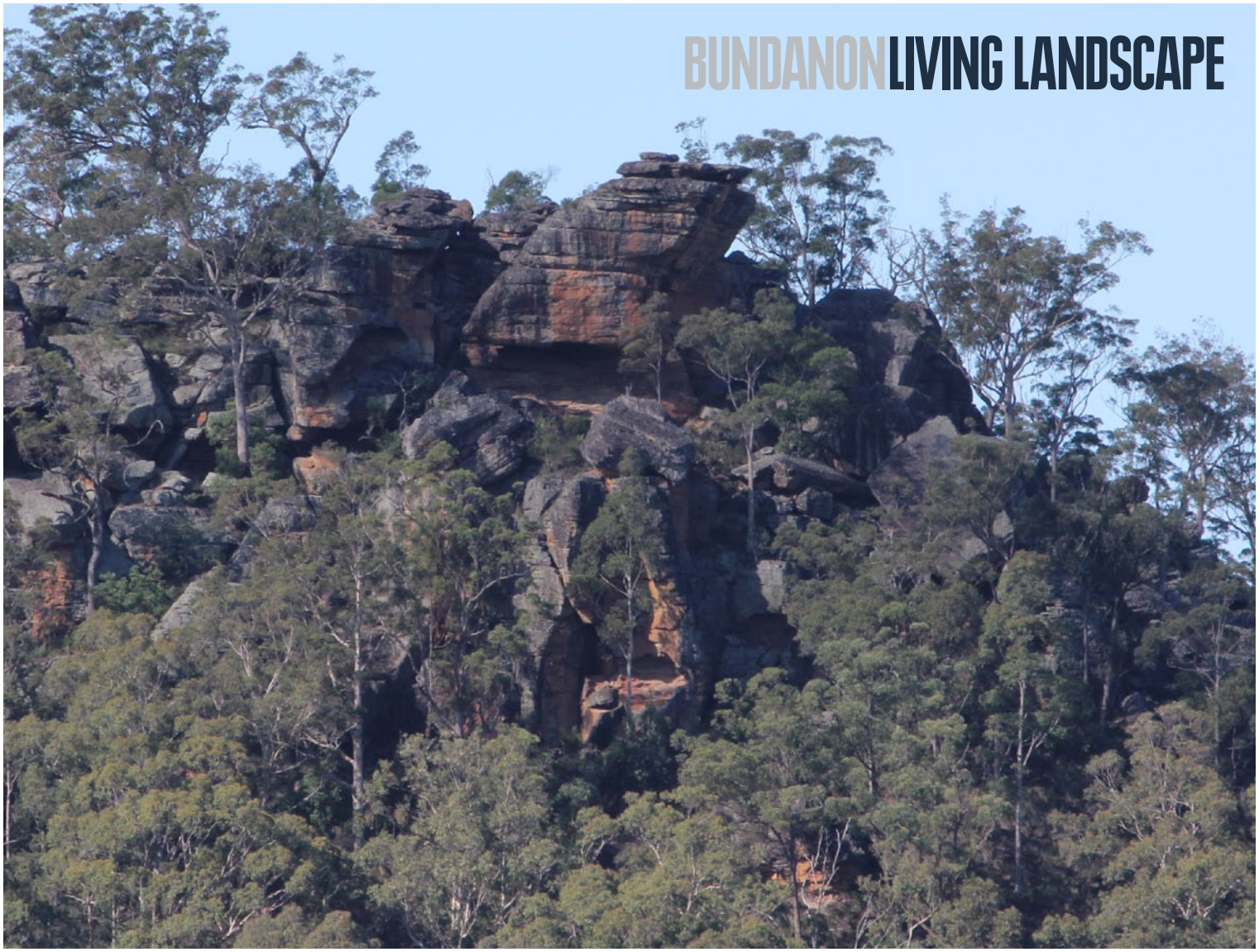


FACT SHEET 3

Landcare Australia

GEOPHYSICAL

The Shoalhaven River has gouged a deep trough through the sedimentary rocks to form the Shoalhaven River Valley. The distinctively horizontal bedding of the sandstone plateau has eroded to form tall vertical cliffs. These imposing banded blocks of rock have forced the river to turn and change course along several reaches of the river.

Image: Detail of Pulpit Rock

GEOLOGY

Permian Period Geology

The geology of the Permian Period consists of sedimentary shales and sandstones of the Shoalhaven Group. The soil parent materials are derived from the Berry Formation and the Megalong Conglomerates. The highest areas of the site, between the western escarpment and the high voltage electricity easement, are overlayed with rock of the Berry Formation which includes undifferentiated siltstones, shales and sandstones. These sedimentary rocks remain undisturbed in the horizontal orientation that they were laid down. The soils derived from this geology on site are situated on a gently undulating plateau and are shallow and poorly drained. The shale influences would provide the soil with moderate water holding and cation exchange capacity however the sand and silt components of the soil are generally low in fertility.

The Megalong Conglomerates derive the following formations:

1. Nowra Sandstone is comprised of quartz and sandstone. These are located on the top of the ridgeline to the east of the high voltage electricity easement where the Berry Formation has been completely eroded. The soils along this narrow ridge are extremely shallow or non-existent; bare, rock outcrops predominate and deeply eroded fissures are common.

2. Wandrawandian Siltstone is comprised of siltstone and sandy siltstone which may be pebbly in part. This geology is situated on the side slopes of the narrow ridge line down to the river or to the river flats. The soils overlying this rock are deeper than the ridge top soils.

3. Conjola Formation is comprised of conglomerate, sandstone and silty sandstone. This geology is only found along the lower contours of the river flats within the Eearie Park property. These are also deeper soils compared to the eroded plateau and ridges; although they are also erosional soils, the lower slopes would be influenced by deposition of alluvial material during flood events.

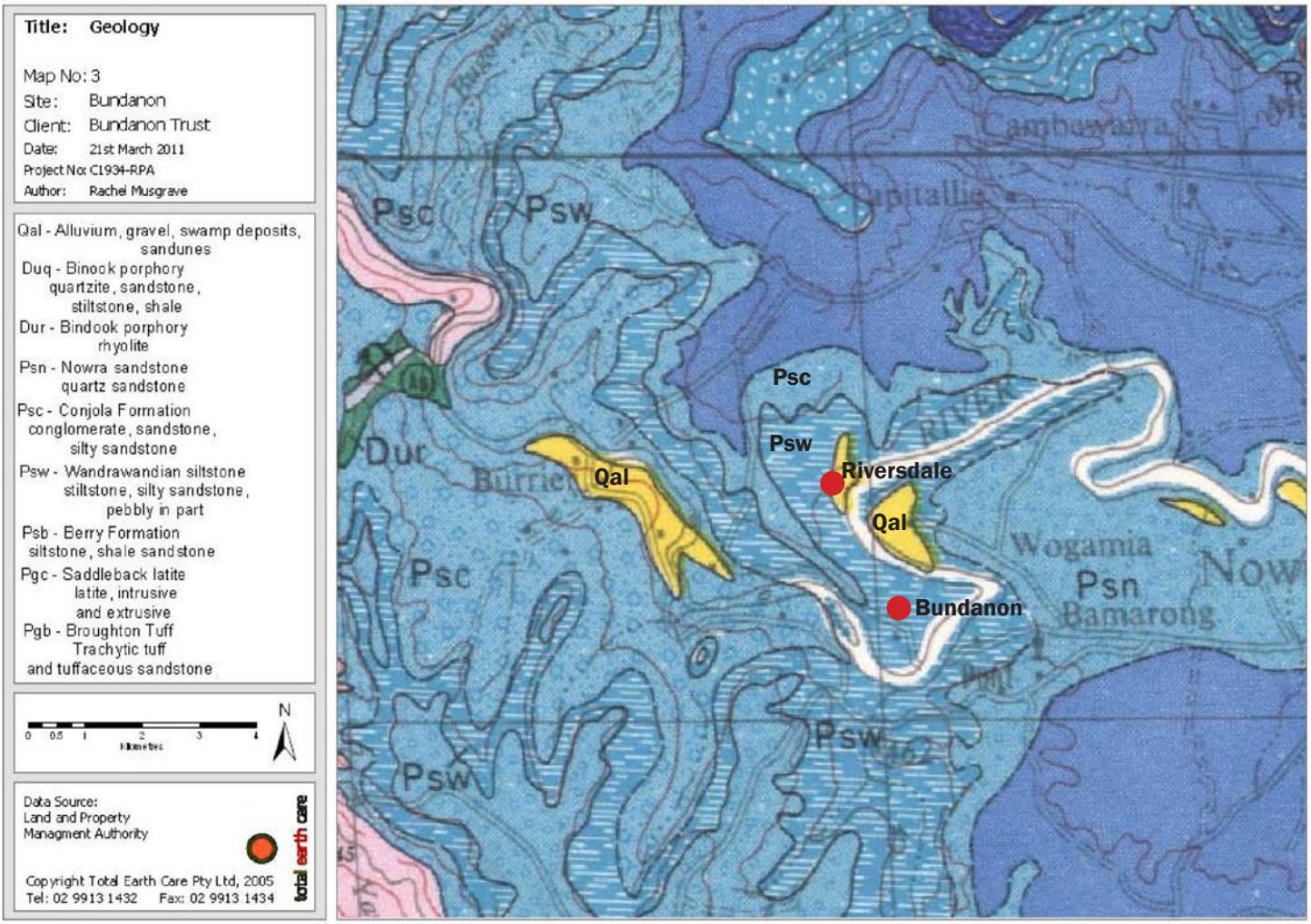


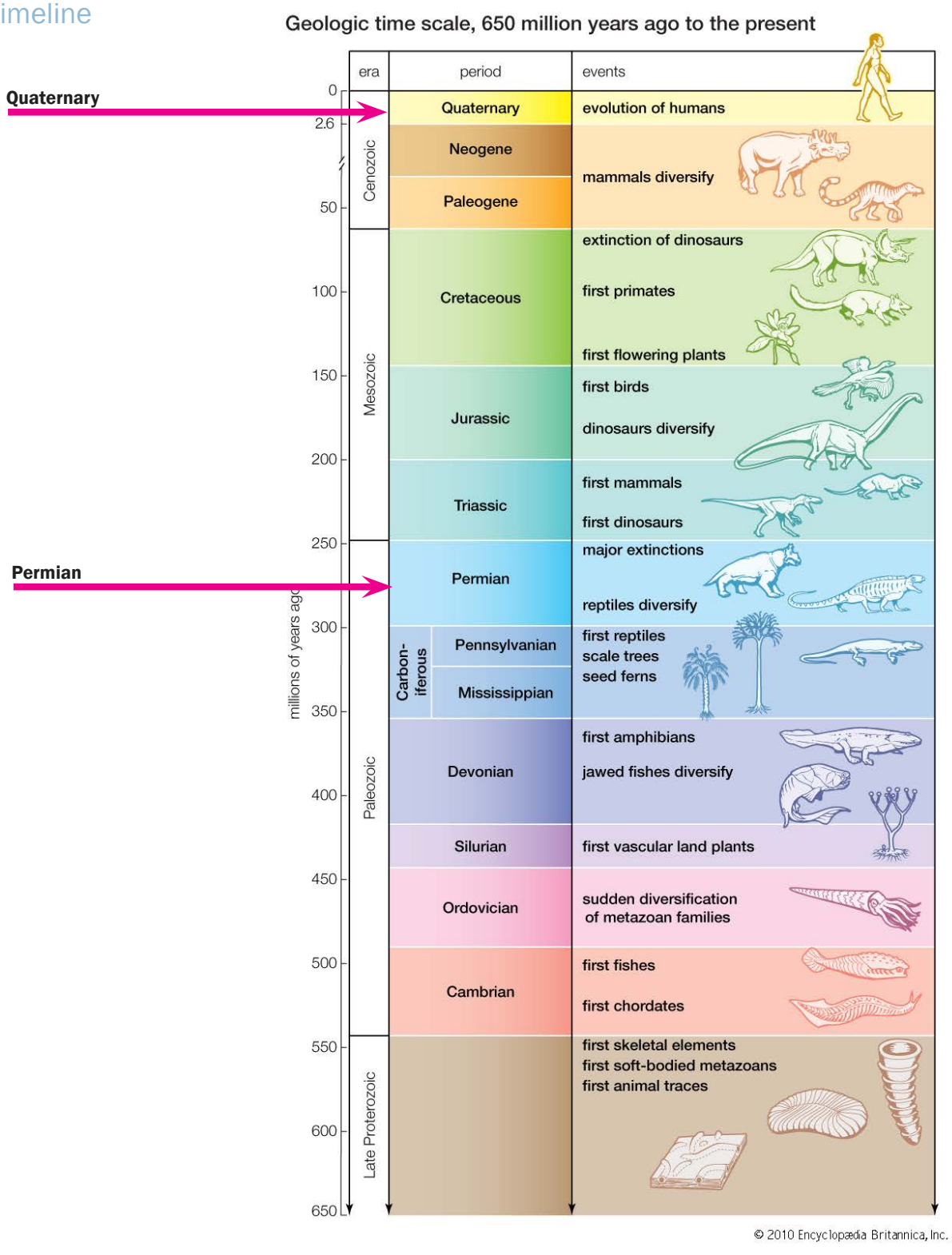
Image: Geophysical Map from Total Earth Care Land Management Plan

Quaternary period geology

Historic aerial photographs of Bundanon in the 1940s show that extensive gravel beds have been exposed after a large flood event had removed finer textured top soils. These soils are more likely to be quaternary alluvium. This depositional zone appears to correlate with the location of a naturally occurring bedrock weir in the river. Quaternary sands are also present on the flood plains of the creeks and the creek/river confluence at Riversdale.

Quaternary alluvium, gravels and swamp deposits are also present in a very small area on the western boundary of the Eearie Park flood plain. This depositional zone appears to correlate with the location of a naturally occurring bedrock weir in the river. This shallow point in the river is understood to historically have been the first inland causeway used for moving stock by the early settlers. Quaternary sands are also present on the flood plains of the creeks and the creek/river confluence at Riversdale.

Geological Timeline



Rock and fossil examples found at Bundanon

Image: Evidence of fossils- possibly a worm- in siltstone along Bundanon Road

Image: Dropstone of quartz in siltstone revealed in a cutting along Bundanon Road.

Image: Petrified wood in a sandstone boulder which was split by lightning strike in 2010, located adjacent to the Cedar Walk Track; Image: Detail of hand-chiseled Nowra Sandstone in a block from Bundanon Homestead

TOPOGRAPHY

Image: view from Riversdale Downstream

Image: Henry Goodall views Bundanon and downstream from Pulpit Rock

The landscape can generally be described as being an eroded plateau of sedimentary rock. The Shoalhaven River, which drains 6920 square kilometres of land most of which is located westward of Bundanon, has gouged a deep trough through these sedimentary rocks to form the Shoalhaven River Valley. The distinctively horizontal bedding of the sandstone plateau has eroded to form 50 metre tall vertical cliffs. These imposing banded blocks of rock have forced the river to turn and change course along several reaches of the river.

A vast wedge of rock has been removed by the erosive power of the Shoalhaven River and its southern tributaries. While the weaker rocks were being stripped from above the resistant Nowra Sandstone, the streams were extending gorges back into it and to the rocks beneath, and creating cliff lines along the river.

The gorge cut by the Shoalhaven River is very sinuous. Burrier, upstream from Eearie Park and Nowra are about 13km apart as the crow flies, but the river travels almost 30km between them. The river flows in deeply entrenched meanders, following major intersecting joints in the sandstone. The 5km straight stretch known as Long Reach, visible from the Boyd Education Centre at Riversdale, lies along a dominant joint aligned to the North East. Along the cliffs, large joint blocks of sandstone have broken off and collapsed onto the slopes or floodplain below, or even into the channel due to destabilisation.

The dissected remnants of the Nowra Sandstone also form a sloping surface, known as the Yalwal Ramp. This rises to the southwest from sea level near Nowra to over 900 metres in the upper part of the Clyde River catchment. The slope of Nowra Sandstone is not due to tectonic (uplift) forces. It happened as sediment was deposited in the Sydney Basin; the weight of the late Permian-Triassic sediment depressed the underlying older sedimentary mass. Much later the hardened Nowra Sandstone was uplifted to its present position.

Aspect

The Bundanon complex of buildings all sit on low lying rises above the floodplain of the river and have extensive views to the south over wide flat paddocks.

The Riversdale homestead and the Boyd Education Centre are located on an east facing side slope which provides uninterrupted views over a magnificent 8 kilometre long perfectly straight reach of the river and huge flat paddocks on the opposite bank. Riversdale also has views of rolling paddocks in a small enclosed valley to the North.

There are a number of significant features of the landscape, including **Pulpit Rock**, on the southern side of the Shoalhaven River opposite Bundanon Homestead; **The Amphitheatre**, located under the northern escarpment above Bundanon heritage complex; and the steep sandstone cliffs of **Eearie Park**. These are detailed in the focus sections which follow.

PULPIT ROCK

The most obvious of the colourfully layered cliffs along the Shoalhaven River is Pulpit Rock, which is located on the opposite bank of the river to the Bundanon homestead. Pulpit Rock is the subject of many of Arthur Boyd's paintings and is also of Aboriginal cultural significance.

In Aboriginal cultural heritage, spiritually, the landscape is imbued with meaning, embedded in prominent topographic features. Creation/dreaming stories for the Shoalhaven River have been recorded and connect to landforms surrounding the river.

Pulpit Rock, has connections with local Indigenous people. During interviews for the Lower Shoalhaven River Valley Aboriginal Cultural Mapping Place Project, local Aboriginal man David Thomas remembers while picking peas at Bamarang [probably in the 1950s-1960s], looking up at Pulpit Rock and seeing the outline of a man with a spear standing on the cliff. In the same study, Aboriginal man George Perry talks about caves in Pulpit Rock being the home of the 'little hairy man - a Dooligal - and old yellow boy'. As a child he was too scared to go up there. He said the electric fences in the paddocks were to keep the hairy man from stealing the cows.

Pulpit Rock is often linked through its name with Arthur Boyd's references to biblical subject matter in his paintings, such as the work below.

Image: Arthur Boyd, *Peter's fish and crucifixion*, 1993, oil on canvas

Image: View of Pulpit Rock from Bundanon Homestead

Geological features

The pattern of sheer rock faces on the outer bends of the river and wide flat paddocks on the inner bends is repeated along the property's river frontage. Smaller creeks that drain into the river from the Bundanon properties have further eroded the plateau to create fingers of rock that reach out to the river as it meanders past the property.

A number of geological features and processes can be observed at Pulpit Rock.

Caves

Along the Shoalhaven River cliffs are a number of small caves, which have been eroded by water seeping through the rocks. Mostly they extend back up and into the rock and some extend horizontally along prominent bedding planes. Electron microscopy imagery of rock from caves shows that the natural cement which holds the sand grains together has been removed. This breakdown of sandstone is extremely slow.

Image: Pulpit Rock Detail

Joint Block Collapse and Block Gliding

This geological process is common in sandstones and other strongly jointed rocks. Nowra Sandstone is notable also for a much more unusual type of block movement known as Block Gliding. In many places, long narrow fissures parallel the cliff face, often switching from one major joint to another. This is not the result of erosion. The fissures have slabs of sandstone across them that have once fitted into one side or the other. Large blocks have moved outwards away from the cliffs, opening up the fissures behind them. The movement has been triggered by the release of confining pressures in the original rock mass. During regional uplift, high horizontal pressures were locked into the rock mass. Some blocks glide over weaker siltstones on which they lie.

The weathered sandstone of Pulpit Rock is an excellent example of block gliding and joint block collapse and can be seen clearly in this detailed photo diagram using white lines to show the rock strat and red lines to demonstrate the direction and height of sliding. The boulders underneath this formation and the caves are also evidence of block collapse.

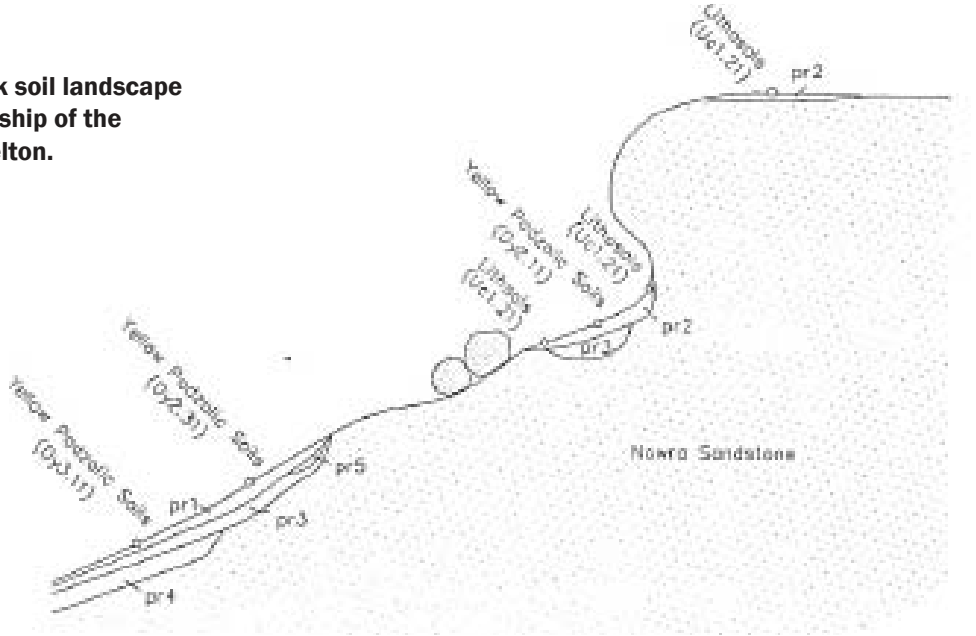
Image: Pulpit Rock detail showing joint block collapse

In geology, a joint is a brittle-fracture surface in rocks along which little or no displacement has occurred. Present in nearly all surface rocks, joints extend in various directions, generally more toward the vertical than to the horizontal. In unweathered rocks, joints are relatively inconspicuous, but upon weathering they become marked, especially in a soluble rocks.

Pulpit Rock and soils

In 1992, P. A. Hazelton, made a detailed study of the soils of Pulpit Rock. This was published in Soil Landscapes of the Kiama 1:100 000 Sheet in association with the Department of Conservation and Land Management Sydney. Hazelton describes Pulpit Rock:
Geology -Nowra Sandstone, medium to coarse-grained quartzose sandstones containing rounded pebbles of scattered quartz throughout the beds.
Topography-Convex weathered rugged sandstone cliffs with steep to very steep talus slopes. Crests are broad and slopes are steep with benches, drainage lines are narrow and incised. Extensive caves and concave weathered pinnacles associated with block gliding. Scattered large rocks and boulders are common.
Relief<80m
Slopes>30%
Erosion- Rock falls are common on scree slopes. There is evidence of minor rill erosion and moderate slumping on batters.The diagram below shows the location of soil types Pr1- Pr6 on Pulpit Rock as a cross section.

Schematic cross-section of Pulpit Rock soil landscape illsutrating the occurence and relationship of the dominant soil materials. from P.A Hazelton.

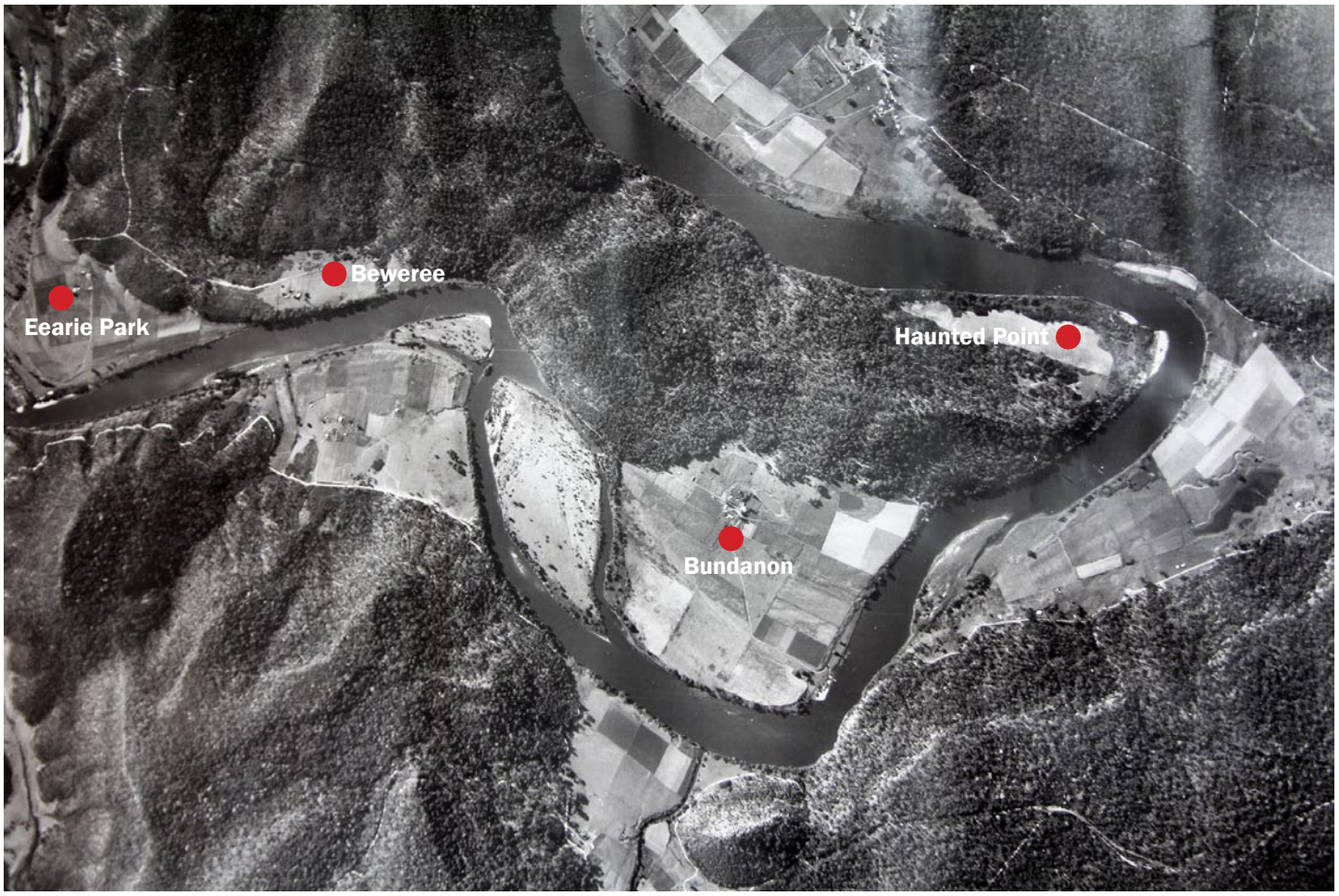


Pulpit Rock Soil Materials

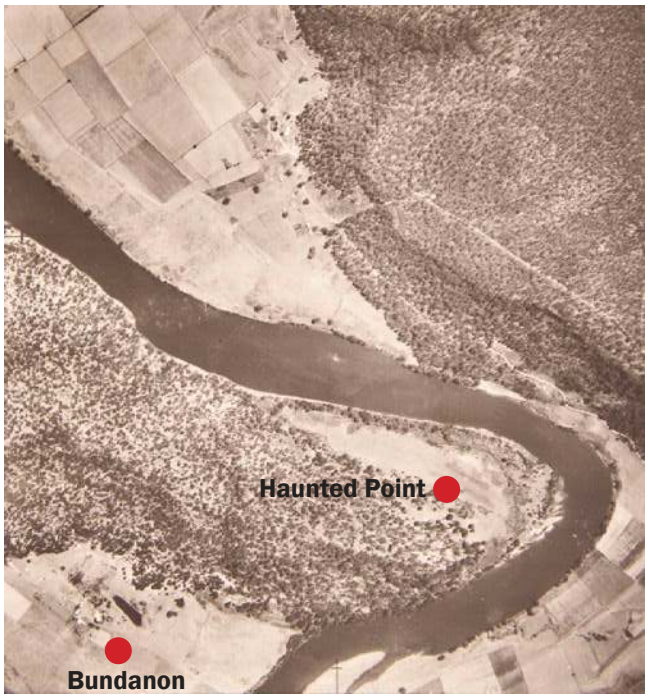
Dominant Soil Materials					
Code	pr1	pr2	pr3	pr4	pr5
Description	hardsetting moderately pedal brown fine sandy loam	Loose brownish grey sand	Bright brown strongly pedal medium clay	Mottled bright bown massive medium clay	Bright Yellowish brown sandy clay loam
Type	Topsoil	Topsoil	Subsoil	Subsoil	Subsoil
Colour	brown to dull yellowish brown	brownish grey	bright brown	bright brown with yellow and grey mottles	bright yellowish brown
Texture	fine sandy loam	sand to loamy sand	sandy clay	medium clay	sandy clay loam
Structure	moderatelt pedal, 50-100mm polyhedral to sub-angular blocky peds	apedal single-grained	strongly pedal, 10-20mm angludar blocky peds	apedal massive	apedal massive to weakly pedal
Fabric	rough faced	sandy	rouch, porous	dense	earthy to rough faced, porous
pH	5	5	4.5	3.5	5
Stones	20-50 % 60-200mm angluar dispersed	2-10% 206mm rounded, dispersed, common	20-50%, 20-60mm rounded dispersed	nil	nil
Occurence examples	top of lower slopes	overlaying bedrock on crests, midslopes	underneath pr2 on midslopes, under pr1 and 5 on lower slopes	on lower slopes	underneath pr1 on lower slopes

RIPARIAN ZONES AT BUNDANON: EVIDENCE FROM THE PAST

Photographs from the Bundanon Trust archive can be used to assess the condition of riparian zones at different periods in the property's history



Copy of aerial photograph taken April 1949 of the Bundanon Trust properties, the Shoalhaven River with the Wogamia property to the north-east of the river. This photograph clearly shows the land use and amount of cleared land used for farming, of these parts of the properties at this time. Farm land paddocks are cleared to the river. The island is largely clear of flora.



Above: View Shoalhaven River, from Pulpit Rock over looking Bundanon circa1949

Left: Aerial photograph of Shoalhaven River, showing the Wogamia property to the east of the river, with Haunted Point north-west and the Bundanon property with Homestead and farm buildings in the south-west corner of the image taken sometime in the 1940s. The forest areas appear more open and less dense than the 1949 photo. Haunted Point has much more cleared area.

THE AMPHITHEATRE

The predominant rock formation in the area is Nowra Sandstone, characterised by layers of stone and pebbles. Nowra sandstone is part of a Permian rock sequence (279-230 million years ago). The Permian period was a time when reptiles and large non-flowering plants dominated the earth and at that time this area was subsiding and was covered by sea.

This depression is called the Sydney Basin because its' centre lies in Botany Bay. The remains of melting Icebergs dropped sand, pebbles and small stones onto the sea bed, while rivers deposited many layers of small pebbles, sands and mud over a large area. Abundant fossils of shellfish are found in the lower part of the Nowra sandstone, which indicate that these sedimentary rocks were laid down in shallow water. (see diagrams and photos)

The resulting sandstone was elevated 600 metres about 100 million years ago and the Shoalhaven River eroded the valley. The sea flooded the valley as far as Burrier.

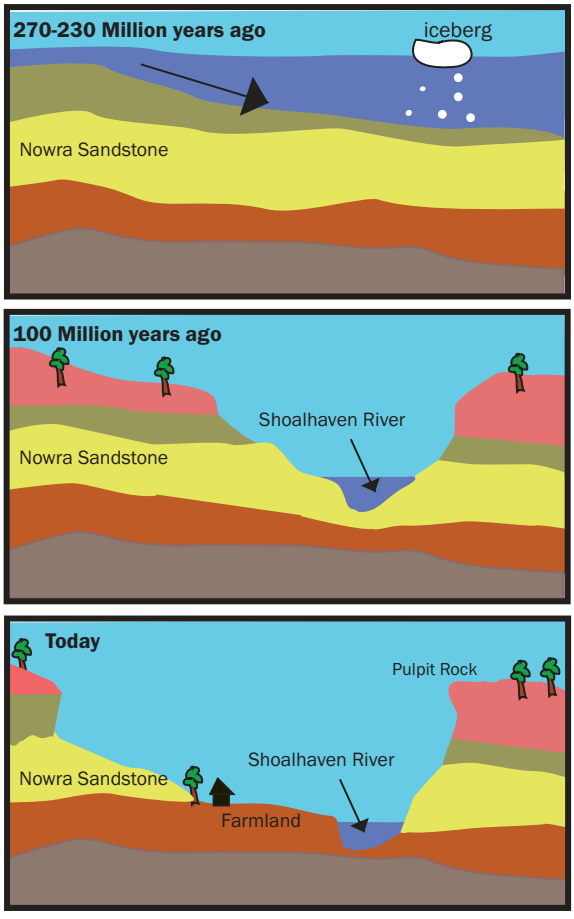


Image: Geology Diagrams adapted from originals by Jim Walliss, showing the formation of the Shoalhaven Valley

Geological features of the Amphitheatre

Joints

Sedimentary rocks such as sandstone usually show two sets of joints at right angles to one another, each extending down perpendicular to the bedding; one set extends in the direction of dip and the other in the direction of strike (trend of the line of intersection of the bedding and the horizontal). The distance between joints varies from about two centimetres to a few hundred metres; in alternating strata the degree of jointing may vary from bed to bed and in some cases is related to the compaction of sediments during rock formation.

Crossbedding

Crossbeds are thin layers formed by sand avalanching down the face of large sandbars in the ancient Triassic rivers. Water can move through the rock, down the many partings between the crossbeds, so crossbedded sandstones are generally more easily eroded than flat-bedded sandstones. Crossbedding encourages cave development, and eroded crossbed plates jut out inside many caves.

Image: Amphitheatre Rocks

Image: Amphitheatre detail showing crossbedding

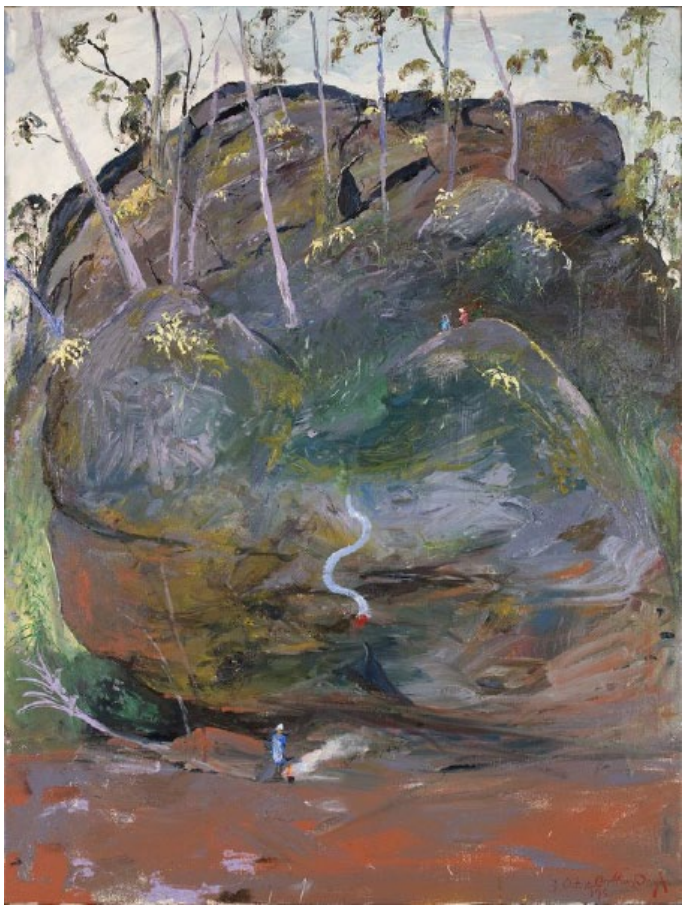
Image: Amphitheatre cave detail showing honeycomb weathering

Right: Conglomerate in a large boulder at the amphitheatre. The conglomerate is made up of rock particles and pebbles which are left on sedimentary layers due to a storm event. The larger the rock particles, the more intense the storm.

The Amphitheatre as inspiration

The Amphitheatre is an awesome example of the geology of the region with it's boulders, caves and tall trees. It has been the inspiration for many works by Arthur Boyd and artists in residence.

In the painting by Arthur Boyd below, a lone figure stands at the base of a massive bolder. He is boiling a billy on a small fire. Two people are half way up the rock on the left hand side. The Sydney Rock Orchids which bloom in Spring can be seen flowering.



Arthur Boyd, *The Amphitheatre* (1993) oil on canvas

Image:Touched by the Earth environmental program at the Amphitheatre

Black Nectar by Keith Armstrong

Black Nectar was a site-specific light & sound installation that asked audiences to take slow, sensory walks through the inky-blackness of Bundanon's forests at night, charting personal courses through seasons of change, animality and imagination – far beyond the blinding lights and howling tones of our contemporary existence. This artwork was produced as a SITEWORKS 2014 commission.

Images: Black Nectar by Keith Armstrong, Siteworks 2014. Above, Preparing the site installation; below, night view. Photos Heidrun Lohr.

WATER CATCHMENT CHARACTERISTICS

Land management activities within a sub-catchment up-slope of the Bundanon Trust properties, such as road building, housing or clearing of land, may increase the speed and volume of water that flows through the creeks. Land clearing would also increase the speed of soil erosion and the subsequent deposition of soil/sediment in the Bundanon Trust properties creeklines. Conversely, dam building and contour ploughing or deep ripping of the land higher in the catchment will reduce the amount of water and silt that might reach a creek within Bundanon.

The Shoalhaven River additionally has tidal influences that impact upon it. Most importantly the tides increase the salinity of the water in the river adjacent to the Bundanon properties making it un-useable for farming. Additionally, the salinity of ground water, used for irrigation, would also be increased especially during drought periods when irrigation water is most needed.

The property has six Sub-catchments that feed the Shoalhaven River. Four of these sub catchments, and the Shoalhaven River, drain water from properties other than Bundanon. The remaining two drain water only from land controlled by the Bundanon Trust. This is of significant relevance in that pollutants such as agricultural chemicals, fertilisers and weed propagules and water borne pests and diseases are likely to be transported onto the Bundanon Trust properties from other properties higher in the catchment.

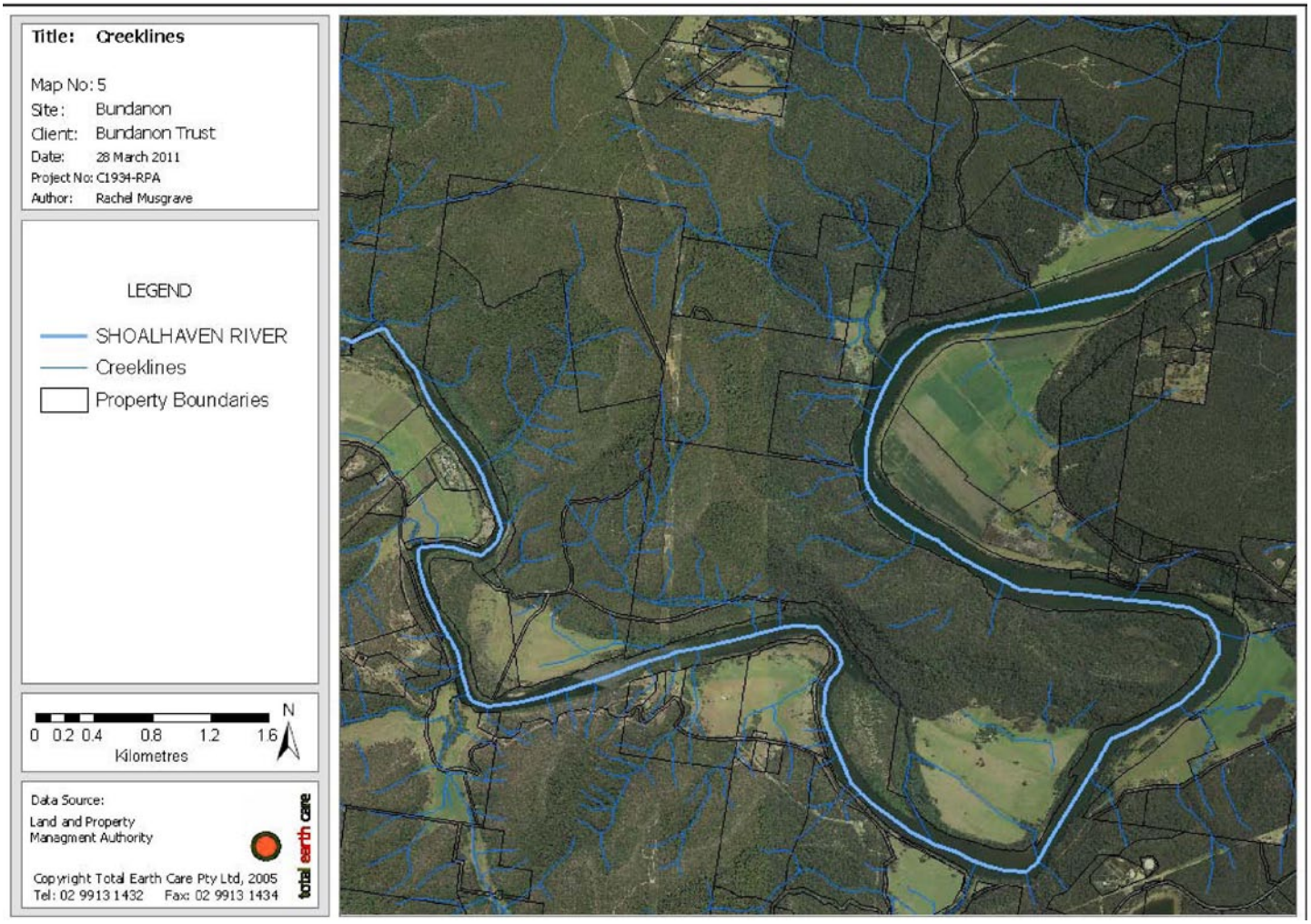


Image: Creeklines

SOILS

Bushland topsoil

The soils in the un-grazed steep bushland areas have relatively deep mulch layers and have greater plant species richness. The south facing slopes, north of the homestead are protected from the northern aspect and are well vegetated and correspondingly the soils have higher levels of organic matter. The soils are generally silty-sandy soils and are highly erodable. The bushland topsoils that have been grazed are generally on steeper ground and are situated below rock outcrops. They have lost their native vegetation cover (which binds the soil surface) and are subsequently depleted. The organic soil horizon is very thin and the volume of decaying mulch is similarly thin and the fertility is correspondingly low. The steepness of the ground suggests that surface erosion has removed much of the organic matter and the A-soil horizon. Much of this bushland has also been infested with Lantana.

Paddock topsoil

The soils in the paddocks are silty - sandy soils that have some structure. If consistent with the silt content they should have moderate colloidal capacity, moderate water holding capacity and with the sand content should also be well drained and have reasonable air filled porosity. At first inspection they appear to be moderately fertile and suitable for a wide range of agricultural uses.

Soil Erosion and Sedimentation

The soils within the arable lands on site are stable (non-eroding) apart from the river banks which have been de-stabilised through the action of the Wombats digging into the river banks; the wave, wind, a tide action of the river and rain/sheet erosion on the four wheel drive tracks leading across the paddocks and to Haunted Point and the Amphitheatre.

Adjacent Land Use

The subject site is almost completely contained within the Shoalhaven river banks to the south. The exception to this is a privately owned property which abuts the western boundary of Eearie Park on the river flat country. NPWS protected lands (an island and opposite bank), grazing farmland, a soil extraction and green-waste composting facility and a commercial camping and caravan park are located on the opposite bank of the Shoalhaven River. The river is frequently used for recreational water skiing and boating. The wake caused by boat traffic has caused river bank erosion which threatens the vegetation and other life forms that require a fully vegetated and naturally eroded bank structure at water level. The river is a vector for weed seed and disease via flood events and recreational river users who alight on the Bundanon river banks. Bundanon is surrounded by small animal grazing farms and rural lifestyle properties to the north and east. These properties are ostensibly bush-blocks; no open/ cleared paddocks are contiguous with the Bundanon boundaries. This continuous bushland surrounds the property and provides a significant buffer to the ecological communities within Bundanon.

Image: Bundanon beach on the Shoalhaven River

SOIL DEGRADATION PROCESSES

There are four substantial soil degradation processes occurring on site.

River Bank Erosion

The river banks erode by a combination of wind, boat wash, tides and floods. The periodic loss of soil from high on the river flats should also be noted.

Creek Bank Erosion

The erosion of the banks of the creeks are caused by vehicles, wombats digging in the bank, and through the loss of density of riparian vegetation to smothering weeds that do not bind the soil as well as the native riparian species. Stream/creek bed erosion 'head cut' is also occurring which in turn undermines the banks, which then collapse changing the whole profile of the creek. This erosion then fills pools in the creeks with silt and reduces their habitat value.

Road erosion and creek siltation

The third degradation process is the soil that is washed from the Bundanon road during rain events. Soil washing from the roads will slowly fill the creeks with silt and change the microclimatic conditions and ecology of the streams.

Topsoil Erosion

The LMP identified that the speed with which topsoil erosion appears to be occurring on site is greater than would naturally occur. The native plant community in these areas are depauperate of plants in the shrub and groundcover strata. Consequently, the soil is not being bound and there is a steady migration of topsoil from the steep side slopes above the northern and western paddock at Riversdale and north from Haunted Point. It is assumed that these two areas were grazed and burned, and in time lost their forb layer which had bound the soil. Now that grazing no longer occurs, Lantana camara has infested the slopes but it provides little protection against erosion. The soil on these slopes is very smooth and with little groundcover seeds tend to be washed down-slope and do not germinate on the bared ground.

Water Degradation

Water degradation in many ways generally it is a consequence of eroding soil being deposited into the creeks and rivers. Soil particles not only affect the clarity of the water, which impacts on ecological processes, but they also contain chemicals that become dissolved in and contaminate the water. Chemical alteration of the water can also wherever machinery chemicals are spilled and washed into waterways, or leach into the ground water. Agricultural chemical spray drift may also directly contaminate water bodies.

Image - the beach at Eearie Park on the Shoalhaven River after the June 2012 flood event. Sand deposits change the shape and character of the riverside and deposit weeds downstream.

Image: the creek at Riversdale

Image: Bundanon, Shoalhaven River frontage with lantana infestation

SITEWORKS: TEN TRENCHES AND BEYOND

SITEWORKS is a multi-disciplinary collaboration investigating the imaginative, empirical and interpretive possibilities of the Bundanon property. The project, which commenced in 2009 is an exploration and conversation between artists, scientists, historians, archaeologists and local people about the histories of Bundanon. The site is redolent with meaning, from the stories of Indigenous, Colonial and Boyd occupation, to the rhythmic traces of the flooding of the Shoalhaven River over thousands of years. The participants explore the potential of the Bundanon site to inspire, inform and support independent research.

Ten Trenches was an interdisciplinary arts-science project, which took place at Bundanon in 2009. At its core was a collaboration between two brothers: Tim Cohen, an environmental scientist researching the indicators and effects of sea-level rise on New South Wales river systems and Michael Cohen, a site-based performance and installation artist. Two teams of collaborators worked together at Bundanon using a series of deep trenches, auger holes and soil samples as the tools of their enquiries, resulting in a field day of conversations with artists, scientists and the public and performances and installations into the evening.

The Science of SITEWORKS with Dr. Tim Cohen

Analysis of the trenches and drill holes highlighted a long but discontinuous sedimentary history for the Bundanon site. Using a range of geo-chronological techniques, the scientific research determined that the 'modern' floodplains that we see today formed 5,000 years ago and not 8,000 years ago as previously hypothesised. These floodplains themselves rest on ancient alluvial surfaces that reflect periods of the Earth's history when it was experiencing the last Ice Age.

Furthermore, the science research also demonstrated that the Shoalhaven River has either migrated or avulsed (jumped) from the location near the Homestead to its current position between 5,000 and 1,200 years ago. Importantly the research has shown that not only did it reach its present position 1,200 years ago but it appears that the current river channel and its huge levees (15–20 m high) were built in—300 years during a warmer period on the planet termed the Medieval Climatic Anomaly (MCA). This riverside levee may hold a vital clue to the nature of the climate in southeastern Australia during the MCA and will be the focus of future palaeoenvironmental research.

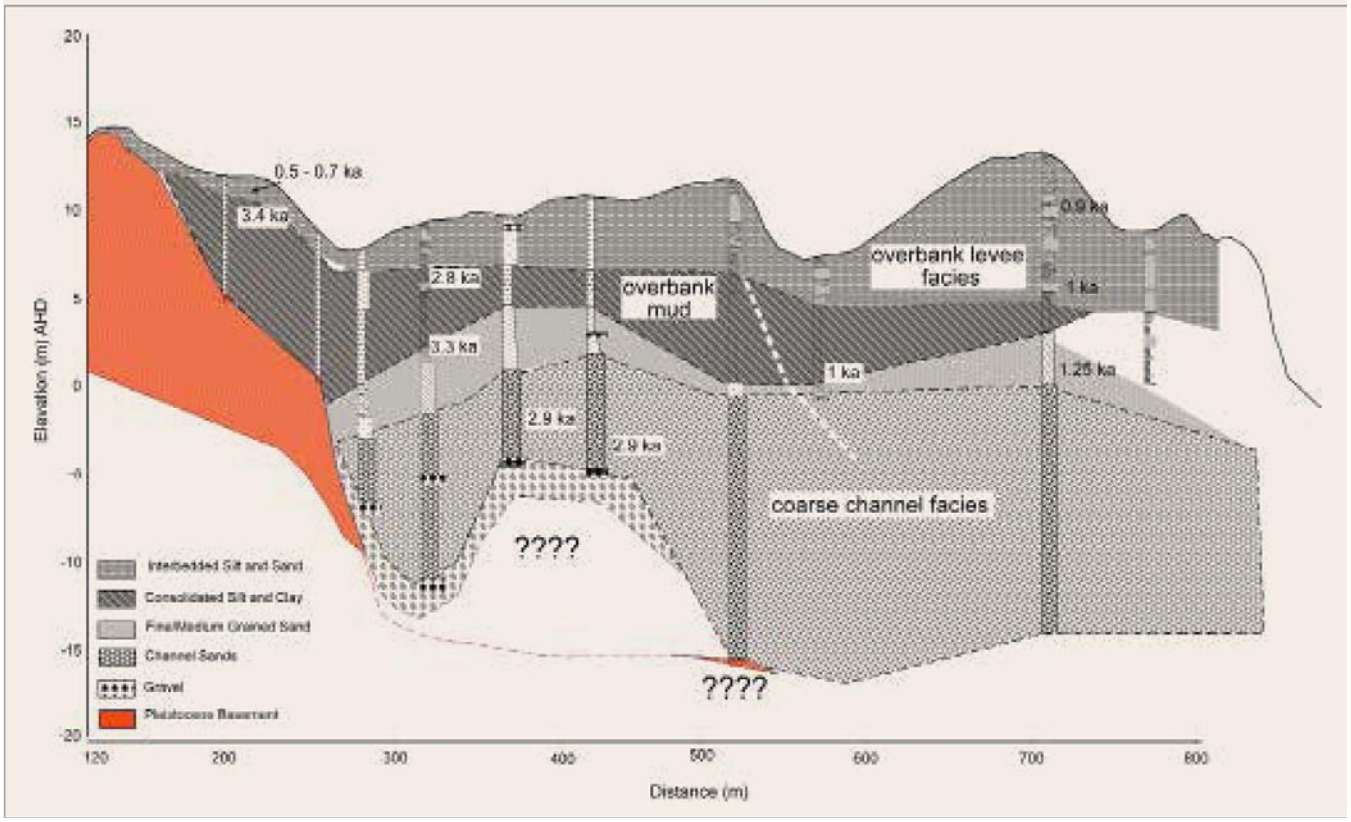
One of the additional findings that has stemmed from this work has been the ability to identify the controlling factors in determining how far upstream sea level rise will impact the landscape on the Shoalhaven River. Hydraulic modelling along with additional sedimentary analysis has shown that a geological bottleneck downstream of the site plays a critical role in determining the level of present and predicted flood levels. The science team is aiming to implement this technique across the eastern seaboard of Australia to determine the spatial extent of the impacts of predicted sea level rise.

Image:Ten Trenches 2009 Core sample drilling

"We know that the river was once very close to the old Homestead so it would have been a much shorter walk for a swim." Tim Cohen

Image:Tim Cohen and Ten Trenches Talk

Diagram showing the age of the floodplain sediments of the Shoalhaven River at Bundanon, Tim Cohen 2009



Images clockwise:Ten Trenches 2009, Students from Kildare Catholic College learn about soil science from Dr Tim Cohen at Bundanon; Performance, Ten Trenches 2010; Images Doug Spowart and Bundanon Trust.

To view Siteworks films go to the following links
2012 Siteworks http://vimeo.com/54820826 2012 The Conversation http://vimeo.com/51381493