HERITAGE ASSESSMENT REPORT

NAME:	Nelly Creek Fossil Flora Complex	**PLACE:**	26546

ADDRESS: Arabana Country
South of Kati Thanda (Lake Eyre South),
Oodnadatta Track, Callanna SA, 5733
CL6178/960, Outside of Hundreds

This heritage assessment considers that the place meets criteria (b) and (c). Refer to Summary of State Heritage Place for final approved wording, including criteria statements.

Palynologist N. Alley collecting fossil leaves and pollen samples, Eyre Formation, Nelly Creek carbonaceous clay lens beneath slightly silicified sandstone, channel deposits.

Source: Government of South Australia. Department of State Development. Report Book, 90/00015

ASSESSMENT OF HERITAGE SIGNIFICANCE

STATEMENT OF HERITAGE SIGNIFICANCE

The Nelly Creek Fossil Flora Complex comprises seven fossil sites containing numerous palaeobotanical fossils (leaves, wood and pollen) dating from the Eocene Epoch (~56–33 Million years ago (Ma)). The Nelly Creek site is considered to be Middle-Late Eocene in age and includes many mummified fossil leaf assemblages that are rarely found elsewhere in South Australia. The combination of mummified fossil leaves and its central Australian locality differentiates Nelly Creek from all other South Australian fossil sites.

The species preserved in the fossils at the site expand the known range of extinct and extant native plant species, with many not found anywhere else within the State. Additionally, the anatomy of the preserved flora differs greatly from those found at other South Australian fossil sites and appears to denote a transitional period in climate not shown in any other fossil assemblages in the State. As such, the place can be considered of State and National interest.

The Nelly Creek Fossil Flora Complex is also highly likely to yield information that will build knowledge of Eocene environments within South Australia, including climate change and the aridification of the State.

STATEMENT OF PALAEONTOLOGICAL DESIGNATION

Nelly Creek Fossil Flora Complex is a palaeochannel located South of Kati-Thanda Lake Eyre. It is a rare and outstanding Eocene Fossil Flora assemblage (~56-33 Ma) dating from the Middle-Late Eocene. Although the channel runs for over 13 km, the significant fossil localities are found within a ~7 km stretch as defined by the State Heritage Place boundary. Nelly Creek Fossil Flora Complex contains seven separate sites that have yielded examples of fossil flora in the form of leaves, pollen and wood.

The complex depicts a preserved environment no longer found today in modern South Australia. The site contains a mix of dry-adapted flora, such as a possible early eucalyptus[1], to wet rainforest indicators such as Dacrydium. The impressive preservation of the site also makes it an outstanding example of fossil flora within South Australia. The fossil plants are predominantly preserved as 'mummified' specimens in which the organic material of the leaf is preserved rather than replaced by rocks and minerals. This is an exceptionally unusual form of preservation, found in only one other fossil site in South Australia.

The site is also the type locality for at least six plant species, and is expected to yield more type specimens with further research. Examples of type specimens include *Dianellophyllum eocenicum* with features resembling those in the extant genus *Dianella* (flax lilies). Two other examples of *Dacrydium* (Conifers) were also identified from the site. These conifers are the earliest examples of the genus within South-Eastern to Central Australia.

Nelly Creek Fossil Flora Complex has the potential to reveal significant new information about South Australian plant species and climate change through further detailed research. Numerous palaeobotanists believe that the site has great research potential due to its geographical location and the exceptional preservation of collected material. Designation of the fossil site will help to protect the site, enabling much-needed further research and increased understanding of the ancient fossil flora of South Australia.

The significant palaeontological features contained within the complex are:

- Seven Middle-Eocene fossil sites with abundant fossil flora

- Extremely well-preserved mummified and silicified fossil floras in the form of leaves, wood and pollen
- Type locality for at least six species of plants
- Eyre Formation directly overlying the Winton Formation, providing unique geological information
- An extensive assemblage that with further research can contribute to the unravelling of the natural evolution of the State

Relevant South Australian Historical Themes

1. Natural Environment

    1.1 Tracing climatic and topographical change

    1.2 Tracing the evolution of plants and animals

Comparability / Rarity / Representation:

The *Fossil Heritage Survey for South Australia* (2021) identified over 800 fossil sites in South Australia. Nelly Creek was categorised as a notable site and high priority for assessment due to its age (Eocene) and the quality and rarity of its plant fossils.

Of the 800 fossil sites identified in the survey, 73 contain deposits of fossil flora (botanical fossils) of varying quality, including fossils of preserved leaves, seeds and pollen. Botanical fossils, are rarer than animal fossils due to the decomposition process. Hard, largely mineral-based material such as bones are more readily preserved than soft, organic material like leaves.

Of the 800 fossil sites, only 33 are from the Eocene Epoch. The Eocene was a time of change with warm temperatures resulting in the majority of the country being covered in rainforest-like vegetation.

Within the State, only four fossil sites contain well-preserved examples of fossil flora from the Eocene, including type specimens. Type specimens are the fossil(s) that when discovered are used to describe a species and are regarded by the scientific community as the baseline for identification of the species. These sites being:

- Maslin Bay to Aldinga Bay Coastal Cliff Section Geological Site, Maslin Beach (SHP 14040), Middle Eocene,
- Nelly Creek Fossil Flora Complex (subject of this assessment), Middle-Late Eocene,[2]).
- Poole Creek Fossil Flora, Cenozoic

Each of these sites contains rare examples of high quality specimens of Eocene Fossil Flora. However, Nelly Creek contains specimens that are not found anywhere else within South Australia.

The unique assemblage so far collected from the Nelly Creek Fossil Flora Complex creates plentiful opportunity for further research. The size of leaves collected to date are disproportionately small in comparison to sites of a similar age. This could indicate a warmer environment, though it is also believed that this evidence could be a result

of biased collection[3]. Large leaved fossils such as Dacrydium, regarded as rainforest indicators, have also been found at the fossil site.

Similarly, examples of the species Myrtaceae differs from other sites with potential for some specimens to be found as an early form of Eucalyptus[4]. Additionally, specific flora families such as Podocarpaceae and Proteaceae from Nelly Creek Fossil Flora Complex are rarely found at other Eocene sites. Most notable, perhaps, is the lack of Lauraceae, a common rainforest family. Of the 169 plant specimens thus far described from Nelly Creek, only one was identified as Lauraceae. However, Lauraceae makes up a relatively large portion of the assemblage at all other Eocene fossil sites within Australia.[5]

The leaf specimens found at Nelly Creek Fossil Flora Complex are perplexing to the scientific community and require further research to reveal information about the complex plant life and enable investigation into what that means for climatic conditions at the time of deposition. As a result, the place is of high scientific importance to not only South Australia but also globally.

A comparative analysis using a number of variables was undertaken in the *Fossil Heritage Survey for South Australia* to ascertain the importance of each of the 800 fossil sites. The findings from the survey are briefly explained here for the four Eocene fossil flora sites.

Age and Fossil Type

Nelly Creek Fossil Flora Complex is an exceptional Eocene fossil site that ranges in the Middle-Late Eocene (~38-33Ma).

Maslin Bay to Aldinga Bay Coastal Cliff Section Geological Site (SHP 14040) is the closest in age to the Nelly Creek Fossil Flora Complex,[6] however, the two sites are distant from each other and contain different fossil flora,[7] including pollen specimens.

There is also reasonable evidence to suggest that Poole Creek Fossil Flora Complex is Middle Eocene in age[8], however, recent research has proposed that the site maybe Middle to Late Eocene in age[9], nevertheless, the site contains different fossil flora to Nelly Creek and no pollen or mummified specimens.

Condition, Integrity and Importance of Specimens

The Nelly Creek Fossil Flora Complex is regarded as a 'fragile' site, best accessed when there is no water running through the palaeochannel.[10] The complex is highly regarded in the scientific community, as the fossils located there have a high level of preservation and the site also contains examples of extremely rare mummified fossil leaves.

In comparison to compressed fossils, mummified fossils:

- Present a high level of clearness that is not impacted by the grain size of the matrix,

- Allow both sides of the specimen to be examined, and
- Enable cuticle analysis, resulting in more precise species identification.

Nelly Creek also contains pollen that is used to correlate the age of fossil sites, for example, in comparison to pollen found at the Maslin Bay to Aldinga Bay Coastal Cliff Section Geological Site (SHP 14040) or those without pollen such as Poole Creek Fossil Flora.

Nelly Creek is the recognised type locality of numerous fossil plant specimens. Examples of type specimens found at Nelly Creek Fossil Flora Complex include but are not limited to:

- *Myrtaciphyllum eremeaensis*, a new species identified from the site[11]
- *Dianellophyllum eocenicum*, the only known species of the *Dianellophyllum* form genus worldwide,[12]
- *Dacrydium mucronatus, and*
- *Dacrydium fimbriatus*[13].

In comparison to the other Eocene fossil flora sites in South Australia, Nelly Creek is highly important due to the nature of the plant assemblage found there. The protection of Nelly Creek Fossil Flora Complex will enable scientists to better understand the State's past climate.[14]

The fossil flora sites at Maslin Bay contain specimens that could be correlated with a rainforest-type environment. 40-54% of the leaves at these sites are referred to as notophyll, that is, they have leaves with a leaf size of 2,025–4,500 square millimetres.[15] In contrast, only 20% of the (so far collected) Nelly Creek fossil flora are these sizes. The remaining 80% of the Nelly Creek flora are smaller and are known as microphyll. Microphyll are plants that are often associated with sclerophyllous environments (adapted to dry environments and heat).[16]

These results would suggest that Nelly Creek Fossil Flora's fossil assemblage differs greatly from those around the State. However, researchers are doubtful of this[17], blaming collection biases, in which researchers selectively choose samples instead of randomly. Therefore, despite the aforementioned results, the environment at Nelly Creek cannot be fully understood with the current research completed there. Instead, the abundant leaf fossils still present at the site likely hold great importance in determining the environment of the past, making them highly significant.

The Nelly Creek Fossil Flora assemblage is likely to provide numerous answers to significant palaeobotanical questions about South Australia and the Eocene environment. In tandem with other fossil flora sites information can be used to more accurately identify and define our understanding of the palaeoclimate at the time of deposition.

Potential for Further Research

Nelly Creek offers substantial potential for further research. Due to its remote location, it has been less researched than other similar fossil sites. So far, 269 fossil leaves

representing 16 taxa have been discovered. Palaeobotanists consider the site is highly likely to yield many more fossils. Fossils are known to be routinely revealed during seasonal rain events.

Assessment against Criteria under Section 16 of the *Heritage Places Act 1993*. All Criteria have been assessed using the 2020 Guidelines.

(a) it demonstrates important aspects of the evolution or pattern of the State's history.

Criterion arguments have considered the *Guidelines for State Heritage Places*:

> *The place should be closely associated with events, developments or cultural phases which have played a significant part in South Australian history. Ideally it should demonstrate those associations in its fabric.*
>
> *Places will not normally be considered under this criterion if they are of a class of things that are commonplace, or frequently replicated across the State, places associated with events of interest only to a small number of people, places associated with developments of little significance, or places only reputed to have been the scene of an event which has left no trace or which lacks substantial evidence.*

The Nelly Creek Fossil Flora Complex demonstrates important aspects of the State's natural history, including representing several periods of evolution. However, the place not only demonstrates this significance, but also has considerable potential to demonstrate many more aspects of our history, which means it could be said to meet both criterion (a) and criterion (c) for similar reasons.

Criterion (a) focuses on the 'State's history'. The first test asks which 'historic theme' is demonstrated by the place. In this case, the theme is 'natural history'. However, criterion (c) talks about the 'history, including its natural history'. Given that the Nelly Creek Fossil Flora Complex is considered to meet criterion (c) because of its significant associations with natural history as well as its *potential* to demonstrate important aspects of our natural history, it seems more relevant to consider the place meets (c) because of its historical significance and potential, rather than meeting criterion (a) using a similar argument.

It is recommended that the nominated place **does not fulfil** criterion (a).

(b) it has rare, uncommon or endangered qualities that are of cultural significance.

Criterion arguments have considered the *Guidelines for State Heritage Places*:

> *The place should demonstrate a way of life, social custom, industrial process or land use which is no longer practised, is in danger of being lost, or is of exceptional interest. This encompasses both places which were always rare, and places which have become scarce through subsequent loss or destruction.*
>
> *Places will not normally be considered under this criterion if their rarity is merely local, or if they appear rare only because research has not been done elsewhere, or if their distinguishing*

characteristics have been degraded or compromised, or if they are at present common and simply believed to be in danger of becoming rare in the future.

The Burra Charter states: "Cultural significance means aesthetic, historic, scientific, social or spiritual value for past, present or future generations," and is embodied within the fabric of the place.

In the case of the Nelly Creek Fossil Flora Complex, its cultural significance lies in its considerable scientific value, in particular through its remarkable fossil record, the types of fossils found in the complex, their age, the quality of preservation, and the species represented. The complex contains rare fossils that contribute to an understanding of the evolution of the State over a geological time period, including recording climate variance from the Middle Eocene to the modern day.

The Nelly Creek Fossil Flora Complex contains mummified leaves. This form of preservation is both rare and scientifically significant. Of the 800 fossil sites identified in the *Fossil Heritage Survey for South Australia* (2021), only two contain mummified leaves including Nelly Creek. These fossils require very specific conditions to be successfully preserved and are therefore both rare and highly sought after. The complex has been recognised for yielding exceptionally high quality data about the flora (see Comparison/ Rarity/ Representation).

Nelly Creek is one of 33 Eocene fossil sites identified in South Australia, only 13 of which have fossilised plants in varying states of preservation. Compared with other Eocene fossil flora sites in South Australia, only one other site contains a similar, high level of preservation of fossil specimens.

Despite the relatively low level of research completed at Nelly Creek in comparison to more accessible sites, Nelly Creek has been identified as the type location for at least six fossil plant specimens, including two species of *Dacrydium*. Given the high level of preservation and high potential for more finds, the scientific community anticipates identifying further type specimens at the Nelly Creek Fossil Flora Complex.

In addition to individual species of note, Nelly Creek contains a fossil assemblage that could provide unique insights into the natural history of South Australia. The fossils at Nelly Creek, including several unique species, demonstrate an assemblage that could provide extensive knowledge if given the opportunity for in-depth research. The scientific importance of the site could not be replaced if lost and for this reason it is identified as rare. Overall, the complex is considered to have great potential to make an exceptional contribution to our understanding of climatic change during the Eocene period.

Thus, the fossil assemblage at Nelly Creek has a number of rare qualities that are considered to be of scientific and cultural significance to South Australia.

It is recommended that the nominated place **fulfils** criterion (b).

(c) it may yield information that will contribute to an understanding of the State's history, including its natural history.

Criterion arguments have considered the *Guidelines for State Heritage Places*:

> *The place should provide, or demonstrate a likelihood of providing, information that will contribute significantly to our knowledge of the past. The information should be inherent in the fabric of the place. The place may be a standing structure, an archaeological deposit or a geological site.*
>
> *Places will not normally be considered under this criterion simply because they are believed to contain archaeological or palaeontological deposits. There must be good reasons to suppose the site is of value for research, and that useful information will emerge. A place that will yield the same information as many other places, or information that could be obtained as readily from documentary sources, may not be eligible.*

The Nelly Creek Fossil Flora Complex has yielded many fossils in the past and is considered by palaeobotanists to be highly likely to continue to yield numerous fossils in the future. The mummified leaves present at Nelly Creek record plant families, genus and species. The specimens can provide vital information to help understand the climate, environment and ecological interactions that occurred from the Middle–Late Eocene, just prior to the beginning of the aridification of South Australia approximately 15Ma.

Nelly Creek's mummified fossils provide detailed and precise information about species through the quality of cuticle preservation. The site also contains abundant pollen fossils, enabling detailed reconstruction of the palaeoenvironment. The abundance and condition of the pollen enables the identification of the age, diversity and history of the site.

While some investigation and research has occurred at Nelly Creek, the site remains understudied. Thus far, 16 specimens have been positively identified at Nelly Creek, including at least six type specimens. Palaeobotanists anticipate the site is highly likely to yield many further examples.

The fossils at Nelly Creek have an extremely high quality of preservation, with many remaining in excellent condition. Palaeobotanists also anticipate that Nelly Creek Fossil Flora Complex is highly likely to contain further high quality specimens in excellent condition. Consequently, the complex has high potential to yield information that will contribute to building our understanding of the vegetation, climate and environment of central South Australia. In particular, the site is likely to yield meaningful information about past environmental conditions and the impact of climate change on vegetation during the Eocene.

Nelly Creek Fossil Flora Complex is the only fossil assemblage to contain mummified and silicified specimens of Eocene age in central Australia. The geographical location is unique. This combined with the high quality of the fossil assemblage and high potential for research, means that Nelly Creek has and will continue to greatly contribute to our understanding of the State's natural history.

It is recommended that the nominated place **fulfils** criterion (c).

(d) it is an outstanding representative of a particular class of places of cultural significance.

Criterion arguments have considered the *Guidelines for State Heritage Places*:

> *The place should be capable of providing understanding of the category of places which it represents. It should be typical of a wider range of such places, and in a good state of integrity, that is, still faithfully presenting its historical message.*
>
> *Places will not be considered simply because they are members of a class, they must be both notable examples and well-preserved. Places will be excluded if their characteristics do not clearly typify the class, or if they were very like many other places, or if their representative qualities had been degraded or lost. However, places will not be excluded from the Register merely because other similar places are included.*

The Nelly Creek Fossil Flora Complex can be considered to be a member of a number of classes of place. Broadly speaking, it is a scientific site or a fossil site, both of which could be considered to be of cultural significance. More specifically, it is a plant fossil site and/or an 'Eocene plant fossil site'.

In the context of South Australia, Nelly Creek Fossil Flora Complex is considered a pivotal and notable example of an 'Eocene fossil flora site' or even a 'Fossil flora site'. However, as these sub-classes only occur rarely in South Australia, and there are not a wide range of such places against which to compare, the class of place is not considered to be of cultural significance.

With regard to the broader class of fossil sites, Nelly Creek has a number of features worth considering. However, two factors reduce its ability to meet this criterion.

Firstly, most of the notable characteristics of the fossil site are rare rather than 'typical of a wider range of such places'. For this reason, the place is considered to meet criterion (b) to a high degree, rather than criterion (d).

Secondly, although the Nelly Creek Fossil Flora Complex has already produced a number of fossils with high preservation and intactness, the vast majority of the site has not yet been investigated. So far, 269 fossils and 16 taxa have been initially described from Nelly Creek – in comparison, more than 2,000[18] fossils have been recorded at Maslin Bay.

Although Nelly Creek is believed to have considerable potential for yielding well-preserved and significant finds, further research should be completed and a fuller understanding of the site recorded before the site can be considered to be an outstanding representative of a fossil site.

Therefore, criterion (d) is not yet considered to be met. The potential of the site to yield vital information about the State has been explored under criteria (b) and (c) and the recommendation is to list the site under those criteria.

It is recommended that the nominated place **does not fulfil** criterion (d).

(e) it demonstrates a high degree of creative, aesthetic or technical accomplishment or is an outstanding representative of particular construction techniques or design characteristics.

Criterion arguments have considered the *Guidelines for State Heritage Places*:

> *The place should show qualities of innovation or departure, beauty or formal design, or represent a new achievement of its times. Breakthroughs in technology or new developments in design would qualify, if the place clearly shows them. A high standard of design skill and originality is expected.*
>
> *Places would not normally be considered under this criterion if their degree of achievement could not be demonstrated, or where their integrity was diminished so that the achievement, while documented, was no longer apparent in the place, or simply because they were the work of a designer who demonstrated innovation elsewhere.*

This criterion relates to the human-made qualities of a place. As the Nelly Creek Fossil Flora Complex is a natural site, it is not considered to demonstrate a high degree of aesthetic, creative or technical accomplishment nor is it an outstanding representative of particular construction techniques or design characteristics.

It is recommended that the nominated place **does not fulfil** criterion (e).

(f) it has strong cultural or spiritual association for the community or a group within it.

Criterion arguments have considered the *Guidelines for State Heritage Places*:

> *The place should be one which the community or a significant cultural group have held in high regard for an extended period. This must be much stronger than people's normal attachment to their surroundings. The association may in some instances be in folklore rather than in reality.*
>
> *Places will not be considered if their associations are commonplace by nature, or of recent origin, or recognised by a small number of people, or not held very strongly, or held by a group not widely recognised, or cannot be demonstrated satisfactorily to others.*

The Nelly Creek Fossil Flora Complex is located within the Arabana People's Native Title Determination and is approximately 700 metres south of Kati-Thanda (Lake Eyre South). Kati-Thanda (Lake Eyre) is a highly significant place for the Arabana People, however, it is recommended that Arabana cultural knowledge and spiritual attachment to Kati-Thanda and surrounding areas is more appropriately recognised by the Arabana People under the provisions of the *Aboriginal Heritage Act 1986*.

Additionally, while the site is of importance to the scientific community, particularly palaeobotanists, a connection to small communities of researchers does not resonate with the wider South Australian community and is not considered to be sufficient for the site to meet the criterion.

It is recommended that the nominated place **does not fulfil** criterion (f).

(g) it has a special association with the life or work of a person or organisation or an event of historical importance.

Criterion arguments have considered the *Guidelines for State Heritage Places*:

> *The place must have a close association with a person or group which played a significant part in past events, and that association should be demonstrated in the fabric of the place. The product of a creative person, or the workplace of a person whose contribution was in industry, would be more closely associated with the person's work than would his or her home. Most people are associated with many places in their lifetime, and it must be demonstrated why one place is more significant than others.*
>
> *Places will not generally be considered under this criterion if they have only brief, incidental or distant association, or if they are associated with persons or groups of little significance, or if they are associated with an event which has left no trace, or if a similar association could be claimed for many places, or if the association cannot be demonstrated. Generally the home or the grave of a notable person will not be entered in the Register unless it has some distinctive attribute, or there is no other physical evidence of the person's life or career in existence.*

The Nelly Creek Fossil Flora Complex is not considered to have a special association with any person, organisation or event of State significance.

Perhaps the person most associated with the site is Dr Neville Alley, a palynologist who spent much of his career studying pollen and other microscopic organic material. Dr Alley has undertaken many explorations and searches for fossil flora material throughout South Australia and the world. However, as the complex is one of many sites he investigated, there is no evidence of a stronger association or attachment with Nelly Creek than other places he has worked.

It is recommended that the nominated place **does not fulfil** criterion (g).

PHYSICAL DESCRIPTION

Nelly Creek Fossil Flora Complex is located approximately 55km North-West of Marree in central Australia.[19] The fossil assemblages begin just under 1km South of Kati Thanda (Lake Eyre South) and continues for approximately seven kilometres along the width of the creek bed. At least one assemblage has been identified 400m west from a small bow in the palaeochannel.

The site is made up predominantly of clay, sands, silts and silcretes in which the compressed and mummified fossils are found. A number of nearby bore holes have also yielded fossilised material outside of the creek bed itself. The most notable fossil sites have been included within the proposed State Heritage Place.

Elements of Significance:

Elements of heritage significance include (but are not necessarily limited to):

- Seven fossil site 'hotspots' (identified on site plan) over seven km along a seasonal riverbed which is richly fossiliferous.

- Area containing high abundance and diversity of fossil flora specimens that are highly palaeontologically and scientifically significant
- Additional fossil sites not yet fully identified but located with bore hole sampling
- Taphonomically unique mummified, well-preserved fossil leaf specimens
- Carbonaceous and/or silicified and compressed wood, leaves and pollen
- Type locality for at least six ancient rainforest plant species

Elements not considered to contribute to significance of the place include (but are not necessarily limited to):

- Built tracks, walkways and signage

HISTORY

Geological Time (Dates approximate)

During the Jurassic, approximately ~199-145Ma, Australia began separating from Gondwana and started its northward movement towards the equator. Before this northward movement, the majority of the Australian continent experienced light summers and dark winters and was covered in vegetation comprised of large evergreen trees.[20]

Between ~150 and ~100 Ma the environment was largely fluvial (rivers) and/or lacustrine (lakes). However, from approximately 138-97.5Ma, Nelly Creek was under marine conditions. After this period, the seas regressed, allowing for the terrestrial environments seen today.

At ~70 Ma, the climate was believed to be uniformly humid. During the Palaeocene and Early-Eocene (~66- 50 Million years ago), the environment within central Australia was 'warm temperate with seasonally high precipitation'.[21] Mean annual temperatures were 18-19 degrees Celsius and rainfall approximately 1400 mm/year. The temperature and rainfall levels created ideal conditions for rainforest plants to grow, and such vegetation is reflected in the fossil record.

During the Middle Eocene, the age of the fossil flora preserved at Nelly Creek (subject of this assessment), the area was believed to be a river channel. The fossils found at Nelly creek reveal that sclerophyllous forest (forest adapted to long periods of dryness and heat) and mesophyll vines (those more often found in a rainforest) dominated at this time. This mix of environments indicates that the area potentially had a dry season (Sclerophyllous) and semi-deciduous monsoon-like forests (Mesophyll).[22] At this time, it is thought that the mean annual temperature was >20 degrees Celsius and the warm and strongly seasonal environment created distinct macroflora which are smaller than other Middle Eocene-aged floras. [23]

In central Australia, approximately ~60 Ma, there were believed to be large amounts of transient swamp-like land in the west and sandy alluvial fans common in the east. These would sporadically return until the Early Oligocene (~33 Ma).

By ~38 Ma (Middle Eocene), Tasmania and Antarctica finally separated, allowing the Antarctic Circumpolar current to form, causing cooling throughout the Antarctic and Australia.

It is during these continental and climatic changes that the Nelly Creek Fossil Flora Complex was deposited with leaves that were then preserved in clay and mummified. Mummification requires unusual preservation conditions to occur and results in a high level of preservation of the leaf cuticle, allowing for detailed analysis of the fossil

leaves at a higher resolution than those compressed in rock. Around the time of deposition at Nelly Creek, the environmental conditions were likely monsoonal in Central Australia[24]

Over time central Australia's lakes would periodically dry and return, allowing for sporadic survival of rainforests until the Late Miocene. Open grasslands came to dominate, with rainforests standing only close to water sources as an annual dry period developed. [25]

By ~20 Ma, while the North of Australia remained monsoonal and rainforest-like, the rest of the continent became drier and had more duricrusted (a hard soil layer produced through evaporation of water and precipitation of minerals, common in arid areas) ground surface. At this point, lakes were still common within the Australian outback.

At ~10 Ma, central Australia became increasingly arid, nearing modern levels of aridity[26]. South Australia had moved below the Tropic of Capricorn and within the latitudes that most often develop desert environments.

First Nations Interactions (overview)

The Arabana People have an ongoing association with Kati-Thanda (Lake Eyre) and surrounding areas. In the mid-1800s, the Arabana People were recorded as living to the south and west of Kati-Thanda (Lake Eyre) and may have camped at times near or at the Nelly Creek Fossil Flora Complex. At the time of this assessment, no sites of Aboriginal Heritage interest have yet been identified or recorded by the Arabana People in close proximity to the proposed Nelly Creek Fossil Flora Complex.

Scientific Investigation and Collecting

The site has a long history of scientific research. The first in-depth assessment of the fossil flora at Nelly Creek was conducted by Christophel *et al*. in 1992. The flora was dominated by an unidentified microphyllous flowering plant with unknown affinities and fossil records.[27]

Investigation of the fossil assemblage shows that the flora once living at Nelly Creek were well-adapted to drier environments. The preserved flora demonstrates evidence of sunken stomata (areas of the leaf where the leaf can intake O_2 and CO_2 and moisture), thick cuticles (protective layers of the leaf), and very few examples of epiphyllous fungi which requires high amounts of moisture to thrive.[28] All of these features are often associated with drier climatic conditions.

Numerous expeditions and six South Australian Resources Information Gateway (SARIG) collection expeditions have occurred since 1984, resulting in a body of research. A collection of fossils from the Nelly Creek Fossil Flora Complex are held in the Palaeobotany Collection, Botany Department, Adelaide University. Other collections are unknown.

The site was identified as one of South Australia's most important fossil sites (In combination with Poole and Stuarts creeks) by The Australian Heritage Council's 2006 publication *Australia's Fossil Heritage: A catalogue of important Australian fossil sites*. The sites were re-evaluated individually by Heritage South Australia's 2021 *Fossil Heritage Survey for South Australia*.

Chronology

Year	Event
~56Ma	Beginning of the Eocene Era & Palaeocene-Eocene Thermal Maximum
~38Ma	Middle-Late Eocene (Age of Fossil Site and Deposition) – Antarctica separates from Australia, Monsoonal conditions are common in central Australia
~30Ma	Tectonics altering environmental factors within Australia as the Continent Moves Northward
~15-5Ma	**Beginning of Central Australia's Aridification in earnest. Environment dried and plant assemblages changed greatly**
Pre-1836	Aboriginal People operate trade routes throughout the area
Post 1836	European arrival in the area
~1860	Nearby Marree Township Founded as Hergott Springs
1986	Area of fossil site discovered by Roger Callen
1992	**First paper published on the fossil flora[29] at Nelly Creek and the area is recognised as a site of great palaeontological interest**
1980-Present	Subsequent explorations
1994	**April. Recognised as a Geological Monument by the South Australian Division of the Geological Society of Australia[30]**
2006	**Included as part of 12 sites in Australian Heritage Council's *Australia's Fossil Heritage: A Catalogue of Important Australian Fossil Sites*[31]**
2021	Included as priority for assessment in *Fossil Heritage Survey for South Australia*.

References

Alley N & Hill, RS Personal Communication (2022)

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SITE DETAILS

NAME:	Nelly Creek Fossil Flora Complex	**PLACE NO.:**	26546

DESCRIPTION OF PLACE:	Eocene age fossil flora complex consisting of seven sites containing mummified fossil leaves, abundant fossilised pollen spores and fossil wood. The fossils can be found within a mostly dried palaeochannel that can be seasonally wet. The rock found in the area is silcrete, clay, sand and silts.	
REGISTER STATUS:	Provisional Entry: TBA	
CURRENT USE:	Creek Bed	
LOCAL GOVERNMENT AREA:	Out of Hundreds	
LOCATION:	**Town/Suburb:**	South of Kati Thanda (Lake Eyre South)
	Title Reference:	CL6178/960 D34847A2
	Plan No.:	34847
LAND DESCRIPTION:	**Hundred:**	Out of Hundreds
	Encumbrance:	Native Title Holder: Arabana Aboriginal Corporation RNTBC (Determination Date: 22 May 2012)
		Miscellaneous Crown Lease: CL6178/960 – Arabana Aboriginal Corporation RNTBC

PHOTOS

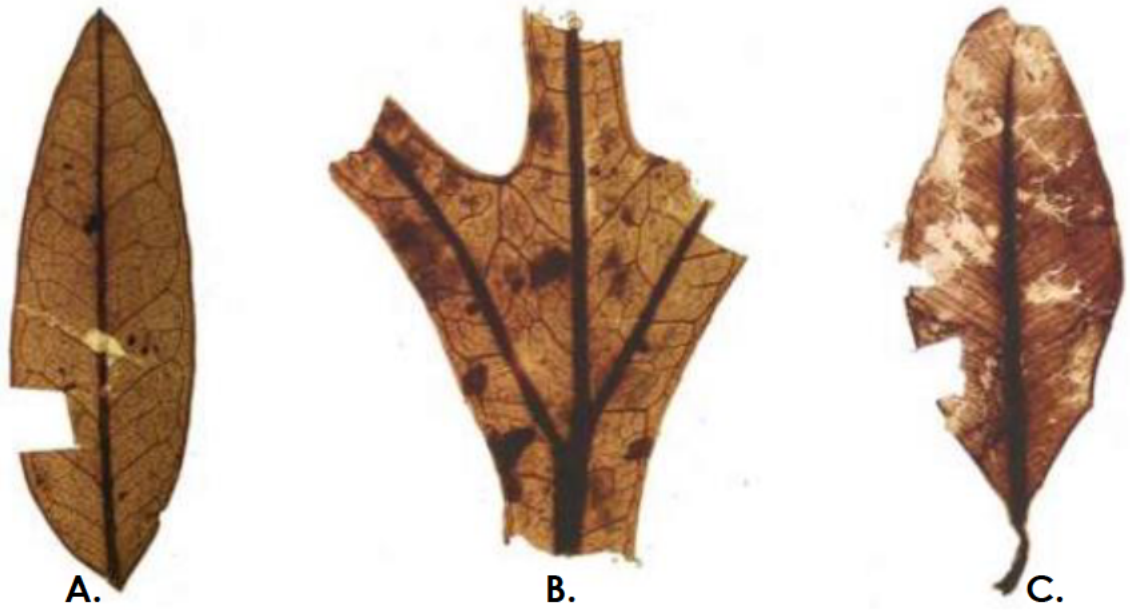
NAME:	Nelly Creek Fossil Flora Complex	**PLACE NO.:**	26546

Fossil Logs at the Nelly Creek Fossil Flora Complex with Geologist Graham Krieg in background.

Source: Photo 047115, Neville Alley, 1999

PHOTOS

NAME:	Nelly Creek Fossil Flora Complex	**PLACE NO.:**	26546



Fossil Leaf specimens collected at the Nelly Creek Fossil Flora Complex locality

A, B, C – "Fossil leaves extracted from Eyre Formation in Nelly Creek".

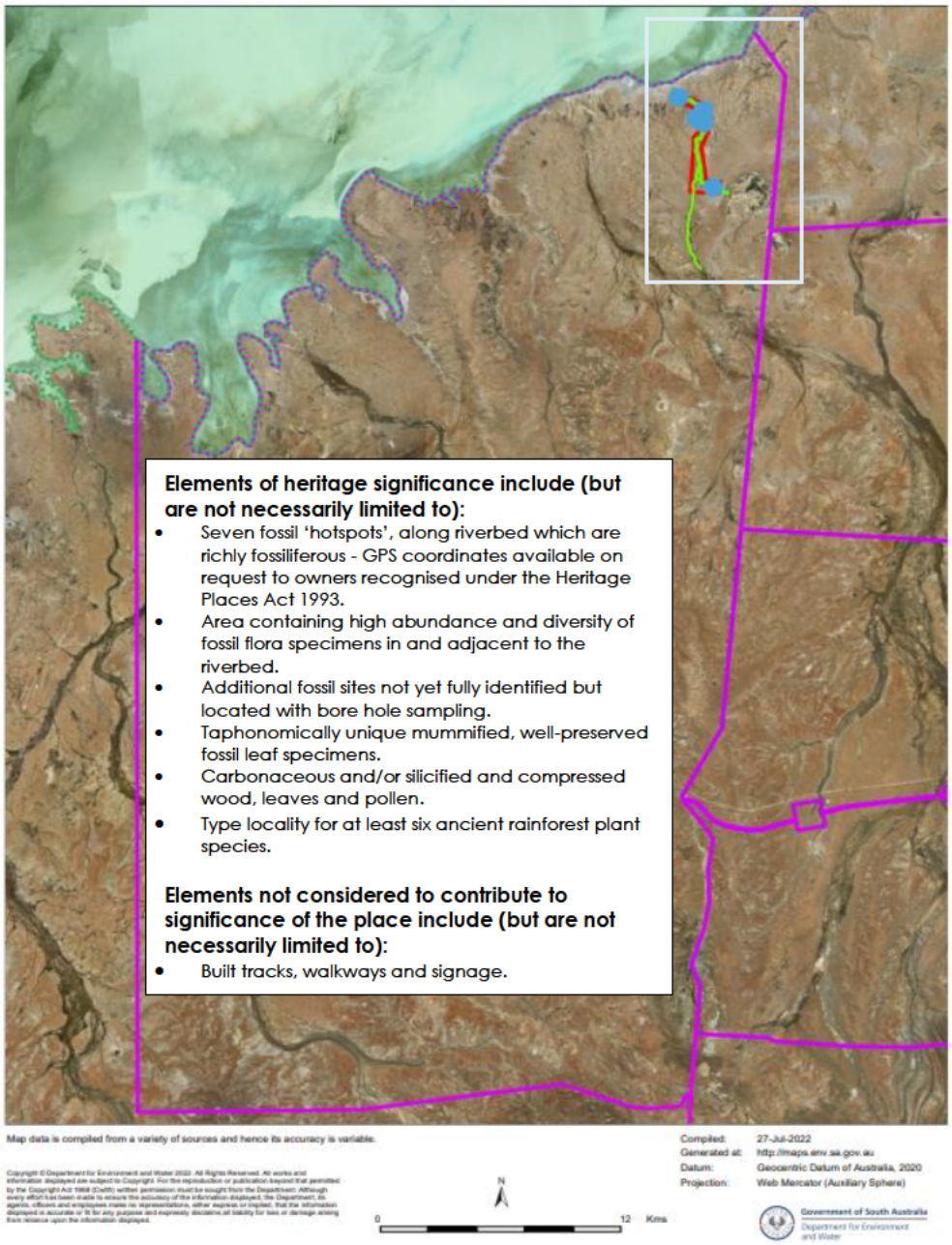
Source: Neville Alley 1999. A; Photo 047290 B; Photo 047288, C; Photo 047289

D – Carbonised leaf fossils in Eyre Formation, Nelly Creek.

Source: Callen, RA, 1986. Photo 039583.

SITE PLAN

NAME: Nelly Creek Fossil Flora Complex **PLACE NO.:** 26546



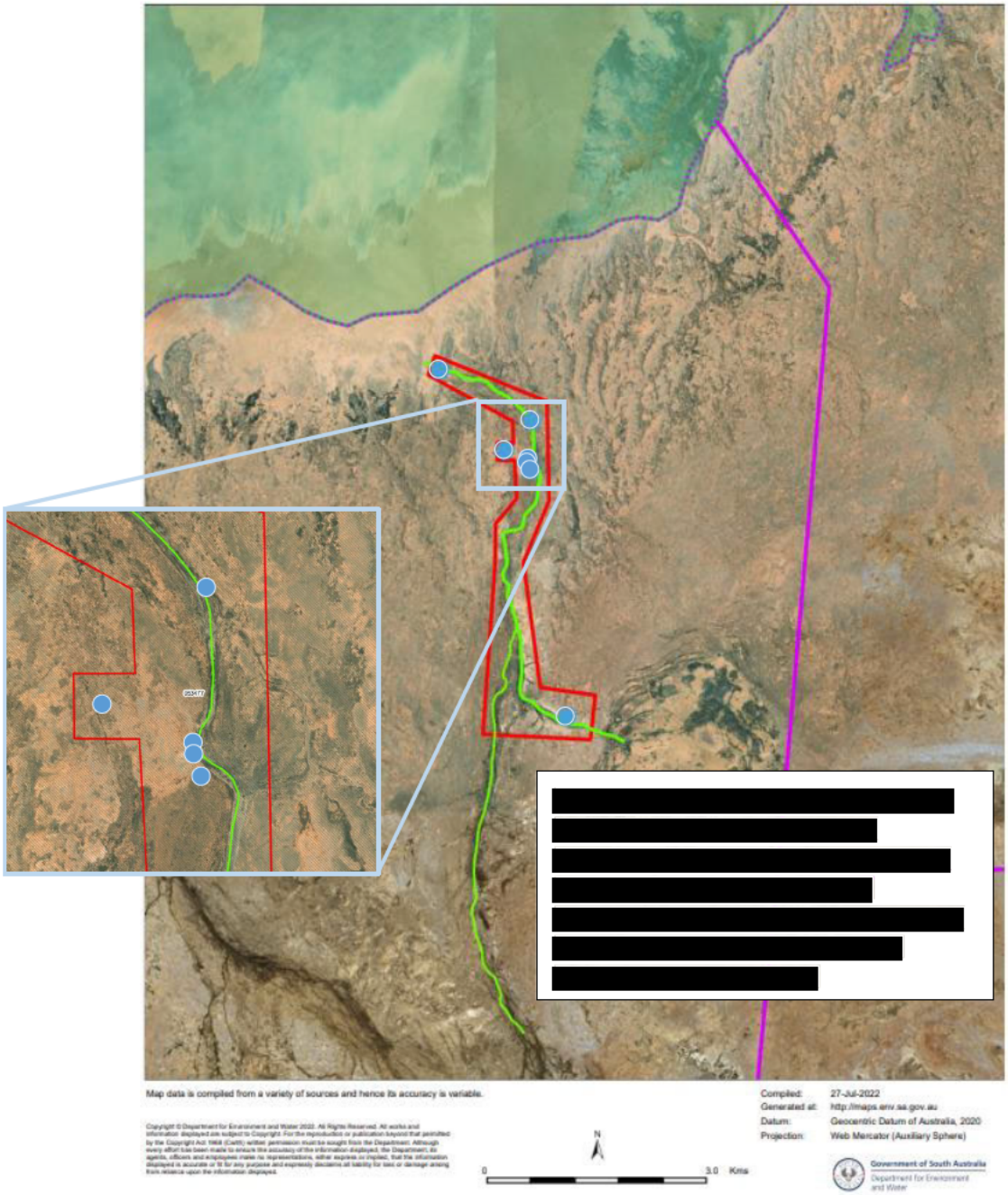
Nelly Creek Fossil Flora Complex, South of Kati Thanda (Lake Eyre South), Oodnadatta Track, Callanna SA 5733, CL6178/960, Outside of Hundreds.

LEGEND **N ↑**

- Parcel boundaries (Indicates extent of Listing)
- Hotspot Areas
- Palaeochannel Watercourse
- Outline of Elements of Significance for State Heritage Place
- Area of interest depicted in subsequent Site Plan

SITE PLAN - DETAIL

NAME: Nelly Creek Fossil Flora Complex **PLACE NO.:** 26546



Nelly Creek Fossil Flora Complex, South of Kati Thanda (Lake Eyre South), Oodnadatta Track, Callanna SA 5733. CL6178/960, Outside of Hundreds.

SHP Length: ~7km Creek Length: Entire: ~13.5km, Within SHP: ~8.5km

LEGEND **N ↑**

- Parcel boundaries (Indicates extent of Listing)
- Hotspot Areas
- Palaeochannel Watercourse
- Outline of Elements of Significance for State Heritage Place

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