SUSTAINABLE WATER MANAGEMENT – IMPLICATIONS FOR UK MINERAL EXTRACTION

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Abstract

There is a demand for more sustainable aggregate production but what does this mean? There appears to be general agreement that sustainability requires a balance between economic development, social development and environmental protection but the optimum balance will vary depending on your perspective. Site water management affects both the environment and costs and making it both effective and sustainable should be a priority.

With sustainability more to the forefront of our minds, are we actually doing anything differently from before or are the solutions typically due to the application of common sense? How can you calculate the optimum solution? Can you monetise the solution by calculating an environmental, social, economic cost/value? How can you put a value on each positive and negative impact? These questions are very difficult to answer.

In many cases it probably is common sense as the most sensible and cost effective approach is usually close to the most sustainable one. However, if you look back over time at planning and operational decisions, there are likely to be many examples where you might have done things differently if sustainability was on the agenda.

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Introduction

With the demand for more sustainable aggregate production, and with increasing energy costs, the drivers for better use of resources and more efficient production are also increasing. Water management represents a key requirement for any site; therefore making it both effective and sustainable should be a priority.

The European Water Framework Directive is focussed on ensuring water bodies achieve good ecological status, and the Environment Agency regulator may shift focus to more active ecological monitoring as well as control by planning and licensing. Climate change resilience, renewable energy and targets for emission reductions are becoming increasingly important. Planning requirements and regulation, including the impending Transfer Licence scheme, will provide external drivers for increased knowledge of the potential impacts resulting from site activity. The government is considering an ecosystems services[1] approach to development and it remains to be seen how this will affect the extractive industry.

[1] An ecosystems approach provides a framework for looking at whole ecosystems in decision making, and for valuing the ecosystem services they provide, to ensure that society can maintain a healthy and resilient natural environment now and for future generations (Department for Environment, Food & Rural Affairs, 2013).

The Mineral Products Association (MPA) commented at the MPA/RTPI (Royal Town Planning Institute) mineral planning conference on 22 May 2013 that the initial signs are that during the current economic down-turn, the minerals industry has focussed on more production from existing quarries, including hard rock aggregates, and that the appetite to tackle new planning applications is reduced. Part of this may be related to the perceived risk of the new and untested sustainability agenda within the planning process.

Corporate responsibility and image will be significant in reinforcing the sustainability agenda. Non-Governmental Organisations (NGOs) are increasingly active with their own agenda for sustainability, and the future may see an increase in claims for environmental damage to habitat and water resources. Companies need to assess their environmental risks and obtain insurance as appropriate. In particular, operational risks associated with site discharge require particular attention.

The strategic and operational impact of natural events such as the recent (2012) drought together with subsequent floods and future climate change resilience are all important factors to incorporate into a view of what sustainable water management should be for the extractive industry. Internal economic drivers for effective water management include rising fuel costs associated with pumping, mains water supply costs and the desire for increased extraction depths. Balanced against these are the potential environmental costs of derogated water resources, flood risk and sensitive ecosystems. Achievement of sustainable water management requires good planning and monitoring linked directly to the site operations, as well as planning objectives. The basis for any sustainable water management plan is a sound conceptual model of the site including an integrated understanding of the various groundwater, surface water and rainfall components.

A range of approaches can be used to assess water management options and environmental impact dependent on the site setting. Initial scoping analytical equations may be satisfactory but more complex linked, steady state or transient water balances are sometimes required. For large development schemes numerical modelling using MODFLOW/FEFLOW is often a cost effective option to support sustainable water management, allowing the assessment of various extraction scenarios to optimise reserves and to minimise environmental impact.

Sustainable Development

What sustainable development actually is, how it can be measured, and its implications for the extractive industry, is subject to debate. This makes the need for proper definition and measurement important, as having goals which are not clearly defined may lead to inconsistency in approach and application. The National Planning Policy Framework (NPPF) (Department for Communities and Local Government (DCLG) 2012) states that sustainable development is about "change for the better". It also defines "sustainable" as meaning "ensuring that better lives for ourselves don't mean worse lives for future generations". Sustainable development has also been defined as "meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland Report, 1987).

There appears to be general agreement that sustainability is a balance of economic development, social development and environmental protection with all three components required for sustainability to be achieved (Figure 1). The MPA vision statement states "that our members are recognised and valued for supplying essential materials for a sustainable future in a manner that is economically viable and socially and environmentally responsible". NPPF (DCLG, 2012) states that there is a presumption in favour of development which is sustainable. However, for any given development, what the optimum sustainable solution may often vary for each stakeholder. A compromise is required based on an integrated understanding of the diverse issues involved, and sound scientific analyses.

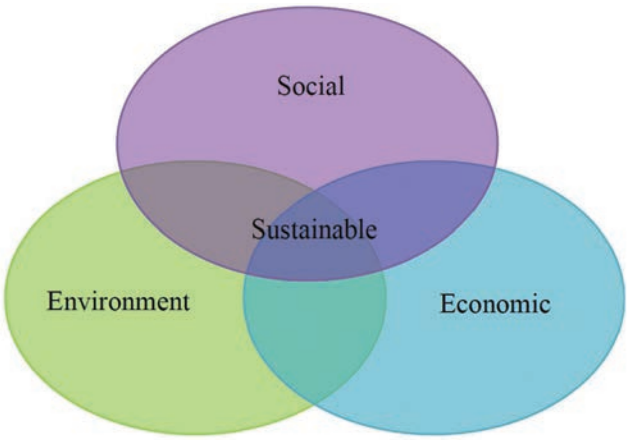

Figure 1. *Three pillars of sustainability*

What Is Sustainable Water Management?

Water management is a very important component of the environmental protection element of sustainable development. However it also has implications for economic development both on the broad scale of aggregate supply costs to supporting regional growth, and production costs at the site scale. Water management has strategic economic implications if greater extraction depths are attainable, prolonging quarry life and potentially permitting greater investment in sustainable solutions. Site restoration and after use creates a range of opportunities (Ellis et al., 2008) including biodiversity, renewable energy, flood alleviation and water resources (reservoir) supply. Social progress may be linked to amenity value of the final restoration and other opportunities it presents for rural regeneration.

Climatic factors must be considered and may be crucial to the long term viability of a quarry. For example it is not simply the potential damage caused by flooding but the commercial consideration of the interruption to business if a site becomes inoperative for a prolonged period. The majority of businesses in the UK affected by flooding go out of business within 5 years due to poor contingency planning and lack of suitable insurance (Brownfield Briefing Conference, 2013). Contamination is a frequent accompaniment to flood events whether it be due to spillage of stored fuel, chemicals and sewage, or suspended solids liberated from site storage bunds and settlement lagoons. Specific environmental insurance may be prudent to protect against potential operational claims.

Flood risk assessments are required for all new major developments (DCLG, 2012) and should be incorporated within the site water management strategy. Sources of flooding include river/fluvial, coastal/tidal, pluvial surface water run-off, groundwater, and failure of reservoirs and canals. Quarries should be aware of stringent inspection requirements of the Reservoir Act (1975[2]) for above ground structures containing more 10,000m^3 of water. All forms of flooding should be considered within a flood risk assessment along with appropriate contingency plans in the event of a flood.

Climate change is happening with the occurrence of more extreme weather events, including intense rainfall and droughts. With increasing economic pressures the temptation to cut back on spending and maintenance is a challenge and should be resisted to prevent increased risk of environmental impacts. The government and

[2] The Floods and Water Management Act (2010) has amended the Reservoirs Act (1975) such that a large raised reservoir is now defined as a reservoir or lake holding 10,000m^3 or more.

insurance companies are in the process of agreeing new insurance terms for properties classified by the Environment Agency as within a high flood risk area. Quarries may have a part to play in mitigating the flood risk both to the site and for other receptors downstream.

Water Management Planning

It is important to be prepared and have a water management plan for both day to day management and more extreme events. Otherwise, crisis management may be required if serious environmental impacts occur (e.g. low flows or contaminant spill); or there is not enough water for operational purposes such as mineral washing. It is noted that during last year's (2012) drought the imposition of drought orders was only avoided by anomalously high summer recharge.

It is recommended that the strategic importance of water at each site is reviewed to check its availability for activities such as mineral processing and dust suppression, plus potential regulatory constraints imposed by the Environment Agency or water companies on mains supply. Low groundwater levels could potentially render abstraction boreholes ineffective. Hands Off Flow conditions (HOF) could potentially limit surface water abstraction or groundwater if the licence contains conditions relating to surface water receptors.

The water management plan should incorporate data from previous hydrological and hydrogeological assessments and if possible an outline plan should be developed from the beginning of the initial planning application. The water management plan requires monitoring data of appropriate frequency, reviewed on a regular basis and linked to triggers for management action before key planning, abstraction licence and Environmental (discharge) permit conditions are breached.

Conceptual Model And Site Water Balance

Sustainable water management requires an integrated assessment of the all the water elements of the system. Developing a hydrological/hydrogeological conceptual model, updated and refined over time, is key to delivering this aim. Supporting data collection is necessary to monitor and refine the model and may allow adaptation and significant improvements to sustainability for minimal investment, with a short payback time. Collection of pumping and other flow data is considered essential and modern telemetry and data management systems make this increasingly easy. Typically, quarry water sources comprise groundwater, surface water, rainfall and mains water. Inflow of rainwater and groundwater to the site will typically be controlled in the following ways:

- A component may be required to mitigate environmental impacts from quarrying. For example, unacceptable loss of baseflow to a stream would typically be mitigated by discharging a component of the quarry inflow back to the stream.
- A component of water may be utilised to fill site water requirements such as mineral washing, dust suppression etc.
- Excess water may be discharged via an environmental permit (discharge activity) to ground or more typically to a water course as per the terms of a permit. This excess water may originate from groundwater dewatering or from rainfall run-off.
- If the site does not have adequate water supply then mains water may be utilised, or more typically, water may be abstracted from a nearby stream or underground aquifer (an abstraction licence will usually be required).

The site should be seen in the context of the wider catchment which is subject to a range of stresses of differing scales and variability such as: low flows due to over abstraction; high nutrient loading; and potential drought or flood conditions.

The general objective of the Water Framework Directive is to achieve 'good status' for all surface waters by 2015. 'Good status' means both 'good ecological status' and 'good chemical status'. In this it is important to note that, in most UK streams, flow will only be assessed as a supporting element for good ecological status i.e. assessment of flow is only required if the ecology is not in good status. This raises the potential for mitigating other pressures on the ecology rather than flow impacts, an approach that can be both cost effective and be seen as being consistent with the Government's enthusiasm for offsetting.

It is likely that serious site specific environmental impacts will have been identified and mitigated but on a catchment scale cumulative water quality/quantity impacts from other activities in the catchment may result in unacceptable impacts. The Catchment Abstraction Management Strategy (CAMS) is the basis for Environment Agency regulation and control of the amount of water taken from water bodies (groundwater and surface water features), to ensure there is enough water to support a healthy river environment. It assesses how much water is reliably available on a catchment by catchment basis.

The site conceptual model may be relatively easily translated into a site water balance for either qualitative or more detailed quantitative assessment. Figure 2 shows a quarry water management train broken down into a series of sources, sinks and stores. The water balance can then be used to identify potential efficiencies and environmental impacts and solutions.

Water auditing

Energy consumption associated with pumping and dewatering is an important aspect in the extractive industry (Ellis el al., 2010). Water audits can help to identify where inefficient and unsustainable practices are taking place. This information may be available in the form of abstraction returns required to be collected for abstraction licences or discharge volumes from discharge activity environmental permits. The impending transfer licence scheme, plus natural events such as the recent drought and subsequent floods, will provide external drivers for increased knowledge of the potential impacts resulting from site activity. This will increase monitoring requirements as without sufficient data it is difficult to ascertain the most sustainable and cost effective solution

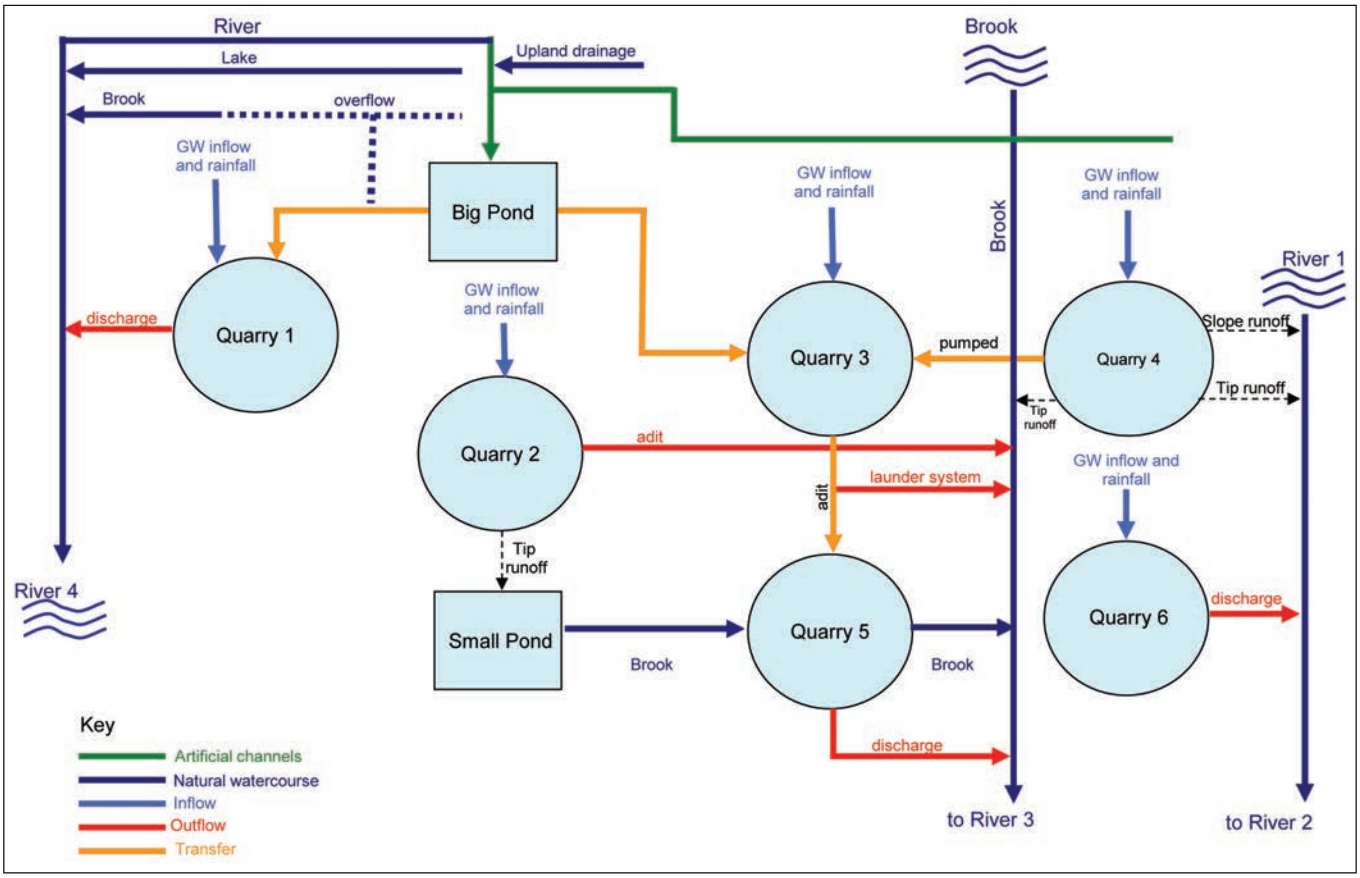

Figure 2. *Quarry water management train.*

and is likely to be lead to greater scrutiny from regulators. For example, with the impending implementation of the transfer licence scheme a full abstraction licence may be required if data is insufficient to demonstrate water is not being consumed.

Mains water is expensive, but of high quality, and may be required in some instances. However, it is clearly not sensible, sustainable or the best solution for mineral washing or wheel washing. The quality of the water should be fit for purpose and re-use of water will improve sustainability. General site rules should be to recycle water where possible, keep settling ponds and interceptors clean, get leaking pipes repaired, have emergency procedures in place to avoid pollution of water and make regular inspections of water discharges.

Impact assessment

Hydrogeological impact assessment is often viewed as a cost burden but is an essential part of a sustainable water management scheme. Potential impacts on water resources are considered during the planning process and appropriate mitigation measures put in place. A series of tools are often used in the process and should be revisited and validated or updated during the life of the development to minimise the risk to the environment. Tools and approaches which can be applied, with increasing complexity and data requirements are summarised as follows:

- Scoping analytical equations
- Steady state or transient water balances
- Detailed flow modelling – e.g. MODFLOW or FEFLOW

Used correctly a water balance model may allow on-going monitoring of a site to provide advanced warning of any potential environmental impact to sensitive receptors whilst at the same time screening out the effect of climatic variations which may cause a breach of more standard trigger level type controls.

Case Studies

Limestone Quarry

A water balance method has been used to support limestone extraction from a large quarry in South Wales (Streetly, 2008). The site is adjacent to a number of sensitive receptors and a transient water balance model provided the necessary confidence for the regulators to allow development (Streetly, 2008) within a hydrogeological setting of such complexity that it is often considered not to be amenable to quantification.

Freemans Quarry is operated by CEMEX UK Materials Ltd for the extraction of Carboniferous Limestone. A hydrogeological impact assessment was carried out to support a planned increased depth of working, and subsequent restoration of Freemans Quarry. It was concluded that only occasional, limited dewatering would be required to work bench 3 and that any minor impacts from working the lower, bench 4 could be mitigated by discharge of the water to local soakaways. A recharge-runoff model was used to develop transient water balances to quantify the dewatering requirement more accurately. A spreadsheet model was designed to simulate a daily time series for groundwater heads and discharges. Modelling was undertaken using explicit time stepping and changes in groundwater levels were derived from recharge, from groundwater flows and from discharges to boundary conditions (either to springs or dewatering abstractions). The model was calibrated to existing conditions. Future scenarios were then run for benches working to lower levels. Some impacts were predicted on springs at lower benches and appropriate mitigation measures developed.

Sand and Gravel Quarry with infill

Infilling of sand and gravel quarries with inert waste can be considered a sustainable practice if it allows land to be returned to agriculture or facilitates additional habitat creation by extending wetted margins. However, one potential impact which warrants further assessment is the potential for groundwater flooding caused by infilling with material of low hydraulic conductivity. This can result in a barrier to groundwater flow and has the potential to increase groundwater levels (and therefore cause flooding) up hydraulic gradient of the site. This is often an issue in Greater London from the cumulative impact from historical landfills and lined reservoirs. A two dimensional groundwater flow model was constructed for a proposed sand and gravel quarry (wet working), and subsequent inert landfill in order to quantify the impact on local groundwater levels. Groundwater levels were simulated to increase by 0.1m at a distance of 200m up hydraulic gradient of the site (Figure 3). A significant groundwater flood risk was not indicated by the model. A slight reduction in groundwater feeding lakes down-gradient of the site and other surface water features nearby was predicted. To mitigate this impact it was proposed to direct the increase in runoff recharge from the site preferentially to the south of the site to counteract any possible impact.

Sand and Gravel Quarry

Often a flood risk assessment is required for planning purposes and it is cost effective to combine this with other elements of site water management, such as silt settlement and dewatering requirements, to ensure an integrated water management plan for the site. One of the prime requirements is that the quarry does not increase flood risk to receptors off site. For a typical sand and gravel quarry (Figure 4) a water balance was constructed based on the response of the site water management system to the 1 in 100 year storm event including an additional allowance for climate change. A simple spread sheet model using rainfall intensity was used to determine sustainable drainage (SUDS) options for run-off attenuation and the required freeboard capacity for different elements of the water management system.

Conclusion - Is It Just Common Sense?

With sustainability more to the forefront of our minds are we actually doing anything differently from before or are the solutions typically due to the application of common sense? Two people from the industry were asked their thoughts as to what sustainable water management is and whether it is just common sense.

Person 1 comments that "we have always tried to use water in the most efficient manner, there has been a change of focus on restoration and discharge quality"

Person 2 defined sustainable water management as "using water in an efficient way while minimising impacts on the environment".

There was a strong opinion that sustainable water management is not always common sense and based on experience far from the most obvious. Water management approaches are often adapted as

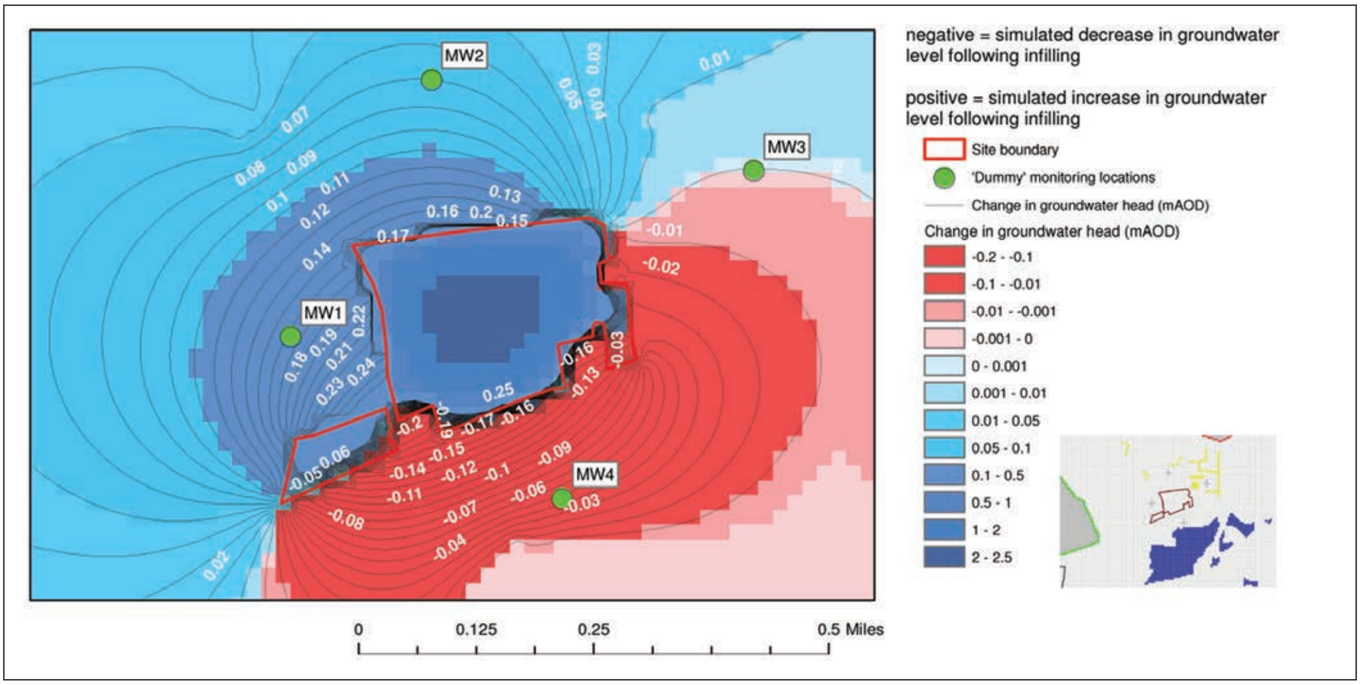

Figure 3. *Modelled changes to natural groundwater levels.*

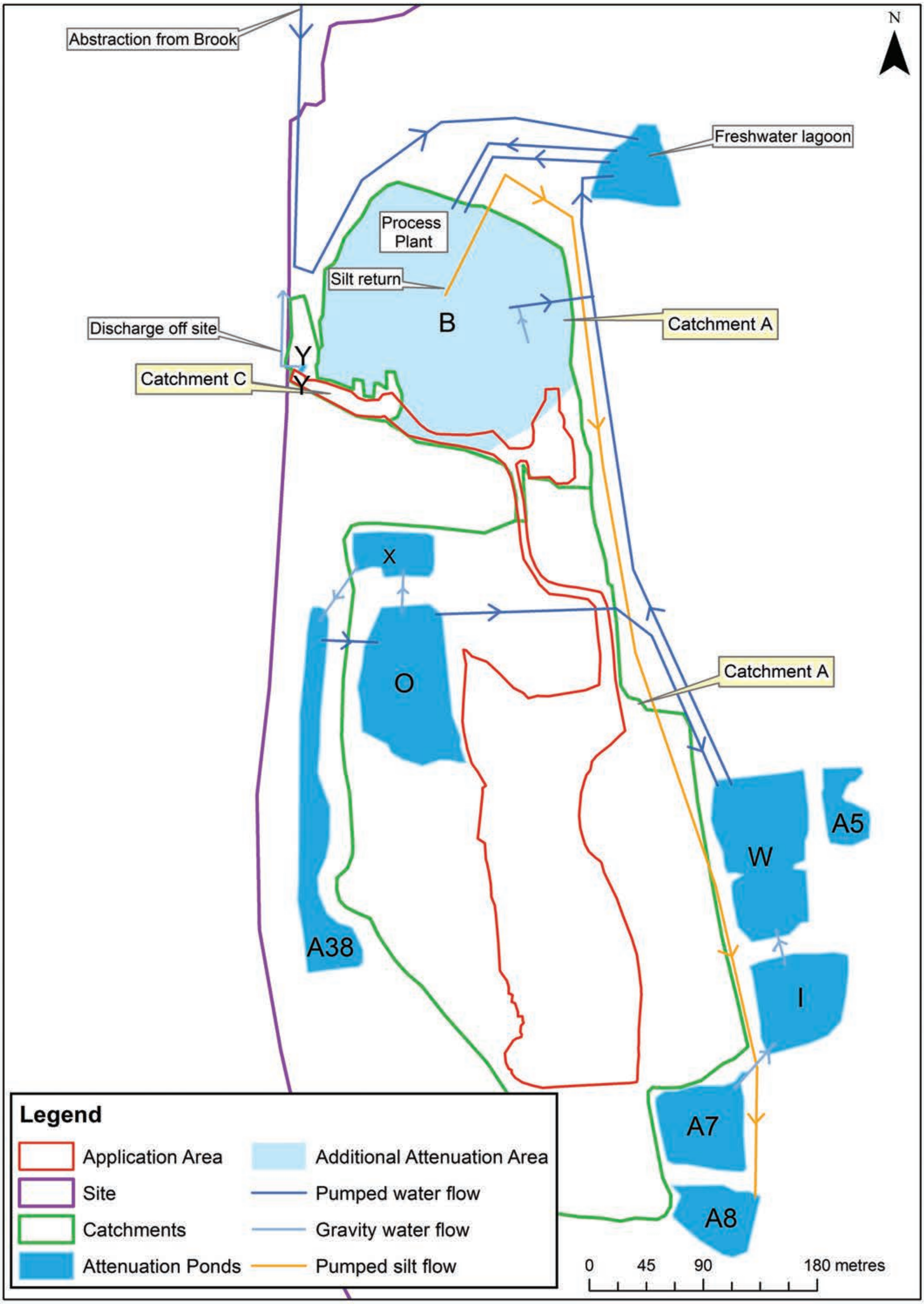

Figure 4. *Typical sand and gravel quarry sustainable water management system.*

knowledge increases and operational requirements change. An example was given that water is often abstracted from a river, used and pumped back to the river where in fact a closed system would be more sustainable. The need for sufficient monitoring to understand what the most efficient use of water was stressed and that technology can play a strong role.

In particular, it was suggested that much more could be done for the assessment of hard rock quarries where lifetime is 10's of years. In this case water audits and close collaboration between a hydrogeologist and quarry manager at least every 5 years would be a sensible approach. This would identify the most sustainable approaches and additional data requirements as well as any risks to the business. More strategic planning should work out to be cost effective in the long term with crisis management avoided. An example of one such crisis management experience related to a lack of water which could have been identified a number of years previously, prior to a catchment becoming over licensed.

Often site practices such as dewatering have developed over many years across many phases of work. What was originally efficient may no longer be so and a review could lead to significant savings. The importance of the different cost factors may change over time, such as with rising energy bills and potential for increased environmental costs. The views of regulators and other stakeholders on the interpretation of sustainable development is of increasing importance.

How can you calculate the optimum solution? Can you monetise the solution by calculating an environmental, social, economic cost/value? How can you put a value on each positive and negative impact? These questions are very difficult to answer.

In many cases it probably is common sense, as the most sensible and cost effective approach is close to the most sustainable one. However, if you look back over time at planning and operational decisions there are likely to be many examples where you might have done things differently if sustainability was on the agenda. As education and technology have improved so have people's views of a sustainable solution evolved. From the impacts of the industrial revolution to the present day it can be argued that things have improved, driven by, among other things, the development of a concept of sustainability.

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