STATE COMMISSION ASSESSMENT PANEL
A COMMITTEE OF THE STATE PLANNING COMMISSION

SCAP Agenda Item 3.1.1
14 November 2019

#4581539

FRV Services Australia Pty Ltd
Chaff Mill Solar Farm

Chaff Mill Road, Stanley (north-east of Mintaro)
433/V003/18

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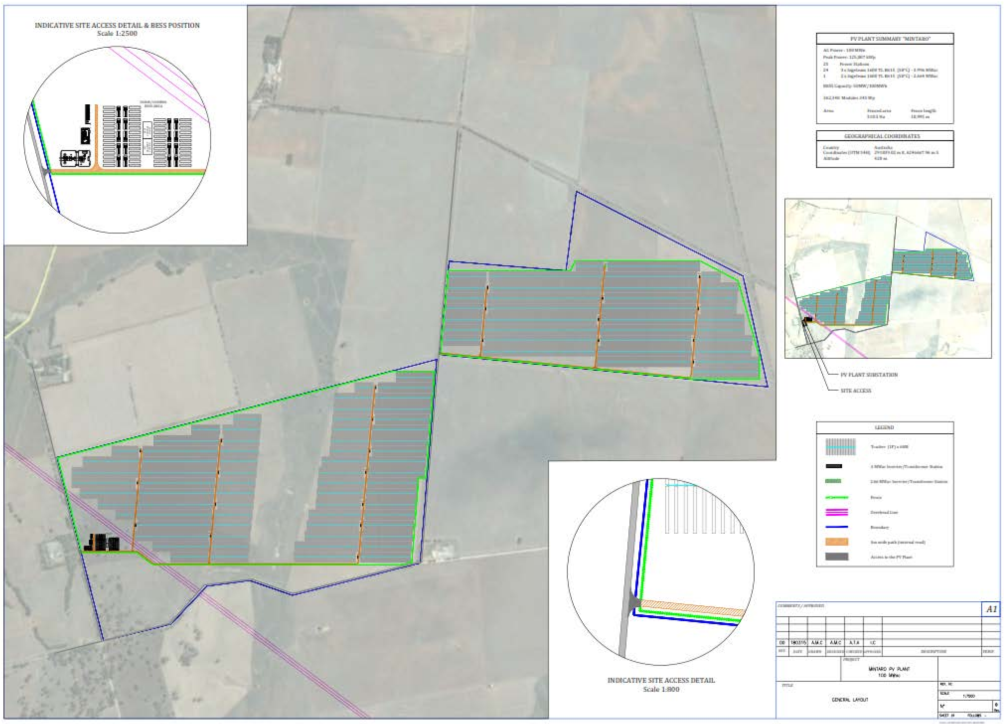


OVERVIEW

Application No	433/V003/18
Unique ID/KNET ID	APPIAN 3309, Knet 2018/14173/01
Applicant	FRV Services Australia Pty Ltd
Proposal	Construction of a 100MW solar farm and associated infrastructure including: arrays of solar panels mounted on single-axis tracker framing; inverter stations; a 50MW battery energy storage system; substation (containing a minimum 100MVA transformer); overhead line from substation to existing 132kV transmission line; site office; onsite parking; refuse storage area; internal access roads; perimeter security fencing
Subject Land	Chaff Mill Road, Stanley
Zone/Policy Area	Primary Production Zone
Relevant Authority	Minister for Planning
Lodgement Date	14 June 2018
Council	Clare and Gilbert Valleys Council
Development Plan	Clare and Gilbert Valleys Development Plan Consolidated 10 November 2016
Type of Development	Crown application
Public Notification	Section 49: Development exceeds $4 million
Representations	Twenty-three (23), ten (10) wishing to be heard
Referral Agencies	Native Vegetation Council (DEW), Commissioner of Highways (DPTI), Country Fire Service, Essential Services Commission Aboriginal Affairs and Reconciliation (DPC)
Report Author	Sharon Wyatt, Principal Project Officer Lee Webb, Senior Environmental (Specialist) Planner

BACKGROUND

On 27 June 2019, the State Commission Assessment Panel (SCAP) considered a development application for the construction of a 100MW solar farm and associated infrastructure at Chaff Mill Road, Stanley. The SCAP resolved to defer making a recommendation to the Minister for Planning, to enable further clarification to be provided on fencing height and frost risk, and to take into account any additional concerns from the hearing of verbal representations.

ADDITIONAL CLARIFICATION

(a) Frost – *applicant to provide a monitoring and mitigation strategy/plan that commits the proponent to monitoring and detailing frost events that occur post construction (for the life of the project) and outlines mitigation strategies that they intend to implement in the event that monitoring shows an increase in frost events or exacerbation on adjoining land*.

Prior to the SCAP meeting of 27 June 2019 the applicant commissioned a review of frost implications for the development site and immediate locality. This study concluded that the solar farm is likely to contribute to a slight increase in air temperature under the arrays, which is likely to alleviate the cold near-surface air temperature, reducing the frost risk rather than increasing it on adjacent agricultural properties.

Following the SCAP meeting, the applicant provided a draft Frost Monitoring and Mitigation Strategy. As part of this strategy the applicant has made a commitment to monitoring frost events that occur post-construction and providing this information to the SCAP and / or other government statutory regulators for the life of the project. A frost monitoring system will be installed that meets industry standard practice for monitoring frost in agricultural areas. All meteorological equipment will be installed inside the Chaff Mill Solar Farm property boundary and will be owned and maintained by Chaff Mill Solar Farm. If approved, the final specification of the equipment to be used will be determined during the detailed design phase.

The applicant has also committed to the installation and commissioning of the metrological hardware and data connection as soon as possible following final Development Approval to collect baseline data prior to construction, noting that no year is typical, and therefore the baseline data collected cannot be expected to represent an average year or typical year.

Collected data will then be provided to a suitably qualified, independent and experienced climate scientist and agricultural frost specialist. The engaged consultant would analyse the data and prepare a report on their findings which the proponent proposes to submit to SCAP annually.

The Strategy outlines a methodology to collect and analyse data, identify potential impacts (if any) and implement a mitigation strategy if required. The hierarchy of mitigation identified is:

- Changes to solar farm maintenance activities (e.g. revising the weed and vegetation management plan)
- Changes to operational behaviour of the solar farm (e.g. changes to the overnight stow angle of the solar panels)
- Changes to the design of the solar farm, where practicable (e.g. adjust the location of a fence line, or landscaping to redirect cold air flow).
- Installation of active mitigation methods on Chaff Mill Solar Farm land, where practicable (e.g. frost fans)

The applicant maintains there will be no additional frost risk as a result of the development and has advised that it will not commit to financial compensation to adjoining landowners or financial contributions to the cost of mitigation measures located on adjoining land areas to the Chaff Mill Solar Farm.

(b) <u>Fencing</u> – *applicant to provide details of alternative boundary fencing that is more suited to the rural landscape (i.e. from a visual perspective). SCAP acknowledged that high security fencing is required to be installed around the substation, BESS, and associated infrastructure - this request was specific to the boundary fencing only*.

The applicant has revised its Boundary Fence Design. The fence originally proposed consisted of a chain link fence with 50mm mesh, topped with 3 strands of barbed wire.

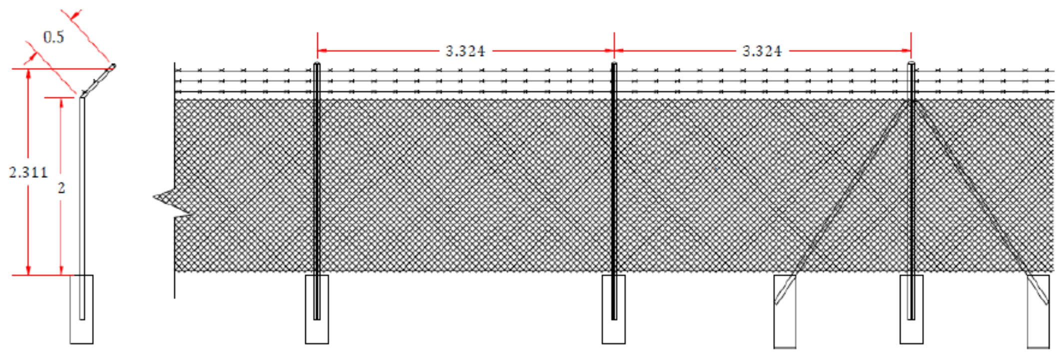


Figure 1: Original proposed fence design

Following further investigation and discussions with industry experts, the applicant identified two options for perimeter fencing that would still meet the required Australian Standards that allows for mesh fabric that is PVC coated. This coating is commonly available in green, black or uncoated galvanized.

The applicant consulted a Visual Impact Assessment specialist with regard to the available colours and enquired which of the options would best integrate into the existing rural / agricultural landscape. The visual impact specialist advised that plain galvanized (i.e. uncoated) mesh is the best choice of colour to blend in with the surrounding environment. Based on this advice the applicant proposes to install an uncoated galvanised chain link mesh for the Chaff Mill Solar Farm Fence.

To soften the visual impact of the fence, the applicant proposes to remove the 3-strand barbed wire topper. The removal of the three rows of barbed wire will also reduce the height of the boundary fence from 2.3 m to 2.1 m.

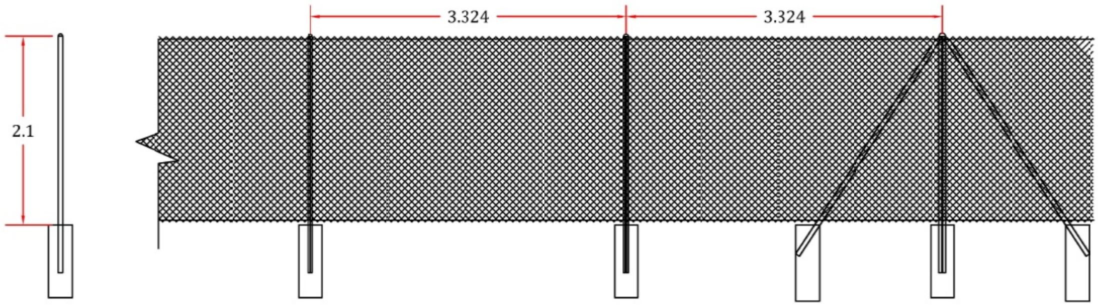


Figure 2: Proposed revised fencing design'

ASSESSMENT

Frost Risk

Following concerns raised by representors, the SCAP requested examples from other solar farm sites with similar climatic and topographic conditions (in Australia and overseas) to be cited to demonstrate whether such an effect has or has not been observed elsewhere.

Representors expressed concerns that the solar farm structures and boundary fencing could potentially pose a physical impediment to the movement of frost across the landscape, which could slow the rate at which cold air would drain away. This could expose surrounding land (especially upslope of the site) to a greater level of frost exposure and subsequent crop damage.

DPTI sought advice from the Bureau of Meteorology (BoM) on the physical and meteorological processes related to frost. A general analysis of climatological data from weather stations in the Mid North Region was undertaken, with data from the Snowtown, Nuriootpa, Eudunda and Yongala observation stations analysed to identify any regional climate trends. Observations are also available from Clare, but the dataset only extends back to 1994 and could not be compared with the other stations.

On clear nights (i.e. without cloud or significant moisture in the atmosphere) the temperature of the ground and the air above progressively falls during the night. The depth of the colder air mass increases and, in the absence of wind to mix the air, a temperature inversion will form separating the cold air near the ground from warmer air above. For frost to form, the temperature at ground level needs to be 0 °C or less.

Frosts tend to occur more commonly in valleys because of the drainage of cold dense air downhill. A common weather pattern that may lead to frost is the presence of a large, slow moving high pressure system that moves over land following the passage of a cold front. The cold front firstly displaces a warmer air mass that preceded it, replacing it with a colder and often drier air mass. A slow moving high pressure system can lead to multiple nights with clear skies and light winds, and repeated frost events. Frosts are also more common in Australia during El Nino years and during droughts, when there is generally less rainfall, and clear skies and dry air are more common.

The Mid North Region is one of the most frost prone areas in the State (refer to Figure 3).

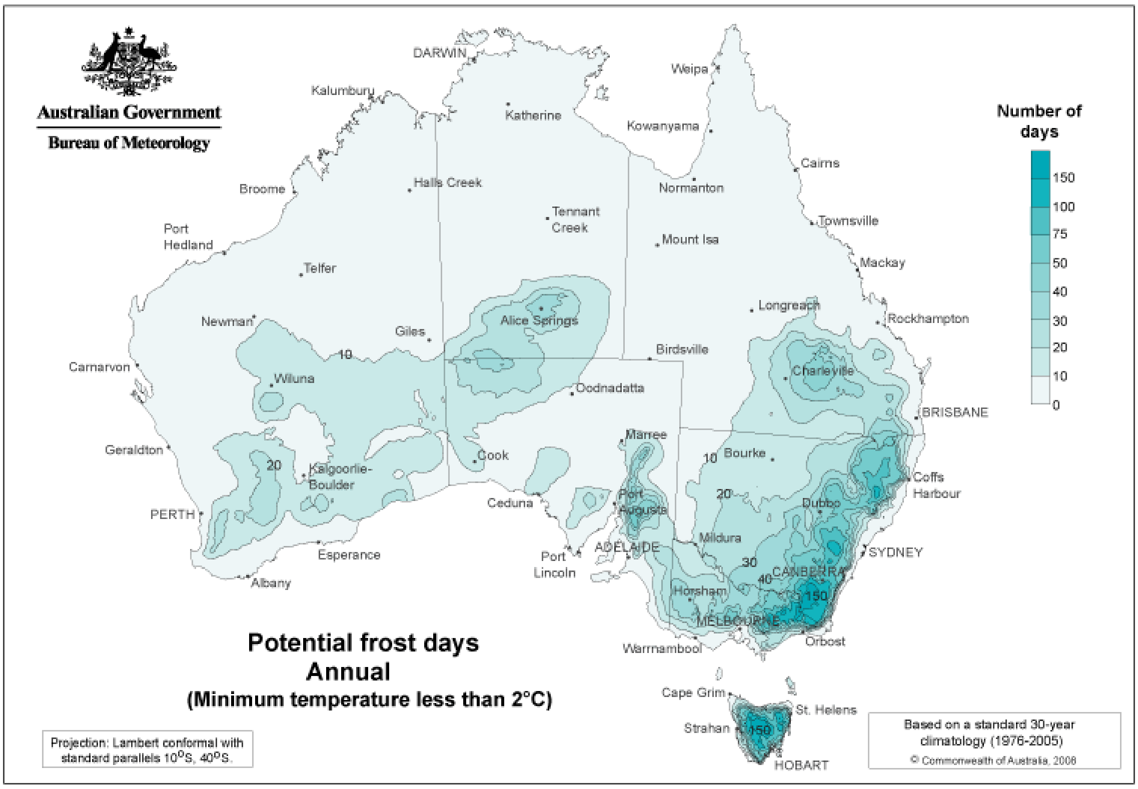


Figure 3: The average number of days per year from 1976-2005

The report by the BoM provides an analysis of climatological data related to frost in the Mid North Region. The report indicates that minimum temperatures across the region have generally increased over time, which is consistent with increases in temperature observed across Australia in all seasons, with both day and night-time temperatures showing warming (ie. since 1958). The data shows that whilst some colder than average autumn and spring seasons have occurred recently, warmer than average seasons have been more common. For winter, however, four of the past five winters have been colder than average.

Consequently, there is generally a decrease in the number of frost days per year, with the decrease most noticeable from 1970 onwards.

	Average Frost Days 1958-1987	Average Frost Days 1988-2018	Difference	%
Snowtown	32.9	30.2	- 2.7	↓ 8.1
Nuriootpa	35.6	25.7	- 9.9	↓ 27.8
Yongala	67.9	60.4	- 7.5	↓ 11.0
Eudunda[7]	9.6	9.9	+ 0.3	↑ 3.2

The report found that minimum temperature data from Snowtown, Nuriootpa, and Yongala all showed a decrease in the annual number of frost days between 1958-1987 and 1988-2018, consistent with the expectations from a warming atmosphere. In contrast there was a very slight increase in the number of frost days per year at Eudunda between 1965-1987 and 1988-2018, albeit from a smaller number of frost days. Trends at Nuriootpa also show that after a period of decreasing frost days between about 1960 and 1998, there has been a period since when the annual number of frost days has stabilised. At Snowtown, a decreasing trend occurred between about 1960 and 1991, but since then there has been an increasing trend in annual frost days.

The differences across the region could be due to many factors, including the altitude and local topography, the rainfall and cloud cover climatology of the location, and the local environment such as soil type and vegetation.

The conditions that lead to frost events (and frost severity) can be highly variable due to local topography and micro-climate, which can vary within a paddock. Frost incidence is influenced by a range of variables, with climate change likely to be a driving factor, especially on soil moisture (i.e. crop stress) and cloud cover level (i.e. more clear nights).

Clear night skies are important to the development of frost events because they allow thermal radiation from the soil surface to escape freely to space. The rate of cooling and final temperature of the plant canopy is determined in part by the balance between thermal radiation emitted to space and radiation absorbed from the soil. Local topography is also important, as cold air tends to run down slopes and drainage lines, and will pool in flats and basins. Barriers such as tree or fence lines can impede flow and allow cold air to accumulate higher in the landscape.

The severity of the frost event and hence the extent of the subsequent damage is therefore variable across the landscape. Topographic and management practices aimed at mitigating the severity of frost concentrate on influencing the heat balance or drainage of cold air. While these practices may help for lighter frosts, severe frost events of long duration are likely to overwhelm such measures.

The soil heat bank refers to the amount of heat absorbed and retained by the soil during the day. This heat is then radiated back into the crop canopy overnight to warm flowering heads, minimising frost damage. The amount of heat stored depends on a number of factors such as row spacing which affects canopy closure, soil colour, stubble loads and soil moisture. A moist soil profile will store more heat than a dry soil.

A solar farm could affect the following factors that influence frost:

- The amount of heat stored in the soil during the day – solar panels could shade soils to reduce stored heat, although this could be countered by the heat absorbed and radiated by the panels (i.e. the 'heat island effect').
- The amount of heat radiated to the atmosphere at night – shading could reduce soil temperature and the amount of heat radiated to the atmosphere, although the panels could trap warm air or reduce the level of radiation.
- Soil moisture levels – shading could reduce the amount of evaporation to help retain moisture.
- Wind speed – panels could disrupt wind pattern and reduce wind speed at ground level, although this would also depend on their orientation and profile.
- Surface 'roughness' – the panel support structures (especially the panel mounting posts) and security fencing could be obstacles that slow the movement of frost.

The applicant's response document considers that the solar arrays are also likely to act as a heat sink, and the horizontally stowed panels will also prevent longwave radiation emitted from the ground surface to escape to space under clear skies at night, effectively 'closing the atmospheric window' and absorbing and re-radiating the long wave radiation towards the ground. Both effects will contribute to an increase in air temperature under the arrays. The slightly warmer air will drain downhill and, in the near field, is likely to slightly alleviate the cold near surface air temperature, reducing the frost risk rather than increasing it on adjacent agricultural properties.

It should be noted that the solar farm would have a high degree of permeability that would reduce the above effects. The applicant's response considers the solar arrays have significant space for air flow below the stowed solar panels at night and between the mounting posts. The chainwire fence will have the maximum allowable 50 mm pitch between the links, providing for air to flow through the structure. By comparison with the solar farm, other common agricultural practices and features in the local area are expected to provide a greater potential for air flow blocking. Vineyards, wheat and other crops, road and rail line embankments, tree lines, shed and building structures and areas of natural vegetation with multistorey canopies may all feature in this environment and are considered to have a greater wind blocking potential.

Topography (i.e. landforms and gradients) is a key factor that influences frost behaviour. The applicant's response also provides an assessment of frost impact potential that includes a detailed study of the terrain within and surrounding the site.

The study identified that, at a regional-scale, the topography at the solar farm site and neighbouring agricultural properties appears to be relatively simple and flat with gentle undulations. At a micrometeorological scale the terrain is relatively complex, and under stable, calm conditions can lead to the formation of frost accumulation in hollows. A myriad of small undulations and drainage lines in multiple directions weave through the landscape, with different sections of the solar farm site and each neighbouring agricultural property draining in different directions. No single property in its entirety is likely to drain under calm air conditions towards a single point along a boundary. The study also found that the creek line on the western parcel played a critical role in providing a path for wind (and cold dense drainage air) to flow across the landscape. This gully area will be free from any built obstruction with the solar array being setback from the gully.

Given this variability, it is considered that any discernible effect from a solar farm would be very limited and unlikely to result in any significant local or regional impacts on climate. When considered against the background long-term trend of increasing minimum temperatures (and decreasing frost incidence) due to a warming climate, any effects would be mitigated to some degree. The surrounding locality is within a frost prone area, where frost movement is slow (i.e. does not drain away freely) due to the topography. The Clare Valley wine region (including Mintaro) is considered to be located a sufficient distance away and separated by a ridgeline that it is unlikely to be affected.

Fencing

Clarification was sought from industry providers on the applicability of *AS2067: Substations and high voltage installations exceeding 1 kV a.c* for solar farms, including any requirement to provide a fenced perimeter around the solar panels. Security fencing around high voltage equipment was already acknowledged as a necessary safety and security feature. SA Power Networks (SAPN) has confirmed that AS2067 standard fencing must be applied around the entire site (i.e. including the solar fields) not just the substation and connection area; and that standard stock fencing would not be suitable as it does not meet AS2067.

DPTI-Planning staff have visited both completed and solar farms under construction, and the visual impact of perimeter fencing – compared to the extensive panel fields and other infrastructure they contain (of a greater height, bulk and scale) – should not be unduly obtrusive within a more open, rural landscape. However, the extent of visibility is dependent on the setback from public roads, intervening roadside landscaping and topography, and the height, materials and finish of construction, which can help 'break-up' direct views of more lengthy fence lines and soften their appearance.

Notwithstanding the requirements of the Australian Standard, the application of a standard of works more common to substations to more extensive, lower voltage infrastructure, that seeks to enclose hundreds of hectares of panels, with extensive road frontages in more remote or sparsely populated rural areas, is not a planning requirement *per se* but rather a public safety requirement.

However from an appearance perspective, the alignment of the amended fence design will be offset from the property boundary in some sections, whilst no-barb wire strands are required (which also helps to lower the overall height level). A galvanised finish, and a fencing style that is relatively permeable, is also supported.

Plate 1: Perimeter fencing at Terregra Solar Farm at Murray Bridge

CONCLUSION

The proposed solar farm has been sited to minimise its visual impact, as far as reasonably possible, and to take advantage of the operational efficiencies with the existing Mintaro substation and its transmission line to Waterloo.

The existing rural landscape will be significantly modified as a result of the development, and whilst there will be opportunities to obscure or soften certain elements, the 380ha footprint will be substantial, and the solar fields will be highly visible. However, the design of the panels, including non-metal frames, helps minimise the potential impacts associated with reflection and/or glare, whilst a mandated boundary setback will also provide additional relief, in combination with the opportunity for landscape screening.

Recognising that security fencing around the solar farm must meet Australian Standards, the amended fencing design proposed with the removal of the barbed wire, and use of uncoated galvanised steel is considered to be an acceptable compromise, and should not unduly affect the agricultural/rural character of the surrounding land.

An uncoated, galvanized mesh will be more noticeable in the short term due to a more shiny appearance, but over time will develop a darker oxidized layer on the metal surface (estimated to occur within one year of installation).

In relation to the issue of frost impacts, there is no conclusive evidence to suggest that there will be any impact on frost incidence or severity that may result from the development. Whilst it is acknowledged that the frost study undertaken by the BOM was not specific to the subject site, the overall conclusion of that study is that occurrence of frost in the mid north of the State is already changing with a warming climate.

The applicant has proposed the implementation of a Frost and Monitoring Mitigation Strategy that includes the collection of general meteorological and site specific data on frost events prior to construction, and the over the life of the development. In addition, a management strategy could be developed to monitor and mitigate any frost impacts that can be attributed to the establishment and operation of the solar farm. If adopted, consideration would need to be given to how such a monitoring strategy would be developed and maintained, and whether or not the BOM should be involved (or perhaps a local university), to establish the scientific parameters and reporting process.

The greatest impacts in terms of noise, traffic generation, dust and general nuisance will be experienced during the 18 month construction period. To appropriately manage these, it is recommended that the applicant prepare a Construction Environmental Management Plan (CEMP) which demonstrate how the development will comply with the relevant environmental protection policies.

On balance, whist it is recognised that the development will result in a loss of primary production land and a visual change to the landscape, the negative impacts associated with the ongoing operation of the development can be suitably managed.

The establishment of renewable energy facilities is specially envisaged and encouraged within the Primary Production Zone, and consistent with the overall objectives of the Clare and Gilbert Valleys Development Plan to provide facilities that benefit the environment, the community and the state.

If no further information is required, and all relevant assessment matters have been considered, this planning report can be endorsed by the State Commission Assessment Panel pursuant to Section 49(7e) of the *Development Act 1993*, and a formal recommendation with appropriate conditions provided to the Minister for Planning for his further review and decision.

Sharon Wyatt
PRINCIPAL PROJECT OFFICER
PLANNING AND LAND USE SERVICES (DPTI)

Lee Webb
SENIOR SPECIALIST (ENVIRONMENTAL) PLANNER
PLANNING AND LAND USE SERVICES (DPTI)

SCAP Request for Information

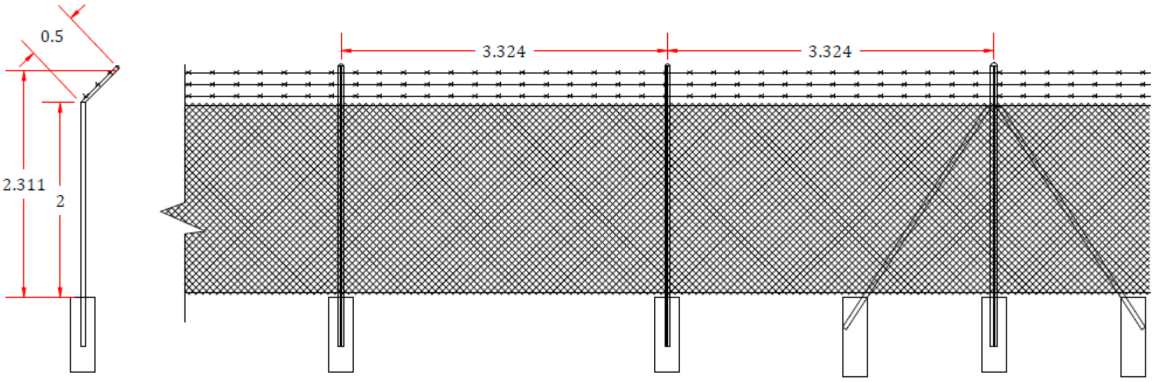
SUBJECT	**Boundary Fence Design Revision**
PROJECT NAME	**Chaff Mill Solar Farm**
PROJECT NUMBER	**PS103225 / PS113630**
PROPONENT	FRV Services Australia Pty Limited (FRV)
DISTRIBUTION	Sharon Wyatt – Principal Project Officer Major and Crown Development SCAP
PREPARED BY	Edie Mather: Development Manager, FRV
CONTACT	Bronte Nixon: Principal Environmental Scientist and Planner, WSP
CLASSIFICATION	Highly Confidential: Not for Circulation or Publication
DATE PREPARED	19th August 2019

FRV is seeking Development Approval for the construction and operation of Chaff Mill Solar Farm - a 100MW solar farm, located 3.5km north-east of Mintaro in the Clare Valley, South Australia.
FRV have included a security boundary fence in the design of the solar farm.
On 26th July 2019 SCAP requested FRV revise the boundary fence design to give a visual appearance more suited to the rural landscape of the Chaff Mill Solar Farm site.

1. Initial Boundary Fence Design

A boundary fence is required on all utility scale solar farms to restrict access to the electrical installation and to reduce risk of theft or vandalism by forced entry. The Substation and Battery Energy Storage System will have additional fences designed to Australian Standards and electrical safety authority specifications. The State Commission Assessment Panel (SCAP) has informed that these higher-level security fences do not require further consideration or modification and as such are not discussed in this document.

The initial design of the boundary fence was replicated from other solar farms FRV has developed and built in Australia; i.e. Royalla Solar Farm, Moree Solar Farm, Clare Solar Farm and Lilyvale Solar Farm.
This design incorporates a chain link fence with 50mm mesh, topped with 3 strands of barbed wire. The fence is designed to comply with *AS1725.1:2010 Chain link fabric fencing Part 1: Security fences and gates - general requirements* and *AS 2067:2016 Substations and High voltage Installations exceeding 1kVa.c.* which nominates that the maximum opening of the wire/mesh screens shall not exceed 50mm (Section 5.2.4).



Above: Original Proposed fence design for Chaff Mill Solar Farm

Above: Solar farm boundary fences installed at FRV solar farms in Australia (taken during construction)

2. Revised Fence Design

SCAP requested that FRV reconsider the design of the boundary fence in order to balance visual aesthetics with function and compliance. FRV looked for an alternative fence design that would maintain compliance with *AS1725.1:2010.* Without this compliance FRV anticipates that there would be increased insurance costs. There is also an issue of potential liability to FRV for a site which is not considered "secure" under the standard. If a member of the public was able to access the site, FRV would likely be significantly exposed without the protection of the standard.

Following further investigation and discussions with industry, FRV identified two options for fence modifications that still fall within *AS1725.1:2010*.

PVC Coated Chain Wire Mesh

AS1725.1:2010 allows for mesh fabric that is PVC coated. This coating is commonly available in green and black.

Above: Chain wire mesh; black coated (left), green coated (centre) and uncoated galvanized (right)

FRV consulted a Visual Impact Assessment specialist with regard to the three available colours and enquired which of the three options would best integrate into the existing rural / agricultural landscape. Advice received was that when assessing fence-colours, the contextual landscape for colour consideration is the sky. In other words, when a person looks at a fence it is generally with sky as the backdrop. With this in mind; visual impact assessment specialists generally agree that plain galvanized (i.e. uncoated) mesh is the best choice of colour. This is demonstrated in the above photographs.

Black was considered the most noticeable and contrasting colour and therefore not an appropriate choice for the fence in this landscape.

Green would only blend in if well matched to the vegetation colour and if the land behind the fence is rising into view. The site of Chaff Mill Solar Farm changes seasonally and is not green year-round. The green was also considered brighter and more contrasting that the grey uncoated metal.

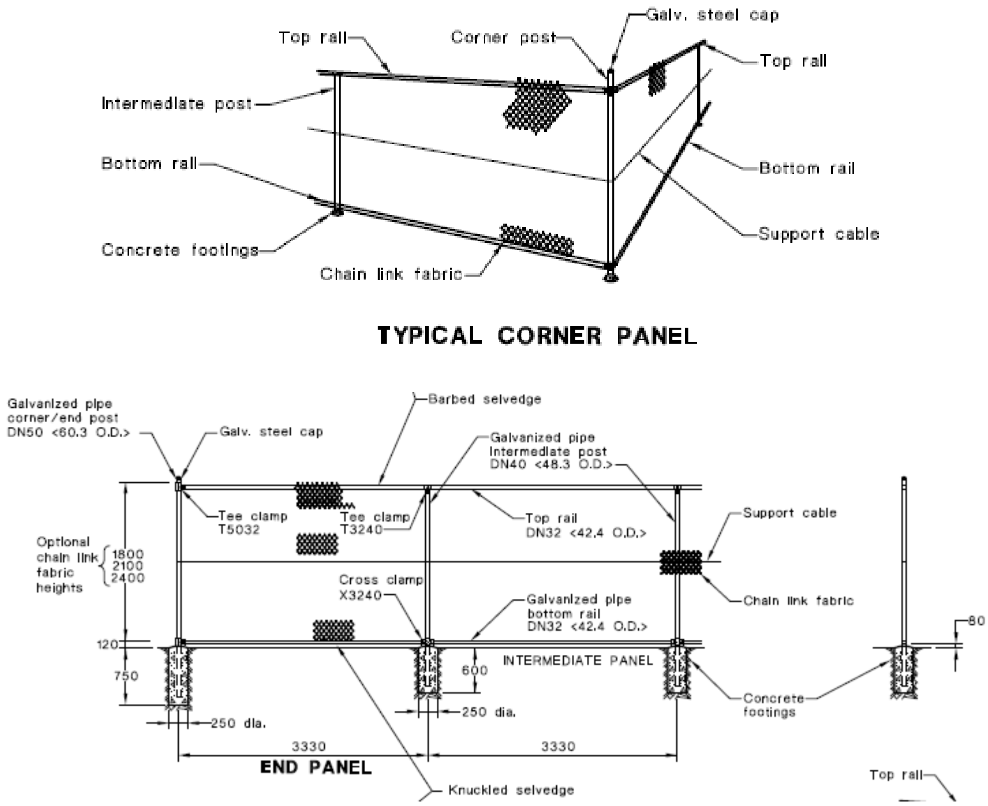
Above: Seasonal variation in colors of the landscape at the Chaff Mill Solar Farm site.

The uncoated galvanized mesh would initially be noticeable as the metal will be new and shiny but would blend in more as the fence aged and developed a grey oxidized layer on the metal surface. This generally occurs within one year of installation.

Based on this advice FRV will specify uncoated chain link mesh for the Chaff Mill Solar Farm Fence.

Removing the barbed wire topper

AS1725.1:2010 provides alternative fence configurations without the 3-strand barbed wire topper (described as 'plain top' in the standard). These are detailed in Appendix J '*Security fencing installations Type 2-T-B/P-T (top and bottom rails/plain top)*' and Appendix H '*Security fencing installations Type 1-R-L/P-T (Rail-less/plain top)*'.



Above: Figure J1 type 2-T-B/P-T (top and bottom rails / plain top) Security fencing from AS1725.1-2010

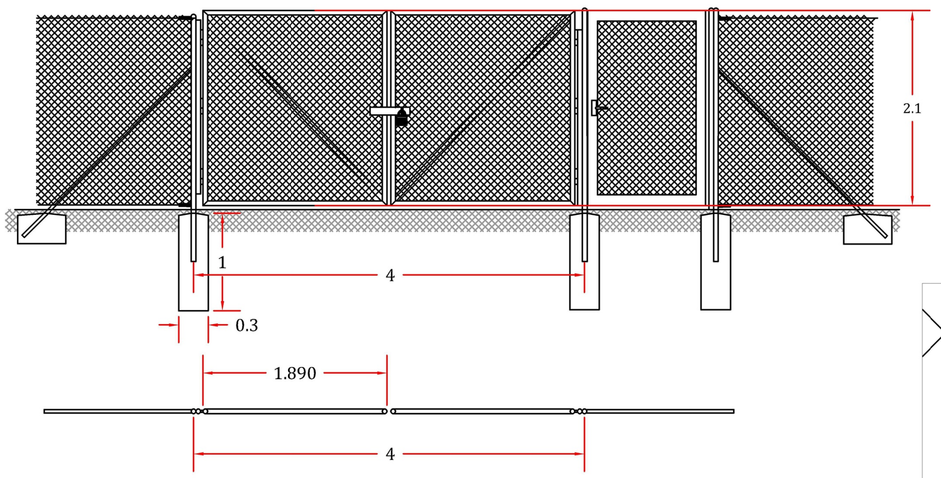
These options are still classified as a security fence, although they are considered as to be of a slightly lesser class. It is possible other security measures may need to be increased to compensate for this (e.g. additional security cameras on the boundary fence).

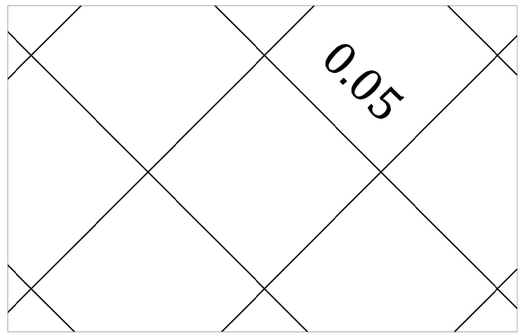
FRV believe that removing the 3-strand barbed wire topper from the original fence design will lessen the overall visual impact of the boundary fence. The barbed wire is considered to be the most imposing, or 'prison like' style element of the fence. Removing this element will be the most effective way to soften the appearance of the fence and make it more suitable for its rural setting, whilst still maintaining the required function and compliance of the fence. The removal of the three rows of barbed wire will also reduce the height of the boundary fence from 2.3 m to 2.1 m.

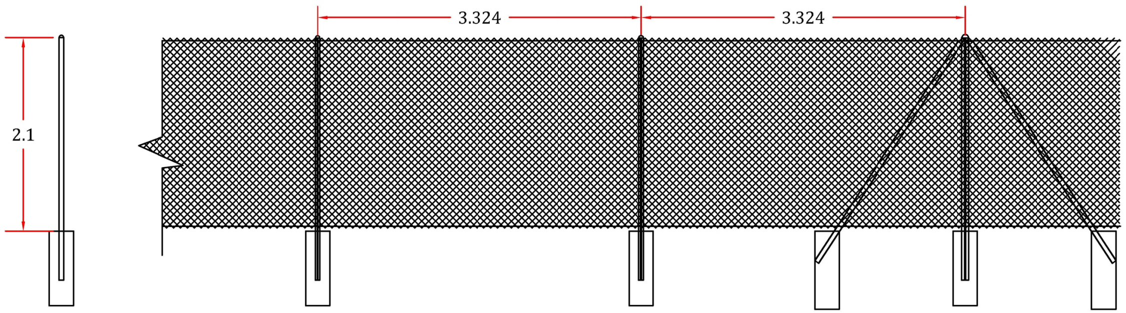
In summary, after investigating several options, FRV can confirm that:

- The three-strand barbed wire top will be removed from the boundary fencing.
- The fence will comprise uncoated galvanized chain wire mesh, which will be a more acceptable feature of the landscape.
- The overall height of the fence will reduce to 2.1 metres.

The revised indicative fence drawing is provided below.







Notes

- Maximum fence mesh height: 2.1m

- Fence mesh is uncoated galvanized chain wire.

Units m

REV.	DATE	DRAWN	DESIGNED	CHECKED	APPROVED	DESCRIPTION	VERIF.
03	190820	J.L.M.	J.L.M.	J.L.M.	A.R.		
02	190227	A.F.R.	A.F.R.	A.R.	A.R.		
01	190204	A.F.R.	A.F.R.	A.R.	A.R.		

PROJECT: CHAFF MILL PV PLANT 100 MWac

FRV FOTOWATIO RENEWABLE VENTURES

A3

TITLE: FENCING DETAILS

REF. N°: –

N.° – 0 Rev.

SHEET 05 FOLLOW



Frost Monitoring and Mitigation Strategy

FRV

Chaff Mill Solar Farm

July 2019

1. Background

1.1 Chaff Mill Solar Farm

FRV Services Australia Pty Limited (FRV) is seeking Development Approval for the construction and operation of a 100MW solar farm, located 3.5km north-east of Mintaro in the Clare Valley, South Australia.

The proposed solar farm would be developed on a 380-hectare site consisting of two parcels of land located to the east and west of Chaff Mill Road.

The site is in an agricultural area and is largely cleared of native vegetation, comprising grazing and cropping land. The adjacent and surrounding land use is largely agricultural, with some livestock and horticulture land use on large rural land holdings.

The site selection was influenced by a range of factors including availability of solar resource, proximity to grid infrastructure (specifically the Mintaro Substation and the 132kV Mintaro to Waterloo transmission line), terrain, and environmental conditions.

1.2 Frost and Microclimate

FRV is committed to a thorough community engagement process and has engaged extensively with key stakeholders, neighboring properties and the wider community to inform the planning process.

Key issues raised during the consultation process were identified and addressed in the Section 49 (Crown) Development Application. One of these was the potential exacerbation of existing frost conditions on properties adjacent to the solar farm.

To investigate this concern the following approach was initially undertaken:

1. Review of Solar Farm Assessment Guidelines.
2. Review of all other solar farm assessments, approvals and conditions of consent documents in Australia.
3. Desktop assessment of solar farms and frost / radiative heat loss impacts.
4. Academic literature and scientific study review of solar farms and frost / radiative heat loss impacts.
5. Discussions with agricultural, climatology and meteorological scientists in South Australia, Australia and overseas.

It was found that at the time of the initial assessment, there were no references to micro-climate or air temperature implications or requirements in any regulatory or policy guidelines in South Australia, interstate or internationally.
In a review of other solar farm Development Applications and Environmental Impact Statements; it was found that none of them looked at the issue in any detail.

Websites, reports and academic papers were then reviewed to try and obtain an understanding of the potential radiative heat loss and frost exacerbation issues and impacts associated with solar farm development. Very little information on the topic was found to exist.
In subsequent discussions with research scientists, climatologists and meteorologists; the climate impacts of a 380-ha solar farm were considered to not be significant; inparticular, the addition of access roads within and around a solar farm were believed to further mitigate any local climate impacts due to enhanced air flow.

Due to this general and widespread lack of existing information FRV commissioned a specialist study in response to representations from the community received as part of the public notification process. The basis for the issues raised in the submissions is that the solar array and its boundary fence may act as barriers to air flows which occur under frost-forming conditions. In the community submissions, it was thought that these barriers could allow cold air to accumulate on the adjacent uphill agricultural properties, possibly exacerbating existing frost events and causing damage to crops.

The study comprised a detailed desktop and modelling analysis by an independent third-party specialist to undertake an '*Assessment of Frost Formation and Impact Potential*'. The primary objective of the study was to investigate the issue of potential flow-blocking as a result of the development of the proposed solar farm. FRV engaged *Air Environment* for this work - an Australian technical research company specialising in air science, meteorology and climatology. The study was undertaken by Andrew Balch and Dr Michael Power; air quality, air science, meteorological and topographical modelling specialists who are CASANZ-certified and have strong links to Australian government regulators.

The commissioned study found no evidence from the background review or the modelling outputs that would suggest an exacerbation of existing frost formation. Further, it found that no data could definitively prove or disprove the impact of a solar farm on frost formation without real world measurements taken from the constructed solar farm and a solid and continuous pattern of baseline frost events.

It was identified that the creek line within the western parcel of the project area played a critical role in providing a path for air flow across the landscape. As such, the proposed solar farm will not alter this creek line, no development is proposed inside the creek gully, and there is a significant setback provided from the creek banks to the solar panels.
The design of the solar farm and setbacks of the arrays to the creekline should allow air circulation to be maintained throughout the site, and the risk posed by any identifiable micro-climate impacts and increased frost occurrences is considered to be negligible.

The solar arrays are not a solid or continuous structure and the design of the solar arrays (with up to 9m spacing between each array) encourages air flow through the site. At night the panels are stowed in a near horizontal position, approximately 2m above the ground. The near horizontally stowed panels will prevent longwave radiation emitted from the ground surface to escape to space under clear skies at night, effectively 'closing the atmospheric window' and absorbing and re-radiating the long wave radiation towards the ground. Hence, the solar farm is expected to contribute to an increase in air temperature under the arrays. The slightly warmer air is likely to slightly alleviate the cold near-surface air temperature; hence reducing the frost risk rather than increasing it.

The proposed solar farm boundary fence is a chain wire mesh with 50mm openings (as required by Australian Standards), allowing air flow through the structure, and is therefore considered to be a minimal air flow blockage.

The study also noted that common agricultural practices and features in the local area such as vineyards, crops, road and rail embankments, tree lines, buildings and natural vegetation with multiple storey canopies provide a greater potential for air flow blocking than the proposed solar farm.

1.3 FRV commitment

Although there is no evidence that crop damaging frost will be exacerbated by Chaff Mill Solar Farm, FRV understand there is still continued community concern for this issue. The community's concern for impact on their lively hood is not taken lightly by FRV. Chaff Mill Solar Farm will be a long-term part of the community and so FRV see the importance of committing to responding to the community's concerns.

As previously noted, there is no data that can definitively prove or disprove the impact of a solar farm on frost formation without real world measurements taken from the constructed solar farm. FRV is therefore committing to monitoring frost events for the lifetime of the Chaff Mill Solar Farm, and to investigating mitigation methods in the unlikely event that frost is found to increase as a direct result the solar farm. This commitment reflects FRV's desire to do what is best for both the project and for the local community.

2. Frost Monitoring

FRV commits to monitoring frost events that occur post-construction and providing this information to the State Commission Assessment Panel (SCAP) and / or other government statutory regulators for the life of the project. The methodology for this is process is outlined below.

2.1 Design of the Monitoring System

The design of the monitoring system will include the identification and specification of all meteorological equipment and the determination of the installation locations of this equipment on site. This will be carried out by a suitably qualified climate scientist with experience in frost monitoring. FRV have had initial discussions about the monitoring requirements with Agriclimatologist Dr Stuart Powell from Climate Consulting.

The equipment selected will be industry standard practice for monitoring frost in agricultural areas. This equipment will monitor and log two variables required to detect frost formation: *inversion strength* and *katabatic wind drift*.

All meteorological equipment will be installed inside the Chaff Mill Solar Farm property boundary and will be owned and maintained by Chaff Mill Solar Farm and their selected independent agriclimatologists and meteorological advisors. This equipment will be installed in addition to the meteorological stations used for standard solar farm operation and maintenance purposes.

Exact equipment specifications will not be determined until a detailed analysis of the site and corresponding design is undertaken. An indicative example of expected equipment, however, is:

- 2 x 12m masts, one on the eastern parcel and one on the western parcel, to measure inversion strength i.e. the difference in temperature at 12m and near ground or crop height.
- Multiple sensors to measure temperature and katabatic wind drift, wind speed and wind direction.

Examples of Frost Monitoring Equipment

Left: Weather Station; Centre: Weather Station with Mast; Right: Long range remote sensor in the field

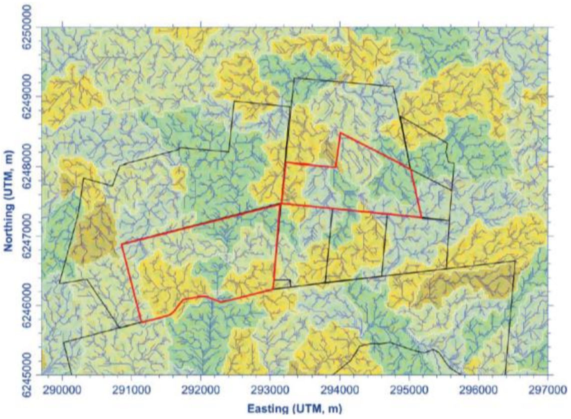
Topographic mapping of the site indicates the terrain is complex with many hollows and dips, therefore the most appropriate locations for the sensors must be determined as part of the design phase, by a suitably qualified climate scientist.

It is expected that the sensor locations will comprise a representative combination of:

- Locations along the solar farm boundary fence

- Locations within the solar farm, amongst the rows of panels
- Locations in clear areas between panels and the boundary of the land.

Locations would also be informed by the terrain study in the '*Assessment of Frost Formation and Impact Potential'* report by Air Environment. This report identified drainage lines in to and out of the solar farm and adjacent neighbouring properties.



Property	Number of drainage lines out of solar farm into property	Number of drainage lines from property into solar farm	Property boundary which borders solar farm	Critical wind direction causing flow toward solar farm boundary
G & D Johnson (southern property)	2	4	Northern	Southerly
G & D Johnson (eastern property)	0	2	Western	Easterly
J & D Mitchell (boundary with eastern parcel)	3	0	Eastern	Easterly
J & D Mitchell (boundary with western parcel)	1	6	Southern	Northerly
J Faulkner	0	5	Southern / eastern leg on southern boundary	Northerly / easterly
Sandow (northern property)	0	0	Southwest corner	None
Sandow (southern property)	1	5	Northern / western	Southerly / easterly
A Kelly	2	0	Northern (partly)	Southerly
M Faulkner	1	3	Northern	Southerly

Left: Watershed map showing gravity fed flow drainage lines (blue) across the Solar Farm (red boundary) and neighbour properties (black boundaries).

Right: Drainage lines into and out of Chaff Mill Solar Farm Site and surrounding properties

2.2 Data collection

Once installed, the equipment is expected to be network-connected for remote data read and download via an online portal. Data would be downloaded at regular intervals (such as monthly or quarterly) by FRV and provided to a suitably qualified and independent climate scientist consultant for review. This action would form part of the Operation and Maintenance procedures for Chaff Mill Solar Farm.

The installation and commissioning of metrological hardware and data connection will commence as soon as possible following final Development Approval to collect baseline data prior to construction. This is vital as frost data from the operational solar farm alone cannot determine the impact of the solar farm on frost formation. If the Development Approval is granted for Chaff Mill Solar Farm, FRV will endeavour to start monitoring as soon as practicable and will collect baseline site data up to the start of construction. The duration of this pre-solar farm baseline monitoring phase is subject to the Development Approval and construction timelines.

It is important to note that no year is typical, and therefore the baseline data collected cannot be expected to represent an average year or typical year. It is expected that several years of data, in addition to the baseline data period, would need to be collected before any clear conclusions could be made on the impact of the solar farm on frost formation.

2.3 Analysis and Reporting

The raw data collected from the onsite equipment would be provided to a suitably qualified, independant and experienced climate scientist and agricultural frost specialist. Possible consultants include but are not limited to Dr Stuart Powell of *Climate Consulting* or Andrew Balch and Dr Michael Power of *Air Environment*.

The engaged consultant would analyse the data and prepare a report on their findings which would be submitted to SCAP. It is envisaged that this will be a succinct data summary and interpretation, submitted annually. The contents of the annual summary document will ultimately be determined by the selected specialist. However, as a minimum the reporting is expected to contain a summary of the past 12 months of data and a description of conclusions drawn from this data.

As the data collected from the onsite monitoring system would be commercially sensitive, FRV does not intend to make this data publicly available. An annual summary of this data will be provided only to SCAP and/or statutory referral agencies. FRV consider this Monitoring and Mitigation Strategy and resulting data and subsequent annual summary reports to be to be commercially sensitive and therefore request that these documents are not made publicly available and that the results are retained only by the South Australian Government. FRV cannot make any provisions for the data generated as part of this project to be used for any other purpose than that already identified in this document. FRV cannot make provisions for any data generated to be used by third parties for the purposes of research. All data is commercial in confidence and cannot be shared or published without the explicit written approval of FRV.

3. Frost Mitigation

Based on the lack of existing information and on the conclusions of the '*Assessment of Frost Formation and Impact Potential'* report by Air Environment, FRV does not expect that Chaff Mill Solar Farm will exacerbate frost on adjacent land. It is important to note that frosts are a known and naturally occurring event in the Clare Valley region and as such, FRV cannot commit to implementing mitigation measures for *existing* frost conditions and occurrences.

Whilst FRV will commit to monitoring frost conditions and investigating and implementing mitigation measures if required or when determined by statutory regulators, FRV will not commit to financial compensation to adjoining landowners or financial contributions to the cost of mitigation measures located on adjoining land areas to Chaff Mill Solar Farm. Alternatively, FRV commit to a recognised mitigation hierarchy arrangement comprised of *avoiding* impacts in the first instance, followed by *mitigating* impacts in the second instance.

The following are potential mitigation strategies FRV will investigate and implement on the Chaff Mill Solar Farm site in the event an increase or exacerbation in frost on adjoining land is shown to be directly caused by the construction of the Chaff Mill Solar Farm (i.e. not a result of background climatic conditions, natural variability and climate change).

3.2 Methodology

1. Impact Avoidance

In the planning phase of the project a number of design allowances were made to help *avoid* potential impacts relating to flow-blocking and frost exacerbation. These have included:

- Design of the security fence utilising a 50mm mesh to reduce flow-blocking potential.
- Committing to a weed management program which will keep weeds low and hence reduce flow-blocking potential
- Increasing the distance between solar arrays to allow for the continued flow of air. Arrays will now be placed up to 9 metres apart.
- Ensuring that the natural cold air drainage path of the landscape (i.e. Wookie Creek) remains free from solar panels and other infrastructure. The buffer distance either side of the creek will be 150 metres at the northern point (i.e. 300 metres wide in total); allowing a wide area for wind flow across the landscape.
- The panels will be stored almost horizontally at night; maximising wind flow through the site and helping to re-radiate longwave radiation towards the ground. This will lead to slightly increased temperatures under the arrays; potentially mitigating frost effects in the near-field.
- Rows of panels will be supported on approx. 100mm wide posts, spaced at intervals of approx. 6 meters; further minimising flow-blocking potential.

2. Data Collection and Analysis

The data collection and monitoring activities outlined above in Sections 2.2 and 2.3 will be implemented prior to construction and following commissioning for the duration of the operational life of the project. Raw data will be collected from the site in real time and provided to an appropriately qualified specialist for interpretation and reporting. Based upon patterns established from baseline data and post-construction data, and considering any allowances made for external factors such as seasonality, climate change, and extreme weather events, analysis will be undertaken to determine potential impacts.

3. Identify Impacted Area

In the event that frost-exacerbation impacts are identified, data will be compared between sensor locations on site to identify the location or the element of the solar farm that is potentially blocking cold air drainage (e.g. a section of fence or row of solar panels).

4. Collect Further Data

Once an affected area is identified there may be a need for more detailed data or further investigation. This could take the form of a single survey or temporary additional equipment placed on site. The need for additional data and the method of collecting this data would be defined by the climate scientist performing the annual analysis. Potential examples of this include, but are not limited to:

- installing additional temporary sensors in a defined area to gain higher resolution data, or,
- thermal image aerial survey of the site by UAV in the pre-dawn hours. The capture area of this survey could be extended into the adjacent properties by approx. 100- 200m if needed. The data and imagery collected could be used to generate thermal maps showing changes in relative temperature over the area.

5. Implement Mitigation

If a need for mitigation measures is identified by annual reporting, FRV propose that a hierarchy of mitigation measures are iteratively implemented, starting with those methods that can most rapidly put in place. Measurements from the monitoring system would be reviewed to confirm if the mitigation method is successful or if escalation to the next level of mitigation may be required. This would be an iterative process until data shows a method has sufficiently reduced frost conditions to pre-solar farm (i.e. accepted baseline) levels.

FRV's proposed hierarchy of mitigation methods include:

I. Changes to solar farm **maintenance** activities

e.g. revising the weed and vegetation management plan

II. Changes to **operational behaviour** of the solar farm

e.g. changes to the overnight stow angle of the solar panels

III. Changes to the **design** of the solar farm, where practicable

e.g. adjust the location of a fence line, or landscaping to redirect cold air flow.

IV. Installation of **active mitigation methods** on Chaff Mill Solar Farm land, where practicable

e.g. frost fans or other methods identified by independent frost and / meteorological specialists

Examples of frost fans

Active mitigation methods such as frost fans are known to be costly and could require significant redesign of the solar farm to accommodate them on site. Mitigation measures cannot compromise the performance or safe operation of Chaff Mill Solar Farm and cannot be unreasonably costly.

Mitigation actions would only be considered where frost can be *directly* attributed to the construction solar farm and not attributed to other background factors such as weather events, climate change and natural variability.

6. Reporting

Any investigation or implementation of mitigation methods would be reported in the annual frost monitoring summary to be provided to SCAP.

FRV is committed to a low-carbon future and the continued growth of renewable energy in South Australia. FRV is also committed to operating with environmental and social integrity and engaging openly with the community and its neighbours. FRV commit to working closely with SCAP and other statutory and / or regulatory authorities and their advisors (including the South Australian Bureau of Meteorology) to ensure the avoidance or management and mitigation of any impacts that are demonstrated to be a direct result of our solar farm.

Frost climatology of the Mid North, South Australia

Bureau of Meteorology
Level 4, 431 King William Street
Adelaide, South Australia 5000

Executive Summary

Analysis of trends in frost for the period 1958 to 2018 has been undertaken for the Mid North of South Australia using observation from Bureau of Meteorology automatic weather stations. Whilst data for four stations has been presented, only two (Snowtown and Nuriootpa) can be considered highly reliable, where data has been controlled for inhomogeneities, such as station relocation or changes in exposure.

Analysis of high quality ACORN-SAT observation sites at Snowtown and Nuriootpa in South Australia's Mid North has shown a general decline in the incidence of frost, consistent with a warming climate. Within this signal a slight increase in frost is evident (against broader trend) from the late 1980s and 1990s at Snowtown and Nuriootpa. These more recent trends are consistent with the rising incidence of drier winters and strengthening of the mid latitude sub-tropical ridge.

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1. Introduction

Definitions

Frost: A deposit of ice crystals or frozen dew drops on objects near the ground, formed when the surface temperature drops below freezing point. Nocturnal radiation cooling is the most common mechanism for frost formation in Australia and occurs under clear skies with light or calm winds [1] [2] [3].

- **White frost**, also known as hoar frost, is a deposit of ice crystals formed on objects when the surface temperature drops below 0 °C. This can occur by direct deposition when water vapour turns directly to solid ice upon contact with a frozen surface. Frost may also form through the freezing of dew drops that have already formed on the surface before the temperature drops below 0 °C. This is the most common form of frost observed in Australia.
- **Black frost** occurs when the temperature drops to below 0 °C, but the adjacent air does not contain enough moisture to form white frost on exposed surfaces. This happens when the dew point temperature of the air (the air temperature at which dew forms) is below 0 °C. This causes an internal freezing of the vegetation, leaving it with a blackened appearance and killing it. Black frost occurs without any visible signs of white ice appearing on exposed surfaces. Black frost is uncommon in the agricultural areas of Australia, but more likely in dry or drought years when there is less moisture in the air.
- **Rime** is a deposit of ice formed by the rapid freezing of super cooled liquid water on contact with a surface that is below 0 °C. This is rare in Australia outside alpine areas.

Frost formation

Radiation frost forms because of radiative cooling of the land surface, and the adjacent air, to below freezing at night. During daytime, the land surface absorbs incoming shortwave solar radiation from the sun. At night, as it does during the day also, the land radiates outwards this energy as longwave infrared radiation. Clouds and water vapour in the atmosphere absorb this outgoing energy and re-radiate it, some of which is directed back to the ground. Cloud cover therefore acts like a blanket to trap heat and slow the nocturnal cooling of the land. On clear nights, without cloud or significant moisture in the atmosphere, the temperature of the ground progressively falls during the night. As the ground cools, the air near the surface also cools through contact with it and the cooling gradually extends to air above. The depth of this colder air mass increases during the night as the ground continues to cool. In the absence of wind to mix the air, a temperature inversion will form separating the cold air near the ground from warmer air above. The colder air becomes denser than the surrounding air so will flow downhill under the influence of gravity and accumulate, or pool, in valleys and low lying topography. Frosts tend to occur more commonly in valleys because of the drainage of cold dense air downhill, but frost is also common where general elevation is high due to the general cooling of air with height in the atmosphere. Valleys are often frost prone because of the pooling of cold air that has flowed down-slope.

For frost to form, the temperature at ground level needs to be 0 °C or less, but air temperature observations, as recorded by the Bureau of Meteorology in a Stevenson Screen, are taken at a standard height of 1.2 metres above the ground[1] [4] [5]. Because the air at the surface is usually cooler than the air above it at night, frost may form on the surface or on near-surface vegetation when the air temperature at 1.2 metres is below 4 °C and becomes likely when it drops below 2 °C. For this report, a '**frost day**' is defined as a day where the observed minimum temperature was less than 2 °C.

Factors affecting frost formation

- **Cloud cover** slows the cooling of the land surface by trapping the daytime heat and preventing the temperature dropping as low as it might otherwise in the absence of cloud.
- **Winds** mix the colder near-surface air with warmer air from above, therefore slowing down the nocturnal surface cooling and preventing or weakening the formation of a temperature inversion.
- **Humidity** also acts to reduce frost formation. If the air near the ground contains sufficient moisture, dew or fog will form as the air cools. Small amounts of latent heat are released as the water vapour transitions to liquid form, thereby warming the air slightly and decreasing the likelihood of frost. Water vapour, and fog, in the atmosphere also reduces nocturnal cooling in the same way cloud cover does.
- **Topography** also plays an important role in frost formation. Valleys are usually more prone to frost, with slopes, ridgelines and peaks less prone, due to the downslope flow of colder air which pools in valleys. Ridges and peaks are also more likely to be windier than valleys because they may be exposed to stronger winds present at higher altitudes. Ridges and peaks may also extend above the temperature inversion, so may be noticeably windier and warmer than the nearby valleys at night.
- **Soil moisture** may play a role in frost formation because a moist soil will absorb more heat during the day and slow the rate of cooling at night.
- **Non-meteorological factors,** such as soil type and colour, vegetation coverage and type, and stubble on the ground may also affect minimum temperature and frost formation by altering the ground's ability to absorb incoming solar radiation during the day and also emit long-wave radiation at night [6].

In South Australia, the occurrence of frost almost always requires clear skies, and calm or near-calm winds, for a significant proportion of the night.

Overnight minimum temperatures can vary quite substantially with topography, and it is not unusual on clear, calm nights for valley locations to be 5 °C or more colder than nearby ridges and peaks, which in turn can have a dramatic influence on frost frequency. Because of these local-scale variations, specific points within the Mid North region may have an average frost frequency either significantly higher or significantly lower than their nearest Bureau of Meteorology observation site, but longer-term trends are likely to be relatively consistent.

[1] A limited number of stations also report minimum temperature at ground level, but the number of stations and the length of available data is much less than for screen-level minimum temperature.

Weather patterns conducive to frost in South Australia

A common weather pattern that may lead to frost is the presence of a large, slow moving high pressure system that moves over land following the passage of a cold front. The cold front firstly displaces a warmer air mass that preceded it, replacing it with a colder and often drier air mass. The high pressure system then establishes light winds, and sometimes, but not always, clear skies. If the cold front has come from a long way south, bringing northwards a polar air mass, the air is even more likely to be very cold and dry. A slow high pressure system can lead to multiple clear calm nights, and repeated frost events. If the preceding day is also cold, then the surface can drop to below freezing earlier in the night, and this can lead to a longer duration frost event. Frosts are also more common in Australia during El Nino years and during droughts, when there is generally less rainfall, and when clear skies and dry air are more common.

Figure 1-1 below shows an example of a common frost weather pattern in South Australia. A cold front, connected to a low pressure system to the south, crossed the southeast of the State on the night of 6th September 2019 (a), resulting in relatively warm temperatures on the morning of the 7th September with 6.0 °C at Snowtown Automatic Weather Station (AWS). A ridge of high pressure extended into the west of the State on the night of the 7th (b) but the temperature only dropped to a minimum of 5.9 °C at Snowtown AWS on the morning of the 8th due to winds only dropping to about 10 km/h. A large high pressure system then moved slowly over the State on the nights of the 8th and 9th September (c and d) resulting in the clear skies and light or calm winds that allowed the temperature to drop to -1.1 °C and -1.7 °C at Snowtown AWS on the mornings of the 9th and 10th September 2019.

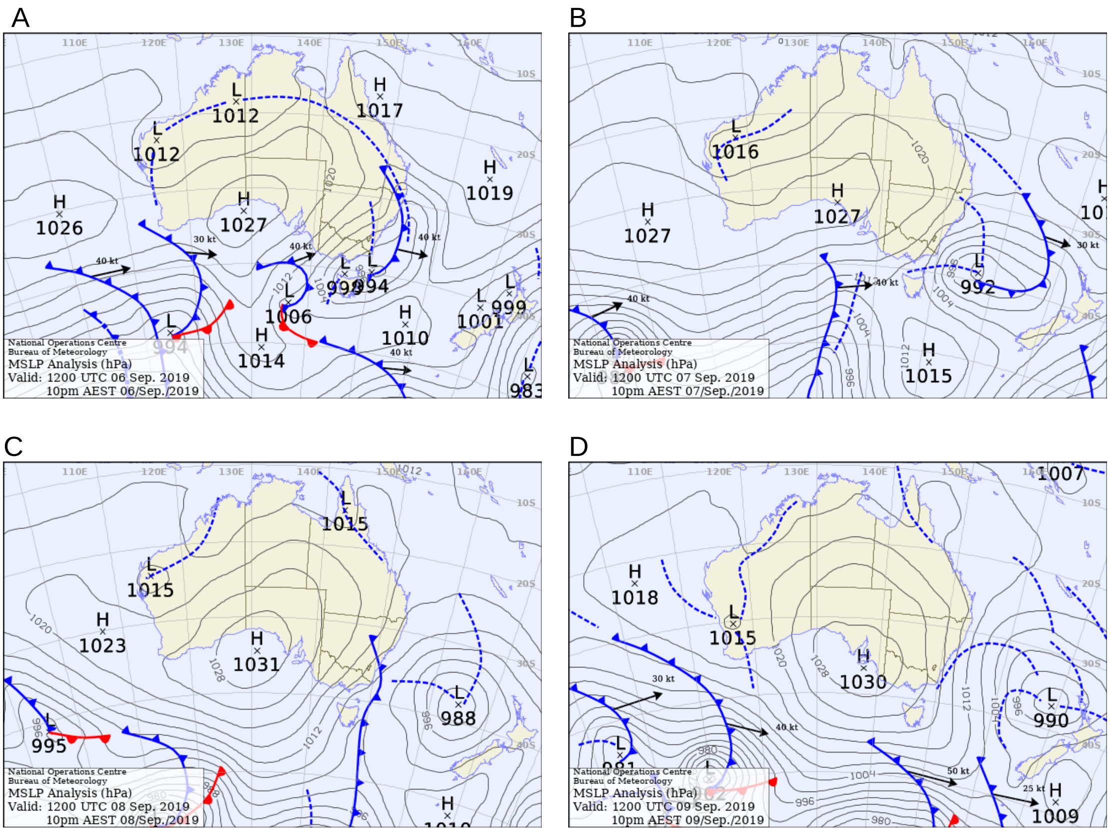

Figure 1-1: A common weather system that results in frost in SA, whereby a cold front crosses the State and is followed by a large, slow high pressure system.

2. Frost Climatology Methodology

A thorough study of frost climatology and trends would need to examine a number of meteorological and non-meteorological factors. In addition to minimum surface air temperature observations, a comprehensive study would also need to investigate observations of wind speed and direction, atmospheric moisture, cloud cover and rainfall. Such an exhaustive study would also need to include details about topography, soil type and moisture, vegetation coverage and land use changes.

The purpose of this report is to provide a quick analysis of the incidence of frost in the Mid North, and therefore shall focus on minimum surface air temperature observations of less than 2 °C using site-based data. A more meteorologically complete, and spatially exhaustive, investigation may be possible using the Bureau of Meteorology's Atmospheric high-resolution Regional Reanalysis for Australia (BARRA) [7], which takes all available observations and uses a weather model to consistently fill in the details across the domain.

Site-based data sources available for this report include the Australian Climate Observations Reference Network – Surface Air Temperature (ACORN-SAT) dataset [8] [9]. This dataset has quality controlled daily maximum and minimum temperature data available for both Snowtown and Nuriootpa dating back to 1910 and 1957 respectively. The ACORN-SAT data has been developed to monitor climate variability and change in Australia, and is comparable through time, making adjustments for historic changes in observing practices and observing locations, which enable climates researchers to better understand long-term changes in monthly and seasonal climate, as well as changes in day-to-day weather, such as the frequency of heat and cold extremes. The adjustments are particularly important when assessing frosts, as local-scale effects which influence temperature observations, such as local topography (which will change if a site moves), or aspects of the local site environment such as buildings and vegetation, generally have their largest influence on clear, calm nights, when most frosts occur. Further information is available at http://www.bom.gov.au/climate/data/acorn-sat/.

Direct minimum temperature observations from the Bureau of Meteorology are also available from Yongala and Eudunda, since 1957 and 1965 respectively. Observations are also available from Clare AWS, but since this dataset only extends back to 1994 it has not been included in this report. Unlike the Snowtown and Nuriootpa data, none of these observations have been adjusted for site changes or other non-climatic effects. The Eudunda site has had no significant changes since 1965 but is within the town, and will therefore generally be warmer than an equivalent rural site. The Yongala site moved in 1990, 2001 and 2014, with the last move taking it outside the town boundary.

The location of the site-based observations are shown below in Figure 2-1. The elevation above sea level of these observation sites varies significantly, from 109 m at the current Snowtown AWS, 275 m at the current Nuriootpa AWS, 415 m at Eudunda and 521 m at Yongala (Figure 2-2).

This report will firstly present the background minimum temperature climatology of South Australia from the ACORN-SAT dataset, with a focus on both Snowtown and Nuriootpa, then investigate the average annual and monthly number of frost days, observed minimum temperature less than 2 °C, at Snowtown, Nuriootpa, Yongala and Eudunda. The time period considered for this study will be from 1958 to 2018. Data from Snowtown does date back to 1910, however data was unavailable for most of 1957, so data from 1958 will be used for consistency with the other locations. To investigate trends over time, the average number of frost days per month and per year shall be compared between 1958-1987 and 1988-2018.

Figure 2-1: The location of observation sources.

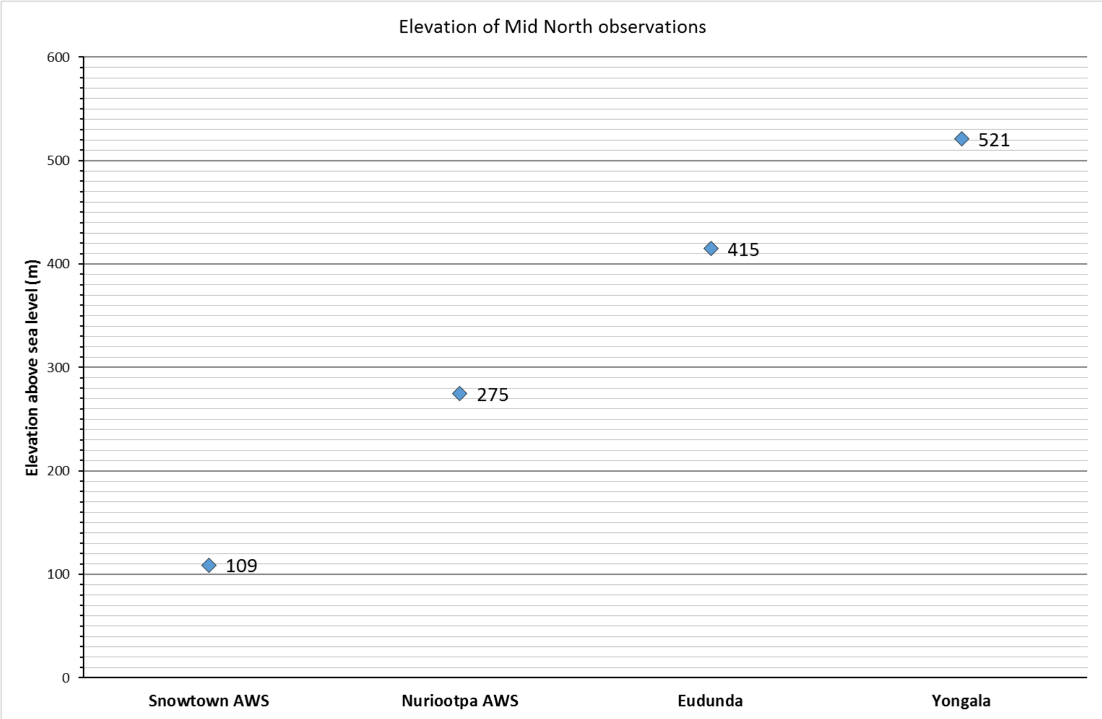

Figure 2-2: The elevation of Mid North observation locations.

3. Frost Climatology and Trends

Trends in minimum temperature

The State of the Climate 2018 report by the Bureau of Meteorology and CSIRO [10] states that "Australia's climate has warmed by just over 1 °C since 1910", and that "Increases in temperature are observed across Australia in all seasons with both day and night-time temperatures showing warming." However, the report does not give any further specifics about minimum temperatures or frost.

Climate data available from the Bureau of Meteorology [11] (derived from the ACORN-SAT dataset) shows the trends and anomalies in minimum temperatures across Australia. Figure 3-1 shows the trends in minimum temperature across South Australia since 1960 during summer, autumn, winter and spring. Warming is observed across the Mid North district of South Australia in each of these time periods, with the greatest warming evident during December, January and February.

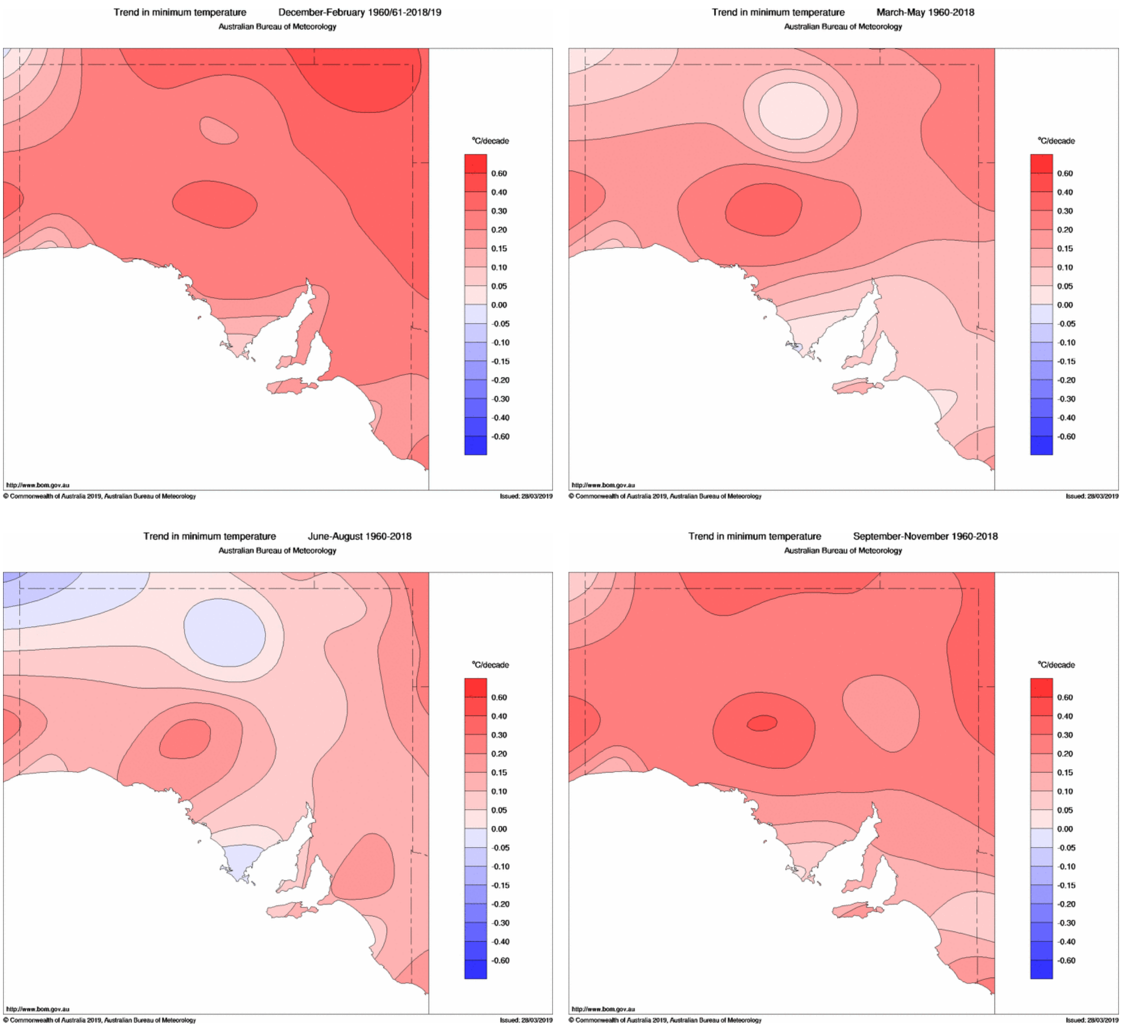

Figure 3-1: Trend in minimum temperature in South Australia from 1960-2018 summer (top left), autumn (top right), winter (bottom left) and spring (bottom right).

Figure 3-2 shows the anomalies of minimum temperature at Snowtown each year, highlighting the increased frequency of warmer than average years recently. The warming is particularly evident in the summer months, and all summers since 2005 have been warmer than average. The data shows that whilst some colder than average autumn and spring seasons have occurred recently, warmer than average seasons have been more common. For winter, however, four of the past five winters have been colder than average.

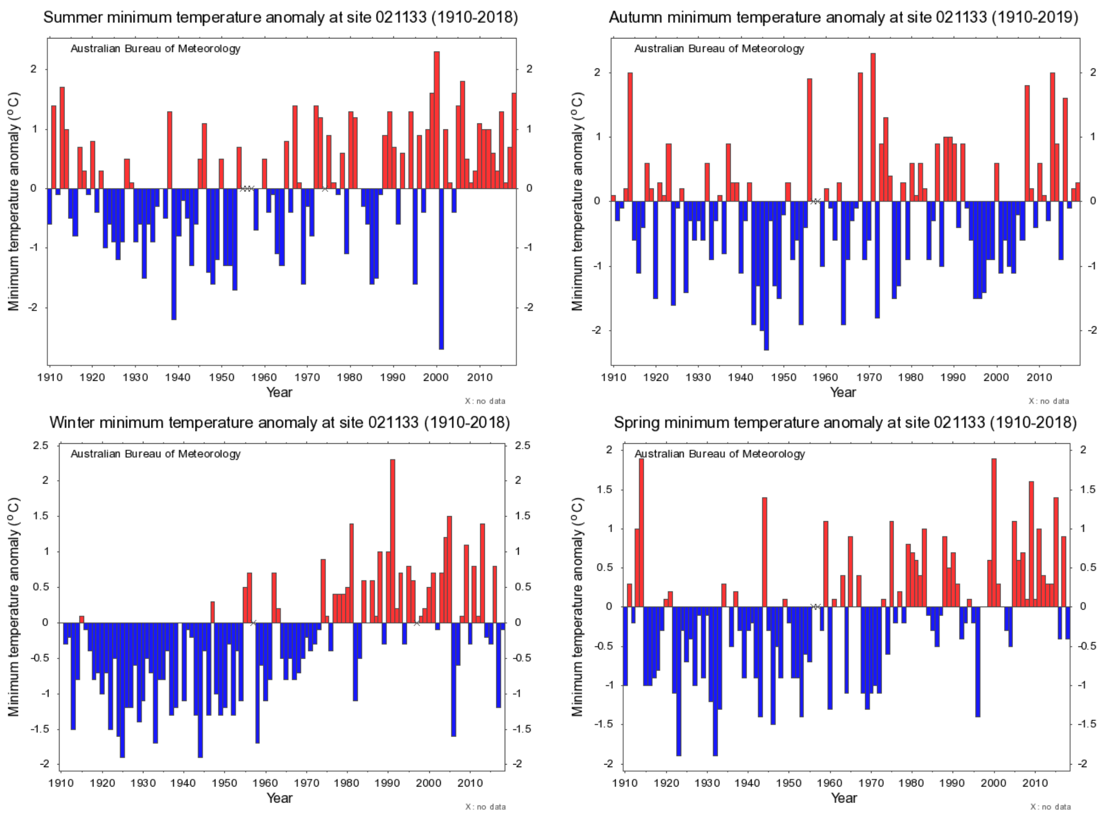

Figure 3-2: Minimum temperature anomalies at Snowtown from 1910-2018 for summer (top left), autumn (top right), winter (bottom left) and spring (bottom right).

Figure 3-3 shows the anomalies for the minimum temperature at Nuriootpa each year, which also shows recent increased frequency of warmer than average years. As at Snowtown, all summers since 2005 have been warmer than average, and while some colder than average autumn, winter and spring seasons have occurred, warmer than average seasons have been more common. Unlike at Snowtown, Nuriootpa does not show as many recent colder than average winters.

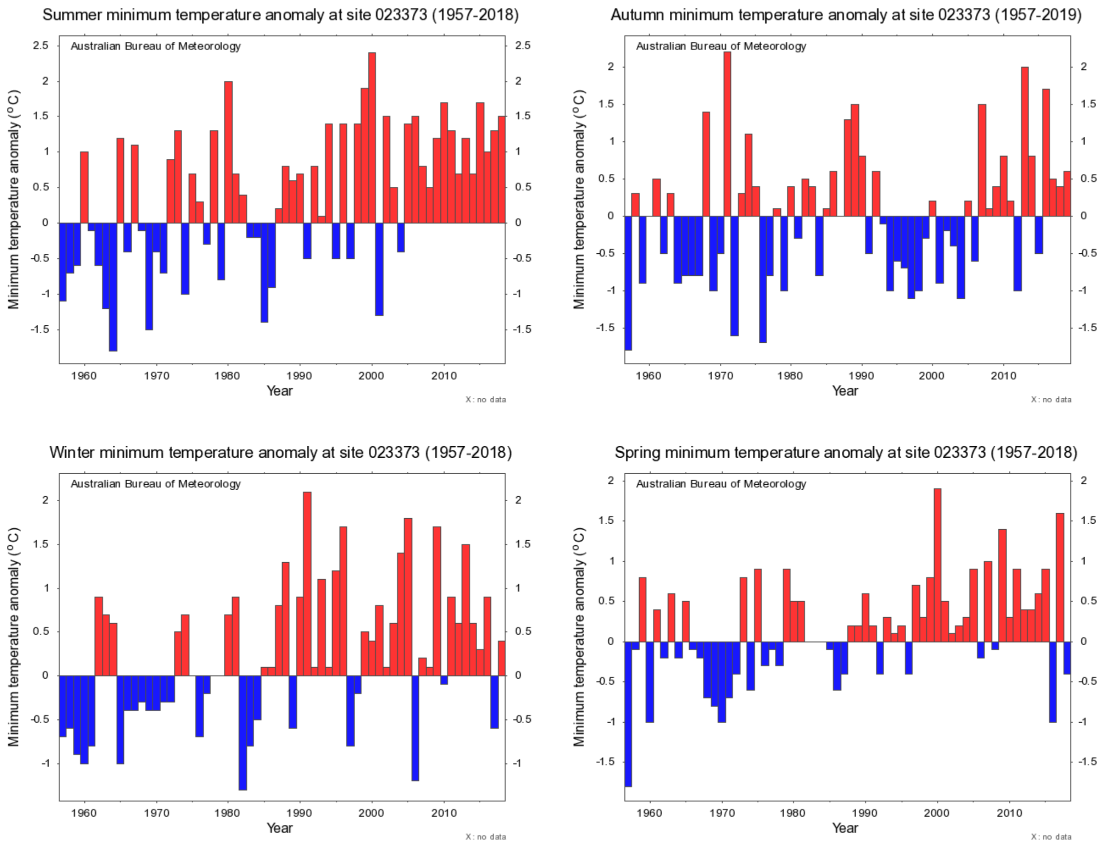

Figure 3-3: Minimum temperature anomalies at Nuriootpa from 1957-2018 for summer (top left), autumn (top right), winter (bottom left) and spring (bottom right).

Background climatology of frost in the Mid North

Frost is common in the Mid North district of South Australia between late autumn and early spring. The Bureau of Meteorology climatology of potential frost days around Australia [12], based on a minimum temperature of less than 2 °C, shows some areas of the Mid North may experience more than 30 nights per year of frost (Figure 3-4).

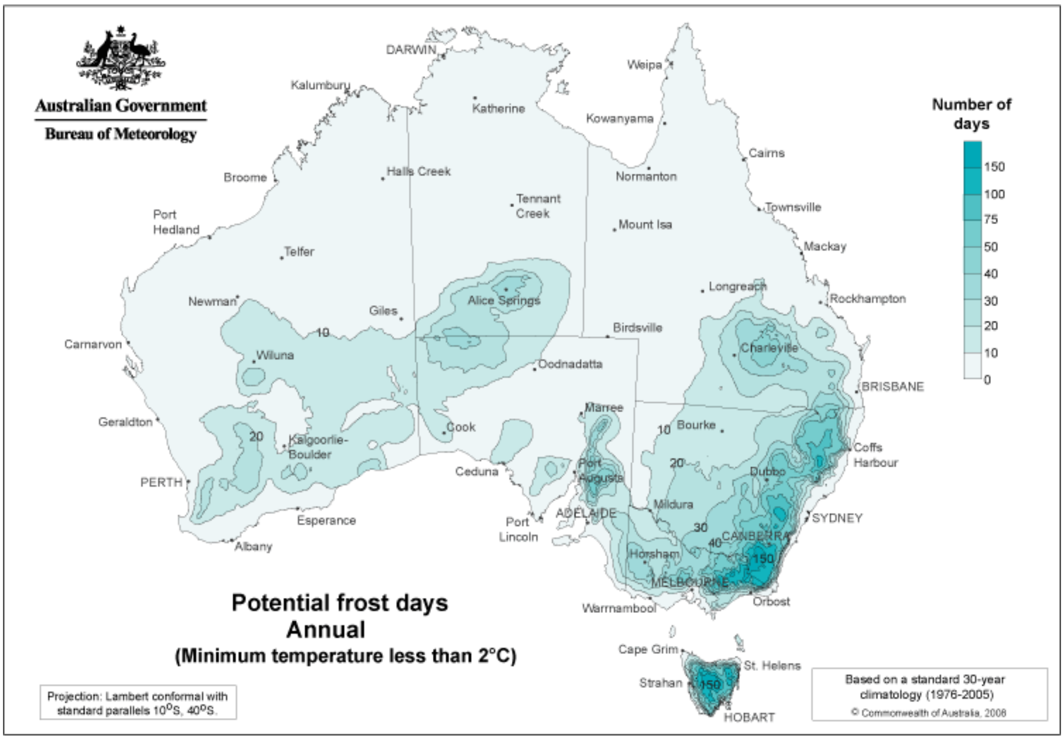

Figure 3-4: The average number of days per year with a minimum temperature below 2 °C as an indicator for potential frost days during the 30-year period 1976-2005 [12].

Frost climatology at Snowtown, Nuriootpa, Yongala and Eudunda

Figure 3-5 shows the annual number of frost days at Snowtown between 1958 and 2018. The average number of frost days per year at Snowtown between 1958 and 2018 was 31.5, but ranged from a minimum[2] of 15 in both 1988 and 2000 and maximum of 57 in 2006. The majority of frost days occurred in late winter and early spring with 7.9 frost days on average in August, 6.7 in September, 6.1 in July and 5.4 in June. There were also 2.7 frost days on average in October, 2.1 in May, and less than 1 day in both April and November (Figure 3-6, Table 3-1).

Nuriootpa (Figure 3-7) averaged 30.6 frost days per year from 1958 to 2018, with a minimum of 10 in 1988 and a maximum of 57 in 1959. The majority of frost days occurred in the winter months with 8.0 frost days on average in July, 7.5 in June and 6.5 in August. There was also on average 3.4 frost days in May, 3.1 in September, 1.2 in October and less than 1 in both April and November (Figure 3-8).

[2] For all stations, some years had a significant number of days where no data was available, so years which had 10 days or more missing were excluded when determining the lowest number of frost days per year

At Yongala the average number of frost days per year from 1958 to 2018 is greater than the other locations analysed at 64.1, with a minimum of 42 in both 1988 and 2009, and a maximum of 94 in both 1976 and 1994 (Figure 3-9). The majority of frost days also occurred in the winter months with 14.0 frost days on average in July, 13.0 in August and 12.5 in June. There was also on average 9.1 frost days in September, 7.9 in May, 4.4 in October, 2.3 in April and less than 1 in November (Figure 3-10). It is likely that this region experiences more frost days because of the higher elevation.

At Eudunda the average number of frost days per year from 1965 to 2018 was much less than the other locations analysed at just 9.7, with a minimum of 0 in 1988 and a maximum of 35 in 1997 (Figure 3-11). As with the other locations, other than Snowtown, the majority of frost days also occurred in winter with 2.9 frost days on average in July, 2.6 in August and 2.2 in June. There was also on average 1.1 frost day in September, and less than 1 day in both October and May (Figure 3-12). It is likely that the siting, in a relatively enclosed yard within the town, contributes to higher minimum temperatures being observed there than in rural environments. The local topography is also a factor, as Eudunda is on a slope elevated above the plains to the east, whereas the other sites are in relatively flat terrain.

Table 3-1: The average monthly and annual number of frost days at Snowtown, Nuriootpa, and Yongala 1958-2018 and Eudunda 1965-2018.

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Snowtown[3]	0	0	0	0.4	2.1	5.1	6.1	7.9	6.7	2.7	0.4	0	31.5
Nuriootpa[4]	0	0	0	0.5	3.4	7.5	8.0	6.5	3.1	1.2	0.3	0	30.6
Yongala[5]	0	0	0.1	2.3	7.9	12.5	14.0	13.0	9.1	4.4	0.9	0	64.1
Eudunda[6]	0	0	0	0	0.4	2.2	2.9	2.6	1.1	0.4	0	0	9.7

[3] From ACORN-SAT data
[4] From ACORN-SAT data
[5] Uncorrected observations
[6] Uncorrected observations

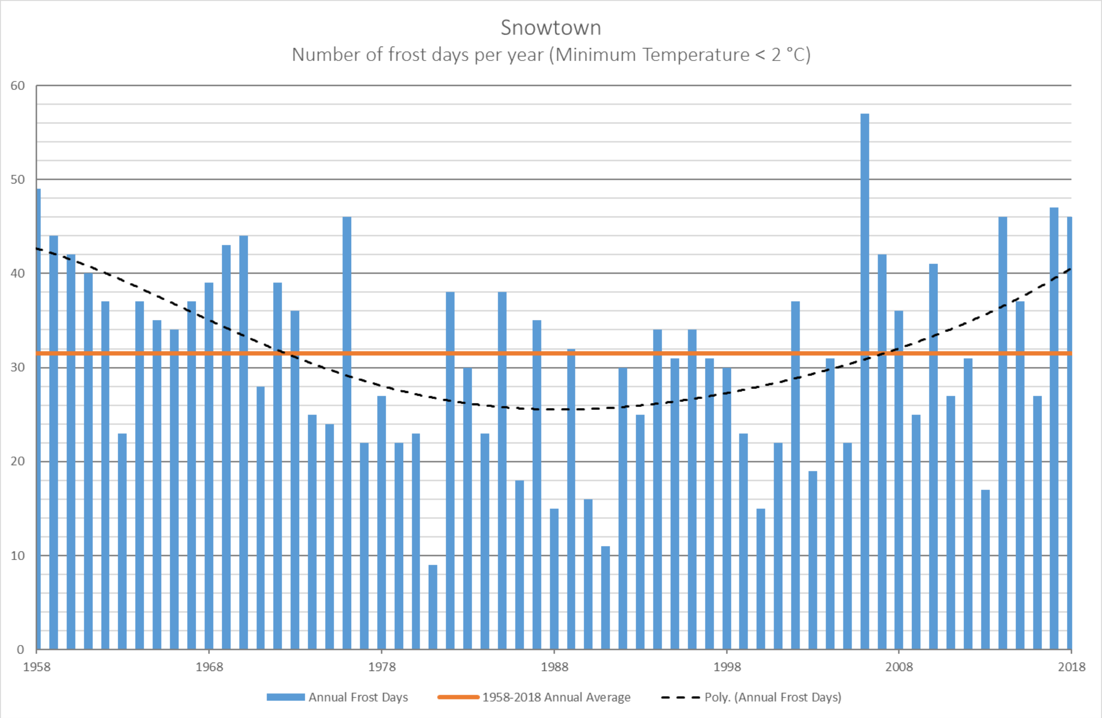

Figure 3-5: The number of frost days per year at Snowtown from 1958 to 2018 (blue), along with the average (orange), and a 5th order polynomial trend line (black dashed line).

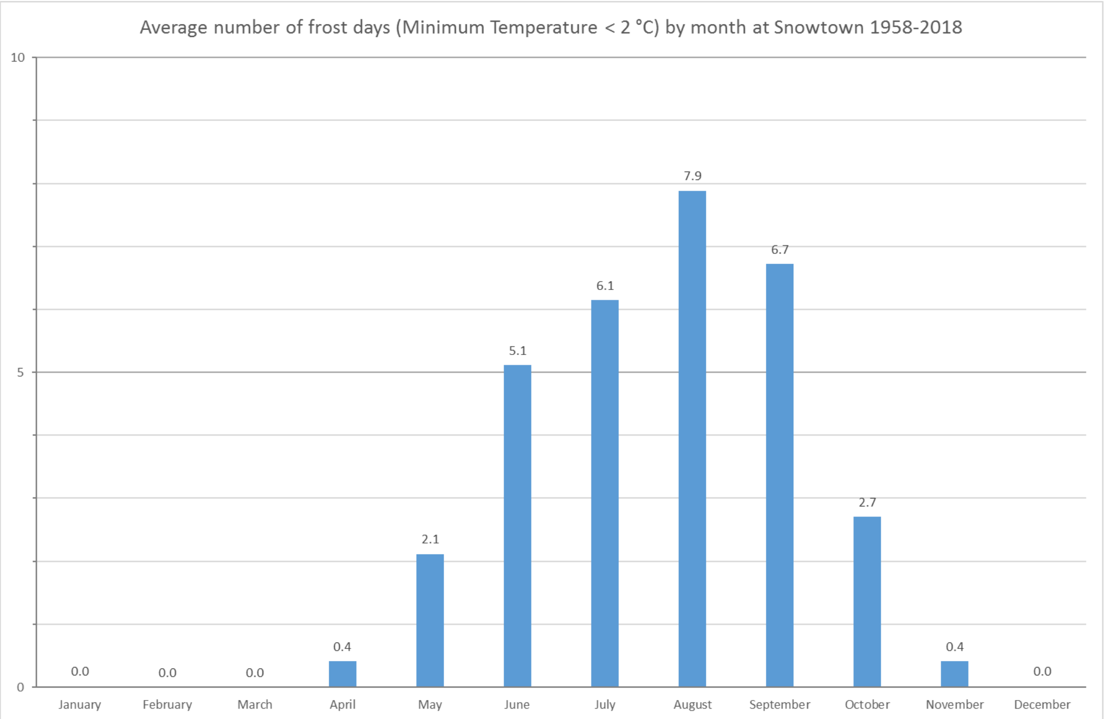

Figure 3-6: Average number of frost days per month at Snowtown 1958-2018.

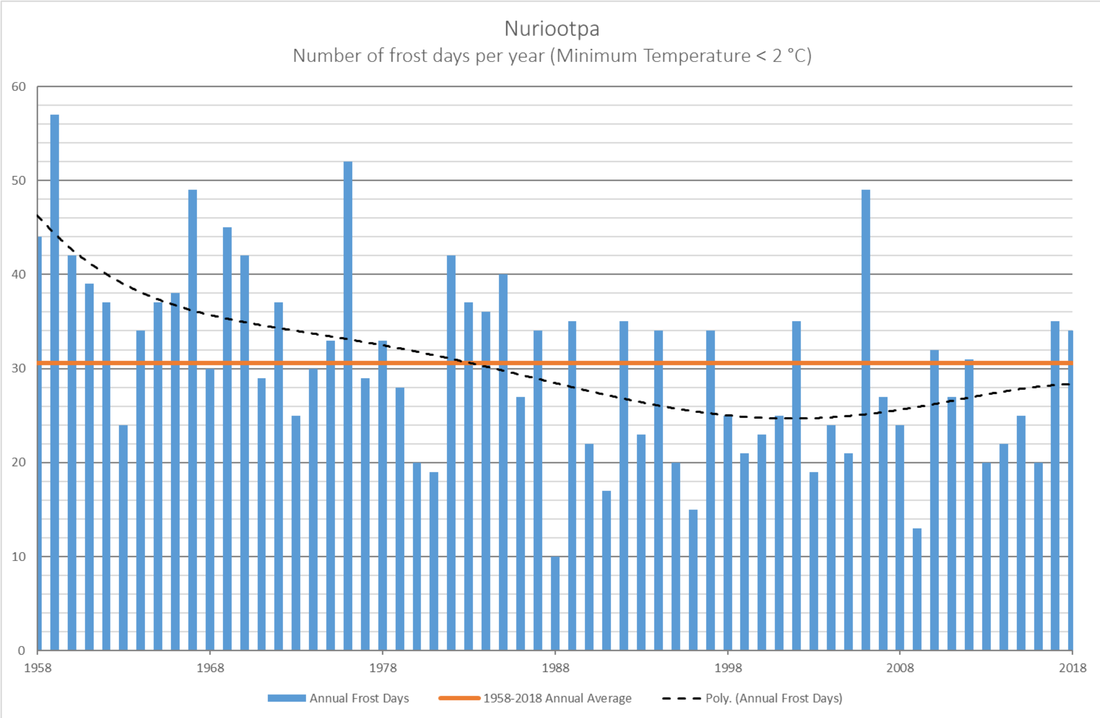

Figure 3-7: The number of frost days per year at Nuriootpa from 1958 to 2018 (blue), along with the average (orange), and a 5th order polynomial trend line (black dashed line).

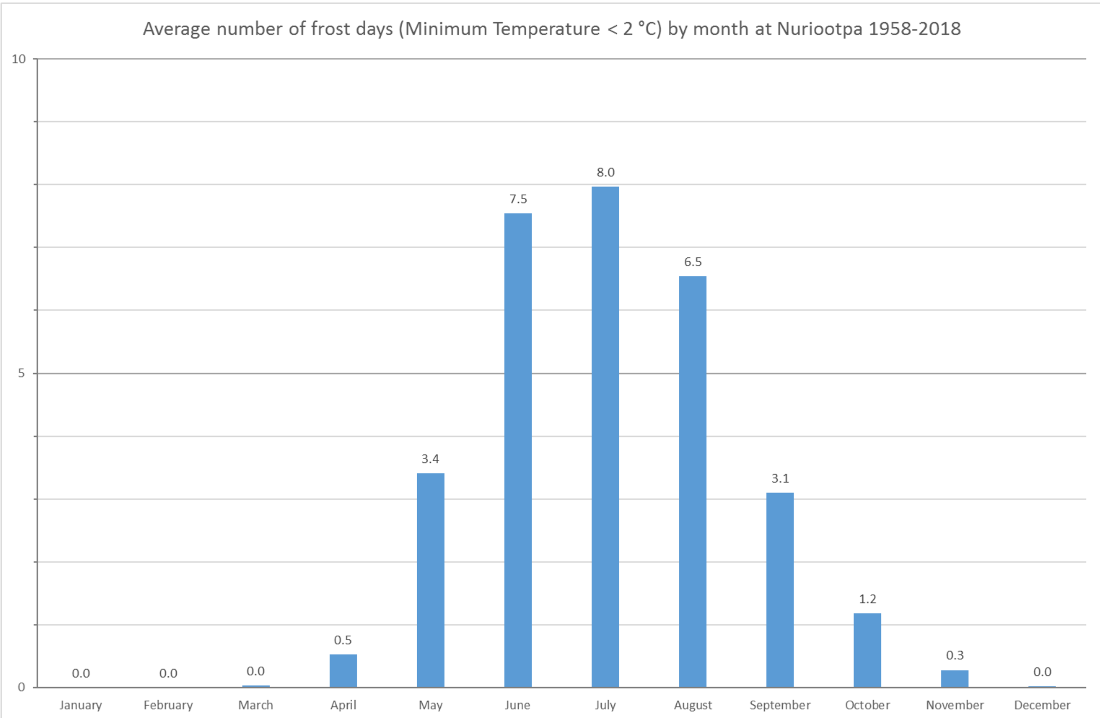

Figure 3-8: Average number of frost days per month at Nuriootpa 1958-2018.

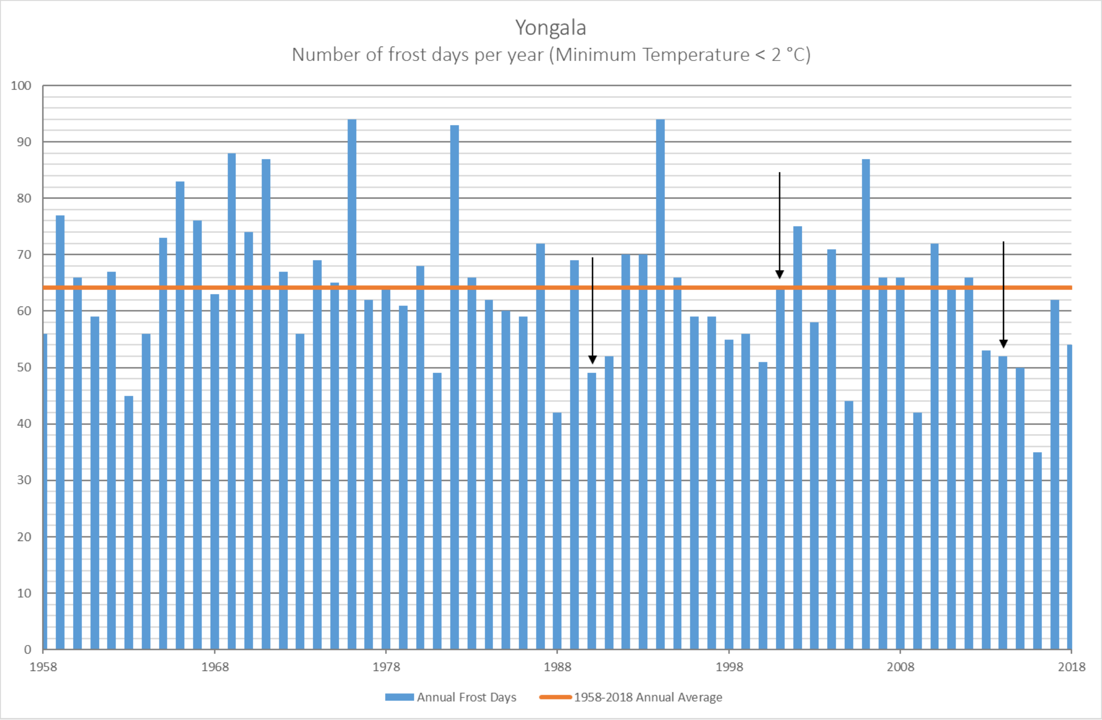

Figure 3-9: The number of frost days per year at Yongala from 1958 to 2018 (blue), along with the average (orange). Note that site changes occurred in 1990, 2001 and 2014, as shown by the black arrows, with the last move taking it outside the town boundary.

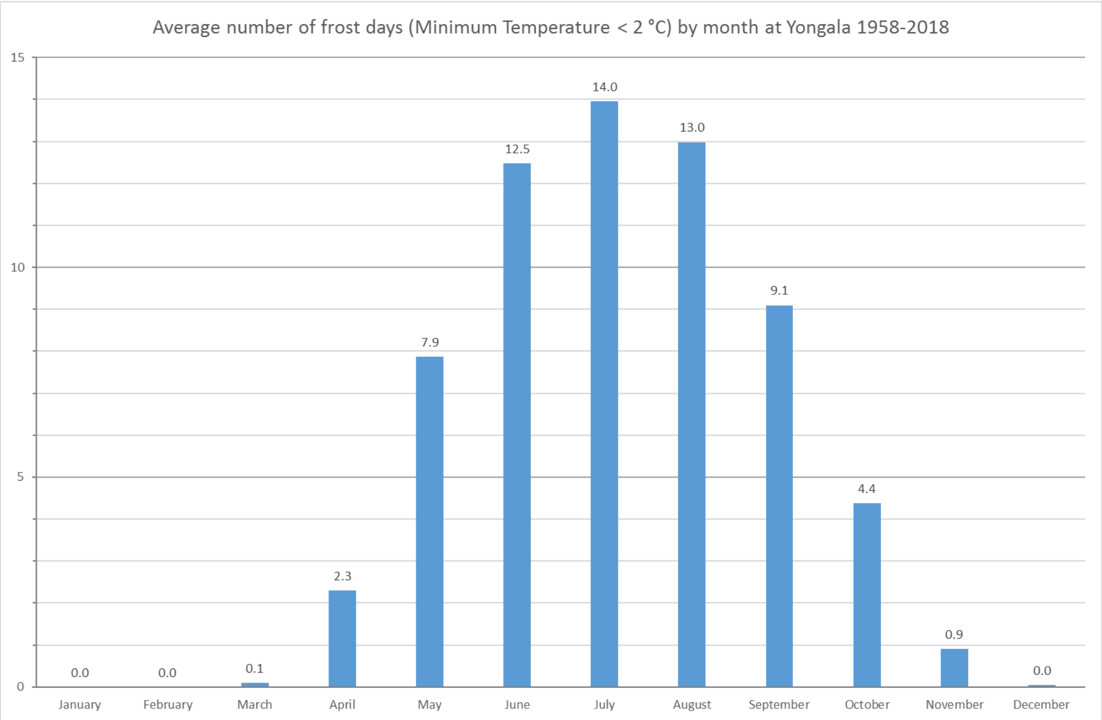

Figure 3-10: Average number of frost days per month at Yongala 1958-2018.

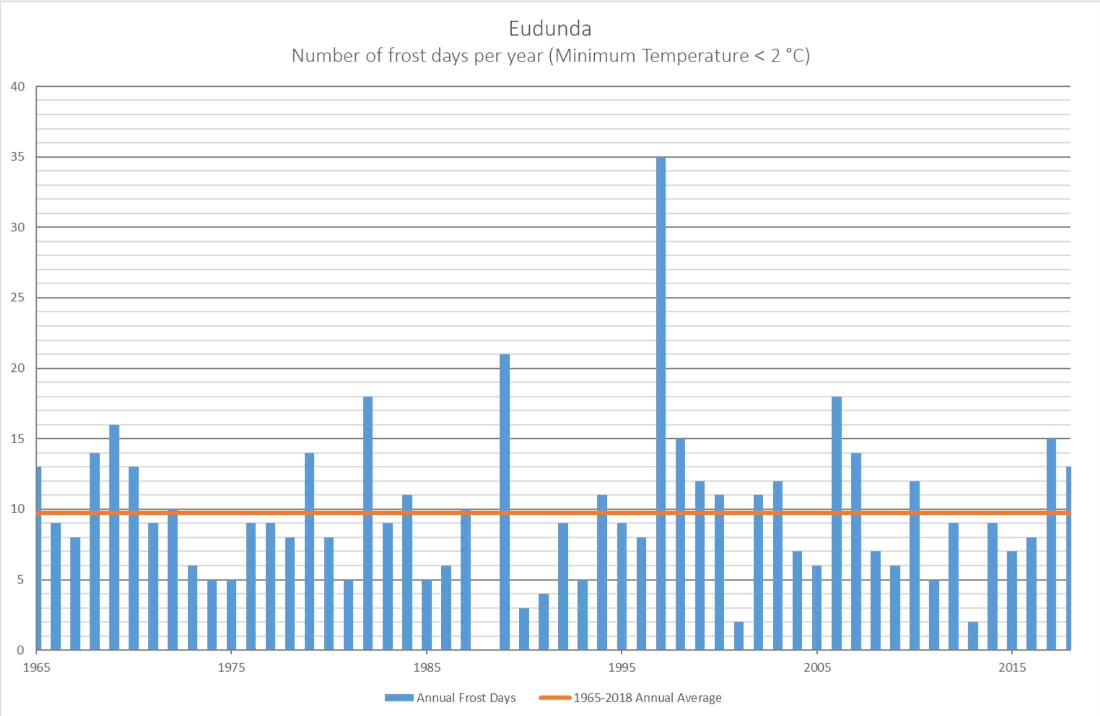

Figure 3-11: The number of frost days per year at Eudunda from 1965 to 2018 (blue), along with the average (orange).

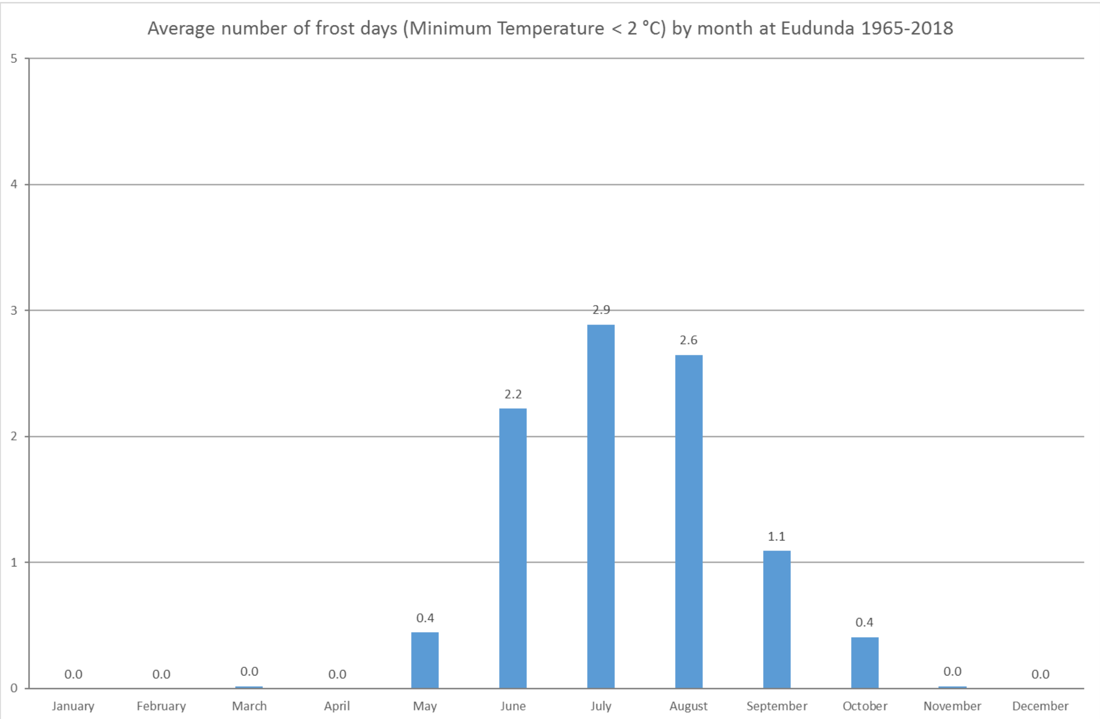

Figure 3-12: Average number of frost days per month at Eudunda 1965-2018.

From Figure 3-7, it can be see that at Nuriootpa there is a decrease in the average number of frost days per year over time, with fewer years with above average number of frost days occurring in the second half of the dataset. The average number of frost days between 1958 and 1987 was 35.6, but between 1988 and 2018 the average decreased by around 27% to 25.7 frost days per year (Table 3-2). This is consistent with the expectations of a warming atmosphere and the increase in warmer than average temperatures shown in Figure 3-3. The decrease in frost days was most apparent in June and July (Figure 3-13), but May and September also show significant decreases in frost days. The number of frost days during August, however, actually increased slightly.

The average number of frost days per year at Snowtown also decreased, but not as significantly as at Nuriootpa. The average number of frost days per year at Snowtown from 1958 and 1987 was 32.9, and this decreased by around 8% to 30.2 between 1988 and 2018 (Table 3-2). Decreases in frost days occurred in April, June, July and September, but as occurred at Nuriootpa also the number of frost days in August increased (Figure 3-14).

There was also a decrease in the average number of frost days per year at Yongala between 1958-1987 and 1988-2018, decreasing by around 11% from 67.9 to 60.4 frost days per year. In contrast to the other station, the average number of frost days per year increased by around 3% at Eudunda, from 9.6 frost days per year between 1965 and 1988 to 9.9 between 1988 and 2018.

Table 3-2: The average annual number of frost days at Snowtown, Nuriootpa, and Yongala and Eudunda 1958-1987 and 1988-2018.

	Average Frost Days 1958-1987	Average Frost Days 1988-2018	Difference	%
Snowtown	32.9	30.2	- 2.7	↓ 8.1
Nuriootpa	35.6	25.7	- 9.9	↓ 27.8
Yongala	67.9	60.4	- 7.5	↓ 11.0
Eudunda[7]	9.6	9.9	+ 0.3	↑ 3.2

[7] Average for Eudunda 1965-1987 and 1988-2018

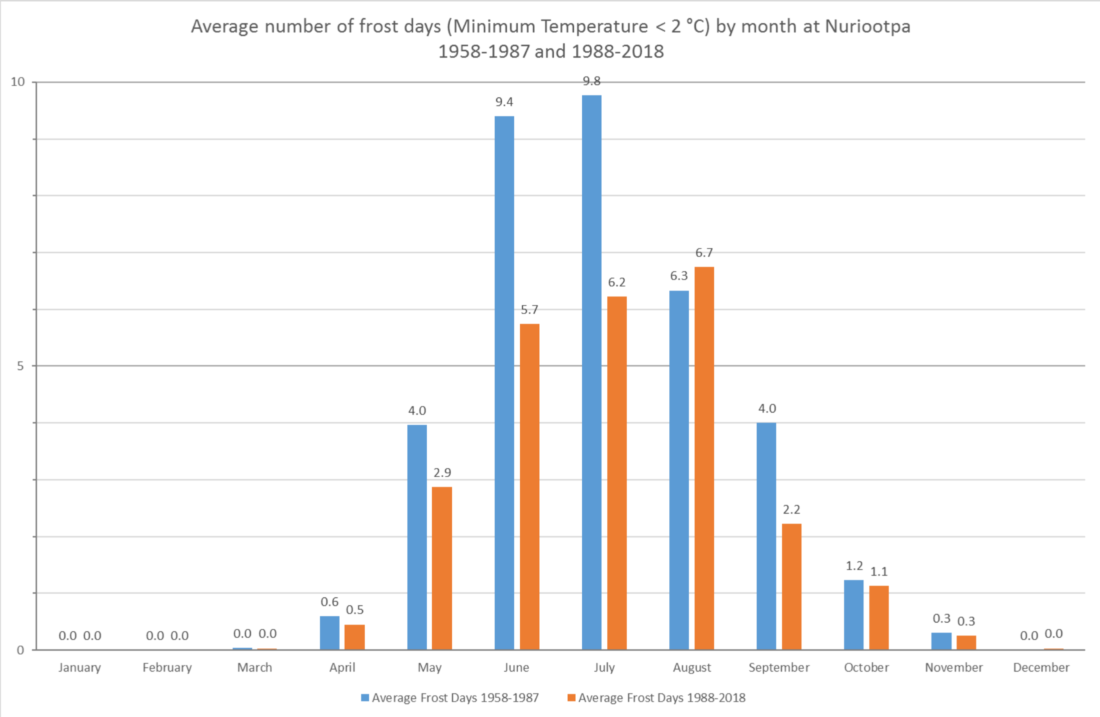

Figure 3-13: Average number of frost days per month at Nuriootpa 1958-1987 and 1988-2018.

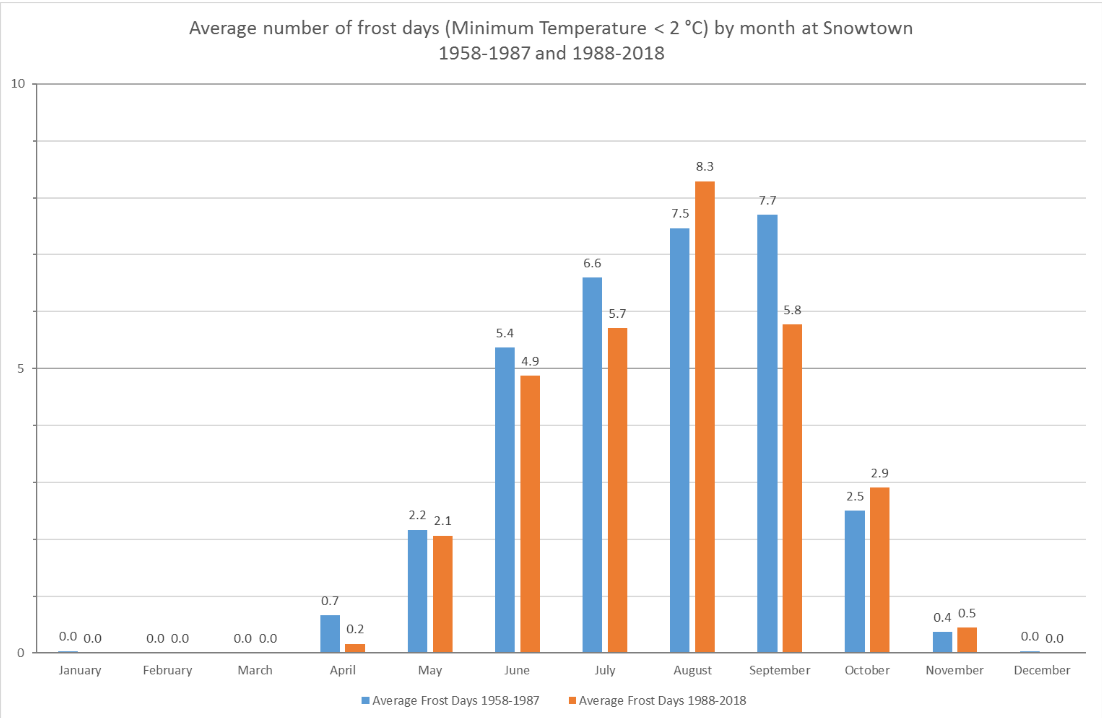

Figure 3-14: Average number of frost days per month at Snowtown 1958-1987 and 1988-2018.

4. Discussion

Frost is a common feature in the Mid North district of South Australia, and the region has been described as one of the high frost risk areas of southern Australia [6]. Most frost days, observed minimum temperatures of less than 2 °C, occurred during winter but they were also common in late autumn and early spring.

The average annual number of frost days varies significantly across the region, from just 9.7 at Eudunda, 30.6 at Nuriootpa, 31.5 at Snowtown and 64.1 at Yongala. There is also considerable variation between years, with the annual number of frost days varying from 15 to 57 at Snowtown, from 10 to 57 at Nuriootpa, from 42 to 94 at Yongala and from 0 to 35 at Eudunda. The seasonal patterns of frost also vary between locations, with Snowtown observing a greater proportion of frost days in September than the other locations.

The minimum temperature data presented here from Snowtown, Nuriootpa, and Yongala all showed a decrease in the annual number of frost days between 1958-1987 and 1988-2018, consistent with the expectations from a warming atmosphere. In contrast there was a very slight increase in the number of frost days per year at Eudunda between 1965-1987 and 1988-2018, albeit from a smaller number of frost days.

Trends at Nuriootpa also show that after a period of decreasing frost days between about 1960 and 1998, there has been a period since when the annual number of frost days has stabilised (Figure 3-7). At Snowtown, a decreasing trend occurred between about 1960 and 1991, but since then there has been an increasing trend in annual frost days (Figure 3-5).

The differences across the region could be due to many factors, including the altitude and local topography, the rainfall and cloud cover climatology of the location, and the local environment such as soil type and vegetation.

There are a number of factors that could lead to variations in minimum temperatures and the number of frost days over time. These include changes in rainfall, moisture, cloud cover, wind speeds and temperature driven by inter-annual climate variability and large-scale climate influences such as El Nino [13], the Southern Annular Mode (SAM) [14], the Indian Ocean Dipole [15], and the background warming from anthropogenic climate change.

A positive phase SAM during winter, where westerly winds and cold fronts are further south than normal, has been shown to be linked to decreased rainfall and a decrease in minimum temperatures in southern Australia [16]. Likewise it has been shown that the strength and latitude of the subtropical ridge can influence minimum temperatures in southeast Australia, with a strong ridge during May to August linked to cooler mean minimum temperatures and increased frequency of cold nights [17].

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Surace, Jessie (DPTI)

From:	Wyatt, Sharon (DPTI)
Sent:	Friday, 8 November 2019 2:30 PM
To:	Surace, Jessie (DPTI)
Subject:	FW: Query re: solar farms and requirement for AS 2067:2016 fencing around entire site

From: Frank Halman [mailto:Frank.Halman@sapowernetworks.com.au]
Sent: Thursday, 8 August 2019 9:12 AM
To: Wyatt, Sharon (DPTI) <Sharon.Wyatt@sa.gov.au>
Subject: RE: Query re: solar farms and requirement for AS 2067:2016 fencing around entire site

Hi Sharon

Yes that is correct, around entire Solar Farm.
Stock Fence would not be suitable from what has been presented to me.

regards, Frank

Frank Halman
Network Project Manager – Strategic Projects
SA Power Networks

Direct: 08 8404 4703
Mobile: 0418 143 927

From: Wyatt, Sharon (DPTI) <Sharon.Wyatt@sa.gov.au>
Sent: Thursday, 8 August 2019 9:03 AM
To: Frank Halman <Frank.Halman@sapowernetworks.com.au>
Subject: RE: Query re: solar farms and requirement for AS 2067:2016 fencing around entire site

Thanks Frank.

So just to confirm, so I can be clear going back to the SCAP – AS2067 standard fencing must be applied around the entire site (i.e. including the panels) not just the substation and connection area. Is this correct?
I ask as I know the SCAP are leaning towards 1.8m stock fencing around the site perimeter (not the substation) and if my interpretation is correct that AS2067 fencing is required around the entire site, this type of fencing would not meet the AS.

Many Thanks
Sharon

From: Frank Halman [mailto:Frank.Halman@sapowernetworks.com.au]
Sent: Thursday, 8 August 2019 7:44 AM
To: Wyatt, Sharon (DPTI) <Sharon.Wyatt@sa.gov.au>
Subject: RE: Query re: solar farms and requirement for AS 2067:2016 fencing around entire site

Good morning Sharon

Apologies for time to get back to you, I wanted to make certain I covered all bases here first.

The formal response I received from our Technical standards Group is as follows:

Hi Frank,

In short, they need to comply to AS2067. Please see below the scope of AS2067:

5 AS 2067:2016

STANDARDS AUSTRALIA

Australian Standard

Substations and high voltage installations exceeding 1 kV a.c.

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard provides minimum requirements for the design and erection of high voltage installations in systems with nominal voltages above 1 kV a.c. and nominal frequency up to and including 60 Hz, so as to provide safety and proper functioning for the use intended.

For the purposes of this Standard, a high voltage installation is considered to be:

(a) An electricity network substation, under the control of an electricity network operator or entity authorized by a licence or other legal instrument to convey electricity.

(b) The high voltage parts of an electrical installation of a power station including all auxiliary systems and interconnecting lines and cables between power stations if on the same site.

(c) Electrical installations built at offshore platforms, e.g. offshore wind power farms.

(d) The high voltage parts of an electrical installation that are not covered in (a) or (b) above. This may include but not be limited to consumer and customer electrical installations serving premises such as factories, commercial facilities, industrial plants, institutional facilities and mine sites.

Section 5.2 talks about fencing:

5.2 OUTDOOR INSTALLATIONS OF OPEN DESIGN

5.2.1 General

The layout of open type outdoor installations shall take into account the minimum phase-to-phase and phase-to-earth clearances given in Tables 3.1 and 3.2.

The design of the installation shall be such as to restrict access to danger zones, taking into account the need for operational and maintenance access. External fences shall therefore be provided and, where safety distances cannot be maintained, permanent protective facilities shall be installed. For electrical installations on a mast, pole or tower, external fences may not be required if the installation is inaccessible from ground level to the general public and meets the safety distances given in Clause 5.7.

I have had this confirmed as a requirement from 2 other sources within the business.

I know there are different styles of fencing that can be utilised also, not personally being able to name those however.

Please let me know if you do have further questions regarding this.

kind regards, Frank

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SA Power Networks

From: Wyatt, Sharon (DPTI) <Sharon.Wyatt@sa.gov.au>
Sent: Wednesday, 31 July 2019 3:21 PM
To: Frank Halman <Frank.Halman@sapowernetworks.com.au>
Subject: Query re: solar farms and requirement for AS 2067:2016 fencing around entire site

Hi Frank

As discussed, we have received an application for a solar farm that include a comment that the solar farm must meet AS 2067 regarding the standard of fencing around the entire site for public safety purposes.

As part of its consideration of this application the State Commission Assessment Panel (SCAP) notes that AS 2067 standard fencing is required for 'substations and high voltage installations exceeding 1kV a.c.'. The SCAP is wanting clarification as to if the panels and associated cabling would be considered to be 1kV a.c or does this relate to the substation infrastructure only. The question is raised as this particular solar farm is proposed in a more prominent tourist area and will be surrounded by cropping agricultural land that is fenced with more standard stock fencing/ If not required by the AS the SCAP will consider conditioning for a different type of fencing more suited to the area.

Fundamentally the question is what parts of a solar farm would be considered to exceed 1kV a.c.?

Any assistance to answer this would be greatly appreciated.

Kind regards
Sharon

Sharon Wyatt
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