Delivering Water Security for All During Shale Gas Production

A report by the PyTerra Research Consortium
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DISCLAIMER

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Delivering Water Security for All During Shale Gas Production

SUMMARY

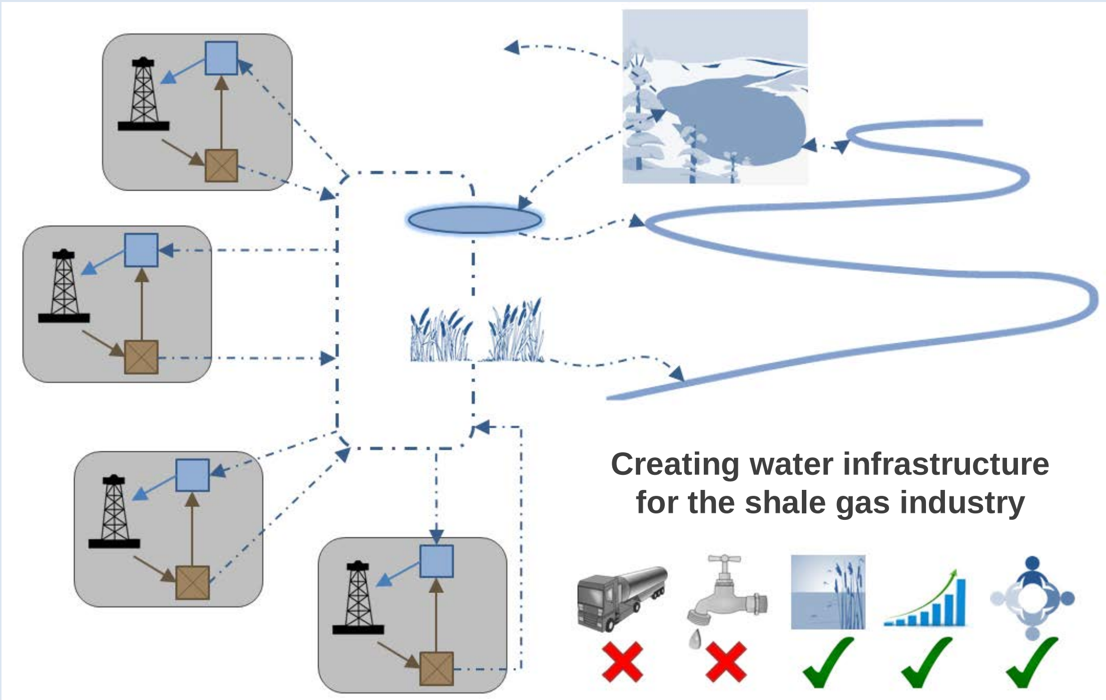
If the UK is to develop a shale gas industry, how is it going to manage its biggest environmental challenge – water?

This is an issue, not because of the perceived risk to ground water, but also because of the wider – and more pertinent – environmental impacts.

There are two key impacts which need to be addressed: how are local water supplies going to cope; and how is 'produced water' going to be sustainably managed?

It is therefore reasonable for those communities where a shale gas industry is going to take root, to ask how local infrastructure is going to be developed in order to: a) allow this industry to operate efficiently and safely; and b) protect and preferably enhance local communities and local natural environments.

This study approaches these challenges with a simple concept: that a holistic approach to water resource management during shale gas development, supported by 'smart' technologies, would best address these two questions.



The findings clearly show the potential benefits to shale gas developers, communities and the environment if local water infrastructure is planned and developed at a catchment scale rather than allowing ad hoc developments to address their singular water needs.

Government, its agencies and the shale gas industry therefore need to start thinking about a holistic approach to water management at a catchment level if it wants a shale gas industry to sustainably grow. Otherwise development will increasingly be at odds with the environment and local communities, and shale gas developers will not achieve the efficiencies which an integrated approach can deliver.

INTRODUCTION

This study explores the potential for taking a holistic and sustainable approach to the management of water during shale gas exploitation. It particularly considers how this might apply to a developing UK shale gas industry. This approach tests the benefits of using an innovative water management concept which maximises the use of the natural environment but is supported by 'smart' technology – the PyTerra system. PyTerra is a systems approach to synchronising multiple parts of a water network in order to achieve multiple objectives.

This concept is based on the prior research work undertaken jointly by PyTerra and WSP Parsons Brinckerhoff, which demonstrated that a holistic approach to water is needed if many of the global water challenges are to be resolved. However, this approach will not be deliverable without use of appropriate 'smart' systems which allow the real-time, adaptive control of both natural and piped water networks and which can deliver multiple benefits for multiple stakeholders.

The project therefore tests a conceptual water management system which monitors and controls the quality and flow of water in real-time across the locality where fracking operations are under way. It is an adaptive system which can respond automatically to changing local circumstances such as variable gas yield and predicted rainfall. Part of the management system is dedicated to controlling the water within each well pad. A second part also provides water infrastructure for gas development, but only over a limited period before returning it to community use. A third part is provided by, or developed on behalf of, local communities where other freshwater services can also be supplied, such as flood prevention and irrigation. All these parts are automatically controlled in real-time by a 'smart' system, using local sensors to provide data. The two sections of infrastructure outside of each well pad can be controlled by a third party such as the local water company or local authority. Each well pad, or series of well pads, then has its independent system under the control of the shale gas developer and this 'talks' to the third party system. In this way, the overall system can run on a self-optimising basis without compromising the basic requirements of each party.

SCOPE

The technical objective of this project is to demonstrate through modelling how the PyTerra system could be further developed to safeguard the long term water needs of shale gas operations without conflict to the water needs of local communities and ecosystems. Moreover, it aims to show how the water management process can be delivered more cost effectively, and how local communities can derive significant benefits if developers invest into local water infrastructure which also serves local needs.

The study achieves these objectives and goes further than anticipated in developing a computational model of a hydrological base case and test case. The advantages and impacts accruing to local communities and environments are exemplified by using three geographic scenarios: West Sussex, Lancashire and Scotland. A benefit/cost model then appraises these scenarios in terms of both quantitative and qualitative criteria.

The study specifically delivers two technical outputs:

- Results from a laboratory based experiment to test the capacity of constructed wetland plants to treat water with high salt concentrations, and to determine design strategies for removing constituents of concern.
- Formulation of an adaptive algorithm which can optimise the flow of water across the test case to achieve both volume and quality targets.

TEAM

The lead partner was PyTerra, supported by its commercial partners, WSP Parsons Brinckerhoff (hydrological modelling and cost benefit analysis) and Pervasive Intelligence (academic coordination and optimisation), and academic partners, the University of Surrey (optimisation), Imperial College London (water quality and treatment) and Cardiff University (constructed wetlands).

METHODOLOGY

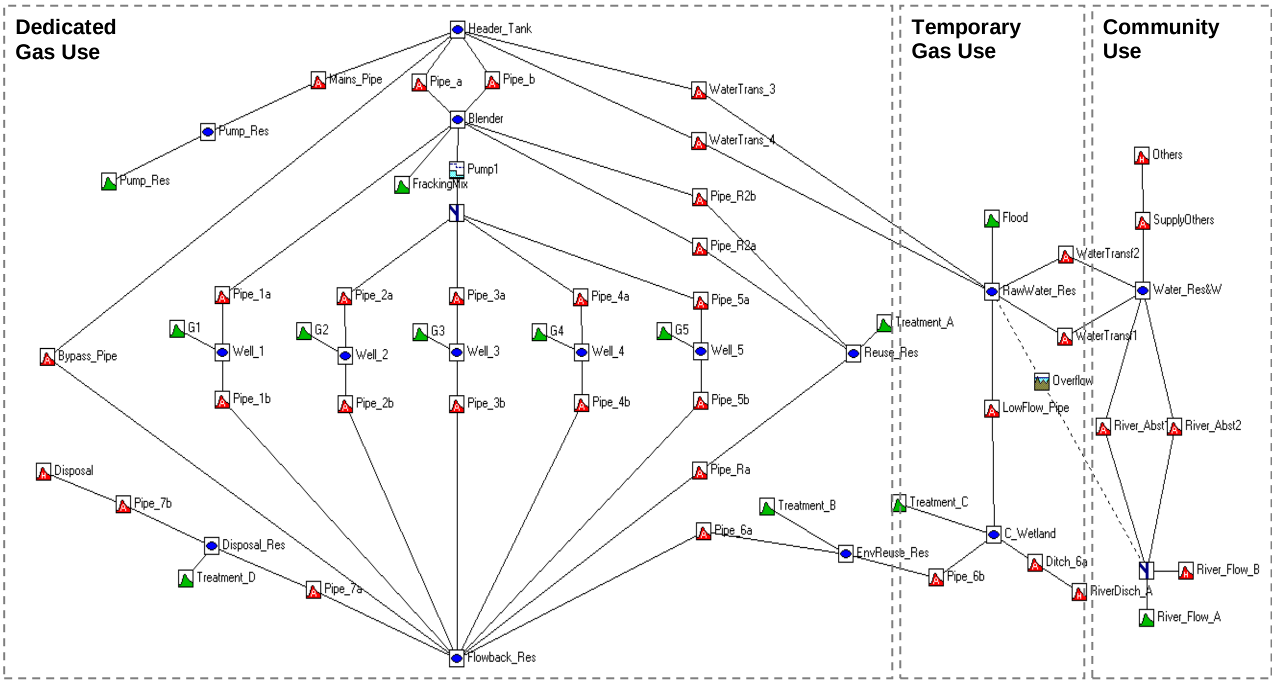
The project ran for eight months, from April to November 2015. Academic research into specific areas of the PyTerra approach provided input to hydrological modelling and cost benefit analysis by WSP Parsons Brinckerhoff. These included:

- Typical concentration ranges of contaminants in produced water and appropriate treatment solutions;
- Use of constructed wetlands for treating produced water based on laboratory testing;
- Design of an integrated water processing network to both supply water and treat produced water; and
- Optimisation algorithm development for the programming of an integrated water processing network.

This research was then applied to a conceptual hydrological model of an integrated network across five wells, comparing a test case scenario against a (traditional) base case. Each model was based on a network of nodes where sensor data would be collected and hydraulic control devices would be activated. Their operation would be optimised to achieve two fundamental objectives:

- To minimise the trucking of produced water off-site (and thereby minimise environmental impact); and
- To minimise the use of piped-in potable water from the local water company (and thereby minimise the reliance on costly third-party-controlled water supplies which may be limited in times of water shortages).

The diagram below is an illustration of the test case network model that was developed and tested.



BENEFITS

The following beneficial outcomes from a PyTerra approach were identified by the team.

Regulatory – Permitting and Permissions:

- *Shorter permitting times;*
  because water infrastructure will have been pre-planned and a template for water management will have been pre-agreed with the regulatory authorities.
- *Greater regulatory and local acceptance;*
  because the approach will have been tested and accepted more broadly prior to use.
- *Long term sustainability;*
  because of the development of long term water infrastructure contributing strategically to water needs across a catchment area.
- *Mitigating environmental impacts;*
  because this approach is responsive to local environmental needs, using the storage, treatment and supply of water to enhance local biodiversity.
- *Other non-shale benefits: e.g. flood risk, water supply;*
  because the water infrastructure can be designed to enhance existing water infrastructure, taking the load off existing agencies to invest in new capital projects.

Social and Economic

- *Supporting the development of local water infrastructure;*
  because the water infrastructure can be designed to provide multiple benefits to multiple stakeholders, helping to make the capital and operating costs more sustainable.
- *Releasing more land for development;*
  because new water services can economically be provided on the back of this infrastructure.
- *Supporting gas (i.e. energy) supply locally;*
  because it makes it more attractive for shale gas developers to invest in developing new wells.
- *Shale gas developers can gain a social licence to operate;*
  because this approach creates benefits and better protects communities and the environment.
- *Shale gas developers can operate more cost effectively;*
  because trucking of produced and fresh water is reduced, water supply is more cost effectively provided, and risk of delay through water-related issues is mitigated.

Environmental

- *Legacy of a sustainable water infrastructure in the longer term;*
  because an integrated approach, using natural means such as constructed wetlands, forms part of a wider water network across a catchment area.
- *Wider area monitoring of surface and groundwater;*
  because investment in a network of ground and surface water sensors becomes viable.
- *Improve water quality status of rivers;*
  because new infrastructure is available to treat and dilute water courses in need of improvement.

CONCLUSIONS

An integrated water management approach to shale gas operations can provide significant regulatory, social, economic and environmental benefits when appropriate real-time and adaptive optimisation of water flow and quality is used to manage the supply of water for wells and the re-use of flowback water for further well exploitation.

However, it is essential that critical water management infrastructure, including constructed wetlands, raw water reservoirs and re-use reservoirs, are planned, designed and approved by collaborative working between Government, the local planning authority, regulatory bodies and the shale gas operator(s) operating in the area.

Nevertheless, by working together, shale gas operators can significantly reduce the cost of water management by taking an early approach to the development of water infrastructure.

This inevitably raises a number of critical questions:

- Which body should take the lead in developing such infrastructure?
- How will this infrastructure be afforded?
- When should such infrastructure be implemented?

Whilst the team have initial views on these issues, only a considered follow-up study undertaken with key stakeholders will adequately provide guidance.

At a more detailed technical project level, the following findings were made:

- Advanced water treatment processes such as reverse osmosis and thermal distillation are unable to handle the very high total dissolved solids concentrations in many produced waters (100,000+ mg/l) and are highly energy intensive. There is a need for new onsite treatment strategies and technologies to address this water quality challenge.
- Constructed wetlands have the potential to be developed and trialled further to demonstrate their contribution to produced water treatment, in combination with other treatment processes. They have the potential benefit of being cheaper and 'greener' than technological solutions and having a residual value to local communities once their shale gas duties are complete. This use of natural systems in industrial treatment processes is still a relatively new field and will benefit from further study and trials.
- Sensor technology, which would be used particularly to measure Total Dissolved Solids (TDS) in produced water, currently is limited to concentrations of up to 120,000 mg/l. With actual concentrations ranging beyond 260,000 mg/l, this provides an ongoing technical challenge.

RECOMMENDATION

This report recommends an industry-based study be set up which considers the wider costs and benefits of developing strategic water infrastructure to support a future UK shale gas industry. It should also consider the implications for the UK's wastewater treatment infrastructure which currently does not take into account a shale gas industry. It would bring together all key stakeholders and, if considered appropriate, lay down suitable principles of development with respect to water management.

ABOUT

COMMERCIAL PARTNERS

David Arscott, PyTerra

David is Director and owner of PyTerra, an innovative software development company which develops systems to support a holistic approach to water resource management. He initiated and was the lead partner on this project. With a background in architecture and management consultancy, his expertise lies across three key areas: strategic planning; programme management; and product development. In 2004 he was awarded Best New Exporter by UKTI for the latter. He previously led a research project with Kingston University under a Jumpstart Connect funded project in 2006 for 'A System for Generating Task Related Intelligence for Use in Project Based Field Environments'. David is now leading a partnership of commercial and academic organisations to establish a systems approach to resolving the challenges of flood, water availability and pollution whilst making a positive contribution towards environmental sustainability. He is a contributor to journals and conferences on this subject.

Bruno Venturini, WSP Parsons Brinckerhoff

Bruno has over 20 years' experience in water resources, flood risk management and modelling studies. He has a leading role in the UK water modelling team on projects as bid leader, project director, project manager and technical specialist in a diverse range of water projects, with business development acting as a strong element of his role. Bruno specialises in water cycle, drainage and flood risk strategic planning for large catchments and major towns in the UK and overseas. WSP Parsons Brinckerhoff is one of the world's leading professional services firms, providing integrated solutions across many disciplines. The firm provides services to transform the built environment and restore the natural environment, and its expertise ranges from water management, through environmental remediation to urban planning, from engineering iconic buildings to designing sustainable transport networks, and from developing the energy sources of the future to enabling new ways of extracting essential resources. It has approximately 32,000 employees, mainly engineers, technicians, scientists, architects, planners, surveyors, other design professionals, as well as various environmental experts, based in more than 300 offices, across 35 countries, on every continent.

Dr Matthew Casey, Pervasive Intelligence Ltd

Pervasive Intelligence was created in 2013 to provide services in the development, evaluation and commercialisation of emerging digital technologies. Matthew has experience as a professional software engineer, project manager, consultant and researcher, working for companies including IBM and as an academic at the University of Surrey. With expertise in machine learning, image analysis, sensor processing and data analytics, coupled with extensive knowledge of a range of development platforms and emerging technologies, Matthew now helps universities realise impact with their research, and companies to gain access to new technologies to fuel their innovations. Matthew is a Chartered Engineer (CEng), Chartered Information Technology Professional (CITP), Professional Member of the British Computer Society (MBCS) and a Fellow of the Higher Education Academy (FHEA). He has published over 30 articles on a range of subjects in international journals, conferences and workshops, and run commercialisation projects both from within and outside university.

ACADEMIC PARTNERS

Dr Clive Cheong Took, Department of Computer Science, University of Surrey

Clive is a Lecturer in Computational Intelligence at the University of Surrey. He was awarded his first class bachelor degree in Telecommunication Engineering at King's College London and received his PhD in Signal Processing from Cardiff University. He is an associate editor of the IEEE Transactions on Neural Networks and Learning Systems. He has served on technical committees of various IEEE machine learning and signal processing conferences such as the World Congress on Computational Intelligence and the International Conference on Acoustic, Speech and Signal Processing. He is an affiliate Member for IEEE Signal Processing Theory and Methods Technical Committee, and a member of the IEEE Computational Intelligence Society. Currently, his research on the optimisation of water distribution is funded via a strategic Knowledge Transfer Partnership in collaboration with WSP Parsons Brinckerhoff and PyTerra. His other research interests include multi-objective optimisation, signal processing and machine learning.

Dr Michael Templeton, Department of Civil and Environmental Engineering, Imperial College London

Michael is a chartered civil engineer and Reader in Public Health Engineering in the Department of Civil and Environmental Engineering at Imperial College London. He holds a bachelor's degree in engineering science and a PhD in civil-environmental engineering, both from the University of Toronto. His research focuses on the occurrence and control of chemical and biological contaminants in water, innovative water treatment processes, and effective water supply and sanitation interventions in low-income countries. He is a member of the Water Quality and Health Technical Advisory Group of the World Health Organization, the chair of the Water Supply and Quality Panel of the Chartered Institution of Water and Environmental Management, and a member of the Water Expert Panel of the Institution of Civil Engineers. He serves on the editorial boards of several journals, including Water Science and Technology and Environmental Science: Water Research and Technology.

Dr Akintunde Babatunde, School of Engineering, Cardiff University

Akintunde is a Chartered Engineer, Chartered Environmentalist and a member of Council of the Society for Environmental Engineers. He obtained his PhD in Civil Engineering from the University College Dublin (UCD), Ireland, and he is currently a Lecturer in the Civil and Environmental discipline at the Cardiff School of Engineering. His research is focused on systems and processes for sustainable water engineering and associated links with bioenergy. He has particular experience and achievement in constructed and engineered wetland systems; he is an active member of the International Water Association specialist group on constructed wetland systems, and he is a regional coordinator for the group. He is also an Editor for Water Science and Technology.