



INFRASTRUCTURE

MINING & METALS

NUCLEAR, SECURITY & ENVIRONMENTAL

OIL, GAS & CHEMICALS

Water Conservation at Construction Projects 2013

Water in Mining 2013

Paper Number: 193

Water Conservation at Construction Projects

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ABSTRACT

Bechtel's Mining & Metals projects across the globe are executed in remote arid and semi-arid countries where providing even basic water supplies impose considerable challenges. Opportunities for water conservation measures using a Six Sigma initiative were proactively pursued to address the potential businesses impacts of limited availability of water resources. The initiative investigated areas driving water-optimisation during concrete operations and camp management. This paper details the water conservation evaluation of alternatives and cost/benefit analysis based on current and predicted water usage for mine development projects. Optimisation of water consumption through institutionalising more prescriptive standards for camp design and defining water conservation requirements have resulted in a new standard specification. Based on our projected mining project workload across the globe, it is estimated that for the period 2012 -2015, a potential 5.5 M m³ water savings resulting in \$11 M USD could be realised for construction camps and savings of 4 M m³ of peripheral concrete process water resulting in potential cost savings of \$8 M USD could be achieved as a result of these revised standards.

INTRODUCTION

The Bechtel Corporation Mining and Metals (M&M) business line is focused on the engineering and construction of mine and metallurgic plant mega projects across the globe. The Bechtel Group of companies is committed to the principle of sustainable development and to providing its customers with innovative approaches for enhancing projects to achieve sustainability objectives. Bechtel's Sustainable Development policy establishes the commitment to contribute to sustainability and protecting the environment; minimising and mitigating unavoidable impacts; restoring environmental resources as needed; and using resources efficiently.

In 2009 M&M directed efforts into further investigating conservation opportunities and environmental performance improvement strategies. A Strategic Gap Analysis was performed leading to a management commitment to investigate environmental sustainability improvement opportunities via application of Six Sigma methodologies.

At the time these investigations commenced, the majority of active projects were located in Australia, which had been experiencing extreme draught for several years. Additionally, work projected was focused in the Andean highlands of Chile, Peru and Argentina, all known to experience considerable limitations in water availability.

The initial investigation conducted into water consumption during construction revealed that optimisation of water usage was a relatively unexplored subject and provided opportunities for significant improvement.

INVESTIGATING WATER USAGE

During the initial phase of this project it was noted that there was an overall lack of data related to water consumption during construction. The project team therefore focused the initial stage of the project on identifying and understanding the drivers around lack of data and implementing measures to initiate data collection (FIG 1).

After the development of this work, a Strategic Gap Analysis was done for M&M where management commitment to investigate environmental sustainability improvement opportunities through the utilisation of Six Sigma methodology was formally established as one of the key focus areas. A team of subject matter experts was formed to explore all the opportunities related to the optimisation of water consumption during construction, focusing process improvement efforts on areas with water optimisation opportunities (FIG 2).

SIX SIGMA PROCESS IMPROVEMENT PLAN STRATEGY AND METHODOLOGY

Early in the Process Improvement Project (PIP) lifecycle, it was evident that the standard Six Sigma PIP approach would not be appropriate due to the lack of historical data and formalisation of requirements for data collection on construction projects. Additionally, with the lack of a formal process for water optimisation during construction, it was identified that a DMADV (Define, Measure, Analyse, Design and Validate) methodology to investigate and improve the process was most appropriate. Through the use of Six Sigma

Tools, Lean Tools, Innovation Tools, and Data Collection (FIG 3) a strategy for improvement was developed for water optimisation.

In the innovative design approach it is important to clearly define the objective, in this case “optimisation of water usage during construction.” To validate this initial job statement, the team applied a job-scoping tool to help see upstream and downstream of our selected statement and determine if we were focusing our innovation effort at the correct level.

A mind mapping tool was used to capture general and specific items related to the Water Optimisation idea (FIG 4). This tool allowed for the identification of key elements in the work process, the first being management support and the clear identification of roles and responsibilities. Additionally, the relevance of individual behaviour of employees was identified as having an impact on the success of optimisation efforts. The focus was agreed to be directed on areas where water was required in large quantities with the consideration that no water optimisations were formally implemented before. The results from these efforts identified two areas of focus for the defined phase of the project:

- Optimise water utilisation at construction camps
- Optimise water utilisation during concrete production

It was agreed that water usage during plant operations would not be included in the project moving forward as these efforts were dependent on client support and outside the sphere of influence for the purposes of the current project.

INVESTIGATING WATER USAGE IN CAMPS

To investigate camp water use, metrics were established to track and monitor effectiveness. The primary metric being the amount of water (in litres) used per person/per day (segregated by water type/source/type of use) with the assumption that tracking the source of camp water, amount of water used, and type of water used (e.g. town, tank, etc.) we could ascertain if water optimisation measures implemented by projects were successful.

The absence of design standards and the use of tribal knowledge in its place was consequently resulting in construction camps designed to provide anywhere from 300 to 450 litres/person/day of water. The fluctuation in design and the methods used to determine the per capita water requirements were contributing to errors in the sizing of camp water treatment systems. Additional impacts included: increased maintenance costs, disruption to the potable water supply, and water treatment system upsets.

Due to the lack of a formalised monitoring program, a robust data set across all projects was not available; however, two projects were able to provide camp water consumption data to establish a baseline. One project was based in Africa, which had installed water flow meters in the camp to determine the source of substantial leaks in the water supply system. The second project, based in Australia, had installed water flow meters to support this initiative.

FIG 5 shows water usage in litres/person/day at the Australian project camp from October 2011 through April 2012. High usage rates observed in January were a result of incorrectly set tapping bands which ultimately required the repair of 144 bands. Additionally, in January 2012 the camp manager commenced a water conservation campaign consisting of notices around camp concerning water usage and water conservation awareness signs. Water consumption at the African project between October 2011 and April 2012 is shown in FIG 6. The noise in the graph is the result of regular draining of the water tanks and significant leaks.

Secondary metrics were established to monitor: the number of days demand for water outweighed supply, number of complaints from camp occupants regarding optimisation efforts, and number of occurrences where camp occupants bypass water savings devices.

When investigating water supply and demand in 2012, it was discovered only two projects experienced time spent where water demand was not met. One project located in northern Canada experienced shortages due to frozen pipes. The second project was located in Saudi Arabia and water shortages were attributed to off project action shutting down the water treatment facilities in the local area.

Analysis of water usage data revealed that the design standard was in excess of actual water usage in many camps. Additionally, potable water and sewage treatment facilities were often being designed in isolation of camp and other temporary facilities, so the benefits of water-saving devices specified in facility design were not being captured in treatment system specifications and capital costs. This has the potential to result in installation of never-used capacity in camp water systems, or engineering selection of reduced design targets, based on experience and not data.

The outcome of investigations into construction camp water optimisation established a target of 15% reduction of water usage by the close of 2013 through revision of design standards for camps and establishment of camp operating standards related to water optimisation (FIG 7).

INVESTIGATING WATER USAGE IN CONCRETE PRODUCTION

Water usage during the production of concrete on construction projects can represent one of the single biggest costs during the construction phase (outside of permanent plant material and labour). In the past, improvements have focused on optimising water usage during the concrete mixing stage; however, given the well-defined strict mix-strength requirements, only an incremental water/cost savings could be found in this area. It was identified through our investigations that the use of water in the peripheral activities (including: aggregate washing, cleaning concrete trucks inside and out, dust suppression on truck routes, and during curing stages) during concrete production was largely uncontrolled and unknown and therefore mismanaged. Similar to findings in the camp water usage investigations, it was identified that on most sites there were no requirements for control or measurement of water usage during these peripheral concrete activities. It was identified that one of the primary reasons for the lack of control and measurement of water use in concrete production was our approach to concrete batch plant management. Concrete batch plants are generally sub-contracted out and often not included in our prime contracts. Therefore, they are not managed to the level of detail which would allow the organisation to control the process. Additionally, the water required for producing and placing concrete is generally not supplied either by us or the concrete contractor, but by the mine operator to which the service is rendered.

The investigation involved interviewing several concrete contractors (Cementos BioBio, ReadyMix, Petreos, and Yura) to determine water usage in their production/placement processes and this resulted in the following breakdown of water use:

- One m³ of concrete requires 250 L of water for production
- One m³ of aggregate requires 1,000 L of water for washing

Further data was captured over an eleven month period on a project in Peru. The results of this investigation indicated that each cubic meter of concrete produced would require approximately 310 L of water during the mixing process and 820 L of water for peripheral activities (FIG 8).

There were several peripheral activities that were found to be as major water consumers in the overall concrete production and placement process:

- Aggregate washing – ensuring the aggregate used for the mix is clean and free of soils that will weaken the concrete bonds.
- Cleaning of concrete trucks – Water washing concrete trucks inside and out after each use.
- Dust suppression – Keeping the truck routes watered down to reduce dust created during concrete production activities.
- Concrete Curing Water - Water usage during concrete curing stages to ensure appropriate hardening.

The concrete production water related activities measured during the 2011/12 investigation at the project concrete plant tested a number of theories and resulted in two notable findings:

- Truck Washing - The lack of standardisation for external washing of trucks resulted in excessive water usage. An analysis of these cleaning techniques indicated that use of excess water resulting in water wastage was found to be statistically significant. Also, it was observed that re-use of wash-water was not adequately practiced.
- Aggregate Washing – There was a lack of historical records documenting water consumption and techniques during aggregate washing. As a result, inaccurate water usage estimates were used during aggregate washing processes. It was observed that significant excess water volume was consumed during aggregate washing.

The outcome of investigations into concrete productions established a target reduction level of 30%, excluding mixing water, by the close of 2013 through water re-utilisation practices (FIG 9).

COST ANALYSIS

In order to facilitate the cost analysis, Capital Expenditure (Capex) and Operational Expenditure (Opex) costs were used, as well as the annual savings potential associated with water optimisation, this facilitated visualisation of the potential benefits associated with optimising the water use.

The cost per thousand litres of potable water was established at \$2 USD based on actual cost data from a typical Australian construction project, US EPA Case Studies (EPA, 2005), and in-house water experts. For the purposes of the construction camp water cost analysis, we based the estimate on the cost of potable water per thousand litres, the number of M&M's projects expected to be constructed through 2015 and the number of people expected to be housed in camps during that time. An average rate of current water consumption of 291 litres/person/day was utilised, although it is important to note that usage of water can

vary considerably depending on location and workforce. Hot, humid and/or dry climates, in addition to extremely cold and arid environments, could contribute to excess water usage. The results of the cost analysis identified that the business should expect to consume/use 36.4 M m³ of water in its construction camps between 2012 and 2015. If 15% of the water usage is optimised, this would result in a savings of 5.5 M m³ of water and \$11 M USD in costs.

With regard to the cost analysis of water use during concrete production, based on the projected global M&M project workload between 2012 and 2015, it is forecasted that approximately 16 M m³ of concrete will be produced at our sites. The water optimisation strategy aims at conserving approximately 4 M m³ of peripheral concrete process water resulting in a potential cost savings of roughly \$8 M USD due to these efforts alone. The cost of poor quality (COPQ) identified for both investigations was estimated with consideration to the M&M workload from year 2012 until 2015 including the estimated volume of concrete and population at camps. The total amount of \$18.2M USD of savings was established as possible considering a 15% of improvement in water utilisation at camps and 30% of optimisation at concrete production during the period of the estimation.

It should be noted that the cost analysis is based on the treatment cost to make raw water into potable water. It does not take into account supply chain costs such as piping and pumping from the source to the treatment plant, from the treatment plant to the camp, which may be considerable if the camp does not have a nearby water source, nor the cost of treating waste water generated. These factors could potentially double or triple the cost of water. Additionally, the availability of raw water in countries where we are working is expected to decline in 2014, creating the potential requirement for pumping desalinated water from coastal areas at a much higher cost for these projects.

CONCLUSIONS

Estimates of M&M's camp population were over 100,000 residents in accommodations on projects in Australia, Chile, Peru, Argentina, and West Africa by 2015. At the commencement of this project camp/workforce impacts on water use and water treatment requirements had not been a primary consideration in project cost, design, and control efforts. Additionally, costs associated with camp water supply were not being captured in Bechtel estimates.

The work performed on this project has verified the cost implications of water optimisation and identified that mechanical means of reducing water consumption through the use of water-efficient devices does not increase project costs. Savings of over \$10 M USD from 5.1 M m³ of water are possible through revised standards and practices within the scope of work investigated.

The findings identified using Six Sigma tools allowed for the identification of potential causes as to why water optimisation measures were not being implemented and consequently, what actions were required to improve the project goal. By understanding water usage and needs, we improve our performance while at the same time reduce our risk of running out of water during construction by not appropriately estimating and budgeting for the amount of water to be used. An increased understanding also ensures the appropriate design of water systems.

The lack of requirements and direction for water optimisation at construction sites was resulting in additional costs and waste on project sites. The initial response identified during the development of this work was related to the modification of one of our corporate construction procedures to include details on the appropriate data collection to track the water utilisation and establish minimum conservation requirements to be implemented for all project sites. In January 2012 a new corporate procedure was published including the changes listed below:

- New responsibilities related to collection of data for water consumptions;
- Inclusion of water conservation measures to reduce potable water usage in camps including water-efficient fixtures and water saving devices;
- Changing the standard limits for water utilisation in terms of litres per person per day to a maximum volume of 250 litres/person/day;
- Defining the metering requirements including the requirement for installation of water measurement devices in all Bechtel M&M managed camps; and
- Defining the reporting requirements as monthly detailed reporting.

Following on from the construction procedure, the following improvement actions were identified:

- Utilisation of rain water tanks where geography and environment are conducive;
- Utilisation of waterless dust suppressants in place of water trucks;
- Where project location is conducive to the utilisation of grey water in toilets consideration to utilisation is required to be demonstrated;
- Use only sufficiently treated grey water for native landscaping and outdoor uses;

- Reduce the number of personal laundry facilities in camps and provide and promote the use of same day centralised laundry service;
- Consideration of storm water ponds in areas where geography and the environment are conducive must be demonstrated;
- Where project location is conducive to the utilisation of closed loop systems, investigate and communicate the benefits of a closed loop system (grey water only) to the major stakeholders and evaluate the possibility of its usage;
- Develop project performance measurements for water usage at camps to be monitored and reviewed corporately;
- Considering the location of the camp, develop standard design, supplier, installation, maintenance instructions for the usage of evaporation reduction covers (reservoir covers);
- Develop a concrete plant water management procedure, including requirements for reutilisation of both aggregate and truck washing water;
- Specifications detailing the need for controlling and optimising water consumption during site inductions;
- Install water-meters at concrete plants and collect data;
- Train and coach all drivers on the use and optimisation of water consumption when washing trucks, including prohibiting any other activity while the trucks are being washed (talking on the mobile phone, for example);
- Train personnel in charge of aggregate washing on the water quantity required; and
- Have an automated sprinkling control system in each truck for road sprinkling, installation of a water meter in the truck.

Water usage metrics have been captured across all M&M projects since January 2012 and more water meters have been installed on pilot projects, with the capture of these metrics now mandatory across all projects. The most notable result of these efforts has been the increased awareness of water usage and thereby increased behaviours relating to improving conservation measures (awareness leading to action). Currently the organisation is working to create a database of water usage demographics for all projects which would enable the modelling of expected water usage by project location and preferable design of water treatment systems for future construction sites.

ACKNOWLEDGEMENTS

We would like to thank all those team members involved in the Six Sigma PIP teams, with particular thanks to Shaun Kennedy, Kim Boyd, Younes Arian, Kristen Brook, Rebecca Green, Ringo Arevalo, John Gruber, Jorge Jana, Patricio Recabarren, Jorge Sepulveda, Dominic Myhill, Robert Janssen, Marty Haase and Doug Simpson.

This paper is approved to publish under the Bechtel Technical Information Program (BTIP) corporate approval system.

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FIGURE CAPTIONS

FIG 1 – Fishbone diagram identifying causes for lack of water data capture

FIG 2 - Focus Areas for Optimisation of Water Consumption during Construction

FIG 3 - Process Improvement Methodology for Construction Water Optimisation

FIG 4 - Mind Mapping Exercise

FIG 5 – Camp Water Usage – Australian Project

FIG 6 – Camp Water Usage – Africa Project

FIG 7 - Improvements to Camp Water Use for Water Re-utilisation

FIG 8 – Water Use during Concrete Production

FIG 9 - Improvements to Water Re-utilisation in Concrete Production

FIGURES

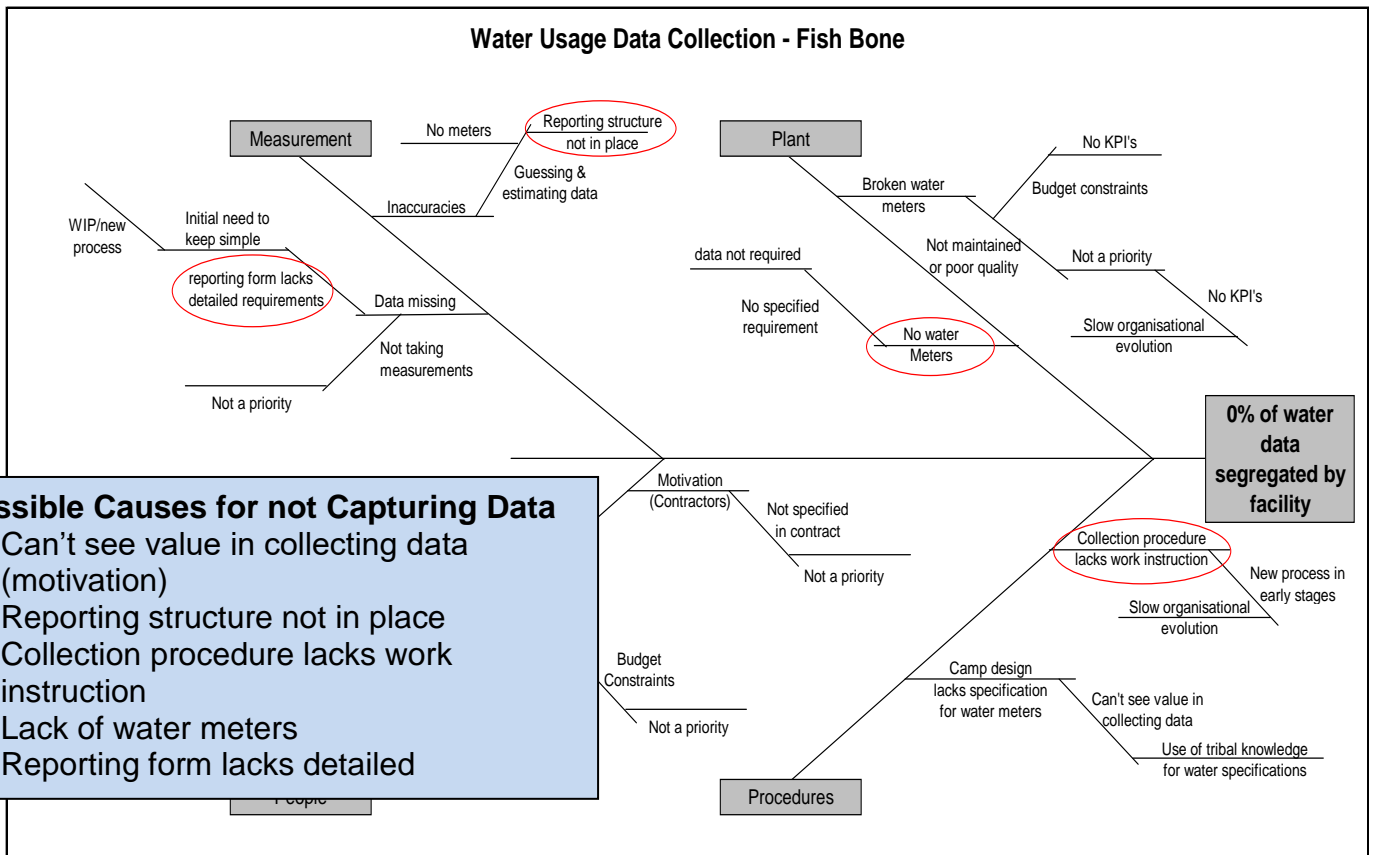


FIG 1 - Fishbone diagram identifying causes for lack of water data capture.

OPTIMIZATION OF WATER CONSUMPTION DURING CONSTRUCTION

WATER CONSUMPTION METRICS

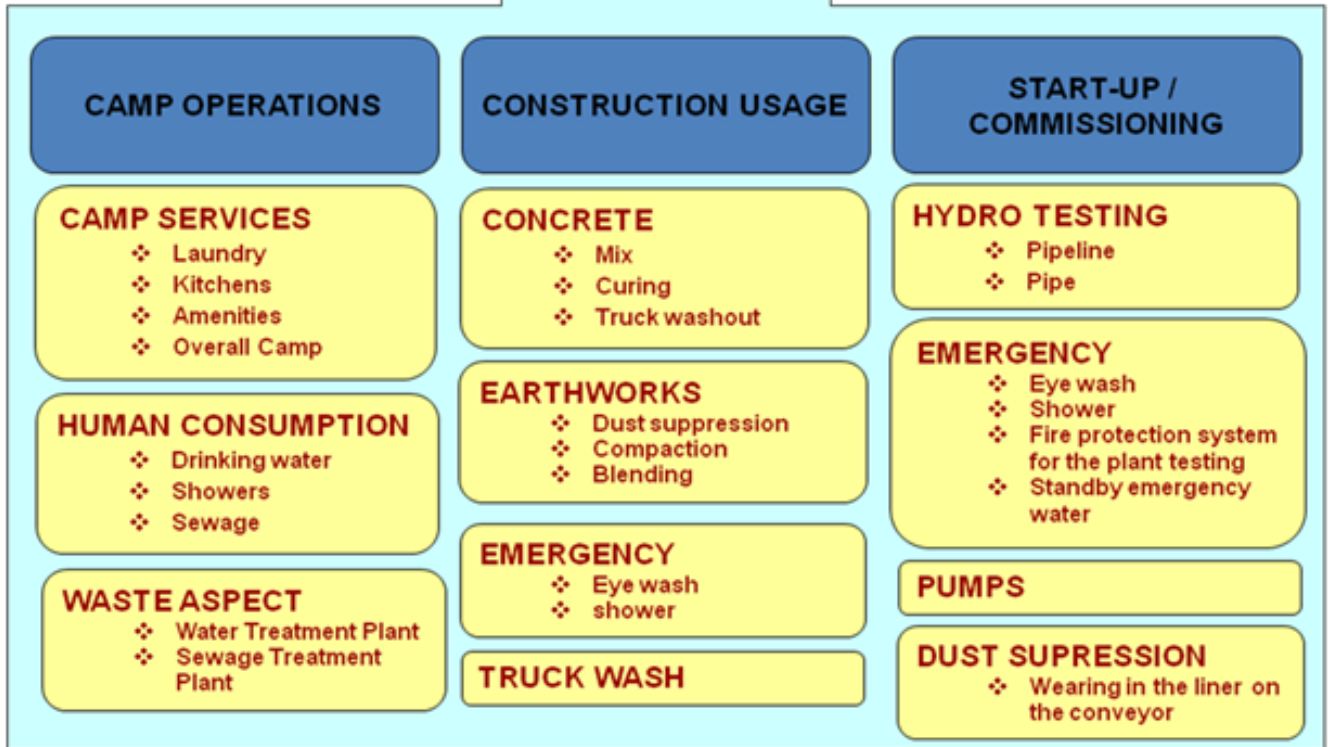


FIG 2 Focus Areas for Optimisation of Water Consumption During Construction

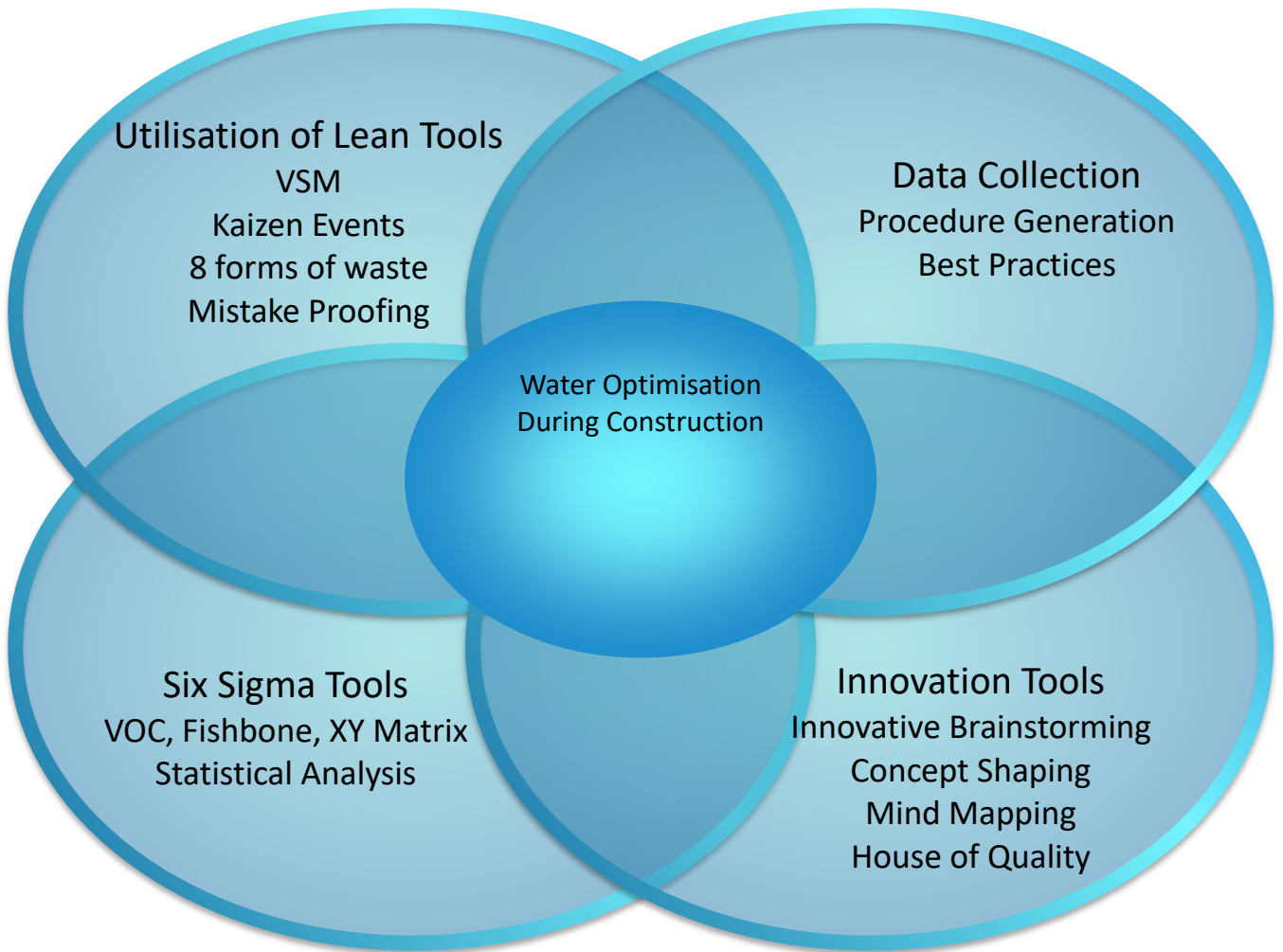


FIG 3 Process Improvement Methodology for Construction Water Optimisation

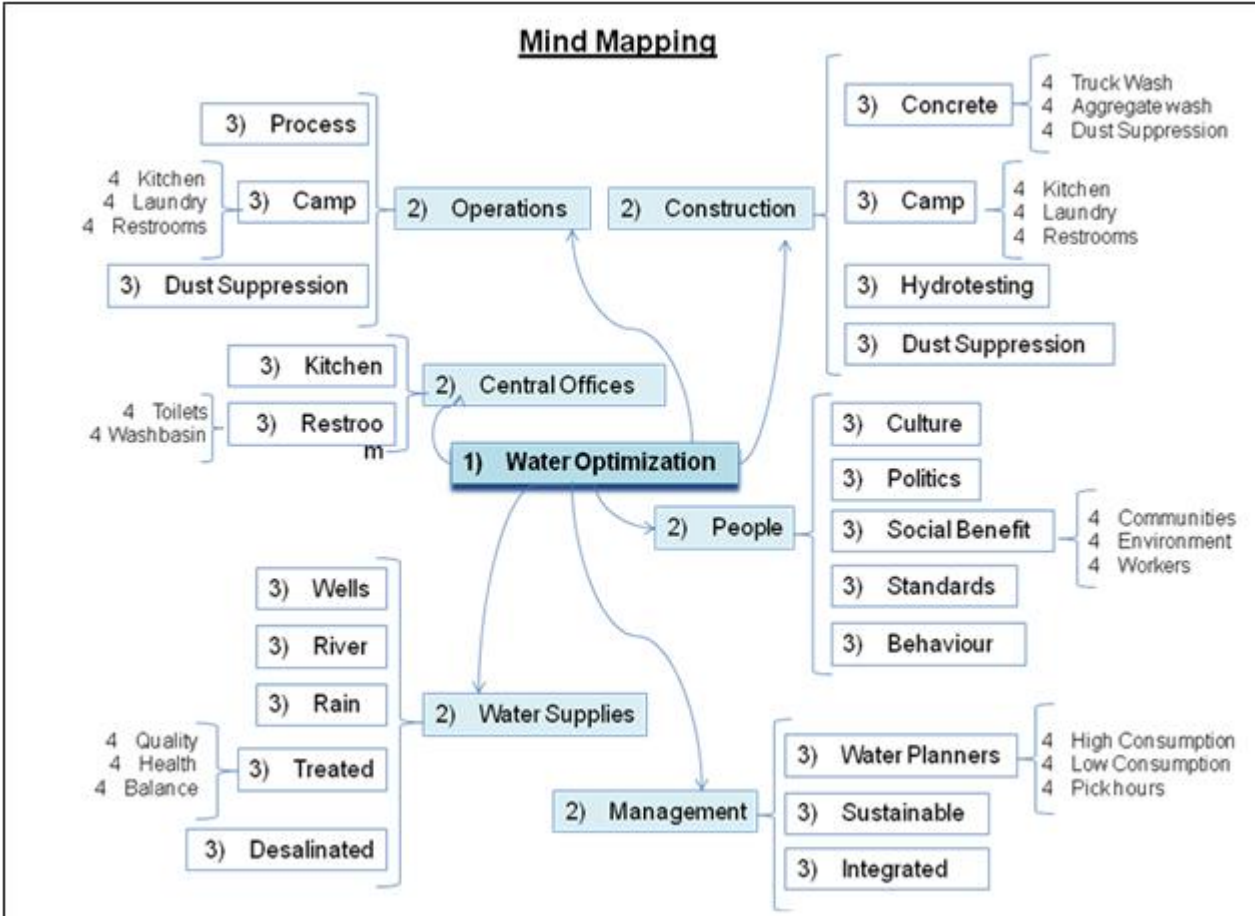


FIG 4 Mind Mapping Exercise

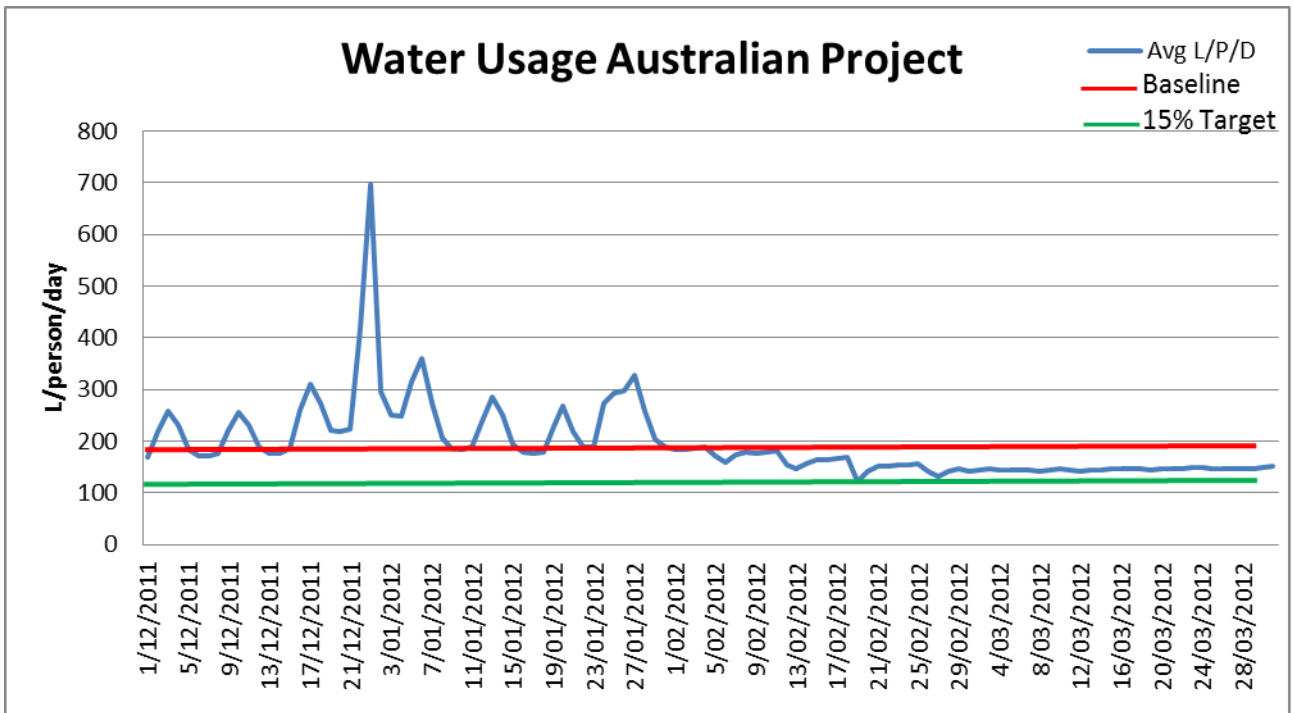


FIG 5 Camp Water Usage – Australian Project

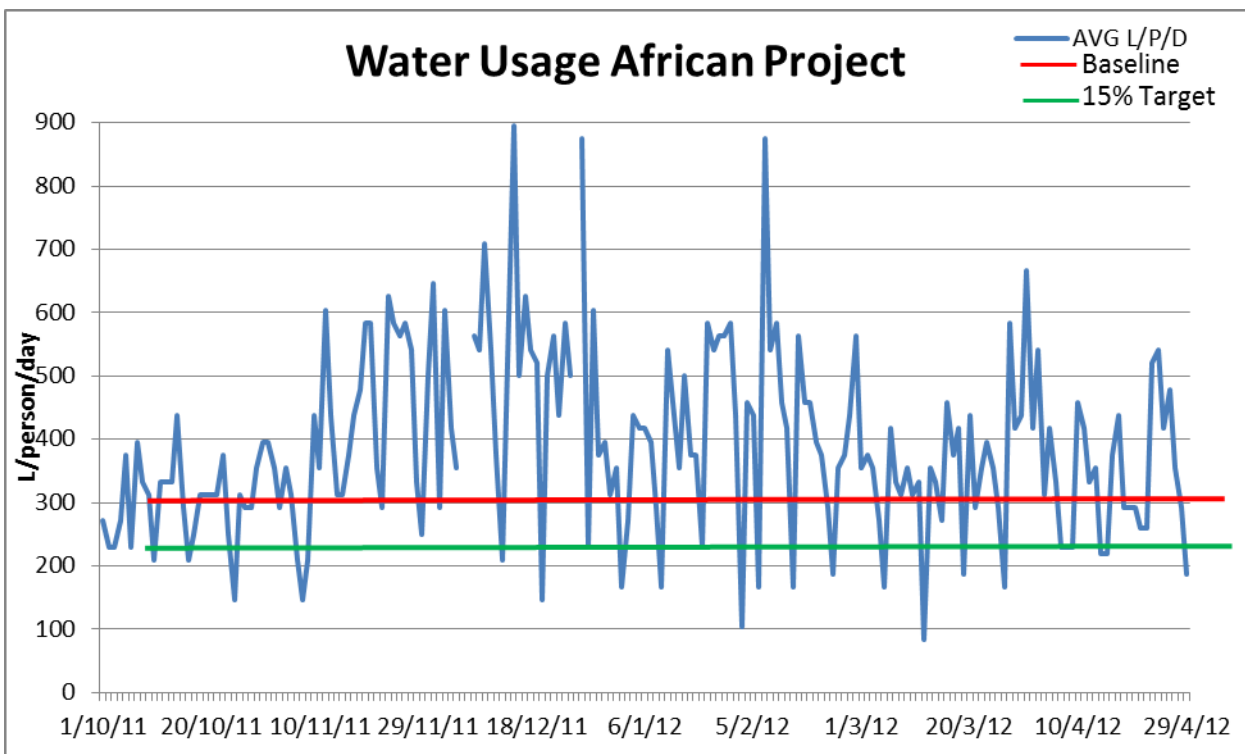


FIG 6 Camp Water Usage – Africa Project

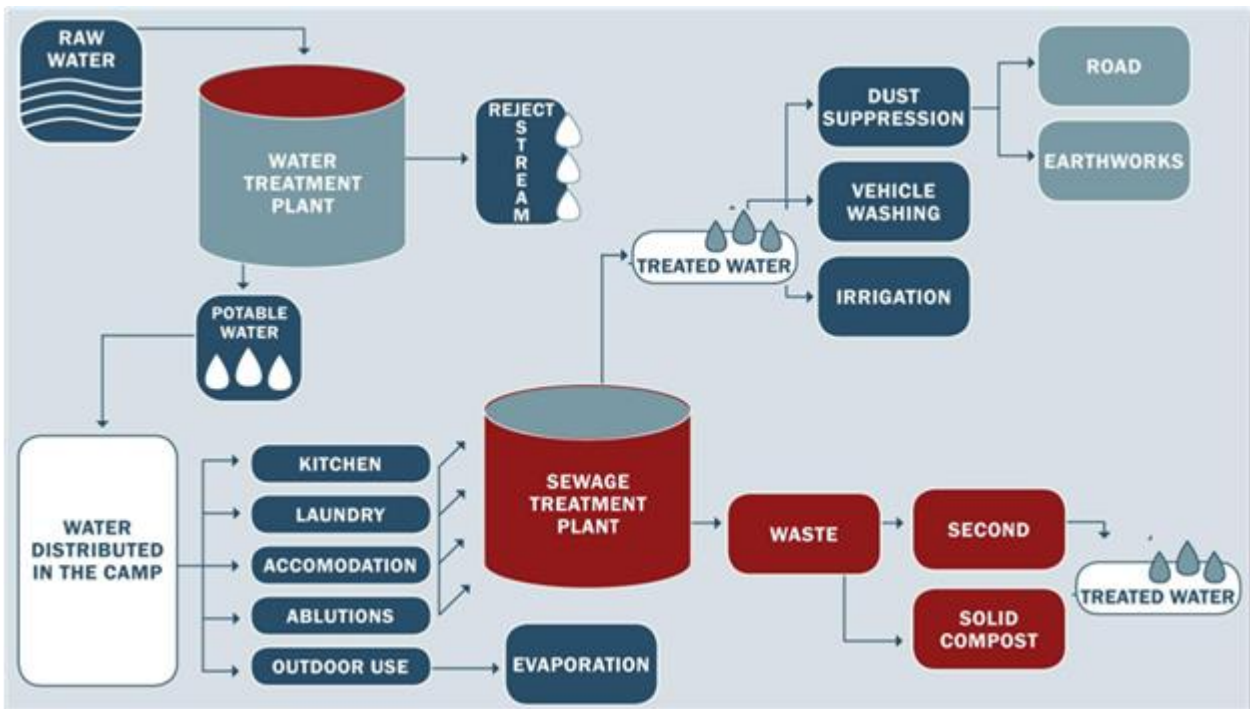


FIG 7 Improvements to Camp Water Use for Water Re-utilisation

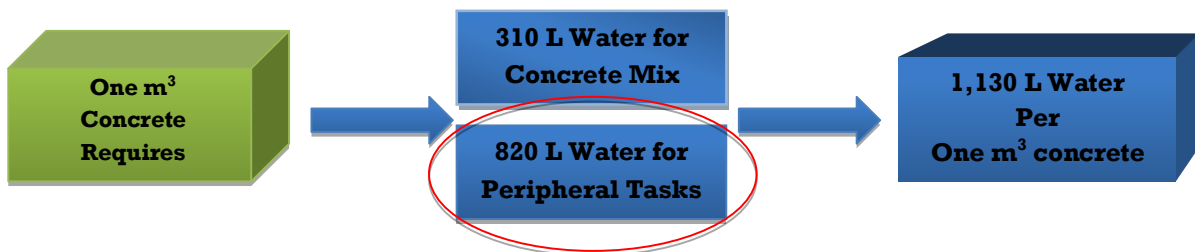


FIG 8 Water Use during Concrete Production

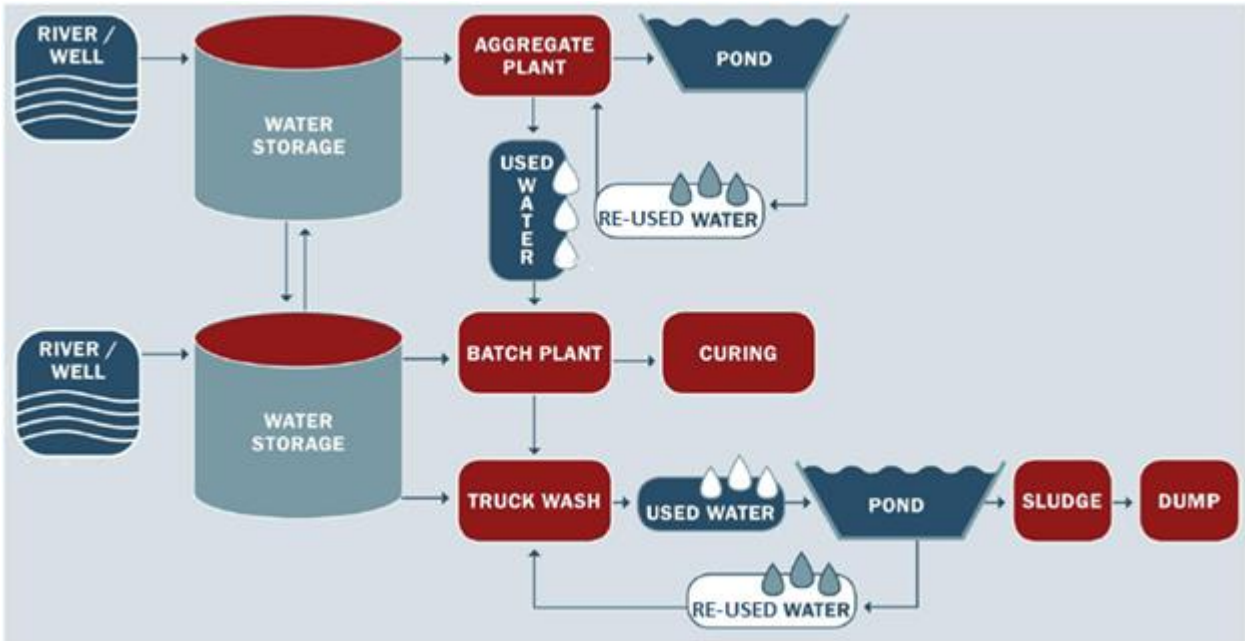


FIG 9 Improvements to Water Re-utilisation in Concrete Production