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MAKING WATER

Desalination: option or distraction for a thirsty world?

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Making water

Option or distraction for a thirsty world

Seawater desalination is rapidily emerging as one of the major new sources of freshwater for the developed and some areas of the developing world, raising significantly the overall energy intensity, potential climate impact and cost of water supplies. This dramatic upscaling of the industry is occurring against a backdrop of unresolved questions on the potential environmental impacts of large scale processing of seawater habitat and the discharge of increasing volumes of concentrated brine wastes. WWF is concerned that as large desalination plants become "the new dams" attention is being diverted from less costly and more environmentally benign alternatives – water conservation, water use efficiency improvements and water recycling. WWF believes that better economic and environmental outcomes would flow from improved and consistent processes to assess water needs and the optimum mix of both supply and demand side measures that could be deployed to meet them. Where seawater desalination is established to be a part of meeting a real water need in the most cost effective and least damaging way, desalination plants need to be sited, constructed and operated to best minimise or mitigate their environmental impacts.

As the world increasingly comes to the realisation that a combination of population increases, development demands and climate change means that freshwater will be in chronically short supply in rich and poor areas of the world alike, there is increasing interest in desalination as a technique for tapping into the vast and infinitely tempting water supplies of the sea.

This is no new dream, and it has been technically possible to separate the salt and the water for centuries. But widespread desalination for the purpose of general water supply for land-based communities has been limited by its great expense and it is notable that the area where desalination currently makes by far the greatest contribution to urban water supplies is in the oil-rich and water poor States around the Persian Gulf.

Now, however, improvements in the technology of desalination, coupled with the rising cost and increasing unreliability of traditional water supplies, are bringing desalinated water into more focus as a general water supply option with major plants in operation, in planning or under consideration in Europe, North Africa, North America, Australia, China and India among others.

In 2004, it was estimated that seawater desalination capacity would increase 101 per percent by 2015, an addition of an additional 31 million m3 a day. The dominant membrane based technologies would also be used extensively in desalinating brackish waters and recycling water generally. But these forecasts, regarded as bold at the time, seem certain to be exceeded by wide margins. In one example, the forecast was for China and India to be desalinating 650,000 m3/day by 2015, but China alone has recently announced plans to be desalinating 1 million m3 of seawater a day by 2010 increasing to 3 million m3 a day by 2020.

But those who look to desalination as the future panacea to the world's water problems may be glossing over considerable environmental, economic and social difficulties. Despite improved techologies and reduced costs, desalinated water remains highly expensive and sensitive in particular to increases in energy costs. Our knowledge of impacts is largely based on limited research from relatively small plants operating in relative isolation from each other. The future being indicated by public water authorities and the desalination industry is of ever larger plants that will frequently be clustered together in the relatively sensitive coastal environments that most attract extensive settlement.

The difficulties are both direct and indirect, but they warrant closer attention than they seem to be receiving from some of the desalination industry's most enthusiastic proponents and some of the regulatory bodies currently considering large scale desalination.

Direct problems include the still significant problem of cost, the pollution emitted by desalination plants and the energy they consume. Seawater, it has been pointed out, is also habitat. The larvae and small organisms most vulnerable to disappearing up a poorly designed desalination plant inlet pipe play key roles in marine ecosystems. And our knowledge of the impacts and behaviours of the concentrated brines and diverse other chemicals issuing from the outlet pipe is far from comprehensive, both generally and in relation to particular sites.

There are also serious greenhouse gas emission implications in driving the energy intensive plants, which could thereby contribute a key driving factor behind the looming chronic water shortages in many of the areas where desalination is being actively considered.

Less directly, the quite possibly mistaken lure of widespread water availability from desalination also has the potential to drive a major misdirection of public attention, policy and funds away from the pressing need to use all water wisely. Desalination in these terms is firmly in the long established tradition of large infrastructure supply side solutions to an issue in which the demand side of the equation is usually poorly considered – as are the needs of the environment and the people who might be in the way.

There is also the question of equity to consider. Desalination through its cost and technical requirements is likely to be mainly used in addressing the water worries of the already wealthy. There are few indications that a growing desalination industry left to its own devices will pay much attention to the more pressing water needs of the many people in developing nations living in arid areas with brackish or contaminated groundwater supplies. This may be an issue of particular importance to the many millions living in areas of developed countries where overdrawing of groundwaters has allowed the oxidation and mobilisation of dangerous soil elements such as arsenic and flourides. The reverse osmosis membrane technologies used increasingly in desalination have been used successfully in a limited way in parts of India to remove dangerous contaminants from rural drinking water – there are clear humanitarian reasons to deploy the technology much more widely.

Reverse osmosis membrane technologies have great potential for increasing water use efficiency through recycling, for decontaminating water and for environmental repair through purifying or providing water for such purposes as rejuvenating wetlands, augmenting streamflows and recharging aquifers. Manufacturing or recycling water can also relieve the pressure on overstressed natural water sources, allowing them the opportunity for recovery. Indeed as the economic and energy costs of manufacturing water are closely related to the level of contaminants, desalination of seawater is commonly more expensive than desalination of brackish water or treatment and recycling of waste water.

The considered view of WWF is that seawater desalination has a limited place in water supply, which needs to be considered on a case by case basis in line with integrated approaches to the management of water supply and demand. Central to such an approach is the protection of the natural assets of catchments, rivers, floodplains, lakes, wetlands, aquifers and vapour flows which ultimately provide, store, supply, and purify water and provide the best and most comprehensive protection against extreme or catastrophic events.

Given the rapidly occurring convergence of technologies seawater is best regarded as just one of a number of potential feedstocks for an end product of “manufactured water”. Manufactured water, particularly that sourced from waste waters, can play a significant role in supplying water while reducing pressure on natural systems.

To that end, WWF proposes an approach similar to that recommended for large dams by the World Commission on Dams that says that proponents should first assess the need and then consider all options to select the best solution. Desalination plants, accordingly, should only be constructed where they are found to meet a genuine need to increase water supply and are the best and least damaging method of augmenting water supply, after a process which is open, exhaustive, and fully transparent and in which all alternatives, especially demand side and pollution control measures, are properly considered and fairly costed in their environmental, economic and social impacts.

WWF is calling on governments, financing agencies and relevant areas and peak bodies of the water industry to work to endorse and help develop specific protocols that start from these premises. We also note that we are not alone in this. The prestigious Pacific Institute made recommendations to this general effect in relation to California and similar comments have been made to the industry by a senior World Bank official.

Desalination – a current summary

WWF's survey of world desalination trends shows that while desalination capacity is mounting, so are the related problems and awareness of possible environmental impacts. Developments in specific areas are covered in more detail later in this report.

In **the Middle East** large scale desalination from some of the world's saltiest and more enclosed seas has long been a necessary component of water supplies and is becoming more so as the scale of contamination and depletion of groundwater supplies becomes apparent. The area continues to be a major focus of new desalination investment along with a swathe of new entrants in **North Africa.** The water continues to be heavily subsidised for the majority of users for economic and social reasons, and the proportion of agricultural use is high in some areas. The capital and energy requirements of soaring water demand are challenging to the area, even for nations like Saudi Arabia and Israel. Despite the region's abundant supplies of conventional energy sources, nuclear power is being actively canvassed as an option for meeting future water supply needs.

In **the United States**, a dramatic increase in proposed seawater desalination projects is running into increasing opposition on environmental and cost grounds, not helped by the well publicised difficulties experienced in bringing some much vaunted new generation projects on-line. Government agencies hold that desalination is necessary for the high growth, water poor areas of the south and west, but also concede it is generally uneconomic. While municipalities lobby for increased federal funds, the former head of California's inquiry into desalination is now arguing there are better, cheaper, and more environmentally benign ways of ensuring water security in the State.

Spain's long experience with desalination has given Spanish companies a prominent role in the world desalination industry. The abandonment of large scale but controversial plans to transfer water from the wetter to drier areas of the country has fuelled proposals for a rapid doubling of its already considerable desalination capacity to make up the shortfall. But while other countries struggle to reconcile the high cost of desalinated water to urban water users, plans are approved to devote an astonishing and increasing proportion of Spain's desalinated water to agriculture. These plans are running into difficulties in getting agriculture to take (and pay for) desalinated water supplies while there is groundwater left, even if it is illegal to pump it. Spain's real problems however lie in a lack of effective development controls in high growth but dry areas and inefficiently controlled water use generally. The country is perhaps a leading first world example of how a long history of investments in water supply infrastructure has failed to provide water security.

As major **Australian** cities face an increasingly tenuous water future its first large scale desalination plant is now operating in one State, two other States are going ahead with large plants and two further states are considering desalination options. But while conditions are relatively favorable to expanding desalination capacity and while it could build needed diversification into water supply systems, water conservation in the driest continent still has a long way to go and would be a better priority in many areas.

In the **UK,** London's major water supplier – part of a conglomerate that includes a major Spanish desalination industry player - believes a major desalination plant is a key requirement for future water supplies but the city's mayor disagrees, castigating the company for losing vast quantities of water through leaking mains. The issue of the plant's approval has been before a planning tribunal. However, the cost of desalinating seawater is generally deterring some other UK water authorities that have examined the issue. Studies show UK citizens using considerably more water than continental Europeans in an equivalent climate, indicating considerable potential remains in cost effective conservation and efficiency measures.

Significant actual and looming water shortages have led **China** into a rush to develop large scale desalination to complement existing massive plans to divert water from the south to the north of the country. On a slightly lesser scale and with a greater component of nuclear desalination, the same is happening in **India**. But the growth in water decontaminating capacity is generally not extending to the extensive areas in India and south and south east Asia where arsenic and flouride contamination of water is a major health and humanitarian issue. In both countries, optimistic and recent world wide industry investment projections from only a few years ago look certain to be exceeded several fold and China is gearing up to potentially challenge the US, French and Spanish domination of desalination equipment and infrastructure provision.

WWF position on desalination

The considered view of WWF is that seawater desalination has a limited place in water supply, which needs to be considered on a case by case basis in line with integrated approaches to the management of water supply and demand. Central to such an approach is the protection of the natural assets of catchments, rivers, floodplains, lakes, wetlands, aquifers and vapour flows which ultimately provide, store, supply, and purify water and provide the best and most comprehensive protection against extreme or catastrophic events.

Resource planning *before* large infrastructure planning

Better water resource planning and management should precede major water infrastructure developments of any sort, including desalination and other water manufacturing plants. Seawater desalination plants will need additional consideration in the context of marine resource management plans. The need to increase water supplies, as opposed to reducing demand, must be justified before assessing the best options for doing so. If enabling industry, irrigated agriculture or urban growth is advanced as the principal reason for the need to increase supplies, it is essential that effective land use planning schemes exist in which sustainability is given a high priority. These should include optimum and mandatory water and energy efficiency requirements for all new development.

Consultative and transparent assessment for large scale infrastructure

Assessment of major water infrastructure, including desalination plants, should be comprehensive, consultative and transparent. All alternative means of supply should receive equitable consideration, including especially gains from water efficiency and conservation measures, water recycling and supporting the functioning of natural water supply systems. Desalination is most properly regarded as one of a number of related processes using increasingly similar technologies to produce "manufactured water". Decision makers need to consider the overall role for manufactured water and various possible options for manufacturing water before considering desalination possibilities. Manufacturing water through the recycling of wastewater is commonly both economically and environmentally superior to desalinating seawater.

Minimising environmental impacts of large scale desalination plants

Desalination plants should be sited, planned and operated to minimise environmental impacts. The design of intake systems should proceed from the premise that seawater is also habitat. Outflows for concentrated brines need to avoid sensitive marine areas and incorporate adequate dilution, mixing and dispersal elements. Where possible, effluent flows should be reduced to "zero spill" solid wastes for safe storage or possible use. Adequate impact monitoring against assessed baselines should be mandatory.

Climate-neutral desalination

Desalination plants need to be designed to be climate neutral, obtaining 100 percent of their considerable energy needs from additional renewable energy, green energy purchases or through Gold Standard carbon offsets and taking maximum advantage of evolving energy efficiency and energy recovery technologies.

Subsidy-free desalination

No subsidies should be applied to the price of desalinated water, to avoid market distortions that would reduce incentives to conserve and use water efficiently. Where subsidies are thought necessary for social reasons they should be applied transparently in ways that do not impact on water prices.

Consider the downstream effects

Decisions on desalination plants need to consider "downstream effects" which can include support of unsustainable or environmentally damaging development such as water wasting irrigated agricultural or tourism developments, or support for outdated and environmentally damaging power generation technologies.

Address the research gaps

The research base on the cumulative environmental impacts of large scale desalination is clearly inadequate. Research is needed particularly on the long term consequences of intake structures on concentrations of small marine organisms, on behaviour and impacts of concentrated brines and on impacts of diverse other chemicals including biocides and anti-fouling treatments. Further research may improve the prospects for finding economic uses for for brine wastes.

The Freshwater Crisis

There is growing realisation that much of the world is now facing or will soon face chronic shortages of the freshwater without which life is not possible. Nor is this an issue solely for the developing world, where it is estimated that 1.1 billion people are currently forced to live without adequate water supplies and more than twice that number without adequate sanitation. Some first world cities have clearly hit crisis levels with their water supplies and many if not most others are facing difficult choices on securing their future water supplies in the immediately forseeable future.

A lack of a commodity as basic as water has a cascade of effects elsewhere. As WWF recently noted in the report Rich Countries, Poor Water : “From Seville to Sacremento to Sydney, water is now a key – sometimes the key - political issue at the local, regional and national level.” Whole industries and cities which have grown up on the premise of abundant and cheap water are now finding that neither is the case. Dramatic increases in the cost of so basic a commodity are impacting on the whole economy and will do so increasingly in the future.

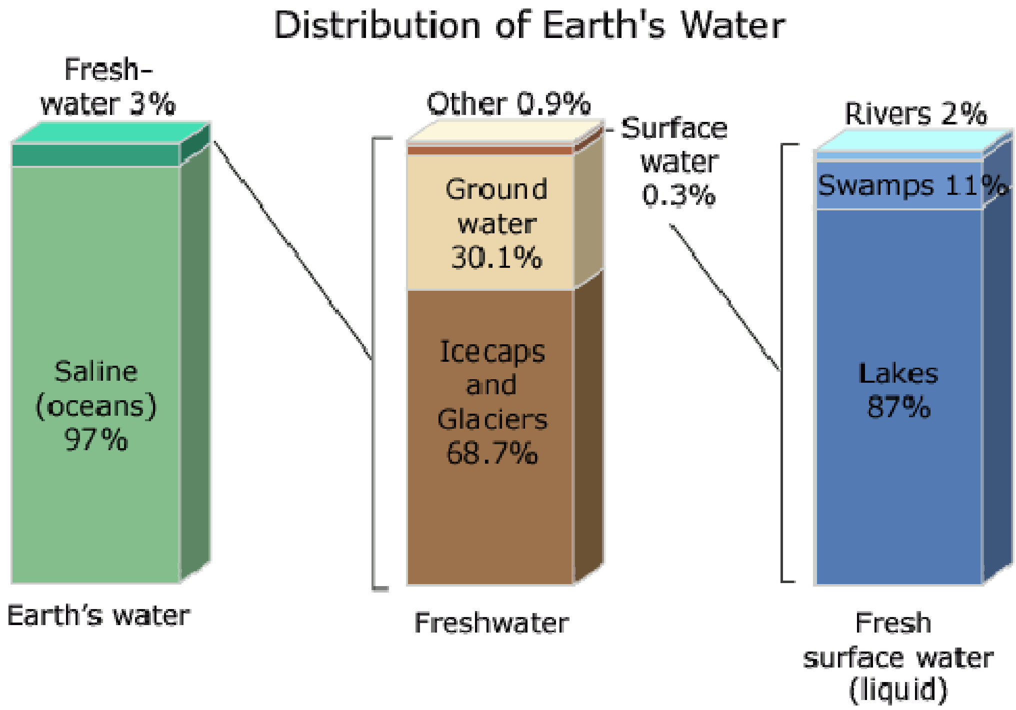
There is increased interest also in the highly contentious issue of how much of the water needed by the poorest of the poor is being eaten, worn or otherwise consumed by the world's wealthy in the form of the “virtual water” embodied in food, fibre and even jewellry. A cotton T-shirt for instance - even one with an ecologically friendly message – is the product of 4100 litres of water from someone else's river system or aquifer.

The health of the river systems and aquifers is also forcing its way to the forefront of public consciousness as whole landscapes lose their ability to absorb, provide and purify water. This not only threatens water supplies but also increases risks and impacts associated with pest species, disease vectors and catastrophic weather events. The environment, we now know to our cost, must also have its share of available water.

Also, and perhaps even more ominously, humanity in recent decades has made unprecedented alterations to global hydrological cycles that we barely understand – dramatically reducing the flow of rivers, plundering ancient groundwater supplies, and disrupting vapour and sediment flows. Scientists are still trying to work out what this might mean, with some predicting the consequences may rival and will worsen the adverse climate consequences of unintended and uninformed human changes to the composition of the atmosphere.[1]

Water, water everywhere. Nor any drop to drink

It is hardly surprising then that looming shortages of freshwater have encouraged many to look more seriously to where the overwhelming majority of the water is – the sea, source of the famous lament “Water, water everywhere. Nor any drop to drink”[2]. It has been technically possible to take the water and leave the salt ever since seawater was boiled in one vessel and the vapour condensed into another. The water produced this way is too pure for human health and is commonly remineralised to some degree for human consumption mainly by being mixed with other water supplies in the supply chain.



U.S. Geological Survey
http://ga.water.usgs.gov/edu/waterdistribution.html

In addition to the sea, there is a potential water supply in vast reserves of naturally brackish ground and surface water. Indeed, the lower concentration of salts means that the desalination of brackish water is often a more economic desalination proposition than pure seawater. As well, there are large reserves and flows of water that have been contaminated by human activity or use, with irrigation being the main contaminating activity and salt being the most significant contaminant.

In some areas, drainage works or excessive draw down of ground waters have meant that common but fixed soil elements are subject to oxidation and mobilisation within the soil profile. This can contaminate surface and groundwaters with significant concentrations of acids and elements such as iron, copper, arsenic and flouride. These contaminants can also be associated with water brackishness, particularly in arid areas. Such contaminated waters are a serious health and humanitarian issue in some soutern and southeastern Asian countries where excessive wells were sunk on the advice of and with the assistance of aid agencies.

The revolution in manufactured water

Water and waste water treatment are now well established technologies that have arguably made greater contributions to human health than most medical breatkthroughs. Making water, while technically possible, was historically mainly restricted to ships, islands and particular applications where very pure water was required. As the process relied on boiling water, energy use was significant and the costs of large scale water manufacturing prohibitive. The costs could be reduced by combining water production with other processes producing heat, with the most common pairing being combined power generation and brackish or seawater desalination. Even with some technical innovations such as using multiple chambers and lowering pressure so water boiled at temperatures as low as 45° C, large scale thermal water desalination has been almost entirely restricted to the wealthy, energy rich and water poor countries surrounding the Arabian Gulf.

Large scale desalination's move beyond the Arabian Gulf is occuring not only due to increased water shortages in other wealthy areas but also to a revolution in membrane technologies which has dramatically lowered the cost of desalination. But the same revolution is transforming water decontamination generally and providing a boost to water recycling. Essentially, water can now be manufactured from a variety of feedstocks from wastewater to seawater using the same basic technologies and processes. Manifestations of this technical convergence are rapidly beginning to mount, from industry giants such as Veolia Water trading on their general water competence and the US municipal desalination lobby - the US Desalination Coalition - transforming itself recently into the New Water Supply Coalition to "seek congressional support for the development of new water supply projects nationwide including water recycling, seawater and brackish groundwater desalination and groundwater reclamation projects".[3]

The cost and complexity is related to the number, variety and concentration of contaminants in the feedstock and the required level of treatment. Borrowing terms from waste water treatment, levels of treatment are being described as primary, secondary and tertiary, with tertiary treated "manufactured water" being, for all practical purposes, pure water.

More and more a matter of membranes

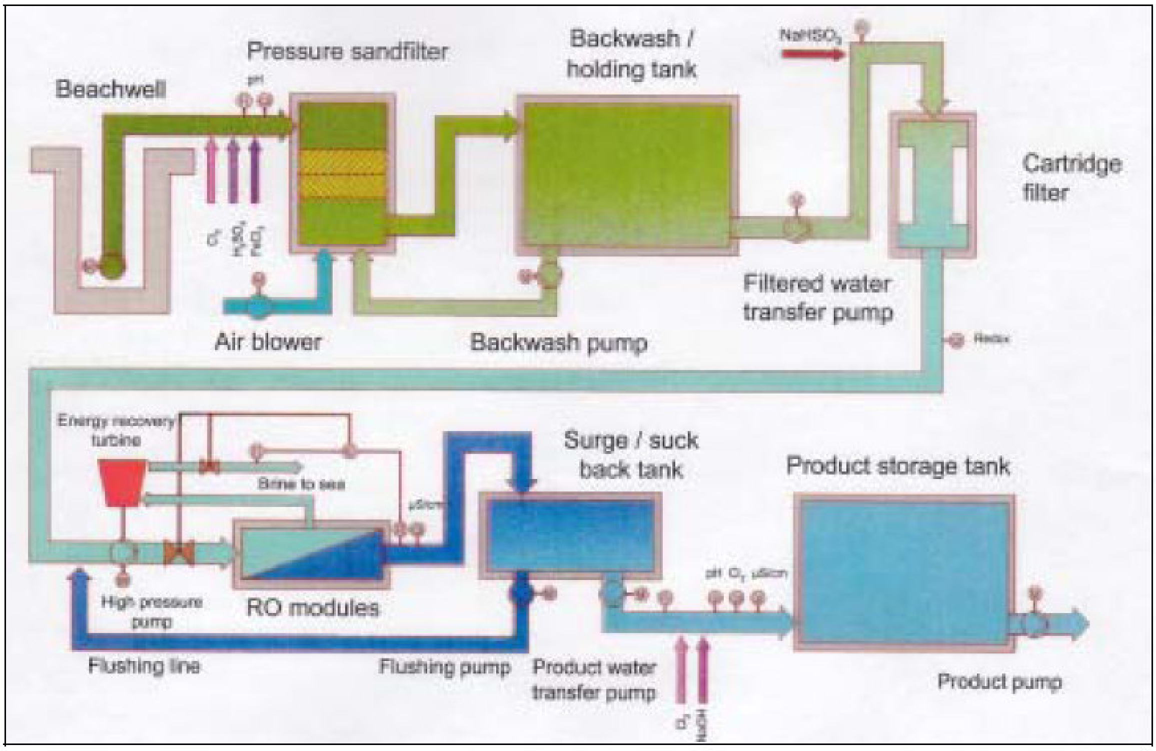
Historically, desalinated water was derived from thermal processes. This can be done on a large scale and produces the highest quality output water but energy costs are high. In general, large scale thermal desalination is restricted to being a cooperative venture with power generation in the energy rich and water poor Arabian Gulf states, but still accounts for around 40 percent of worldwide distillation capacity. Most plants carry out the distillation in multiple chambers where pressure is manipulated to reduce the boiling temperature. Variations on this theme include the thermal distillation industry leader Multi Stage Flash (MSF), the older Multiple Effect Distillation (MED) now undergoing a modest revival, and technologies applying heat through vapor compression (VC or MVC). Low energy, low technology thermal distillation is possible using energy sources such as the sun (solar distillation), but the area required for large scale water production is generally prohibitive and facilities remote from their markets can lose any energy savings in pumping costs. However, small scale solar distillation can augment the water supplies of small communities and has been successfully trialled in Botswana.[4] Greenhouses and residential units that combine space heating with passive solar distillation of low quality water have been trialled in Spain and Germany[5].

Although large scale thermal desalination plants continue to be built in Arabian Gulf states, the great majority of the world's new and planned desalination capacity is based around the use of membranes which allow or exclude the passage of molecules between two bodies of liquid. The most significant by far of the membrane technologies is reverse osmosis (RO), now widely used in water decontamination, purification, recycling and desalination.

Osmosis is a natural process in which adjacent cells are kept in liquid chemical balance by the movement of water molecules into the more concentrated solution. The membranes used in Reverse Osmosis (RO) allow the passage of water molecules while barring the passage of salt or other contaminant molecules. In RO, pressure is applied to the concentrated solution to force freshwater molecules through the membrane. Costs increase with the level of contaminants and for the level of treatment required. RO seawater desalination remains expensive and energy intensive, but is much less so than any large scale thermal distillation. Other advantages are the modular design of the plants. Plant capacity increases are possible for increased product volumes and increased levels of treatment and it is possible and relatively common to add additional stages to the process both before and after the membrane sequences. The RO process can be utilised from the scale of small hand held and powered units to ever larger manufacturing plants. At 320,000 m3/day the world's currently largest RO facility at Ashkelon, Israel is now not far behind the world's largest desalination plant, the 455,000 m3/day MSF facility at Shuweihat in the United Arab Emirates. It is becoming increasingly common to build and commission RO desalination plants in stages – Sydney Water in Australia for instance is commissioning a 125,000 m3/day plant that can be rapidly scaled up to 500,000 m3/day; Spain is adding Carboneras 2 to Europe's current largest plant the Carboneras 1.

Another membrane-based technology is **Electrodialysis** where electrical currents are used to move charged salts through membranes. A small proportion of worldwide desalination capacity is based on this technology, mainly in smaller and specialised contexts.

Membrane distillation is a combination of thermal and membrane technologies, where water vapor, usually produced as a result of the application of low grade energy, is separated and collected through a membrane. Commercially it is of little significance.



Desalination plant configuration

Desalination: The environmental impacts

Like any large scale industrial process, making water has a number of actual or potential environmental impacts. In brief, water is extracted from a source supply on a large scale, considerable amounts of energy are used in evaporating this source water or forcing it through filters and membranes, and at the end of the process large volumes of liquid or less commonly solid waste concentrates are released. Along with issues of siting and constructing the plants these might be regarded as the direct impacts of the process. In the view of many researchers however, the key environmental issues may relate to two key indirect impacts – the greenhouse gas and other implications of the considerable energy requirements of making water, and the environmental impacts of the subsequent development enabled by the availability of manufactured water.

Manufacturing water also has some potential environmental benefits. New membrane technologies can mitigate the one way flow of water from source to human use to waste through supporting much higher rates of water recycling. Manufacturing water can reduce demands on natural water sources and the need for other damaging infrastructure such as dams and water transfers. Water manufacturing processes can also be used for environmental purposes such as treating contamination, augmenting stream flows and recharging aquifers.

Direct impacts

Water intake issues

Source waters for water manufacturing processes can vary from waste waters to contaminated brackish ground or surface waters to seawater. The concern with seawater and some other source waters are that they are also habitat for a variety of marine or aquatic life. Appropriate intake design can mitigate many of the potential impacts on larger life forms but the key long term cumulative impact may be with the removal of small life forms such as plankton, eggs and fish larvae.

Discharge issues

Anything in the source waters can be expected to show up in a more concentrated form in the discharges from water manufacturing plants, along with any chemicals added during the treatment processes or from other processes such as corrosion. There may also be thermal issues with the discharges. In the case of seawater desalination, the main discharge issues can included elevated levels of salt and other constituents of seawater such as boron, dead sea life which consumes oxygen while decomposing, chemicals added to change the composition of the water for processing and to reduce contamination and clogging of filters and membranes, corrosion byproducts and the heat added for or during processing.

Plant siting and construction issues.

Water manufacturing plants compete for land with other uses. To reduce costs, it is usually preferable to site plants near to where the water is to be used, which means they are often in areas of already intensive use where overall impacts on often sensitive environments are already high or unsustainable. These issues should be but are often not addressed during normal land use planning assessment, but a particular additional issue with water manufacturing plants is the construction of intake and outlet structures in or across sensitive coastal or marine environments.

Indirect impacts

Energy use effects

Generally, water manufacturing is a highly energy intensive process. Depending on energy sources, large scale water manufacturing therefore has the potential to add significantly to the greenhouse gas emissions held largely responsible for climate change.

Downstream effects

Water availability is a constraining influence on development in many environmentally sensitive areas around the world. Water manufacturing can reduce this constraint, promoting unsustainable levels of other development. Politically, the potential availability of manufactured water can negatively impact on efforts to conserve water, use water more efficiently and recycle waste water.

Processing habitat – intake issues

One analysis of desalination has suggested that depletion of marine life "may represent the most significant direct adverse effect of seawater desalination".[6]

These conclusions are generally drawn from experience with coastal power stations using seawater for cooling purposes. In technical terms, marine life can suffer *impingement* effects from death or injury from contact with intake structures or death from *entrainment* if they are taken into the water manufacturing process. However, the issue is difficult to study and is not well studied either generally or in relation to specific sites and proposals. A California Energy Commission (CEC) study for instance noted that:

"Only seven of the 21 coastal power plants have recent studies of entrainment impacts that meet current scientific standards; all of these recent studies have found adverse impacts of entrainment. Entrainment losses quantified in these studies are equivalent to the loss of productivity of thousands of acres of coastal habitat. Impingement impacts add to the entrainment losses because often the same species that lose early life stages to entrainment lose adults and larger juveniles to impingement."[7]

A Californian Coastal Commission study found the impacts are highly site specific and variable according to the design of intake structures. [8] From the point of view of reducing impacts to marine life, "beach wells" where seawater infiltrates through sand into the intake system is clearly preferable to all forms of open ocean intakes. However, beach wells reduce flows and the water volumes available for treatment, and are consequently not favoured by the industry for larger desalination plants. They also need careful design and construction to avoid damage to coastal aquifers. A noteworthy trial of underocean floor intake and discharge for seawater desalination is proposed for the City of Long Beach in California. Proponents hope that the demonstration system will reduce costs as well as impacts, through reducing filter and membrane flushing and cleaning requirements, plant down times and the need for chemical additives.[9]

Entrainment losses can also be reduced by not taking water from close to the ocean surface where there are the greatest concentrations of small marine life, but this increases impingement losses to economically valuable species and involves greater construction costs and damage potential.

WWF endorses the CEC view that "seawater . . . is not just water. It is habitat and contains an entire ecosystem of phytoplankton, fishes, and invertebrates." It also finds the lack of studies on this subject alarming – in contrast to the consideration given to desalination plant discharges, the issue of entrainment losses of sealife is often not raised at all or raised in a highly superficial way in the consideration of specific desalination plants. Clearly, there is a requirement that the issue of the subtraction of marine life receives more study and that the issue is specifically considered in the assessment of individual desalination plant proposals. As impacts will only manifest themselves over an extended period, approval conditions should include baseline studies and periodic reviews.

As a matter of policy, intakes should seek to minimise both construction and operation impacts on marine life. Beach well intakes are clearly preferable where feasible, but where not, feedwater intakes should be located in areas of low biological content.

Beach well/WWF Spain

The brine issue

The main waste of desalination plants is brine. Common practice with seawater desalination plants is to discharge the concentrated brine back to sea. Generally, the industry maintains this can be done safely; in reality, there is much we do not know about salinity in the oceans and perhaps more pertinently in semi-enclosed seas.

On the grand scale, NASA Oceanography is looking forward to the release in about two years of the first satellite capable of real-time world-wide measures of sea surface salinity. The Aquarius mission will in fact gather more sea surface salinity readings in its first two months of recording than have been collected in the last 125 years.

Notes the programme “few know that even small variations in Sea Surface Salinity (SSS) can have dramatic effects on the water cycle and ocean circulation. Since 86% of global evaporation and 78% of global precipitation occur over the ocean, SSS is the key variable for understanding how freshwater input and output affects ocean dynamics. By tracking SSS we can directly monitor variations in the water cycle: land runoff, sea ice freezing and melting, and evaporation and precipitation over the oceans.”[10] Indeed, sea surface salinity is regarded as a key but largely missing indicator in climate research, with NASA commenting that “Global SSS data will allow us to create unprecedented computer models that bridge ocean-atmosphere-land-ice systems, with the goal of predicting future climate conditions”.

One of the unknowns is how sensitive the ocean's salinity systems are, and whether they could ever be affected by a relentlessly growing desalination industry discharging more and more brine. But while open ocean effects might seem more in the realm of the improbable, it would seem logical to go looking for indicators in more enclosed water bodies that have been hosting extensive desalination operations for decades.

Researchers in 2000 noted that the Gulf of Aqaba was "one of the most delicate places for desalination" but "unfortunately, this region is also one of the few urban and industrial centers in the study area where the water demand is high and new plants are under preparation". The Gulf is naturally more saline than the Red Sea, which is itself more saline than the general salinity levels of the Indian Ocean. One key finding of the research from the Gulf of Aqaba suggests that organisms living in elevated salinity levels may already be living near their salinity limits.

The Arabian Gulf has some of the most threatened coral reefs in the world, with rising temperatures and high salinity levels implicated in the loss of reefs. A large proportion of global desalination capacity is located around the shores of the Gulf and this capacity is set to increase significantly. Most plants are linked power and thermal desalination plants and some local effects of outlets on reefs have been noted, but these are attributed as much to the heat as the salinity of the discharges. Although the salinity of the Gulf has been increasing and saline plumes have been associated with fish kills in the northern Gulf, desalination is only one of a number of possible contributing factors. Others include reduced river flows, coastal landworks and land use changes and oil industry discharges.

Brine output/ WWF Spain

Young plants of Posidonia oceanica © WWF-Shoreline

Some key coastal marine vegetation is known to be highly sensitive to salinity. *Posidonia oceanica* is a sea grass unique to the Mediterranean region, which forms "prairie" meadows in shallow waters near the coast. It plays a key role in the sustainability of the Mediterranean ecosystem by retaining the soil and ensuring more than one thousand different species feed and reproduce themselves. *Posidonia* prairies are listed as priority habitats under the European Union's Habitat Directives. For the *Posidonia* to thrive, two essential conditions are required: sun, for which it needs to grow in low-depth waters close to the coast, and a constant level of salinity. Unfortunately, *Posidonia* prairies have come into conflict with the rapid expansion of seawater desalination in Spain.

Conteracting brine behaviour

Concentrated brines are negatively bouyant in seawater, giving them a tendency to sink and spread along the seabottom, displacing normally saline water from hollows. This can have a devastating effect on seabottom life which impacts more broadly on the entire bay or shallows ecosystems.

These effects can be mitigated by adequate dispersal and mixing of concentrated brine wastes. On occasion, brine flows are mixed with other waste water flows, such as power plant cooling water discharges, to dilute them before discharge.

Where liquid disposal of concentrated brines is required this should involve adequate dilution, mixing and dispersal, should be restricted to areas of low biological sensitivity and should be subject to adequate monitoring regimes. Disposal at surface level is preferable to seabottom disposal

The solid option?

WWF Spain has suggested that “zero spill” waste treatment – generally by reducing brine concentrates to solid or minimal volume wastes - should be considered the preferable way of treating the brine wastes of desalination. Among the safe disposal options are former salt mines and in some cases would be valuable inputs for the chemical industry. This would minimise a major concern with desalination. Research into more efficiently and economically concentrating wastes should be a priority.

Clearly, more research needs to be done on the salinity tolerances of organisms and ecosystems and caution needs to be exercised on the possible cumulative effects of multiple desalination proposals for waters that are partly enclosed, where the seas are relatively shallow and where the dispersal effects of waves or currents are relatively low.

Keeping the membranes clean

Membrane performance is affected by chemical scaling from impurities in water, by biological growth and by simple clogging of the membranes. The widespread use of chemicals to overcome these issues is another potential issue with discharges from desalination plants.

As described in assessment documentation for one plant a typical pretreatment process to prevent fouling of the membranes includes the removal of suspended solids, chlorination or disinfection of the water, the addition of iron chloride as a coagulant and sulphuric acid to adjust pH. Several times an hour the filtration system is backwashed with a 12 percent solution of sodium hypochlorite, a biocide. On the way to the membranes the feedwater is treated with an antiscalant (phospinocarboxylic acid) at a rate that depends on the quality of intake water – in this case it was forecast at about 4-6 mg/L. The antiscalant is discharged with the brine. The product water is then treated with lime to bring its acidity into line with drinking water standards. Sodium metabisulphite is added to the discharge water to neutralise any free chlorine. A broad-spectrum biocide (containing 2,2 dibromo–3–nitrilopropionamide) is added to the filtration and RO systems at approximately weekly intervals to prevent growth of microorganisms. Two to four times a year depending on the degree of membrane fouling, both filtration and RO membranes undergo “chemically enhanced cleaning” with acidic detergents. Most if not all of these treatments are discharged with the waste brine stream, although the discharge of the cleaning wastes to sewer was raised as a possibility for this particular plant. Gross characteristics of the discharge water compared to the intake water include a small increase in temperature, increased acidity, a doubling of suspended solids and increased iron and sulfate content. The biocides used are described as breaking down in relatively short periods and most are described as having a low potential for bioaccumulation.[11]

Perth's desalination plant however is one where a relatively high level of attention was paid to environmental issues. In many cases the level of documentation and assessment of the chemical regimes for treating water, filters and membranes is far less specific. If there are persistent membrane issues, something that sometimes shows up in practice, operators can be tempted to use more damaging chemicals in heavier concentrations. Florida's troubled Tampa Bay desalination plant was found in violation of sewer discharge permits for just these reasons, while chemical discharges from many other desalination plants are unlikely to be subject to stringent monitoring.

For thermal desalination plants there are some added complications, related to the heat of the discharge and the presence of metal corrosion byproducts, including copper. To date, these corrosion byproducts and the thermal pollution characteristic particularly of linked power station cooling and thermal distillation discharges have been of more concern than the cleaning and defouling chemicals used in RO desalination systems. Thermal distillation sequences are also more commonly including membrane elements, which introduces traces of anti-fouling, scaling and cleaning chemicals to discharges.

Watering the greenhouse: the climate change implications of large scale desalination

Any major expansion of an energy intensive process such as desalination carries the risk of supporting a significant expansion of greenhouse gas emissions. Indeed, in some areas, this indirect impact of desalination has emerged as both a key policy concern and an issue increasingly raised in opposition to large scale desalination plant proposals.

To put it in context it should be noted that the energy intensity of water in most nations is both significant and increasing as water is sourced from deeper or further away. More marginal water in many areas has meant increases in water treatment costs and there is a long term trend to increase the level of wastewater treatment. Energy production is also a water intensive process with large power generating facilities requiring large quantities of water for steam and cooling purposes in particular. It is notable that unanticipated water shortages around the world in recent years have reduced or threatened power generation from hydro, nuclear and coal powered generating facilities. Many jurisdictions are now anxious over the long term impacts on power generating capabilities of long term changes in water availability from the degradation of water sources or climate change. In other words, energy and water issues need to be considered together.

Seawater desalination, in most cases the most energy intensive of potential water sources, will add in a significant way to an existing process. Precise figures depend on the location but to take one example, the Pacific Institute estimated that the water sector was responsible for 19 percent of electricity use and 32 percent of natural gas use in California in 2001. The Institute calculated that the then current proposals to provide six percent of the State's water through seawater desalination would have increased water-related energy use by five percent over 2001 levels.[12] Spain's Carboneras desalination plant uses one third of the electricity supplied to Almeria province.[13]

In a general sense, the increased demand for energy for desalination implies a commensurate increase in the carbon emissions linked to climate change. Worldwide, the electrical power generating sector is the world's most significant single generator of carbon emissions, responsible for 37 percent of global emissions. Always operating large scale desalination plants are also generally unsuited for variable power sources and tend to add to the base load power requirements most likely to be generated by burning fossil fuels. A comparison of the emissions intensity of various desalination technologies – using an average European fuel mix for power generation – showed the great advantage of RO (1.78kg CO_2 per m3 of produced water) over the thermal distillation technologies of multistage flash (MSF) (23.41 kg CO2/m3) or multiple effect distillation (MED) (18.05 kg CO2/m3).[14]

Actual contributions to carbon emissions of individual desalination plants or proposals are however, highly variable with power requirements, the use of energy recovery technologies and, most significantly, the fuel mix used to generate power. The differences can be dramatic as the following examples show.

> The analysis of emissions intensity of various desalination technologies showed that MSF distillation emissions could be as low as 1.98kg CO2/m3 if the process was 100 percent driven by waste heat (Most MSF facilities are coupled with power generation plants). Likewise RO emissions varied considerably with the fuel mix used for power generating, from 0.08 kg CO2/m3 (Norway) to 3.08 kg CO2/m3 (Portugal)
>
> The emissions intensity of California power is lower than the US average, reflecting more use of natural gas and less of coal.[15] The Pacific Institute estimated an average seawater desalination energy demand of 3.4 kWh per m3, which would translate to carbon emissions of 0.94 kg per m3. Performing a similar exercise for the other US high growth low water states however produces much higher emissions of 2.2 kg CO2 per m3 (Texas) and 2 kg CO2 per m3 (Florida).
>
> An Australia Institute analysis of the greenhouse impact of Sydney's ultimately proposed 500,000 m3/day RO plant held that the energy demands would be 4.93kWh per m3 and emissions would equate to 5.2 kg of CO2 equivalent per m3 from the State's mainly coal fired power stations. Annual greenhouse

emissions would be 945,000 tonnes of CO_2 equivalent – in more colourful terms the institute noted "The emissions are the equivalent of putting another 220,000 cars on the road, or burning 2 litres of petrol for every 1,000 litres of water."[16]

Across Australia, the WA Water Corporation's newly operational Kwinana desalination plant is setting new records as the largest so far constructed in the southern hemisphere and the largest anywhere to be powered by renewable energy. The 130,000 m3/day plant uses the same power as 30,000 homes and increased the corporation's energy use by 50 percent, but purchases the equivalent of all its power requirements from a newly constructed windfarm.

Clearly, the West Australian precedent is to be preferred if desalination is not going to become a key contributor to the climate change problems.

Posidonia oceanica, Cres, Croatia © WWF-Mediterranean/P. Kruzic

Flow on effects of large scale desalination

The concern of many communities and environmental lobbies however is less with the processes of desalination than with what it enables. It is a concern shared by some official bodies such as California's Monterey Bay National Marine Sanctuary (MBNMS), which noted:

"Clearly the most contentious and controversial issue surrounding desalination is its potential to induce community growth. Along most of California's central coast, freshwater supply is the limiting factor for community growth. With the addition of an unlimited source of freshwater, growth can be allowed to occur. While this issue is not addressed directly by Sanctuary regulations, it is of major concern. Increased development of the coastline adjacent to the MBNMS could lead to degradation of water quality and many other challenges to the protection of Sanctuary resources. It is up to local jurisdictions to ensure that a proliferation of desalination facilities does not lead to unsustainable community growth, through responsible planning, and limitations in plant capacities."[17]

California, it should be noted, has much more extensive development controls than the great majority of the areas where desalination is now being touted as a solution to real or forecast water shortages. In the Mediterranean and Middle East in particular, the desalination survey conducted for this report showed a high correlation between desalination and unsustainable urban and tourism development and horticulture and high levels of existing environmental damage – particularly to natural water sources. Indeed, a lack of effective land use planning mechanisms is commonly associated with a lack of effective water extraction and use mechanisms, resulting in a free for all where urban development, tourism and agriculture all take what they can get. Natural reserves in such areas have to contend with continual encroachments from unregulated or poorly regulated development and side effects such as effluent flows, falling water tables and sometimes illegal development within the reserve area itself.

Adding additional water supplies to areas without adequate land use planning or water use controls only perpetuates and extends environmental damage. It is often also difficult to believe in such circumstances that desalination plants will be planned, constructed and operated to mitigate their environmental effects.

WWF does not believe that large scale desalination should be contemplated in the absence of effective land use planning schemes in which sustainability is given a high priority.

A new lease of life for ageing power stations?

Coastal power stations using seawater in flow through cooling systems have long been a controversial issue in California, with opponents maintaining their intake and outflow systems do unacceptable damage to the marine environment. A number of high profile desalination plants propose to operate in tandem with such power stations, to make use of the existing intake and outflow structures, to save costs through the lower energy requirements of using warmed seawater as feedstock and to use the power station outflow to dilute brine wastes. This has fed community concern that desalination will give a new lease of life to the power stations.

Fuelling the nuclear option

Desalination is emerging as a major driver for nuclear power, particularly in Asia, the Middle East and North Africa. Among nations considering nuclear power to produce water are the currently non-nuclear States of the Gulf Co-operation Council countries (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates), Jordan, Libya, Algeria, Tunisia, Italy, Turkey, Syria and Indonesia. Current nuclear energy states France, Israel, India and Pakistan, China, Japan, Russia, Kazakhstan, and the USA are also involved in their own or the IAEA's nuclear desalination projects[18].

Programmes in Iran and North Korea, the current focii of world concern on nuclear weapons proliferation, are not nearly as well canvassed by the International Atomic Energy Agency or the World Nuclear Association but there is little doubt that Iran would seek to use nuclear power to produce water. As far back as 1977, a large 200,000 m3/day desalination facility was proposed for Iran's Bushehr nuclear power plant but lapsed in the long construction delays.

Desalination: An industry and its economics

World interest in desalination is rising sharply. The size of the global desalination industry is reported in many publications with an astonishing degree of precision – for instance, it can be read that in 2005 the 10,402 desalination plants worldwide were producing 35,627,374 m3 of water a day. Rarely is it mentioned that this figure is a compilation which can include "plants that have been built but never operated, operated but then shut down, or are still operating" and also can "include plants scheduled for completion by 2004 that were never completed".[19] The proportion of plants in these categories is quite high – in an allied listing of the 100 largest desalination plants proposed, operating or under construction, over half of the US plants indicated as operational are not.[20]

Even greater complexities bedevil the task of getting comparable cost figures for water produced by desalination compared to other water production or savings methods. Such comparisons are usually conducted on the basis of the cost of product water, with the most efficient (and largest) RO plant at Ashkelon, Israel initially producing water at $US 0.52/m3. However, the land for Ashkelon was provided at no cost by the Israeli government, and the Pacific Institute legitimately queried how production costs could be compared with California plants where expensive coastal land was a significant cost factor. However, in turn, the California project most likely to go ahead was quoted as producing water at $US 0.57/ m3 – after subsidy assistance of $US 0.20/m3. In addition to subidies, other issues in comparing desalination plants include varying capital amortization periods and rates.

Figures produced by and about the desalination industry accordingly should be treated with a great deal of caution. What can be said with confidence on desalination costs is that:

> Local and site specific factors have a large influence on costs, with energy costs being the major factor. Also important are the salinity and other characteristics of the feedstock water, coastal land costs and costs of mitigating environmental impacts.
>
> Energy costs are the largest component of the operating costs of desalination plants. On 2003 estimates by the US Bureau of Reclamation, energy accounted for 44 percent of the "typical" costs of an RO desalination plant and close to 60 percent of the costs of a "typical" large thermal distillation plant. The energy proportion of total costs rises with energy costs.
>
> Desalinated seawater is expensive water compared to most alternatives in most locations.
>
> To some extent the high cost of desalinated water can be offset by the greater reliability of supply. However it has not generally been economic to maintain sizeable desalination plants as a reserve capacity to be activated as needed in times of drought.
>
> Rising energy costs are now counteracting or overwhleming the benefits of incremental improvements in desalination technology. This is a trend that is likely to continue.

Looking for the breakthrough technology

Reverse Osmosis (RO) is the desalination technology of choice for the great majority of current proposals outside the Arabian Gulf where thermal distillation based on cheap and subsidised energy has historically supplied the bulk of freshwater requirements, and is now significant there as well.

RO is essentially the product of many years of intensive research undertaken with public funding and a high level of government support in the United States from the 1950s to the 1980s. It is currently regarded as a mature technology, exhibiting continuous incremental improvements in materials, methods and overall efficiency – estimated at a commendable four percent efficiency improvement a year by the US Bureau of Reclamation.

But the Bureau, commissioned to draw up a plan for desalination and related technologies to fill a general US water shortfall without significant increases in water costs, concluded that "continuing along this path will result in future evolutions of current-generation technologies that continue to produce water that is too expensive for many applications". In other words, the technical solution to the US water supply problem was dependent on a greatly accelerated research programme "that will result in cost-effective, efficient revolutionary desalination and water purification technologies that can meet the nation's future needs"[21].

An official review of the Bureau's "roadmap" for desalination endorsed its views on the need for a breakthrough technology, with a number of contenders including intelligent membranes and nanotechnology being mentioned. But it also noted that "current funding levels within the federal government for non-military application of desalination are insufficient to fund research efforts that would trigger a step change in performance and cost reduction for desalination technologies".[22]

There is the possiblity that some breakthrough on the technical or cost front will be an outcome of research in other areas such as Europe or China. In the industry, levels of research investment are not high. A perusal of the papers in the journal "Desalination" supports a view of incremental improvement in theoretical knowledge and practice occurring in a number of key areas.

The more enthusiastic projections of the industry should therefore be viewed with some scepticism. Although a desalination plant is more and more often raised as a possible inclusion in a water plan and is more and more tempting as an electoral promise, the reality is that desalinating seawater remains an expensive water supply option, closely tied to energy costs.

Desalination and alternative water supplies

Valid comparisons of water supply options are clearly highly dependant on locality factors like rainfall, topography and the characteristics of natural surface and underground water systems as well as other factors like energy availability and cost. Many cities have also exhausted the immediately neighbouring and readily available natural water supply options. The take on rivers and aquifers may be at or beyond capacity and potential reservoir sites are commonly already utilised, As cities and regions source their water from deeper underground or further away, water transport costs have also begun to loom much larger in the general water supply equation.

Consultants to the Australian Prime Minister on water supply options for Australian cities noted that low cost water supply options depended on "favourable locations and situations" for the options. Seawater desalination costs over three Australian cities accordingly could vary from AUD $1.15 to $3.00 a m3 of product water (USD $0.95- 2.50). Options with a noticeably lower mid-point in their range included demand management, irrigation water purchases, stormwater re-use, groundwater extraction and dams. Noticeably more expensive options were to augment supply through household rainwater tanks and long distance pipelines.[23]

The Pacific Institute's analysis of desalination in California analysed the energy content of competing water supplies. Seawater desalination was the most energy intensive of water sources in San Diego county, a multiple of 1.3 times the energy intensity of water sourced from the State water grid, twice that of the Colorado River Aqueduct, four times that of brackish water desalination and eight times as energy intensive as groundwater or reclaiming waste water.[24] Energy costs are increasingly reflective of overall water costs.

The US Desalination Coalition (now the New Water Supply Coalition, a lobby composed of US municipal authorities), proposed a 2005 bill for qualified desalination facilities to be eligible for payments of $0.62 for every thousand gallons of freshwater produced for the initial ten years of a project's operation.

The US Congressional Budget Office opposed the subsidy, on the basis that the real issue was that payments for water by US consumers rarely reflected supply costs and additional subsidies "would compound the distortion of price signals. An alternative means of improving the viability of desalination would be to allow prices charged to water users and received by water producers in general to more fully reflect the cost of supply."[25]

According to a World Bank official conversant with the Bank's studies of desalination, “Saving water rather than the development of new sources is often the best “next” source of water both from and economic and from an environmental point of view. Water demand management can include a reduction of a prevention in the further growth, of final water demand through improved public awareness, universal and more reliable metering, control of illegal connections and more appropriate water tariffs. It can also include measures to reduce levels of physical leakage in the distribution network, which are often very high. Desalinated water should only be a last resort, after all appropriate water demand management measures have been implemented and after carefully evaluating alternative options for conventional bulk water supply, which usually consist of long-distance transfers of surface water or groundwater” [26]

The economics of desalinated agriculture

Desalinated seawater is or is intended to be an important agricultural input in some Mediterranenan or Middle Eastern areas, although actual extent of agricultural use is sometimes obscure. This project was informed, for instance, that a significant number of Spanish farmers are shunning desalinated water in favor of continuing to illegally pump groundwater. In other areas, such as Saudi Arabia, groundwater based agriculture is facilitated by utilising sometimes distant desalination water to provide cities with potable water supplies.

Particularly in the face of increasing energy costs, it seems highly unlikely that desalinated agriculture is economic anywhere. According to a 2005 study by the UN Food and Agriculture Organisation (FAO), "applying water desalination technology to agriculture is generally cost-ineffective; in particular, water desalination is currently much less economical than the re-use of treated wastewater in agricultural applications" and its application was "effectively used only in the case of certain high-value crops and when capital costs are subsidized by governments"[27] .

Additional subsidies may take the form of preferential water pricing for farmers and production subsidies for crops.

Loading the bases: an inadequate basis for desalination

The large scale supply side answer to water supply problems regrettably involves a long history of loading the bases so that the answer to a perceived, forecast or sometimes even manufactured water crisis is invariably a large scale infrastructure project. With all large infrastructure projects, there are dangers in the authorities and industries that build and operate such facilities being frequently the key entities exerting influence on evaluation and decision making processes. Key elements of poor decision making on water infrastructure can involve :

- Denying public access to information
- Excluding key interested parties from involvement in decision making processes
- Consideration of no alternatives or limited alternatives
- Considering alternatives in a distorted way by for instance exaggerating their cost in comparison to unrealistically low costings of the preferred project
- Systemic overestimation of benefits and underestimation of costs of projects
- Neglect or underestimation of social and environmental costs of projects
- Outright corruption – the purchase of favorable decisions

It would be encouraging to believe that large scale desalination projects will be approached differently. However, in many of the cases studied in this brief it was apparent that demand side responses to water supply issues had received only cursory attention.
Sydney Water Corporation, the proponent of a large scale desalination plant, conducted an analysis of the relative merits of similar sized potable water recycling and desalination plants. The analysis shows

potable water recycling to be by far the most expensive option – after it included and costed a requirement for the recycled product to be piped and pumped from the coast to be mixed with the waters of a distant dam.[28]

The desalination industry

In preparing this report, WWF approached both the international desalination industry associations for information. No response was received, even to the question as to why there were two competing international industry and research associations both based in the United States. It is interesting to note that the Pacific Institute, in its examination of desalination in California, also noted that “repeated attempts to contact private companies about the status of their desalination plants were ignored” (Cooley et al p.25).

The industry also seems to be undergoing something of a transformation as the number and size of projects increases and the size of projects increases. The former dominance of water supply authorities and specialist water companies is being replaced rapidly by partnerships between diverse infrastructure companies and construction conglomerates. This adds the risk that often underfunded and resourced regulators will find it difficult to adequately address environmental and other community concerns in the face of development interests clamoring for water and large and politically influential corporations clamoring for contracts.

As a study of Saudi Arabia's water supply system noted, "Foreign manufacturers of desalination plants, irrigation systems, pumps, pipelines, earth-moving equipment etc… associate closely with the power elites. Non-economic and environmentally unsound schemes like food self-sufficiency are packaged attractively with slogans that evoke national sentiment. In the absence of a free press, environmental groups and other ethicist egalitarian non-governmental organizations find it difficult to introduce into water policy a balancing economic or environmental perspective. Consequently, there has been no effective voice saying that desert agriculture was a seriously negative economic and environmental option. Once the high-water-using irrigation schemes were in place, domestic water supply requirements had to be addressed via desalination and pipeline technologies. This outcome benefited not only the new farming entrepreneurs but also the desalination equipment and pipeline suppliers along with their local sponsors (Elhadj 2004, p.17). Elsewhere in the region, it has been noted that Israeli and Jordanian construction companies have been among the strongest proponents of the Red Sea-Dead Sea water supply and desalination proposal over other alternatives such as allowing or supplementing Jordan River flows.

Desalination - a world view

Many of the conclusions to which this study of desalination comes have been informed by a survey of current desalination developments and their context in key regions. It is not an exhaustive survey, but it does illustrate:

The rapid growth of desalination capacity generally, and the trend to larger and larger desalination plants

The extent to which the technology is regarded with misgivings in some countries.

The degree to which desalination as a supply side technology continues to prevail over more serious consideration of demand management.

The degree to which desalinated water is subsidised to end users.

The degree to which desalination is linked to unsustainable urban, tourism and agricultural development in some areas.

Full steam ahead in the Middle East

The world's most significant desalinators – by a clear margin – are the oil rich but water poor nations around the Arabian Gulf, with some estimates being that around 60 percent of the area's water needs are met through desalination and that more than 50 percent of the world's total desalination capacity is located around the Arabian Gulf and a large proportion of the remainder takes water from the Red Sea and eastern Mediterranean. Many of the plants combine seawater distillation with power generation but although plants of this type are still being constructed there is now a pronounced move towards large Reverse Osmosis plants.

Despite the already large capacity, massive increases are planned as nations grapple with soaring water demand. In various measures there are common elements in depletion and contamination of the area's limited other freshwater resources, agricultural enterprises which are looking for new water after having substantially contributed to this degradation, rapid urbanisation and burgeoning tourism development.

Saudi Arabia – struggling to keep up with demand

The Saudi Government owned Saline Water Conversion Company (SWCC) is the world's largest desalination enterprise with 30 plants producing more than 3 million m3/day and 5000 mW of power – 50 percent of the kingdom's water needs and 20 percent of its power needs. Over the next 20 years, according to SWCC, the kingdom will need an additional 6 million m3/day of water and 30,000 more mW of power generating capacity.[29] SWCC itself is to be privatised, which may be one indication that providing for Saudi Arabia's water needs is expected to be challenging. The investment community certainly thinks so, with one influential analysis concluding that "Growth in the region would be stronger but for concerns about Saudi Arabia's ability to finance its required capacity within the timeframe."[30] Other organisations with reservations about the general Arabian Gulf and Red Sea desalination model include the World Bank, which has noted that subsidised natural gas underpins much of the combined thermal distillation and power generation, "Energy subsidies distort the choice of desalination processes in favor of energy-inefficient technologies," a bank spokesman said[31].

Confused outlook on environmental issues

In theory, the long established desalination industry on the relatively enclosed seas surrounding the Arabian peninsular should have provided the ideal real world laboratory for examining some of desalination's environmental impacts. Continuing work in the Gulf of Aqaba, the most enclosed water body in the area which already hosts significant desalination capacity and has more proposed, may yet provide such data with researchers pointing to the possiblity that much of the marine growth and life in seas of already elevated salinity may be near the limits at which any further increases in salinity can be tolerated.[32] There have been reports of increased salinity causing fish deaths in the Arabian Gulf, but the main reason for the Gulf's elevated salinity is low run-off and high evaporation rates. Dumping of saline water, whether as a byproduct of oil production or extensive desalination works is held less responsible than dam building and irrigation works on the Tigris and Euphrates Rivers. One notable feature of the Arabian Gulf is that "a counterclockwise ring-shaped residual water current links all the (desalination) locations, and the plants receive their feed water from a water body which is under the influence of the upstream plants". Thermal pollution from the discharges of joint power station/desalination plants have been raised as a risk factor for increasing the possibility of coral bleaching in the Arabian Gulf.[33]

Individual projects undergo various levels of environmental assessment but strategic or cumulative impact assessment is uncommon. In some areas, as the World Bank has noted, "the legal basis and institutional capacity for environmental asessments in general is weak".[34] However there are many activities that impact on the Arabian Gulf and it would be difficult to isolate the impact of desalination plants and the power plants they are most usually associated with. The level of damage from land reclamation activities is likely to be the largest and most immediate environmental issue in the Arabian Gulf, although the availability of water from desalination undoubtedly facilitates current high levels of unsustainable coastal and island development.

Not surprisingly for such dry countries there is a long tradition of water use restrictions, some of which are supported by religious traditions. However, these useful traditions began to break down under conditions of rapid development which, particularly in agriculture, were underwritten by large scale groundwater abstractions. It is hard not to agree that "given the inefficiency of agricultural production in desert environments, it is anomalous to deplete mainly non-renewable groundwater reserves in the Riyadh and Qaseem Regions so that farms in the forbiddingly arid and hot Najd plateau are irrigated, while desalinated water for household use is piped from hundreds of kilometers away."[35] A key weakness is the combination of some of the world's lower water tariffs with its highest water production and distribution costs. These are justified on social grounds. There are undoubtedly large potential gains from conservation and efficiency measures but they will need support from the pricing system and some investment in addition to the well used exhortations for Saudis to use water more frugally.

Desalination in Israel

Israel has been looking to large scale desalination as its main way of resolving a water crisis brought on according to one government report by “a policy of brinkmanship . . . guided by short term economic considerations”. Elements of the crisis included reductions in both the quality and quantity of water supplied to Israelis, contamination and depletion of natural water sources and successive droughts in the early part of the century. Recurrent droughts, fears of the future impact of climate change and water related provisions in international agreements between Israel and other states in this highly volatile area also complicated the position. “Delay in introducing desalination” and “delay in adjusting demand and water prices to the desalination era” were also identified as contributing factors[36]. A master plan adopted in 2002 called for the construction of major seawater RO desalination plants to supply 400 million m3 of water in 2005-2006, with a foreshadowed 750 million m3 of capacity to be provided by 2020.

Not mentioned in this analysis however were the prodigious water demands of Israeli agriculture, which like Spain (see below), is growing unsuitably thirsty crops in fundamentally dry areas – substantially for export. The inevitable result has been a dramatic drop in groundwater levels and associated stream flows.

This then is the background to Ashkelon, currently the largest seawater RO plant in the world with a capacity of 320,000 m3/day (100 million m3 a year). The plant, powered with its own dedicated gas turbine power station, is at the cutting edge of efficiency and produces water for about $US 0.52 a m3. Notes an industry source: “Ashkelon produces around 13% of Israel's domestic consumer demand – at one of the world's lowest ever prices for desalinated water. It has been suggested that it could be many years before this plant's achievement is matched.”[37]

Israel plans to use its desalinated water not only to fulfil shortfalls in supply but also to facilitate replenishment of its natural reservoirs. Associated plans include the restoration of damaged or contaminated natural water sources and infrastructure and commitments to lift an already high level of water and effluent recycling.

Pollution of rivers and the marine environment is becoming an increasing issue in Israel but effluent desalination plants are a long way down the list of concerns, behind raw sewage from a lack of treatment facilities in Gaza and overflows and inadequate treatment from Israeli facilities and industrial and water treatment sludge from Israeli facilities.[38] Indeed, there is a concern that the flows of pollution into the Mediterranean will increase desalination costs, which are related to the quality of intake water and more frequent membrane servicing[39].

Desalination for the sake of a dying Dead Sea

Schemes to link the Mediterranean, the Dead Sea and the Red Sea have a considerable history. Now those plans have been revived under the umbrella of the peace treaty between Israel and Jordan as a way of providing desalinated water to needy cities such as Amman while rescuing the shrinking Dead Sea. The two governments and the Palestinian Authority recently agreed to participate in a feasibility study of a “peace conduit” from the Gulf of Aquaba to the Dead Sea, with a large desalination facility powered by renewable hydrostatic energy close to the Dead Sea.

However, the project has its opponents, some of whom would prefer to see desalinated water from Israel's northerly Mediterranean facilities used to help address over-extractions and low flows in the Jordan River as the key cause of the Dead Sea's woes. There are also concerns that imported Red Sea water will harm the delicate Dead Sea ecosystem.

Dead Sea region

Salts from the Dead Sea

Battling over desalination in the USA

The world's desalination industry owes a massive debt to US taxpayers and administrations for the long decades of research effort that underpin its current technologies. Up until now, the main benefits have been enjoyed in the Middle East and Spain, but a looming water supply crisis in the USA has seen desalination come back into favor. But implementing President John F Kennedy's dream of endless freshwater from the ocean is still problematic, partly because of the gap between what is technically possible and what is economically feasible, and partly because plans for more and more large desalination plants are beginning to arouse community concerns on environmental impacts. It has not helped the industry that some of the initial headline projects have run into difficulties.

Per capita, the US is the world's largest water user, with the US Bureau of Reclamation forecasting that "assuming continued per capita water use, 16 trillion additional gallons (60 billion m3) per year will be required in the United States by 2020 for municipal and light industrial uses". [40] Fully half the projected future population growth is predicted for just three already water-stressed states – California, Texas and Florida. Texas is proceeding cautiously with a major emphasis on brackish water desalination, while Florida's initial unhappy experience with desalination has helped fuel fierce debates in California which are now holding up a number of major proposals. Of 11 US plants listed among the world's 100 largest existing or proposed plants in 2005, most are still pending.

Trouble at Tampa Bay

America's first, much heralded new generation desalination plant, a 95,000 m3/day facility at Tampa Bay, Florida was approved in 1999 and scheduled to be supplying water at a competitive cost of less than $0.50 /m3 in late 2002. A succession of contractor bankruptcies, and technical difficulties with both filters and membranes have meant the plant has never operated at anything like its planned capacity. The $US 110 million plant closed for repairs in 2005 and began regular water production again in April 2007, although it was scheduled to take some time to reach its operating capacity. Liability for the $48 million repair bill – mostly linked to failures of filters and membranes to perform adequately – is before the courts. [41] The manifest failures of Tampa Bay have proved to be a potent example to California communities opposing desalination plants.

Debating desalination in California

Interest in desalination has developed rapidly in California over recent years, but there has also been a rise in the level of community and institutional misgivings about desalination. Some of the community concern has grown on the back of campaigns to close down coastal power stations that use flow-through cooling systems likely to damage marine ecosystems as some of the desalination proposals have envisaged working in tandem with these unpopular power stations. However the number of new proposals also took many by surprise, with the Monterey Bay Marine National Sanctuary for instance listing desalination as a management issue on noting that their three existing plants (one very small) could possibly be joined by "approximately ten additional facilities in the Sanctuary region that are in some stage of initial consideration."[42] The Pacific Institute (see below) noted in 2006 that "In the past five years, public and private entities have put forward more than 20 proposals for large desalination facilities along the California coast. If all of the proposed facilities were built, the state's seawater desalination capacity would increase by a factor of 70, and seawater desalination would supply 6% of California's year 2000 urban water demand."

In response to both the rising interest and the rising concern, the State directed its Department of Water Resources to conduct a study of the possibilities for desalination, the possible impediments to desalination and the role that the State should assume. It was chaired by DWR Deputy Director Jonas Minton and concluded that sea and brackish and seawater desalination "where economically and environmentally appropriate" could be included "as as an element of a balanced water supply portfolio, which also includes conservation and water recycling to the maximum extent practicable". It also usefully recommended that cumulative impacts had to be considered where a number of plants were considered for an area, as did desalination's impacts on growth.[43]

California's long list of desalination proposals have however not enjoyed any smooth path to approval, construction and operation. Part of the considerable community opposition has been related to the co-location of most large seawater desalination proposals with coastal power stations which were already controversial for the effects of flow through cooling structures on the marine environment:

> Proponents of the Carlsbad City 189,500 m3/day desalination plant in the San Diego area, have received municipal level approvals and have water supply contracts in place and are now awaiting final State level authorisations. The plant, co-located with the Encina power station, was originally scheduled for construction beginning in 2005 and completion in 2008. Its proponents now maintain it will be operational in 2009.
>
> Huntington Beach desalination plant, like Carlsbad a co-located 189,500 m3/day plant proposed by private operator (and original Tampa Bay developer) Poseidon Resources, has also now received most of its permits over fierce community opposition. Construction was originally scheduled to begin in 2004 and the plant to be operational in 2006, but Poseidon is now forecasting construction beginning this year (2007) and completion in 2009.
>
> Pilot plants have been constructed by the Marin Municipal Water District drawing water from San Francisco Bay and for one of two contending desalination proposals to be constructed at Moss Landing on the Montery Peninsular, as a possible prelude to larger scale proposals.

In one innovative project, Long Beach Water has been operating a pilot plant to test whether multiple passes of seawater through nanofiltration membranes could be a viable alternative to RO desalination. Initial results have been promising both in terms of the water quality and an up to 30 percent saving in energy. The experimental plant is also conducting research on the feasibility of subsurface intake and discharge wells which has the potential to address some key environmental difficulties with desalination. The US Bureau of Reclamation, which drew up the desalination roadmap, is involved in the trialling of what is now know as the "Long Beach method" .

However, the necessity of some large scale water supply projects – including desalination – is also being questioned. California's Planning and Conservation League (PCL) in 2004 estimated California's additional water needs to account for both population increase to 2030 and environmental restoration (a need to return 1.2 million Ml to the environment) amounted to 3.7 -4.2 million Ml of water. Of this requirement, PCL quoted Pacific Institute calculations that 2.4-2.8 million Ml would be available through urban water conservation savings, 1.8 million Ml through water recycling and up to 740,000 Ml through continuing agricultural efficiency improvements. Considerable additional water could be made available through groundwater desalination or other decontamination and stormwater capture.

A limited role was forseen for small coastal desalination plants using beach well intake systems, but PCL said unscreened large scale ocean desalination had "unacceptable environmental impacts and is not as cost-effective as other available options".[44] Among those involved in the assessment was PCL water policy advisor Jonas Minton, the former chairman of the State desalination study.

The Pacific Institute study similarly concluded that that "most of the recent seawater desalination proposals in California appear to be premature. Among the exceptions may be desalination proposals where alternative water-management options have been substantially developed, explicit ecosystem benefits are guaranteed, environmental and siting problems have been identified and mitigated, the construction and development impacts are minimized, and customers are willing to pay the high costs to cover a properly designed and managed plant"[45].

A third stream of opposition to large scale desalination in California relates to concern that it will further drive what is already seen to be coastal over-development. The Monterey Bay National Marine Sanctuary has labelled this "clearly the most contentious and controversial issue surrounding desalination"[46].

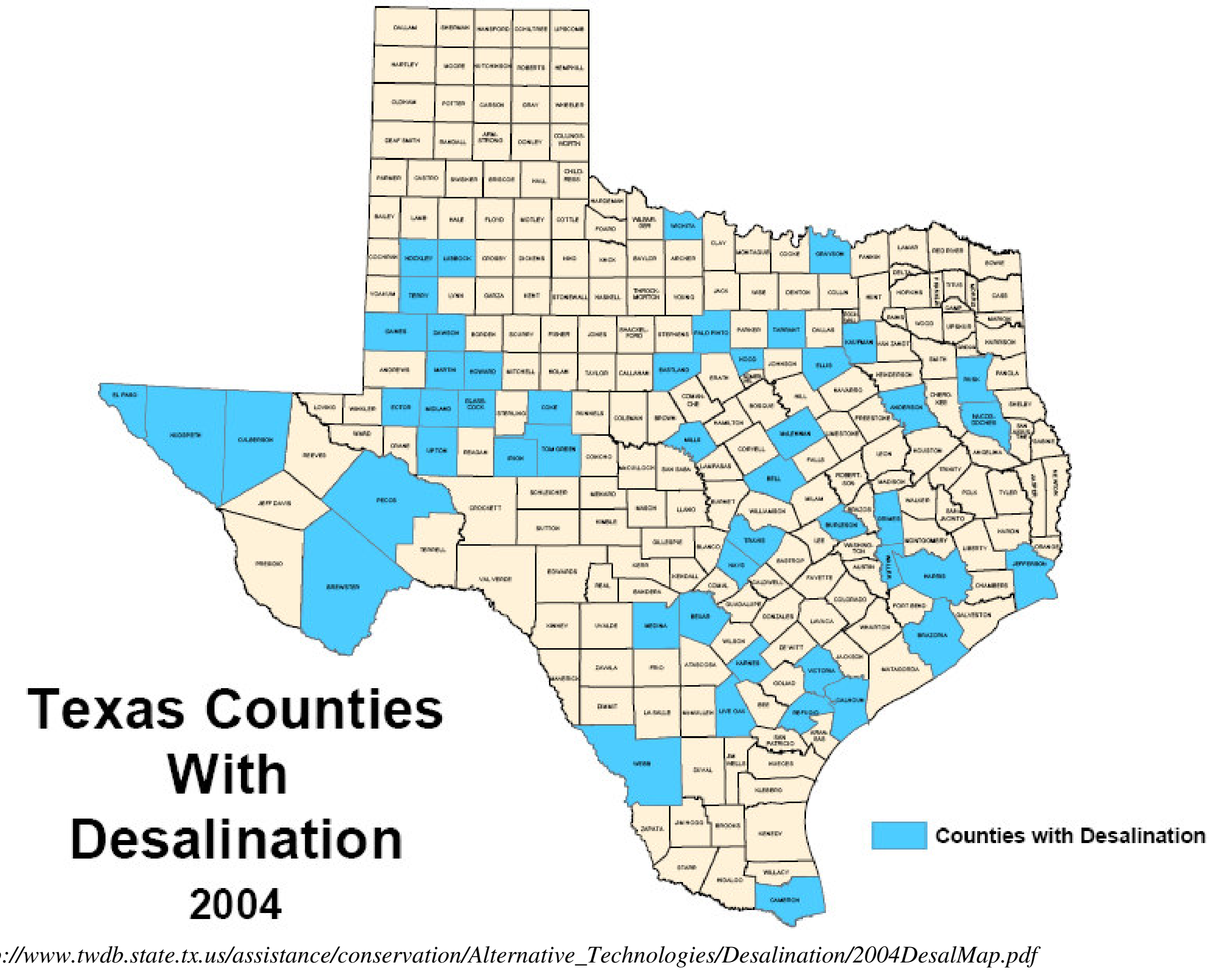
Seeking subsidies in Texas

Texas is also the site of multiple large seawater desalination proposals that have stalled, although here there is little evidence of the controversy over desalination that is surrounding many California proposals and expense seems to be the main issue. The State is no stranger to desalination – in 2004, there were 100 desalination plants processing mainly brackish ground and surface water with a total capacity of about 151,400 m3/day. Excluding industrial installations, 24 areas were getting all or part of their municipal water from desalination, for a total municipal capacity of 87,000 m3/day.[47]

In 2002, the State governor signalled a move to substantial seawater desalination and a flurry of proposals were launched even as the Texas Water Development Board (TWDB) was ordered to examine and report on the issue. By 2005 the international listing of the world's 100 largest existing or proposed desalination plants included four Texas plants.

- A 104,088 m3/day brackish water desalintion plant in El Paso, to have been operating in 2004
- 94,625 m3/day seawater plants for Brownsville (2005), Freeport (2005), and Corpus Christi (2006)[48]

As of 2007, only one of these large plants was approaching construction, let alone operation . An alternative 28,400 m3/day brackish water desalination plant had been constructed at Brownsville in 2004 and the El Paso plant is scheduled to proceed in partnership with the Defence department in the near future. In December 2006, the TWDB recommended that a $70 million grant and a $45 million low interest loan be provided to the Brownsville Public Utilities Board to construct a "full-scale seawater desalination demonstration plant" by 2010. Interestingly, the TWBD added as additional reasons for this investment "the potential to help meet environmental flow needs, and in particular, the environmental flow needs of the Rio Grande" and the non-economic issue that seawater "is relatively free of the increasingly contentious ownership and allocation issues associated with groundwater and surface water in Texas".[49]



http://www.twdb.state.tx.us/assistance/conservation/Alternative_Technologies/Desalination/2004DesalMap.pdf

Spain – a new way of endlessly chasing supply

Spain has the largest desalination capacity in the western world and its desalination industry is a key player world wide, with Spanish companies involved in developing the desalination capacities of the US, the UK and the Middle East among others. One recent accounting of capacity was "more than 700 plants producing 1,600,000 cubic metres each day, or enough for about 8 million inhabitants"[50] while another was for 900 plants producing 1.5 million m3/day.[51] According to these reports, this capacity was set to double with the urgent construction of around 20 new plants. However, other reports put the number of new plants as high as 29 by 2009.[52]

Behind the frenetic construction was the 2004 cancellation of the controversial Ebro River transfer project, once the centrepiece of Spain's National Hydrological Plan. This had been criticised as likely to repeat the experience of the previous Tagus-Segura River transfer which had worsened conditions in both the donor and receiving basins. (Indeed, there is now a proposal for a desalination plant to prop up this system). Spain has also long ranked highly among the nations most committed to large dams;however many of these dams remain continually at chronically low capacities.

In one sense, therefore, the new rush of enthusiasm for desalination is consistent with Spain's traditional approach to securing water in one of Europe's driest countries – a long history of massive investments in water supplies. But more and more voices are expressing a view that Spain's real water problems lie more with unrealistic expectations and poor water management.

Desalination plant in Alicante/ WWF Spain

Carboneras – highly subsidised water for heavily subsidised agriculture?

While other developed nations baulk at the high cost of desalinated water for urban uses, Spain is devoting an astonishing proportion of its desalinated water to agriculture – at 22 percent the highest level in the world, according to Jose Antonio Medina, president of the Spanish Desalination and Water Re-Use Association AYEDR. At that stage he predicted the then about to be constructed Carboneras plant with a planned capacity of 145,000 m3/day, was to be 90 percent allocated to agricultural supply.[53] However, these and other claims around the amount of desalinated water going to agriculture are subject to some dispute. WWF Spain noted that farmers continued to access groundwater even when its use was illegal while in the growing debate surrounding the construction of desalination plants, it was more acceptable to announce that water is intended for agriculture rather than tourism or urban development.

The 120,000 m3/day capacity plant at Carboneras was completed in 2004 and is claimed to be Europe's largest seawater reverse osmosis plant[54]. Operated by a consortium of Spanish desalination companies it was in 2006 judged to be the "greatest achievement" of the industry - but the opening was delayed by funding disputes with the Almeria farmers it was principally designed to serve.

But the key background is the transformation of the dry Almeria hinterland into Europe's most concentrated sea of horticultural glasshouses in the period 1987-2004.[55] In 1996, the three key aquifers of the Almeria coastal plain were listed as over-exploited, there were fears of saltwater intrusion into the seaward margins of the aquifers and problems of contamination with agricultural chemicals in surface and subsurface waters.[56]

Depending on the level of illegal and unregulated extractions, the existing, new and proposed desalination plants in the area may help relieve pressure on the aquifers. But the cost of desalinated water even from new generation RO usually precludes its use in agriculture. Precise Almeria figures are elusive, but one general study of Spain notes that "since 1983, the Spanish Government has been supporting water desalination to obtain a price of drinking water similar to the average price of water used by households," [57] The study notes that the agricultural water price was just 3 percent of the urban water price, and that in drought periods "water at 'market price' was 'sold' by agriculture concessionaires to urban concessionary companies". In 2006, the Director-General of Acuamed, a government company which commissions desalination plants and buys and distributes the product water, was quoted as saying that desalinated water from new plants would not be subsidised "for golf courses or for human consumption". According to this interview, farmers would be supplied at a charge of 30 euro cents a cubic metre plus the transport costs, while the cost of producing the water was estimated at 50 euro cents a cubic metre.[58] However, other research indicated that farmers were effectively paying 12-25 euro cents/m3 for water; some might thus be inclined to not take the desalinated water or only take enough to improve the quality of contaminated groundwater.[59]

One possible conclusion that desalination in Spain, for all its technical excellence, is but another way of pouring highly subsidised water into irrigated agriculture with an option for farmers in receipt of such water to sell it on - in effect spreading the subsidy into unsustainable urban and tourism development.

Watering the golf estates

Spain's burgeoning tourism industry has in recent years become significantly more water intensive, with more and more emphasis on second home development in resort settings, often arranged around 18 hole golf fairways. In the Almeria area it is difficult to avoid mention of the extensive water features of appropriately titled golf resort Desert Springs[60] to the north of Carboneras. A more general overview of the prospects for desalination notes that "Spain built a record-breaking 800,000 new properties in 2005, most concentrated along the southern coast; that figure is higher than the combined new properties built in France, Germany and the UK."[61] There seems to be little practical recognition of the reality that Spain's driest areas are set to become drier.

What Spain exhibits is an over-riding emphasis on finding supply, high levels of illegal and unregulated water extractions, slipshod efforts at enforcement and negligent land use planning. Perhaps most perversely, the perceived availability of water has underwritten a significant move for the traditional dryland Mediterranean staples of olives and grapes to become intensively irrigated crops producing market surpluses. Spain's natural environment, many of its nature reserves and indeed, the natural assets found so attractive by many of the foreign residents and tourists are being damaged by development which is underwritten by an assumption that water will always be available and be made available – whatever the economic, environmental and political costs.

Conflicts of interest in Spain's water debate

Not surprisingly, the developed nation with the most developed capacity in desalination also has an extensive dialogue on the costs and benefits of the technology. On one side, the call for a new approach is being led by the New Water Culture Foundation which was established during the debate over the National Hydrological Plan and the Ebro water transfer proposal. The NWCF has the support of WWF, which has formulated a set of proposals for the installation of new desalination plants. (See box)

However, Spain suffers in its ability to conduct a dispassionate debate on desalination because the environment ministry also includes the government-owned entity charged with dramatically boosting the nation's desalination capacity. The Aguas de las Cuencas Mediterráneas S.A.- a company more commonly known as AcuaMed - has policy, environmental and commercial roles but there is little doubt that its major preoccupations are the supply of additional water and the associated “contracting, construction, acquisition and operation of all types of hydraulic works”.[62] Fully 50 percent of the augmented supply is envisaged as coming from desalination.

WWF-Spain's recommendations for installation of new desalination plants:

Revised demand estimates which includes consideration of the effects of controlling illegal consumption, implementation of demand management and cost recovery charging.

Full environmental assessment at the levels of the revised National Hydrological Plan, the basin or regional impacts, and project level (including desalination plant proposals)

A more gradual increase in desalination capacity, in line with revised demand estimates. This would also take advantage of improvements in desalination technologies.

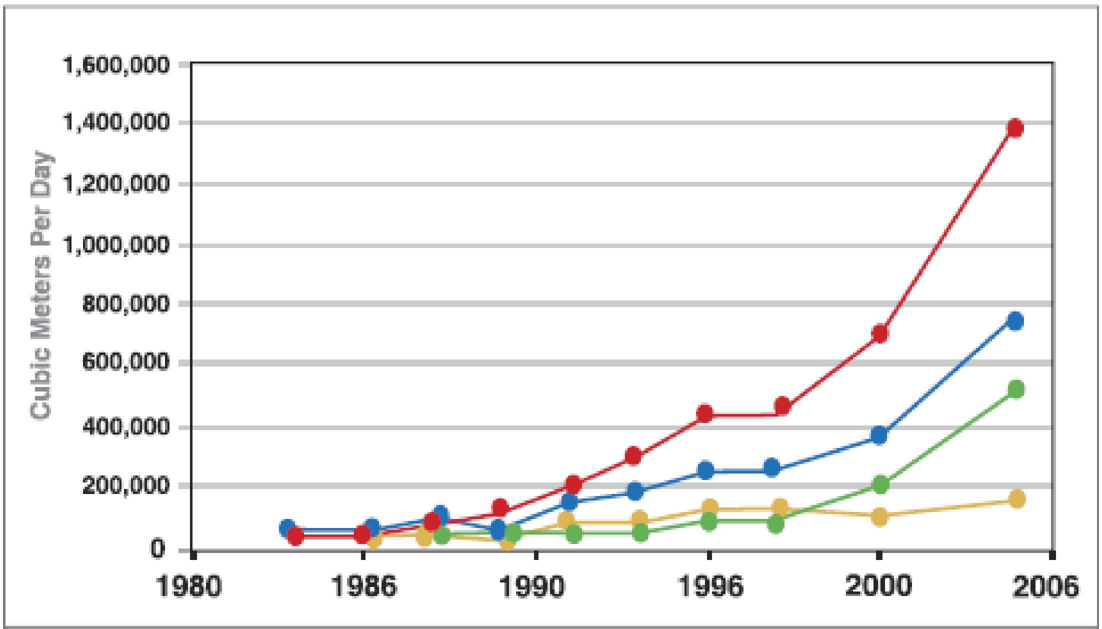
Restricting plants to existing industrial areas of Spain's Mediterranean coast. No construction permitted in natural areas, near reserves or onshore from *Posidonia* sea grass areas.

New desalination plants to be powered with renewable energy to avoid large increases in the greenhouse impacts of supplying water.

Examination of zero spill options for brine waste from desalination plants, including finding uses for the salt or transfering it to existing salt mines.

Where zero spill is not feasible or until it is feasible, brine should be disposed of in the least damaging topography, at surface rather than seabed level and with sufficient diffusing and mixing with seawater.

Use of Desalinated Water in Spain



Total Production
Urban Usage
Agricultural Usage
Industrial Usage

The production of desalinated water in Spain doubled from 2000 to 2004. The Spanish government predicts that production will double again in another five years.

Source: AEDYR

Explosive growth in India and China

Desalination growth is outstripping all expectations, even greatly optimistic ones, in India and China, where water problems affect large areas containing extremely large populations. According to projections by Veolia Water, one of the world's largest water treatment and desalination companies, the two rapidly developing nations are “gearing up to launch major projects with a view to achieving a production capacity of 650,000 m3/day by 2015”. This may be modest by Middle East standards, but it could also be a considerable underestimate. China alone recently announced plans to be desalinating nearly double that volume five years earlier.

India – desalinating booms as decontamination needs remain unmet

It is generally conceded that India is facing immense problems meeting its water needs in a period of rapid development. Issues include variable rainfall and population distribution and a high reliance on groundwater supplies which are becoming severely depleted. In large areas, dropping water levels have exposed dangerous soil elements to oxidation, introducing contaminants such as arsenic and flourides into the water supplies of millions.

Until recently, desalination and related technologies were mainly used in industry to provide water or in waste water treatment and re-use, and this is accelerating. India's burgeoning nuclear power sector is also seeing synergies in producing water as well as power. The under-construction Kudankalum nuclear power station in Tamil Nadu State for instance has two associated desalination plants for its own needs and those of an associated industrial park, including what is described as India's first multi-vapour compression desalination facility.

Small scale reverse osmosis plants have been used to render drinking water safe by removing contaminants such as arsenic and flouride compounds, but there have been many problems with keeping the equipment maintained and operating in small or remote communities with sometimes erratic power supplies. India's central Salt and Marine Chemicals Research Institute has developed an ox-powered desalination and decontamination unit capable of producing 0.7 m3 of water an hour. But, apart from a few demonstration plants, there is as yet little sign across south or south east Asia of any mass deployment of desalination-like technologies to address what may well be the world's largest single case of mass poisoning. As aid agencies took a prominent role in advising and funding the sinking of numerous wells that contributed to exposing dangerous elements to oxidation and mobilisation in the soil profile, there would seem to be a moral case for them to assist in effectively deploying water decontamination technologies.

Water short China embraces desalination

By world standards, China is relatively short of water with per capita supplies of less than a quarter of the world average. Moreover, water distribution and population distribution are mismatched, a factor behind extravagant plans to transfer southern river water to the populous but much drier north of the country. Additionally, some 40 percent of China’s population lives in the coastal areas that form only 13 percent of the country’s land area – another mismatch that is stoking interest in seawater desalination.

A 2005 list of "large" seawater RO desalination plants in China contained 22 plants ranging from just 30 m3/day to two of a still quite modest 5000 m3/day. The same publication listed 18 prospective plants ranging from 200 to 200,000 m3/day including a 160,000 m3/day nuclear desalination facility at Yantai City. However, the same article rather alarmingly noted that seawater desalination processes "will not influence the ecology".[63]

China's 2005 desalination capacity was just 120,000 m3 a day and western investment predictions reflected this relatively modest achievement. But over the last year China has announced plans to be desalinating 1 million m3 of seawater a day by 2010 increasing to 3 million m3 a day by 2020.[64] The market is to be supported to a level of up to 24 percent of water supplies in some currently water short coastal areas, by restricting freshwater to projects in nominated areas. There is also heavy investment, both Chinese and foreign, in China's desalination equipment manufacturing capacity and it seems likely that the nation will be a future major player in desalination, particularly in the developing world.

The China National Offshore Oil Corporation was reportedly planning to build a massive 1.4 million m3/day plant in Tangshan, northern Hebei province, partly to supply water to Beijing. [65] If such a plant were to be built it would be around three times the size of the current largest RO seawater desalination plant.

A string of news reports underlines that China's growth is putting great strain on its freshwater resources, with rivers in particular suffering from depleted flows, soaring agricultural power and urban water demands and sometimes staggering levels of contamination. Although there is some encouragement to conservation, it receives little support from the pricing structure, leaving water suppliers debt-laden and unable to upgrade infrastructure.

Leaks versus desalination in the UK

An inquiry was convened after the City of London denied planning permission for a Thames Water proposal to build a 140,000 m3/day £200 million ($US 397 million) desalination plant at Beckton on the Thames. London Mayor Ken Livingstone submitted to the inquiry that the plant would be energy intensive, would contribute to greenhouse gas emissions and, perhaps most tellingly, that around 915,000 m3/day of water a day is lost through leaks in London's water distribution system. The company argues that "reducing leakage can't close the gap between supply and demand quickly enough" and that higher costs were attached to other supply options.

The background to the controversy shows up some familiar themes, in that a large and expensive supply side infrastructure project was receiving consideration ahead of the possibility of much more concerted action on the demand side of the equation. As well as the issue of leaks from aging water mains, there were issues of inadequate water pricing and metering and patchy supplier and regulatory support for water efficiency measures.

In the longer term the indications are that climate change could mean greater variability in the water supplies available to southern England. Slow official realisation of this and a notable lack of emphasis on conservation and efficiency measures have taken the area's vital aquifers and rivers to historically low levels. In this context, the continuing frantic roll-out of housing subdivisions – including up to 160,000 new homes in the Thames Gateway by 2016 - with little planning consideration of how water requirements would be fulfilled into the future is a clear indication that southern England needs a coherent and effective plan much more than it needs a desalination plant.

The River Thames, UK © WWF-Canon / Emma Duncan

“Bottled electricity” under scrutiny in Australia

The world's driest continent – well on its way to becoming drier as a consequence of climate change – is also hosting energetic debate on the merits of large scale desalination. Perth's new desalination plant is the largest in the southern hemisphere and it is be followed by another of similar size within four years. A smaller plant has been approved for Queensland while a Sydney plant which has been on again, off again for a number of years will now be built. A large desalination plant may be tied to the world's largest uranium mine in South Australia, and consideration of desalination possibilities for the nation's second largest city of Melbourne has also started.

Commendably, some of the large scale proposals in Australia feature renewable energy use. However, in all the areas where desalination projects are proposed much potential remains for cheaper water sourcing through conservation, efficiency and recycling initiatives. All the areas are also characterised by rapid development in a context of inadequate consideration of the resource base in development planning and approvals. This extends to consideration of water availability and the natural environmental assets critical to its supply, quality and the mitigation of floods and droughts.

Sydney: On again, off again desalination

Historically huge reserves, a low priority for water management in government and a monolithic water authority has meant that Sydney defers to second-placed rival Melbourne as far as the enlightened management of water supplies is concerned. Persistent drought, thought to be linked at least in part to early effects of climate change, is increasingly challenging this complacency. Water conservation and efficiency measures have shown considerable promise, with Sydney Water reporting that its fairly unambitious programme of water savings had found enough water for around 138,000 households in the period 1999-2004 – mainly by plugging leaks in its own reticulation systems. But despite this success, the emphasis remained on large scale supply side solutions, notably a proposed $A 2 billion ($US 1.6 billion) up to 500,000 m3/day desalination facility to supply a third of the city's water requirements – a proposal initially derided by the then State premier who called desalinated water “bottled electricity”. The label stuck, a fact probably regretted by the government when it approved the plant not long afterwards. However, in a further backflip just months later in early 2006, the government announced the plant was not immediately necessary, citing recent rains and the discovery of new groundwater reserves. Plant construction was to be triggered automatically when reservoir levels fell to a prescribed amount. Sydney Water Corporation meanwhile invested $A120 million ($US 100 million) to go through all the preliminary stages necessary to build and bring the desalination plant into operation within 26 months. However in early 2007, the government pre-empted the triggers in the run-up to an election and announced the go ahead to a 125,000 m3/day plant that could be rapidly scaled up to 500,000 m3/day.

According to SWC, the infrastructure and operating costs of desalinated water are much less than equivalent costs of water recycling. An independent research paper estimated that desalinated water produced in a carbon neutral manner would need to retail at almost three times the then water price[66].

Queensland: Desalination in a confused policy context

A more modest desalination plant of 125,000 m3/day was raised in the context of the future water supply strategy of south east Queensland, historically one of the fastest growing areas of Australia. The area has in recent years been plagued by water shortages, manifested in recurrent drought, historically low reservoir levels and water restrictions. The plant is to be located in one of the highest growth coastal corridors on the Gold Coast and will be operated by a local authority which in recent years has made a determined commitment to water saving and efficiency. The project, canvassed in an overall water strategy, commenced with extensive consultation and consideration of alternative sites, but as the water supply crisis rapidly worsened, State government leaders began warning of a water “armageddon”. Earlier the government had sidestepped calls for increased water recycling by deferring the issue to a referendum. However in January 2007 it was suddenly announced that the referendum would be cancelled and an extensive water recycling scheme would be added as well as the desalination plant, now to be pushed through without an environmental impact study. The plan originally included mitigation for its greenhouse impacts which could include a proportion of renewable energy use [67]but it is unclear whether this commitment is to be maintained. Both the recycling and desalination plants are to be based around RO technology.

At an underlying level, Queensland has long been characterised by a confused overall approach to its water supplies and associated environmental assets. One key problem, recognised in theory in a succession of government planning studies but not addressed in practice, has been a failure to manage growth and anticipate resource and environmental constraints. The march of housing estates has been proceeding with a mainly only rhetorical consideration of such issues as water availability and the impacts on catchments - an approach sometimes derided as perpetually “planning to have a plan”. In reality, as with other Australian state governments, the Queensland government’s approach to least cost water provision has not lead to the most sustainable approach that was possible. Many conservationists see the choice of desalination at this stage as sign of failure to accelerate alternative water supply and demand management options over the previous ten years or more. Such measures could have prevented or certainly delayed the current crunch of growing water demand and limited available supply.

An additional issue common to a number of Australian States is that rational resource planning processes are regularly corrupted to justify poorly planned projects being thrown up from the realm of populist politics. In Queensland, the State government has committed itself to building additional dams in the face of considerable opposition, despite the most recent large dam amply fulfilling numerous predictions that it would be an uneconomic and environmentally damaging white elephant[68.] With a looming shortage of rivers in which it is politically, environmentally or economically feasible to promise a dam, there is a danger that the promise first and justify later approach might extend to large desalination plants.

Perth: The thirstiest city embraces desalination

Western Australia has had prior experience of desalination, with a small 220 m3/day plant commissioned in 1995 to supply a substantial portion of the water supply needs of Rottnest Island off the capital city of Perth. The plant, now upgraded to produce 500 m3/day of freshwater from saline groundwaters, provides 70 percent of the island's water needs. Environmental recognition and awards have flowed from the coupling of a wind turbine to the desalination plant during the recent upgrade[69.]

Perth, however, has not been noted for the same careful approach to water management as Rottnest Island. High and poorly planned growth, a permanent reduction in rainfall partially related to climate change and a past reckless resort to groundwater exploitation when reservoir levels began to fall has been the background to an acceptance that Perth's water future will be highly expensive. Perth possibly enjoys the most favorable economic environment for large scale desalination – especially when desalination proposals are lined up against fanciful schemes to find Perth's future water from distant dams in the far north of the State. The State government in 2004 approved what is the largest desalination plant in the southern Hemisphere, a 45Gl per year (123,000 m3/day) desalination facility with the cost initially estimated at $350 million[.70] The plant, which started operating in late 2006 supplies 17 percent of Perth's water supply, and will draw its water from and return brine and other wastes to environmentally sensitive Cockburn Sound. Impacts on the area are to be monitored. In linking the plant's energy consumption to a new wind turbine “farm”, the government also claimed that the plant would be the world's largest to be powered by renewable energy.[71]

As this report went to press, the WA government announced a second, similarly sized desalination plant would be built by 2011, to bring total desalinated water supplies to around a third of the Perth total. The plant was chosen as an alternative to the government's initially preferred option of exploiting new groundwater reserves, which had attracted opposition on environmental grounds. The plant was also planned to take renewable energy supplies. A private water desalination plant is also being proposed to provide water to the Goldfields area of the State; if it goes ahead, this will reduce some of the pressure on water supplies to Perth.

Water conservation and efficiency measures are included in Perth's water future planning, but there are many avenues that could be exploited at much lower cost than desalination. For instance, residential developers and builders are currently encouraged rather than required to meet water and energy efficiency standards.

Can desalination help not hinder Australian water management?

A recent federal study of water supply options for Australian cities notes that there is no one simple answer to the nation's current and looming water supply issues and that the best mix of options varies greatly in cost and yield from location to location. However desalination is regarded in the study as a potentially cost effective option in many areas, ranking behind the purchase of irrigation waters from farmers, demand management, stormwater re-use and tapping into groundwater reserves. “Voluntary water conservation is often the most affordable, environmentally sensitive option available to urban water users,” the study notes.

Interestingly, the study appears to rule out desalination as a major option for fast growing SE Qld on environmental grounds, largely because the location of the largest population centres would call for waste brine to be discharged into the largely enclosed waters of Moreton Bay. Otherwise, it finds that “careful attention is required to minimise impacts on the marine environment” but “there are generally technical solutions and this is largely a question of cost”.

In some limited cases in Australia desalination may provide the best option from the triple bottom line perspective of sustainability. Unfortunately however, the growing financial feasibility of large scale desalination has helped support the continuation of the supply side dominated culture of water management in Australia. The question remains where to find the next large water source to meet growing water demand thus usurping the more basic question of how to best -- and most sustainably -- meet our water needs.

Beyond the current vogue for seawater desalination, there could well be a significant future for desalination related technologies in Australia in addressing land degradation and water recycling issues. The nation has significant salinity problems in groundwaters and some rivers. There are also relatively low levels of urban water recycling. Although public acceptance of recycled water is currently low, Australian cities will not forever be able to maintain a largely one way flow from dam to sea.

The risk remains that the wealthy Australian governments will continue to choose the politically easier option of new major desalination plants to meet growing water demands, before pursuing all of the potential available from implementing the less popular, but more sustainable options of greater demand management, water efficiency, and water recycling. More fundamentally, major desalination plants, like long distance water pipeline proposals, are now being used to avoid creating and implementing water and resource planning policies that acknowledge and respect the ecological constraints of catchments and regions. It remains to be seen whether desalination plants will in the long term contribute to moving towards a more sustainable water management regimes in Australia, or instead be used to prop-up existing sub-optimal (from a sustainability perspective) water management regimes that in fact need further reform.

Bottled folly

“Desalination - which the Premier, Bob Carr, once memorably dismissed as "bottled electricity" - is the most expensive and least environmentally sound solution to Sydney's water problem. The plant, once built, will supply 500 megalitres a day - a third of the city's water - but will use the equivalent of two-thirds of the output of one medium-sized coal-fired power station to do it. Those who see something of an anomaly in burning more coal to supplement water supplies which coal-induced climate change has caused to dry up can relax, Mr Carr says: the extra power will be generated by gas-fired power stations (producing fewer greenhouse emissions) or the emissions will be offset with carbon trading credits. It will, of course, cost more that way, and the vast amounts of electricity involved will have to be brought from distant power stations at further expense. This costly process should have been the Government's last resort in its search for ways to supplement Sydney's water supply. Instead, it looks like its first and only option, apart from prayers for rain.

Editorial, Sydney Morning Herald, July 12, 2005

Desalination as distraction

All of the areas where seawater desalination is rapidly assuming a more prominent water supply role had more cost effective and less potentially environmentally damaging alternatives available. This is particularly true of demand management, water conservation and water efficiency measures, where many of even the more advanced economies such as Australia do not uniformly require easily achievable water and energy efficiency standards in new buildings.

The extent to which a furore in favour of desalination is associated with unsustainable urban development, excess water intensive tourism development for arid areas, and unsustainable arid area export agriculture is also disturbing. Many of these relatively dry or drying areas have high levels of water consumption. Many of the areas where there is most intensive desalination activity also have a history of damaging or degrading natural water resources, particularly groundwater. What such societies need is a new attitude to water not a new water supply.

It is in this sense that desalination, which fits a familiar supply paradigm, caters to the edifice complex of institutions and politicians, and offers up opportunities of a new stream of contracts to the infrastructure industry, is essentially a distraction to the need to use all water wisely for the maintenance of both human societies and the natural systems on which they depend.

The World Bank, in conducting a study of desalination in Asia, the Middle East and North Africa, sounded a strong and similar note of caution about desalination.

"A key conclusion of the study is that desalination alone cannot deliver the promise of improved water supply. The ability to make the best use of desalination is subject to a series of wider water sector related conditions. In some countries weak water utilities, politically determined low water tariffs, high water losses and poor sector policies mean that desalinated water, just like any other new source of bulk water, may not be used wisely or that desalination plants are at risk of falling into disrepair. Under these conditions, there is a risk that substantial amounts of money are used inefficiently, and that desalination cannot alleviate water scarcity nor contribute to the achievement of the MDGs. It may be preferable not to engage in desalination on a large scale unless the underlying weaknesses of the water sector are seriously addressed. A programme to address these weaknesses should include a reduction of non-revenue water; appropriate cost recovery; limited use of targeted subsidies; sound investment planning; integrated water resources management; proper environmental impact assessments; and capacity building in desalination as well as in water resources management and utility management. **In any case, desalination should remain the last resort, and should only be applied after cheaper alternatives in terms of supply and demand management have carefully been considered.** *(emphasis added)*

A second conclusion is that the private sector can play a useful and important role in funding and operating desalination plants, but only if the above conditions are met. If these conditions are absent, there is a risk that excessive investments in desalination become a drain to the national budget, either directly under public financing or indirectly through implicit or explicit guarantees under private financing."[72]

Making water – a basis for sound decisions

Beyond desalination

Seawater desalination has been pushed into particular prominence as a way of resolving looming water shortages in many areas of the world. Other options for the provision of industrially produced water, such as recycling water, are consequently receiving less than their due amount of attention.

Recent developments in membrane technologies mean that the machinery and processes for making water by removing contaminants are becoming increasingly similar. In fact, as cost is closely related to the proportion of contaminants in the feed water, using similar processes to recycle wastewaters will often be economically and is invariably environmentally preferable to removing the salt from seawater.

Manufactured water is a clear water supply option for most areas and will be a necessity in some such as islands, or the extensive areas of southern and southeast Asia and other places where drinking water supplies are now laced with dangerous contaminants such as arsenic. Membrane technologies can be deployed from a scale that varies from hand held units to plants with capacities currently edging up to production volumes of 500,000 m3 of water a day.

While the sea is clearly the greatest available volume of potential feedstock for water manufacturing, proceeding straight to a desalination plant excludes viable options for sustainable water use in the same way that proceeding straight to a new dam often did in the past and unfortunately still does at times.

Making economically and environmentally sound decisions on large scale projects

The world is currently witnessing an unprecedented and dramatic growth in the number of proposals for large scale desalination proposals. **It is of concern to WWF that there currently exists no consistent, viable framework for assessing when "making water" is justified on environmental, economic or social grounds.** WWF's position on large scale desalination plants is that:

Resource planning before infrastructure planning

Immense damage has been done and large and unnecessary social and economic costs have been incurred in the past through ad-hoc development of major water infrastructure. A key antidote to a recurring pattern of resources being damaged while the water needs of human and natural communities are unevenly or poorly met is integrated water resource planning and managment at the national, catchment and more local levels. WWF believes that the environment should be well conserved as the source of water for people and nature.

It should be noted that all governments committed at the 2002 World Summit on Sustainable Development to preparing national Integrated Water Resource Management (IWRM) plans to help deliver the 2015 Millenium Development Goals. Integrated water management planning at the catchment level is now well proved as a mechanism for providing for water needs and protecting environmental assets.

As large infrastructure proposals, proposals for large scale desalination plants need to flow from or at the very least be evaluated in the context of a relevant water resource management plan. The large proportion of plants that will desalinate seawater and impact on marine areas similarly need evaluation in the context of a relevant marine resource plan.

As well as indicating where desalination may augment water supplies, such IWRM planning may well point to areas where desalination technologies can be used to reduce stress on or repair natural water systems.

Towards an assessment process for large scale desalination plants

Individual projects need to be and in many jurisdictions are assessed in relation to planning schemes for particular sites. But this is not a sufficient level of assessment to cover whether water needs have been realistically assessed, that particular proposals are the least cost way of meeting needs and that new water supplies will not promote unsustainable land and resources use.

The pioneering work of the World Commission on Dams pointed the way to an assessment process for large scale water infrastructure projects generally. WWF believes that a compatible process could and should be established for large scale desalination projects. This to ensure that any proposed plant is needed and is the best option for meeting the identified water needs after open, comprehensive and equivalent consideration of the costs and impacts of all options.

WWF considers such a model process should include:

Considering desalination and in particular seawater desalination as an option

- only after integrated water resource management plans are in place at the catchment and local levels and these demonstrate a need to augment water supplies.
- for seawater desalination, only after relevant marine protection plans are in place
- only where robust land use planning schemes that give adequate weight to environmental constraints exist and are enforced. These may include provisions to manage demand through the exclusion of thirsty developments such as irrigated agriculture or golf courses from water scarce districts.
- only after all no regrets conservation and efficiency measures have already been undertaken or allowed for in the assessment of water needs in the proposed area of supply. Implementation plans backed by adequate resourcing should exist for medium and longer term water conservation and efficiency measures.
- only where water, including agricultural water, is appropriately priced to reflect the full costs of supply. Where social reasons exist for reducing the real cost of water, the subsidies should be directed specifically to the target group, should be transparent and should not be applied to the water price.
- only where the capital expenditure devoted to desalination plants could not be more productively or cost-effectively be devoted to:
    - demand management as an alternative to additional supply
    - using related technologies to recycle water.
    - using related technologies to treat “impaired water” resulting from prior poor environmental practice
    - restoring the functioning of damaged natural water supply systems

Minimising the environmental impact of large scale desalination plants

Desalination infrastructure should proceed only where plants are sited, constructed and operated to minimise adverse environmental impacts. The major direct impacts are associated with the frequent requirement to site plants in sensitive coastal areas already subject to pressure from urbanisation, their high levels of energy demand, the design and operation of intake and outflow structures and effluent issues with concentrated brines, biocides and chemicals used in cleaning and defouling and corrosion byproducts. Where possible:

- Seawater desalination plants should not be sited in areas where intake or outlet pipes would open into or traverse sensitive marine or coastal environments.
- Intakes should be screened to the maximum possible extent with subsurface or beach wells being a preferable technology to open ocean intakes. Care needs to be exercised however that no damage is inflicted on coastal aquifers.
- "Zero spill" solutions should be considered the preferable way of treating wastes. Reducing brines to solid or minimal volume form with safe disposal options including former salt mines would minimise a major concern with desalination. In some cases, such wastes would be valuable inputs for the chemical industry. Research into more efficiently and economically concentrating wastes should be a priority.
- Where liquid disposal of concentrated brines is required this should involve adequate dilution, mixing and dispersal, should be restricted to areas of low biological sensitivity and should be subject to adequate monitoring regimes. Disposal at surface level is preferable to seabottom disposal.

Making "Bottled electricity" climate neutral

As a very energy intensive process whose product was once famously labelled "bottled electricity", desalination needs to be powered in such a way that it does not become a significant major new contributer to increasing emissions and climate change risk. Accordingly, plant promoters and approval agencies need to ensure that:

- Plants use the most energy efficient technologies
- Plants are developed in stages to take advantage of improving energy efficiency.
- With due regard to the need to site plants to protect sensitive areas, plants are sited to minimise the energy required to pump water to consumers
- Plants are powered through renewable energy, purchase green energy or use "Gold Standard" offsets for all their emissions

Coastal desalination plants particularly need to consider the implications of climate change, which is predicted to lead to sea level rises, more severe extreme coastal weather events and increased risks of saline intrusion into coastal aquifers.

Desalination and subsidies

In a long drawn out and continuing process, water is coming to be more appropriately valued in many jurisdictions and this is proving to be a powerful driver of water conservation initiatives and water use efficiency improvements. Desalinated water similarly needs to be appropriately priced in a way that is devoid of public subsidies and reflects the economic and environmental costs of production and supply.

This is clearly not the case in many if not most of the areas where desalination currently provides a significant proportion of the water supply. Where subsidies are thought necessary for social reasons, they should be in the form of transparent and direct payments to target groups rather than actions that impact on water prices. To do otherwise is to weaken incentives for water efficiency and conservation.

It should be noted that most current desalination technologies were substantially researched and developed at public expense, most significantly in the USA.

Downstream impacts

Much of the controversy surrounding desalination is less related to the process itself or the direct environmental impacts than it is to the development that will be enabled by the availability of new water supplies. In California, one key concern has been that add-on desalination is being used as a pretext to extend the life of “flow through” cooling systems used by coastal power stations which have been under regulatory pressure for their impacts on marine life and water quality.

The more general concern, apparent in all the areas studied by WWF, is that supplies of desalinated water will underpin unsustainable and environmentally damaging development. In naturally dry areas where groundwater has been depleted and contaminated supporting export horticulture, rapid real estate development and increasing the acreage of golf courses and resort pools, such concerns are easy to understand. Certainly some of the areas where desalination is being most enthusiastically proposed are also characterised by poor development controls, few or ineffective constraints on resource use and perverse subsidies that support environmentally damaging activity.

Clearly, there needs to be specific consideration as to whether the approval of large scale desalination plants will have undesirable flow-on effects. However, more durable remedies would come from pricing water correctly, removing subsidies (in particular on agricultural inputs and outputs) and establishing robust planning and development controls on resource and land use.

Further research on environmental impacts

Most of the desalination research effort is being devoted to improving desalination's technical performance. However, there is much that is not known on the cumulative environmental effects of large scale desalination, with particular attention needed to the cumulative impacts of intake structures on aquatic or marine life, the behaviour and effects of concentrated brine discharges, and the disposal or discharge effects of a considerable list of potential other pollutants including heat, corrosion byproducts and the biocides and chemicals used in regular flushing and periodic maintenance of filters.

Complicating the shortfalls in knowledge on general impacts of desalination processes are the highly site specific conditions of coastal or catchment topography, substrate and aquifer structures and currents and wave patterns that can amplify or modify impacts on aquatic, terrestrial or marine communities.

Water authorities and the growing desalination industry cannot have it both ways. They cannot assert a commitment to environmental responsibility without also committing substantially to research into potential long term cumulative impacts of an industry that is rapidly scaling up its presence in many areas of the world.

A note on measures

Jurisdictions considering desalination use a dizzying array of measures of volume. This report will use measures based on multiples of litres, as follows.

1Kl (Kilolitre) = 1000 litres = 1 cubic metre (m3)
1 Ml (Megalitre) = 1000 Kl = 1 million litres
1 Gl (Gigalitre) = 1000 Ml = 1 billion (thousand million) litres = 1 mcm (million cubic metres)

Conversions from other units of volume are

1 acre foot = 1.233 Ml= 1233 m3
1 million gallons (US) = 3785 m3

Practical Salinity Unit
Used to describe the concentration of dissolved salts in water, the UNESCO Practical Salinity Scale of 1978 (PSS78) defines salinity in terms of a conductivity ratio, so it is dimensionless. Salinity was formerly expressed in terms of parts per thousand (ppt) or by weight (parts per thousand or 0/00). That is, a salinity of 35 ppt meant 35 pounds of salt per 1,000 pounds of seawater. Open ocean salinity is generally in the range from 32 to 37.

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WWF's mission is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature, by:

- conserving the world's biological diversity
- ensuring that the use of renewable natural resources is sustainable
- promoting the reduction of pollution and wasteful consumption

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