APPENDIX 16.1: LONG TERM FOREST PLAN

Tangy Wind Farm Long Term Forest Plan

2020 - 2045

A. Description of Woodlands

A.1 Property Details			
Property Name:	Tangy Wind Farm		
Grid Reference: (e.g. NH 234 567)	NR860 294	Nearest town or locality:	Kilkenzie by Campbeltown
Local Authority:		Argyll and Bute	
LTFP Plan area (hectares):		**270.75ha**	

Owner's Details - Tangy Wind Farm is leased by SSE			
Address:	Inveralmond House, 200 Dunkeld Road, Perth		
Postcode:	PH1 3AQ	Country:	UK

Agent's Details – Author of Forest Plan				
Title:	Mr	Forename:	Neil	
Surname:	McKay			
Organisation:	Neil McKay Forestry Consultant Limited		Position:	Director
Primary Contact Number:	+44(0)7748995 234		Alternative Contact Number:	+44(0)1576 710296
Email:	mckayforestry@outlook.com			
Address:	Grange Farm, Tundergarth, Lockerbie			
Postcode:	DG11 2QG		Country:	UK

A.2 Location and Background

Provide details on the wider context of the LTFP area. Append a 1:25,000 or 1:50,000 map with contours and the grid reference of the main forest entrance. The map should show the estate boundary based on the Business Reference Number (BRN) and the woodland boundary, if different.

The site is located approximately 9km north-west of Campbeltown, Kintyre's largest settlement. The closest villages are Bellochantuy, 2km north-west of the site, and Kilchenzie, 3km south of the site.

Current wind farm consent (August 2018)

The consented repowering (Tangy III) would involve the removal of the existing 22 turbines (some of which have been generating since 2003) and then replacing them with 15 new larger modern turbines over an extended area. Replacing the existing turbines would allow the site to continue to benefit from the excellent coastal wind resource combined with the significant advances in modern turbine technology and efficiency. The total installed capacity would also significantly increase the installed generating capacity of the wind farm and maximise the energy yield from the site. To ensure maximum turbine efficiency, the repower includes extending the existing site boundary into the conifer plantations to the north.

Proposed Development (Tangy IV)

The Tangy IV Wind Farm Forest Plan is for a 16 turbine layout.

Similarly, as is normal with this type of development, a degree of design change and micro-siting will possibly take place. The Forest Plan will be amended in accordance with the Tolerance Table C.4.

The application site boundary includes different ownerships and planting years from 1974 through to replanting in 2014. Only one ownership area has so far entered into felling and replanting while the other ownerships are ready to be restructured. The development is partially within a well forested area with upland commercial plantations being established by both the private and state forestry sectors. Tree growth in these areas benefit from a mild wet climate but are restricted by wind and poor soil strength.

For the purposes of this Forest Plan compartments and sub compartments outside the Plan area are considered as neighbouring land and are dealt with separately by each of the owners/managers.

A.3 Existing Schemes & Permissions

Provide details on any existing forestry permissions, grants, EIA approvals, previous plans, or cases in progress.

Type (e.g. Felling Licence)	Ref. No.	Details
Tangy Forest Long Term Forest Plan	Case No: 4886194	BRN: 164310 MLC: 155/0039 Area: 151.48Ha August 2013
Lussa Forest Land Management Plan	2018 - 2027	Area: 7999Ha Approved February 2018

A.4 Stakeholder Engagement

Include a summary of the main points from Scoping and where they are addressed in the plan. Append pre- and post- scoping maps, and the full Scoping Report.

Scoping – Main Points	LTFP Reference (section/page):
Forestry Commission Scotland ES scoping:	
The criteria for determining the acceptability of woodland removal and further information on the implementation of the policy is explained in the Control of Woodland Removal Policy	C.2.5 Replanting proposals
If timber is to be disposed of on site, details of the methodology for this should be submitted. Areas of retained forestry or tree groups should be clearly indicated and methods for their protection during construction clearly described.	C.2.1 Felling
If areas of woodland are to be temporarily removed but then replanted shortly afterwards (typically within 1-5 years) this should be indicated in the ES, and details of the replanting plan provided.	C.2.5 Replanting proposals
Where there is a change in land use (e.g. to non-woodland habitats) the woodland should be described in sufficient detail (e.g. including details of the age of the trees; the species type and mix; the soil types; etc	C.2.5 Replanting proposals
Design approaches which reduce the scale of felling required to facilitate the development	C.2.1 Felling

should be considered and integration of the development with the existing woodland structure is a key part of the consenting process	
Trees cleared for turbine bases, access roads and any other wind farm related infrastructure must be replaced by replanted on-site or on an alternative site (compensatory planting). The restocking plan should show which areas are to be replanted and when during the life of the windfarm.	C.2.5 Replanting proposals C.2.14 New (Compensatory) Planting
The plan should clearly identify and describe the restocking operations including changes to the species composition, age class structure, timber production and traffic movements.	C.2.1 Felling C.2.5 Replanting proposals
It should be made clear that both felling operations and compensatory planting (if relevant) must be carried out in accordance to good forestry practice as defined in the UK Forestry Standard 4 (UKFS)	C.2.1 Felling C.2.5 Replanting proposals C.2.14 New (Compensatory) Planting
A key component of this is to ensure that even-age woodlands are progressively restructured in a sustainable manner: felling coupes should be phased to meet adjacency requirements and their size should be of a scale which is appropriate in the context of the surrounding woodland environment.	C.2.1 Felling
In particular we note that the revised application increases the tip height of the proposed turbines, in light of this: - there should be more scope to phase, or reduce the scale of felling on the site. - it should be possible to increase the maximum top height of the restock above 10m.	C.2.1 Felling C.2.5 Replanting proposals

A.5 Long Term Vision and Management Objectives

Tell us how you intend to manage the forest in the long term and your goals for its development.

Vision

Describe your long term vision for the LTFP area.

The long term vision for the area covered by Tangy Wind Farm Forest Plan is to create a woodland environment which is compatible with the current wind energy generation technology. An acceptable balance between tree cover and wind energy generation has been achieved.

The woodland within this area will be managed to develop into a productive conifer crop which can be harvested when it reaches a *mean height* of 10 metres. The attainment of this height is predicted as being approximately 21 years after replanting. The wind energy land use and forest cover requirements will be both presented for review at this time.

As the wind farm plan area is integral with the forest owners' other forest holdings, the review will be considered in the context of the individual forest owners' objectives.

Management Objectives

Give your objectives of management and also how you will manage the forest area sustainably. Your objectives should be specific and you should also be able to measure their outcomes.

No.	Objectives (including environmental, economic and social considerations)	Indicator of objective being met
1	Manage the woodland in the context of the construction and operation of the wind energy development.	Tangy IV wind farm constructed and generating renewable energy withgin the contect of a felled and replanted woodland.
2	Through design, the woodland habitat will be compatable with the operation of the wind farm	Wind energy is not reduced beyond feasable generation perameters.
3	To maintain a critical mass of productive conifer crop which will provide a harvestable product.	A marketable forest product will be availabe for harvesting as a short rotation forest crop.
4	To protect and enhance local ecologicaly important features within the site such as riparian zones.	Improved biodoversity within the riparian zones which are redesigned to UK Forestry Standards guidelines.
5	To respect and cooperate with the different landowners' and	The three forest owners are able to include this area within their

No.	Objectives (including environmental, economic and social considerations)	Indicator of objective being met
	leaseholder's, broader land management objectives. This includes not compromising forest owners' UK Forestry Standards compliance.	broader forest holdings in terms of sustainable forest management.

A.6 General Site Description

Provide details under each of the headings below. Append maps if appropriate for each subsection.

A.6.1 Topography

There is a general southerly aspect to the Forest Plan area across an elevation range approximately between approximately 140 – 225m AOD (Above Ordnance Datum).

The site reaches maximum elevations of 260m AOD in the north-east. The terrain is gently to moderately sloping, with slopes generally less than 8°.

Localised slopes are present to the Allt nan Creamh and Cnocan Gean.

See also Tangy IV Wind Farm EIA Report Figure 11.2

A.6.2 Geology and Soils

Forest soils classification is summarised by:

Code	Group	Type
6	Peaty Surface-water Gley	Typical peaty surface-water gley
9e	Flushed Blanket Bog	Trichophorum-Calluna-Eriophorum-Molinia bog
11b	Unflushed Blanket Bog	Calluna-Eriophorum blanket bog

See also Tangy IV Wind Farm EIA Report Chapter 11: Geology, soils and hydrology.

EIA Report Figure 11.3: Superficial Geology Map identifies Till, Devensian-Diamicton, an area of Peat and smaller areas of Alluvium.

The bedrock geology is understood to be comprised of the Stonefield Schist Formation on the western area of the site. According to the British Geological Society this is a metamorphic bedrock formed approximately 542 to 1000 million years ago. This formation was originally sedimentary in origin and has been later altered by low-grade metamorphism to its current facies.

The Eastern area of the site consists of the Glen Sluan Schist Formation.

The central region of the site has two bedrock formations running as linear sub-crops orientated in a north-west to south-east direction. The eastern band is the Loch Tay Limestone Formation. The western band is the Neoproterozoic Basic Minor Intrusion Suite, Amphibolite & Horneblende Schist.

The peat encountered across the site is typically brown pseudo-fibrous peat with a thin surface of peaty topsoil. With a moderate amount of decomposition and large content of root structure; typical Von Post Classification values range between [H4] to [H7]. Beneath the peat, although spatially variable in its extent, a variety of glacial deposits are understood to be present. These materials are remnants from the last glacial retreat. All are erosional, transported sediments of glacial diamicton, sands and gravels, cobbles and boulders in a matrix of clay and silt.

Peat has been found to form a deep deposit across the north-eastern part of the study area. Deposits elsewhere have been found to be relatively shallow. The calculated mean peat depth across the recorded deposits is 0.55m, with a maximum recorded peat depth of approximately 3.6m in a deep pocket of peat recorded on the north-eastern boundary of the study area.

A.6.3 Climate

In terms of forest potential Tangy Wind Farm Forest Plan area can be summarised as having a mild but windy climate with little winter frost or significant snow. The strength of the wind is a limiting factor to tree stability when combined with wet soils.

The climate of Western Scotland is relatively mild due to the strong maritime influence. The warm Gulf Stream also has a strong influence on Western Scotland. With winds mainly blowing from the sea the annual mean temperatures are in the range 9.5 to 9.9 °C in coastal areas.

Kintyre is among the sunniest parts of Western Scotland where the average annual sunshine totals approach 1450 hours.

Kintyre is one of the more exposed areas of the UK, being close to the Atlantic. The strongest winds are associated with the passage of deep

depressions close to or across the UK. The frequency and strength of depressions is greatest in the winter half of the year and this is when mean speeds and gusts are strongest.

The direction of the wind is defined as the direction from which the wind is blowing. The wind rose for the development site shows the clear prevailing winds are westerly and south-westerly. The range of directions between south and north-west accounts for the majority of occasions and the strongest winds nearly always blow from this range of directions. Spring time also tends to have a maximum of winds from the north east, due to the build-up of high pressure over Scandinavia at this time of year.

A.6.4 Hydrology

The Forest Plan area involves the catchments of the Allt nan Creamh, Allt na Ceardaich, Allt a' Ghoirtein and Tangy Burn.

See also Tangy IV Wind Farm EIA Report Chapter 12: Surface Water Figure 12.1: Hydrological Features

River Basin Management Plans (RBMP)

No watercourses within the Forest Plan boundary have been classified under SEPA's RBMP. Glenlussa Water in proximity to the Forest Plan area has been classified under the RBMP.

Drinking Water Protected Areas (DWPA)

Peninver Water Treatment Works (WTW) is approximately 6.9km from the site boundary; felling and replanting will be carried out within the catchment of the Allt Harvie, which drains into the Glenlussa Water, south of Lussa Water approximately 1.1km from the application boundary (NGR 1707 6285).

Private Water Supplies

Although a number of private water supplies have been identified in and around the Tangy IV Wind Farm, within the Forest Plan area only one source is located inside the planted area shown in EIA Report Figure 12.1

A.6.5 Windthrow

Windthrow has been evident within the forest area for a number of years. All three forest ownerships exhibit some degree of windthrow in a variety of age classes.

Tangy Forest Plan reports damage having occurred, within P1989 compartments, during the storms of 2012.

Aerial imagery used in developing the 2014 Environmental Statement clearly show the extension of significant blown areas within P.1975 compartments within Lagalgarve Forest. (Appendix Plate 6) It is also noticed that the P1988 compartments, outside the Tangy Wind Farm Forest Plan area has areas of wind throw.

There are pockets of wind throw within the FES P.1975 compartments.

A.6.6 Adjacent Land Use

A.6.7 Access

Lagalgarve Forest has unimproved access through Lagalgarve Farm, there is no connection to the forest area covered by this plan.

Tangy Forest has Servitude Rights of Access over shared road for all forestry purposes through Tangy Farm via the minor public road and access the A83 north of Kilkenzie.

The forest access is yet to be developed.

Lussa Forest has established an internal forest road system to the north which joins the A83 north of Bellochantuy.

The wind farm development has access through the existing Tangy Wind Farm, Tangy Farm and the minor public road to the A83.

There is little or no public access taken within the forest area to date.

Argyll and Bute Council confirmed there are no known rights of way within the study area of the wind farm (November 2013).

A.6.8 Historic environment

See also Tangy IV Wind Farm EIA Report Chapter Figure 13.1

Site No.	HER No.	Site Name	Site Type	Designation	Importance
3	2968	Alt nan Creamh	Hut Circle	None	Regional
10	2977	Alt nan Creamh	Sheiling Huts	None	Local
	*304772**	*Avro Anson I: North Channel*	*Ditched Aircraft*	*None*	*n/a Arbitrary*

					grid reference
13	2985	Tangymoil	Cup Marked Stone	None	National

* This asset does not have an HER reference, therefore the Canmore ID is provided for information.

Allt Nan Creamh Hut Circle (Asset 3) is associated with Allt Nan Creamh Burnt Mound (Asset 2). Both assets are situated on a gentle north facing slope overlooking Allt Nan Creamh. The hut circle has an internal diameter of 9.5m and although the wall dimensions are vague a boulder slab construction is evident. The hut circle has been badly damaged by forest ploughing and planting. Such assets in upland marginal areas are well known in the archaeological record and many date to the late Bronze Age. They are believed to have been abandoned during the climatic downturn in this period when they became unsustainable as settlement sites. Although damaged during forestry operations, taking into account its importance as evidence of prehistoric domestic activity and its potential to increase our knowledge of prehistoric domestic activity through material remains this asset has been assessed as being of Regional importance.

Cup marked stones (Appendix Plate 8) are a form of prehistoric art and comprise hollows pecked out of rock with a stone hammer. Some are surrounded by one or more concentric rings and other examples are joined by linear grooves. Such rock art is difficult to date although some examples have been discovered incorporated into graves, the likely period of their use spans the Neolithic and Bronze Age. In consideration of their importance as evidence of prehistoric art, and their group value, these assets have been assessed to be of National importance.

A.6.9 Biodiversity

There are no statutory ecological designations present within the area of Tangy Wind Farm Forest Plan. However, using the Land Information Search (LIS) it is noted outside the site:

- Native Woodland – Integrated Habitat Network
- SSSI – Tangy Loch
- SSSI - Bellochanty and Tangy Gorges
- SPA – Kintyre Goose Roosts
- Wetlands of International Importance - Ramsar

No habitats of greater than local value have been identified on site.

Four species of bat have been recorded on or near the proposed development over the course of the bat surveys:

- soprano pipistrelle;
- common pipistrelle;
- Leisler's bat; and
- Daubenton's bat.

No otter resting places in the form of holts or couches were recorded at the site during the surveys. Three otter spraints were recorded along the Allt na Creamh river that runs adjacent to the north-western edge of the proposed development and through the northern part of the site, confirming otter presence on-site, as shown on EIA Report Figure 10.8. The site is therefore considered to have local value for otter.

No evidence of water vole was recorded during the survey work. The site is not considered to have any value for this species.

No red squirrel signs or sightings were observed during the survey work. The site is not considered to have any value for this species.

One badger sett with three holes was recorded on-site.

See also Tangy IV Wind Farm EIA Report Chapter 10: Ecology and Nature Conservation

A.6.10 Invasive Species
There is no evidence of *rhododendron ponticum* which may be expected in the woodland areas of Argyll.

A.7 Woodland Description

Provide a brief description of woodland types and any relevant past management. Also complete the Tables below, with reference to Appendix 2 of the Long Term Forest Plan – Applicant's Guidance.

This Long Term Forest Plan is concerned with a defined area within the planning site boundary which, through a process of assessment and consultation, requires forest felling and replanting to ensure the satisfactory construction and operating of the new wind farm turbine layout.

The forests within the plan area are parts of three separate ownerships and management arrangements, as shown on the accompanying Felling Plan.

Two forest units are privately owned by different parties. The third central section is National Forest Estate managed by Forest Enterprise Scotland (FES).

All are established productive conifer forests typical of traditional upland plantations in the west of Scotland. The overriding influence on the performance and character forests is its coastal location affected by a mild, wet but windy, climate on generally waterlogged soils. Forest rotation length is largely determined by terminal height (at which windthrow is predicted to reach levels requiring clearfelling).

The three forest ownership entities are Lagalgarve forest, West Lussa and Tangy Forest;

1. The family owned Lagalgarve forest is the most westerly unit and extends to the lower slopes of the development site. This presents some earlier established plantations which are now over-mature and have significant sections of windblow. No felling or replanting has taken place in this area to date. The overall management objective is as investment for family succession.

2. Forest Enterprise Scotland manages the section of woodland which forms part of the West Lussa Forest. Within this forest there has been felling and restocking under two consecutive forest design/land management plans. Part of the area outside the site boundary has been felled and replanted with a further area planned for felling imminently. These areas are outwith this plan remit.

3. Tangy Forest is managed by a forest investment company and is entering into the timber production phase. Some windthrow is already present. Tangy Forest has a current approved Forest Plan.

Forest condition varies with elevation and soil type from good timber achieved (Appendix Plate 5) to windblown (Appendix Plate 6) with growth rates and quality ranging through to checked on waterlogged soils.

Data is provided by the land owners or their managers where available. Additional information is drawn from LiDAR and aerial imagery and site observations.

Table 1 - Area by species

This shows the current and future species composition within the entire Long Term Forest Plan area.

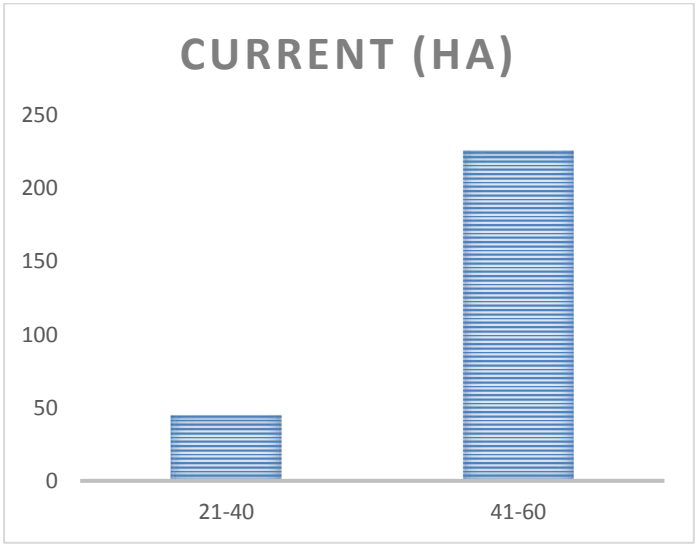
Area by species						
Species	**Current***		**Year 10***		**Year 20***	
(Add relevant species groups, or OG/OL)	**Area (ha)**	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**
Sitka spruce (some LP)	270.75	100	196.32	68%	196.32	68%
NBL			3.50	1%	3.50	1%
Designed Open Ground			30.43	10%	30.43	10%
Peatland restoration			27.72	10%	27.72	10%
Wind Farm Infrastructure (including bat buffer clearance areas)			31.73	11%	31.73	11%
Total		**100**		**100**		**100**

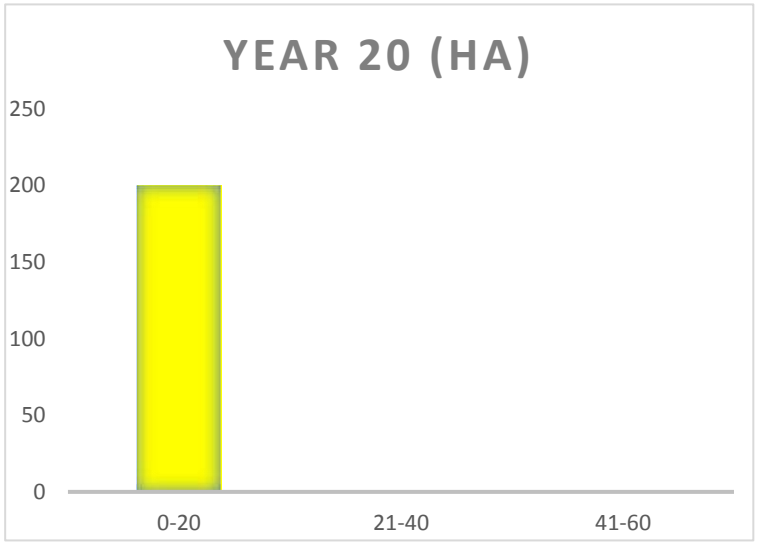
* Of whole Forest Plan area (including open ground (OG)). Any mixtures such as Mixed Conifer (MC) should be broken down and included as an individual species component where a species occupies more than 10%.

Table 2 – Area by age

This shows the woodland area broken down by age class and will show how well the woodland is distributed across the age classes. This information can be provided as a chart below. Double click on the chart below and paste your area figures into the spreadsheet that appears.

Age class (years)	Current	Year 20
	Area (ha)	Area (ha)
0-20		199.85
21-40	44.92	
41-60	225.83	
61-80		
81-100		
100+		
Total	270.75	199.85


CURRENT (HA)
250
200
150
100
50
0
21-40
41-60


YEAR 20 (HA)
250
200
150
100
50
0
0-20
21-40
41-60

A.8 Plant Health

Provide details on any known plant health issues within the LTFP area and their effect on the forest plan.

There is no evidence of tree health issues within this Forest Plan area. Current observations have reported no presence of *Dothistroma or Phythophthora ramorum.*

B. Analysis of Information

B.1 Constraints and Opportunities

Identify constraints and opportunities. Append maps as appropriate and provide map reference.

Factor	Constraint	Opportunity
Wind farm infrastructure	Design of roads, turbine and other infrastructure dictate the overall sub-compartment structure.	Separate management units with good road access.
Wind energy production	A tree height limitation of 10m is presently agreed, after which felling of the replanted site will take place.	10m tree height should provide marketable timber resource.
Watercourses	Loss of planting ground.	Biodiversity enhancement through enlarging the riparian zones.
Deep peat/ poor tree growth	Loss of planting ground due to poor tree growth.	Revisiting the forest edge design. Appropriate peatland restoration.
Fragile public road access	harvesting plans must take into consideration likely restrictions when assessing the viability of any haulage operation.	A Timber Traffic Management Plan will be required to mitigate the risk of accelerated damage due to intensive haulage operations

Outline how you intend to incorporate the constraints and opportunities into the management objectives.

The wind farm design layout provides an outline for new compartment boundaries which will allow future management options. The replanting design considers how this layout will encompass the environmental "constraints" such as buffer zones for bats and riparian enhancement zones.

The felling and replanting processes provides the opportunity to review the land use where tree growth on deep peat is poor. The decision for an area of peat restoration follows the management options given within the Forestry Commission Practice Guide *Deciding future management options for afforested*

deep peatland.

In a similar manner the replanting design will include open space and access to the historic sites identified.

The unfavourable effect of tree growth on wind energy performance is treated by compromising turbine performance with a limitation of tree height. The compromise *mean tree height* of 10m is sufficient to provide a timber product without recourse to managing forestry waste regulations.

Recognition of the fragility of the minor public road for timber haulage is mitigated by land owner agreements to move some timber from site through the internal forest road system on the National Forest Estate.

C. Management Proposals

C.1 Silvicultural Practice

Outline silvicultural practice and management prescriptions. Include any past management practice that is relevant and the strategies to address the issues identified during the analysis phase.

The decision process requiring the felling of the selected area for the wind farm construction and operation was detailed in the Tangy III Wind Farm Environmental Statement Appendix 16.2 Forestry. The preferred option for wind energy production is to clear the area and maintain free of trees, however, through consultation a compromise position is to fell the selected area and to replant to a keyhole design.

According to the Argyll and Bute Council Woodland and Forestry Strategy Tangy Wind Farm Forest Plan area falls into two categories;

- Land with limited flexibility for the growth and management of tree crops and
- land with moderate flexibility for growth and management of tree crops.

The current practice for this site type, as demonstrated by neighbouring forest areas, is a clearfell and replant rotational system.

The proposals for Tangy Wind Farm Forest Plan area will follow this procedure with a limitation to *mean tree height* of 10m. This may be described as a "short rotation" silvicultural system. At this point the felling and replanting options will be reviewed in the context of wind turbine performance, further repowering options and future forest management.

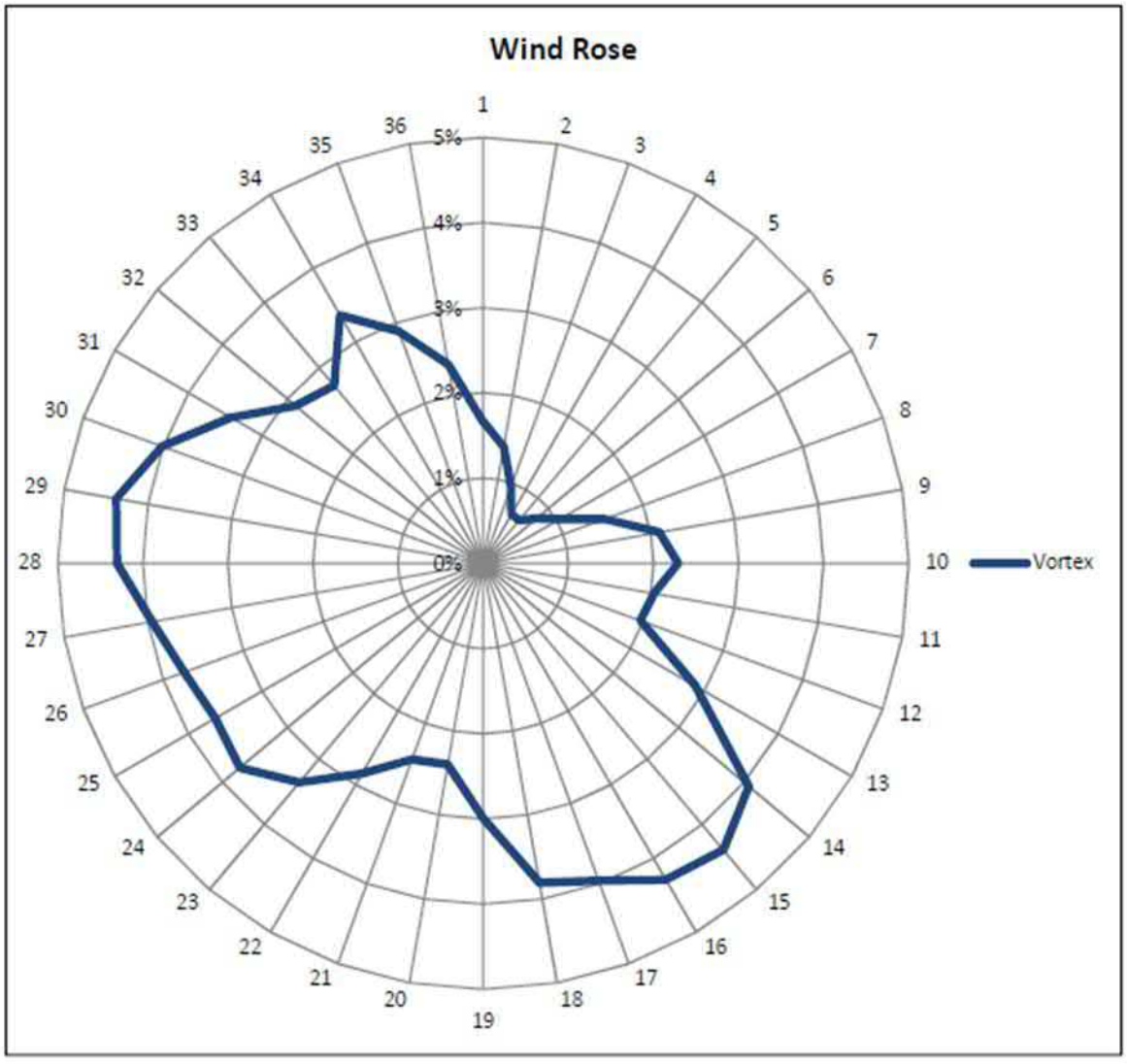
C.2 Prescriptions

Please provide maps as set out in Appendix 2 of the Forest Plan Applicant's Guidance and complete the associated Tables. Provide any further details required along with the map references.

C.2.1 Felling

The felling requirements have been identified as part of the overall site design whilst taking account of other constraints. Wind resource analysis modelling has been carried out using Computational Fluid Dynamics (CFD) and has reduced the area considered suitable for wind resource, within the planning boundary.

The felling design is governed by the wind energy requirements of the wind farm. The wind rose below illustrates the significance of the wind direction and the requirements to clear fell and replant. Also where the wind direction is less influential and felling requirements are reduced.



The north-west forest area within Lagalgarve Forest comprises the complete P. 1988 compartments and is not required for felling for the development. However, forest design is integral with the overall land management. The optimal felling date for this crop is circa 2025, although there is already evidence of some windblow within this area which may indicate this as optimistic. This section of forest will be restructured to continue as a productive unit. Opportunities will be taken to extend the riparian native broadleaf planting into the open ground below the development boundary.

An appropriate felling line (Felling Plan) has been developed in conjunction with Forest Enterprise Scotland which gives enough clearance for the wind farm development while minimising the felling area. The current restocked areas P.2010 and P.2014 do not impact the proposed development due to their location and/or topography. Outside this area (i.e. beyond the agreed felling line) is under the management of the FES West Argyll Forest District with no further requirements or implications for the proposed development.

The landscape photomontage, VP Ranachan Hill, illustrates a straight edge on the eastern boundary, this will be less evident with FES continued felling and restocking in the wider area.

Tangy Forest, the south east forest area within the proposed development is one part of two units in the locality under the same ownership. The CFD results similarly suggested that a significant part of this development would not require felling for the benefit of the turbines. This woodland was all planted in 1986 and sits within a relatively more sheltered area. The restructuring of this unit will likely to be circa 2025 and will develop biodiversity through open space and native broadleaves associated with the Allt Trasda watercourse.

Tree felling and timber extraction:

It is noted through site investigations that tree sizes and crop condition vary from wind thrown large tree size to stunted poor growth however the overall tree size and site conditions are favourable to current standard harvester felling with extraction of shortwood products by standard forwarders.

The principles of felling produce to the side and creating a brash mat will be adopted as good practice. The techniques set out in Forestry Commission Technical Note Protecting the Environment during Mechanised Harvesting Operations will be followed. Furthermore, the felling and extraction operations will follow UK Forestry Standards Forest and Water Guidelines pertinent at the time of harvesting. To avoid potential diffuse pollution, and other adverse events, good site pre-planning and on-going site management and monitoring will minimise any adverse effects on watercourses.

Following the current Forestry and Water Scotland pocketbook guidelines around watercourses, including connected ditches and drains operations will;

- Prepare and follow the site plan, paying particular attention to the main extraction route locations
- Minimise the risk of diffuse pollution by assessing the drainage system and identifying watercourses and drains
- Ensure that roadside drains are disconnected before work commences
- Plan for bad weather and work sensitive areas in drier conditions
- Only use band tracks where necessary
- Always try to fell away from watercourses and lift any brash

and tops out of the buffer zone

- Minimise water crossings; Use pipes and log bridges when crossing is unavoidable (and remove these when site work is completed)

- Stack from in-wood where site conditions allow
- Use brash or cut-offs to deflect water from extraction routes onto the forest floor
- Maintain brash mats, patching holes before they become waterlogged
- Utilise alternative working options for sites that lack brash.

The operations will not;

- Operate machines in watercourses
- Track machines for long distances on forest roads
- Repeatedly track harvesting machinery within sensitive areas (eg buffer areas, wetlands, designated areas)
- Continue to work sensitive areas during prolonged and heavy rain
- Stack timber in roadside drains or buffer areas
- Run extraction routes where run-off is likely to enter a watercourse

Follow the 'Keep Your Distance' guide for harvesting;

Minimum working distances from watercourses, including connected ditches and drains

Width up to 1m	Fuels and Oils
5m	No refuelling within 10m* of any watercourse, No storage or handling of fuels and oils within buffer areas
No harvesting, brash tracking	

*Construction Environmental Management Plan details may specify a greater distance.

Accordingly, timber harvesting operations will require sufficient infrastructure to enable the transfer and despatch the timber volumes through forest/windfarm roads to public highway.

Road haulage direction;

Timber volumes released during the harvesting will be transported to the public highway and onward by conventional timber lorries. The direction of haulage will be split between timber from Forest Enterprise Scotland being hauled north west to link with the internal forest road system to link with the A83 north of Bellochantuy.

Timber from the two privately owned woodlands will be hauled through the existing Tangy Wind Farm via the minor public road and access the A83 north of Kilkenzie.

Timber haulage will be governed by statutory Department of Transport regulations and operators will follow the FISA Forest Haulage Safety Manual 2018 or later updates.

Typically, round timber from the Kintyre peninsular is transported onward through the timber handing facilities at Ardishaig and Campbeltown.

Timber products and markets;

Mean tree volumes range from 0.45m^3 to 0.03m^3 giving a range of products from sawlogs through to small round wood.

Markets outwith the area;

- BSW Ltd; Fort William and Carlisle
- Adam Wilson & Sons Ltd. Troon
- Balcas; Sawmill in Enniskillen, Northern Ireland and Combined Heat and Power plants in Enniskillen and Invergordon.
- Drenagh Sawmills; Limavady, Northern Ireland
- Iggesund Paperboard
- UPM Caledonian

Depending on market conditions and exchange rates at the time European mainland and Scandinavian outlets may be available.

C.2.2 Thinning

Tree removal, which results in a temporary reduction in basal area, made after canopy closure to promote growth and greater value in the remaining trees.

Thinning options for the second rotation crop will be limited for a number of reasons;

- Wind hazard Class exposed slopes and wet ground conditions are not conducive to crop stability during or after the thinning operations.
- The maximum 10m tree height for felling would be the earliest tree height for thinning.

C.2.3 LISS

Lower Impact Silvicultural systems are defined as forest management decisions including group selection, shelterwood or under-planting, small coupe felling, coppice or coppice with standards, minimum intervention and single tree selection systems which are suitable for windfirm conifer woodlands and most broadleaved woodlands.

With the short rotation period planned for the area of the wind farm Lower Impact Sylvicultural Systems are not considered viable.

Soil type and exposure together limit the options for LISS even in subsequent rotations.

C.2.4 Long Term Retentions (LTR) / Natural Reserves

Long-term retention is defined as trees retained for environmental benefit significantly beyond the age or size generally adopted by the woodland enterprise.

Natural reserves are predominantly wooded, are permanently identified and are in locations which are of particularly high wildlife interest or potential. They are managed by minimum intervention unless alternative management has higher conservation or biodiversity value.

The concept of LTR and wooded natural reserves are not conducive to wind resource or other habitat constraints within the area of Tangy Wind Farm Forest Plan.

There are more suitable opportunities for LTR and natural reserves within the broader forest holdings under the same ownerships.

Peatland restoration has been identified for an area of deep peat where the tree growth is poor (<YC 8) following FCS Practice Guide "*deciding future management options for afforested deep peatland."*

C.2.5 Restocking Proposals / Natural Regeneration

ESC analysis

Ecological Site Classification (ESC) is the aid to select tree species, and to make related decisions based on the appreciation of the ecological potential of sites.

The ESC analysis for Tangy Wind Farm Forest Plan area is summarised below:

Species (provenance)	**Suitability**
Lodgepole pine	Suitable
Macedonian pine	Suitable
Scots pine	Marginal
Sitka spruce (QCI)	Marginal
Downy birch	Suitable
Grey alder	Suitable
NVC Woodland analysis Woodland Type	**Suitability**
W4 Birch with purple moor grass	Very Suitable

ESC analysis

Forest owners' objectives, the success or otherwise of the current crop and the compromise by the wind farm developers lead to a general replanting with Sitka spruce.

The replanting design incorporates the permanent wind farm layout in terms of access roads, infrastructure and specified buffer zones around each turbine. Replanting also provides for the opportunity to adopt current environmental standards, including UKFS Requirements, regarding watercourses and peatland restoration.

Replanting around the in-forest water supply for Lagalgarve/Tangytavil will increase the buffer to 50m commensurate with current good practice as stated in UK Forest Standards.

Bat buffer zones;

The basis for leaving the buffers unplanted is that bat species tend to follow linear features such as tree lines or hedgerows when commuting/foraging and are less likely to cross open spaces. Guidance in the UK (the Natural England TIN051) specifies a minimum buffer distance of 50m from the edge of the feature and the blade tip of the turbine to reduce the risk of bat species flying close to turbines. However, this 50m cannot be used to measure the distance from the turbine base at ground level so the following equation is used to calculate the distance between the edge of the feature and the centre of the turbine tower at ground level:

$$b = \sqrt{(50 + bl)^2 - (hh - fh)^2}$$

bl=blade length (m)

hh=hub height (m)

fh=feature height (m)

As a range of turbine specifications could be used for the Tangy wind farm, the turbine with the largest buffer distance has been selected to minimise the risk to bats. This turbine has a blade length of 65m and a hub height of 85m. The feature height has been taken to be 10m (as planting following clear felling is to be allowed to grow up to a height of 10m). The above equation it looks like this:

$$b = \sqrt{(50 + 65)^2 - (85 - 10)^2}$$

$$b = \sqrt{(115)^2 - (75)^2}$$

$$b = \sqrt{13225 - 5625}$$

$$b = \sqrt{7600}$$

$$b = 87.2m$$

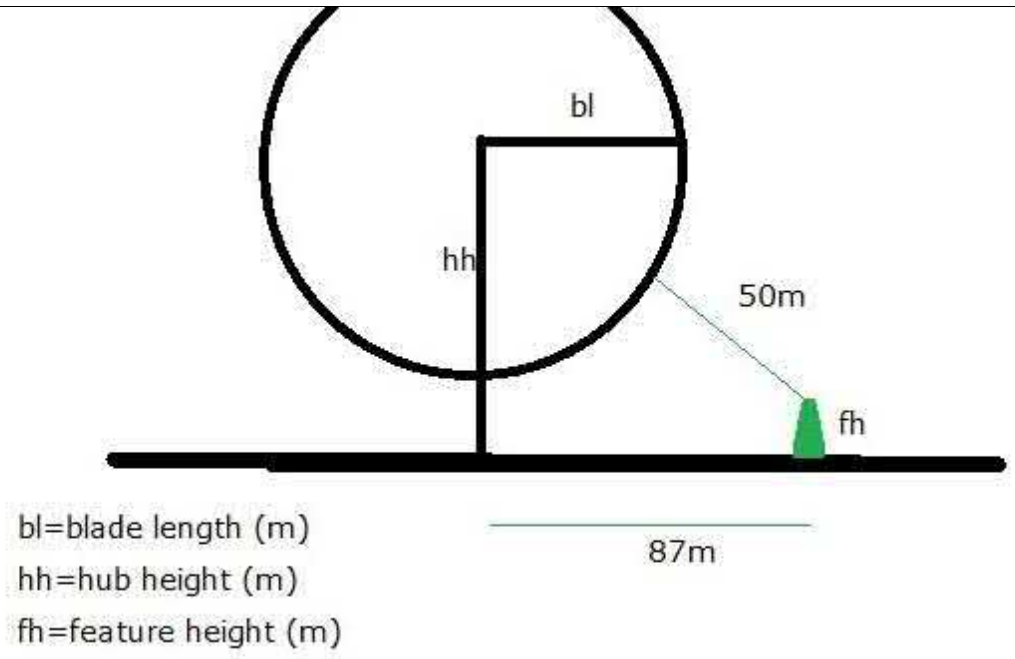


Figure 1 bat buffer illustration

The outline technical details for replanting are as follows:

Cultivation and drainage;

The purpose of cultivation within the areas selected for replanting is to assist early establishment through aeration of soils, providing local drainage and weed suppression. Cultivation may enable correct plant spacing determined by the species choice and sylvicultural systems selected. In the longer term cultivation may help to develop good root architecture which assists satisfactory growth and may assist in preventing early onset of windthrow.

The most suitable method of cultivation for managing the restock of upland spruce is currently excavator mounding at 1.9m centres to provide a stocking figure of 2700 trees per hectare.

The associated drainage system will be planned and used with combinations of culverts and cut-off drains, sumps, silt traps and vegetated buffer zones to stop drainage water going directly into a watercourse as the guidelines for Forest and Water.

Follow the 'Keep Your Distance' guide for cultivation;

Minimum working distances from watercourses, including connected ditches and drains

Width up to 1m	Width 1- 2m	Width >2m	Fuels and Oils
5m	10m	20m	No refuelling within 10m* of any watercourse, No storage or
No ground prep machinery	No ground preparation	No ground preparation	

				handling of fuels and oils within buffer areas

*Construction Environmental Management Plan details may specify a greater distance.

Ground Preparation and drainage operations will;

- Follow the 'Keep Your Distance' guide
- Choose the most appropriate technique and machinery for the site
- Identify all watercourses and ensure appropriate buffer areas are in place
- Use silt traps/sumps and vegetated areas to reduce sediment run-off
- Ensure drain gradients do not exceed 2 degrees
- Block existing drains which connect directly to watercourses
- Minimise water crossings and use pipes and log bridges

Won't

- Operate machinery or equipment in any river, burn or ditch
- Connect drains directly to watercourses
- Undertake ground preparation on waterlogged ground.

Planting stock;

The proposed productive conifer crop for the long term contribution to objectives of the woodland area has been determined through the ESC process and forest owners objectives as Sitka spruce. With the understanding that the primary land use is wind energy production and as the trees grow they have an increasing impact on wind energy available and wind turbine performance it is proposed to use planting stock with slower growing characteristics.

Whereas current research projects aim to increase the economic value of future Sitka spruce plantations substantially by using new breeding techniques to combine high growth rate with good timber qualities, the requirements for tree growth within wind farm sites require a modest to low rate of growth. A standard QCI or Alaskan provenance may be suitable.

Typical bare rooted planting stock in the size range of 40-60cms will be suitable.

Table 3 – Felling

This shows the scale of felling within the felling phases in the context of the whole Forest Plan. This includes any areas of 'LISS – Fell' (i.e. removal of final overstorey).

Total Forest Plan Area:	**289.60**							
Felling	Phase 1	%	Phase 2	%	Long Term Retention	%	Area out-with 20yr plan period	%
Area (Ha)	**270.75**	100	0	0	0	0	0	0

Table 4 – Thinning

This shows the area of thinning over the first 10 years of the Forest Plan.

Species	**Thinning (ha)**
N/A	N/A
Total	**N/A**

Table 5 – Restocking

This table provides information on the restocking proposals for the first 10 years of your Forest Plan. Restocking should be listed on a coupe by coupe basis.

Felling Phase	Map Identifier(s)	Species to be planted	Area (ha) to be planted
Phase 1		Sitka spruce	197.07
		NBL	3.50
		Designed open ground	29.72
		Wind farm infrastructure including bat buffer zones includes an area at T9 outside the felling area.	31.73
		Peat restoration area	27.72
		Total Restocking Area	289.72

C.2.6 Protection
Protection against weevil; *Hylobious* spp remain a significant threat to the successful establishment of a replanted conifer site. Because the greatest damage is caused by adults developing and emerging from stumps at least 18 months from the time of felling, it should be possible for plants planted soon after felling to have grown through their most vulnerable period. However, in practice significant damage may be caused by insects invading from nearby older restocking sites within the first 18 months. The proposed management strategy to reduce *hylobious* damage to enable successful establishment will be through restock cultivation (as above), healthy planting stock with a robust root collar diameter and rapid replanting after felling. As current practice trees may be treated with pesticide before planting followed by a programme of top up pesticide application based upon survey observations. Continued engagement with ongoing research into biological control and physical barriers may provide alternative methods. Cooperation must be afforded to the Tangy Wind Farm forest owners' chemical reduction policies in accord with forest certification through UK Woodland Assurance Scheme. All personnel applying pesticides will be suitably trained (NPTC PA1 and PA6). Chemical usage will be in accordance with the leaseholders' chemical management instructions. Protection against deer; The three forest ownerships currently have their own deer stalking practitioners. Cooperation and coordination will be required to ensure browsing levels are kept to acceptable levels. It is not envisaged that deer fencing will be required and only localised use of tree shelters to protect broadleaved trees will be considered.

The deer management plan will consist of this cooperation with acceptable levels of damage.

Protection against livestock;

The stock fence between the forest area and adjacent farmland will require maintenance or replacement to prevent stock trespass into the newly replanted woodland. Where newly constructed wind farm roads cross the agricultural and forest marches, adequate gates or grids will be required.

C.2.7 Fence erection / removal

The species selected for replanting have been proven to be established without the need for deer fencing in the neighbouring woodlands and are not being considered for the area of this Forest Plan.

There is no intension to erect additional fences for this Forest Plan area. Where internal fences denote ownership boundaries consideration will be made as to their removal or retention.

C.2.8 Road Operations

The road layout is illustrated on the layout wind farm layout plan.

Within the Forest Plan area the wind farm roads will be constructed in accord with the Construction Environment Management Plan which covers all aspects of borrow pits, water crossing, silt traps and other measures to prevent diffuse pollution.

C.2.9 Public Access
In accordance with the Land Reform (Scotland) Act 2003, Chapter 2 Part 6(1) (g), general public access rights are removed from the construction site for health and safety reasons. There are no core paths within the study area that will be affected by the proposed development. There will be some local access restrictions across the site during construction. The access restrictions would include the temporary suspension of activities such as hunting and fishing. Any disruption to access during construction is considered to be short-term and temporary in nature. In the longer term public access restrictions will be removed and the Forest Plan area will be open in accordance with the Scottish Outdoor Access Code.

C.2.10 Historic Environment
During felling and replanting the sites noted within the Forest Plan area will be protected as UKFS requirements detailed in Forests and Historic Environment. Specifically, the areas will be avoided with timber harvesting machinery and replanting will be kept back some 20m from the area. Site no. 3. Hut circle is within the wind thrown compartment and will be cleared using the benefits of a timber harvester to cut off and pull trees away from the area to be forwarded away from the site. On replanting the area as identified will not be replanted and a route connecting site 3 with the open ground associated with sites 1 and 2. Adjacent to the Forest Plan area.

Site no. 10. Sheiling huts is already identified within FCS LMP and will not be replanted as it sits within the Allt nan Creamh riparian open ground.

Site no. 13. Tangymoil cup marked stone will require marking and protecting during the timber harvesting operations. Open ground will be left around the historic feature which ties in with the open ground associated with Allt a' Ghoirtein riparian zone.

The unverified location of the Avro Anson I will be dealt with as found and additional advice at the time of timber harvesting.

Any other sites of interest released during timber clearance will be responded to by taking advice if or as they arise.

C.2.11 Biodiversity

The Forest Plan replanting design will improve biodiversity opportunity through the increase of open space throughout the site but with the primary benefit being associated with the opening up of watercourses allowing enrichment of the riparian environment on:

- Allt nan Creamh and its tributaries to the north
- Allt Ceardaich, Allt a Ghoirtein and Tangy burn with their associated tributaries to the west and south and
- Allt Harvie to the east

The Tangy Wind Farm Habitat Management Plan will detail the measures will be taken to promote the recovery of a peatland habitat, principally through raising the water table. These are likely to consist of blocking the existing forest drains and measures to manage unwanted natural regeneration of conifer species. The prediction of conifer regeneration is not an accurate science and influenced by the abundance of seed locally at the time of felling and prevailing winds. The site

conditions in the area to be cleared are favourable to natural regeneration in terms of maturing conifer seed source and peaty conditions. However, nearby felled and restocked forest areas do not appear to have an abundance of natural regeneration. Accordingly, a programme to monitor conifer regeneration with plans to react to the findings shall be in place.

C.2.12 Tree Health
The appropriate species selection and provision of healthy planting stock on correctly cultivated ground should promote a healthy second rotation on this site. Forest monitoring will include tree health observations.

C.2.13 Invasive species
Forest monitoring will include invasive species monitoring and if noted plans drawn up in response.

C.2.14 New (Compensatory) Planting
Compensatory planting measures included within the Scottish Government Control of Woodland Removal Policy will be adhered to. As a default, 'compensatory planting' (or compensatory natural regeneration) implies an equivalent woodland area, on appropriate site types and with at least the equivalent woodland-related net public benefits, and must take place in Scotland.

The area determined as required for compensatory planting will be based on the areas not replanted resulting from the wind farm infrastructure within the area of the Tangy Wind Farm Forest Plan.

Draft plans identify some areas adjacent to the wind farm location providing environmental connectivity to lower ground. A separate area with potential for new planting is located south of the B843 Machrihanish – Campbeltown, near Bleachfield Farm.

An agreed compensatory planting plan will be submitted prior to commissioning of the wind farm.

The UK Forestry Standards will be referenced throughout all activities in relation to Forestry activities, using the General Forestry Practice Guidelines.

C.2.15 Other:	Deer Management Plan

The outline deer management plan is provided.

Deer management within the wind farm area would largely follow the existing deer management practices currently employed in the area, balancing the requirements of landowners both internal to the site, those of the neighbouring forest, as well as farming interests.

A collaborative approach shall be adopted to provide a deer management plan for the wind farm area.

Sika and Roe deer present are estimated to be in low numbers; only limited signs of bark stripping by Sika has been evidenced during forest survey work.

Adequate protection of young trees should be included for and areas of broadleaved planting will require additional specific protection in terms of tree shelters.

This protection will be extended to any areas of Compensatory Planting.

C.3 Environmental Impact Assessment and Permitted Development Notifications

Please indicate the total area (hectares) for each project type and provide details as requested by sensitive or non-sensitive area.

Type of Project	Sensitive Area		Non-sensitive Area		Total
Afforestation	0 %Con	0 %BL	0 %Con	%BL	ha
Deforestation	0 %Con	0 %BL	100 %Con	0 %BL	31.73 ha

Provide further details on your project if required.

31.73 ha reflects the ground taken by the wind farm infrastructure including open ground associated with the Bat buffer clearance zones. This is the figure carried forward as Compensatory Planting.

C.4 Tolerance Table

	Map Required (Y/N)	Adjustment to felling period*	Adjustment to felling coupe boundaries**	Timing of Restocking	Changes to Restocking species	Changes to road lines	Designed open ground ***	Windblow Clearance* ***
FC Approval normally not required	N	Fell date can be moved within 5 year period where separation or other constraints are met	Up to 10% of coupe area	Up to 2 planting seasons after felling	Change within species group e.g. evergreen conifers or broadleaves		Increase by up to 5% of coupe area	
Approval by exchange of email and map	Y		Up to 15% of coupe area	Between 2 and 5 planting seasons after felling subject to the wider forest and habitat structure not being significantly compromised		Additional felling of trees not agreed in plan Departures of more than 60m in either direction from centre line of road	Increase by up to 10% Any reduction in open ground within coupe area	Up to 5 ha
Approval by formal plan amendment may be required	Y	Felling delayed into second or later 5 year period Advance felling into current or 2nd 5 year period	More than 15% of coupe area	More than 5 planting seasons after felling subject to the wider forest and habitat structure not being significantly compromised	Change from specified native species Change between species group	As above, depending on sensitivity	More than 10% of coupe area Colonisation of open areas agreed as critical	More than 5 ha

Note

*Felling sequence must not compromise UKFS in particular felling coupe adjacency. Felling progress and impact will be reviewed against UKFS at 5 year review.

** No more than 1 ha, without consultation with FCS, where the location is defined as 'sensitive' within the Environmental Impact Assessment (Forestry) 1999 Regulations (EIA).

*** Tolerance subject to an overriding maximum of 20% designed open ground.

****Where windblow occurs, FCS must be informed of extent prior to clearance and consulted on clearance of any standing trees.

D. Production Forecast

Append your production forecast.

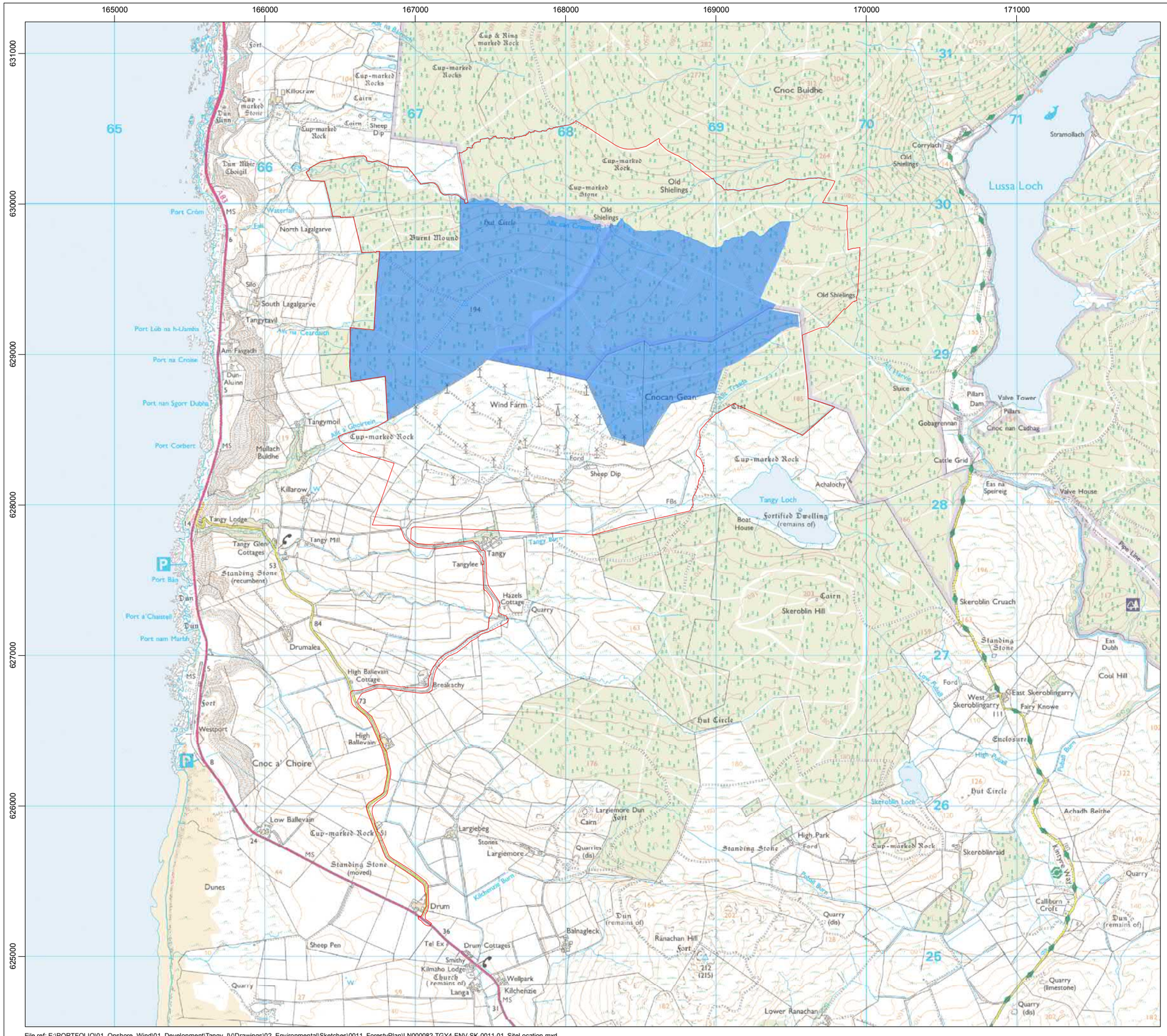
		YC 16		
Planting year	Age at 2020	m^3/ha	ha	Total m^3
1974	46	643	101.09	65,001
1975	45	623	124.43	77,520
1986	34	412	44.92	18,507
Total timber volume			270.44	161,028
At a conversion rate of 1.43 m^3/green tonne				112,606.85
This equates to number of timber lorry loads				5,119

(nb minor area discrepancy of 0.31 ha)

Appendices

Provide a list of appendices:

Item number	Title
Fig 1	Site Location
Fig 2	Current species plan
Fig 3	Concept plan
Fig 4	Felling plan
Fig 5	Timber haulage plan
Fig 6	Restocking plan
Plate 1	Low productivity on deep peat
Plate 2	Checked spruce on deep peat
Plate 3	Limited broadleaf potential
Plate 4	Watercourse will benefit with opening
Plate 5	Quality spruce within Lagalgarve
Plate 6	Wind thrown crop within Lagalgarve
Plate 7	Some evidence of bark stripping
Plate 8	Cup marked stone



Legend

- Forest Plan Area
- Wind Farm Site Boundary

0 0.25 0.5 1 km

N

Project Name

TANGY

Drawing Title

FOREST PLAN SITE LOCATION

Rev	Date	Remarks	Drwn	Chkd
R0	02/07/2018	First issue	CaT	NM

Drawing Number

LN000082-TGY4-ENV-SK-0011-01

Scale	Plot Size	Datum	Projection
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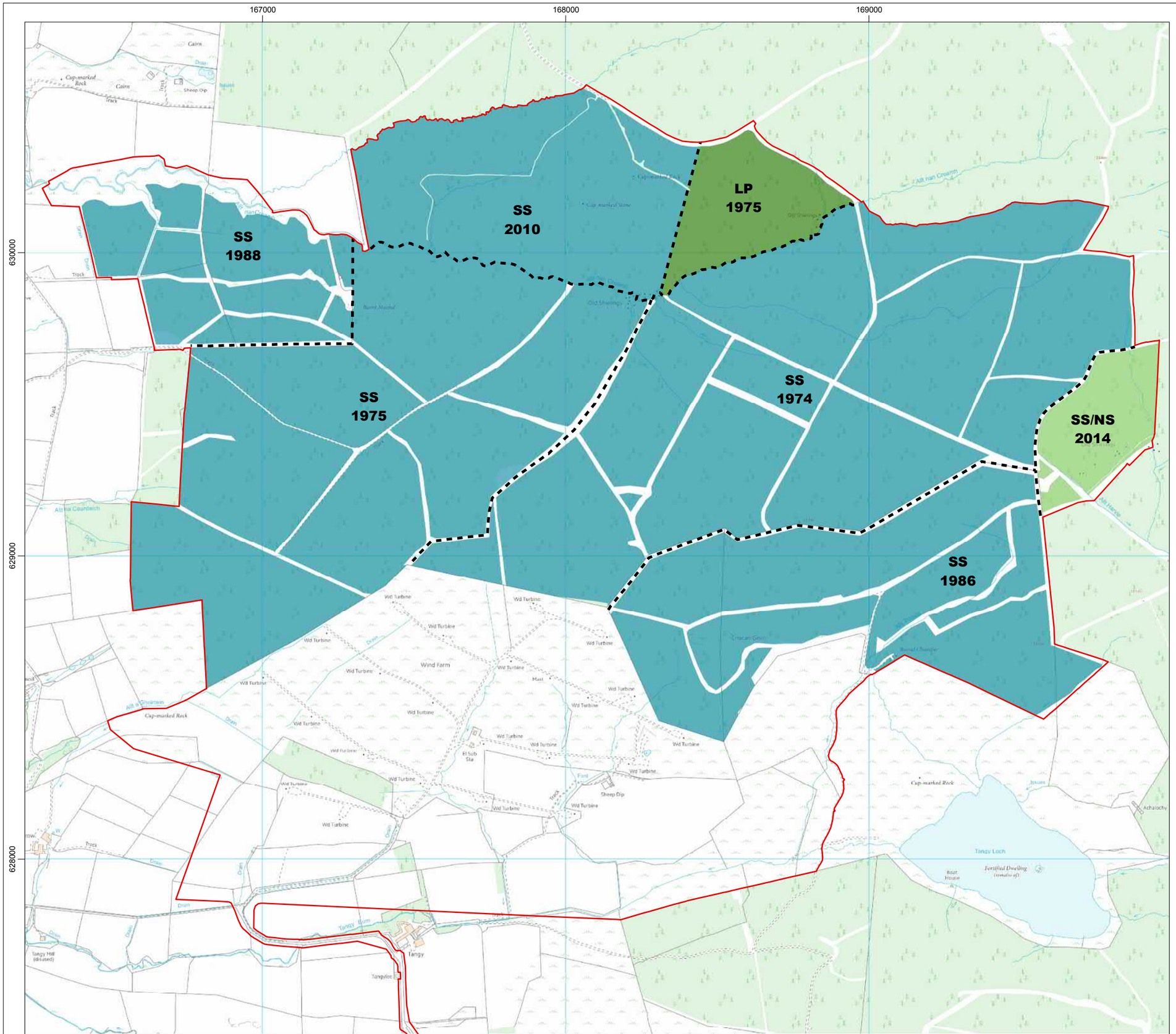

Legend

- LP
- SS
- SS/NS
- Wind Farm Site Boundary

0 125 250 500 Meters

N

Project Name

TANGY

Drawing Title

FOREST PLAN - CURRENT SPECIES

Rev	Date	Remarks	Drwn	Chkd
R0	02/07/2018	First issue	CaT	NM

Drawing Number

LN000082-TGY4-ENV-0005-02

Scale	Plot Size	Datum	Projection
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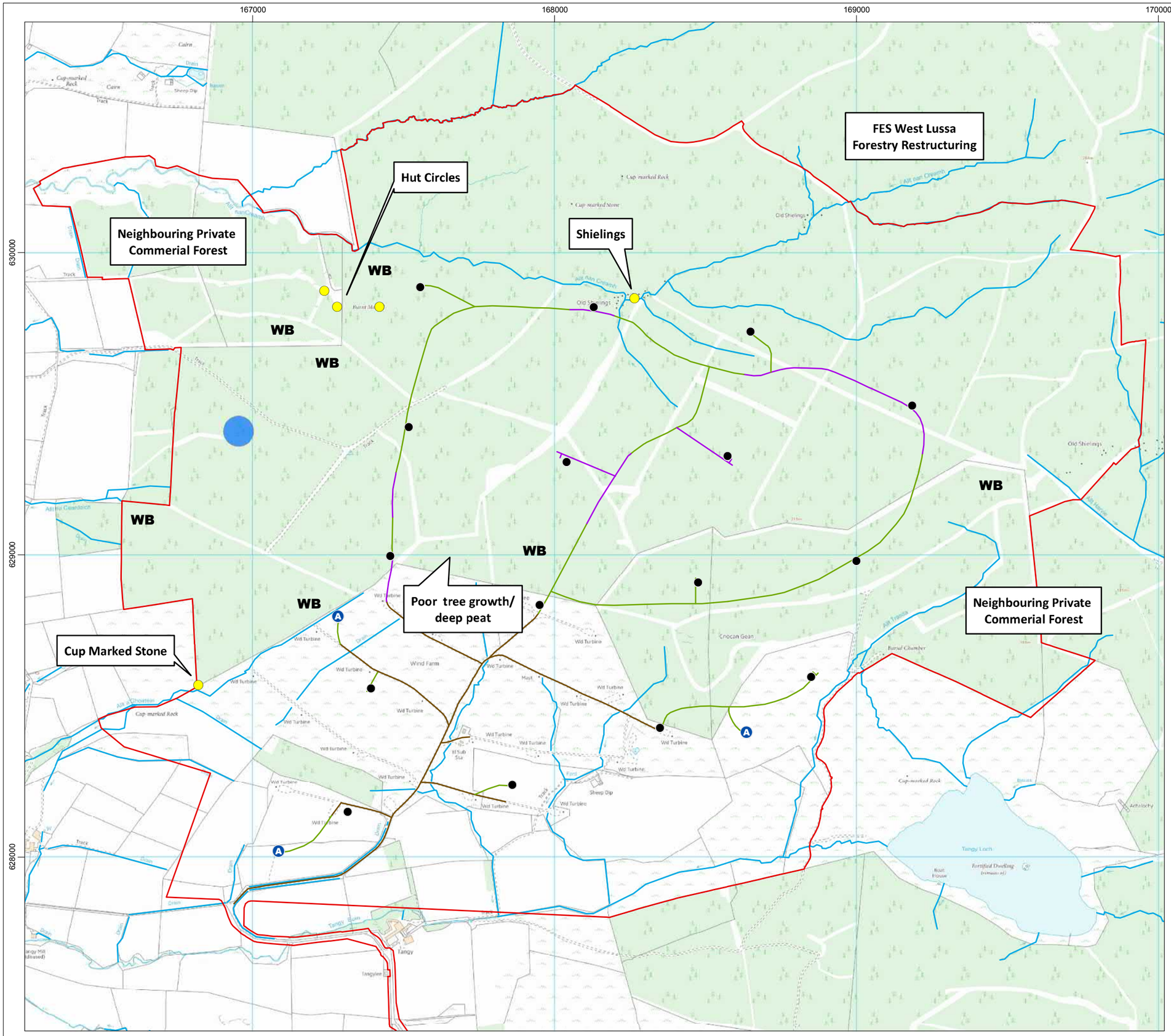

Legend

Permanent Infrastructure

- Turbine
- Permanent Met Mast
- New Cut Track
- New Floating Track
- Existing Track to be Reused
- Wind Farm Site Boundary

Restocking Constraints

- Archaeological Feature
- Private Water Supply Clearance Area

WB - Wind Blown

0 125 250 500 Meters

N

Project Name

TANGY

Drawing Title

FOREST PLAN - CONCEPT

Rev	Date	Remarks	Drwn	Chkd
R0	17/07/2018	First issue	CaT	NM

Drawing Number

LN000082-TGY4-ENV-0011-03

Scale	Plot Size	Datum	Projection
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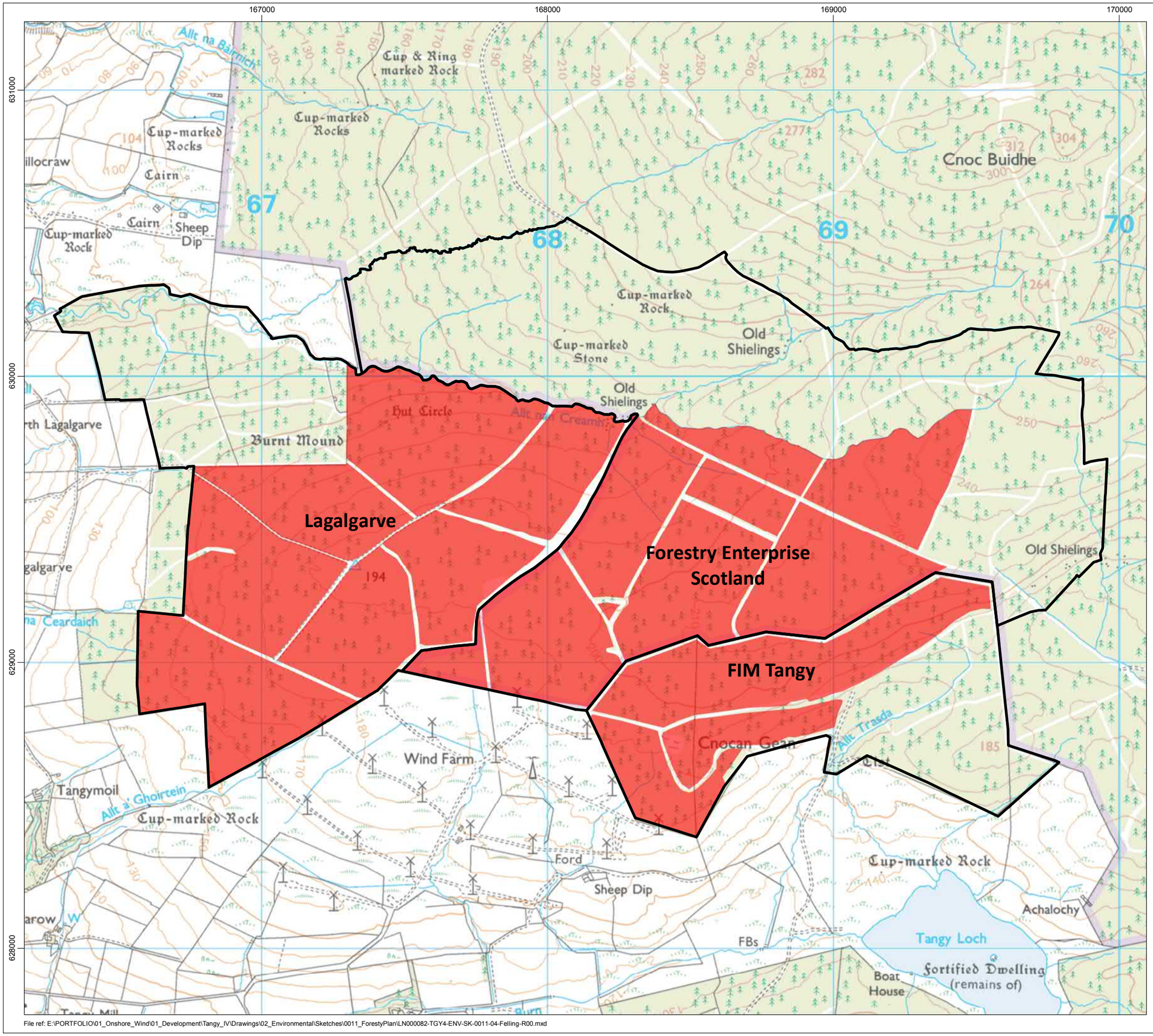

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Legend

- Landowner
- Phase 1 Felling (270.75ha)

0 125 250 500 Meters

N

Project Name

TANGY WIND FARM FOREST PLAN

Drawing Title

FELLING

Rev	Date	Remarks	Drwn	Chkd
R0	17/07/2018	First issue	CaT	NM

Drawing Number

LN000082-TGY4-ENV-SK-0011-04

Scale	Plot Size	Datum	Projection
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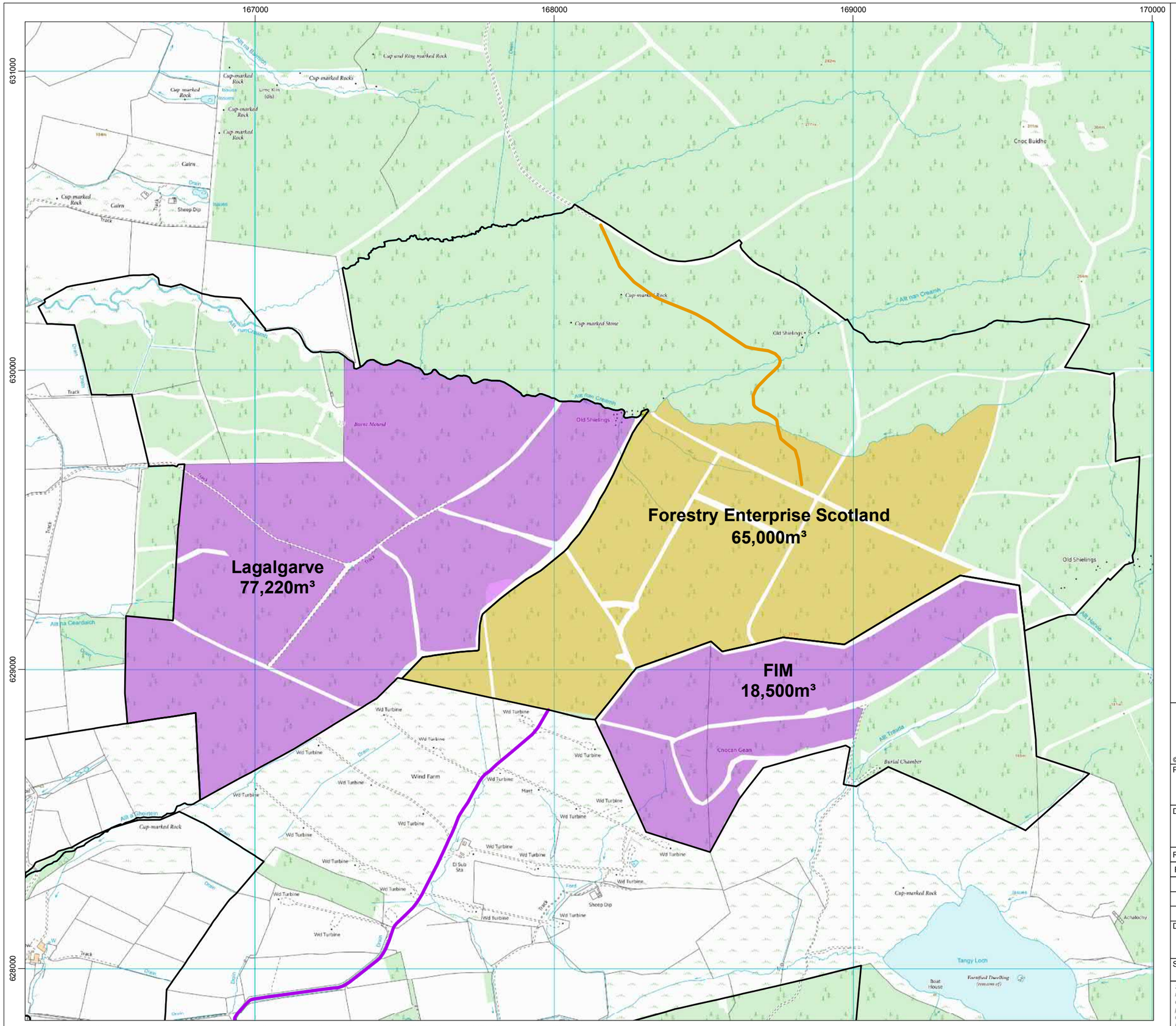

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Legend

- Timber Haulage to A83 via public roads at NR 655 280
- Forestry Enterprise Scotland Timber Haulage
- FIM and Lagalgarve Timber
- Forestry Enterprise Scotland Timber
- Landowner

0 125 250 500 Meters

N

Project Name

TANGY WIND FARM FOREST PLAN

Drawing Title

TIMBER HAULAGE

Rev	Date	Remarks	Drwn	Chkd
R0	17/07/2018	First issue	CaT	NM

Drawing Number

LN000082-TGY4-ENV-SK-0011-05

Scale	Plot Size	Datum	Projection
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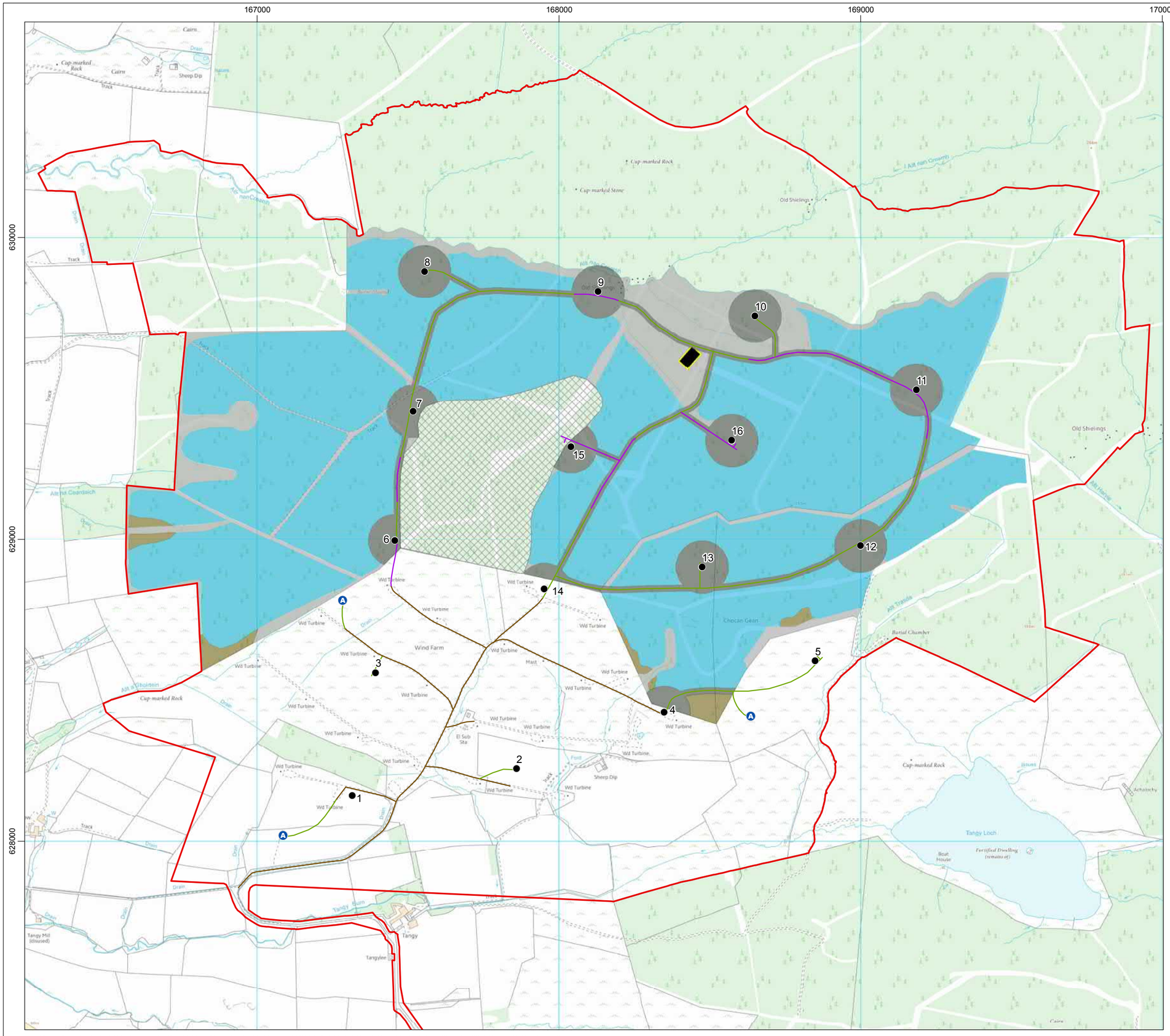

Legend

Permanent Infrastructure

- Turbine
- Permanent Met Mast
- New Cut Track
- New Floating Track
- Existing Track to be Reused
- Substation
- Site Boundary

Replanting Plan

- NBL Replant (3.50ha)
- SS Replant (196.35ha)
- Peat Restoration Area (27.72ha)
- Designed Open Ground (30.43ha)
- Wind Farm Infrastructure and Bat Clearance (31.73ha)

0 125 250 500 Meters

N

Project Name

TANGY WIND FARM FOREST PLAN

Drawing Title

RESTOCKING

Rev	Date	Remarks	Drwn	Chkd
R0	06/07/2018	First issue	CaT	NM

Drawing Number

LN000082-TGY4-ENV-SK-0011-06

Scale	Plot Size	Datum	Projection
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Plate 1

Plate 2

Plate 3

Plate 4

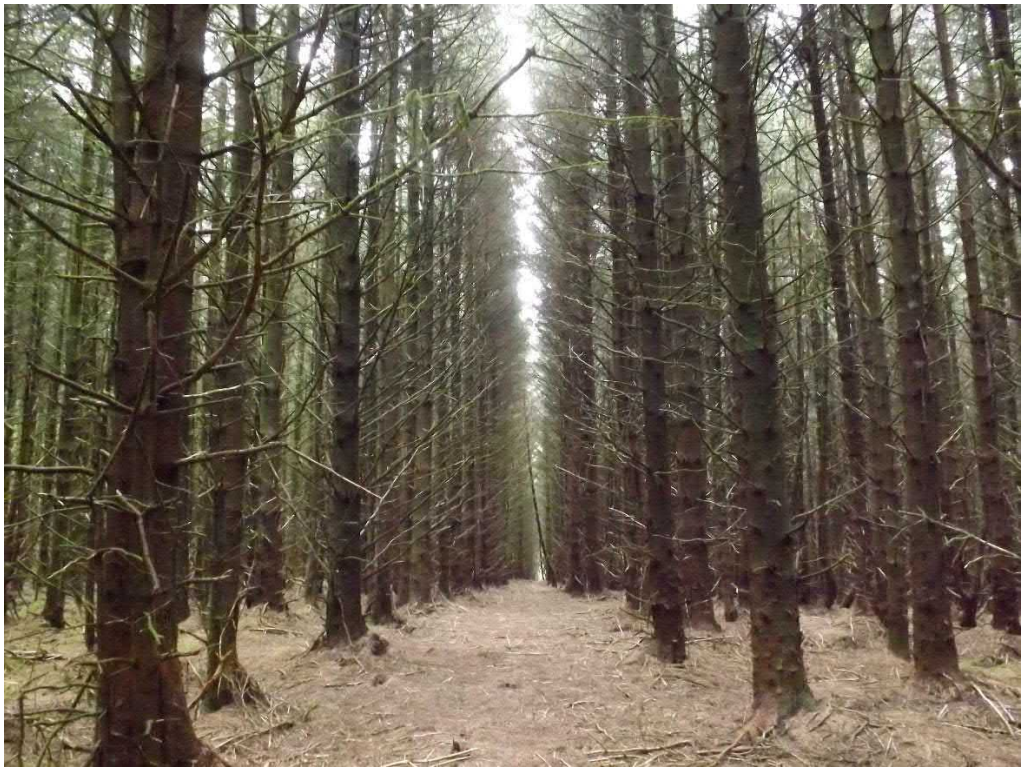

Plate 5

Plate 6

Plate 7

Plate 8

APPENDIX 17.1: SHADOW FLICKER ASSESSMENT

tnei

A specialist energy consultancy

Shadow Flicker Assessment

Tangy IV Wind Farm

SSE Renewables

12431-003
17 March 2018

COMMERCIAL IN CONFIDENCE

sse

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TNEI Services Ltd **Company Registration Number: 03891836**		**VAT Registration Number: 239 0146 20**
Registered Address Bainbridge House 86-90 London Road Manchester M1 2PW Tel:+44 (0)161 233 4800 Fax:+44 (0)161 233 4801	West One Forth Banks Newcastle upon Tyne NE1 3PA Tel:+44 (0)191 211 1400	Queens House 19 St. Vincent Place Glasgow G1 2DT Tel:+44 (0)141 428 3180

TNEI Africa (Pty) Ltd **Registered: Mazars House, Rialto Rd, Grand Moorings Precinct, 7441 Century City, South Africa** **Company Number: 2016/088929/07**
1st Floor Willowbridge Centre Carl Cronje Drive Cape Town South Africa, 7530 Tel: +27 (0)21 974 6181

Executive Summary

TNEI Services Ltd was commissioned by SSE Renewables to undertake an assessment of the potential for shadow flicker occurrence resulting from the installation of 16 wind turbines at the proposed Tangy IV Wind Farm. The shadow flicker assessment was used to assess the potential for shadow flicker occurrence resulting from the proposed development at the nearest receptors.

Under certain combinations of geographical position, time of day and year, wind speed and wind direction, the sun may pass behind the rotor and cast a shadow over neighbouring buildings' windows. When the blades rotate and the shadow passes a window, to a person within that room the shadow appears to flick on and off; this effect is known as shadow flicker. Where moving shadows are cast over the ground (rather than a building's windows), this is known as 'shadow throw'. There are no guidelines to quantify the effect and there is no requirement to assess 'shadow throw', therefore 'shadow throw' has not been considered further in this assessment.

In the United Kingdom, there is no standard for the assessment of shadow flicker and there are no guidelines which quantify what exposure levels would be acceptable. However some information specific to shadow flicker can be found in the Scottish Government's web based renewables advice on *'Onshore Wind Turbines'* which states: *'Under certain combinations of geographical position, time of day and time of year, the sun may pass behind the rotor and cast a shadow over neighbouring properties. When the blades rotate, the shadow flicks on and off; the effect is known as "shadow flicker". It occurs only within buildings where the flicker appears through a narrow window opening. The seasonal duration of this effect can be calculated from the geometry of the machine and the latitude of the potential site. Where this could be a problem, developers should provide calculations to quantify the effect. In most cases however, where separation is provided between wind turbines and nearby dwellings (as a general rule 10 rotor diameters), "shadow flicker" should not be a problem. However, there is scope to vary layout / reduce the height of turbines in extreme cases.'*

Sixteen 130 m rotor diameter wind turbines were modelled in this assessment. Seven shadow flicker assessment locations (SFAL's) located within 1,300 m (10 times rotor diameter) of the proposed wind turbines were assessed.

It has been shown that under worst case conditions, the maximum theoretical occurrence of shadow flicker amounts to 48.2 hours per year and a maximum of 0.51 hours per day which is experienced at Killarow Farm (SFAL2). The times of day when shadow flicker could occur at the Killarow Farm is between 04:40 and 06:30 (GMT) during the months of April through to August.

It should be noted that these are the theoretical maximum number of shadow flicker hours and do not take into account weather conditions (i.e. when there is total or partial cloud cover), local visual obstructions (such as trees, hedges or other structures), turbine orientation and turbine operation. In reality, the amount of time when shadow flicker occurs will be less than that predicted. Accordingly an assessment has also been undertaken to estimate the 'likely' number of shadow flicker hours taking into account typical sunshine hours for the region. Consideration of likely sunshine hours suggests likely occurrence of shadow flicker of 15.4 hour per year and a maximum of 0.16 hours per day at Killarow Farm (SFAL2).

The potential for cumulative effects with other nearby wind farm developments has been considered but no cumulative effects are predicted as there are no other wind farms within 10 rotor diameters of the SFALs.

If the Scottish Government are minded to grant planning consent for the proposed wind farm it may be appropriate to include a shadow flicker related planning condition to ensure that the amenity of local residents is protected. Inclusion of a condition requiring implementation of a shadow flicker control system would ensure that the turbines do not operate during periods where shadow flicker is predicted, the result of which would be that no shadow flicker would occur at any of the identified receptors.

Contents

TABLES

ANNEXES

1 Introduction

1.1 Brief

1.1.1 To undertake a shadow flicker assessment for the proposed Tangy IV Wind Farm in order to quantify the potential shadow flicker occurrence that will be incident at sensitive dwellings located to the south / south-west of the site.

1.1.2 To present the results in the form of a report with reference to current Planning Policy and Guidance.

1.2 Background

1.2.1 TNEI Services Ltd was commissioned by SSE Renewables to undertake a shadow flicker assessment for the proposed Tangy IV Wind Farm (hereinafter referred to as the 'proposed development'). The proposed development is located approximately 8 km to the north west of Campbeltown in Argyll and Bute. The approximate Ordnance Survey grid reference for the proposed development is 167470, 628131.

1.2.2 This shadow flicker assessment models 16 wind turbines with a 130 m rotor diameter and an 84.9 m hub height (149.9m to tip). These dimensions have been used in the assessment to provide a worst case assessment area.

1.3 Conditions Required for Shadow Flicker

1.3.1 Under certain combinations of geographical position, time of day and year, wind speed and wind direction, the sun may pass behind the rotor and cast a shadow over neighbouring buildings' windows. When the blades rotate and the shadow passes a window, to a person within that room the shadow appears to flick on and off; this effect is known as shadow flicker. It occurs only within buildings where the flicker appears through a window aperture and only in buildings within 130 degrees either side of north relative to a turbine can be affected.

1.3.2 Where moving shadows are cast over the ground (rather than a building's windows), this is known as 'shadow throw'. There are no guidelines to quantify the effect and there is no requirement to assess 'shadow throw', therefore it has not been considered further in this assessment.

1.4 Potential Impacts associated with Shadow Flicker including Photosensitive Epilepsy

1.4.1 Shadow flicker can result in a degradation of amenity when people are within the rooms affected by the phenomenon.

1.4.2 The flickering effect caused by shadow flicker also has the potential to induce epileptic seizures through a condition known as photosensitive epilepsy. Around 1% of people in the UK have epilepsy although only 3% of these suffer from photosensitive epilepsy. The common frequency at which photosensitive epilepsy might be triggered varies from person to person, though generally it is between 3 and 30 flashes per second (hertz (Hz)); sensitivity under 3 hertz is not common (The National Society for Epilepsy, 2016 [(1)]). Most commercial

scale (>1 MW) wind turbines in the UK rotate much slower than this, at between 0.3 and 1.0 Hz; therefore, health effects arising from shadow flicker will not have the potential to occur unless the operating frequency of a particular turbine is between 3 and 30 Hz and all other pre-conditions for shadow flicker effects to occur exist. The potential impacts associated with the proposed development are considered in Section 5.4 of this report.

1.5 Timestamps and Co-ordinates

1.5.1 Please note that unless otherwise stated, all times are presented in GMT (Greenwich Mean Time) and all grid coordinates refer to the British National Grid Survey grid using Eastings and Northings.

2 Planning Policy and Guidance

2.1 Overview of Shadow Flicker Policy and Guidance

2.1.1 There is no standard for the assessment of shadow flicker accepted in the whole of the UK and there are no guidelines which quantify what exposure levels would be acceptable. In assessing the potential shadow flicker impacts of the proposed development the following guidance and policy documents have been considered:

- Local Policy;
- National Planning Policy;
- Web Based Renewables Advice: *'Onshore Wind Turbines'* [6]; and
- An update of the UK shadow flicker evidence base produced by the (former) Department for Energy and Climate Change (DECC) [8].

2.2 Local Planning Policy

2.2.1 The adopted Development Plan for the area comprises the Argyll and Bute Local Development Plan (LDP) which was adopted on 26 March 2015. The Local Plan sets out a settlement strategy and spatial framework for how the Council wants to see Argyll and Bute develop to 2024 and beyond.

2.2.2 The Plan contains a number of overarching polices, the aim of which is to deliver high standards of development. POLICY LDP STRAT 1 – Sustainable Development in relation to achieving sustainable development proposals states that developers should: *'Avoid having significant adverse impacts on land, air and water environment'*.

2.2.3 Policy LDP 6 – Supporting the Sustainable Growth of Renewables sets out the criteria to which all applications for wind turbine development will be assessed against including: *'Impacts on communities and individual dwellings, including visual impact, residential amenity, noise and shadow flicker'*.

2.2.4 Supplementary Guidance 2: Renewable Energy was adopted in December 2016 and contains a reference to the Policy LDP 6 and also states that shadow flicker is likely to be relevant to applications for micro scale wind. It can be assumed that the same applies for large scale wind farms. There are no further references made.

2.2.5 A new Local Development Plan is currently under production; however it is not due to be adopted until June 2020 and so has not been considered in this report.

2.3 National Planning Policy

2.3.1 Scottish Planning Policy (SPP) (2014) [8] is the statement of the Scottish Government's policy on nationally important land use planning matters. Paragraphs 161 to 166 relate to 'Onshore Wind' and provide guidance on the preparation of a spatial framework within the development plan for Local Authorities. Paragraph 169 relates to Development Management and sets out the criteria that are likely to be considered in deciding all applications for energy infrastructure developments. It states that proposals should take account of spatial frameworks for wind farms (where relevant) and that considerations may

include visual impact, residential amenity, noise and shadow flicker on communities and individual dwellings.

2.4 Web Based Planning Advice - Onshore Wind Turbines

2.4.1 The 'Onshore Wind Turbines' web based document states that, as a general rule, flicker effects have been proven to occur only within ten rotor diameters of a wind turbine. The guidance states:

'Under certain combinations of geographical position, time of day and time of year, the sun may pass behind the rotor and cast a shadow over neighbouring properties. When the blades rotate, the shadow flicks on and off; the effect is known as "shadow flicker". It occurs only within buildings where the flicker appears through a narrow window opening. The seasonal duration of this effect can be calculated from the geometry of the machine and the latitude of the potential site.

Where this could be a problem, developers should provide calculations to quantify the effect. In most cases however, where separation is provided between wind turbines and nearby dwellings (as a general rule 10 rotor diameters), "shadow flicker" should not be a problem. However, there is scope to vary layout / reduce the height of turbines in extreme cases.'

2.4.2 Whilst it is possible to predict periods when shadow flicker could theoretically occur using industry standard software packages, within the UK there are no relevant guidelines to quantify what exposure levels would be acceptable.

2.5 Department of Energy and Climate Change (DECC) - Update of UK Shadow Flicker Evidence Base

2.5.1 In March 2011, the Department of Energy and Climate Change issued a report titled 'Update of UK Shadow Flicker Evidence Base.' The report was prepared for DECC by Parsons Brinckerhoff (PB). The report summarised the findings of research undertaken by PB with a view to enabling DECC to 'advance current understanding of the shadow flicker effect.' The report:

'Presents an update of the evidence base which has been produced by carrying out a thorough review of international guidance on shadow flicker, an academic literature review and by investigating current assessment methodologies employed by developers and case study evidence.'

2.5.2 The PB report concludes that an assessment area of 10 rotor diameters, 130 degrees either side of north is appropriate whilst noting that an adjustment may be appropriate for sites with different latitudes. PB found that a worst-case scenario is usually reported but noted that this is sometimes accompanied by a more 'realistic' approximation which takes account of variables like sunshine hours. The report confirms that the industry software packages WindPro, WindFarm and WindFarmer provide similar outputs.

3 Methodology

3.1 Shadow Flicker Modelling

3.1.1 It is possible to calculate the total theoretical number of hours per year that shadow flicker may occur in a building from the relative position of the turbine to the building, the geometry of the wind turbines, the latitude of the wind turbine site and the size / orientation of the windows potentially affected.

3.1.2 The potential for shadow flicker to occur and the duration of such an effect depends upon the following factors:

- the location of the building relative to the turbines;
- the distance from the turbines;
- the turbine hub-height and rotor diameter;
- the time of year (which impacts the trajectory of sun's path across the sky);
- the proportion of daylight hours in which the turbines operate;
- the frequency of bright sunshine and cloudless skies (particularly at low elevations above the horizon); and
- the wind direction (which impacts on turbine orientation).

3.1.3 Several specialist software packages are available which can take account of the variables listed above to determine the maximum theoretical number of shadow flicker hours which could occur at each window location. For this assessment details regarding the turbine dimensions / locations and the size, position and orientation of the windows at the buildings being assessed were entered into the 'Windfarm' software which is produced by REsoft [(11)].

3.1.4 The Windfarm software was then used to predict all periods when shadow flicker can theoretically occur.

3.2 Consultation

3.2.1 The scoping opinion issued by the Energy Consents Unit (dated 16 October 2017) included a consultation response from Argyll and Bute Council in relation to shadow flicker. Argyll and Bute Council stated that the:

'Consequences for the occupiers of property and countryside users should be assessed in terms of noise, shadow flicker, air quality, lighting and private water supplies'

4 Baseline

4.1 Description

4.1.1 The immediate area surrounding the site is rural with only a few scattered buildings. There are a small number of residential buildings which would be theoretically susceptible to shadow flicker.

4.2 Study Area

4.2.1 The candidate wind turbines modelled in this assessment each have a rotor diameter of 130 m, therefore the study area has been limited to 1,300 m and 130 degrees either side of north around the proposed turbine locations, as shown on Figure A1.1 (Annex 1). Buildings located outside 130 degrees either side of north have been excluded from the analysis as no direct path between the sun, the turbine and these buildings resulting in shadow flicker could occur.

4.3 Identification of Potential Receptors

4.3.1 Initially, a desk based assessment was undertaken using Ordnance Survey mapping data and aerial photography to identify potentially sensitive receptors within the study area; twelve such receptors were identified. This information formed the basis for the site survey which was undertaken in order to assess the receptors.

4.3.2 The site survey was undertaken in March 2018. Following the site survey, all twelve residential dwellings were chosen for the detailed assessment. Where a number of receptors were located in very close proximity, they were modelled as a single shadow flicker assessment location (SFAL); consequently seven SFALs were included in the assessment. Details of the SFALs are provided in Table 4.1. The building survey results which include information on window size, number and orientation are included in Annex 2.

Table 4.1 – Shadow Flicker Assessment Locations (SFAL)

SFAL	Easting (m)	Northing (m)	Distance to nearest turbine* (m)
SFAL1 - Tangymoil	166244	628594	1,148
SFAL2 – Killarow Farm	166269	628025	1,053
SFAL3 – Tigh Na Mara	166079	628171	1,236
SFAL4 – Tangy Mill	166275	627740	1,117
SFAL5 - Tangylee	167489	627768	419
SFAL6 – Property north of Tangy Mill Croft	166067	627768	1,305
SFAL7 – Tangy Mill Croft	166125	627650	1,290

* *Please note the distance to nearest turbine quoted above is approximate and may differ from those reported elsewhere. Distances for the shadow flicker assessment are taken from the nearest turbine to the façade/window of the building.*

4.4 Information Gaps

4.4.1 The process has been as inclusive as possible with a total of twelve residential receptors buildings near to the proposed development being assessed. No information gaps have been identified.

5 Assessment Results

5.1 Prediction of the Likely Effects

5.1.1 Table 5.1 below details the shadow flicker modelling results and summarises the predicted frequency of occurrence of shadow flicker at the worst case window on each building (with respect to 'Theoretical Hours per Year'). A detailed listing of the potential for shadow flicker occurrence at each receptor is included in Annex 3. In addition Figures A1.3 to A1.9 (in Annex 1) show the potential shadow flicker occurrence at the most affected window of each receptor and illustrate the times of year and times of day when shadow flicker could theoretically occur.

Table 5.1 – Theoretical Predicted Levels of Shadow Flicker

SFAL/ Window	Frequency of Shadow Occurrence (days/ year)	Max Hours of Shadow per Day	Mean Hours of Shadow per Day	Total Theoretical Hours per Year
SFAL1/12	126	0.47	0.36	45
SFAL2/03	118	0.51	0.41	48.2
SFAL3/01	28	0.44	0.35	9.8
SFAL4/04	80	0.51	0.43	34.8
SFAL5/05	0	0	0	0
SFAL6/07	54	0.44	0.34	18.4
SFAL7/08	76	0.46	0.4	30.7

5.1.2 The calculations used to determine the numbers in Table 5.1 assume a 'worst case' scenario with the following assumptions:

- the sky is always clear (i.e. no account of climatic conditions such as clouds or precipitation has been made);
- there are no objects such as trees or buildings surrounding the windows that may block the view to turbines;
- the turbine rotors are always aligned face-on to the window, providing the maximum opportunity for shadow flicker; and
- the rotors are always turning (i.e. no account has been taken of calm winds or shut-down periods).

5.1.3 Similarly, when the sun is close to the horizon, at dawn and dusk, the intensity of the sun's rays is reduced and they are less likely to cast distinct shadows. It is generally considered that when the sun is lower than 2° above the horizon, that shadow flicker is unlikely to occur

to any significant extent. This has been accounted for in the modelling by excluding periods where the sun is less than 2° above the horizon.

5.2 Evaluation of the Likely Effects

5.2.1 Under worst case conditions, the maximum theoretical occurrence of shadow flicker amounts to 48.2 hours per year, experienced at Killarow Farm (SFAL2). The times of day when shadow flicker is likely to occur varies between 04:40 and 06:30 (GMT) during the months of April to August.

5.2.2 It is important to note however that the instances of shadow flicker will always be less than that predicted by the model as these are based on a worst case scenario. The occurrence of shadow flicker is only possible during the operation of the wind turbines (i.e. when the rotor blades are turning) and when the sky is clear enough to cast shadows. It is important to consider the following facts when making an assessment:

- Climatic conditions dictate that the sun is not always shining. Regional Met Office data gives actual sunshine hours for the Argyll and Bute region to be 32% of total daylight hours[1]. Cloud cover during other times may obscure the sun and prevent shadow flicker occurrence. While some shadow may still be cast under slightly overcast conditions, no shadow at all would be cast when heavy cloud cover prevails. It is considered that weather conditions will reduce actual occurrence of shadow flicker by at least half, compared to calculated levels;
- objects such as trees or walls may surround windows and obscure the view of the turbines and hence prevent shadow flicker; and
- during operation, the turbine rotors will automatically orientate themselves to face the prevailing wind direction. This means the turbine rotors will not always be facing the affected window and in fact will sometimes be 'side-on' to the window. Very little of the blade movement would be visible during such occurrences and therefore the potential for shadow flicker is reduced.

5.2.3 As detailed above, shadow flicker can only occur during daylight hours and when the sun is shining. The total theoretical hours per year given in Table 5.1 above assume all hours of daylight are sunny with clear skies. For the most affected SFAL, the total theoretical shadow flicker hours are 48.2 hours per year. Using historical data provided by the Met Office, the total theoretical hours can be re analysed to provide a more realistic estimate of the likely shadow flicker levels. Actual sunshine hours is given to be 32%* of all daylight hours therefore the potential 'likely' hours of shadow flicker per year would be 15.4 hours.

5.2.4 This figure does not take account of the other factors listed in Section 5.2.2 above which may reduce levels further.

5.2.5 The 'likely' hours of shadow flicker occurrence at Tangymoil (SFAL1), Tigh Na Mara (SFAL3), Tangy Mill (SFAL4), Tangylee (SFAL5), Property north of Tangy Mill Croft (SFAL6) and Tangy

* Calculated based on figures available at https://www.metoffice.gov.uk/public/weather/climate/ for Campbeltown, 1,412.5 hours of sunshine a year (1412.5/4380*100 = 32%) (last accessed 16/03/2018).

Mill Croft (SFAL7) are 14.4, 3.1, 11.1, 0, 5.9 and 9.8 per year respectively when considering the same methodology detailed in Section 5.2.3.

5.3 Potential Cumulative Effects

5.3.1 The nearest wind farm to the site of the proposed Tangy IV Wind Farm (except Tangy I and II, which would be decommissioned if Tangy IV were to be built), consented, operational or otherwise, is the Beinn an Tuirc Wind Farm (Phase 3), located approximately 4,000 m to the north east. Given the distance between the two schemes, and the respective hub heights (130 m and 90 m, giving a 10 rotor diameter study area of 1,300 m and 900 m respectively), the relative study areas will not cross as the distance between the schemes is too great. Accordingly no cumulative shadow flicker is predicted to occur.

5.4 Photosensitive Epilepsy

5.4.1 The possibility that shadow flicker could induce photosensitive epilepsy has also been considered. Whilst the exact turbine to be used on site is not yet known, information provided by the manufacturer for an indicative candidate turbine, the Nordex N131, details that the turbine has a maximum r.p.m. of 13.6[2]. Given the turbine will have three blades, the frequency at which a blade will pass a particular point will be in the order of 40.8 times per minute, which equates to 0.68 flashes per second (hertz). This is significantly less than the 3 to 30 hertz frequency range commonly considered to induce photosensitive epilepsy (The National Society for Epilepsy, 2016 [(1)]). Consequently, shadow flicker caused by the proposed development is predicted to have no adverse health effects. While some people are sensitive at higher frequencies, it is uncommon to have photosensitivity below 3 hertz and consequently shadow flicker caused by this development is predicted to have no adverse health effects.

5.4.2 The potential for cumulative shadow flicker occurrence has been investigated. Shadow flicker is predicted to occur from no more than one turbine at a given time and as such there are no predicted cumulative effects.

5.5 Mitigation Measures

5.5.1 There are no relevant UK guidelines which quantify what exposure levels of shadow flicker are acceptable. Where particular combinations of circumstances arise which increase the potential for nuisance, mitigation may be required to reduce the level of exposure to acceptable levels.

5.5.2 Mitigation measures are available to counteract shadow flicker occurrence to reduce the possibility of nuisance. These include planting tree belts between the affected window and the turbines and shutting down the turbines using turbine control systems during periods when shadow flicker could occur.

5.5.3 Inclusion of a condition requiring implementation of a shadow flicker control system would ensure that the turbines do not operate during periods where shadow flicker is predicted, the result of which would be that no shadow flicker would occur at any of the identified receptors.

[2] Available at http://www.nordex-online.com/fileadmin/MEDIA/Produktinfos/EN/Nordex_Delta_Broschuere_en.pdf (last accessed 16/03/2018)

6 Conclusions

6.1.1 A shadow flicker assessment has been undertaken for the seven Shadow Flicker Assesment Locations (SFALs) within 1,300 m of the proposed wind turbine locations. The turbines modelled in this assessment each have a rotor diameter of 130 m.

6.1.2 It has been shown that under worst case conditions, the maximum occurrence of shadow flicker amounts to 48.2 hours per year experienced at Killarow Farm (SFAL2). The times of day when shadow flicker could theoretically occur at this location is in the early morning time from April to August.

6.1.3 It is important however to note that these are the theoretical maximum number of shadow flicker hours per year. They do not take into account weather conditions (i.e. no sun or partial cover), local visual obstructions (such as trees, hedges or other structures), turbine orientation and turbine operation. In reality, the amount of time when shadow flicker occurs will be less than that predicted. It is also important to note that affected windows may well be in rooms that are not generally in use at the times when the effect may occur. The 'likely' occurrence of shadow flicker at the worst affected property, Killarow Farm (SFAL2), is predicted to be 15.4.

6.1.4 If the Scottish Government are minded to grant planning consent for the proposed wind farm it may be appropriate to include a shadow flicker related planning condition to ensure that the amenity of local residents is protected. Inclusion of a condition requiring implementation of a shadow flicker control system would ensure that the turbines do not operate during periods where shadow flicker is predicted, the result of which would be that no shadow flicker would occur at any of the identified receptors.

7 Glossary of Terms

Shadow Flicker: The term 'shadow flicker' refers to the flickering effect caused when rotating wind turbine blades periodically cast shadows over neighbouring properties as they turn, through constrained openings such as windows.

Shadow Throw: Shadow throw occurs when a shadow is cast by turbine(s) across the ground at frequent intervals.

Photosensitive Epilepsy: is a form of epilepsy in which seizures are triggered by visual stimuli that form patterns in time or space, such as flashing lights, bold, regular patterns, or regular moving patterns.

8 References

1. **Epilepsy Society.** https://www.epilepsysociety.org.uk/photosensitive-epilepsy#.Wo1uz6jFLcs.

2. **Scottish Government.** Web Bases Renewables Advice 'Onshore Wind Turbines'. *Scottish Government.* [Online] 2014. http://www.gov.scot/Topics/Built-Environment/planning/Policy/Subject-Policies/Utilities/Delivering-heat-electricity/renewables-advice.

3. Parsons Brinckerhoff prepared for the Department of Energy and Climate Change, Update of UK Shadow Flicker Evidence Base, March 2011. [Online] http://webarchive.nationalarchives.gov.uk/20110405153950/http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/renewable/planning/on_off_wind/shadow_flicker/shadow_flicker.aspx.

4. **Scottish Government.** Scottish Planning Policy. *Scottish Government.* [Online] http://www.gov.scot/Publications/2014/06/5823.

5. **ReSoft Ltd.** WindFarm Release 4.2.1.9. (1997-2014).

Annex 1 – Figures

Figure A1.3 – Predicted Shadow Flicker Times at SFAL1

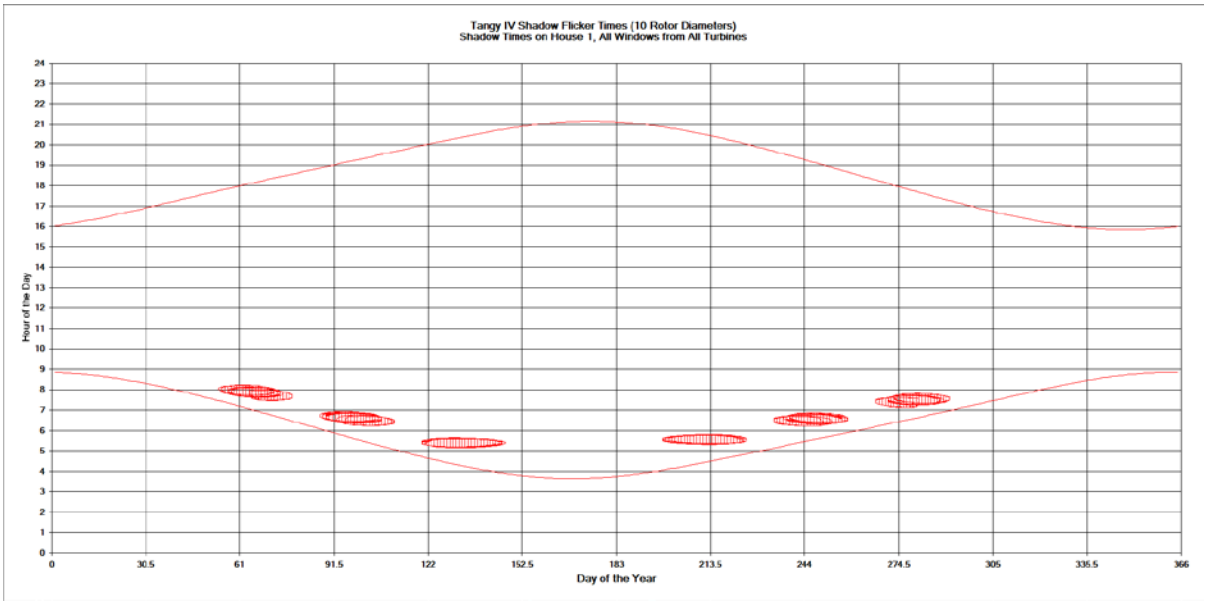


Figure A1.4 – Predicted Shadow Flicker Times at SFAL2

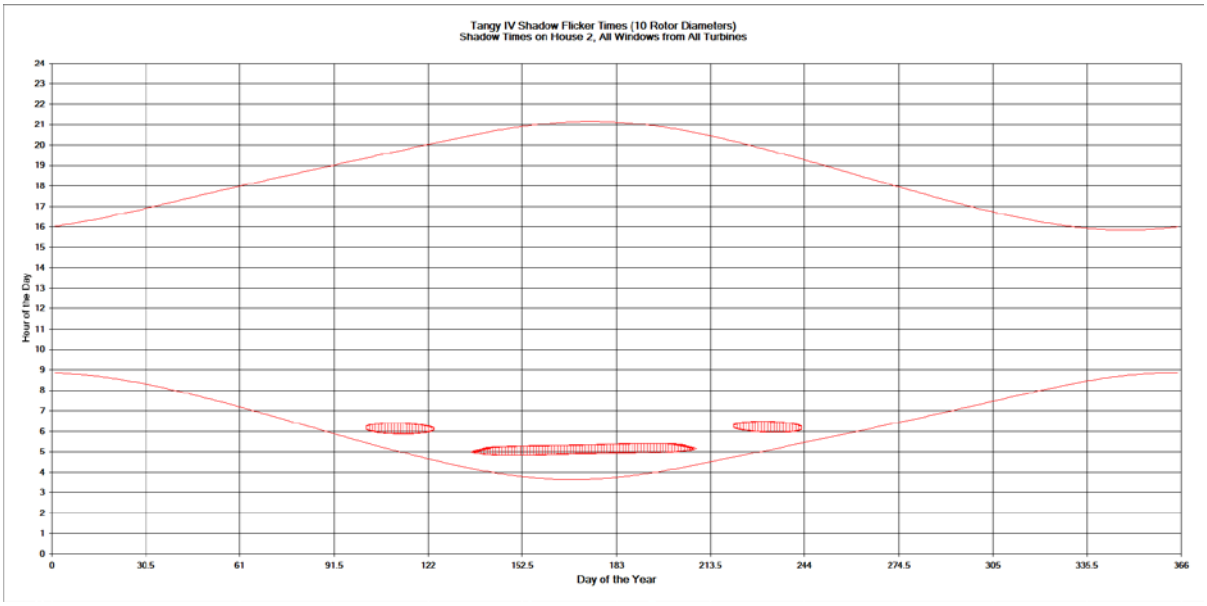


Figure A1.5 – Predicted Shadow Flicker Times at SFAL3

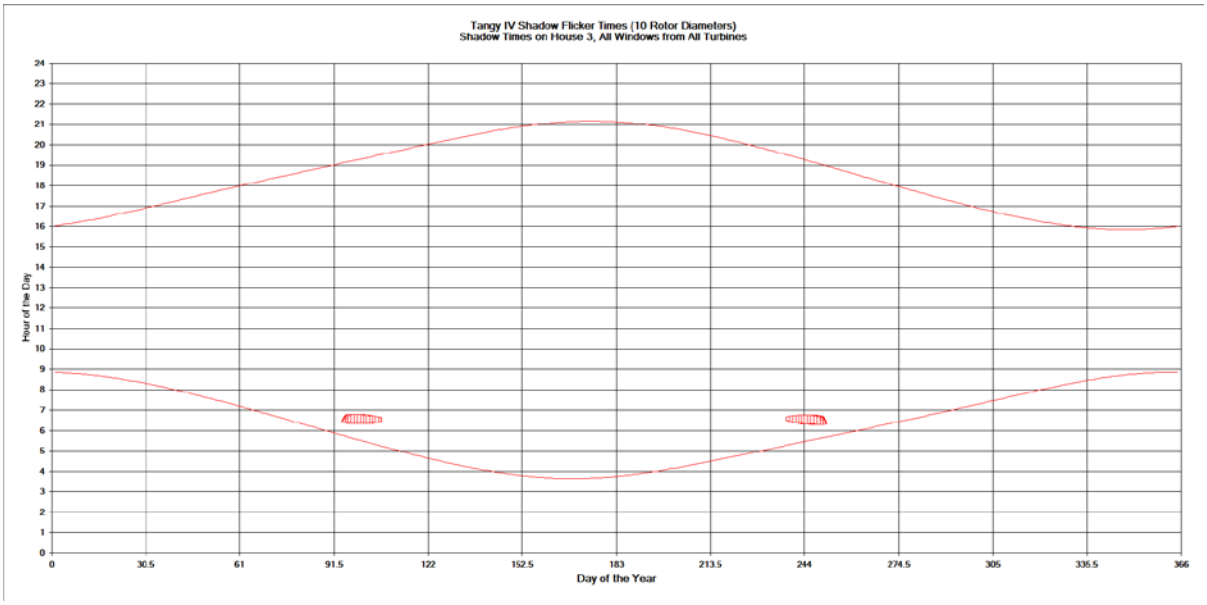


Figure A1.6 – Predicted Shadow Flicker Times at SFAL4

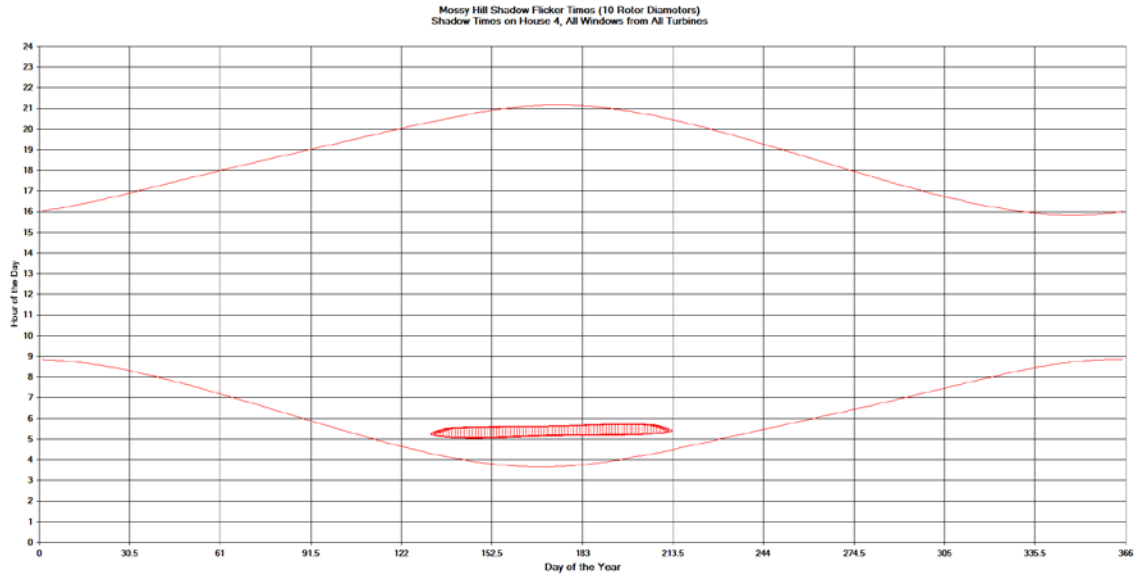


Figure A1.7 – Predicted Shadow Flicker Times at SFAL5

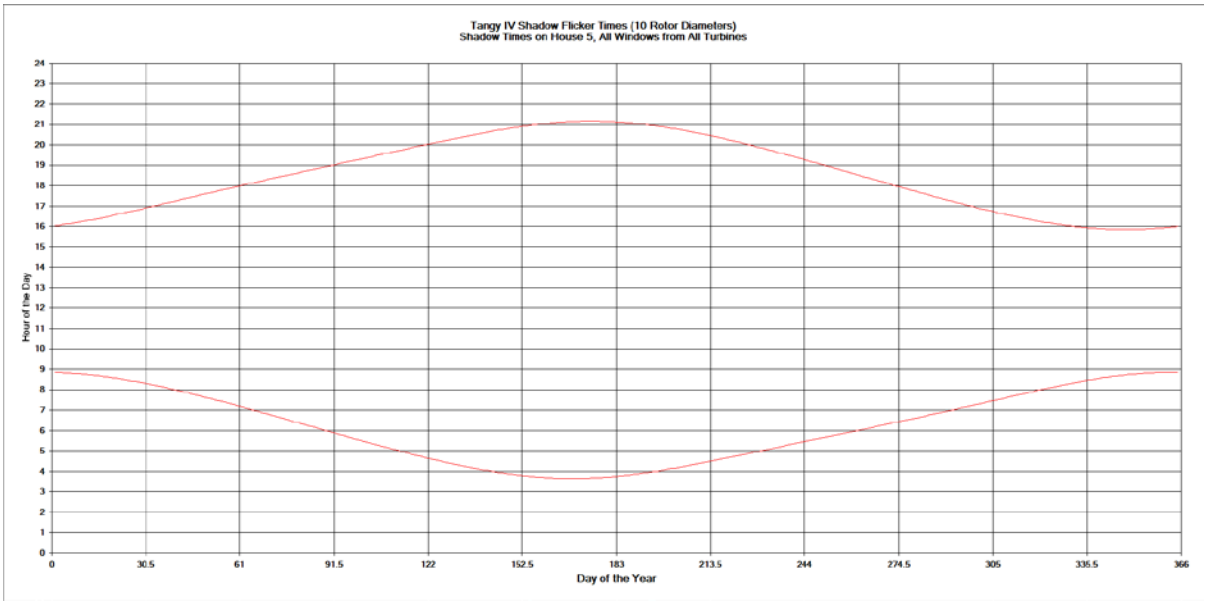


Figure A1.8 – Predicted Shadow Flicker Times at SFAL6

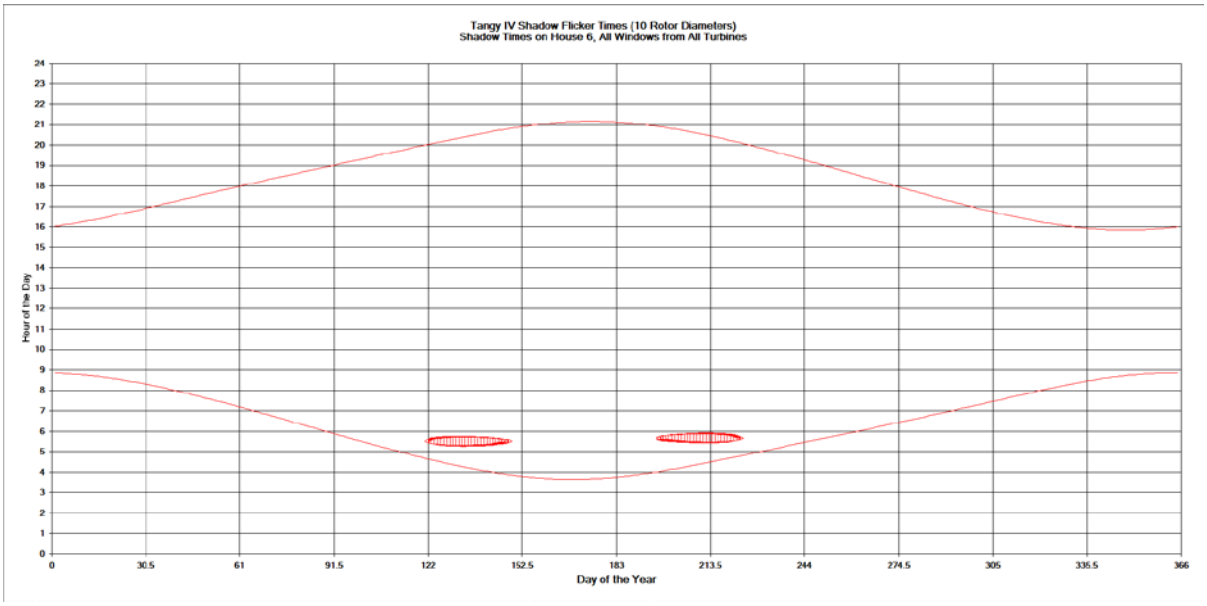
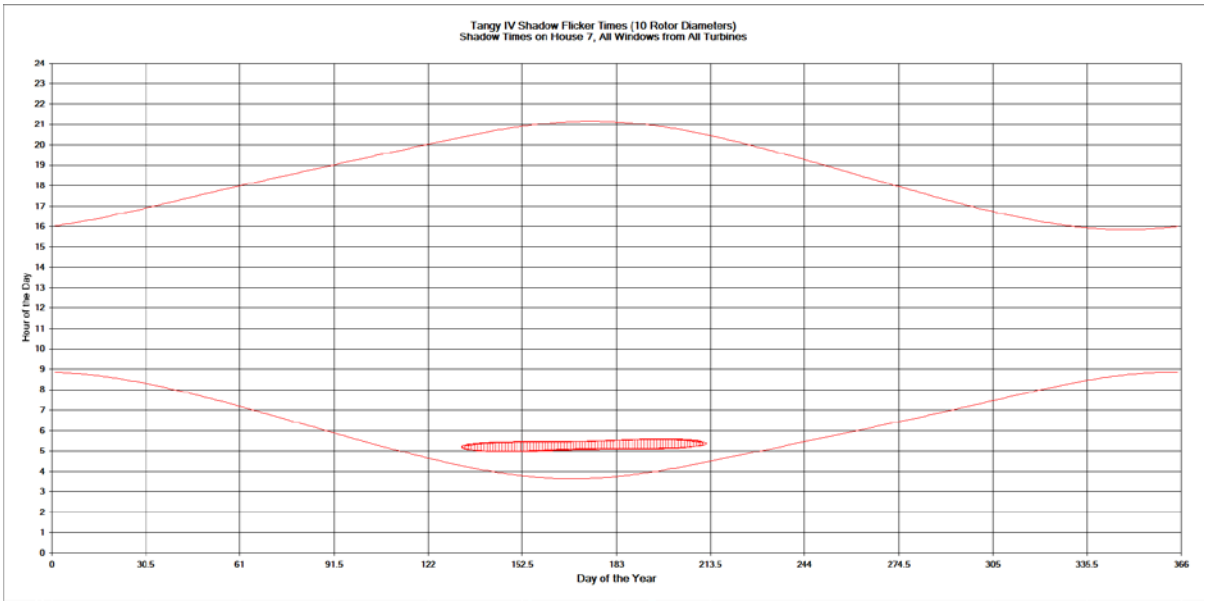


Figure A1.9 – Predicted Shadow Flicker Times at SFAL7



Annex 2 – Building Survey Results

SFAL	Window	Easting (relative to building location coordinates)	Northing (relative to building location coordinates)	Windows					Approach taken to with regards to window size for modelling
				Width (m)	Height (m)	Elevation (m.agl)	Aspect (° from north)	Tilt (° from vertical; top backwards positive)	
1	1	-26	-45	12	2.2	1.2	70	0	Informed by Site Survey
1	2	-22	-50	1	2	1.5	340	0	Informed by Site Survey
1	3	-18	-51	2	1.5	5	340	60	Informed by Site Survey
1	4	-12	-53	1.5	2	1.2	70	0	Informed by Site Survey
1	5	-29	-46	12	5	2.3	70	80	Informed by Site Survey
1	6	-4	7	0.5	1	2	80	0	Informed by Site Survey
1	7	-4	5	0.5	1	4.5	80	0	Informed by Site Survey
1	8	-2	-1	0.5	1	2	80	0	Informed by Site Survey
1	9	-2	1	0.3	1	2	170	0	Informed by Site Survey
1	10	-1	-7	0.5	1	2	80	0	Informed by Site Survey
1	11	-2	-3	0.5	1	2	80	0	Informed by Site Survey
1	12	-2	-6	0.5	1	4	80	30	Informed by Site Survey

SFAL	Window	Easting (relative to building location coordinates)	Northing (relative to building location coordinates)	Windows					Approach taken to with regards to window size for modelling
				Width (m)	Height (m)	Elevation (m.agl)	Aspect (° from north)	Tilt (° from vertical; top backwards positive)	
1	13	-2	-9	1	1.2	2	170	0	Informed by Site Survey
1	14	48	12	0.5	0.5	1.8	165	0	Informed by Site Survey
1	15	45	13	0.5	0.5	2.3	165	0	Informed by Site Survey
1	16	47	16	0.5	0.5	4	165	0	Informed by Site Survey
1	17	45	15	0.5	0.5	3.8	165	60	Informed by Site Survey
1	18	0	0	1	1	2	0	0	Informed by Site Survey
2	1	-11	4	0.4	0.7	4.3	2	0	Informed by Site Survey
2	2	-9	4	0.5	0.7	1.3	2	0	Informed by Site Survey
2	3	-8	4	1	1.5	3.5	2	0	Informed by Site Survey
2	4	-5	4	0.5	0.7	4.3	2	0	Informed by Site Survey
2	5	-5	4	1	1.3	1.5	2	0	Informed by Site Survey
2	6	-1	4	1	1.3	1.5	2	0	Informed by Site Survey

SFAL	Window	Easting (relative to building location coordinates)	Northing (relative to building location coordinates)	Windows					Approach taken to with regards to window size for modelling
				Width (m)	Height (m)	Elevation (m.agl)	Aspect (° from north)	Tilt (° from vertical; top backwards positive)	
2	7	-1	2	0.5	0.5	4.3	2	45	Informed by Site Survey
3	1	11	0	1	1.3	2	170	0	Informed by Site Survey
3	2	8	-1	0.6	0.8	2.3	170	0	Informed by Site Survey
3	3	6	-1	1	1.3	2	170	0	Informed by Site Survey
3	4	3	-2	0.5	1.9	1.1	170	0	Informed by Site Survey
3	5	1	-4	1	1.3	2	170	0	Informed by Site Survey
3	6	0	-4	1	1.3	2	170	0	Informed by Site Survey
4	1	8	3	0.8	1	3.5	92	0	Informed by Site Survey
4	2	4	7	0.8	0.5	0.3	2	0	Informed by Site Survey
4	3	7	7	0.8	1.2	2	2	0	Informed by Site Survey
4	4	7	7	0.8	0.5	0.3	2	0	Informed by Site Survey
4	5	8	1	0.8	1.2	2	92	0	Informed by Site Survey

SFAL	Window	Easting (relative to building location coordinates)	Northing (relative to building location coordinates)	Windows					Approach taken to with regards to window size for modelling
				Width (m)	Height (m)	Elevation (m.agl)	Aspect (° from north)	Tilt (° from vertical; top backwards positive)	
4	6	8	-3	0.8	1	2	92	0	Informed by Site Survey
5	1	-37	-27	1	1.8	4.3	55	0	Informed by Site Survey
5	2	-37	-27	1	1.8	2	55	0	Informed by Site Survey
5	3	-35	-30	1	1.2	4.5	55	0	Informed by Site Survey
5	4	-36	-27	1	1	1.5	325	0	Informed by Site Survey
5	5	-34	-26	0.8	0.8	4	325	45	Informed by Site Survey
5	6	-34	-26	0.8	1.2	1.5	325	0	Informed by Site Survey
5	7	-30	-23	0.8	1.2	1.5	325	0	Informed by Site Survey
5	8	-25	-20	0.8	1.2	1.5	325	0	Informed by Site Survey
5	9	-25	-20	0.8	1.2	1.5	325	45	Informed by Site Survey
5	10	-23	-18	0.8	0.8	4	325	45	Informed by Site Survey
5	11	-23	-18	0.8	0.8	4	325	45	Informed by Site Survey

SFAL	Window	Easting (relative to building location coordinates)	Northing (relative to building location coordinates)	Windows					Approach taken to with regards to window size for modelling
				Width (m)	Height (m)	Elevation (m.agl)	Aspect (° from north)	Tilt (° from vertical; top backwards positive)	
6	1	4	6	0.8	1	1.5	10	0	Informed by Site Survey
6	2	8	2	1	1.2	1.5	100	0	Informed by Site Survey
6	3	10	1	0.5	1.3	1.5	10	0	Informed by Site Survey
6	4	10	-3	1	1.5	1.5	100	0	Informed by Site Survey
6	5	7	-5	1	1.2	1.5	100	0	Informed by Site Survey
6	6	9	-7	0.8	1.3	1.5	10	0	Informed by Site Survey
6	7	10	-10	1	1.5	1.5	100	0	Informed by Site Survey
6	8	9	-14	1	1.5	1.5	100	0	Informed by Site Survey
6	9	4	-18	1	1	1.5	100	0	Informed by Site Survey
6	10	3	-21	1	1	1.5	100	0	Informed by Site Survey
6	11	7	-26	1	1	1.5	100	0	Informed by Site Survey
6	12	11	-32	0.8	0.8	1.5	100	0	Informed by Site Survey

SFAL	Window	Easting (relative to building location coordinates)	Northing (relative to building location coordinates)	Windows					Approach taken to with regards to window size for modelling
				Width (m)	Height (m)	Elevation (m.agl)	Aspect (° from north)	Tilt (° from vertical; top backwards positive)	
7	1	-2	6	1	1.5	2	15	0	Informed by Site Survey
7	2	0	5	0.3	0.5	2	15	0	Informed by Site Survey
7	3	1	5	0.8	1.3	2	15	0	Informed by Site Survey
7	4	5	7	1	1	1.5	15	0	Informed by Site Survey
7	5	6	5	1	1	1.5	105	0	Informed by Site Survey
7	6	7	4	1	1	1.5	15	0	Informed by Site Survey
7	7	8	4	0.3	0.5	2	15	0	Informed by Site Survey

Annex 3 – Detailed Listings

House/ Window	Days per year	Max hours per day	Mean hours per day	Total hours
01/01	68	0.49	0.39	26.2
01/02	0	0	0	0
01/03	0	0	0	0
01/04	60	0.47	0.38	22.9
01/05	70	0.49	0.38	26.7
01/06	123	0.47	0.36	44.2
01/07	124	0.47	0.36	44.5
01/08	125	0.47	0.36	44.7
01/09	73	0.47	0.36	26.6
01/10	125	0.47	0.36	44.9
01/11	126	0.47	0.36	44.8
01/12	126	0.47	0.36	45
01/01	74	0.47	0.36	26.7
01/01	74	0.49	0.39	28.6
01/01	75	0.49	0.38	28.6
01/01	77	0.49	0.37	28.8
01/01	130	0.49	0.37	48
01/01	52	0.45	0.34	17.9
02/01	118	0.51	0.41	47.9
02/02	118	0.51	0.4	47.4
02/03	118	0.51	0.41	48.2
02/04	118	0.51	0.41	48
02/05	118	0.51	0.4	47.7
02/06	117	0.52	0.41	47.6
02/07	118	0.51	0.41	47.9
03/01	28	0.44	0.35	9.8
03/02	28	0.44	0.34	9.6
03/03	28	0.44	0.34	9.5
03/04	26	0.44	0.34	8.8
03/05	26	0.44	0.36	9.4
03/06	26	0.44	0.36	9.4
04/01	82	0.52	0.45	36.6
04/02	80	0.51	0.43	34.7
04/03	82	0.52	0.44	36.4
04/04	80	0.51	0.43	34.8
04/05	81	0.52	0.45	36.4
04/06	80	0.52	0.45	36.2

House/ Window	Days per year	Max hours per day	Mean hours per day	Total hours
05/01	0	0	0	0
05/02	0	0	0	0
05/03	0	0	0	0
05/04	0	0	0	0
05/05	0	0	0	0
05/06	0	0	0	0
05/07	0	0	0	0
05/08	0	0	0	0
05/09	0	0	0	0
05/10	0	0	0	0
05/11	0	0	0	0
06/01	52	0.44	0.33	17.4
06/02	52	0.44	0.34	17.8
06/03	53	0.44	0.34	17.9
06/04	54	0.44	0.34	18.2
06/05	54	0.44	0.33	18.1
06/06	54	0.44	0.34	18.2
06/07	54	0.44	0.34	18.4
06/08	0	0	0	0
06/09	0	0	0	0
06/10	0	0	0	0
06/11	0	0	0	0
06/12	0	0	0	0
07/01	80	0.45	0.38	30.5
07/02	79	0.45	0.38	30.3
07/03	79	0.45	0.39	30.5
07/04	79	0.45	0.39	30.6
07/05	78	0.45	0.39	30.6
07/06	78	0.45	0.39	30.6
07/07	78	0.45	0.39	30.4
07/08	76	0.46	0.4	30.7

APPENDIX 18.1: AVIATION RADAR RISK ASSESSMENT

PAGERPOWER

Aviation and Radar Risk Assessment

Prepared for:

SSE Renewables Developments (UK) Ltd

Tangy IV Wind Farm

January, 2018

www.pagerpower.com

ADMINISTRATION PAGE

Issue	Date	Detail of Changes
1	January, 2018	Initial issue

Pager Power Limited, South Suffolk Business Centre, Alexandra Road, Sudbury, CO10 2ZX

T:*+44(0)1787 319 001* E:*info@pagerpower.co.uk* W:*www.pagerpower.com*

EXECUTIVE SUMMARY

Report Purpose

This report has assessed the potential impacts of the proposed Tangy IV Wind Farm on aviation and radar operations. The Development is to be located at the same site as the existing Tangy I and II wind developments. Consent has been granted for sixteen additional turbines with a height of 125 metres above ground level. This report has assessed the effect of increasing the proposed height to 149.9 metres above ground level.

Findings

Navigation Aids

- The Development is 6.23 km from a Non-Directional Beacon, a navigation aid for pilots, at Campbeltown Aerodrome.
- There is a DVOR (a navigation aid) located 7.18 km from the nearest turbine within the Development. No published procedures at Campbeltown Aerodrome are reliant on the DVOR.
- The Development is 7.18 km from a Distance Measuring Equipment (DME) located to the east of the aerodrome. This is within the NATS safeguarding range, however concerns are unlikely in practice.
- No significant change in impact on navigation aids is predicted due to the proposed turbine height increase.

Aerodrome Physical Safeguarding (Collision Risk)

- The Development would breach the Outer Horizontal Surface (OHS) at Campbeltown Aerodrome. The existing Tangy I and II turbines and the elevated terrain at the site area, both already breach the OHS at the aerodrome.
- The extent of the surface breach will be greater for the new turbines than for the existing ones and the consented ones.

Procedures at Campbeltown Aerodrome

- No increase in minimum sector altitudes would be required as a result of the Development.
- The missed approach procedure for aircraft approaching runway 11 is to continue east while climbing to 2,000 feet above mean sea level, then head north, then west over the Development location to join the hold to the west of the aerodrome.
- This procedure means that aircraft pass within 500 metres horizontally of the existing, consented and proposed turbine locations. The vertical clearance between the aircraft, as per the written procedure, and the turbine tips is:
    - Between 1,135 and 1,270 feet for the existing turbines.
    - Between 870 and 1,086 feet for the consented turbines.
    - Between 788 feet and 1,004 feet for the proposed turbines.
- A typical vertical clearance requirement is 984 feet. This clearance is maintained by the existing developments, but not by the consented or proposed developments.
- It is possible that the proposed tip height increase, from 125 metres to 149.9 metres (above ground), would be of greater concern with regard to this missed approach procedure.

Other considerations

- No significant impacts are predicted on radar installations.
- No concerns are predicted with regard to military low flying.

Next Steps

- Recommended next steps are:
    - Further assessment of potential infringement of the missed approach procedure at Campbeltown Aerodrome.
    - External assessment, via the CAA and HIAL, of the missed approach procedure at Campbeltown Aerodrome.
    - Further engagement with HIAL.

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ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 43 countries within Europe, Africa, America, Asia and Australia.

The company comprises a team of experts to provide technical expertise and guidance on a range of planning issues for large and small developments.

Pager Power was established in 1997. Initially the company focus was on modelling the impact of wind turbines on radar systems. Over the years, the company has expanded into numerous fields including:

- Renewable energy projects.
- Building developments.
- Aviation and telecommunication systems.

Pager Power prides itself on providing comprehensive, understandable and accurate assessments of complex issues in line with national and international standards. This is underpinned by its custom software, longstanding relationships with stakeholders and active role in conferences and research efforts around the world.

Pager Power's assessments withstand legal scrutiny and the company can provide support for a project at any stage.

1 INTRODUCTION

1.1 Report Purpose

Pager Power has been retained to assess the possible impact of a proposed wind farm called 'Tangy IV', hereafter referred to as 'the Development', on aviation and radar. This report contains the following:

- Development details.
- Identification of relevant:
  - Radar (military/civil and on airfield/En Route).
  - Licenced aerodromes.
  - Navigation aids.
  - Military Low Flying.
- Technical assessment.
- Conclusions and next steps.

1.2 Context

The Development is to be located at the same location as the existing Tangy I and Tangy II wind farms. Combined, there are currently 22 turbines with tip heights of 75 metres above ground level at the site (15 within Tangy I and a further 7 within Tangy II).

Tangy IV, which comprises 16 turbines, is likely to replace the existing wind developments. The new wind turbine heights are 149.9 metres, which is taller than the existing turbines.

2 DEVELOPMENT DETAILS

2.1 Tangy IV

The Development will comprise 16 turbines with a tip height of up to 149 metres above ground level and a rotor diameter of up to 130 metres. Figure 1 below shows the Development location (provided to Pager Power by the Developer).

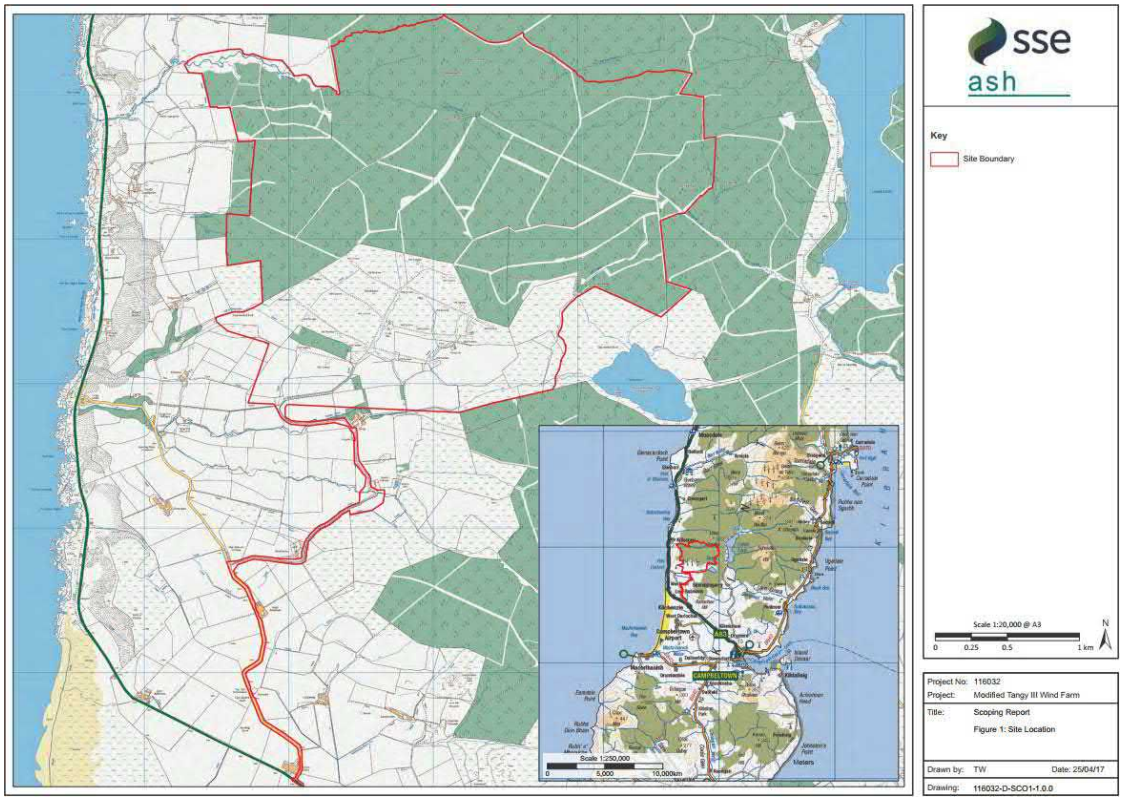


Figure 1 *Development location*

The layout that has been assessed within this report is shown in Table 1 below.

Turbine	Easting	Northing	Turbine	Easting	Northing
01	167315	628150	09	168130	629820
02	167860	628240	10	168650	629740
03	167392	628558	11	169185	629495
04	168349	628427	12	169000	628979
05	168850	628597	13	168475	628908
06	167456	628996	14	167951	628835
07	167517	629424	15	168040	629307
08	167555	629887	16	168573	629327

Table 1 *Assessed layout*

3 TECHNICAL BACKGROUND

3.1 Potential Radar Impacts

Wind turbines can affect radar by reflecting or obstructing the emitted radar signal. The most commonly affected radar types are set out in Table 2 below.

Radar Type	Short Description	Potential Turbine Impacts	Wind Farm Safeguarding Criteria
Primary Surveillance Radar (PSR)	This is a non-cooperative radar system, designed to detect moving targets (aircraft) by emitting a radar signal and receiving an echo. The time delay between emitting the signal and receiving the echo, combined with the bearing of the rotating radar antenna, allow the range and bearing of the target to be determined. In the UK, such radar are used by military and civil operators, both for En-Route purposes and for operations at specific airports.	Reflections of the radar signal by wind turbines could lead to wind developments falsely being displayed as targets (aircraft) on an air traffic controller's screen. Other concerns such as obstruction of the radar signal and overloading receivers can be raised but are unlikely to be technically or operationally significant.	Civil En-Route PSR installations are safeguarded by NATS in the UK, out to distances of over 100 km in some cases. Civil on-aerodrome PSR installations are typically safeguarded within 30 km, however there is no formal cut-off distance. Military PSR installations are typically safeguarded to their maximum instrumented range.
Secondary Surveillance Radar (SSR)	This is a cooperative radar system, designed to send and receive information via an aircraft's transponder. In the UK, such radar are used by military and civil operators, both for En-Route purposes and for operations at specific airports.	Reflection of the signal from the radar or the aircraft transponder can affect the accuracy of the range and bearing information displayed on the radar operator's screen. Other concerns such as obstruction of the radar signal can be raised.	Civil and military SSR installations in the UK are typically safeguarded to ranges of 10-30 kilometres.

Radar Type	Short Description	Potential Turbine Impacts	Wind Farm Safeguarding Criteria
Meteorological Radar	Meteorological radar are used to monitor and predict precipitation / rainfall.	Reflection of the radar signal can affect the apparent precipitation levels displayed on the radar screen. Obstruction of the radar beam can be a concern, particularly if the turbine(s) are above the horizontal relative to the centre of the radar.	Meteorological radar installations are rarely safeguarded beyond 20 km.
Precision Approach Radar (PAR)	An on-airfield radar designed to guide aircraft to the touchdown point very accurately. The radar is directed towards the end of the runway that is being used, and does not rotate. In the UK such radar are used exclusively by the military.	Reflections of the radar signal by wind turbines can affect the radar's accuracy and performance.	Safeguarding is typically within a defined 'cone' emanating from runways that have an available PAR approach. Beyond approximately 20 nautical miles, concerns are highly unlikely.

Table 2 *Commonly affected radar types*

3.2 Navigation Aids

Navigation aids are ground-based installations that emit and/or receive radio signals in order to help aircraft navigate more accurately. Some commonly affected navigation aids are shown in Table 3 below.

Navigation Aid	Short Description	Potential Turbine Impacts	Wind Farm Safeguarding Criteria
VHF Omni-Range (VHF)	Ground station that emits a reference and variable radio signal that allows a pilot to determine the aircraft bearing relative to the beacon location.	Reflection or obstruction of the emitted signal can affect the accuracy of the information received by a pilot.	Typically safeguarded to approximately 10 km by NATS in the UK.
Distance Measuring Equipment (DME)	Ground station that emits a signal designed to help pilots accurately determine their distance from the beacon location.	Reflection or obstruction of the emitted signal can affect the accuracy of the information received by a pilot.	Typically safeguarded to approximately 10 km by NATS in the UK.

Navigation Aid	Short Description	Potential Turbine Impacts	Wind Farm Safeguarding Criteria
Air-Ground-Air Station	Ground station that facilitates voice communication, via radio, between operators on the ground and pilots of aircraft.	Reflection or obstruction of the emitted signal can affect the quality of the communications.	Typically safeguarded to approximately 10 km by NATS in the UK.
Instrument Landing System (ILS)	Runway approach aid that emits two radio signals that, in combination, give vertical and horizontal guidance to a pilot approaching a runway.	Reflection or obstruction of the emitted signal can affect the accuracy of the ILS data received by a pilot.	This can vary – it is most significant for developments that are in line with an airport's runway.
Non-Directional Beacon (NDB)	A ground station that emits a signal in all directions, containing information for station identification.	Reflection or obstruction of the signal could affect the quality of the signal reaching the aircraft.	This can vary.

Table 3 *Commonly affected navigation aids*

3.3 Aerodromes

Technical Considerations

Licensed and military aerodromes are safeguarded against physical obstructions (collision risk) based on assessment of Obstacle Limitation Surfaces (OLSs).

The rules for defining each OLS are published by the Civil Aviation Authority (CAA) and the Military Aviation Authority (MAA) for licensed civil and military aerodromes respectively.

The dimensions of an OLS are determined by various technical parameters including runway length[1]. Proposed wind developments are assessed against OLSs to minimise collision risks.

Operational Considerations

The impacts of proposed wind developments on operations at nearby aerodromes must be assessed, particularly where technical impacts are predicted.

3.4 Military Low Flying

Military low flying can take place anywhere in the UK. The MOD publishes a map showing which areas are strategically of most concern with regard to wind turbine developments specifically.

[1] Formally based on declared distances for civil licensed aerodromes, in practice these are closely correlated to physical runway length in most cases.

4 ASSESSMENT

4.1 Methodology

Potentially affected aviation and radar installations have been identified. Technical assessment has been undertaken based on the issues set out in the previous section.

The aim of the assessment is to establish the effect of the height increase from 125 metres above ground level to 149.9 metres above ground level. The former has already been consented subject to conditions.

The presence of the Tangy I and Tangy II developments, located at the same site as the proposed turbines, has also been considered within the overall assessment.

4.2 Radar Impacts

The Development is unlikely to affect any radar installations. Specifically:

- On-airfield radar are unlikely to be affected due to the Development's distance from licensed and military aerodromes that are equipped with radar.
- The NATS Tiree En-Route radar is not predicted to have line of sight to the turbines. The NATS Lowther Hill En-Route radar is predicted to have marginal[2] line of sight to one of the sixteen turbines – this is unlikely to be significant in practice.
- Meteorological radar installations are unlikely to be affected due to the distance of the Development from any such radar.

4.3 Navigation Aids

The following navigation aids are the most significant with regard to the Development:

- NDB at Campbeltown Aerodrome.
- DVOR east of Campbeltown Aerodrome.
- DME east of Campbeltown Aerodrome.

Figure 2 on the following page[3] shows the relative locations of the navigation aids.

[2] Predicted visibility of less than 2 metres at a range of more than 100 km.
[3] ©2018 Gettmapping plc, Terrametrics, DigitalGlobe, Google

Figure 2 *Navigation aids*

NDB Impact

The NDB is located approximately 6.23 km from the nearest turbine. The beacon is located to the south of the Development.

The potential impact of the Development would be similar to the impact of the existing Tangy I and II developments.

The height increase, from 125 metres to 149.9 metres (above ground), is unlikely to make a material difference regarding impact on the NDB.

DVOR Impact

The DVOR is collocated with the DME to the east of Campbeltown Aerodrome.

It is understood that the DVOR was scheduled to be decommissioned by NATS as part of their work to refine their operations and that ownership was subsequently transferred to Campbeltown Aerodrome.

A review of the published procedures at the airport has been completed. No procedures that rely on the DVOR have been identified.

The height increase, from 125 metres to 149.9 metres (above ground), is unlikely to make a material difference regarding impact on the DVOR.

DME Impact

The DME is collocated with the DVOR to the east of Campbeltown Aerodrome. It is safeguarded by NATS. The NATS AIP states that:

Due to terrain, coverage at low level is reduced in Sectors R123°-163°, R208°- 238° and R348°-083°

The Development is located mostly within the sector 348-083 degrees, such that coverage in the direction of the Development is already compromised to some extent.

The height increase, from 125 metres to 149.9 metres (above ground), is unlikely to make a material difference regarding impact on the DME.

4.4 Aerodromes

The nearest licensed aerodrome is Campbeltown Aerodrome, which is operated and managed by Highlands and Islands Airport Limited (HIAL).

Physical Safeguarding – Campbeltown Aerodrome

All proposed turbines within the Development are located beneath the Outer Horizontal Surface (OHS). All turbines breach the surface – largely due to the elevated terrain at the site location which itself breaches the surface in parts.

This means that the existing Tangy I and II developments will breach the OHS. It also means the consented turbines at 125 metres would breach the OHS.

No other surfaces are affected.

Operations – Campbeltown Aerodrome

Figure 3 below[4] shows the missed approach procedure for aircraft approaching Runway 11 at Campbeltown Aerodrome.

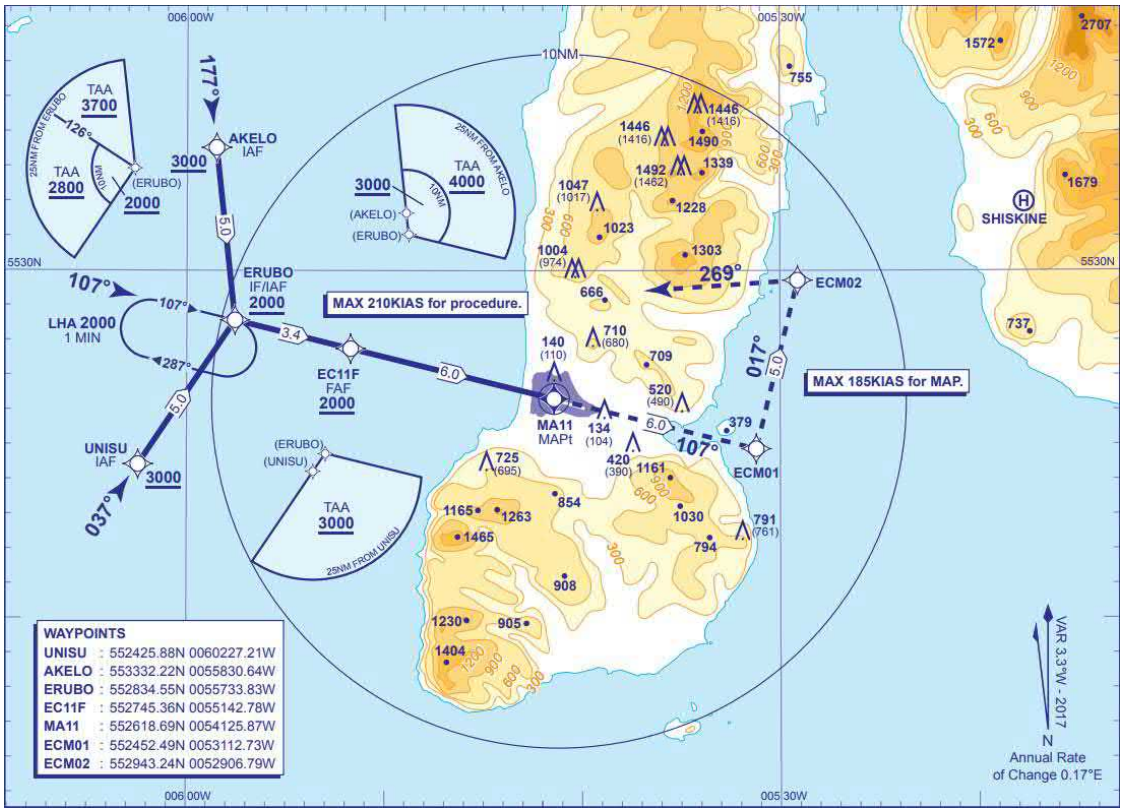


Figure 3 *Missed approach procedure (chart)*

Figure 4 on the following page[5] shows this path overlaid onto imagery of the Development location.

[4] Source: NATS AIP accessed January 2018
[5] ©2018 Gettmapping plc, Terrametrics, DigitalGlobe, Google

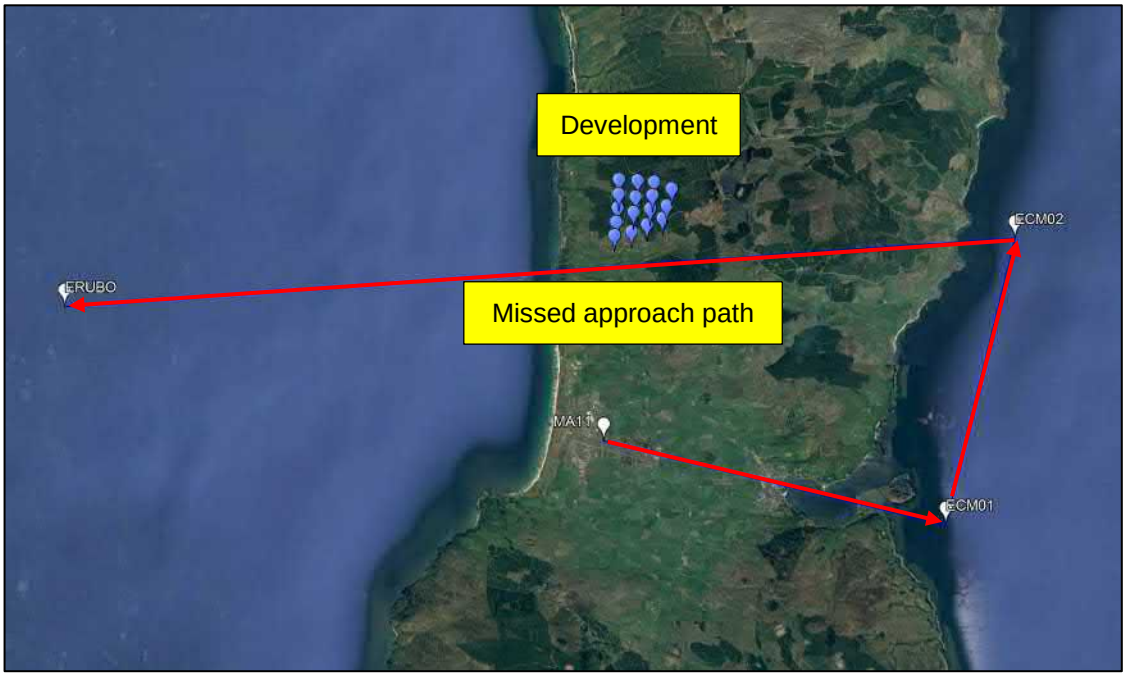


Figure 4 *Missed approach procedure (aerial)*

Aircraft following this missed approach path will pass within 500 metres of the Development. The turbine elevations will range from 996 feet to 1,212 feet above mean sea level.

Aircraft following this missed approach procedure would be at 2,000 feet or more above mean sea level, which means the vertical clearance above the turbine tips would be between 788 and 1,004 feet.

For the consented tip heights of 125 metres above ground level, the vertical clearance would be between 870 feet and 1,086 feet.

For the existing turbines, the vertical clearance is between 1,135 and 1,270 feet.

Typically, the required vertical clearance between an aircraft flying such a procedure and an obstacle would be 984 feet (300 metres).

The typical recommended clearance is maintained by the existing development. It is not maintained by the consented development even for a tip height of 125 metres above ground level.

It is possible that the proposed tip height increase, from 125 metres to 149.9 metres (above ground), would be of greater concern with regard to this missed approach procedure.

Further assessment of the procedure is recommended in order to ascertain whether safeguarding rules are breached by the Development.

4.5 Military Low Flying Impacts

The Development is located within an area that is low priority with regard to military low flying. The MOD has advised in May 2017 that it has no objections.

No impact on military low flying is predicted.

.

5 OVERALL CONCLUSIONS

5.1 Analysis Results

The assessment has found that the change in impact due to the proposed turbine height increase is likely to be insignificant for:

- Radar installations.
- Military low flying.
- Navigation aids.

Potential concerns are possible for:

- Procedures at Campbeltown Aerodrome – specifically the missed approach procedure for aircraft approaching Runway 11.

5.2 Recommendation

It is recommended that further investigation of the potential impacts on instrument flight procedures at Campbeltown Aerodrome is undertaken. This can be progressed via:

- Further technical assessment.
- External assessment via HIAL and the CAA.
- Consultation with HIAL.

Pager Power Limited
South Suffolk Business Centre
Alexandra Road
Sudbury
Suffolk
CO10 2ZX

Tel: +44 1787 319001 **Email:** info@pagerpower.co.uk **Web:** www.pagerpower.com

APPENDIX 18.2: INSTRUMENT FLIGHT PROCEDURE ASSESSMENT

PAGERPOWER

Instrument Flight Procedure Assessment

Prepared for:

SSE Renewables Developments (UK) Ltd

Tangy IV Wind Farm

February, 2018

www.pagerpower.com

ADMINISTRATION PAGE

Issue	Date	Detail of Changes
1	February, 2018	Initial issue

Pager Power Limited, South Suffolk Business Centre, Alexandra Road, Sudbury, CO10 2ZX

T:*+44(0)1787 319 001* E:*info@pagerpower.co.uk* W:*www.pagerpower.com*

EXECUTIVE SUMMARY

Report Purpose

This report has assessed the potential impacts of the proposed Tangy IV Wind Farm on missed approach procedure for aircraft approaching runway 11 at Campbeltown Aerodrome. Aircraft flying this procedure would pass to the south of the Development.

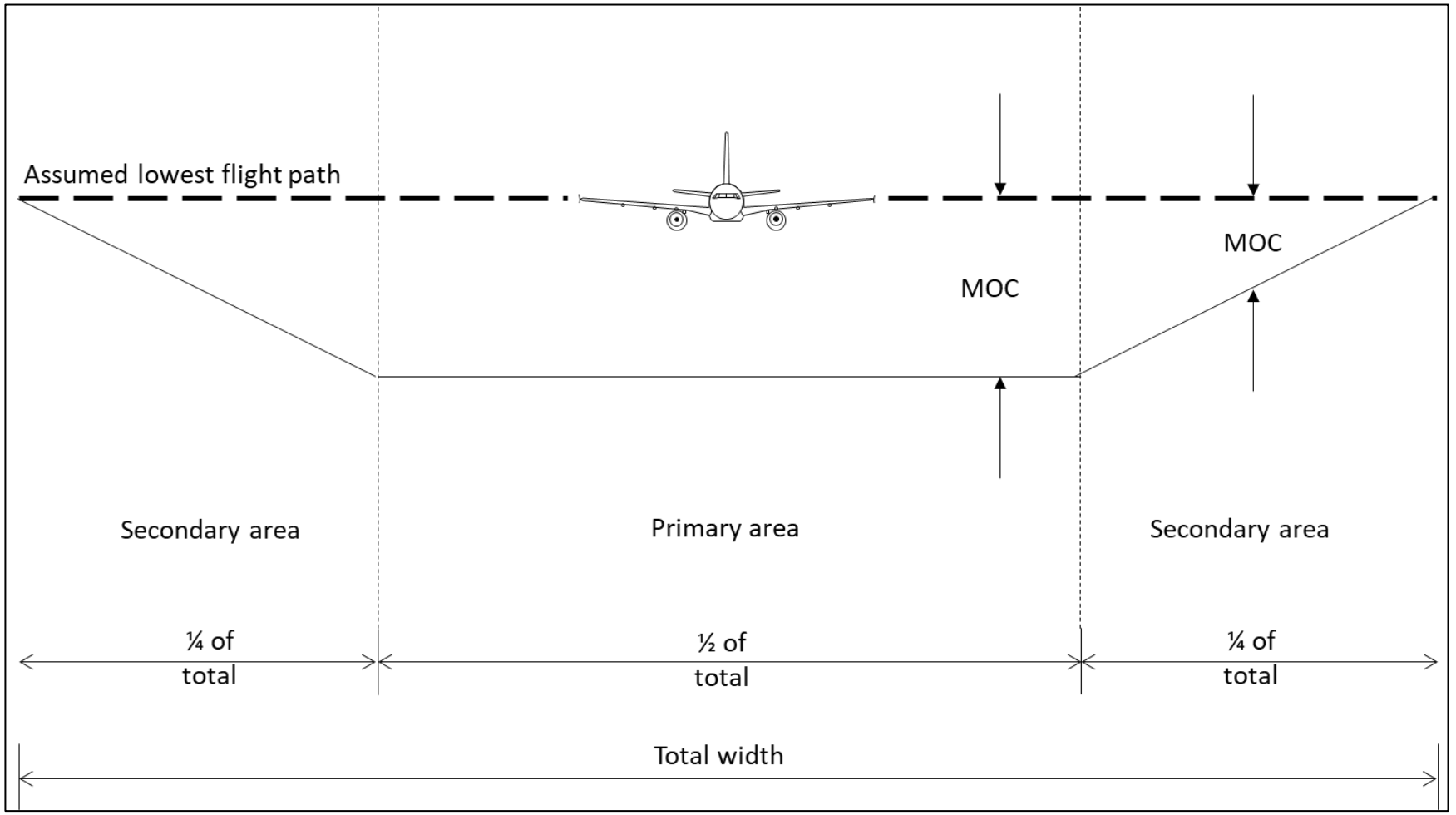
The safeguarding process for this procedure has been assessed in accordance with the guidance set out in the International Civil Aviation Organisation (ICAO) Doc 8168 Procedures for Air Navigation Services (PANS-OPS). The procedures set out in this document are the international standard used in many countries around the world.

Findings

- The Minimum Obstacle Clearance (MOC) that must be maintained beneath an aircraft flying missed approach is defined as shown in the figure on the following page.
- At the Development location, the MOC is 50 metres. This means the tip of the turbines would have to be at least 50 metres below the aircraft if they were located within the 'primary area' beneath the flight path.
- The aircraft altitude specified within the procedure is 2,000 feet (609.6 m) above mean sea level. All proposed turbine tips within the Development are more than 50 metres below this altitude. If the turbines were 149.9 metres above ground level, the most elevated turbine tip within the development would be 1,211 feet (369.2 m) above mean sea level. This is a clearance of 240 metres, which is more than four times the required clearance.

Recommendation

- This report should be made available to HIAL.
- It is likely that external assessment from the CAA in conjunction with HIAL will be required to confirm the safeguarding criteria for Instrument Flight Procedures are maintained. It is recommended that this external assessment is initiated.


Assumed lowest flight path
MOC
MOC
Secondary area
Primary area
Secondary area
¼ of total
½ of total
¼ of total
Total width

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ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 43 countries within Europe, Africa, America, Asia and Australia.

The company comprises a team of experts to provide technical expertise and guidance on a range of planning issues for large and small developments.

Pager Power was established in 1997. Initially the company focus was on modelling the impact of wind turbines on radar systems. Over the years, the company has expanded into numerous fields including:

- Renewable energy projects.
- Building developments.
- Aviation and telecommunication systems.

Pager Power prides itself on providing comprehensive, understandable and accurate assessments of complex issues in line with national and international standards. This is underpinned by its custom software, longstanding relationships with stakeholders and active role in conferences and research efforts around the world.

Pager Power's assessments withstand legal scrutiny and the company can provide support for a project at any stage.

1 INTRODUCTION

1.1 Report Purpose

Pager Power has been retained to assess the possible impact of a proposed wind farm called 'Tangy IV', hereafter referred to as 'the Development', on the Missed Approach Procedure for aircraft approaching Runway 11 at Campbeltown Airport.

1.2 Previous Analysis

An aviation and radar risk assessment[1] identified the missed approach procedure for aircraft approaching runway 11 at Campbeltown Aerodrome as a potential concern.

Aircraft following this missed approach path will pass within 500 metres of the Development.

Figure 1 below[2] shows the missed approach procedure for aircraft approaching Runway 11 at Campbeltown Aerodrome.

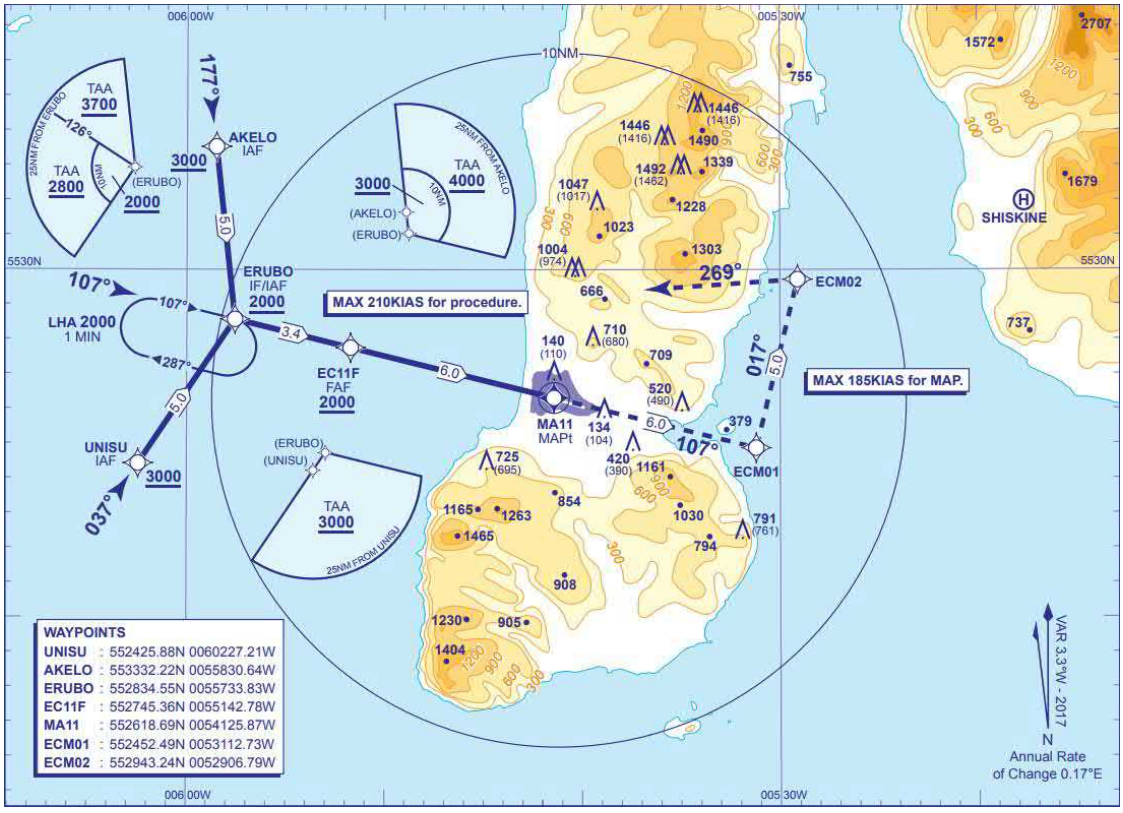

Figure 1 *Missed approach procedure (chart)*

Figure 2 on the following page[3] shows this path overlaid onto imagery of the Development location.

[1] Pager Power, 2018,
[2] Source: NATS AIP accessed January 2018
[3] ©2018 Gettmapping plc, Terrametrics, DigitalGlobe, Google

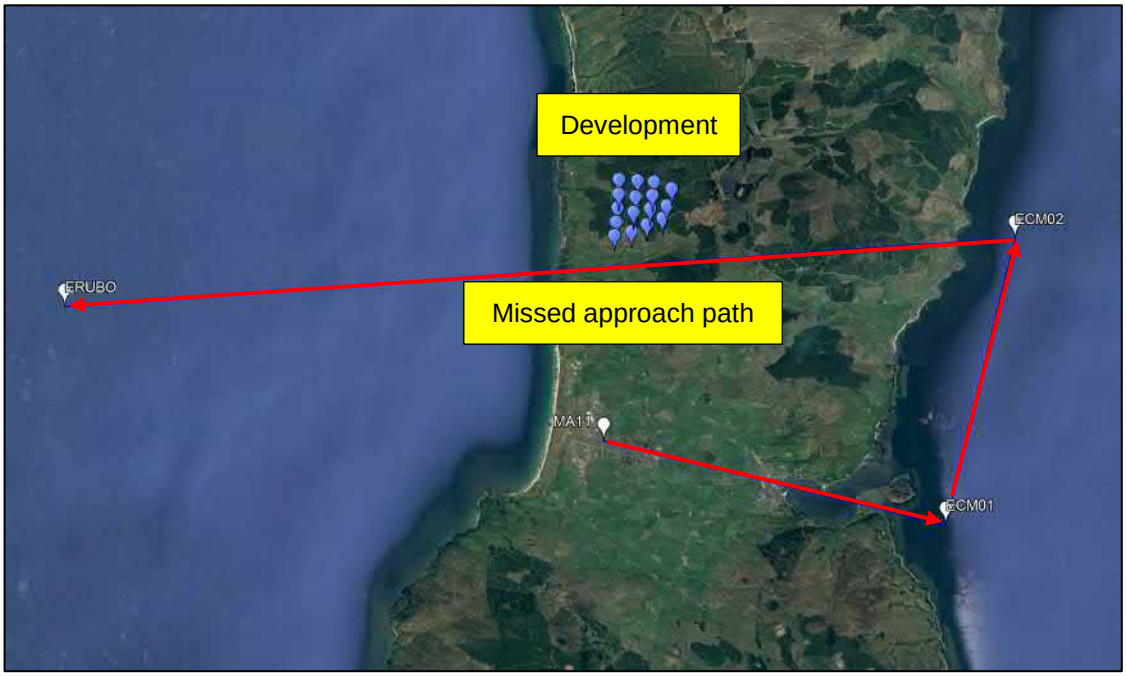

Figure 2 *Missed approach procedure (aerial)*

2 DEVELOPMENT DETAILS

2.1 Tangy IV

The Development will comprise 16 turbines with a tip height of up to 149 metres above ground level and a rotor diameter of up to 130 metres. Figure 3 below shows the Development location (provided to Pager Power by the Developer).

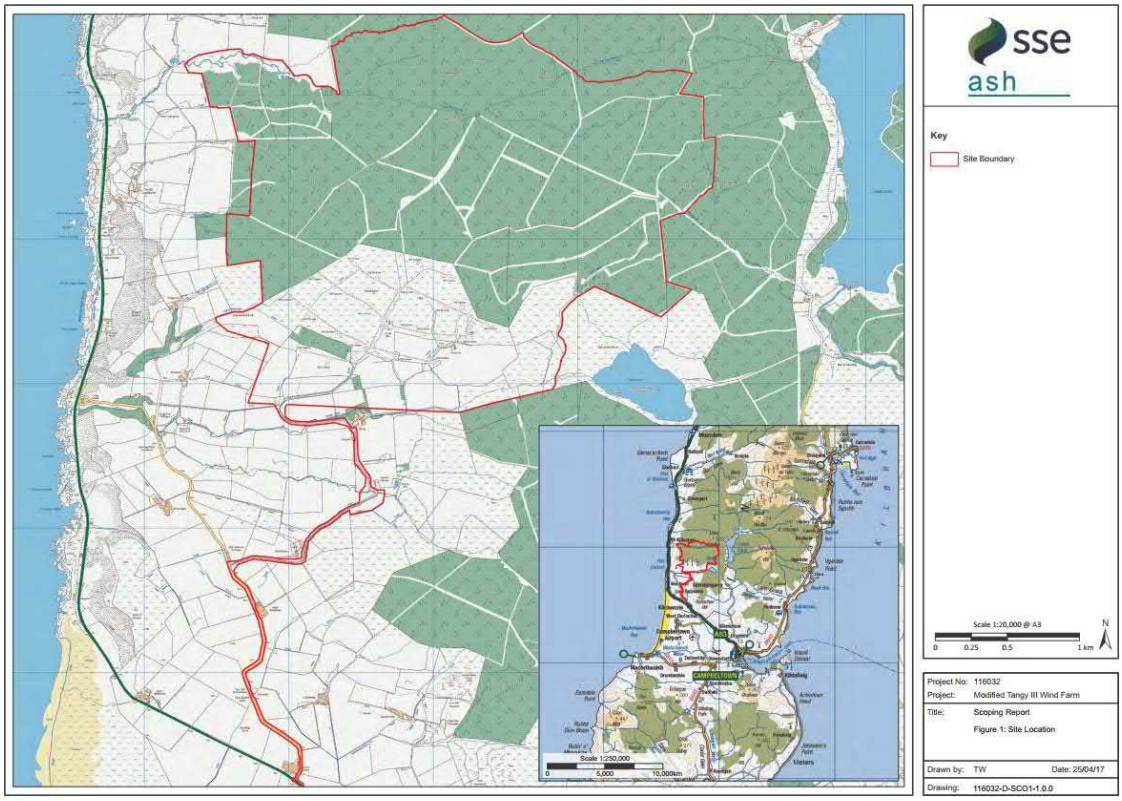

Figure 3 *Development location*

The layout that has been assessed within this report is shown in Table 1 below.

Turbine	Easting	Northing	Turbine	Easting	Northing
01	167315	628150	09	168130	629820
02	167860	628240	10	168650	629740
03	167392	628558	11	169185	629495
04	168349	628427	12	169000	628979
05	168850	628597	13	168475	628908
06	167456	628996	14	167951	628835
07	167517	629424	15	168040	629307
08	167555	629887	16	168573	629327

Table 1 *Assessed layout*

3 LITERATURE REVIEW

3.1 Relevant Documents

The sections below summarise the publications that are relevant with regard to safeguarding Instrument Flight Procedures in the United Kingdom.

3.2 PANS-OPS

The International Civil Aviation Organisation (ICAO) provides a publication called Doc 8168 Procedures for Air Navigation Services (PANS-OPS).

The procedures set out in this document are the international standard used in many countries around the world.

PANS-OPS provides extensive detail regarding the safeguarding of missed approach procedures against obstacles.

The potential impact on the missed approach procedure has been assessed in accordance with PANS-OPS, further details are set out in Section 4.

3.3 CAP 764 – Policy and Guidelines on Wind Turbines

The UK Civil Aviation Authority (CAA) produces a document called Civil Aviation Publication (CAP) 764 titled *Policy and Guidelines on Wind Turbines*. Version 6 is current at the time of writing.

There are references to missed approaches within the document, however these are mostly general without specific measures for safeguarding a missed approach procedure against wind turbines.

3.4 CAP 168 – Licensing of Aerodromes

The CAA produces CAP 168 titled *Licensing of Aerodromes.* Version 10 is current at the time of writing.

There are references to missed approaches within the document, however it does not set out explicit obstacle clearance parameters that are relevant for the Development.

4 PANS-OPS

4.1 Key Sections and Findings from PANS-OPS

The key sections that have informed this assessment are summarised in Table 2 below. The assessment has been undertaken in accordance with Edition 5 dated 2006.

Section Number	Section Name	Key Extract	Relevance	Remarks
1.2.1	*Areas*	*Each segment has an associated area … subdivided into primary and secondary areas… When secondary areas are permitted, the outer half of each side of the area … is designated as secondary area. See Figure I-2-1-1.*	This sets out the general form of the safeguarding zone for obstacles beneath an aircraft.	The figure referred to in the document has been reproduced on reference (see Figure 4 of this report or the executive summary).
6.1.2	*Phases of missed approach segment*	*c) final phase – extends to the point at which a new approach, holding or return to en-route flight is initiated.*	The turbines are potential obstructions in the final phase of a missed approach.	-
6.1.3	*Types of missed approach*	*There are two types of missed approach:* *a) Straight missed approach (includes turns less than or equal to 15 degrees); and* *b) turning missed approach.*	The procedure in question is a turning missed approach.	-
6.4.5.3	*Obstacle clearance for turns at a designated altitude*	*Obstacle elevation/height in the turn area shall be less than:* *TNA/H + d_0 tan Z – MOC* *…* *MOC is 50 m … reducing linearly to zero at the outer edge of the secondary areas*	This describes how to calculate minimal obstacle clearance for a turning missed approach, such as the one being assessed for Campbeltown Aerodrome.	In this equation: TNA/H is the altitude/height of the aircraft at the turn. d_0 is measured from the obstacle to the turn initiation. Tan Z is the tangent of the angle of the missed approach surface with the horizontal plane.

Table 2 *PANS-OPS key sections*

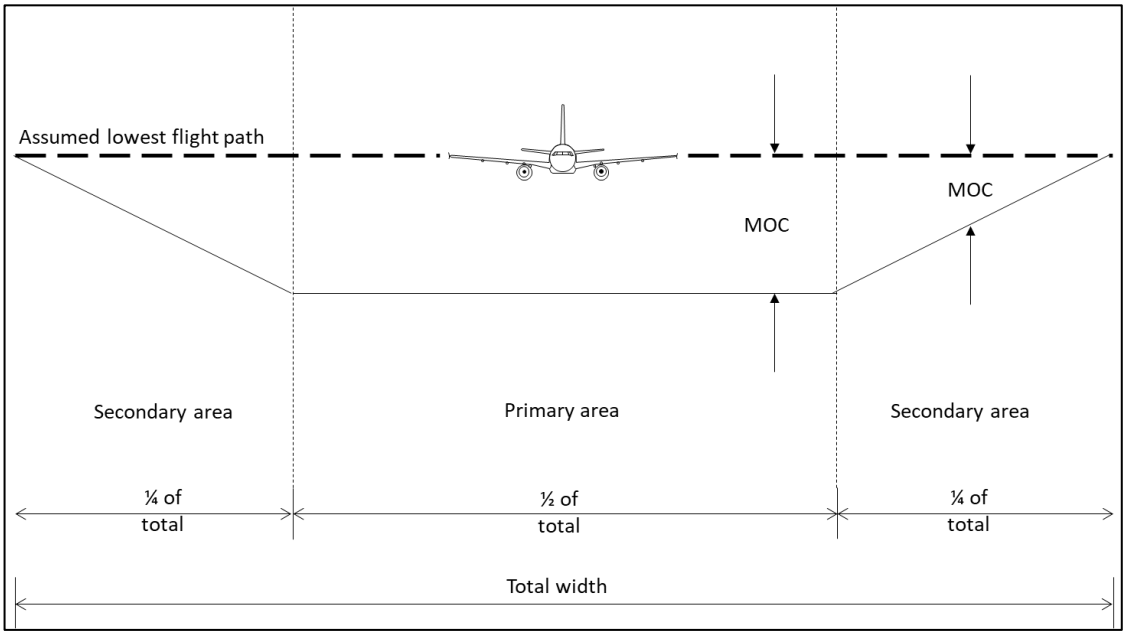

Figure 4 *Obstacle safeguarding – cross section*

5 ASSESSMENT

5.1 Vertical Clearance

The vertical clearance required[4] for aircraft following the missed approach procedure nearest the Development is described by the equation[5]:

$TNA/H + d_0 \tan Z – MOC$

Where:

- TNA/H is the altitude/height of the aircraft when it turns.
    - In this case, the altitude is 2,000 feet above mean sea level as per the procedure.
- $d_0 \tan Z$ is the product of the distance between the aircraft and the turn initiation point and the tangent of the surface relative to the horizontal.
    - In this case, the aircraft is travelling horizontally as per the procedure so this argument of the equation is zero.
- MOC is the Minimum Obstacle Clearance required for a turning missed approach.
    - MOC is defined as 50 metres as per Section 6.4.5.3 of PANS-OPS.

5.2 Calculation

Any turbine blade tips that are more than 50 metres (164 feet) below the aircraft will not cause a safeguarding concern with regard to the missed approach.

Considering turbines with a tip height of 149.9 metres, the blade tip elevation across the Development will range from 996 feet to 1,212 feet above mean sea level.

Aircraft following this missed approach procedure would be at 2,000 feet or more above mean sea level, which means the minimum vertical clearance above the turbine tips would be between 788 feet.

[4] In the primary area – which is the most restrictive
[5] See Table 2 in Section 4

6 CONCLUSIONS

6.1 Analysis Results

- At the Development location, the MOC is 50 metres – i.e. the tip of the turbines would have to be at least 50 metres below the aircraft if they were located within the 'primary area' beneath the flight path.
- All proposed turbine tips within the Development are more than 50 metres below this altitude. If the turbines were 149.9 metres above ground level, the most elevated turbine tip within the development would be 1,211 feet (369.2 m) above mean sea level. This is a clearance of 240 metres, which is more than four times the required clearance.

6.2 Recommendation

- This report should be made available to HIAL.
- It is likely that external assessment from the CAA in conjunction with HIAL will be required to confirm the safeguarding criteria for Instrument Flight Procedures are maintained.

Pager Power Limited
South Suffolk Business Centre
Alexandra Road
Sudbury
Suffolk
CO10 2ZX

Tel: +44 1787 319001 **Email:** info@pagerpower.co.uk **Web:** www.pagerpower.com