3 090 m 3 090 m 3 090 m 3 090 m 3 090 m 3 090 m 3 090 m 3 090 m 3 090 m
- **Slope:** 3% 3% 3% 3% 3% 3% 3% 3% 3% 3%

**SECOND SECTION**

- **Length:** — — — — — 3 000 m² 3 000 m² 12 000 m 12 000 m² 3 000 m²
- **Slope:** — — — — — 3.5% 3.5% 3% 3% 3.5%

**HORIZONTAL SECTION**

- **Length:** — — — — — 0 400 m² 0 400 m² — 0 400 m² 0 400 m²

**TOTAL LENGTH**

- **Length:** 13 000 m 15 000 m 15 000 m 15 000 m 15 000 m 15 000 m 15 000 m 15 000 m 15 000 m 15 000 m

**TRANSITIONAL**

- **Slope:** 30% 20% 14.5% 14.5% 14.5% 14.5% 14.5% 14.5% 14.5% 14.5%

**INNER TRANSITIONAL**

- **Slope:** — — — — — — — — 46% 33.3% 33.3%

**BAKED LANDING SURFACE**

- **Length of inner edge:** 60 m 120 m 120 m
- **Distance from threshold:** — — — — — — — — 1 800 m 1 800 m
- **Divergence (each side):** — — — — — 10% 10% 10% 10% 10%
- **Slope:** — — — — — 4% 3.23% 3.13% 3.13% 3.13%

---

**Notes:**

a. All dimensions are measured horizontally unless specified otherwise.
b. Variable length (see 4.2.9 or 4.2.17).
c. Distance to the end of strip.
d. Or end of runway whichever is less.
e. Where the code letter is F (Column 1 of Table 1-1), the width is increased to 155 m.
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4.2.10 New objects or extensions of existing objects shall not be permitted above an approach surface within 3,000 m of the inner edge or above a transitional surface except when, in the opinion of the appropriate authority, the new object or extension would be shielded by an existing immovable object.

Note — Circumstances in which the shielding principle may reasonably be applied are described in the Airport Services Manual, Part 5.

4.2.11 Recommendation — New objects or extensions of existing objects should not be permitted above the approach surface beyond 3,000 m from the inner edge, the conical surface or inner horizontal surface except when, in the opinion of the appropriate authority, the object would be shielded by an existing immovable object, or after aeronautical study it is determined that the object would not adversely affect the safety or significantly affect the regularity of operations of aeroplanes.

Note — Because of transverse or longitudinal slopes on a strip, in certain cases the inner edge or portions of the inner edge of the approach surface may be below the corresponding elevation of the strip. It is not intended that the strip be graded to conform with the inner edge of the approach surface, nor is it intended that terrain or objects which are above the approach surface beyond the end of the strip, but below the level of the strip, be removed unless it is considered they may endanger aeroplanes.

Precision approach runways

Note 1 — See 9.9 for information regarding siting of equipment and installations on operational areas.

Note 2 — Guidance on obstacle limitation surfaces for precision approach runways is given in the Airport Services Manual, Part 5.

4.2.13 The following obstacle limitation surfaces shall be established for a precision approach runway category I:

— conical surface;
— inner horizontal surface;
— approach surface; and
— transitional surfaces.

4.2.14 Recommendation — The following obstacle limitation surfaces should be established for a precision approach runway category I.

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4.2.15 The following obstacle limitation surfaces shall be established for a precision approach runway category II or III:

— conical surface;
— inner horizontal surface;
— approach surface and inner approach surface;
— transitional surfaces;
— inner transitional surfaces; and
— balked landing surface.

4.2.16 The heights and slopes of the surfaces shall not be greater than, and their other dimensions not less than, those specified in Table 4.1, except in the case of the horizontal section of the approach surface (see 4.2.17).

4.2.17 The approach surface shall be horizontal beyond the point at which the 2.5 per cent slope intersects:

a) a horizontal plane 150 m above the threshold elevation; or

b) the horizontal plane passing through the top of any object that governs the obstacle clearance limit;

whichever is the higher.

4.2.18 Fixed objects shall not be permitted above the inner approach surface, the inner transitional surface or the balked landing surface, except for movable objects which because of their function must be located on the strip. Mobile objects shall not be permitted above these surfaces during the use of the runway for landing.

4.2.19 New objects or extensions of existing objects shall not be permitted above an approach surface or a transitional surface except when, in the opinion of the appropriate authority, the new object or extension would be shielded by an existing immovable object.

Note — Circumstances in which the shielding principle may reasonably be applied are described in the Airport Services Manual, Part 5.

4.2.20 Recommendation — New objects or extensions of existing objects should not be permitted above the conical surface and the inner horizontal surface except when, in the opinion of the appropriate authority, an object would be shielded by an existing immovable object, or after aeronautical study it is determined that the object would not adversely affect the safety or significantly affect the regularity of operations of aeroplanes.

4.2.21 Recommendation — Existing objects above an approach surface, a transitional surface, the conical surface and inner horizontal surface should as far as practicable be removed except when, in the opinion of the appropriate
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4.2.24 Recommendation.— The operational characteristics of aeroplanes for which the runway is intended should be examined to see if it is desirable to reduce the slope specified in Table 4-2 when critical operating conditions are to be catered to. If the specified slope is reduced, corresponding adjustment in the length of take-off climb surface should be made so as to provide protection to a height of 300 m.

Note.— When local conditions differ widely from sea level standard atmospheric conditions, it may be advisable for the slope specified in Table 4-2 to be reduced. The degree of this reduction depends on the divergence between local conditions and sea level standard atmospheric conditions, and on the performance characteristics and operational requirements of the aeroplanes for which the runway is intended.

4.2.25 New objects or extensions of existing objects shall not be permitted above a take-off climb surface except when, in the opinion of the appropriate authority, the new object or extension would be shielded by an existing immovable object.

Note.— Circumstances in which the shielding principle may reasonably be applied are described in the Airport Services Manual, Part 6.

4.2.26 Recommendation.— If an object reaches the 2 per cent (1.5%) take-off climb surface, new objects should be limited to preserve the existing obstacle free surface or a surface down to a slope of 1.6 per cent (1.625%).

Table 4-2. Dimensions and slopes of obstacle limitation surfaces

<table>
<thead>
<tr>
<th>RUNWAYS MEANT FOR TAKE-OFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface and dimensions&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>(1)</td>
</tr>
<tr>
<td>TAKE-OFF CLIMB</td>
</tr>
<tr>
<td>Length of inner edge</td>
</tr>
<tr>
<td>Distance from runway end&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Divergence (each side)</td>
</tr>
<tr>
<td>Final width</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Length</td>
</tr>
<tr>
<td>Slope</td>
</tr>
</tbody>
</table>

<sup>a</sup> All dimensions are measured horizontally unless specified otherwise.
<sup>b</sup> The take-off climb surface starts at the end of the clearway if the clearway length exceeds the specified distance.
<sup>c</sup> 1 800 m when the intended track includes changes of heading greater than 15° for operations conducted in IMC, VMC by night.
<sup>d</sup> See 4.2.24 and 4.2.26.
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4.2.27 **Recommendation.**— Existing objects that extend above a take-off climb surface should as far as practicable be removed except when, in the opinion of the appropriate authority, an object is shielded by an existing immovable object, or after aeromedical study it is determined that the object would not adversely affect the safety or significantly affect the regularity of operations of aeroplanes.

Note.— Because of transverse slopes on a strip or clearway, in certain cases portions of the inner edge of the take-off climb surface may be below the corresponding elevation of the strip or clearway. It is not intended that the strip or clearway be graded to conform with the inner edge of the take-off climb surface, nor is it intended that terrain or objects which are above the take-off climb surface beyond the end of the strip or clearway, but below the level of the strip or clearway, be removed unless it is considered they may endanger aeroplanes. Similar considerations apply at the junction of a clearway and strip where differences in transverse slopes exist.

4.3 **Objects outside the obstacle limitation surfaces**

4.3.1 **Recommendation.**— Arrangements should be made to enable the appropriate authority to be consulted concerning proposed construction beyond the limits of the obstacle limitation surfaces that extend above a height established by that authority, in order to permit an aeromedical study of the effect of such construction on the operation of aeroplanes.

4.3.2 **Recommendation.**— In areas beyond the limits of the obstacle limitation surfaces, at least those objects which extend to a height of 150 m or more above ground elevation should be regarded as obstacles, unless a special aeromedical study indicates that they do not constitute a hazard to aeroplanes.

Note.— This study may have regard to the nature of operations concerned and may distinguish between day and night operations.

4.4 **Other objects**

4.4.1 **Recommendation.**— Objects which do not project through the approach surface but which would nevertheless adversely affect the optimum siting or performance of visual or non-visual aids should, as far as practicable, be removed.

4.4.2 **Recommendation.**— Anything which may, in the opinion of the appropriate authority after aeromedical study, endanger aeroplanes on the movement area or in the air within the limits of the inner horizontal and conical surfaces should be regarded as an obstacle and should be removed in so far as practicable.

Note.— In certain circumstances, objects that do not project above any of the surfaces enumerated in 4.1 may constitute a hazard to aeroplanes as, for example, where there are one or more isolated objects in the vicinity of an aerodrome.
CHAPTER 6. VISUAL AIDS FOR DENOTING OBSTACLES

6.1 Objects to be marked and/or lighted

Note.—The marking and/or lighting of obstacles is intended to reduce hazards to aircraft by indicating the presence of the obstacles. It does not necessarily reduce operating limitations which may be imposed by an obstacle.

6.1.1 Recommendation.—A fixed obstacle that extends above a take-off climb surface within 3,000 m of the inner edge of the take-off climb surface should be marked and, if the runway is used at night, lighted, except that:

a) such marking and lighting may be omitted when the obstacle is shielded by another fixed obstacle;

b) the marking may be omitted when the obstacle is lighted by medium-intensity obstacle lights, Type A, by day and its height above the level of the surrounding ground does not exceed 150 m;

c) the marking may be omitted when the obstacle is lighted by high-intensity obstacle lights by day; and

d) the lighting may be omitted where the obstacle is a lighthouse and an aeronautical study indicates the lighthouse light to be sufficient.

6.1.2 Recommendation.—A fixed object, other than an obstacle, adjacent to a take-off climb surface should be marked and, if the runway is used at night, lighted if such marking and lighting is considered necessary to ensure its avoidance, except that the marking may be omitted when:

a) the object is lighted by medium-intensity obstacle lights, Type A, by day and its height above the level of the surrounding ground does not exceed 150 m; or

b) the object is lighted by high-intensity obstacle lights by day.

6.1.3 A fixed obstacle that extends above an approach or transitional surface within 3,000 m of the inner edge of the approach surface shall be marked and, if the runway is used at night, lighted, except that:

a) such marking and lighting may be omitted when the obstacle is shielded by another fixed obstacle;

b) the marking may be omitted when the obstacle is lighted by medium-intensity obstacle lights, Type A, by day and its height above the level of the surrounding ground does not exceed 150 m;

c) the marking may be omitted when the obstacle is lighted by high-intensity obstacle lights by day; and

d) the lighting may be omitted where the obstacle is a lighthouse and an aeronautical study indicates the lighthouse light to be sufficient.

6.1.4 Recommendation.—A fixed obstacle above a horizontal surface should be marked and, if the aerodrome is used at night, lighted except that:

a) such marking and lighting may be omitted when:

1) the obstacle is shielded by another fixed obstacle; or

2) for a circuit extensively obstructed by immovable objects or terrain, procedures have been established to ensure safe vertical clearance below prescribed flight paths; or

3) an aeronautical study shows the obstacle not to be of operational significance;

b) the marking may be omitted when the obstacle is lighted by medium-intensity obstacle lights, Type A, by day and its height above the level of the surrounding ground does not exceed 150 m;

c) the marking may be omitted when the obstacle is lighted by high-intensity obstacle lights by day; and

d) the lighting may be omitted where the obstacle is a lighthouse and an aeronautical study indicates the lighthouse light to be sufficient.

6.1.5 A fixed object that extends above an obstacle protection surface shall be marked and, if the runway is used at night, lighted.

Note.—See 3.3.5 for information on the obstacle protection surface.
6.1.6 Vehicles and other mobile objects, excluding aircraft, on the movement area of an aerodrome are obstacles and shall be marked and, if the vehicles and aerodrome are used at night or in conditions of low visibility, lighted, except that aircraft servicing equipment and vehicles used only on aprons may be exempt.

6.1.7 Elevated aeronautical ground lights within the movement area shall be marked so as to be conspicuous by day. Obstacle lights shall not be installed on elevated ground lights or signs in the movement area.

6.1.8 All obstacles within the distance specified in Table 3-1, column 11 or 12, from the centre line of a taxiway, an apron, taxiway or aircraft stand taxiline shall be marked and, if the taxiway, apron taxiway or aircraft stand taxiline is used at night, lighted.

6.1.9 Recommendation.—Obstacles in accordance with 4.3.2 should be marked and lighted, except that the marking may be omitted when the obstacle is lighted by high-intensity obstacle lights by day.

6.1.10 Recommendation.—Overhead wires, cables, etc., crossing a runway, valley or highway should be marked and their supporting towers marked and lighted if an aeronautical study indicates that the wire or cables could constitute a hazard to aircraft, except that the marking of the supporting towers may be omitted when they are lighted by high-intensity obstacle lights by day.

6.1.11 Recommendation.—When it has been determined that an overhead wire, cable, etc., needs to be marked but it is not practicable to install markers on the wire, cable, etc., then high-intensity obstacle lights, Type B, should be provided on the supporting towers.

6.2 Marking of objects

General

6.2.1 All fixed objects to be marked shall, whenever practicable, be coloured, but if this is not practicable, markers or flags shall be displayed on or above them, except that objects that are sufficiently conspicuous by their shape, size or colour need not be otherwise marked.

6.2.2 All mobile objects to be marked shall be coloured or display flags.

Use of colours

6.2.3 Recommendation.—An object should be coloured to show a chequered pattern if it has essentially unbroken surfaces and its projection on any vertical plane equals or exceeds 4.5 m in both dimensions. The pattern shall consist of rectangles of not less than 1.5 m and not more than 3 m on a side, the corners being of the darker colour. The colours of the pattern should contrast each with the other and with the background against which they will be seen. Orange and white or alternatively red and white should be used, except where such colours merge with the background. (See Figure 6-1.)

6.2.4 Recommendation.—An object should be coloured to show alternating contrasting bands if:

a) it has essentially unbroken surfaces and has one dimension, horizontal or vertical, greater than 1.5 m, and the other dimension, horizontal or vertical, less than 4.5 m; or
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b) it is of skeletal type with either a vertical or a horizontal dimension greater than 1.5 m.

The bands should be perpendicular to the longest dimension and have a width approximately 1/7 of the longest dimension or 30 m, whichever is less. The colours of the bands should contrast with the background against which they will be seen. Orange and white should be used, except where such colours are not conspicuous when viewed against the background. The bands on the extremities of the object should be of the darker colour. (See Figures 6.1 and 6.2.)

Note—Table 6-1 shows a formula for determining band widths and for having an odd number of bands, thus permitting both the top and bottom bands to be of the darker colour.

6.2.5 Recommendation—An object should be coloured in a single conspicuous colour if its projection on any vertical plane has both dimensions less than 1.5 m. Orange or red should be used, except where such colours merge with the background.

Note—Against some backgrounds it may be found necessary to use a different colour from orange or red to obtain sufficient contrast.

6.2.6 Recommendation—When mobile objects are marked by colour, a single conspicuous colour, preferably red or yellowish green for emergency vehicles and yellow for service vehicles should be used.

Table 6-1. Marking band widths

<table>
<thead>
<tr>
<th>Longest dimension</th>
<th>Greater than</th>
<th>Not exceeding</th>
<th>Band width</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5 m</td>
<td>210 m</td>
<td>1/7 of longest dimension</td>
<td></td>
</tr>
<tr>
<td>210 m</td>
<td>270 m</td>
<td>1/6 &quot;&quot; &quot;&quot; &quot;&quot;</td>
<td></td>
</tr>
<tr>
<td>270 m</td>
<td>330 m</td>
<td>1/11 &quot;&quot; &quot;&quot; &quot;&quot;</td>
<td></td>
</tr>
<tr>
<td>330 m</td>
<td>390 m</td>
<td>1/12 &quot;&quot; &quot;&quot; &quot;&quot;</td>
<td></td>
</tr>
<tr>
<td>390 m</td>
<td>450 m</td>
<td>1/15 &quot;&quot; &quot;&quot; &quot;&quot;</td>
<td></td>
</tr>
<tr>
<td>450 m</td>
<td>510 m</td>
<td>1/17 &quot;&quot; &quot;&quot; &quot;&quot;</td>
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<tr>
<td>510 m</td>
<td>570 m</td>
<td>1/19 &quot;&quot; &quot;&quot; &quot;&quot;</td>
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</tr>
<tr>
<td>570 m</td>
<td>630 m</td>
<td>1/21 &quot;&quot; &quot;&quot; &quot;&quot;</td>
<td></td>
</tr>
</tbody>
</table>

Use of markers

6.2.7 Markers displayed on or adjacent to objects shall be located in conspicuous positions so as to retain the general definition of the object and shall be recognizable in clear weather from a distance of at least 1 000 m for an object to be viewed from the six and 300 m for an object to be viewed from the ground in all directions in which an aircraft is likely to approach the object. The shape of markers shall be distinctive to the extent necessary to ensure that they are not mistaken for markers employed to convey other information, and they shall be such that the hazard presented by the object they mark is not increased.

6.2.8 Recommendation—A marker displayed on an overhead wire, cable, etc., should be spherical and have a diameter of not less than 60 cm.

6.2.9 Recommendation—The spacing between two consecutive markers or between a marker and a supporting tower should be appropriate to the diameter of the marker, but in no case should the spacing exceed:

a) 30 m where the marker diameter is 60 cm, progressively increasing with the diameter of the marker to

b) 35 m where the marker diameter is 80 cm and further progressively increasing to a maximum of

c) 40 m where the marker diameter is of at least 130 cm.

Where multiple wires, cables, etc. are involved, a marker should be located not lower than the level of the highest wire at the point marked.

6.2.10 Recommendation—A marker should be of one colour. When installed, white and red, or white and orange markers should be displayed alternately. "The colour selected should contrast with the background against which it will be seen."

Use of flags

6.2.11 Flags used to mark objects shall be displayed around, on top of, or around the highest edge of, the object. When flags are used to mark extensive objects or groups of closely spaced objects, they shall be displayed at least every 15 m. Flags shall not increase the hazard presented by the object they mark.

6.2.12 Flags used to mark fixed objects shall not be less than 0.5 m square and flags used to mark mobile objects, not less than 0.9 m square.

6.2.13 Recommendation—Flags used to mark fixed objects should be orange in colour or a combination of two triangular sections, one orange and the other white, or one red and the other white, except that where such colours merge with the background, other conspicuous colours should be used.

6.2.14 Flags used to mark mobile objects shall consist of a chequered pattern, each square having sides of not less than 0.3 m. The colours of the pattern shall contrast each with the other and with the background against which they will be seen. Orange and white or alternatively red and white shall be used, except where such colours merge with the background.

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Figure 6-2. Examples of marking and lighting of tall structures

Light spacing (X) in accordance with Appendix 6

Number of levels of lights = \( N = \frac{Y \text{ (metres)}}{X \text{ (metres)}} \)

Note: \( H \) is less the 45 m for the examples shown above. For greater heights intermediate lights must be added as shown below.
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6.3 Lighting of objects

Use of obstacle lights

6.3.1 The presence of objects which must be lighted, as specified in 6.1, shall be indicated by low-, medium- or high-intensity obstacle lights, or a combination of such lights.

Note.—High-intensity obstacle lights are intended for day use as well as night use. Care is needed to ensure that these lights do not create disconcerting dazzle. Guidance on the design, location and operation of high-intensity obstacle lights is given in the Aerodrome Design Manual, Part 4.

6.3.2 Recommendation — Low-intensity obstacle lights, Type A or B, should be used where the object is a less extensive one and its height above the surrounding ground is less than 45 m.

6.3.3 Recommendation — Where the use of low-intensity obstacle lights, Type A or B, would be inadequate or an early warning is required, then medium- or high-intensity obstacle lights should be used.

6.3.4 Low-intensity obstacle lights, Type C, shall be displayed on vehicles and other mobile objects excluding aircraft.

6.3.5 Low-intensity obstacle lights, Type D, shall be displayed on follow-me vehicles.

6.3.6 Recommendation — Low-intensity obstacle lights, Type B, should be used either alone or in combination with medium-intensity obstacle lights, Type E, in accordance with 6.3.7.

6.3.7 Recommendation — Medium-intensity obstacle lights, Type A, B or C, should be used where the object is an extensive one or its height above the level of the surrounding ground is greater than 45 m. Medium-intensity obstacle lights, Types A and C, should be used alone, whereas medium-intensity obstacle lights, Type B, should be used either alone or in combination with low-intensity obstacle lights, Type E.

Note.—A group of trees or buildings is regarded as an extensive object.

6.3.8 Recommendation — High-intensity obstacle lights, Type A, should be used to indicate the presence of an object if its height above the level of the surrounding ground exceeds 150 m and an aeronautical study indicates such lights to be essential for the recognition of the object by day.

6.3.9 Recommendation — High-intensity obstacle lights, Type B, should be used to indicate the presence of a lower supporting overhead wires, cables, etc., where:

a) an aeronautical study indicates such lights to be essential for the recognition of the presence of wires, cables, etc.; or

b) it has not been found practicable to install markers on the wires, cables, etc.

6.3.10 Recommendation — Where, in the opinion of the appropriate authority, the use of high-intensity obstacle lights, Type A or B, or medium-intensity obstacle lights, Type A, at night may dazzle pilots in the vicinity of an aerodrome (within approximately 10 000 m radius) or cause significant environmental concerns, a dual obstacle lighting system should be provided. This system should be composed of high-intensity obstacle lights, Type A or B, or medium-intensity obstacle lights, Type A, as appropriate, for daytime and twilight use and medium-intensity obstacle lights, Type B or C, for nighttime use.

Location of obstacle lights

Note.—Recommendations on how a combination of low-, medium-, and/or high-intensity lights on obstacles should be displayed are given in Appendix 6.

6.3.11 One or more low-, medium- or high-intensity obstacle lights shall be located as close as practicable to the top of the object. The top lights shall be so arranged as to at least indicate the points or edges of the object highest in relation to the obstacle limitation surface.

6.3.12 Recommendation — In the case of chimney or other structure of like function, the top lights should be placed sufficiently below the top so as to minimize contamination by smoke etc. (see Figures 6.2 and 6.3).

6.3.13 In the case of a tower or antenna structure indicated by high-intensity obstacle lights by day with an appurtenance, such as a rod or an antenna, greater than 12 m where it is not practicable to locate a high-intensity obstacle light on the top of the appurtenance, such a light shall be located at the highest practicable point and, if practicable, a medium-intensity obstacle light, Type A, mounted on the top.

6.3.14 In the case of an extensive object or of a group of closely spaced objects, top lights shall be displayed at least on the points or edges of the objects highest in relation to the obstacle limitation surface, so as to indicate the general definition and the extent of the objects. If two or more edges of the same height, the edge nearest the landing area shall be marked. Where low-intensity lights are used, they shall be spaced at longitudinal intervals not exceeding 45 m. Where medium-intensity lights are used, they shall be spaced at longitudinal intervals not exceeding 900 m.

6.3.15 Recommendation — When the obstacle limitation surface concerned is sloping and the highest point above the
Annex 14 — Aerodromes

Obstacle limitation surface is not the highest point of the object, additional obstacle lights should be placed on the highest point of the object.

6.3.16 Where an object is indicated by medium-intensity obstacle lights, Type A, and the top of the object is more than 105 m above the level of the surrounding ground or the elevation of tops of nearby buildings (when the object to be marked is surrounded by buildings), additional lights shall be provided at intermediate levels. These additional intermediate lights shall be spaced as equally as practicable, between the top lights and ground level or the level of tops of nearby buildings, as appropriate, with the spacing not exceeding 105 m (see 6.3.7).

6.3.17 Where an object is indicated by medium-intensity obstacle lights, Type B, and the top of the object is more than 45 m above the level of the surrounding ground or the elevation of tops of nearby buildings (when the object to be marked is surrounded by buildings), additional lights shall be provided at intermediate levels. These additional intermediate lights shall be alternately low-intensity obstacle lights, Type B, and medium-intensity obstacle lights, Type B, and shall be spaced as equally as practicable between the top lights and ground level or the level of tops of nearby buildings, as appropriate, with the spacing not exceeding 52 m.

6.3.18 Where an object is indicated by medium-intensity obstacle lights, Type C, and the top of the object is more than 45 m above the level of the surrounding ground or the elevation of tops of nearby buildings (when the object to be marked is surrounded by buildings), additional lights shall be provided at intermediate levels. These additional intermediate lights shall be spaced as equally as practicable, between the top lights and ground level or the level of tops of nearby buildings, as appropriate, with the spacing not exceeding 52 m.

6.3.19 Where high-intensity obstacle lights, Type A, are used, they shall be spaced at uniform intervals not exceeding 105 m between the ground level and the top light(s) specified in 6.3.11 except that where an object to be marked is surrounded by buildings, the elevation of the tops of the buildings may be used as the equivalent of the ground level when determining the number of light levels.

6.3.20 Where high-intensity obstacle lights, Type B, are used, they shall be located at three levels:

- at the top of the tower;
- at the lowest level of the catenary of the wires or cables;
- at approximately midway between these two levels.

Note — In some cases, this may require locating the lights off the tower.

6.3.21 Recommendation — The installation setting angles for high-intensity obstacle lights, Types A and B, should be in accordance with Table 6-2.

6.3.22 The number and arrangement of low-, medium- or high-intensity obstacle lights at each level to be marked shall be such that the object is indicated from every angle in azimuth. Where a light is shielded in any direction by another part of the object, or by an adjacent object, additional lights shall be provided on that object in such a way as to retain the

Figure 6-3. Lighting of buildings

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general definition of the object to be lighted. If the shielded light does not contribute to the definition of the object to be lighted, it may be omitted.

Table 6-2. Installation setting angles for high-intensity obstacle lights

<table>
<thead>
<tr>
<th>Height of light unit above terrain</th>
<th>Angle of the peak of the beam above the horizontal</th>
</tr>
</thead>
<tbody>
<tr>
<td>greater than 151 m AGL</td>
<td>0°</td>
</tr>
<tr>
<td>122 m to 151 m AGL</td>
<td>1°</td>
</tr>
<tr>
<td>92 m to 122 m AGL</td>
<td>2°</td>
</tr>
<tr>
<td>less than 92 m AGL</td>
<td>3°</td>
</tr>
</tbody>
</table>

Low-intensity obstacle light — Characteristics

6.3.23 Low-intensity obstacle lights on fixed objects, Types A and B, shall be fixed-red lights.

6.3.24 Low-intensity obstacle lights, Types A and B, shall be in accordance with the specifications in Table 6-3.

6.3.25 Low-intensity obstacle lights, Type C, displayed on vehicles associated with emergency or security shall be flashing-blue and those displayed on other vehicles shall be flashing-yellow.

6.3.26 Low-intensity obstacle lights, Type D, displayed on follow-me vehicles shall be flashing-yellow.

6.3.27 Low-intensity obstacle lights, Types C and D, shall be in accordance with the specifications in Table 6-3.

6.3.28 Low-intensity obstacle lights on objects with limited mobility such as aerobridges shall be fixed-red. The intensity of the lights shall be sufficient to ensure conspicuity considering the intensity of the adjacent lights and the general levels of illumination against which they would normally be viewed.

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Note.—See Annex 2 for lights to be displayed by aircraft.

6.3.29 Low-intensity obstacle lights on objects with limited mobility shall be a minimum be in accordance with the specifications for low-intensity obstacle lights, Type A, in Table 6-3.

Medium-intensity obstacle light — Characteristics

6.3.30 Medium-intensity obstacle lights, Type A, shall be flashing-white lights. Type B shall be flashing-red lights and Type C shall be fixed-red lights.

6.3.31 Medium-intensity obstacle lights, Types A, B and C, shall be in accordance with the specifications in Table 6-3.

6.3.32 Medium-intensity obstacle lights, Types A and B, located on an object shall flash simultaneously.

High-intensity obstacle light — Characteristics

6.3.33 High-intensity obstacle lights, Types A and B, shall be flashing-white lights.

6.3.34 High-intensity obstacle lights, Types A and B, shall be in accordance with the specifications in Table 6-3.

6.3.35 High-intensity obstacle lights, Type A, located on an object shall flash simultaneously.

6.3.36 Recommendation.—High-intensity obstacle lights, Type B, indicating the presence of a tower supporting overhead wires, cables, etc., should flash sequentially: first the middle light, second the top light and last, the bottom light. The intervals between flashes of the lights should approximate the following ratios:

<table>
<thead>
<tr>
<th>Flash interval between</th>
<th>Ratio of cycle time</th>
</tr>
</thead>
<tbody>
<tr>
<td>middle and top light</td>
<td>1/13</td>
</tr>
<tr>
<td>top and bottom light</td>
<td>2/13</td>
</tr>
<tr>
<td>bottom and middle light</td>
<td>10/13</td>
</tr>
</tbody>
</table>
The following Section 6.4 has only been recently issued by ICAO. It became effective in March 2009 and is applicable in November 2009.

6.4 Wind turbines

6.4.1 A wind turbine shall be marked and/or lighted if it is determined to be an obstacle.

Note.— see 4.3.1 and 4.3.2.

Markings

6.4.2 Recommendation.— The rotor blades, nacelle and upper 2/3 of the supporting mast of wind turbines should be painted white, unless otherwise indicated by an aeronautical study.

Lighting

6.4.3 Recommendation.— When lighting is deemed necessary, medium intensity obstacle lights should be used. In the case of a wind farm, i.e. a group of two or more wind turbines, it should be regarded as an extensive object and the lights should be installed:

a) to identify the perimeter of the wind farm;

b) respecting the maximum spacing, in accordance with 6.3.14, between the lights along the perimeter, unless a dedicated assessment shows that a greater spacing can be used;

c) so that, where flashing lights are used, they flash simultaneously; and

d) so that, within a wind farm, any wind turbines of significantly higher elevation are also identified wherever they are located.

6.4.4 Recommendation.— The obstacle lights should be installed on the nacelle in such a manner as to provide an unobstructed view for aircraft approaching from any direction.
### Table 6.3 - Characteristics of obstacle lights

<table>
<thead>
<tr>
<th>Light Type</th>
<th>Colour</th>
<th>Signal type/ (flash rate)</th>
<th>Peak intensity (cd) at given Background Luminance</th>
<th>Vertical Beam Spread (°)</th>
<th>Intensity (cd) at given Elevation Angles when the light unit is levelled (cd)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Above 200 cd/m²</td>
<td>50-500 cd/m²</td>
<td>Below 50 cd/m²</td>
</tr>
<tr>
<td>Low-intensity, Type A (fixed obstacle)</td>
<td>Red</td>
<td>Fixed</td>
<td>N/A</td>
<td>10 mm</td>
<td>10 mm</td>
</tr>
<tr>
<td>Low-intensity, Type B (fixed obstacle)</td>
<td>Red</td>
<td>Fixed</td>
<td>N/A</td>
<td>32 mm</td>
<td>32 mm</td>
</tr>
<tr>
<td>Low-intensity, Type C (mobile obstacle)</td>
<td>Yellow/Blue</td>
<td>Flashing (60-90 fpn)</td>
<td>N/A</td>
<td>40 mm (b) (h) 400 max</td>
<td>40 mm (b) 400 max</td>
</tr>
<tr>
<td>Low-intensity, Type D Follow-on Vehicle</td>
<td>Yellow</td>
<td>Flashing (60-90 fpn)</td>
<td>N/A</td>
<td>200 mm (b) 400 max</td>
<td>200 mm (b) 400 max</td>
</tr>
<tr>
<td>Medium-intensity, Type A</td>
<td>White</td>
<td>Flashing (20-60 fpn)</td>
<td>20 000 (b) ± 25%</td>
<td>20 000 (b) ± 25%</td>
<td>2 000 (b) ± 25%</td>
</tr>
<tr>
<td>Medium-intensity, Type B</td>
<td>Red</td>
<td>Flashing (20-60 fpn)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Medium-intensity, Type C</td>
<td>Red</td>
<td>Fixed</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>High-intensity, Type A</td>
<td>White</td>
<td>Flashing (40-60 fpn)</td>
<td>200 000 (b) ± 25%</td>
<td>200 000 (b) ± 25%</td>
<td>2 000 (b) ± 25%</td>
</tr>
<tr>
<td>High-intensity, Type B</td>
<td>White</td>
<td>Flashing (40-60 fpn)</td>
<td>100 000 (b) ± 25%</td>
<td>20 000 (b) ± 25%</td>
<td>2 000 (b) ± 25%</td>
</tr>
</tbody>
</table>

Note.— This table does not include recommended horizontal beam spreads. 6.3.22 requires 360° coverage around an obstacle. Therefore, the number of lights needed to meet this requirement will depend on the horizontal beam spreads of each light as well as the shape of the obstacle. This, with narrower beam spreads, more lights will be required.

a) See 6.3.25
b) Effective intensity, determined in accordance with the Aerodrome Design Manual, Part 4.

c) Beam spread is defined as the angle between two directions in a plane for which the intensity is equal to 50% of the lower tolerance value of the intensity shown in columns 4, 5 and 6. The beam pattern is not necessarily symmetrical about the elevation angle at which the peak intensity occurs.
d) Elevation (vertical) angles are referenced to the horizontal.
e) Intensity at any specified horizontal radial as a percentage of the actual peak intensity at the same radial when operated at each of the intensities shown in columns 4, 5 and 6.
f) Intensity at any specified horizontal radial as a percentage of the lower tolerance value of the intensity shown in columns 4, 5 and 6.
g) In addition to specified values, lights shall have sufficient intensity to ensure conspicuity at elevation angles between ± 0° and ± 5°.
h) Peak intensity should be located at approximately 2.5° vertical.
i) Peak intensity should be located at approximately 17° vertical.
APPENDIX 6. LOCATION OF LIGHTS ON OBSTACLES

Note.—High-intensity obstacle lighting is recommended on structures with a height of more than 150 m above ground level. If medium-intensity lighting is used, marking will also be required.

Figure A6.1. Medium-intensity flashing white obstacle lighting system, Type A
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Height of structure in metres above ground level

Note — For night-time use only.

Figure A5.2. Medium-intensity flashing red obstacle lighting system, Type B
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Figure A.6.3  Medium-intensity fixed-red obstacle lighting system, Type C

Note — For night-time use only

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Note.— *High-intensity obstacle lighting is recommended on structures with a height of more than 150 m above ground level. If medium-intensity lighting is used, marking will also be required.*

Figure A6-4. Medium-intensity dual obstacle lighting system, Type A/Type B
Note.—High-intensity obstacle lighting is recommended on structures with a height of more than 150 m above ground level. If medium-intensity lighting is used, marking will also be required.

Figure A6-5. Medium-intensity dual obstacle lighting system, Type A/Type C
Figure A6-6. High-intensity flashing white obstacle lighting system, Type A
Figure A6.7. High-medium-intensity dual obstacle lighting system, Type A/Type B
Figure A6-8. High-medium-intensity dual obstacle lighting system. Type A/Type C
No 2: Sample of wind farm identification on Australian World Aeronautical Chart (WAC).
No 3: Sample of wind farm identification on RAAF AIS Joint Operation Graphic chart.

Portland wind farm – identified as wind motors.
No 4: Sample of wind farm identification from Calgary Canada VHF Navigation chart.