125 years

Celebrating 125 years of the Upper Nepean Scheme

As the Upper Nepean Scheme celebrates its 125th anniversary, it's remarkable that so little is known by Sydneysiders about such an important piece of infrastructure that once saved Sydney from drought and continues to supply water more than a century later.

The vision for the scheme was simple yet far-sighted: collect water on the Southern Highlands where it rains frequently and heavily, and transfer that water to Sydney to provide a reliable supply.

The solution that was completed in 1888 was ingenious: two weirs on the Upper Nepean rivers collect water which is sent by gravity along a series of tunnels, canals and aqueducts to a large reservoir in Sydney's west, from where it flows by gravity to the city and suburbs.

It was the first time in Australia that water would be collected far away from a city, transported by canals and pipelines, and stored in a major dam. It would also require no energy – water would simply flow by gravity.

It was a scheme of many firsts in Australian engineering and water supply history and in this commemorative publication we celebrate the remarkable achievements of those who planned, designed and built the scheme.

NSW GOVERNMENT

SYDNEY CATCHMENT AUTHORITY

The Upper Nepean – a scheme of firsts

(Continued from front cover)

For all its simplicity and ingenuity, the Upper Nepean Scheme still needed to be funded and constructed. It took two major government inquiries over 13 years before funding was allocated and work finally started in 1880. It was then built in just eight years.

Engineering of the highest standard was required to build the tunnels, canals and aqueducts, because the gradient was so small and yet water needed to flow by gravity all the way to the city.

Prospect Reservoir was another engineering feat. Not only was it Australia's first dam with an earth fill and rock embankment, it is still an impressive example of such a reservoir even by today's standards.

Before the canals or the reservoir could be completed, Sydney was again gripped by drought in 1885. An enterprising engineering firm temporarily connected the missing links in the scheme to provide an emergency supply of water within six months (see inside story – Hudsons' temporary scheme).

But the story of the Upper Nepean Scheme's ingenuity had only just begun.

Barely a decade after its completion in 1888, Sydney ran dangerously low on water during the Federation drought in 1901-02.

Fortunately, the scheme's original design lent itself to progressive expansion. As Sydney's population grew from 296,000 in 1888 to nearly 1.5 million in 1939, four new dams were built on the Upper Nepean to supplement the scheme's supply.

Seventy-eight years have passed since the fourth dam was added to the Upper Nepean Scheme, during which time Sydney built Warragamba Dam, one of the world's largest domestic water supply dams.

Yet even today, the Upper Nepean Scheme continues to supply 20 to 40 percent of Sydney's water.

Water continues to flow along the Upper Canal to Sydney, just as it did 125 years ago. Prospect Reservoir remains an important part of the water supply system.

And the engineers and workers who designed, built and maintained the scheme over the past 125 years continue to deserve our thanks for a job well done.

A scheme of firsts:

- **The Upper Nepean Scheme** – Sydney becomes first Australian city to harvest water far from the city and transfer it by canals and pipelines, and store it in a major dam.
- **Upper Canal** – unique example of nineteenth century hydraulic engineering in Australia, using canal building techniques often at very small grades, relying only on gravity.
- **Prospect Reservoir** – Australia's first earth fill and rock embankment dam, and still one of the largest.

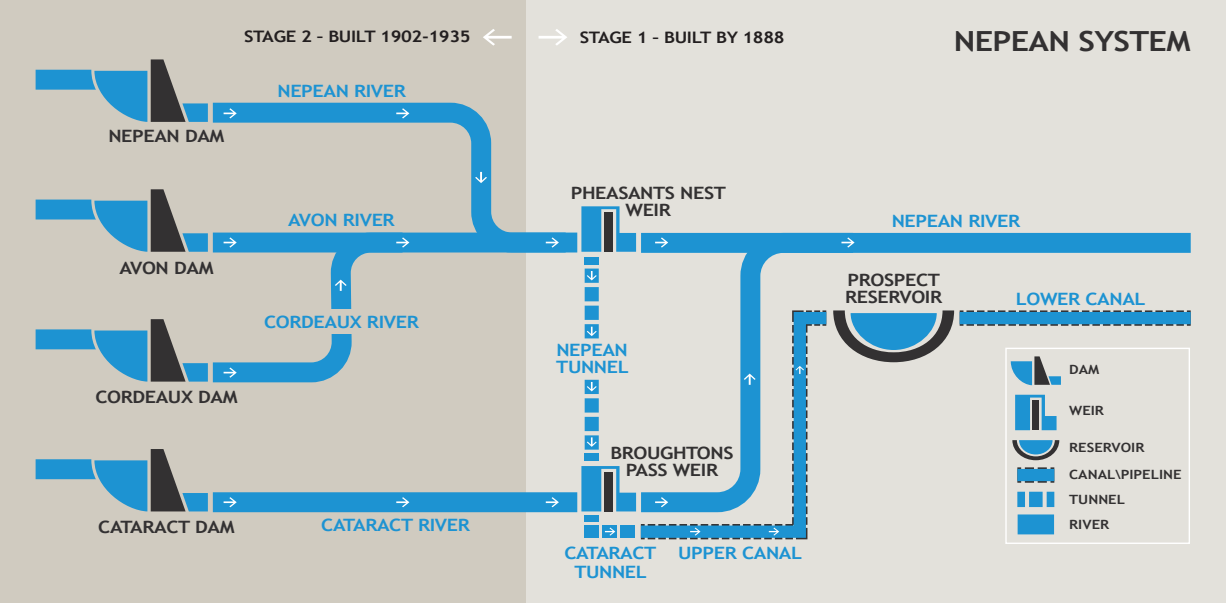
Above: *The blue ribbon of the Upper Canal as it winds its way between Appin and Campbelltown.* *(Photo: A Hollingsworth)*

Left: *Pipelines and aqueducts had to cross gullies and rivers to ensure the water could flow by gravity all the way to Prospect Reservoir.*

Cover image: *The men who constructed Leafs Creek Aqueduct pose for the camera. This photo was taken sometime between 1886 and 1888 by renowned Australian landscape photographer Charles Bayliss and is one of the few images we have of the workers on the Upper Nepean Scheme.*

125 years later, the Bayliss family connection continues with the SCA's own Steven Bayliss, South East Operations Coordinator, overseeing Upper Canal transfers and operation of the Upper Nepean dams.

How it worked



How it worked in 1888...

Rainfall on the Illawarra Plateau south of Sydney flows into the Cordeaux, Cataract, Avon and Nepean rivers.

A weir at Pheasants Nest, just below the junction of the Cordeaux and Nepean rivers, diverts some of the water into the 7km Nepean Tunnel which travels under the town of Wilton and connects with the Cataract River.

A second weir on the Cataract River at Broughtons Pass diverts water into the 3km Cataract Tunnel.

Water emerges from the Cataract Tunnel into a canal at Brooks Point, near Appin and then continues to flow by gravity to Prospect Reservoir.

The entire 64-kilometre length of open canals (44km), tunnels (19km) and aqueducts (1km) is known as the Upper Canal.

From Prospect Reservoir, water flows by gravity along the 7.7km Lower Canal to a basin at Guildford (known as Pipe Head), from where it is piped to a service reservoir at Potts Hill, near Auburn.

From Potts Hills Reservoir water is piped to the Crown Street Reservoir, and a larger service reservoir at Petersham.

From Crown Street and Petersham reservoirs, Upper Nepean Scheme water is supplied to the city and suburbs previously supplied with water from the Botany Swamps Scheme.

...and Stage 2

Construction of the four Upper Nepean dams between 1902 and 1935 essentially did not alter how the Upper Nepean Scheme worked – it simply increased the amount of water the scheme could reliably supply, by storing water in upstream dams rather than relying solely on river flows.

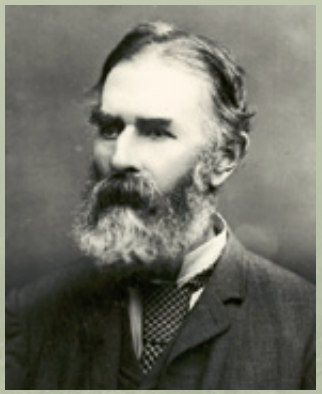
Water from Avon, Cordeaux and Nepean dams flowed to Pheasants Nest Weir, where it was diverted via the Nepean Tunnel to Broughtons Pass Weir. Water from Cataract Dam flowed directly to Broughtons Pass Weir.

From Broughtons Pass water flowed through the Cataract Tunnel and Upper Canal to Prospect Reservoir – as it did before construction of the Upper Nepean dams.

The Lower Canal was replaced with a tunnel and was decommissioned in the 1990s. The Upper Canal continues to flow by gravity, as it has done for 125 years.

Built for our 'health, comfort and prosperity'

Illustration of the Upper Nepean Scheme in the May 1895 'Town and Country journal' which celebrated the transformation of Sydney's water supply.



Edward Orpen Moriarty, Engineer-in-Chief of Harbours and Rivers, led the design and development of the Upper Nepean Scheme.

Long before Warragamba Dam, the Upper Nepean Scheme was the jewel in the crown of Sydney's water supply.

A Royal Commission recommended the Upper Nepean Scheme to "make Sydney the best watered of Australian cities, as it is at present the worst; and will minister to the health, comfort, and prosperity of its inhabitants to distant times".

Although the scheme needed to be expanded almost as soon as it was completed – with four major dams built in the early 1900s in addition to the two original weirs – it remains an important part of Sydney's water supply today.

Until the Upper Nepean Scheme was completed in 1888, the early settlers relied on local water supplies – originally the Tank Stream, then swamps near Centennial Park and Botany Bay.

The early British settlers knew little about conserving or storing water, coming from a place where rivers always flowed and it rained all year round. Nor did they understand much about protecting the water from contamination which could also reduce the supply of drinking water. As a result the colony was regularly on the verge of running out of water.

In 1867, with a growing population, frequent droughts, and continuing public anxiety about water supplies, the Governor appointed a commission to find a reliable and plentiful water supply for Sydney's future.

The five-person commission included Edward Orpen Moriarty, Engineer-in-Chief of Harbours and Rivers for the Public Works Department from 1858-88, and the man credited with the design and execution of the Upper Nepean Scheme.

After two years' investigation, the commission recommended collecting water from the 1,000 square kilometre

Upper Nepean catchment south of Sydney, and transferring it through 64 kilometres of tunnels, canals and pipelines to a huge new reservoir at Prospect. From there it would flow by gravity along a Lower Canal to Guildford where it would connect with the city's existing water supply system.

More than a decade passed and another inquiry was held before the Upper Nepean Scheme was confirmed as the best solution to Sydney's water needs, and work finally began in 1880.

Then in 1885, before the scheme was completed, Sydney was gripped by another major drought. With only 10 days' supply remaining, urgent action was required (see 'Daring emergency scheme' story opposite).

In 1888, the first stage of the Upper Nepean Scheme was completed and water finally flowed from the Upper Nepean weirs along the Upper Canal to Prospect Reservoir to supply the city's needs.

That same year the Board of Water Supply and Sewerage was established to manage all water supply and sewerage infrastructure owned by government and city councils.

Today, Sydney Water manages treated water supply and sewerage. The Upper Nepean Scheme and Sydney's other major dams and raw water supply infrastructure are managed by the Sydney Catchment Authority.

As for the Upper Nepean Scheme, 125 years after it was completed its legacy continues as a valuable part of Sydney's water supply.

Indeed, the Upper Nepean Scheme has lived up to predictions that it "will minister to the health, comfort, and prosperity of its inhabitants to distant times".

A daring emergency scheme to rescue Sydney from water famine

Hudsons' Temporary Scheme

Before the Upper Nepean Scheme could be completed, Sydney was gripped by another drought. In 1885 the Lachlan and Botany swamps were down to about 10 days' supply and the city council asked the government for urgent help.

With Prospect Reservoir only half finished, the Upper Canal still unconnected by pipes across gullies in many parts, the situation was desperate.

The Minister for Public Works seized on a daring temporary solution proposed by a local engineering firm, the Hudson Brothers (who later became Clyde Engineering, now part of Downer EDI).

The Sydney Morning Herald reported on 29 May 1885:

"Mr H. Hudson had suggested to the Government that the gaps in the 'waterworks' between gorges should be connected by timber fluming, and that he guaranteed bringing 3,000,000 gallons of water a day to the Botany Dams at a cost of 60,000 [pounds]."

That's 13.6 million litres of water a day in today's measurements all delivered to Botany Swamps within six months – a mighty promise to deliver on!

With its back against the wall, the government immediately commissioned the scheme.

In just six months of frantic construction activity, the Hudson Brothers built 16 small concrete dams along the Upper Canal and laid 1200 giant cast iron pipes, bridging eight creeks in rugged locations and crossing the Great Southern Railway line near Menangle.

Even more remarkably, between the Lower Canal at Guildford and Botany they built three kilometres of open timber fluming on timber trestles, some of them 21 metres high.

On 30 January 1886, the Mayor of Sydney and the Minister for Public Works officially turned on the flow of Nepean water into the Botany lakes.

Hudsons' Temporary Scheme continued to operate for several more years until the Upper Nepean Scheme was completed as planned in 1888. It was dismantled soon after, ending one of the most colourful chapters in the history of Sydney's water supply.

However, for more than two years Hudsons' Temporary Scheme served a noble purpose, as the Sydney Morning Herald reported on 1 February 1886:

"The real merit of the work consists in it having removed all danger of a water famine."

The Hudsons' Temporary Scheme is shown here as the smaller pipe running alongside the large, permanent Upper Nepean Scheme pipeline. In 1888 the temporary infrastructure was dismantled.

The Upper Canal – an unsung hero of Sydney's history

The Upper Canal is an unsung hero of Sydney's history. A precise piece of engineering still serving the needs of Sydney 125 years later.

Built in the 1880s, now listed on the State Heritage Register, the Upper Canal is still the only way of transferring water to Sydney from the four Upper Nepean dams (Cataract, Cordeaux, Avon and Nepean). These dams supply on average 20 per cent of Sydney's water, but at times can supply up to 40 percent of Sydney's daily demand.

'Green' before its time, it uses no energy other than the earth's gravity to transport water 64 kilometres to Prospect Reservoir in Sydney's west.

"The canal drops just 50 metres in elevation over 54 kilometres after the Nepean and Cataract tunnels – just 0.1 percent grade – a marvellous feat of engineering following the earth's contours. It is a wonderful legacy left to us by the engineers and surveyors of the late 1800s," says Ian Tanner, Group General Manager, Assets and Major Projects, with the Sydney Catchment Authority.

The canal is built from a variety of materials, depending on the nature of the country it passes through.

Where the ground is soft, the canal is trapezoidal in shape and the sides lined with unreinforced concrete slabs. In other sections, the canal is u-shaped and the sides are lined with sandstone masonry. Where the canal is cut into solid rock, it is unlined.

Tunnels allow the canal to pass under hills. These are unlined if cut through solid rock, or lined with brick or sandstone if cut through softer material.

Aqueducts allow the canal to cross creeks and gullies. These were inverted iron syphons resting on sandstone piers.

In all, the Upper Canal has one kilometre of aqueducts crossing nine creeks and the Southern railway line, nineteen kilometres of tunnels and 44 kilometres of open canal.

Many of the original iron pipes remain in use, some lined with plastic sleeves to protect the pipes and keep them waterproof.

Many of the original mechanisms to control and divert the water's flow – such as stop logs, penstocks, and gate valves – are also still in use.

1886

Construction of the Upper Canal in 1886. The primitive huts which housed the workers can be seen on the far right of the photograph.

2012

The Upper Canal as seen from a similar vantage point in 2012, located south of Glen Alpine in Sydney's south-west.

The maintenance men of the Upper canal

For nearly a century, the Upper Canal was maintained by men who lived in isolated cottages along the canal. They walked or rode horses to patrol the length of canal assigned to them, a length of about eight kilometres.

The cottages were phased out in the 1970s and replaced with mobile maintenance teams.

When Garry Smith began on the canal 24 years ago, he was part of a team of 15 workers who travelled the length of the canal each day. Now with the Sydney Catchment Authority, Garry supervises the contractors who carry out maintenance tasks.

"Our main jobs were cleaning the trash racks that collect leaves and other floating debris, repairing fences, mowing, and removing the occasional stray animal," Garry says.

"Cows and kangaroos were the most common animals that would end up in the canal. We'd average one or two of each a year. We could usually rescue most of them safely.

"These days kids swimming illegally in the canal is the biggest problem. Suburbia is getting closer every year, and the canal is not as isolated as it used to be."

The Upper Canal occupies a continuous corridor between 15 to 50 metres wide. Public access is totally restricted for public health, water quality, security and safety reasons.

The Lower Canal –gone but not forgotten

Remarkable for its impressive brick aqueduct and very low grade, the Lower Canal connected the new Prospect Reservoir to the city's existing water supply system at Guildford.

Relying on gravity like the Upper Canal, the Lower Canal dropped just 77 centimetres over its 7.7 kilometre length – a grade of 1 in 10,000. It was another remarkable engineering feat for its time.

The Boothtown aqueduct – built as part of the scheme – allowed the canal to flow across a 225-metre wide valley. Its 22 brick arches, each with a span of nine metres, are still intact today.

After a series of structural failures in the 1890s, in 1907 the aqueduct was replaced with a three-metre wide inverted concrete syphon. Built in the earth bank beside the aqueduct, at the time it was the longest continuous concrete work of its kind in Australia.

The Lower Canal was decommissioned after a pipeline was completed in the 1990s, and the bush reserve surrounding the canal opened to the public in 2003 as a cycleway.

Today, you can walk or cycle along this unique parcel of bushland as it winds through a densely populated area of Western Sydney, and spot many reminders of the ground-breaking Upper Nepean Scheme and its Lower Canal.

Arthur Streeton's 1895 painting of the magnificent new Prospect Reservoir. The painting is now part of the NSW Art Gallery's collection.

Prospect Reservoir – the centrepiece

Prospect Reservoir was the centrepiece of the Upper Nepean Scheme when completed in 1888. After travelling 64 kilometres from Pheasants Nest Weir, water emptied into the giant new 50,000 megalitre reservoir.

Located 35 kilometres west of the city, Prospect's elevation meant that water could continue to flow by gravity all the way to Crown Street Reservoir in the city.

Prospect was the first earth fill and rock embankment dam in Australia, and is still large by today's standards. The top of the embankment was raised by half a metre in 1898.

The embankment is 26 metres high and 2.2 kilometres long. It consists of a clay core with shoulders of compacted earth placed in layers 30 centimetres thick, and compacted by rolling.

A stone roller of a type used in engineering works of bygone days was used to compact the earth. Made from volcanic stone and built in sections with an irregular circumference, a team of 10 horses was needed to pull the roller.

Known as Pincott's roller, it is on display in the grounds of Prospect Reservoir.

NOTE: Prospect Reservoir grounds will be closed to the public during the SCA's dam upgrade works from 1 September 2013 to December 2014. These works will ensure the dam meets the highest standards of safety and continues to provide flexibility for Sydney's water supply.

The 22 arches of the spectacular Boothtown aqueduct still stand today in Greystanes and is a reminder of the former Lower Canal.

Changes over time

Features of the 1888 scheme

- **Pheasants Nest Weir** – 3 metre high weir just below the junction of the Cordeaux and Nepean rivers.
- **Nepean Tunnel** – 7km tunnel from the Nepean River under the town of Wilton to the Cataract River at Broughtons Pass.
- **Broughtons Pass Weir** – 3.5 metre high weir across the Cataract River.
- **Cataract Tunnel** – 3km tunnel from Broughtons Pass Weir to Brooks Point, near Appin.
- **Upper Canal** – 64 kms of canals, tunnels and aqueducts to Prospect Reservoir.
- **Prospect Reservoir** – Australia's first earth fill and rock embankment dam, designed to store 50,000 megalitres of water at Prospect, 35km west of the city.
- **Lower Canal** – 7.7 km canal from Prospect Reservoir to a basin at Guildford, known as Pipe Head, where Nepean water is connected to the city's water supply system.
- **Potts Hill Reservoir** – service reservoir built near Bankstown.
- **Petersham Reservoir** – reservoir capacity increased from 3.6 to 9 megalitres.

Damaged photo from circa 1888 showing some of the surveying instruments used to mark out the route of the Upper Nepean Scheme.

Expansion of the scheme (1902-1935)

A Royal Commission after the Federation drought of 1901-02 recommends expansion of the Upper Nepean Scheme. Four dams are built above the original two weirs which do not alter the way the scheme works – they simply increase the amount of water the scheme can reliably supply, by storing water in upstream dams rather than relying solely on river flows.

Cataract Dam 1902-07
Created by damming the Cataract River, Cataract was the first of the four Upper Nepean dams. Together with Cordeaux Dam, Cataract supplies water to Camden, Campbelltown and Wollondilly council areas via the Macarthur water filtration plant as well as Prospect Reservoir.

Cordeaux Dam 1918-26
Created by damming the Cordeaux River, Cordeaux was the second of four Upper Nepean dams. Together with Cataract Dam, Cordeaux supplies the Camden, Campbelltown and Wollondilly council areas via the Macarthur water filtration plant as well as Prospect Reservoir.

Avon Dam 1921-28
Created by damming the Avon River, Avon was the third and largest of the four Upper Nepean dams. Today, it's main role is to supply the Illawarra region.

Nepean Dam 1925-35
Created by damming the Nepean River, Nepean was the last and smallest of the four Upper Nepean dams, but it has the largest catchment. Today it supplies nearby Bargo, Thirlmere, Picton and The Oaks, as well as the Macarthur and Prospect water filtration plants.

Cataract Dam, built by 1907 to expand the Upper Nepean Scheme.
(Photo: A Hollingsworth)

Improvements and maintenance (1935 to today)

The main features of the Upper Nepean Scheme continue to operate today just as they were designed.

To meet modern dam safety standards, Prospect Reservoir and the four Upper Nepean dams were upgraded between the 1970s and the 1990s. A tunnel linking Avon and Nepean dams, to enable the transfer of water between dams in either direction, was completed in 1973.

In 2008 a $56 million Raw Water Pumping Station was built at Prospect Reservoir to create greater flexibility in Sydney's water supply and to access an additional 28,000 million litres from the reservoir.

In the second half of 2013 the Sydney Catchment Authority will commence Stage 1 of rehabilitation works for the canal worth $9 million. This project aims to reduce risks of failure for such an important piece of water supply infrastructure. Works will stabilise sections of the canal wall where it is vulnerable, increase security fencing, improve local stormwater management, upgrade maintenance access, rehabilitate inlet and outlet points on the aquaducts and install new penstocks, which control the flow of waters.

These works will ensure the reliable supply of Upper Nepean water to Sydney into the future.