BLENDING EVALUATION AS A TOOL FOR MANAGING DISTRIBUTION SYSTEM WATER QUALITY

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ABSTRACT

A blending evaluation is a planning tool that can be particularly helpful when considering introducing new or additional source waters to a water system. A blending evaluation is a systematic approach to addressing the likely water quality impacts of changing source waters and if necessary, potential mitigation approaches. This paper discusses two North American case studies and a blending methodology that could be applied by any water system to plan for and mitigate a wide range of potential water quality issues.

KEY WORDS

Distribution, Blending, Water Quality, Corrosion, Treatment, Source Water

1.0 INTRODUCTION

There are many drivers for introducing new sources of water into an existing water system including: response to drought; increased population growth; system consolidations or annexations; improving supply and operational flexibility; provision of a backup emergency supply; and to improve water quality. For a system to meet changing needs and continue to provide high quality water, the impacts of introducing a new source need to be well understood and addressed prior to implementation of the change. Key impacts of changes associated with blending new sources should include: health; regulatory compliance; system interactions; and aesthetic concerns (Peet *et. al*, 2001; AWWA, 2005).

Prior to introducing a new source, potential water quality issues may be addressed by undertaking a blending evaluation. The evaluation may be relatively simple if the new source water quality, treatment and operating strategies are similar to existing or if a source is to be fully replaced. Blending evaluations can become more complex in large distribution systems with multiple sources and entry points, and with large differences in source water quality.

Some common water quality and system stability issues that may arise as a result of blending include: corrosion scales and heavy metals release and solubilisation; leaching of cementitious materials; changes in disinfectant residual levels; sediment re-suspension due to flow reversals; and observed changes in aesthetic water quality.

2.0 DISCUSSION

2.1 Blending Evaluation Methodology

The methodology presented in Table 1 describes the key steps for conducting a blending evaluation. The methodology commences with understanding the critical objectives for introducing new sources, followed by characterizing the probable range of water quality and impacts and then identifying viable mitigation strategies for an individual system.

This methodology can be a useful planning tool for any water system, regardless of the specific water quality conditions and system materials. The two case studies that follow were conducted using the methodology in Table 1.

Table 1: ***Blending Evaluation Methodology***

Step	Task	Task Detail
Define Objectives	**Objectives**	Define the critical objectives for introducing new source water such as: increase capacity; supply flexibility; improve water quality; and to provide emergency supply. This step should separate the real system needs from system preferences.
Identify System and Sources Information	**Current System Information**	Develop baseline information about the current system including: water quality parameters, treatment regime, water use, system materials, system hydraulics and operational strategies.
	Current System Constraints	Identify any fixed constraints on the current system such as available volume, facility to pre-blend prior introducing a new water source, ability to provide additional treatment.
	New Source Information	Characterize the new potential sources including: current water quality parameters; seasonal water quality changes; and treatment regime. Note any key differences to the current source water.
	New Source Constraints	Identify any operational constraints or requirements in relation to the new source including: available volume; volume restriction or minimum requirement; where source is available (such as inter-connection with existing system, elsewhere in system, or via an existing treatment plant).
Conduct Analysis	**Develop a set of representative scenarios**	Identify the range of possible blends and operating scenarios. Narrow these down to a representative set of scenarios that include blend ratios and probable operational strategies.
	Model scenarios	Use a range of available tools to predict the resultant water quality or ranges of water quality including: water chemistry modelling tools; hydraulic models; and laboratory simulations. Available modelling tools offer varying levels of complexity to suit different situations from simple water chemistry blend calculations to multi-species water quality and network path analysis.
Impacts and Mitigation	**Determine impacts of blending**	Determine whether the resultant blends of water are likely to have any negative impacts on: health; regulatory compliance; system interactions; and aesthetic qualities (such as taste, odour and colour).
	Develop potential mitigation strategies	Develop potential mitigation strategies that will eliminate or minimize the negative impacts. Determine which strategy is the most suitable and cost effective.

2.2 Case Study 1 – Blending low pH, high alkalinity ground water with high pH low alkalinity surface water

A small water system (System A) needed to augment supply capacity to meet increasing demands of projected population growth. System management preferred the flexibility to blend any quantity at any time, up to 100% of water from a new source.

System A relied on four similar ground water sources. The sources exhibited low pH and high alkalinity. The water was treated by disinfection with free chlorine and was not fluoridated. Water quality parameters post-treatment are presented in Table 2. The system management was considering augmenting supply volume by establishing an inter-system connection in the southern part of their system, with a larger neighbouring system (System B).

System A was divided into two hydraulic zones: the northern zone and the southern zone. Water from three wells in the southern zone moved north through the system, blending as a function of system hydraulics, in the northern zone with water from the northern well. System pipe materials included ductile cast iron, asbestos-cement lined iron, and unlined cast iron. The older downtown area, in the southern most part of the northern zone, also contained lead service pipes and lead-containing solder in household plumbing.

System B served a high pH, low alkalinity surface water (refer Table 2) and provided conventional surface water treatment, including disinfection with free chlorine and fluoridation, as well as pH adjustment for corrosion control.

Table 2: ***Key Water Quality Parameters for System A and B***

Parameter	Current Source (System A)	New Source (System B)
Average pH	7.1	8.7
Alkalinity (mg/L as CaCO3)	350	70
Fluoride (mg./L)	0	0.96
Chlorine residual (mg./L)	0.5	1.0

The key constraint on System A was not having an existing capability to treat or blend incoming water from System B, therefore water would enter directly into System A's distribution system. No volume constraints were imposed by System B.

System A's preference for full flexibility without pre-blending meant that a full range of blend ratios with System B's water, was possible. Two key representative scenarios were identified. Scenario 1 looked at blending in the southern zone of A's system and introducing from 0 to 100% System B water in 10% increments. Even with small percentages of System B water, there would still be fronts of 100% B water in A's distribution system because there was no pre-blending. Scenario 2 looked at blending that would occur in the lower northern zone of System A, particularly when water coming from the south contained a high proportion of System B's water.

A full range of blends for each scenario was modelled using the Rothburg, Tamburini Winsor (RTW, 1996) spreadsheet model for water chemistry. Information on system hydraulics was provided by System A and was used to map how blending would occur in the system. The modelling results predicted that both scenarios would lead to large fluctuations of pH and alkalinity across the southern zone, and lower half of the northern zone where lead service pipes were of concern. These and other potential impacts that were identified are presented in Table 3.

Table 3: ***Potential Impacts of Blending System B Water into System A***

Impact	Impact on
Increase in lead levels at consumers taps due to pH/alkalinity instability	Health, Regulations
Potential increase in iron corrosion or mobilization of corrosion scale products, leaching of asbestos cement linings due to pH/alkalinity instability	System Materials, Aesthetics (taste, odour, colour)
Variable fluoride levels from different sources	Health, Aesthetics (consumer attitudes towards fluoride)
Variable chlorine residuals from different sources	Aesthetics (taste, odour), Regulations
Flow reversals and sediment re-suspension due to the new, potentially intermittently used water entry point.	Aesthetics (taste, odour, colour)

(AWWA, 2005; Friedman *et. al*, 2005, Boyd *et.al*, 2008)

Several potential mitigation approaches were identified to eliminate or minimize the impacts presented above particularly to address pH/alkalinity impacts on lead levels. While lead has not been a big issue for systems in Australia, several US systems including Washington DC, which have old lead service pipes, have experienced elevated lead-levels partly attributed to a low system pH (HDR/EES, 2007). Recommended mitigation approaches included:

- Constrain blend ratios to no more than 30% System A sources with System B water, and pre-blend prior entry to the distribution system, to maintain a high enough, and consistent pH
- Isolate north and south service zones and convert south zone to imported System B water
- Import surface water from System B and use it in place of groundwater in System A, and use System A groundwater only as supplemental water supply.
- Pre-blend sources and provide treatment to maintain consistent pH and alkalinity.

Based on the results of this evaluation and other factors, System A decided that the best approach was to purchase all water for their entire system from System B.

2.3 Case Study 2 - Replacing a low pH, high alkalinity spring water with a lower pH ground water

A large water system (System C) used multiple ground water sources and one spring water source. The system management wanted to replace the spring water source with another ground water source, to improve water quality, and to simplify compliance with microbial and disinfection regulations, which were more complex for the spring water source.

The spring water was a moderate alkalinity, low pH source, treated with free chlorine for residual disinfection. The spring water was the primary source for the entire system through the spring and winter months. The system was supplemented in summer months by four similar well sources located throughout the system, each with higher pH and lower alkalinity than the spring source. The intent was to permanently replace the spring water with a fifth well source, which exhibited low alkalinity, and even lower pH than the current spring source. Water quality parameters post-treatment are presented in Table 4. The key constraint on System A was that the new well source would only replace the existing spring source, and the four existing wells would continue to supplement the system in summer.

Table 4: ***Key Water Quality Parameters for System C Current Sources and New Source***

Parameter	Current Well	Current Spring	New Well
Average pH	7.3	6.8	6.0
Alkalinity (mg/L as CaCO3)	50	62	55
Chlorine residual (mg./L)	0.5	0.5	0.5

Two representative scenarios were identified. Scenario 1 represented the complete replacement of the existing spring water. Water quality parameters for the existing spring water and new well source were compared. Scenario 2 consisted of a review of water quality differences between the new well and existing well sources, and a range of blends. The existing and the new well water would blend in the system during the summer months when all of the supplemental wells were in use. Elevated copper levels at consumer's taps were noted from water quality monitoring data, with the majority of elevated sites corresponding to areas served by the lower pH spring water. Customer complaints also appeared to increase each year during the transition from spring water to blends of spring and well water.

Table 5: ***Potential Impacts of Introducing a New Source into System C***

Impact	Impact on
Increase in already elevated copper levels at consumers taps due to lower pH of new well water source and larger seasonal shift in pH than currently experienced	Health, Regulations
Potential increase in leaching of asbestos cement linings due to lower pH	System Materials, Aesthetics
Other changes and fluctuations in water quality parameters due to different sources	Aesthetics (taste, odour),

The key recommended mitigation approach was to implement corrosion control treatment for the new well source to increase pH above 7.5 using aeration or caustic soda addition. This strategy aimed at reducing the elevated copper levels that had been observed. In addition this approach also maintains a consistent pH with the existing well sources, to avoid other issues associated with large pH fluctuations.

An additional recommendation was to track customer complaint data not only by location, but also by predominant source water and predicted blends in that zone. This would help to determine whether there was an actual correlation between customer complaints, and zones impacted by the seasonal transitions and blends of source waters. With this information, an appropriate mitigation strategy could then be developed.

3.0 CONCLUSIONS

The case studies presented describe a range of blending issues and impacts, some of which may not be encountered widely in Australia, due to different system materials and conditions.

However the blending evaluation methodology presented is a widely applicable planning tool for water systems to avoid potential unintended consequences from introducing new source waters.

As Australia continues to explore integrating new source waters, including desalinated water, a blending evaluation is a practical planning tool that can assist with a successful transition.

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