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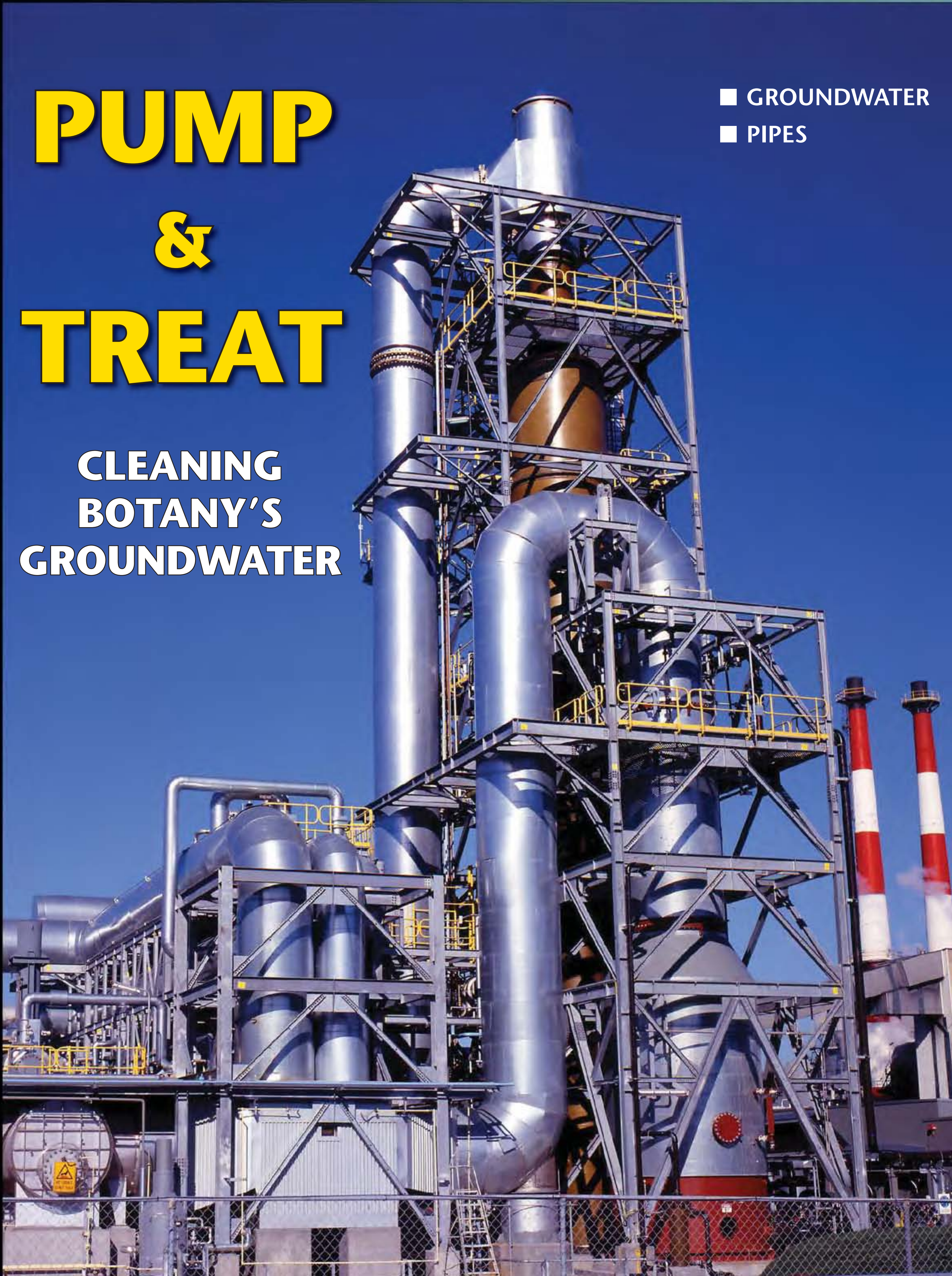
CLEANING BOTANY'S GROUNDWATER



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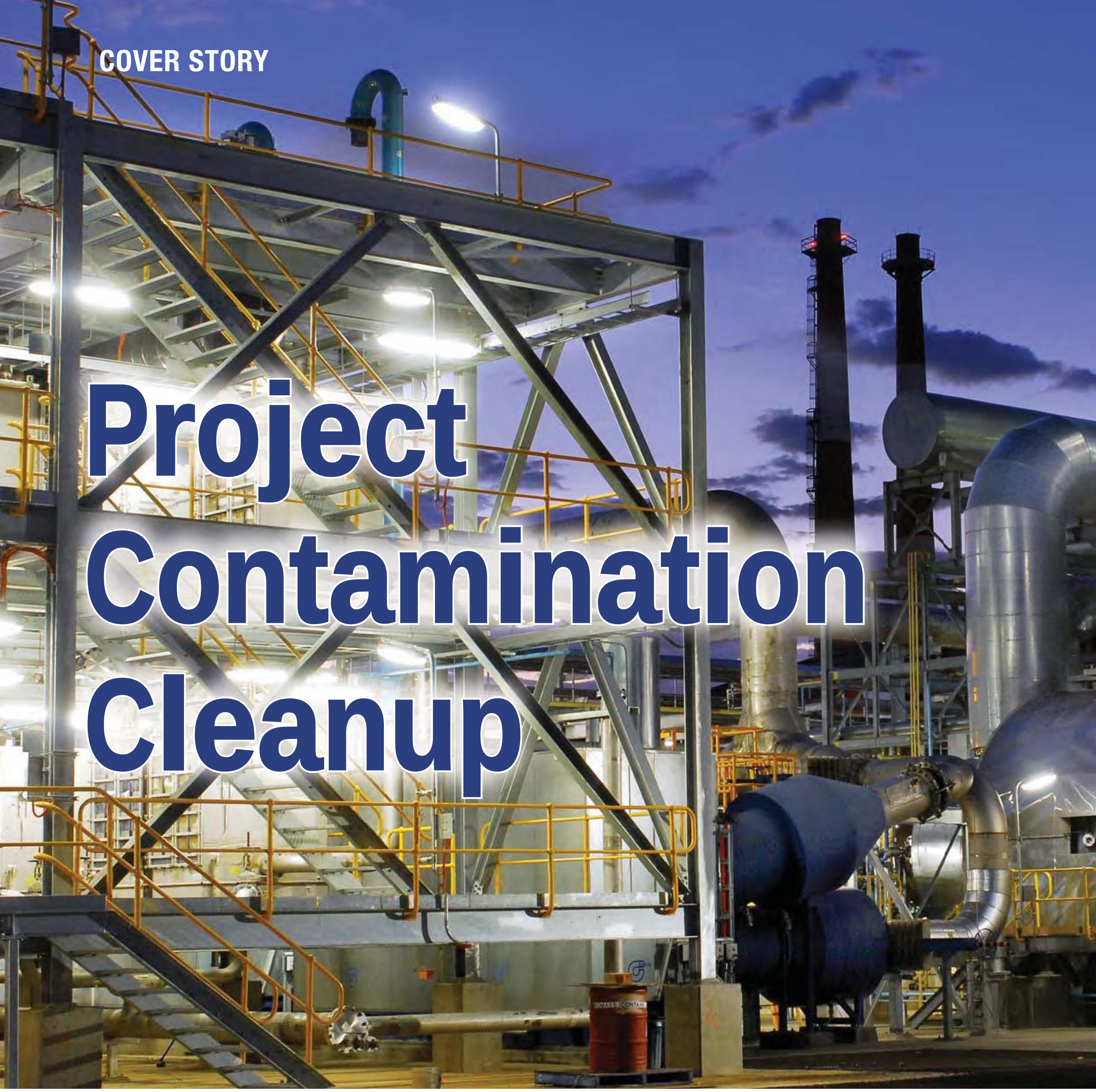

Project Contamination Cleanup

By James Stening, James Fairweather and John Lear

One of Australia's largest groundwater "pump and treat" projects continues at the Botany Industrial Park (BIP) in Sydney. It is an ongoing project that is treating an average of 5ML/d of contaminated groundwater and using the end-product for reuse purposes around the industrial estate, taking demand off Sydney's valuable potable supply.

This is an edit of the paper "The hitchhikers guide to Orica's Botany Groundwater cleanup project" *presented by James Stening at the International Association of Hydrological Sciences conference Groundwater Quality 2007 (GQ07) in December. For more information contact james.stening@orica.com.*

The groundwater treatment plant lights up the site in Botany Industrial Park.

In August 2003, NSW EPA issued a Notice of Clean Up Action (NCUA), which required Orica to develop a groundwater cleanup plan for a site where Orica and its predecessor (ICI Australia) had manufactured chlorinated hydrocarbons (CHCs) from 1945 to 2000.

The cleanup plan originally included development of full-scale bioremediation and hydraulic containment/ex situ treatment ("pump and treat") projects in parallel. However, bioremediation field trials were not concluded in time and did not provide a sufficient level of confidence to enable immediate deployment to meet NCUA requirements. Therefore it was decided in the second quarter of 2004 to only implement the "pump and treat" projects for contaminant containment.

The main part of the Orica Botany Groundwater Cleanup Plan has involved the construction of three hydraulic extraction containment lines which supply groundwater to a specialised plant, constructed to treat the groundwater to meet the most demanding of Australian drinking water and ANZECC marine water quality requirements. The plant was designed to treat the extracted groundwater by removing the dissolved CHC contamination.

One hydraulic extraction line was situated to contain source areas onsite and prevent further contaminant migration, a second line aimed to intercept major contaminant plumes and prevent further contaminant migration, and the third, to limit discharge to Penrhyn Estuary and Botany Bay.

Due to NCUA deadlines, engineering design began in parallel with completion of hydraulic modelling and estimation of associated contaminant data to establish treatment plant feed specifications. Hydraulic modelling of the lower part of the Botany Basin was completed by Dr Noel Merrick (UTS) to define the location, depth and extraction rates required for the extraction well field. The treatment plant capacity was determined to operate at 15ML/d.

Orica then built a $110 million extraction well network and Groundwater Treatment Plant (GTP) to extract and treat contaminated groundwater and produce high quality water for reuse. It took less than two years to design and build the plant – commissioning commenced in late 2005 and groundwater was first introduced to the plant in January 2006. The GTP has a capacity to treat up to 15ML/d and is designed to operate for 30 years.

The GTP plays an essential role in Orica's Botany Groundwater Treatment Project.

The contaminated groundwater is extracted from the three containment areas which are equipped with multiple extraction wells (113 in total) to pump water from the shallow, intermediate and deep aquifers. Extracted groundwater is pumped through the containment pipelines and enters the GTP feed tank where it is blended and dosed with hydrochloric acid, added to minimise mineral scaling in the air strippers.

It is then pumped through the air stripping units, where the volatile CHCs are removed. The air stripping units remove contaminants from the groundwater by blowing air through a falling column of groundwater in a closed structure called a stripping column. This process results in an air stream containing gaseous CHCs, and stripped water with negligible concentration of volatile CHCs.

The removed CHCs are blown through a thermal oxidiser at a temperature around 900°C, and are destroyed. The unit previously operated at a higher temperature, however in order to optimise GTP operation and reduce the amount of greenhouse gas produced in the operation, Orica successfully conducted trials to reduce the temperature from 1000°C to between 875°C and 900°C last September. The Department of Environment and Climate Change (DECC) consequently amended the Environment Protection Licence last November with a new lowest operating temperature limit of 875°C.

The combustion products are principally carbon dioxide, water vapour and hydrogen chloride. The hot gas passes through a waste heat boiler and energy recovery heat exchanger before passing through a quench tower to rapidly drop the gas temperature and avoid dioxin formation. It also passes through a hydrochloric acid absorber and caustic scrubber to remove acid gases. Prior to the release of air from the stack, the cleaned gas is mixed with a hot

Determining the extent of the contaminant plumes

The Botany Industrial Park is located about 10km south of Sydney's central business district and about 1500m hydraulically up-gradient (northeast) of Botany Bay.

The Botany Sands aquifer is a high yielding, and generally good quality water resource. The lithology of the aquifer in the lower reaches consists of fill, windblown sands intercalated with discontiguous peat layers, and a generally competent clayey sand layer overlying Hawkesbury sandstone bedrock. Depth of the aquifer is in the range 20m to 40m. Depth to groundwater is low within the contaminated plumes, ranging from 1m to approximately 10m below ground surface, and generally around 4m to 6m below ground surface. Hydraulic conductivity of the aquifer is high, generally in the range 10m/d to 40m/d, which combined with a high groundwater velocity of 100m/d to 150m/d results in high groundwater flux, high CHC mass flux and a relatively rapid spread of groundwater contamination.

Due to its high yield, the Botany Sands aquifer has historically been heavily exploited for industrial water supply, particularly from the 1940s to the 1980s. This practice had been found by Dr Noel Merrick in 1998 to have significantly influenced the spread of contamination, as well as dropping the water table below sea level at times when pumping was particularly heavy.

Orica and its predecessor (ICI Australia) manufactured chlorinated hydrocarbons (CHCs) at Botany from 1945 to 2000. Major CHCs included carbon tetrachloride (CTC), trichloroethene (TCE), tetrachloroethene (PCE), 1,2-dichloroethane (ethylene dichloride – EDC – an intermediate in vinyl chloride manufacture) and vinyl chloride (VC, itself an intermediate in the manufacture of polyvinyl chloride – PVC). Many byproduct wastes were produced, particularly from production of EDC and CTC/PCE. Whilst some of the wastes were reprocessed on site, there was a significant legacy of drummed waste following progressive closure of CHC manufacture.

Material from these manufacturing operations potentially entered the subsurface (soil and groundwater) through many routes, including direct discharge of wastes – having started up during World War II, there was no connection of the site effluent system to the sewer until the late 1950s and trade waste from the CHC manufacturing plants was directed into an unlined stormwater channel or ponds until then; EDC storage tank leak (a slow leak from the floor of a tank on a ring beam foundation went undiscovered for an unknown number of years); plant operations – spills, leaks from underground drains and effluent pits; and storage of drummed byproduct wastes at many locations on BIP.

Numerous groundwater plumes have evolved from up to nine identified or inferred source areas. CHC properties relevant to plume development include the fact that they are denser than water – they sink through groundwater to impermeable layers; have low solubility in water; many sorb strongly to organic matter; and have a wide range of contaminant mobility.

The plumes are grouped into three specific areas.

The Southern Plumes (S1 to S3) generally comprise CTC, PCE, TCE, EDC, Heavy Ends (byproducts from manufacture of CTC/PCE, including HCB and HCBD) and their daughter degradation products including VC. Total CHC concentrations in these plumes are up to 1000mg/L. The plumes extend from BIP to Botany Bay. Their origins are associated with former CTC, PCE and TCE production.

The second group is known as the Central Plume (C1) and contains the largest contaminant concentrations and contaminant mass, comprising primarily EDC, with lower concentrations of TCE, VC and other daughter degradation products. This plume originates from a leak from an EDC storage tank, mobilised during field investigations in the mid-1990s, and commingles with contamination from other sources from production of EDC and VC. Total CHC concentrations of up to 7000mg/L are measured in this plume, which extends from BIP to close to Botany Bay.

The third, the Northern Plumes (N1 to N5) originate from a number of unsealed drum storage areas spread over the northern parts of BIP. Total CHC concentrations in these plumes are up to 2500mg/L, but are generally below 100mg/L. These plumes extend large distances towards Botany Bay, and partially underflow residential areas.

Other sources of CHC and non-CHC contamination, not associated with Orica's former operations at BIP, have also been identified or inferred in the Botany aquifer. These are associated with other former/ongoing industrial/commercial use.

Plant layout during construction.

The extraction wells pump water from the shallow, intermediate and deep aquifers, thereby containing the contaminated groundwater within three areas.

air steam to improve dispersion and reduce plume visibility.

Groundwater "stripped" of volatile CHCs (stripped groundwater) is treated further in the stripped groundwater treatment section of the GTP to remove iron, aluminium, residual organics, organic acids and ammonia through various sets of filters.

First, the stripped groundwater is pumped to an Actiflo unit where sodium hydroxide and flocculating agents are dosed, and iron and aluminium are removed by precipitation and flocculation. Then, the water passes through multimedia filters (sand and anthracite filtration) before going through granular activated carbon (GAC) to remove non-volatile compounds, such as phenol and chlorinated phenols. The water is dosed with chloramine to suppress biological fouling and then passes through a second bank of multimedia filters. At the final stage, the water is pumped through two sets of reverse osmosis (RO) units to remove salt and other impurities to yield high quality recycled water suitable for industrial reuse. The salty reject stream from the RO units is discharged to sewer.

The final treated water gets either reused by neighbouring industries or discharged to a stormwater canal, which then flows into Botany Bay. The excess discharged treated water is dosed with sodium metabisulfite to chemically remove chloramine from the water before discharging. This last stage was required because, although chloramine is a common disinfectant found in drinking water that has no health risks to humans, it may be toxic to aquatic life.

In March 2007, the GTP entered its fully operational phase and currently treats groundwater at an average rate in excess of 5ML/d. The actual daily treated volume is lower than the plant's design capacity as the Botany area's average groundwater flow rates were later found to be lower than what was initially used in the design model. By pumping at an average rate of over 5ML/d from the containment areas, Orica achieves hydraulic containment of the contaminated groundwater. At times of high rainfall the GTP treats up to 7ML/d.

The plant continues to play its part in containing the contaminated groundwater and is currently supplying six local factories with high quality treated water, replacing demand on Sydney's potable water supply.

This project has required a remarkable multi-disciplinary team effort from Orica's permanent and contract project staff (corporate management, environmental, engineering, technical, operational, approvals management, legal, communications, government relations), Orica's key consultants (notably URS Australia, Dr Noel Merrick of accessUTS, Al Laase of AD Laase Hydrologic Consulting) and Orica's engineering contractors (especially Aker Kvaerner and Kellogg, Brown and Root).

The support of the DECC and the NSW Department of Planning in recognising at the outset the special approval needs of this project, and assisting with development of appropriate mechanisms and allocating necessary resources to expedite required approvals, is also acknowledged. As is the DECC's support in working through commissioning and early operational issues. Other regulatory agencies and landowners were also generally supportive of Orica's fast-track project needs and reasonable in their approval demands. ●