WETLAND MANAGEMENT PROFILE

KARST WETLANDS

Karst wetlands are a type of underground wetland system, with or without a surface water component, commonly associated with caves or other underground cavities. Their structures are moulded by naturally acidic water dissolving bedrock. The components of a karst system, rock, water, soils, flora, fauna, energy, and gases are closely interrelated, and changes to any one of these components can impact on the entire system, including associated wetlands. Like most wetlands, karst wetlands provide a number of economic, cultural and conservation values. As karst wetlands are inherently related to the relationships between water, land, vegetation and soil there are many threats that can impact on their integrity. Some of the major and more direct threats include:

- *pollution*
- *significant land or hydrological disturbance*
- *inappropriate recreation or utilisation.*

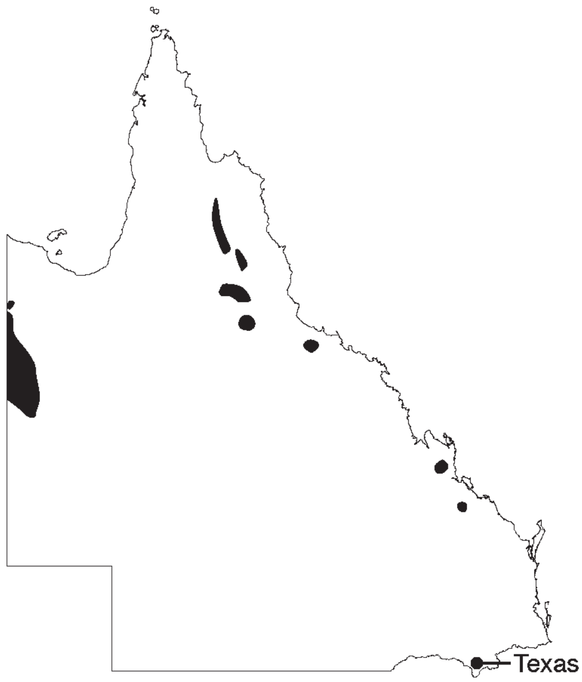
Karst wetlands have a very low capacity to recover from change. For example, pollutants entering a karst wetland may remain in the system for hundreds or even thousands of years. It is therefore important to prevent or manage threats in an appropriate manner.

There is little known about karst wetlands in Queensland. Management may be improved by further understanding where karst wetlands occur, their nature and extent, and the ecosystems and biota that inhabit them.

Description

Karst wetlands are mostly subterranean habitats. They can occur in cave complexes or in very small cavities between rock and/or soil. Karst landforms are those where the topography is formed by naturally acidic water dissolving bedrock, most commonly carbonate rock-like limestone. They are characterised by subsurface drainage and particular landforms including caves, speleothems and occasionally, in the Queensland situation, limestone towers. Karst wetlands can also include surface wetlands, where groundwater may rise to the surface as springs or lakes.

The dissolving of bedrock by naturally occurring acidic water shapes the landforms and drainage patterns of karst systems and their associated wetlands. Rain falling through the atmosphere collects small amounts of carbon dioxide (CO_2) and becomes slightly acidic. As the water reaches the surface of the karst, it permeates through the soil and captures more CO_2 to form carbonic acid (H_2CO_3). This infiltrates any cracks or crevices in the rock and through a complex chemical reaction starts to dissolve the bedrock. The cracks and crevices in the bedrock increase over time and this may lead to the development of subsurface caves.



Map showing karst regions of Queensland. Map: EPA

As the system matures, above-ground water sources, for example streams, begin to lose water to developing cave systems. Eventually, most of the surface drainage is diverted underground and above-ground streams may disappear completely. Most of this water will make its way into the regional karst aquifer.

Subterranean karst wetlands are very diverse and include underground streams, springs, seeps, pools and lakes. Some of these wetlands are temporary (usually those depending solely on seasonal surface water inflows), while others are permanent (usually fed by groundwater from the karst aquifer). There are also examples of karst wetlands that have no direct links to caves or other openings to the surface, and that can only be accessed through bores.

While most karst systems are characterised by a lack of integrated surface drainage systems, surface wetlands do occur in karst. There may be short streams and rivers crossing karst, usually in areas where the aquifer occurs close to the surface, or where the bedrock lacks extensive cracks and joints. Surface karst wetlands are not common in Queensland, and where they do occur they are generally temporary systems that are only active during the wet season. Some surface karst wetlands may be fed by groundwater discharge and exhibit modern or fossil tufas. The build up of tufas, river deposited carbonates, are much like cave flowstones and can form complex braided networks.

Another common feature on the surface of karst systems are closed basins which are called sinkholes or dolines. These are formed at major joints or cracks in the bedrock. Some sinkholes form from the surface enlargement of joints by solution, others form when underground voids collapse leaving an opening to the surface. When the bottom of the sinkhole becomes blocked, or when groundwater levels rise, lakes and other wetlands may form in the sinkhole basin.

There are also wetlands associated with pseudokarst environments, for example, those that are not formed by dissolving bedrock, but have features such as caves that resemble "true" karst. The subterranean lakes found in the Undara lava tubes are an example of pseudokarst wetlands. While many of the threats and management suggestions in this profile are relevant to pseudokarsts this profile focuses on "true" karst wetlands only.

Karst wetlands provide habitat and refuge for a diverse array of fauna and ecological communities both above and below ground. Most of the species found in surface karst wetlands are widespread, but endemic animals and plants that favour alkaline waters may also be present. Subterranean karst wetlands have a much simpler ecology than surface karst wetlands.

Due to lack of light, photosynthetic flora does not occur in the dark recesses of caves but can occur at the entrance where sunlight is present. Invertebrate communities are simpler in structure and generally have smaller populations and lower diversity. However, subterranean karst wetlands support much higher levels of endemism, and the composition of species can be quite different to surface wetlands.

Distribution

Karst wetlands are distributed throughout the world. According to Geoscience Australia it is estimated that up to 15 percent of Australia consists of karst landscapes, four percent of which can be seen at the ground surface. Many karst landscapes occur along the coastal/subcoastal margins of Australia along the eastern, southern and western limits. Some of these extend great distances inland. The Australian Government Department of the Environment and Heritage suggest that the distribution of karst regions within Australia is very patchy, and most of these regions are less than a few thousand hectares in size.

FIFTEEN percent of Australia consists of karst landscapes, four percent of which can be seen at the ground surface.

Karsts and karst wetlands have not been systematically surveyed, mapped, or their values assessed in Queensland and as such the extent of karst wetlands and their values is not fully known. Karsts occur in North Queensland, including the Mitchell-Palmer area, and at Chillagoe, Chudleigh, north of Boulia, Broken River and Fanning River. A relatively small area of limestone karst also occurs near Texas in south-east Queensland, many of which are now inundated by dam waters. All of these karst systems have at least a small aquatic component.

Queensland conservation status

The Queensland *Environmental Protection Act 1994* establishes a general environmental duty upon landowners to take all reasonable and practical measures to prevent or minimise harm to wetlands, having considered such things as the sensitivity of the wetland, recommended practices and financial implications. Karst wetlands have a range of environmental values related to ecological health, public amenity and safety. Some of these values are described in the Cultural heritage values and Ecological values sections below.

The Spring Tower Complex, which is located in the Chillagoe karst region is one Queensland karst wetland that is listed in *A Directory of Important Wetlands in Australia* (2005). There are a number of pieces of legislation such as the Queensland *Integrated Planning Act 1997* that include planning, assessment and permit requirements relating to wetlands listed in the Directory. Any activities that may impact on Directory wetlands (and potentially wetlands in general) must be consistent with this legislation.

There are no specific regional ecosystems that have been described in karst wetlands.

National conservation status

Subterranean karst wetlands are listed as a wetland type under the Ramsar Convention Wetland Classification System. The Convention recognises that karst systems provide natural underground wetlands and provide a resource of environmental, social and economic values. At present there are no karst wetlands contained within Ramsar sites in Queensland.

Some karsts including their wetlands, such as the Chillagoe Karst Region, are listed on the Register of the National Estate. The Australian Government Minister for the Environment and Heritage must have regard to information in the Register in making decisions under the EPBC Act to which the information is relevant.

Cultural heritage values

All wetland ecosystems are of material and cultural importance to Indigenous people and many will have profound cultural significance and values. Indigenous and non-Indigenous (historic) cultural heritage sites have been recorded within wetlands in Queensland. However, most wetlands have not been systematically surveyed or assessed for cultural heritage significance.

Evidence of traditional occupation and use recorded within wetlands include painted and engraved rock art, burials, ceremonial earth and stone arrangements, scarred and carved trees, quarries, middens, stone artefacts and scatters, dwellings, open camps, fish traps, food and fibre resources and historic contact sites. Some areas have particular significance as story places, landscape features and as sites for cultural activities.

Almost all plant and animal species have some form of traditional use or cultural significance (for example totemic significance). Many plant and animal species were used traditionally for food and fibre. For example, the seeds, fruits, leaves, shoots, stems, roots and tubers of plant were processed for food, used to make implements and for medicinal purposes.

Typical karst cave formation.
Photo: EPA

Karst wetlands can be characterised by speleothems.
Photo: EPA

Archaeological evidence of cultural sites, such as stone artefact scatters, are often concentrated along ecotones around the margins of wetlands, and in association with neighbouring regional ecosystems. The clustering of sites along ecotones reflects the concentration of traditional occupation and use within areas of greatest biodiversity.

Ecological values

Karst wetlands provide habitat for a variety of flora and fauna species and ecological communities, often threatened, at both the surface and underground.

Within the caves themselves the groundwater supplied to karst wetlands provides nutrients and moisture which are essential for karst ecology. Light however is a limiting factor. As a result some of the species that occur here are endemic and highly adapted to living in underground karst wetlands.

WITHIN karst wetland caves and subterranean cavities light is a limiting factor, resulting in endemic and highly adapted species.

Subterranean fauna can be divided into numerous groupings according to whether they live in or out of water and the degree to which they rely on karst wetlands to complete their lifecycles. In general subterranean fauna is divided into stygofauna (aquatic groundwater animals) and troglofauna (air-breathing subterranean animals). Stygofauna can be divided into stygobites, stygophiles and stygoxene while troglofauna can be divided into troglobites, troglophiles and trogloxenes.

Stygobites (including some fish species, isopods, syncarids and amphipods) are fully adapted to living permanently underground well away from light. Some are adapted to living in total darkness with relatively constant climates and irregularity of food supplies. Many are endemic, restricted to a wetland or geographic area and are rare or threatened. Some species can exhibit physical characteristics known as troglomorphy, such as loss of pigment, blindness from reduced or absent eyes, long antennae and legs, and changes in reproductive strategies. The latter may render them additionally sensitive to environmental change.

Higher plants do not grow in this environment, however fungi can. For this reason the fauna that does live here rely on food brought in from the outside by stream flows and organic matter that penetrates from above. Because these systems are deep underground and sheltered from outside climatic forces, there is some degree of consistency in the subterranean environment and its wetlands but with a degree of seasonal variation (that is, changes in water and air flow). Where the karst wetland is near the land surface, or connected to the terrestrial environment, there is also some degree of seasonality in ecological processes. However, this becomes increasingly buffered with distance underground. Because of their buffered environment, stygofauna have survived many of the climatic changes that have destroyed their ancient surface-dwelling relatives. They possess many of the features of ancient fossils and as such have been nicknamed "living fossils". Many of these species are extremely specialised and if their environment is destroyed or damaged they are unlikely to find alternative suitable habitat and many will become extinct.

CHILLAGOE THEA

In relatively recent times a freshwater karst wetland in the Chillagoe area was the locality for the discovery of a new genus and species of amphipod (crustacean), *Chillagoe thea. C. thea* is a stygobite. It is thought to be restricted to aquatic subterranean habitats. Like other stygobites, the *C. thea* demonstrates troglomorphy (special adaptations to subterranean life) such as an absence of eyes and loss of pigment. Adult specimens are about 6mm in length.

Although closely resembling a group of amphipods located in east Asia, it is thought that the genera are convergent derivatives from two different root-stocks.

***Chillagoe thea* from the Chillagoe cave area.**
Photo: Stefan Eberhard

CHILLAGOE KARST REGION

Dry prickly vine scrub and jagged limestone outcrops at Chillagoe conceal the breathtaking beauty of the limestone caves within. Many of these caves are protected in sections of Chillagoe-Mungana Caves National Park.

About 400 million years ago, limestone was deposited as calcareous mud and coral reefs surrounding underwater volcanoes. Subsequent tilting, folding and erosion exposed and weathered the limestone which today towers over the surrounding plains. Fluctuating groundwater levels slowly dissolved some of the limestone, creating caverns and passages, some of which have since been decorated by calcite stalactites, stalagmites and flowstones, deposited by surface waters penetrating through the rock. The Chillagoe karst region has some caves that reach the watertable forming subterranean karst wetlands.

Water is generally supplied through groundwater which is fresh, of circumneutral pH, and contains carbonate. There are relatively few accessible caves in the Chillagoe area that contain permanent water. Many may be periodically flooded during wet seasons allowing groundwater-dwelling species to enter the caves.

Few animals can survive inside the dark caves. Only specialised endemic species of fauna can survive here for their entire life cycle. One cave in the region is the locality for a new species of amphipod, *Chillagoe thea* (see box previous page). This species is a stygobite — restricted to subterranean habitats and shows special adaptations to its habitat such as loss of pigment and eyes.

Whilst not obligated to the wetland component of karsts, some troglofauna do take refuge within the caves. In particular, the caves provide nesting and breeding habitat for several species of bats including little bent-wing bat *Miniopterus australis*, eastern bent-wing bat *M. schreibersii oceanensis* and the eastern dusky leaf-nosed bat *Hipposideros ater aruensis*.

Limestone outcrops of the Chillagoe-Mungana Caves National Park.
Photo: EPA

Chillagoe-Mungana Caves National Park cave and wetland.
Photo: EPA

Managing karst wetlands

The geological, chemical and hydrological systems that build and maintain karst wetlands are inherently governed by the relationships between water, land, vegetation and soil. Any change in the input of one or more of these aspects can pose serious threats to the integrity of both karst systems and their associated wetlands.

Runoff from non-karst areas can contribute to subterranean wetlands. This means that threats can be both direct and indirect. Management of karst wetlands must take account of direct threats on karsts such as mining and indirect threats such as pollution. These may be difficult to quantify.

Consequently, development proposals and planning should consider the breadth of the karst wetland's catchment (including that beyond the limestone outcrop) and apply appropriate environmental monitoring and management measures. Activities within the catchment of a karst wetland should comply with appropriate legislation and conditions and follow best practice management regulations, codes of practice and guidelines.

To protect karst wetlands there needs to be an understanding of where they occur and how they might be impacted upon. This can only be resolved by systematic surveys and mapping the extent of the karst wetlands, catchment boundaries and their hydrological interactions.

UNDERSTANDING and recognising the extent of karst wetlands, their catchments and hydrological interactions through systematic surveys and mapping, together with appropriate planning and management, are the keys to protecting karst wetlands.

Mining and quarrying

Some of Queensland's karst landscapes have been subject to mining and quarrying for a variety of products. Mining and quarrying can directly destroy species and their habitat. These activities can cause direct destruction to a karst wetland but may also cause indirect threats to the system through pollution, changing the biological and chemical balance and altering karst wetland characteristics such as water flows. Mining and quarrying can also have impacts on the visual amenity of a site and the value of the site for other uses such as recreation and water use.

The effects of these activities are mostly irreversible and as such are regulated in Queensland through the *Integrated Planning Act 1997* and/or the *Environmental Protection Act 1994*. Any new or modified development may require appropriate development approval under this legislation and must comply with any conditions applied to this approval.

Some karst wetlands are now protected under the Queensland *Nature Conservation Act 1992* through the declaration of protected areas such as national parks. Some are also protected through other national legislation as outlined in the National conservation status section.

Land and water use

Land and water use that changes water flow and the processes feeding karst wetlands can also cause direct or indirect impacts on the wetland. Changes or reductions in water flows through water extraction, damming or diversions can reduce water tables or water input balances which can result in structural failures in karst wetland caves and other underground voids that contain wetlands and impact on the delicate ecological balance on which wildlife depend. Stygobites are particularly fragile to these changes. The removal of water-filtering vegetation or changes to soil cover can cause siltation of watercourses and ultimately karst wetlands, where they are directly fed from external streams, smothering small wildlife.

Any extractive industry within a karst wetland catchment, be it geological, biological or chemical can change balances in karst systems resulting in effects on geological and ecological processes and ultimately the wildlife that live there.

Since catchments for karst wetlands may extend beyond the karst system, land managers should seek advice before installing structures that may alter the hydrology of karst wetlands. Further information about current legislative requirements regarding construction of dams, bores, bund walls, drains and other structures is available from the Queensland Department of Natural and Resources and Mines (NR&M) website (www.nrm.qld.gov.au/).

Land use activities within karst wetland catchments should aim to maintain a constant and adequate level of natural vegetation and ground cover. Activities should be conducted in a manner that prevents or minimises soil disturbance, erosion and water quantity and quality changes. Activities should comply with appropriate legislation, industry codes of practice and guidelines.

REDUCED water tables or water input balances can result in structural failures in karst wetland caves and impact on the delicate ecological balance on which wildlife depend, particularly stygobites.

Managing water pollution and high nutrient or chemical loads

Unnatural substances (for example pesticides) or natural substances (for example sediment) at unnatural levels can enter karst wetlands rapidly and readily through the water systems that supply them. This can cause significant pollution and may impact on the ecology of the wetland. For example, pollution from industry, agriculture, or residential sources pose a risk to karst wetlands. These can enter directly into karst wetlands through streams or indirectly through groundwater.

Pollution should be prevented from entering karst wetlands. Activities that have a high risk of producing pollution that could enter the groundwater of a karst system should be excluded or planned and managed very carefully. Planning and management should develop karst protection areas and consider the boundary of karst wetland catchments and the flow paths within it when assessing pollution risk.

Where there is no alternative to conduct high-risk activities within a karst wetland catchment, risk management solutions may include bunding the site to ensure no spills can escape, treating pollution before it can leave the site and collecting pollution and removing it to a site where it cannot enter the wetland or its catchment. The key management intent is to prevent any pollution entering the karst wetland.

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Human visitation

Human visitation of karst wetlands can be desired for a variety of reasons. Recreation and tourism are some of the main human uses of karst wetlands today, including pursuits such as caving, diving, formal guided tours and photography. Other visitors to karst wetlands may include scientific researchers, explorers and enthusiasts.

Visitors using a constructed path.
Photo: EPA

Continued and unregulated or unmonitored use of karst caves and their associated wetlands can have direct and/or cumulative impacts including:

- compaction, erosion or destruction of cave structures including speleothems;
- contamination of caves and water through the introduction of foreign material including plant and animal material or other pollutants; and
- destruction of fauna and flora.

There is a risk that unplanned and unmanaged activities could destroy the very thing that attracted people to the karst wetland in the first instance. The visitation of karst wetlands, for any purpose, should be conducted in a manner that ensures the activities are sustainable. The key to sustainability is appropriate planning and use. It may be most appropriate to allow restricted access to a limited number of karst wetlands that are considered relatively resilient and prevent access to the more fragile karst wetlands and caves. It may also be appropriate to restore degraded karst wetlands rather than open new areas for further activity. However, it should be noted that the regenerative capacity of karst wetlands is relatively very low. Advice should be sought from an expert management group such as the Australasian Cave and Karst Managers Association www.ackma.org/index.html before authorising recreation in karst wetlands.

It may be appropriate to restrict or prevent access to wetlands via caves by fencing or placing gates at the entrances or requiring approval before entry is permitted. Some existing management strategies restrict access to that granted through guides and supervised tours. Some of these formal visitor nodes have harm-minimisation structures in place such as boardwalks and bridges which prevent damage to sensitive areas. These structures should be built of an appropriate material that will not leach, exude, or chemically react with the surrounding environment and cause a pollution problem.

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Glossary

Amphipods Small, shrimp-like crustaceans. Most amphipods are marine, although a few live in freshwater or are terrestrial.

Aquifer Layer of rock (predominantly sandstone) that holds water and allows water to percolate through it.

Bedrock The solid rock that underlies all soil, sand, clay, gravel and loose material on the earth's surface.

Calcite The commoner, more stable, mineral form of calcium carbonate, $CaCO_3$. It is the dominant component of all limestones and is also the dominant mineral of chemical cave deposits including stalactites and stalagmites. It is white or colourless when pure but may be stained, most commonly to yellows and browns, by included impurities such as iron oxides.

Catchment The area of land drained by a creek or river system.

Circumneutral pH A pH of 6 to 8. Generally a pH of 7 is considered neutral, with measurements below 7 being acidic, and those above 7 being alkaline.

Convergent (convergence) The increasing resemblance over time of distinct evolutionary lineages.

Crustaceans Animals with jointed legs and segmented bodies that have a hardened outer shell and usually live in water, for example prawns, crabs and crayfish.

Ecotone A transition zone between two or more ecological communities.

Endemic Found only in one particular area.

Endemism The level of species that occur naturally only in a specific region or site.

Environmental value Under the Queensland *Environmental Protection Act 1994*, an environmental value is defined as (a) a quality or physical characteristic of the environment that is conducive to ecological health or public amenity or safety; or (b) another quality of the environment identified and declared to be an environmental value under an environmental protection policy or regulation (see www.legislation.qld.gov.au/LEGISLTN/CURRENT/E/EnvProtA94.pdf and www.legislation.qld.gov.au/Legislation%20Docs/CurrentE.htm).

Flowstones Layered deposits of calcium carbonate precipitated on rocks or sediments from water trickling over them.

Hydrological Pertaining to water flow.

Hydrology The science dealing with the properties, distribution and circulation of water.

IUCN Red List A list of globally threatened species assessed and maintained by the World Conservation Union (IUCN). The List provides taxonomic, conservation status and distribution information and highlights those species or groups of species that are facing a higher risk of global extinction.

Isopod Any sessile-eyed (lacking stalks) crustacean with the body composed of seven free thoracic segments, each bearing a similar pair of legs.

Pseudokarst Karst-like terrain produced by a process other than the dissolving of rock, such as the rough surface above a lava field, where the ceilings of lava tubes have collapsed. Features of pseudokarst include lava tunnels, lava tubes, lava stalactites, and lava stalagmites. Pseudokarst is not restricted to lava flows but may occur in a wide variety of rocks.

Ramsar Convention The Convention on Wetlands (Ramsar, Iran, 1971) is an international treaty that aims to halt the worldwide loss of wetlands and to conserve those that remain through wise use and management.

Regional ecosystem The vegetation community that is consistently associated with a particular combination of geology, landform and soil (see Sattler and Williams 1999).

Sinkholes (dolines) Formed by the collapse of cave roofs and are a feature of landscapes that are based on limestone bedrock. The result is a depression in the surface topography.

Speleothem Cave formation, a secondary mineral deposit formed by the accumulation, dripping or flowing of water in a cave, for example stalactites and stalagmites.

Stalactite A cylindrical or conical deposit of minerals, generally calcite, formed by dripping water, hanging from the roof of a cave, generally having a hollow tube at its center.

Stalagmite A cylindrical or conical deposit of minerals, generally calcite, rising from the floor of a limestone cave, formed by precipitation. The water drops on the stalagmite from above.

Stygobite An aquatic animal living permanently underground in the dark.

Stygofauna Aquatic subterranean animal.

Stygophile An aquatic animal that can complete its life cycle within caves but can also do so in suitable habitats outside.

Stygoxene An aquatic animal that visits caves, but must return periodically to the surface for parts of its lifecycle.

Subterranean Beneath the earth's surface.

Syncarids A small aquatic crustacean belonging to an ancient order Syncarida. Their form has changed little over millions of years, and they are sometimes referred to as a living fossil. They are usually found in underground environments.

Topography The shape of the land in terms of elevation, slope and orientation.

Troglofauna Air-breathing subterranean animals.

Troglobite An animal that lives permanently underground in the dark, but is not aquatic.

Troglomorphy The physical characteristics of a troglobite or stygobite.

Troglophile An animal that can complete its life cycle within caves but can also do so in suitable habitats outside.

Trogloxene An animal that visits caves, but must return periodically to the surface for parts of its lifecycle.

Tufas Relatively porous or spongy deposits of calcium carbonate chemically and/or biologically precipitated by groundwaters or surface waters.

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Primary Author: Tony Baker

Contact officer: Senior Conservation Officer, Ecosystem Conservation Branch, Conservation Services Division; ecosystem.conservation@epa.qld.gov.au

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