A MODEL PERFORMANCE BASED CONTRACT FOR WATER CONSERVATION AND WATER DEMAND MANAGEMENT (WCWDM)

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ABSTRACT

37% of all bulk water supplied to the better-administered municipalities in South Africa is wasted either through physical leakage or through the mismanagement of metering and billing systems.

This paper will describe the results and experience gained from a performance based WCWDM contract and will go on to describe the model contract documentation that has been developed by the Strategic Water Partners Network (SWPN), with support from the GIZ Transboundary Water Programme in SADC. This documentation is designed to assist municipalities to appoint a specialist WCWDM contractor using a financial bonus linked to the benefits that are achieved. The model contract provides a basic template which conforms to current South African legislative requirements and best practice.

The model contract allows for options for different performance based incentives and provides a contractual basis on how this can be tendered and applied. This approach can ensure a cost effective outcome due to the contractor being invested in the best possible outcome thus ensuring that creative, innovative and proactive measures are applied.

The Model Performance Based Contract pack includes:

- Model Tender and Contract Document
- Model Bill of Quantities
- Guidelines for using the document as well as for monitoring and evaluation.

BACKGROUND

South Africa is a semi-arid, water scarce country and many of the country's water resources are already fully allocated to different domestic, agricultural and industrial uses. Any further growth in water demand (beyond the 20 year planning horizon) will necessitate expensive measures such as the construction of new dams and long distance water transfer schemes from outside the borders of the catchment, or even the country, or from desalination plants at the coast in order to maintain the current levels of growth. At the same time it is estimated that about 37% of all bulk water used in municipalities is wasted through either physical leakage (25%) or through the mismanagement of metering and billing systems (12%). These values are an estimate based on data obtained from just over half of the municipalities in the country representing 75% of the total municipal water consumption. The other municipalities do not have sufficient data to determine what percentage of their water supply is lost and for what reasons.

In this context, Water Conservation and Water Demand Management (WCWDM) interventions have become critically important in order to address these water losses. It is generally far more cost effective to fix leaks and reduce the wastage of water than it is to build a new dam and transfer scheme from a neighbouring catchment or to upgrade a Water Treatment Plant and its associated reservoirs. WCWDM measures cover a range of interventions, including social interventions such as community education regarding household water efficiency and losses, to the overhauling of billing systems, to the review of the tariffs charged for water, to active leak detection and repair, to better meter management and to better management of water pressures (some of these measures are introduced in more details below). Pressure management is in many cases the single intervention which makes the greatest difference in the shortest time, as water pressures in our distribution systems in South Africa have tended to be excessive, and it has been established that there is a more or less linear correlation between water pressure and the volumes of water leakage. In fact, the South African government has taken a strong stance on WCWDM by issuing the No Drop certification programme for municipalities. In the course of this certification, municipalities will have to demonstrate how they perform in six performance categories, including:

- WCWDM Strategy, Planning and Implementation
- Asset Management
- Technical Skills
- Credibility
- Compliance and Performance
- Local Regulation
- Customer Care.

The combination of the cost of water losses, the country's need to save water as well as the governmental requirements constitute a considerable driver for municipalities to embark on (additional) WCWDM measures. Such measures, in particular pressure management and leak detection are, nowadays, a fairly specialised field and most municipalities in South Africa do not possess the necessary technical skills to carry out this work in-house.

The solution is to contract out certain measures to external contractors or service providers. The purpose of the model contract document is to provide municipalities with a template for the employment of specialists to assist with this work including a performance-oriented element with a financial bonus linked to the value of the water which is saved. The Strategic Water Partners Network (SWPN)[1], with support from the GIZ Transboundary Water Programme in SADC[2], has produced a model performance based WCWDM contract that provides a basic template which conforms to current (as at 2014) South African legislative requirements and best practice in terms of WCWDM optimisation.

CASE STUDY – EMFULENI LOCAL MUNICIPALITY

Background

Emfuleni Local Municipality lies within the Orange-Senqu river basin adjacent to its main tributary, the Vaal River. The demand on this important water resource already exceeds its sustainable supply. Municipalities across Gauteng and beyond purchase their potable water from Rand Water whose source of supply is the Vaal River. The municipalities then provide this water to residential and commercial customers but non-revenue water (NRW) percentages across the systems are high, ranging from 20% to over 40%. Emfuleni had an NRW in excess of 40% equating to a loss of more than 30 million m^3 of water per annum. Like many municipalities, Emfuleni did not have the necessary capacity, instruments or resources to implement the required water conservation and demand management actions. This not only threatens the water supply of the residents, but also poses water risks to businesses, restricting economic development and adding to the strain on the available resource.

Sasol Limited has considerable sizable operations that are dependent on the water supplied from the Vaal River and it had already made significant investments to reduce its water use and to improve its water security. It faced diminishing returns as the costs for further improvements were increasing compared to additional gains in water saving. The need

[1] The Strategic Water Partners Network is a collaboration between the Department of Water and Sanitation and major private sector water users.
[2] The GIZ programme is jointly funded by the German, United Kingdom and Australian governments.

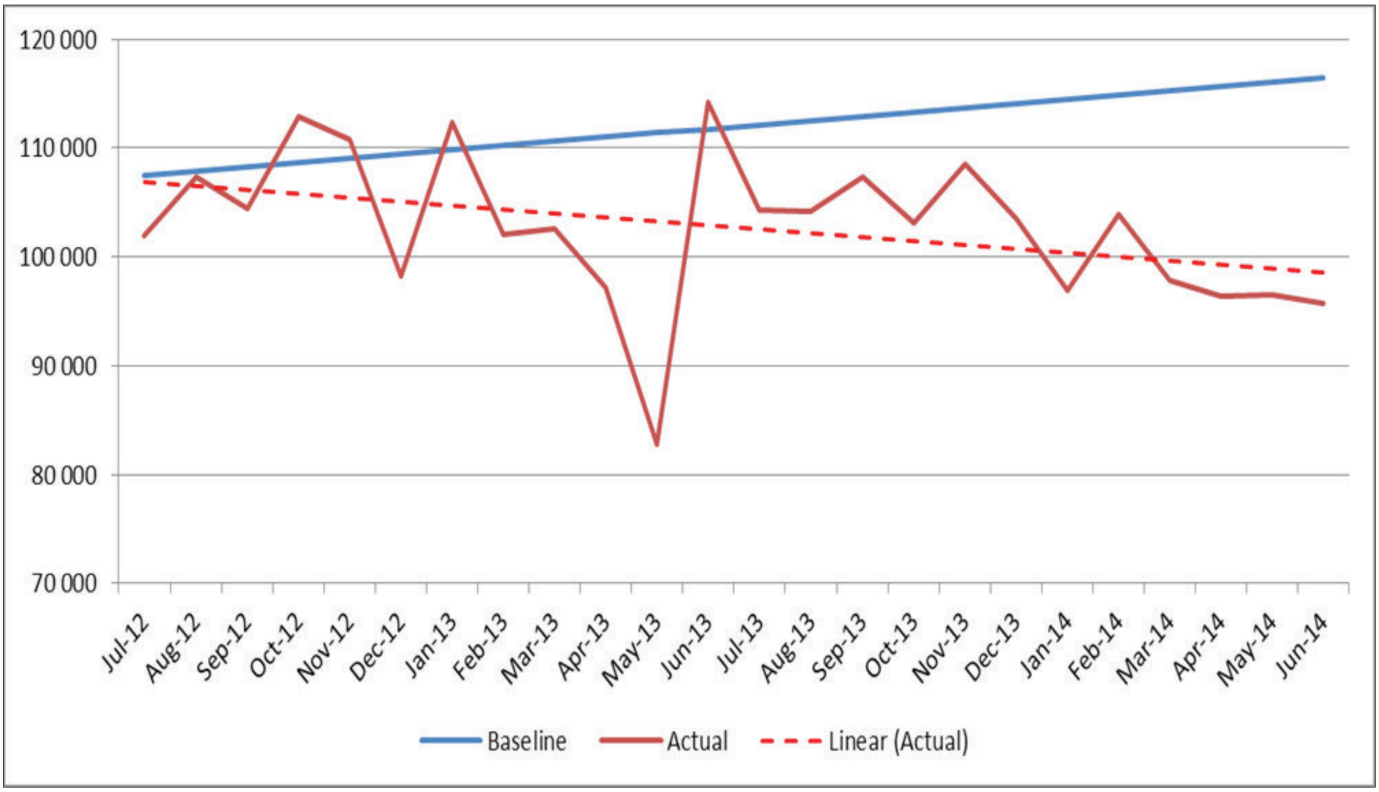

FIGURE 1 Comparison of baseline demand and actual water consumption

to comply with possible imposed water-reduction targets was seen as a significant threat to the company and the security of its water supply had been identified as a risk to future operations.

It was therefore seen as good business sense to redirect these investments to help other users make larger savings. This approach would then lead to significant water savings, and at the same time reduce water risks, both to Sasol and to all users of the resource, including the municipalities.

Project Partnership

The need to offer assistance to Emfuleni was jointly identified by GIZ and Sasol who agreed to approach the municipality on the matter. Following a series of negotiations, Emfuleni, Sasol and GIZ entered into a Memorandum of Understanding (MoU) to implement a Water Conservation and Water Demand Management (WCWDM) project. Under this MoU, initial seed funding of R5 million was made available through the SADC Transboundary Water Management Programme managed by GIZ and Sasol also made R5 million available. The Municipality in turn agreed to ring fence the savings created by the reduction in water use to be re-invested to augment the partnership seed funding and to continue with the water conservation interventions. The underlying principle of the project cooperation was that the seed funding would be used to initiate the project and create financial savings for Emfuleni. These savings would then be utilized to continue and grow the project thus providing Emfuleni with a self-funding process that would allow them to further address water loss problems. The funding from GIZ and the SADC Transboundary Water Project would contribute to reducing the demand on the Orange-Senqu river basin and the funding from Sasol would contribute to the improvements in their level of water security.

Project Scope

Emfuleni has a population of approximately 720 000 in 220 000 households. It also supports considerable industry and commercial operations. In the financial year 2011/12 it purchased some 82 million m^3 of potable water from Rand Water at a cost of around R410 million. Historical trends showed that the annual growth in water demand for the municipality was between 4% and 5% per annum. Non-Revenue Water (NRW) values for the municipality were in the range 35% to 40% resulting in losses of the order of 30 million m^3 per year equating to a cost of R150 million per year.

The Evaton/Sebokeng area was identified by the municipality as being the priority area for the focus of the project. It represented about 40% of the total water consumption of the municipality and water consumption was been charged on a deemed-use basis as a result of few meters being read. This resulted in extremely low payment levels being recorded for the area meaning that any reduction in water consumption would create a direct saving in cost to the municipality.

The priorities of the project were to:

- reduce physical water losses in the prioritised areas through pressure management and the repair of leaking household water systems
- provide education and awareness to the community regarding water conservation issues
- train and develop community plumbers who would be recruited locally.

Contract

Using a performance based contract, a full competitive tender and evaluation process was undertaken by Sasol and the services of an experienced Managing Consultant were procured. The principle of the contract was that the Managing Consultant would be paid for its time (at a lower than normal rate) and for all expenses incurred as per a priced bill of quantities. Additionally a performance bonus would be paid as follows:

- for up to a 10% saving in water costs – 10% of the saving
- for between 10% and 25% saving – 20% of the saving between 10% and 25%
- the performance bonus level was capped at 25%.

The first priority of the project was to establish the water use baseline for the area based on a history of the bulk water supply. A supply area was identified which was served by three Rand Water metered supply points,

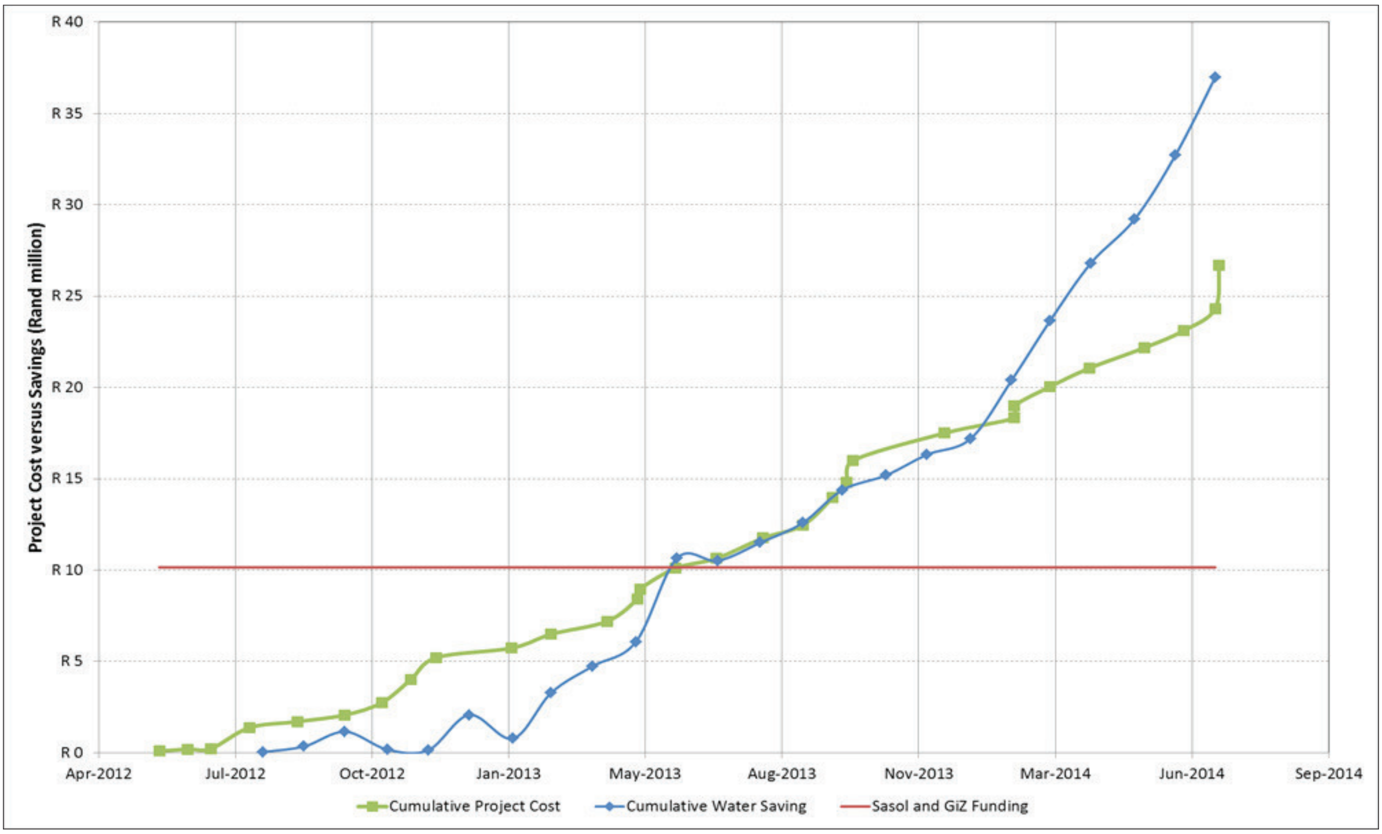

FIGURE 2 Cash flow showing project cost vs. value of water savings (*Source: WRP Consulting Engineers*)

the project area formed the main constituent part of this area. This allowed the use of the historical supply records as well as providing independent third-party meters and meter reading to obtain monthly supply figures to the area.

Given that this historical supply information was available over a multi-year period it was possible to extrapolate the existing water consumption data to create a baseline for the measurement of savings over the duration of the project period. After excluding certain outlier numbers from the calculation, a straight line fit into the actual consumption figures gave an agreed baseline that indicated an annual growth in consumption of around 5%. It should be noted that the baseline is not a single fixed figure but is a line on a graph that reflects the 5% annual growth on a month to month basis. This line was also converted to a specific monthly forecast of the anticipated water consumption without the effect of the WCWDM intervention.

Results Achieved

Through the use of the Performance Based approach, the appointed Managing Consultant was "invested" in the project. It was in their interest to identify problem areas and to come up with solutions to address them and to maximise the savings achieved.

The combined effect of the interventions for the two financial years covered by the project resulted in a reduction in water use of 6.85 million m^3 against the baseline – a saving of R37 million on the municipal water bill over the two years.

More importantly, however, for the last six months of the project the anticipated demand of 21 million m^3 was reduced to an actual consumption of 17.5 million m^3, a reduction of 16.7%. Relating this to the next financial year (2014/15) this will create a reduction in water demand of at least 7 million m^3 and a reduction in water costs to the Municipality of over R40 million. The comparison of the project water demand baseline with the actual monthly consumption is shown in Figure 1.

Against the direct savings of R37 million over the two year life of the project, the total project cost was R27 million of which R5 million was contributed by GIZ, R5 million by Sasol and the balance of R17 million was paid by the Municipality out of the savings achieved. The cash flow showing expenditure versus cost savings is shown in Figure 2.

The cash flow graph above shows the importance of the seed funding that covered the initial cost of the work that had to be implemented before the first positive savings were realised.

The initial requirements were to look at priority areas covering some 20 000 properties in Phase 1. The Managing Consultant eventually addressed over 70 000 properties and was constantly identifying areas where further savings could be achieved.

In addition to the direct measurable results mentioned above, there are a number of indirect benefits:

- the level of awareness and understanding of the need to conserve water has increased in the target areas
- the house owners are starting to take responsibility for fixing leaks in their houses themselves
- this project has paved the way for the Municipality to roll out improved metering and billing practices in the sense that the community is now more aware of their use and, through the curbing of unnecessary high usage, their potential bills have been reduced
- formal up-skilling and employment opportunities for 90 local residents were created by the project
- this project has also improved the capacity of the Municipality to execute large water conservation and demand management projects in their jurisdiction
- the waste water treatment works serving this area has previously been assessed as being hydraulically overloaded as well as receiving a diluted quality of effluent that is not optimal for processing purposes; a major factor in this is the volume of potable water entering the

Ref.	Item	Unit	Amount	
A	Total from BoQ	R	5 000 000	*Total of Reimbursable Items*
B	Baseline Volume porjection: month 7 to end	kl	63 165 870	*Predicted water use without WCDM contract*
C	Expected Efficiency Gain	%	10	*Assumed saving % for tender purposes*
D	Expected saving in water	kl	6 316 587	*Assumed saving in water using the % in row C (B x C)*
E	Performance Bonus Rate	R/kl	0.75	*Rate tendered for Performance Bonus*
F	Expected Performance Bonus	R	4 737 440	*Based on assumed saving and tendered rate (D x E)*
G	Total Tender Price	R	9 737 440	*Performance bonus plus Reimbursable items (A + F)*
H	VAT	R	1 363 242	
I	**Total Tender Price incl VAT**	**R**	**11 100 682**	*Total Tender*
			(yellow)	*Set by Municipality*
			(green)	*Tendered Rate or Amount*

FIGURE 3 Example of calculation of tender amount

sewerage system due to leaks and wastage. A reduction in such leaks and wastage will improve the operating conditions of the waste water treatment plant
- sasol, as the private sector partner, has been recognised as a leader and major role player in the principles of water stewardship and development partnership projects, both internationally and locally, by public authorities and institutions as well as by their peers.

Lessons Learned
- The ability to determine the baseline of water use is important to be able to accurately determine the water savings achieved
- Where a municipality is purchasing water from a third party, this allows for a simple calculation of the monetary value of the savings being achieved as well as providing an independent quantification of the actual water use
- Unexplained monthly fluctuations in demand will occur and will complicate the measurement of savings. The conversion of meter readings to average daily figures will reduce the impact of different meter reading periods on this but it will always be necessary to look at consumption figures over a three or six month period. It is also beneficial to have check meters running on the main supply points
- Community engagement through the awareness and education components is a key element of the programme and should not be ignored;
- The correct application of pressure management is an internationally accepted practice that can have a significant impact on reducing water losses through leaks and wastage – this is particularly the case in Southern Africa where pressures are generally higher than necessary
- The main focus area of this project was to work with the community in respect of education and awareness as well as to repair in-house leaks. This was achieved. For such work to be sustainable, however, it will eventually require the introduction and enforcement of metering and payment systems which is a potential confrontational issue and therefore better dealt with as a separate exercise.

THE MODEL PERFORMANCE BASED CONTRACT

Flowing out of the testing and experience from the Emfuleni project, the Strategic Water Partners Network (of which Sasol is a partner) requested GIZ to assist in developing a Model Performance Based Contract which could be used by municipalities to establish appropriate WCWDM contracts that would build on the success of the work at Emfuleni.

The key concept of a performance based contract is the use of performance-based incentives to provide the specialist WCWDM contractor with a financial bonus linked to the value of the water which is saved through the WCWDM measures employed. Appropriately used, such incentives can ensure the most cost effective outcome.

This is because the contractor is not just performing a service but is invested in the outcome of that service and will therefore be that much more creative, innovative and proactive to ensure that the best possible outcome is achieved.

The model contract contains options for the use of performance based incentives and provides a contractual basis on how this can be tendered and applied.

As the drafting and administration of WCWDM contracts is more specialised than the drafting of conventional water supply construction contracts, this model contract sets out an appropriate process and documentation for both the tender and the final contract.

It is, however, important that the person responsible for compiling the final tender and contract documents is someone with a good background and knowledge on such work and its application within the water environment. The Model Performance Based Contract document pack is available free of charge in electronic format and contains the following documents:

Model Tender and Contract Document

This is issued in Word format so that each user can add specific contract data and can also adjust the documentation (if necessary) to suit both the requirements of the contract and any specific requirements of the issuing authority. The basis of the pricing of the tender provides a schedule that allows each submitted tender price to be compared on an equal basis. It also allows for a mix of both reimbursable items as well as a performance based fee.

The contract uses the General Conditions of Contract for Construction Work (GCC), Second Edition, 2010, published by the South African Institution of Civil Engineering, as the basis for the contractual arrangements and the tender uses the Standard Conditions of Tender as issued by the Construction Industry Development Board (cidb).

The format of the Model Tender and Contract is as follows:
- **Part T1** Tendering Procedure
- **Part T2** Returnable Documents
- **Part C1** Agreements and Contract Data
- **Part C2** Pricing Data
- **Part C3** Site Information
- **Part C4** Scope of Works
- **Part C5** Generally Applicable Specifications
- **Part C6** Particular Project Specifications.

In addition to the above the following additional documents are also included:
- **Standard Conditions of Tender (Construction Industry Development Board)** - These are the standard Conditions of Tender as applied in South Africa. These standard conditions can be amended through the insertion of special clauses in Part T1 of the Model Tender and Contract Document
- **Standard Set of Returnable Schedules required in the Municipal Sector in South Africa** - The South African municipal sector is required to conform to a rigorous process as part of its Supply Chain Management regulations. This process is designed to protect municipalities from corruption, promote the use of BBBEE companies and ensure that a fair and balanced process is used in assessing and awarding tenders. The normal returnable documents that are used are included in this

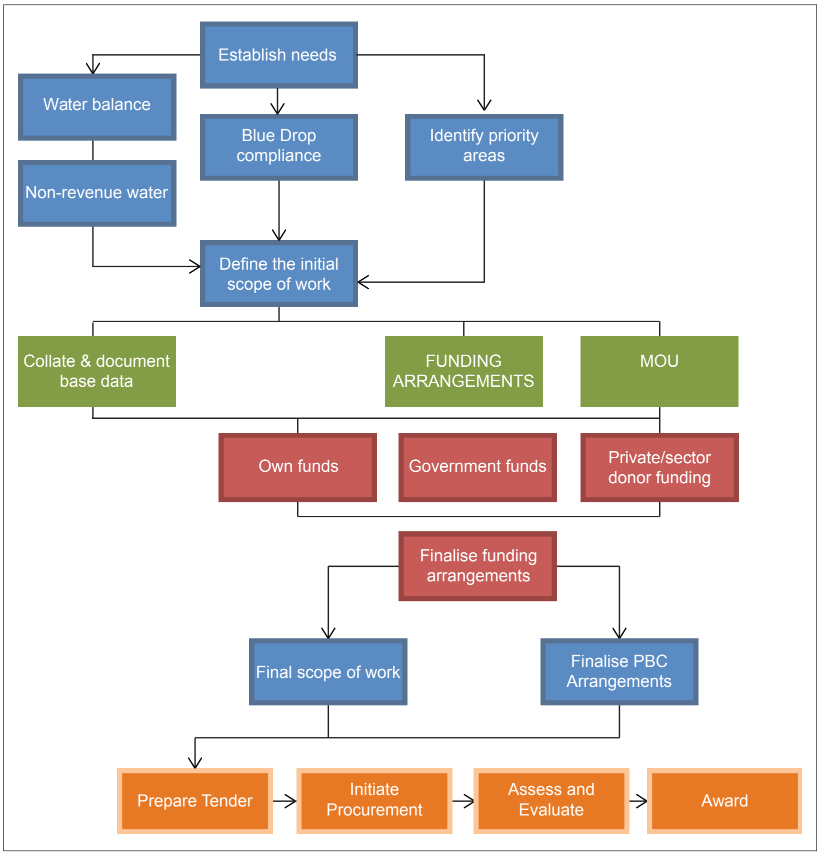

FIGURE 4 Implementation process for a Performance Based Contract

section for use where necessary in tenders. In many cases, municipalities will have their own formats for such schedules and where appropriate, these should be used rather than the standard forms included here.

Model Bill of Quantities

A formatted Model Bill of Quantities is provided as an Excel spreadsheet. This contains typical sections and items that would be applicable to a range of WCWDM interventions. The user is required to select those that are applicable and it may also be necessary to include additional items. The Bill of Quantities deals with work that will be paid for on a reimbursable or measurement basis. It is the skill of the user to decide what work will be covered on this basis and what work (if any) will be included in the performance based portion of the contract.

Guideline for the use of the Model Performance Based Tender and Contract

The Guideline Document provides information for the user of the Model Tender and Contract on when the performance based contract is important and how it should be structured.

Also included are worked examples of the determination of the tender price to include the method of measuring the financial effect of the performance bonus as well as how to determine performance based payments during the contract.

Guideline for Monitoring and Evaluation

A further guideline is provided as to how the Performance Based Contract should be monitored and evaluated both during the contract and on completion.

Selected Lessons from International Experience

A number of interesting examples from other countries are presented in this section. These case studies can inform current thinking although recognition has to be given the varying conditions in the different countries.

Public Private Partnerships – Practice Note

There are very strict rules in South Africa about municipalities entering into contracts that are too long in duration or that attempt to transfer high levels of risk to the private sector. This practice note discusses the factors that would turn a Performance Based Contract into a Public Private Partnership and defines the implications for such an occurrence.

IMPLEMENTATION

The process diagram shown as Fig. 4 gives an indication of the actions that would typically be required for a municipality to implement a WCWDM contract. This process should be followed irrespective of whether a performance based contract is being used or not.

FUNDING MODELS

The involvement of the private sector in the implementation of a Performance Based Contract is not a pre-requisite. It would be perfectly reasonable for a municipality to undertake such work using its own funds to kick start the project, most of which could be expected to give positive returns within a three year cycle.

It is, however, important to remember that nearly every business sector is water-dependant in some way or another. Water stewardship within a company goes beyond being an efficient commercial water user. It means that companies should be contributing to the responsible, sustainable management of freshwater resources. Water stewardship helps governments, companies, investors and others understand their water footprints and become better water stewards. Beyond water footprints and reducing the impact of individual water users, companies are being urged to look outside their own operations and to become involved in advocating, supporting and promoting better water resource governance and utilisation - for the benefit of all people and nature.

On this basis, there is an opportunity for cash strapped municipalities to seek help from local companies and to offer them the opportunity to assist in supporting the local community in terms of water security for all. With a relatively small contribution these companies can help fund the start-up costs of a Performance Based WCWDM contract.

CONCLUSION

In the Model Performance Based Contract, municipalities now have a tool that will help them to be able to prepare an appropriate tender and contract to employ a specialist service provider to assist them in reducing the wasteful component of their water use. The results of such contracts will add to their efforts to comply with the latest No Drop requirements as well as contributing to a reduction in their water consumption.

The option also exists to obtain assistance from a private sector company that is committed to water stewardship to help fund the initial work of the programme with a view of creating a self-sustaining operation for the municipality to continually reduce its water wastage or over-use.

ACKNOWLEDGEMENTS

The documentation for the Model Performance Based Contract was prepared by the team of David Still, Peter Ramsden, David Schaub-Jones and Alex Nash from Partners in Development (Pty) Ltd. GIZ financed and project managed the work on behalf of the Strategic Water Partners Network.

THE ENVIRONMENTAL CONCERNS OF COAL SEAM GAS EXPLORATION IN AUSTRALIA-LESSONS LEARNED

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ABSTRACT

BACKGROUND: Both South Africa and Australia (as well as other countries) have vast reserves of methane gas trapped either in coal or shales up to 1 km or more below the surface. Some of these seams are not pervious (tight gas) and need to be fracced (fracturing is also used) to release the gas. This is a process where high pressure water, sand and fracturing fluids are injected into the wells to open up the coal or shale to release the gas. Unfortunately in most instances because of the depth of the gas it is at a level where groundwater is present which has to be pumped down to a level where the gas can be release to the surface.

ISSUES: The method for fracturing because of previous bad publicity has raised the following concerns from the farming community:
- a possible reduction in available groundwater for farming activities
- the fracturing fluids used might contaminate the available groundwater or aquifers, making it unfit for farming activities
- as most of these produced waters contain dissolved solids because of the coal or shale from which it has been released from, it has to be treated with high cost systems such as Reverse Osmosis (RO) to enable it to be reused for farming activities or released in streams.

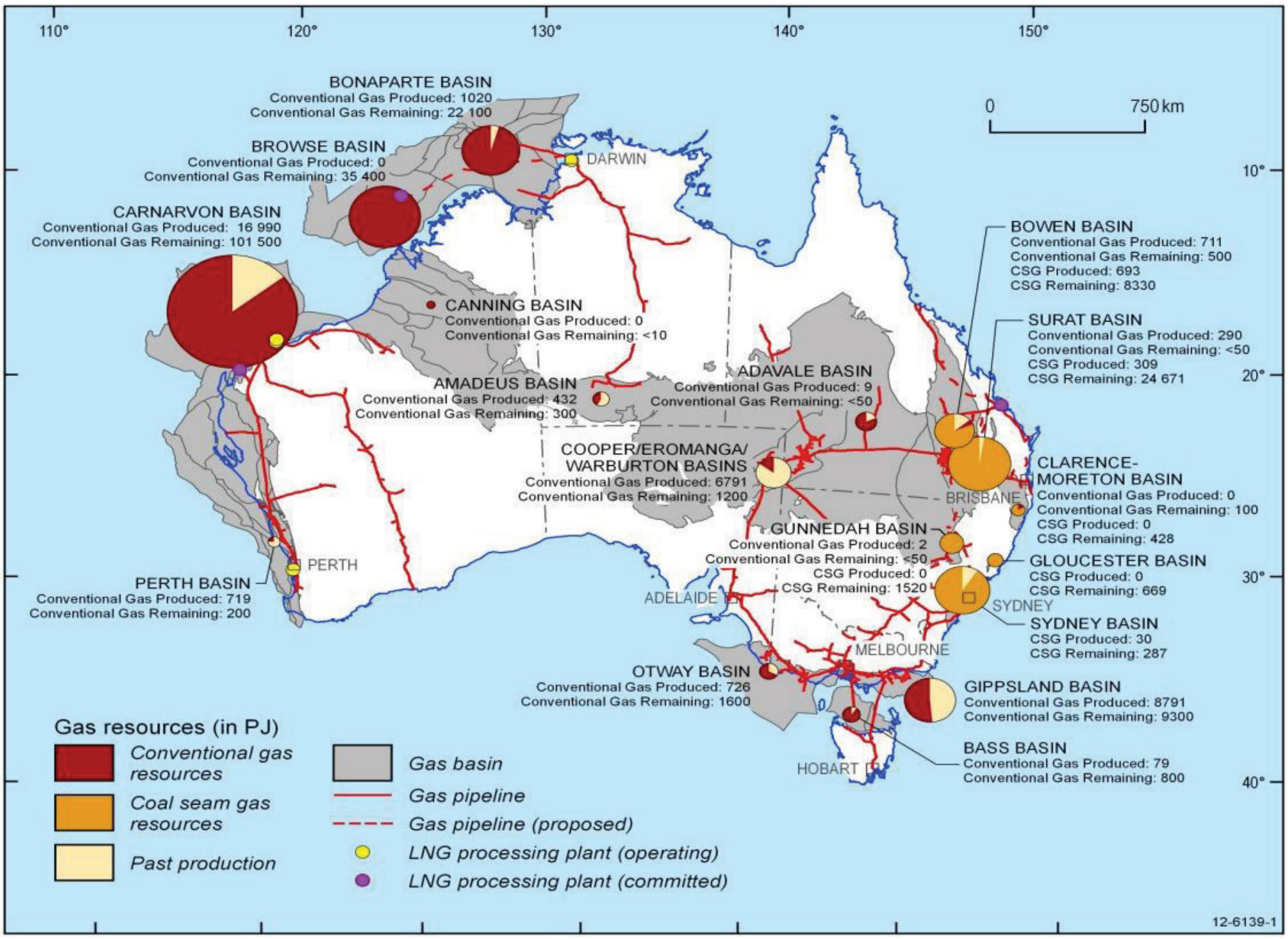
AUSTRALIAN LEGISLATION: The Australian legislation calls for the removal of dissolved solids to a level that is environmentally acceptable before it can be released. It also calls for containment of all salts removed from the RO process as it cannot be released into the environment. This is termed a Zero Liquid Discharge (ZLD) and salt formation from the brine released by the RO process is extremely expensive and special equipment has to be used.

CONCLUSION: It takes huge investments from gas companies to take the Governments and the community along the journey and prove conclusively that this type of development does not have an adverse impact on the environment.

THE ISSUE

Coal and shale seam gas reserves are likely to make a major contribution to future energy needs. However, the new technology for exploiting these reserves, termed hydraulic fracturing or fracturing raises several environmental issues. Australia and South Africa has significant exploitable reserves of natural gas from coals and shale seams, primarily located in the coal basins in QLD and NSW (Australia) but with production potential in most states and territories. Commercial production commenced in Australia in 1996 with slow production growth for its first decade. As with the development of other extractive resource industries, the sustainable development of the sector requires balanced consideration of

FIGURE 1 Location of Australia's gas resources and infrastructure (RET et al, 2012)



its environmental, social and economic impacts, benefits and costs. Activities associated with the development of natural gas from coals seams will affect the environments in which it occurs. Potential environmental issues such as groundwater depletion, produced water management, surface disruption from activities associated with the drilling of wells and the construction of pipelines, and chemical use associated with well drilling and hydraulic fracturing must be managed to minimise environmental impacts.

Australian governments are focused on achieving a balance between developing a world-class industry, protecting the environment, water resources and human health while delivering opportunities and benefits to the Australian community. It is the responsibility of governments to understand and address both the risks and community perceptions involved in the development of natural gas from coal and shale seams and adopt positions that address and respond equally to these risks and perceptions. Governments should aim to provide policies and regulations that encourage the growth of the industry within a regime of relevant, enforced conditions and legislation to protect the environment, human health and facilitate social development and sustainability.

WHAT IS FRACTURING

The methane, formed both by biogenic processes as well as the thermal decomposition of organics, becomes trapped within the high surface area pore networks within the coal. The recovery process involves drilling typically up to 1000 m (and deeper, e.g. 2000 m for shale gas) to locate naturally occurring fractures within the formation and increasing the porosity within the formation to provide conduits for gas migration.

Hydraulic fracturing has been widely used in Australia for more than 40 years to increase the rate and amount of oil and gas extracted from reservoirs. The process of hydraulic fracturing is applied to a minority of operations in Australia.

A sound understanding of the geology, hydrology, hydrogeology and geomechanics is essential to plan the fracturing process and ensure fracture stimulation activities are conducted in a safe manner that protects communities, the environment and water resources. Baseline and ongoing monitoring underpin evidence-based decision-making which ensures that actions taken by regulators and operators on hydraulic fracturing are accountable and enduring.

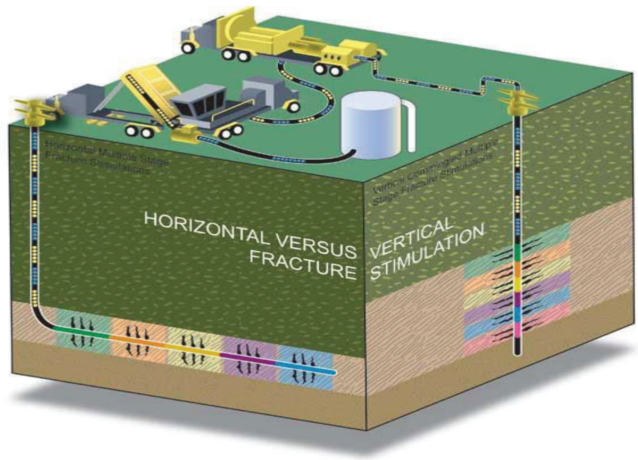
Hydraulic fracturing is also known as fracture stimulation, fraccing or fracking. Hydraulic fracturing is the process through which fractures are produced in geological formations. Most commonly, a fluid made up of water, sand and additives is injected under high pressure through a perforated cased well into a geological formation. The pressure caused by the fluid injection under pressure creates fractures in the coal or shale seam where the well is perforated.

For a vertical well treatment, a fracture might typically extend to a distance between 20 and 250 metres from the well. The fractures grow slowly; for example the initial average velocity may be less than 10 metres per minute and slow to less than 1 metre per minute at the end of the treatment. The 'proppant' in the hydraulic fracturing fluid acts to keep the fracture open after injection stops, and forms a conductive channel in the coal through which the water and gas can travel back to the well. After the fracturing is complete, the majority of the hydraulic fracturing fluid is brought back to the surface over time and treated before being reused or disposed of in accordance with the regulations applying in that jurisdiction. Well integrity standards include arrangements for hydraulic fracturing and are the key mechanism for managing potential impacts. The impacts that arise generally relate to potential aquifer interconnectivity, intersection of induced fractures with existing faults/fractures and/or existing wells, and the potential for chemical contamination.

Prior to obtaining an authorisation to undertake hydraulic fracturing activities, legislation requires operators to:

- provide details of their proposed hydraulic fracturing operations including the location of wells
- detail the chemicals to be used and the toxicity of ingredients and mixtures
- develop a risk assessment that must be carried out for any well prior to it being hydraulically fractured to ensure that the activity is managed to prevent environmental harm.

FIGURE 2 Schematic diagram of the hydraulic fracturing process (June et al 2012)



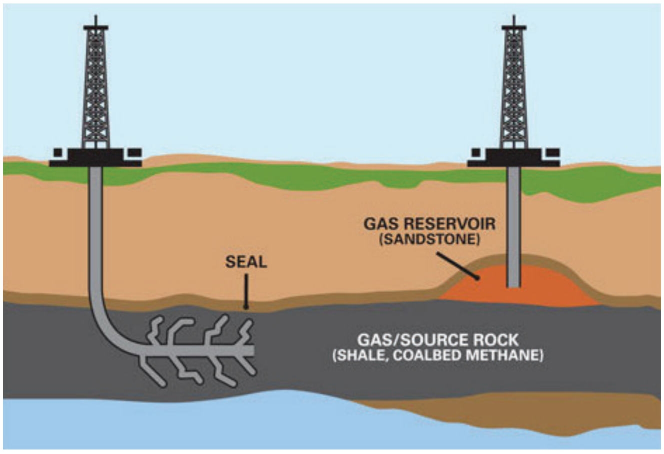


FIGURE 3 Schematic diagram of the differences between Unconventional and Conventional gas extraction

Some commonly-used chemical additives and their uses in hydraulic fracturing fluids include:

- gelling agents (commonly guar gum), cross-linkers, and flocculants – additives used to increase the viscosity of the fracturing fluid as it is pumped under pressure into the crack and joints in the coal, to allow more proppant to be carried into fractures
- breakers – which dissolve the hydraulic fracturing gels such as guar gum so that the fractures can transmit water and gas to the well
- friction reducers and clay controllers – chemicals used to reduce any friction between the fracturing fluid and the bore casing and to control any swelling in clay
- bactericides – such as sodium hypochlorite and sodium hydroxide, which are used to control the introduction of outside bacteria to the coal seam which may restrict gas flow to the well
- surfactants – such as ethanol and the cleaning agent orange oil, which are used to increase fluid recovery from the fracture

- scale and corrosion inhibitors and iron controllers – to prevent the build of scale and rust in the bore
- acids and alkalis – acids injected to dissolve calcite from within the natural cracks and joints in the coal before the fracturing fluids are injected and to balance the acidity of the hydraulic fracturing fluid; and
- monitoring isotopes – isotopes occasionally used to monitor the growth of the factures in the coal seam.

INFLUENCE ON THE COMMUNITY

Coal seam gas reserves represent a major contribution to energy needs, however, gas recovery by hydraulic fracturing (fracking or fraccing), requires careful management to minimise any possible environmental effects. Although the industry is adapting where possible to more benign fracking chemicals, there is still a lack of information on exposure to natural and added chemicals, and their fate and ecotoxicity in both the discharged produced and flow-back waters. Geogenic contaminants mobilised from the coal seams during fracking may add to the mixture of chemicals with the potential to affect both ground and surface water quality.

The potential impact of developments to extract natural gas from coal seams has on groundwater resources is a significant source of community concern. The issues that arise can be broadly categorised as depletion and contamination of water resources, each of which could affect existing groundwater users, inter-aquifer connectivity, groundwater to surface water interactions and groundwater-dependent ecosystems. The responsible management and use of chemicals in operations associated with the production of natural gas from coal seams and potential human health and environmental impacts are key concerns for many communities and a high priority for governments and industry. Industry has developed and continues to research environmentally benign chemicals and formulations for use in operations. Governments are working with industry to better understand potential impacts on human health and the environment through the national chemical assessment process.

FIGURE 4 Community protests against fracturing

In Australia communities have responded with (See Figure 4):

- Guerrilla style protests
- Coordinated grass root groups
- Savvy, well resourced media campaigns and websites, for example:
- Australia – Lock the Gate Alliance lockthegate.org.au
- Britain – Frack Off frack-off.org.uk and No Dash for Gas nodashforgas.org.uk
- Canada – Stop Fracking Ontario stopfrackingontario.wordpress.com
- USA – Americans Against Fracking americansagainstfracking.org and Food and Water Watch foodandwaterwatch.org
- Global Frackdown – globalfrackdown.org

Thus like other locations, community concerns around fracking in Queensland and NSW has led to:

- the formation of lobby groups and ongoing activities
- community legal action
- extensive campaigns involving TV, radio, internet, rallies, letter box drops
- concerts
- landowners blocking land
- calls for an investigations into the impacts of fracking and CSG.

Surveys completed in Australia for the Centre for Coal Seam Gas (CSG) found that of 1007 respondents:

- people lack knowledge of CSG but were interested in finding out more
- those who knew a lot about CSG were likely to indicate that is was having a positive impact on the State, those who knew a little indicated that CSG was having a negative impact
- people's perceptions were guided by stories in the media rather than balanced factual Information
- despite the lack of knowledge people were not confident that the environmental impacts of CSG were well managed, regulated and understood.

The growth of fracking and the CSG industry has led to the establishment of regulations around:

- land access
- social Impact management and engagement
- housing
- strategic cropping land
- CSG water management.

The government has undertaken a number of initiatives including:

- undertaking extensive community road shows and meetings
- creating a CSG Enforcement Unit
- establishing a Gasfields Commission and community reference groups
- establishing a Land Access Implementation Committee
- deploying technical specialists to directly liaise with communities
- senate hearings
- independent expert scientific committees.

ENVIRONMENTAL ISSUES

The selection of a CSG water beneficial use route or disposal route is largely dependent on the proximity of the CSG producer to disposal or beneficial use locations, the cost and complexity of the treatment process (if required) and whether or not water from several producers or sites. The production of coal seam gas (CSG) involves the pumping of water from coal formations to reduce water pressure and release the gas. This can affect overlying and underlying aquifers because of interconnectivity between the formations. A regional groundwater flow model was constructed to predict the impacts of current and planned CSG development on water pressures in aquifers.

As with any large mining or industrial operation, consideration needs to be given to the environmental effects of fracking. The number of hydraulic fracturing products is not trivial. It has been suggested that in the US, between 2005 and 2009, oil and gas service companies used more than 2 500 products containing some 750 chemicals (US House of Representatives Committee 2011). The number used in coal seam gas fracking is considerably less, and in Australia, the Australian Petroleum Production and Exploration Association Limited recently released a list of 45 chemicals that supposedly comprised for that time, 'all chemicals used in Australian coal seam gas fracking fluids' (Australian Petroleum production and Exploration Association Ltd 2010).

In Australia, regulatory agencies can require companies to provide details of proprietary chemicals used in fracking, and as a consequence many coal seam gas companies have proactively listed such chemicals (and Material Safety Data Sheets MSDSs) in some cases) on their websites. Data are also available in publically available EICs. A listing of commonly used fracking chemicals from these sources is as discussed previously, however their use is rapidly changing with a view to choosing more environmentally friendly chemicals.

The detection of benzene in discharge waters has led to bans on the use of BTEX compounds (benzene, toluene, ethylbenzene and xylenes) in fracking fluids. Other geogenic contaminants include metals and radionuclides (Cheung et al 2009, Rice et al 2000). Ecologically Sustainable Development (ESD) is widely used in state and federal legislation that regulates activities such as mining and environmental impacts. ESD aims to balance the environmental, economic and social costs and benefits of a proposed activity. However, the appropriate balance can be difficult to achieve when there is uncertainty about the costs and benefits of particular developments.

Risk management is a necessary addition to the precautionary principle. The application of the precautionary principle should be a proportionate and reasonable response to:

- the level of potential impact (e.g. the principle is most applicable to potential catastrophic or irreversible harm)
- the likelihood of a potential impact occurring (is the risk plausible and reasonably likely to occur)
- the costs of regulatory action, and the opportunity cost of not proceeding.

Environmental legislation provides a robust mechanism to manage projects at the state and federal level. The three LNG projects currently under construction in QLD have approximately 1 000 state conditions and more than 300 federal conditions each.

LEGISLATION

In Australia all underground assets such as coal, gas, gold etc. is owned by the Government and not the farmer. Also most of the CSG field are below some of the most productive farms in Australia which makes it difficult to explore for gas whilst not be detrimental to the farming operations.

Under the Queensland regulatory framework, petroleum and gas tenure holders have rights and responsibilities in relation to the extraction of groundwater in the process of producing petroleum and gas. These responsibilities are to 'make good' impairment of private groundwater supplies caused by the water extraction activities and to carry out monitoring and other management activities.

In practice, different approaches to the management of produced water operate in Australia although natural gas from coals seams is currently only produced in QLD and NSW. There are moves in NSW, VIC and SA to ensure that the extraction of water during petroleum operations is incorporated into water resource planning mechanisms, often by licensing the use of water through the allocation of water entitlements within a planning regime to ensure the sustainable management of Australia's water resources.

Australia's existing development planning framework requires environmental impact approvals from the relevant state or territory and under Commonwealth legislation if they impact on matters of national environmental significance.

For operations, the regulator should ensure that the environmental impact assessment process includes consideration of:

- drilling operations which includes water resource protection, noise management and dust minimisation
- potential impacts of operations to extract natural gas from coal seams on the hydrogeological environment (ideally through a numerical groundwater flow model developed with consideration of the Australian Groundwater Modelling Guidelines - subject to peer review and independent audit) and provide for ongoing monitoring to determine any changes that may impact existing users and the environment
- the requirements for ongoing monitoring, evaluation, and reporting of hydraulic fracturing activities including the use of chemicals (storage, handling, processing, transport, and disposal) with respect to potential human health or environmental impacts
- the implementation of impact mitigation controls and compliance with relevant legislation, standards, and codes of practice as part of the operation.

Queensland (Qld) stipulates that operators are required to undertake a risk assessment to identify the risks that may occur during well construction, operation and abandonment within the state's Code of Practice for Constructing and Abandoning Coal Seam Gas Wells. As previously mentioned, applications for site specific activities in Qld must provide the following information: the quantity of water that is expected to be produced; the flow rate at which the water is expected to be produced; the quality of the water; and the proposed management strategies (in accordance with the Coal Seam Gas Water Management Policy 2012).

This information is collectively known as the water management plan. Operators are also required under the Water Act 2000 to undertake baseline monitoring, spring surveys where applicable, and prepare and submit an underground water impact report which includes a water management strategy and spring impact management strategy.

NSW has similar requirements as part of its Aquifer Interference Policy, which requires applicants to address potential water impacts (including aquifer compaction, deterioration of ambient water quality and significant soil erosion). In all jurisdictions, the management of risks associated with chemicals used in activities to extract natural gas from coal seams is stipulated in safety management plan requirements through both the environmental management plan requirements and health and safety legislation.

Australia's legislative approach to well integrity has been developed from extensive experience in onshore and offshore oil and gas production. It is based on international best practice for well design, construction, maintenance and rehabilitation.

WATER TREATMENT AND DISPOSAL

Water and salt management are major issues associated with coal seam gas production (ALL Consulting 2003). The water pumped into wells (0.2–0.6 ML per well) for hydraulic fracturing returns to the surface as the pressure is reduced (Rutovitz et al 2011). The chemistry of this water is altered as it interacts with the coal seam minerals. In addition, there is water associated with the coal deposits that becomes mobilised as part of the drilling operation. This is generally termed produced water or formation water. It is typically quite saline as well as containing other constituents, both inorganic and organic, of the minerals and coal with which it has been associated in the deposits.

The water used in fracking mixes with produced water during the fracking process, with the composition gradually becoming more characteristic of the produced water. The industry typically refers to 'flow-back water' as the water produced within a few days of the fracking, and 'produced water' after that, even though it may still have characteristics of both types of water. Volumes of produced water can be up to 100 kL day per well, but this typically diminishes over the lifetime of a well which may be as long as 10 years (Refer to Figure 5).

Natural gas is held in coal seams by water pressure. As water is pumped from the coal seams (a process called depressurisation), the pressure is lowered and the gas is released. As water pressure is reduced, gas flow increases and water flow rates decrease from each well, typically to around a quarter to a third of the initial flow over a period of a few months to a few years, depending on the hydrogeological conditions of the seam.

The volume of produced water extracted from each well can vary considerably between wells and regions. The quality of produced water also varies significantly, from near potable to brackish (moderately saline).

Typically, produced water is of a quality that significantly restricts its potential use or disposal unless treated.

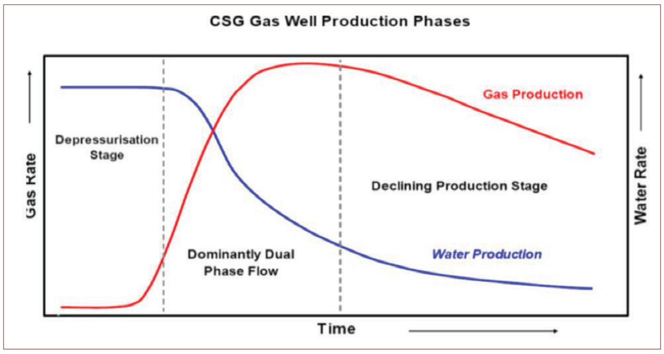


FIGURE 5 Typical gas and water flow in production of natural gas from coal seams (QWC 2012b)

The development of natural gas from coal seams and associated potential impacts on groundwater resources is a significant source of community concern. The issues that arise can be broadly categorised as depletion and contamination of water resources, each of which could affect existing groundwater users; inter-aquifer connectivity; groundwater to surface water interactions; and groundwater-dependent ecosystems.

The key inter-related issues for water management are associated with:
- depressurisation of coal seams potentially affecting surrounding aquifers
- contamination of surface water or groundwater
- management (recovery, storage, transport, treatment and disposal) of produced water and post-treatment wastes and by-products
- beneficial use of produced water (including reinjection)
- safe decommissioning of wells ensuring long-term aquifer integrity.

In addition to lowering groundwater pressures and water levels in bores, the large-scale depressurisation of the coal seams has the potential to release gas into water bores that have been drilled through the coal seams. However, in many cases the water bores tend to be relatively shallow (that is, less than 100 metres) compared to wells, which will limit the potential for gas migration into water bores. In Australia, the CSG Water Management Policy encourages the beneficial use of recycled produced water as a preferred management option. Beneficial uses of treated produced water identified include substitution for water for existing irrigation schemes, new irrigation use, with a focus on sustainable irrigation projects, livestock watering and release to the environment in a manner that improves local environmental values.

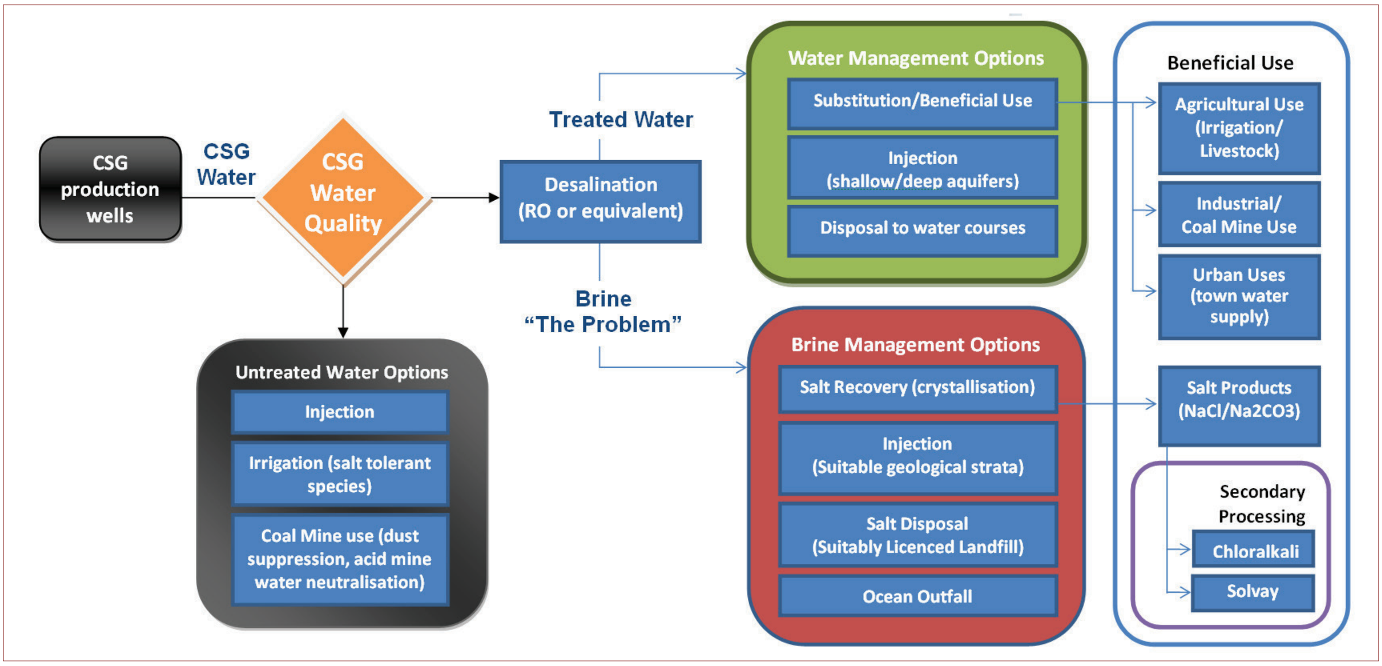
In NSW, the Aquifer Interference Policy outlines preferred disposal options to include reinjection to an aquifer, discharge to a river, on-selling to a nearby industry, agricultural development or potable water supply. Any option requires treatment of produced water to an appropriate water quality standard to have minimal impact on any proposed receiving land and waters. Consideration must also be given to pollution issues, which are regulated under the Protection of the Environment Operations Act 1997 (NSW). In a change from past practices, jurisdictions with the most significant developments have moved to either completely ban or prevent the use of evaporation dams unless there is no feasible alternative. In addition to removing the risk of spills or uncontrolled discharges in the event of flooding, the policy is directed toward maximising the potential beneficial use of produced water and minimising the impact of the production of natural gas from coal seams on other water users in the short and long term.

Water quality from CSG dewatering:
- typically TDS values 1 200 mg/ℓ to 10 000 mg/ℓ
- typically high Sodium, Bi carbonate, carbonate and chloride ions
- high Alkalinity and pH

Significant species:
- Cations – K, Ca, Mg, B, Sr. Ba
- Anions – SiO2, F, Br
- High Sodium Adsorption ratio

What can be produced from these ions:
- Sodium Chloride
- Sodium Carbonate
- Sodium Bicarbonate
- Calcium Carbonate
- Magnesium Carbonate, Magnesium Hydroxide

FIGURE 6 Conceptual CSG water management strategy



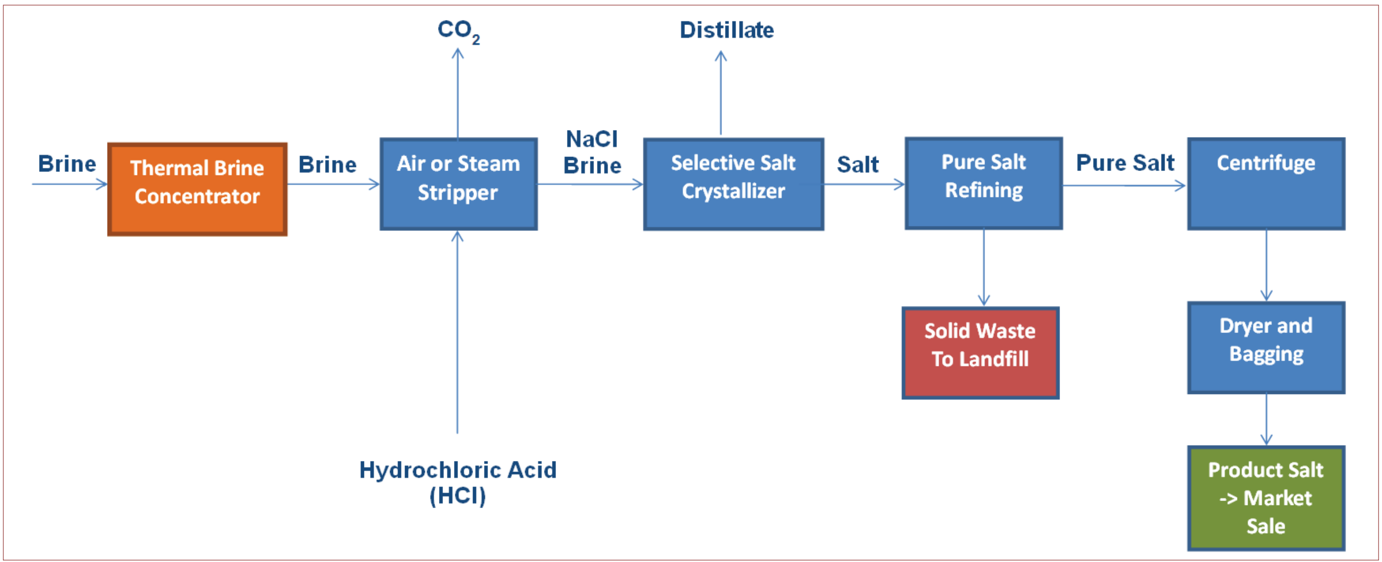


FIGURE 7 Salt recovery facility using enhanced selective crystallization for NaCl recovery—process flow diagram.

- Smaller quantities, Strontium sulphate, strontium carbonate, barium sulphate etc.

Beneficial use of the treated water:
- Aquaculture
- Coal washing
- Dust suppression
- Industrial use
- Irrigation
- Livestock watering

Specific application for water is available under the Environmental Protection (Waste Management) Regulation 2000. Specific application required for Potable/Public water supply. Also RO permeate for Flood Clean-up.

Need to manage excess, produced or associated water implies managing both the "pure "water itself and dissolved ions (salts) it contains. Tendency to focus on the immediate problem, water first and then think about how to manage the salts. Almost always Reverse Osmosis is required to treat the produced water (potentially EDR can also be used, but generally salinity too low for economic thermal desalination as first step). Partial treatment and blending may be an option (See Figure 6).

Reverse Osmosis is a predictable process provided constant feed conditions are achieved. Pre-treatment is a critical design issue. Probable a need exist for up front buffering /storage to aid consistency. There will a brine stream to be managed (See Figure 7).

Several Possibilities to manage the brine stream:
- disposal as brine (to ocean)
- use as brine (feedstock)
- irrigate low salinity or blended
- injection where no detrimental impact
- deep well where containment can be assured
- blend and inject into aquifer.

The range of possible products increased if additional chemicals added. The top minimisation technologies in terms of cost-effectiveness and robustness include enhanced recovery reverse osmosis, solar evaporation ponds and mechanical evaporation/crystallisation. The recovery of salt and deep well injection appears to be the front runners in terms of providing a sustainable and cost-effective disposal route for brine. Brine injection may be accomplished by injecting into deep wells in the immediate vicinity of the CSG production area, injection into the coal seams from where the associated water originated and/or piping of brine to distant aquifers or depleted gas fields. Salt recovery of sodium carbonate/bicarbonate salts and/or sodium chloride may be undertaken via various means, with the most likely method incorporating mechanical vapour compression evaporation and crystallisation.

CONCLUSION

It can be concluded that although technical feasible to conduct environmentally sensitive fracturing (depend on specific site conditions) it is the community that has to be convinced that the fracturing process can be done without any detriment to their farms, houses and ground water assets. This is a long and protracted journey and takes several years to be resolved to the satisfaction of all parties involved. From an Australian perspective it only works if the community and possibly the Government are taken along the journey from the start as all minerals and metals below the surface belongs to the Governments and not to the land owners.

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