OSR 46-522
Rev. 3
12/08/2014

LW Form

Savannah
River Site (SRS)

UNREVIEWED WASTE MANAGEMENT QUESTION EVALUATION (UWMQE)

Page 1 of 6

UWMQE Number: SRR-UWMQE-2016-00002 **Revision:** 0

UWMQE Title: Evaluation of Water to Pre-mix Ratio from Nozzle Flush Frequency Modification

UWMQE Supported Documents

TECHNICAL

Number: USQ-SS-2016-00091	Date: 5/5/2016	Revision: 0
Number:	Date:	Revision:

SUPPORTING

Number: SRR-CWDA-2014-00006	Date: 8/2014	Revision: 2
Number: X-CLC-Z-00050	Date: 10/10/2012	Revision: 0

1. Unreviewed Waste Management Question Evaluation

Proposed Activity Description

The proposed activity adds process water flushes through HCV-7005 into the mixer discharge. This flushing will occur at a maximum of 30 seconds every 5 minutes. The nominal flow rate through these nozzles is 9 gallons per minute.

NOTE: Each question below requires Comment / Justification.

a. Is the Proposed Activity or New Data outside the bounds of the critical inputs/assumptions of the analyses contained in the WD, PA, CA, approved SA(s), or approved UWMQE(s)? For example, does the proposed activity or new information involve a change to the assumed critical design features for a waste tank/disposal unit design as described in the WD, PA, CA, approved SA(s), or approved UWMQE(s) such as critical inputs/assumptions?

Yes ☐ **No** ☒

Comment / Justification:

The proposed activity was reviewed against the Unreviewed Waste Management Question Requirements Document for Saltstone Facility (SRR-CWDA-2011-00196, Rev. 4) and found to result in a water to premix ratio that exceeded Screening Criteria No. 9 from Table 2.2-1 (Nominal cementitious material ratio (0.6 water to premix) for saltstone is not increased). However, the FY 2014 Special Analysis, SRR-CWDA-2014-00006, incorporated hydraulic conductivity values associated with water to pre-mix ratios ranging from 0.59 to 0.64 and determined that the results did not exceed performance objectives.

UNREVIEWED WASTE MANAGEMENT QUESTION EVALUATION (UWMQE)

1. **Unreviewed Waste Management Question Evaluation** - continued

b. Does the New Data involve an increase in the radionuclide inventory or chemical constituents evaluated in the approved WD, PA, CA, approved SA(s), and approved UWMQE(s)?

Yes ☐ **No** ☒

Comment / Justification:

The proposed activity increases the volume of process water added to the saltstone grout. Process water does not contain contaminants of concern modeled in the Performance Assessment. Therefore the Proposed Activity does not result in a change to inventory.

c. Would the radionuclide disposal limits need to be changed to implement the proposed activity?

Yes ☐ **No** ☒

Comment / Justification:

The proposed activity increases the volume of process water added to the saltstone grout. Process water does not contain contaminants of concern modeled in the Performance Assessment. Therefore the Proposed Activity does not require a change to the disposal limits.

d. Is it possible that the Proposed Activity or New Data causes the WD, PA, CA, approved SA(s), or approved UWMQE(s) performance objectives to be exceeded?

Yes ☐ **No** ☒

Comment / Justification:

Section 4.2.1 of the SA indicates that a range of 0.59 to 0.64 has been evaluated as acceptable (SRR-CWDA-2014-00006; X-CLC-Z-00050). The UWMQ screening originator determined that the proposed activity of a normal 8 hour production run would increase the effective water to premix ratio to approximately 0.616 which is within the acceptable range. These hydraulic conductivity values were measured from simulated saltstone that had cured for 28 days.

2. UWMQE Originator

IS the activity within the bounds of the existing WD, PA, CA or approved SA(s) and approved UWMQEs? Yes ☒ No ☐

IS a Special Analysis required? Yes ☐ No ☒

Comment / Justification:

The screening criteria for the water to premix ratio is based on implications to the final (cured) hydraulic conductivity of saltstone. In general, increasing the water to premix ratio will increase the hydraulic conductivity of saltstone. Increased hydraulic conductivity increases the rate at which water moves through the saltstone and carries contaminants into the environment. The most recent Performance Assessment/Special Analysis modeling (documented in the FY2014 SDF Special Analysis (SA) (SRR-CWDA-2014-00006)) assumed a saturated hydraulic conductivity of 6.4E-09 cm/sec based on an average of values presented in Table 3-6 of SRNL-STI-2012-00558. These hydraulic conductivity values were measured from simulated saltstone that had cured for 28 days. Section 4.2.1 of the SA indicates that a range of 0.59 to 0.64 has been evaluated as acceptable (SRR-CWDA-2014-00006; X-CLC-Z-00050). The UWMQ screening originator determined that the proposed activity of a normal 8 hour production run would increase the effective water to premix ratio to approximately 0.616 which is within the acceptable range.

Check one of the following boxes below and forward to peer reviewer.

☐ CANCEL the proposed activity. (Document canceled activities as applicable.)

☐ MODIFY the proposed activity.

☒ PROCEED to PARC approval (if no SA is required).

☐ PROCEED with proposed activity; categorical exclusion applies.

☐ PERFORM Special Analysis.

Originator: Steven P. Hommel /
Print / Signature

Date: ~~7:40 AM~~ SPH 5/10/2016 Time: 7:40 AM

3. UWMQE Peer Reviewer

Concur with the UWMQEO's determination? Yes ☑ No ☐

Comment / Justification:

Peer Reviewer: F. M. SMITH /
Print / Signature

Date: 5/10/16

UNREVIEWED WASTE MANAGEMENT QUESTION EVALUATION (UWMQE)

4. UWMQE AGCC Reviewer

Is there a legal objection to the UWMQEO's determination? **Yes** ☐ **No** ☑

Comment / Justification:

AGCC or Delegate AGCC FM SMITH FOR TF ENGLAND PER TELECON (Print) / FOR TFENGLAND PER TELECON (Signature)

Date: 5/10/16

5. UWMQE VP/GC Reviewer

a. Will VP/GC participate in the UWMQE? for WDD **Yes** ☑ **No** ☑

b. If "Yes" to 5a., Does VP/GC concur with the UWMQEO's determination? **Yes** ☐ **No** ☐

Comment / Justification:

VP/GC or Delegate VP/GC J Kent Fortenberry (Print) / (Signature)

Date: 5-10-2016

6. PARC Chairman

IS the activity consistent with the existing WD? Yes ☐ No ☐

IS a Special Analysis required? Yes ☐ No ☐

Comment / Justification:

IF a Special Analysis is required, **INDICATE** the follow-up action by checking one of the following boxes below and return to the UWMQE Originator

☐ CANCEL the proposed activity (Document canceled activities as applicable)

☐ MODIFY the proposed activity to attempt to eliminate the SA

☐ PERFORM SA

PARC Chairman or Designee: FM SMITH FOR J. CANTRELL PER TELECON
Print

FOR J. CANTRELL PER TELECON
Signature

Date: 5/10/16

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SALTSTONE UNREVIEWED WASTE MANAGEMENT QUESTION (UWMQ) SCREENING

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Proposed Activity/New Data:

The Proposed Activity is additional process water flushes through HCV-7005, into the mixer discharge. This flushing will occur, at a maximum, for 30 seconds every 5 minutes. The nominal flowrate through these nozzles is 9 gallons per minute

NOTE: A "YES" response to any question below results in a positive UWMQ Screening and requires a UWMQE.

REVIEW the following question against the Proposed Activity/New Data.

1. Does the Proposed Activity or New Data involve a change to the facility or procedures that may impact the screening criteria described in the UWMQRD?

Yes ☒ **No** ☒

Provide Explanation / Justification for "No" answer below:

The proposed activity was reviewed against the UWMQ requirements document, SRR-CWDA-2011-00196, Rev. 4 was reviewed. Specifically screening criteria No. 9 on table 2.2-1. The addition of extra water is significant enough to challenge the nominal water to premix ratio of 0.6 therefore this screen flags positive and further evaluation is necessary

2. Does New Data involve any analytical errors, omissions or deficiencies that may impact the screening criteria described in the UWMQRD?

Yes ☐ **No** ☒

Provide Explanation / Justification for "No" answer below:

The PA does not involve any New Data that would impact the inputs or assumptions documented in the UWMQRD. There is no impact to the results or conclusions of the Saltstone Performance Assessment

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SALTSTONE UNREVIEWED WASTE MANAGEMENT QUESTION (UWMQ) SCREENING

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IF questions 1 through 2 are answered "NO", then Proposed Activity may be implemented after proper approvals

IF any of questions 1 through 2 are answered "YES", then forward to C&WDA for development of a UWMQE.

Additional Explanation / Justification for all "NO" answers below:

See attached process history data

IS a UWMQ Evaluation required? Yes ☒ No ☐

J-DCF-Z-00897

Include applicable Doc. # if UWMQE is not required

Originator: John McCrary /
Print Signature

Date: 5/5/16 Time: 1510

AGREE ☒ DISAGREE ☐

Reviewer: Sam Shah / Sam Shah
Print Signature

Date: 5/5/16 Time: 6:45 PM

USQ-SS-2016-00091:

Attachment for UWMQS:

Design Authority Engineer has evaluated the impacts of implementing the Proposed Activity (PA) (J-DCF-Z-00697) on w/p (water to premix) ratio and following summarizes the findings.

Saltstone grout processing is set to operate at target w/p ratio of 0.S9 and the saltsolution flow from the SFT/SSRTs to the mixer is set accordingly. During the grout processing, periodic flushing of the grout hopper are initiated to remove any solids build up in mixer discharge out let and inside the hopper. Process water is used for the periodic flushing and it becomes part of the grout transferred to the SDUs. Tables 1 summarize process water usage for nominal 8 hours runs for the current period (201S-2016) and Table 2 for the 2012/2013 period.

The PA will add additional S40 gallons of process water usage for the flushing (incremental w/p ratio: 0.001266). This is the bounding volume for this PA. The design input to the PA, detailed in J-DCF-Z-00697, Rev. 0, limits the flushes to a maximum duration of 30 seconds and a minimum interval of S minutes. The Saltstone mixing and transfer operation procedure, SW24.6(MODE-1)-4.3, Rev. 26, restricts grout production to 10 hours a day for NFPA 69 compliance. The nominal baseline flowrate for the N1 and N2 nozzles downstream of HCV-700S is 9 GPM. This is based off of baseline data taken on 5/7/16 from the most recent post maintenance test after a full replacement of both nozzle assemblies and their upstream hose connections (w/o 1497142). See figure 1 for a PI screenshot of this baseline. Note the actual flow was ~8.3 GPM. However 9 GPM was used for conservatism. This equates to a maximum total flushing duration of 60 minutes at a flowrate of 9 GPM. The S40 gallon mark can be used proportionately against the incremental value of per 1000 gallons as shown in Table 1 and Table 2. This methodology was used to determine the bounding volume of process water addition.

The impacts on the w/p ratios are as follow:

Period	Target w/p	Incremental w/p from flushes	Incremental w/p by PA	Effective w/p SDUs
2012/2013	0.59	0.022144	0.0007	0.612144
Current (201S/2016)	0.S9	0.024209	0.0013	0.615S09

Table 1:

SS Flush Water to Premix (w/p) Evaluation

	Run Time		Run Time	Process Water Totalizer	
Date	Hr	Min	Hr.	FQ5174	
8/25/15	8	27	8.5	1480	
8/26/15	8	42	8.7	1553	
8/27/15	8	24	8.4	1490	
2/9/16	8	27	8.5	1449	
2/23/16	8	30	8.5	1471	
3/10/16	8	39	8.7	1507	
3/11/16	8	12	8.2	1378	
		Total Hrs	59.4	10328	Gals Process Water for Flushing

Dry Feed, lbs @30 TPH	3,561,000	86,208	lbs process water from flushing

Incremental	w/p	0.024209

Incremental w/p @ 1,000 gal flush water-->	0.002344

Table 2

SS Flush Water to Premix (w/p)
Evaluation
Pre-8/2013 SDU Core Sample

	Run Time		Run Time	Process Water Totalizer	
Date	Hr	Min	Hr.	FQ5174	
10/16/12	7	51	7.9	1116	
10/26/12	8	51	8.9	1208	
3/15/13	7	32	7.5	766	
3/20/13	7	58	8.0	1086	
4/14/13	7	25	7.4	1514	
4/15/13	7	52	7.9	1429	
4/17/13	7	55	7.9	1508	
4/19/13	7	21	7.4	1414	
6/26/13	8	5	8.1	2224	
8/5/13	7	35	7.6	1393	
8/7/13	7	27	7.5	1377	
		Total Hrs	85.9	15035	Gals Process Water for Flushing
Dry Feed, lbs @33 TPH			5,667,200	125,497	lbs process water from flushing
		Incremental	w/p	0.022144	
Incremental w/p @ 1,000 gal flush water-->				0.001473	

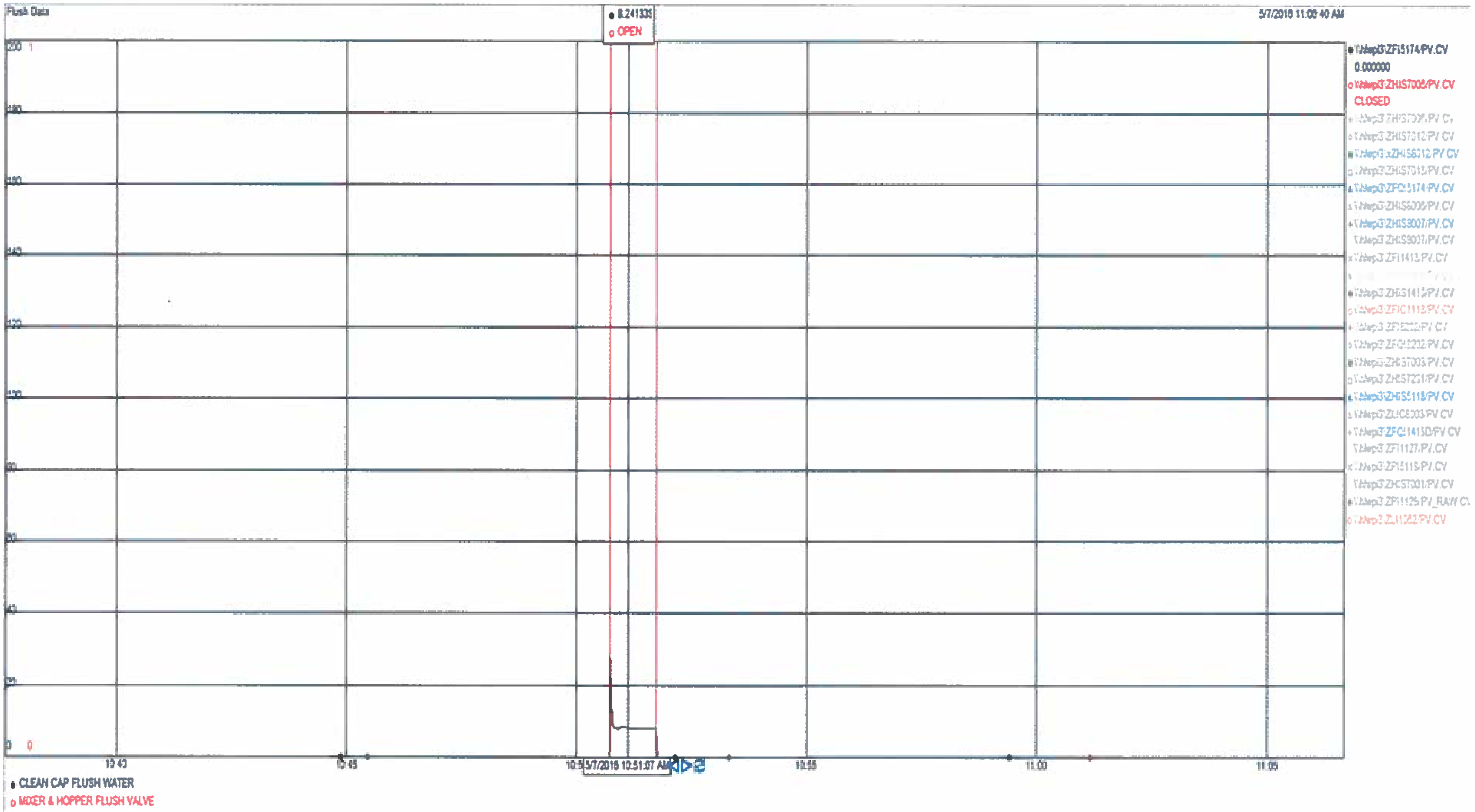

Flush Data
● 8.241339
○ OPEN
5/7/2019 11:08:40 AM
200
180
160
140
120
100
80
60
40
20
0
1
0
10:40
10:45
10:5
5/7/2019 10:51:07 AM
10:55
11:00
11:05
● CLEAN CAP FLUSH WATER
○ MIXER & HOPPER FLUSH VALVE
● \\Mep3\ZFI5174/PV.CV
0.000000
○ \\Mep3\ZHIS7006/PV.CV
CLOSED
\\Mep3\ZHIS7012/PV.CV
\\Mep3\ZFC5174/PV.CV
\\Mep3\ZHIS9007/PV.CV
\\Mep3\ZFI1413/PV.CV
\\Mep3\ZHIS5118/PV.CV
\\Mep3\ZFC1413D/PV.CV
\\Mep3\ZFI1127/PV.CV
\\Mep3\ZHIS7001/PV.CV
\\Mep3\ZFI1125/PV_RAW.CV

Figure 1

4.2.1 Intact Properties of Saltstone and Clean Cap

Saltstone is pumped into the SDUs to a specified level and then a clean cap is placed as necessary in some SDUs above the saltstone to fill the remainder of the free volume in the SDU. In preparing the saltstone and clean cap, the same dry mix is used for both. For saltstone, the water medium is a decontaminated salt solution, containing radionuclides and chemicals, whereas the clean cap uses well water. Thus, the hydraulic performance of the saltstone and clean cap are expected to be similar.

The average saturated hydraulic conductivity from a recent study considered various process water-to-premix ratios with two different curing temperature profiles. [SRNL-STI-2012-00558] The hydraulic conductivity of intact saltstone and clean cap, as used in this SA, is bounded by the operating bands of current facility data. Based on analysis of current production runs at the SPF that were conducted prior to SPF upgrades (Figure 4.2-1) and after SPF upgrades (Figure 4.2-2), the operating band for the water-to-premix ratio would be bounded by a low value of 0.59 and a high value of 0.64. [X-CLC-Z-00050]

Table 4.2-1 provides the measured values for the saturated hydraulic conductivity for the water-to-premix ratio, bounded by 0.59 and 0.64, and for saturated conditions and a high humidity exposure for two different curing temperature profiles. [SRNL-STI-2012-00558] The average value for these runs is 6.4E-09 cm/sec and this value is considered the nominal value for the saturated hydraulic conductivity of intact saltstone and clean cap in the SDUs. Alternative flow sensitivity cases, discussed in Section 4.4, consider two other values for the initial saturated hydraulic conductivity of saltstone and the clean cap. At the higher end of the spectrum, 10 times the maximum reported value in Table 4.2-1, or 4.5E-07 cm/sec, is used to ensure conservatism. At the lower end of the spectrum, the lower bound value is taken to be the minimum value reported in Table 4.2-1, 3.9E-10 cm/sec.

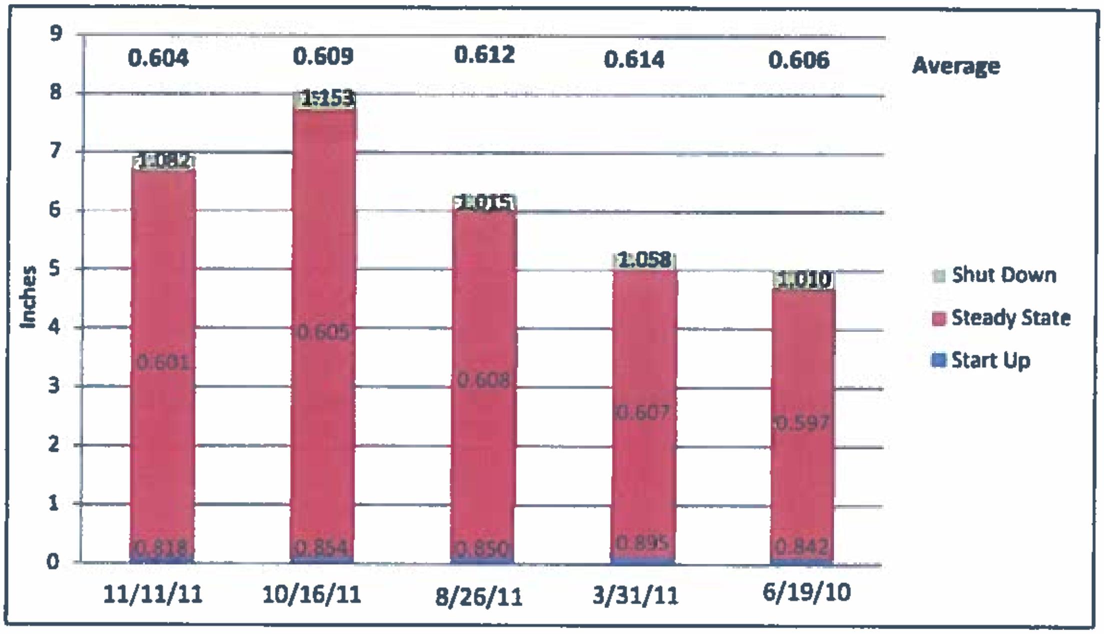
The relatively high initial saturated hydraulic conductivity for saltstone of 4.5E-07 cm/sec is not indicative of how high the initial saturated hydraulic conductivity can be. Rather, this high value was chosen to provide a large variability of flow. Review of the data reported in the *Process Formulations and Curing Conditions that Affect Saltstone Properties*, SRNL-STI-2012-00558, shows that of the seventy-two saltstone simulant samples analyzed, only three of the samples had a measured saturated hydraulic conductivity greater than 1.0E-07 cm/sec. All three of those samples were formulated with a water-to-premix ratio much greater than the current facility operating band analyzed in this SA. However, it is worth noting that compared to data from previous studies, many of the physical properties of saltstone (e.g., the density, porosity, and compressive strength) are more controlled by curing in a high humidity environment rather than the water-to-premix ratio of the saltstone formulation. [SRNL-STI-2012-00558]

Further, a recent study on oxidation and humidity effects on saltstone showed hydraulic conductivity values on the order of 4.2E-09 cm/sec for simulated saltstone after 90 days of curing. [VSL-13R3010-1] Similarly, a summary of hydraulic conductivity values measured over a series of varying conditions (e.g., temperature, humidity, and curing times) indicated that measured saturated hydraulic conductivities for saltstone typically ranged between 2E-09 cm/sec and 5E-09 cm/sec. [VSL-14R3210-1] The results of these recent studies indicate that the assumed saturated hydraulic conductivity of 6.4E-09 cm/sec is an appropriate value for modeling. This study demonstrated that hydraulic conductivity values can be significantly impacted by relative humidity, which is expected to be high during the saltstone curing process. An earlier study on the temperature effects on hydraulic conductivity values did not accurately capture the expected curing conditions with respect to relative humidity, allowing the heating process to dry out the samples. These samples showed artificially increased permeability; hence, the results of this earlier study was not considered valid for modeling purposes. [SRNL-STI-2010-00745; SRNL-STI-2012-00558]

Another important mechanism to transport is the diffusion coefficient. Recent testing on simulated saltstone indicates that the intrinsic diffusion coefficient (analogous to the effective diffusion coefficient used in PORFLOW) is less than 1.0E-08 cm^2/s. [SRNL-STI-2010-00515] This value of 1.0E-08 cm^2/s will be used as the effective diffusion coefficient for intact saltstone and the clean cap.

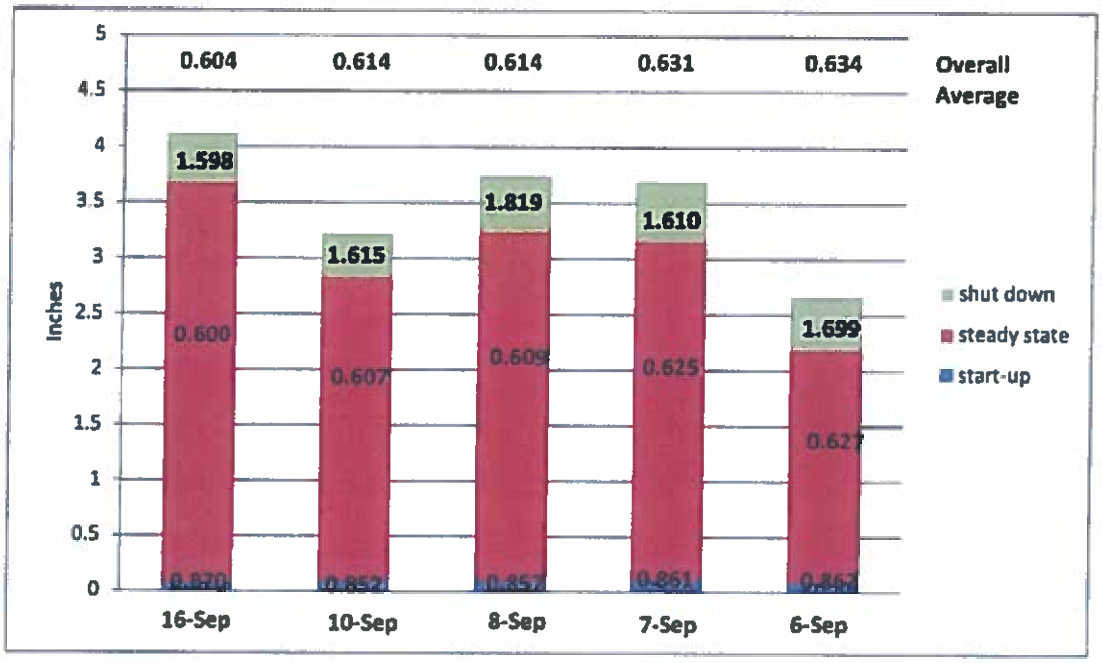
Finally, the recommended moisture characteristic curve (MCC) for saltstone grout is presented in Figure 4.2-3. This MCC was developed using data based on recent testing of simulants cured at 20 °C. [SRNL-STI-2011-00661]

Figure 4.2-1: Water-to-Premix Ratio for Production Runs Prior to SPF Upgrades



[X-CLC-Z-00050]

Figure 4.2-2: Water-to-Premix Ratio for Production Runs After SPF Upgrades



[X-CLC-Z-00050]

Table 4.2-1: Measured Hydraulic Conductivity from SRNL-STI-2012-00558

Final w/p ratio	Hydraulic Conductivity (cm/sec)			
	Cell K Temperature Profile		Cell F Temperature Profile	
	Saturated	Exposed Surface	Saturated	Exposed Surface
0.59	1.7E-09	4.5E-09	1.4E-09	4.3E-09
0.59	1.9E-09	3.9E-10	3.6E-09	1.6E-09
0.6	1.7E-09	1.7E-09	4.1E-09	2.1E-09
0.6	2.1E-09	2.2E-09	3.7E-09	1.3E-09
0.64	3.2E-08	4.5E-08	7.0E-09	1.3E-09
0.64	9.6E-09	1.3E-08	5.0E-09	3.1E-09
Maximum	3.2E-08	4.5E-08	7.0E-09	4.3E-09
Average	8.2E-09	1.1E-08	4.1E-09	2.3E-09
Maximum	4.5E-08		7.0E-09	
Average	9.7E-09		3.2E-09	
Maximum	4.5E-08			
Average	6.4E-09			

Note: "Saturated" indicates that measurements were taken from grout in which the surfaces were covered with liquid to maintain saturated conditions. "Exposed Surface" refers to measurements taken from grout in which the sample surfaces were exposed to the humid environment. [SRNL-STI-2012-00558]

OSR 45-24 (Rev 1-20-2009)

Calculation Cover Sheet

Project/Task N/A	Calculation No. X-CLC-Z-00050	Project/Task No. N/A
Title Analysis of Saltstone Water-to-Premix Ratio During Pre-ELAWD Operation	Functional Classification PS	Sheet 1 of 18
	Discipline Chemical Process	
Calculation Type ☒ Type 1 ☐ Type 2	Type 1 Calc Status ☐ Preliminary ☒ Confirmed	
Computer Program No. Microsoft Excel 2010 ☐ N/A	Version/Release No. 14.0.5128.500	
Purpose and Objective The purpose of this calculation is to examine the water to premix ratio fluctuations during processing at Saltstone prior to ELAWD addition. Several post-ELAWD addition runs are also examined.	DC/RO	Date

Summary of Conclusion

Summary graphs have been created which show the variation of water to premix ratio stability and the average water to premix ratio poured into a vault during each process step.

Revisions

Rev #	Revision Description
0	Original Issue

Sign Off

Rev #	Originator (Print) Sign/Date	Verification/Checking Method	Verifier/Checker (Print) Sign/Date	Manager (Print) Sign/Date
0	Spencer T. Isom Spencer T Isom 10/10/12	☐ Design Check (GS/PS only) ☐ Document Review ☐ Qualification Testing ☐ Alternate Calculation ☐ Operational Testing	Katie-Dara Dixon Katie Dara Dixon 10/10/2012	Aaron V. Staub 10/10/12
		☐ Design Check (GS/PS only) ☐ Document Review ☐ Qualification Testing ☐ Alternate Calculation ☐ Operational Testing		

Additional Reviewer (Print) N/A	Signature N/A	Date
Design Authority (Print) N/A	Signature N/A	Date
Release to Outside Agency (Print) N/A	Signature N/A	Date

Security Classification of the Calculation

Unclassified

Table of Contents

References

1. "Saltstone Facility System Design Description Saltstone Process". G-SD-Z-00003, Rev. 9, June 2012.
2. Perry's Chemical Engineer's Handbook (7th Edition), McGraw-Hill 1997.
3. Dixon, K.D. to Isom, S. T. "Targeted Set Points" June 26, 2012.
4. "DWG - Revised Tank Drawing 2.9 - MG Saltstone Storage Tanks 2A & 2B". WB00001K, Submittal G, April 2011.
5. Edwards, T.B., "Evaluation of the Correlation Between Density and Water Content for Salt Solutions at the Saltstone Processing Facility." SRNL-STI-2012-00602, Rev. 0, September 2012.

Introduction

The current method for calculating the water to premix ratio in Saltstone does not account for process water used during start up and shut down of the facility. Saltstone is also upgrading the current system software to Enhanced Low Activity Waste Disposal (ELAWD), which uses 700 gallons more flush water during 8 hours of operation. In order to better understand how processing will be affected by ELAWD, a closer look at previous processing is being investigated along with new data post-ELAWD additions. This calculation shows the water to premix ratio throughout processing including startup, steady state, and shutdown.

The start-up, steady-state and shut down portions of the process are evaluated separately. The average water to premix ratio (w/p) is to be determined during each step of the process along with the height of grout poured into SDU 4. Five separate days before ELAWD addition were chosen to be evaluated. The dates are as follows:

- November 11, 2011
- October 16, 2011
- August 26, 2011
- March 31, 2011
- June 19, 2010

PI data was collected from several process monitoring equipment every five seconds and exported into excel. An example is found in the Appendix. An example calculation is done using data taken on November 11, 2011. The start-up and steady-state values are from the time 08:57:00, while shut-down examples are done at 16:38:30.

Five separate post-ELAWD additions were chosen to be evaluated as well. The height of grout poured for these dates are evaluated for SDU 2. The dates are as follows:

- September 6, 2012
- September 7, 2012
- September 8, 2012
- September 10, 2012
- September 16, 2012

In addition, a general look at extended processing times is examined. A hypothetical average of the w/p ratio of grout runs longer than 9 hours are calculated.

Open Items
None.

Inputs and Assumptions:

1) Process data was obtained using PI process monitoring software tags: ZDI1053/PV.CV (Salt Feed Tank Specific Gravity), ZFIC1372/PV.CV (Premix Screw FDR Flow), ZFIC1118/PV.CV (Clean Cap Water Flow Control), ZFIC1050/PV.CV (Salt Solution Flow), ZFI5174/PV.CV (Clean Cap Flush Water), ZFI1127/PV.CV (Grout Flow Rate), ZFQI5174/PV.CV (Clean Cap Flush Water Total), ZFQI1050/PV.CV (Salt Solution Total Flow), ZFQI1372/PV.CV (Premix Screw FDR Flow Total), and ZFQI1118/PV.CV (Clean Cap Water Mixer Total).
2) There is 0.13368 ft^3/gal.
   Basis: Perry's Chemical Engineers' Handbook (6th Edition)
3) The density of water is 8.3454 lb/gal.
   Basis: Perry's Chemical Engineers' Handbook (6th Edition)
4) The SDU 4 has dimensions of 98.5 feet by 98.5 feet equivalent to a surface area of 9,702.25 $feet^2$.
   Basis: G-SD-Z-00003, Saltstone Facility System Design Description Document for Saltstone Process
5) Start-up of the facility is considered complete when clean cap flush water ceases.
   Basis: The process is entering a "steady-state" of operation with routine flushes and constant premix additions.
6) Shut-down of the facility is considered to begin when the premix flow ceases.
   Basis: The process is no longer operating in a "steady-state".
7) A new water to premix ratio is calculated starting 5 minutes preceding premix shut off until the flush water is shut off completely.
   Basis: The water to premix ratio is defined only when there is premix being added (cannot divide by zero). In order to account for the change in w/p ratio when clean cap water is entering the system during shut down, an initial amount of premix is needed to complete the calculation.
8) Grout poured into the SDU spreads to form an even layer.
   Basis: Knowledge of previous processing history has shown this to be true.
9) The wt% total solids is calculated with this equation:

$$w_{TS} = 100*(1-[(SG_{SFT} * -0.5711)+1.4385])$$

   Basis: SRNL-STI-2012-00602, Rev. 0, Evaluation of the Correlation Between Density and Water Content for Salt Solutions at the Saltstone Processing Facility

The following inputs deal with example calculations performed in this document.

10) Salt solution flow in gallons per minute is 23.1761
    Basis: PI monitoring tag ZFIC1050/PV.CV
11) Clean cap water flow in gallons per minute is 63.67
    Basis: PI monitoring tag ZFIC1118/PV.CV
12) Flush water flow in gallons per minute is 0
    Basis: PI monitoring software tag ZFI5174/PV.CV
13) Premix flow in tons per hour is 30.1716
    Basis: PI monitoring software tag ZFIC1372/PV.CV
14) Specific gravity of the solution is 1.1744453 during startup and 1.21432 during shut down

Basis: PI monitoring software tag ZDI1053/PV.CV

The actual density values from PI are used in the Appendix (excel spreadsheet) and in the example calculations that demonstrate how the appendix data is calculated. However, the density values have been truncated in the Analytical Methods and Computations Section of this calculation for clarity. The computed values in the calculations use the actual density values from PI in their entirety.

15) Salt solution flow total in gallons is 36514.7
Basis: PI monitoring software tag ZFQI1050/PV.CV
16) Flush water flow total in gallons is 408.342
Basis: PI monitoring software tag ZFQI5174/PV.CV
17) Clean cap flow total in gallons is 725.646
Basis: PI monitoring software tag ZFQI1118/PV.CV
18) Premix flow total in tons is 15516.167
Basis: PI monitoring software tag ZFQI1372/PV.CV
19) Water total at 5 minutes before shutdown is 284594 pounds
Basis: This value is calculated earlier using the same process as Equation 22.
20) Premix total at 5 minutes before shutdown is 15515.708 pounds
Basis: PI software monitoring tag ZFQI1372/PV.CV
21) Average rate of grout pump is 102.4 gal/min
Basis: calculated by Equation 30

Analytical Methods and Computations

Clean Cap and Flush Water

Saltstone PI monitoring software tags ZFIC5174/PV.CV and ZFI1118/PV.CV measure the flush water and clean cap water in gallons per minute respectively. In order to perform later calculations these measurements need to be converted to pounds per hour. These calculations are performed as follows:
Convert gallons/minute to pounds/hour of clean cap or flush water (Input 11 and 12)

$$Water_F\ /Water_{CC}\ \frac{lb}{h} = Water\left(\frac{gal}{\min}\right)\left(60\frac{\min}{h}\right)\left(8.3454\frac{lb}{gal}\right) \qquad \text{(Equation 1)}$$

where:
$Water_F$ = flush water in lb/h
$Water_{CC}$ = clean cap water in lb/h

$$Water_F\ /Water_{CC} = 31881.1\frac{lb}{h} = 63.67\frac{gal}{\min} * 60\frac{\min}{h} * 8.3454\frac{lb}{gal} \qquad \text{(Equation 2)}$$

Salt Solution

The salt solution is added as a mixture of salt and water. In order to calculate the total water added, the amount of water present in the salt solution must be taken into account. For reasons of dimensional consistency the numbers will be converted to pounds per hour for later use. The water contained in the salt solution can be calculated as follows:

Convert gallons/minute to pounds/hour of salt solution

$$Salt\left(\frac{lb}{h}\right)=\left(\frac{gal}{\min}\right)\left(60\frac{\min}{h}\right)\left(8.3454\frac{lb}{gal}\right)(SG_{SFT}) \qquad \text{(Equation 3)}$$

where SG_{SFT} is the specific gravity of the salt solution found using PI software tag ZDI1053/PV.CV (Input 10 and 14).

$$Salt=13629.2\frac{lb}{h}=23.1761\frac{gal}{\min}*60\frac{\min}{h}*8.3454\frac{lb}{gal}*1.17 \qquad \text{(Equation 4)}$$

In order to calculate the water content in the salt solution, the wt% total solids needs to be calculated by the following expression (Input 9):

$$w_{TS}=100*(1-[(SG_{SFT}*-0.5711)+1.4385]) \qquad \text{(Equation 5)}$$

where w_{TS} is the wt% total solids of the salt solution

$$w_{TS}=23.22=100*(1-[(1.17*-0.5711)+1.4385]) \qquad \text{(Equation 6)}$$

The solution to the previous two expressions can be inserted into the following equation to calculate the water content in the salt solution in pounds per hour.

$$Water_{SS}\left(\frac{lb}{h}\right)=Salt\left(\frac{lb}{h}\right)\left(1-\frac{w_{TS}}{100}\right) \qquad \text{(Equation 7)}$$

$$Water_{SS}=10464.1\frac{lb}{h}=13629.2\frac{lb}{h}*\left(1-\frac{22.22}{100}\right) \qquad \text{(Equation 8)}$$

Total Water

The w/p ratio is dependent on how much water is used. This includes what is initially in the salt solution, the amount added during periodic flushes of the hopper and during transient states. The total water is calculated as follows:

Calculate total water used in pounds/hour

$$Water_{Total}=Water_{SS}+Water_{CC}+Water_{F} \qquad \text{(Equation 9)}$$

where $Water_{Total}$ is the total water used in pounds/hour

$$Water_{Total}=42345\frac{lb}{h}=10464.1\frac{lb}{h}+31881.2\frac{lb}{h}+0\frac{lb}{h} \qquad \text{(Equation 10)}$$

In the case shown above, no flush water is being added since the hopper is not being flushed at that time. If the calculation was happening during a periodic flush, there would be a $Water_F$ term.

Premix

For dimensional consistency the premix rate which is measured in tons per hour needs to be converted to pounds per hour. This conversion is calculated as follows:

Convert tons/hour to pounds/hour of premix (Input 13)

$$\Pr emix\left(\frac{lb}{h}\right)=\left(\frac{ton}{h}\right)\left(2000\frac{lb}{ton}\right) \quad \text{(Equation 11)}$$

$$\Pr emix = 60343.2\frac{lb}{h} = 30.1716\frac{ton}{h} * 2000\frac{lb}{ton} \quad \text{(Equation 12)}$$

Water to Premix Ratio

The premix to water ratio is calculated for each step in the process. Start-up and steady-state are calculated as follows:

Calculate the water/premix ratio

$$w/p = \frac{Water_{Total}\left(\frac{lb}{h}\right)}{\Pr emix\left(\frac{lb}{h}\right)} \quad \text{(Equation 13)}$$

$$w/p = 0.702 = \frac{42345\frac{lb}{h}}{60343.2\frac{lb}{h}} \quad \text{(Equation 14)}$$

Calculating the w/p ratio for shut-down is done by use of Saltstone PI monitoring software tags ZFQI1372/PV.CV, ZFQI1050/PV.CV, FQI5174/PV.CV and ZFQI1118/PV.CV which give the total premix, total salt solution, total clean cap flush water and total clean cap water mixer respectively. Since a w/p ratio cannot be calculated at a time when there is no premix addition, a new running difference between the start of 5 minutes before premix is shut off to when all water is shut off, is calculated. By calculating the w/p in this manner, all additional water added after premix has stopped can be accounted for in the grout made in the last 5 minutes of operation. Modified expressions previously used are shown below.

Salt Solution-Shut-Down

The salt solution again must be broken down into its components of salt and water, only instead of units of pounds per hour the units are in terms of pounds. This occurs since the PI monitoring software tags keep a running total of all components added to the grout during the operation period. The following expressions demonstrate how shut-down salt solution calculations are performed (Input 14).

$$Salt(lb) = (gal)\left(8.3454\frac{lb}{gal}\right)(SG_{SFT}) \qquad \text{(Equation 15)}$$

$$Salt = 370058lb = 36514.7gal * 8.3454\frac{lb}{gal} * 1.21 \qquad \text{(Equation 16)}$$

where SG_{SFT} is the specific gravity of the solution feed tank as before

$$Water_{SS}(lb) = Salt(lb)\left(1-\frac{w_{TS}}{100}\right) \qquad \text{(Equation 17)}$$

$$Water_{SS} = 275678lb = 370058lb * (1-\frac{25.50}{100}) \qquad \text{(Equation 18)}$$

where w_{TS} is the wt% total solids as before

<u>Clean Cap and Flush Water- Shut-Down</u>

Clean cap and flush water during shut-down are in units of pounds also. The manipulation of the water is as follows:

$$Water_F \,/\, Water_{CC}\, lb = Water(gal)\left(8.3454\frac{lb}{gal}\right) \qquad \text{(Equation 19)}$$

$$Water_F = 3408lb = 408.342gal * 8.3454\frac{lb}{gal} \qquad \text{(Equation 20)}$$

$$Water_{CC} = 6056lb = 725.646gal * 8.3454\frac{lb}{gal} \qquad \text{(Equation 21)}$$

<u>Total Water-Shut Down</u>

The total amount of water used during shut-down is in pounds instead of pounds per hour as found during start-up and steady-state. The new water running total starts over 5 minutes before premix is shut off. The water total expression is the same and is as stated:

$$Water_{Total} = Water_{SS} + Water_{CC} + Water_F \qquad \text{(Equation 22)}$$

$$285142lb = 275678lb + 6056lb + 3408lb \qquad \text{(Equation 23)}$$

Since the water total has started over, the total water calculated above is the overall total, starting from time zero. In the shut-down portion, only the last remaining amount of water is necessary to account for. So the total amount of water already processed through the system needs to be subtracted from the overall running total. The expression is as follows (Input 19):

$$Water_{SD}(lb) = Water_{Total}(lb) - 284594(lb) \qquad \text{(Equation 24)}$$

$$Water_{SD} = 548lb = 285142lb - 284594lb \qquad \text{(Equation 25)}$$

Premix-Shut Down

The premix during shut-down again is going to be calculated in pounds for consistent units. The new premix running total starts over at 5 minutes before premix is shut off. The difference between the overall total for the entire processing time and the amount of premix used during shut-down needs to be calculated shown below (Input 18 and 20):

$$\Pr emix_{SD}(lb) = [\Pr emix_F(ton) - \Pr emix_I(ton)] * \left(2000\frac{lb}{ton}\right) \qquad \text{(Equation 26)}$$

where:
Premix$_F$ is the value of premix at that point in time given by ZFQI1372/PV.CV
Premix$_I$ is the initial value of premix at 5 minutes before shut down starts

$$\Pr emix = 918lb = [15516.167ton - 15515.708ton] * 2000\frac{lb}{ton} \qquad \text{(Equation 27)}$$

Water to Premix Ratio-Shut Down

Now that the premix total and water total for shut-down has been calculated, a w/p ratio can be evaluated in the following expression:

$$w/p = \frac{Water_{SD}(lb)}{\Pr emix_{SD}(lb)} \qquad \text{(Equation 28)}$$

$$w/p = 0.597 = \frac{548lb}{918lb} \qquad \text{(Equation 29)}$$

The average w/p ratio is calculated for all steps in the process. The following equation is utilized to calculate the average:

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \qquad \text{(Equation 30)}$$

where
n = total numbers given in series
$\bar{x}$ = average value

An example of Equation 30 is shown below. This data is taken from the start-up portion of processing.

$$0.817 = \frac{1}{161}(1.430 + 1.755 + 1.809 + ... + 0.816 + 0.827 + 0.812) \qquad \text{(Equation 31)}$$

Grout Pump

Saltstone PI monitoring software tag ZFI1127/PV.CV measures the rate of grout pumped to the SDU in gallons per minute. To determine the average rate during start-up and shut-down, a plot of

ZFI1127/PV.CV is graphed versus time. The area under the curve is calculated then divided by the duration of the step. The average is used for the steady-state portion of the operation and is calculated using Equation 30.

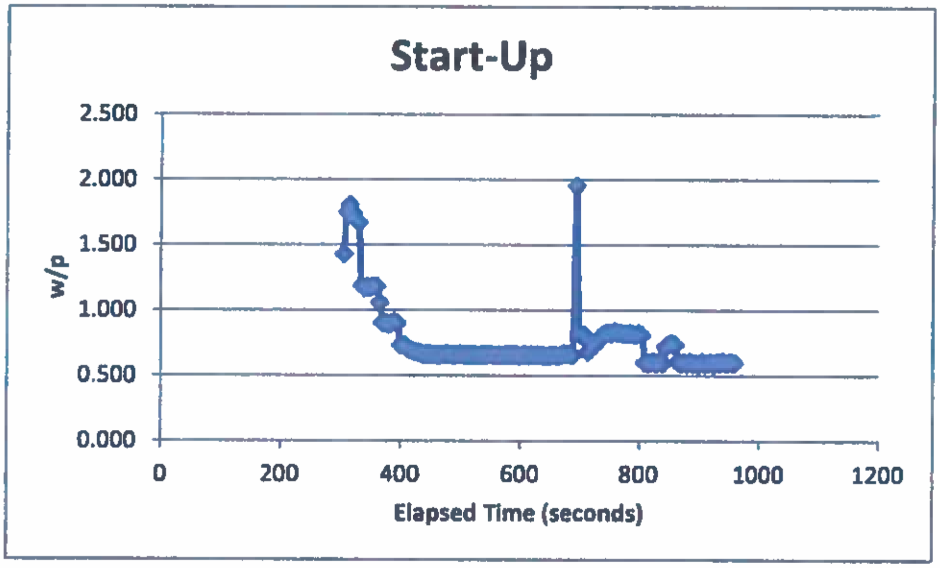
For the average rate of the grout pump again Equation 30 is utilized and the average value is referred to as $\overline{x}_{GP}$:

$$102.4\frac{gal}{\min}=\frac{1}{8}(23.46+22.09+17.86+\ldots+148.00+604.91+139.65)\frac{\text{gal}}{\min} \qquad \text{(Equation 32)}$$

Height Poured into SDU 4

Below is an example diagram where the w/p is graphed against time.

Figure 1. Example of Start-Up Portion of Processing Graph of Elapsed Time vs. W/P Ratio



In order to calculate the height poured into the SDU, the average w/p is multiplied by the duration of the process step as follows with an example from start-up following:

Area (s) = [Time$_{Final}$(s) – Time$_{Initial}$(s)] * average w/p (Equation 33)

$$408.5s=(805s-305s)*0.817 \qquad \text{(Equation 34)}$$

To calculate the volume of grout poured during start-up, steady state and shut-down the following equation is used:

$$Volume(ft^3)=\frac{Area(s)}{60\left(\frac{s}{min}\right)}*\overline{x}_{GP}\left(\frac{gal}{min}\right)*0.13368\frac{ft^3}{gal} \qquad \text{(Equation 35)}$$

where $\overline{x}_{GP}$ is the average rate of the grout pump

$$93.20 ft^3 = \frac{408.5s}{60\frac{s}{\min}} * 102.4\frac{gal}{\min} * 0.13368\frac{ft^3}{gal} \qquad \text{(Equation 36)}$$

Since the SDU 4 dimensions are known to be 9702.25 ft^2 (Ref. 2), the height poured can be calculated as follows:

$$Height(in) = \frac{Volume(ft^3)}{9702.25(ft^2)} * 12\left(\frac{in}{ft}\right) \qquad \text{(Equation 37)}$$

$$0.115in = \frac{93.20 ft^3}{9702.25 ft^2} * 12\frac{in}{ft} \qquad \text{(Equation 38)}$$

By repeating Equations 1 through 38, all days of processing can be assessed prior to ELAWD.

Extended Processing Time

A look at extended processing time is considered below by using the data already collected and extending the time. This is performed in this manner since longer (over 10 hours) runs are not available. The average start up, steady state and shut down w/p ratio and the average start up, steady state and shut down time duration of the 5 separate days are utilized. These averages were calculated by use of Equation 30 and displayed in Table 1.

	Start Up	Steady State	Shut Down
Water to Premix Ratio	0.851	0.605	1.044
Duration (Seconds)	549	24163	943

The average hypothetical w/p ratio is calculated as follows:

$$w/p = \frac{0.851*549 + 0.605*(t - 549 - 943) + 1.044*943}{t} \qquad \text{(Equation 39)}$$

where t is the time duration of process run in seconds

$$0.758 = \frac{0.851*549 + 0.605*(3600 - 549 - 943) + 1.044*943}{3600} \qquad \text{(Equation 40)}$$

The average found in Equation 40 is then divided by the set point as shown in the following equation. The set point is taken to be 0.60. The example below is from the start-up portion of processing.

$$\text{setpoint ratio} = \frac{average}{setpo\text{int}} \qquad \text{(Equation 41)}$$

$$1.263 = \frac{0.758}{0.60} \qquad \text{(Equation 42)}$$

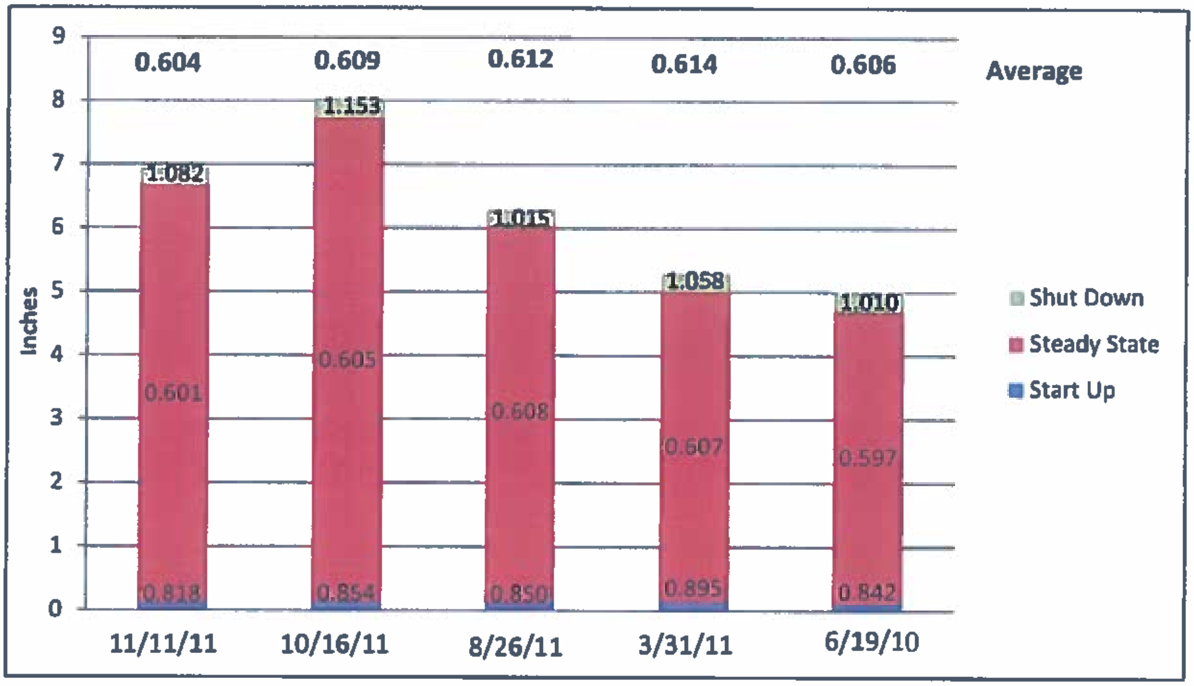
In the above example case, the calculated average w/p ratio during start up at t = 3600 seconds is 1.27 times greater than the intended target setpoint of 0.60.

The same process is performed for post-ELAWD additions. The only variation is the base area of SDU 2 is different than SDU 4. SDU 2 is a circular vault with a diameter of 149.75 ft (Ref. 4) and an overall base area of 17,612.6 ft^2.

Results and Conclusion

Depicted below is a bar graph displaying the height of grout poured into SDU 4 during each step in the pre-ELAWD process and the average water to premix ratio observed during that time period. All five separately chosen evaluation dates are displayed. The number highest on the graph represents the overall average poured for the entire day.

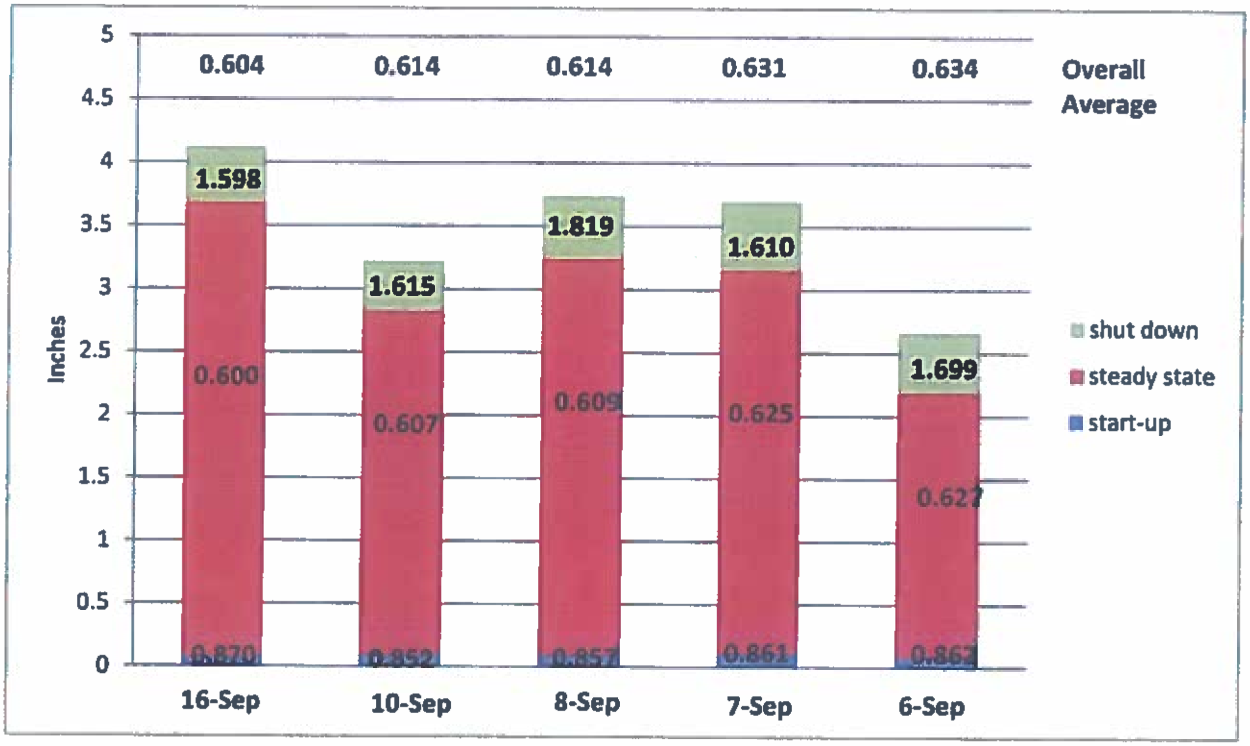
Figure 2. Graph of Height Poured into SDU 4 During Pre-ELAWD Processing



Depicted on the next page is a bar graph displaying the height of grout poured into SDU 2 during each step in the post-ELAWD process and the average water to premix ratio observed during that time period. All five separately chosen evaluation dates are displayed. The number highest on the graph represents the overall average poured for the entire day.

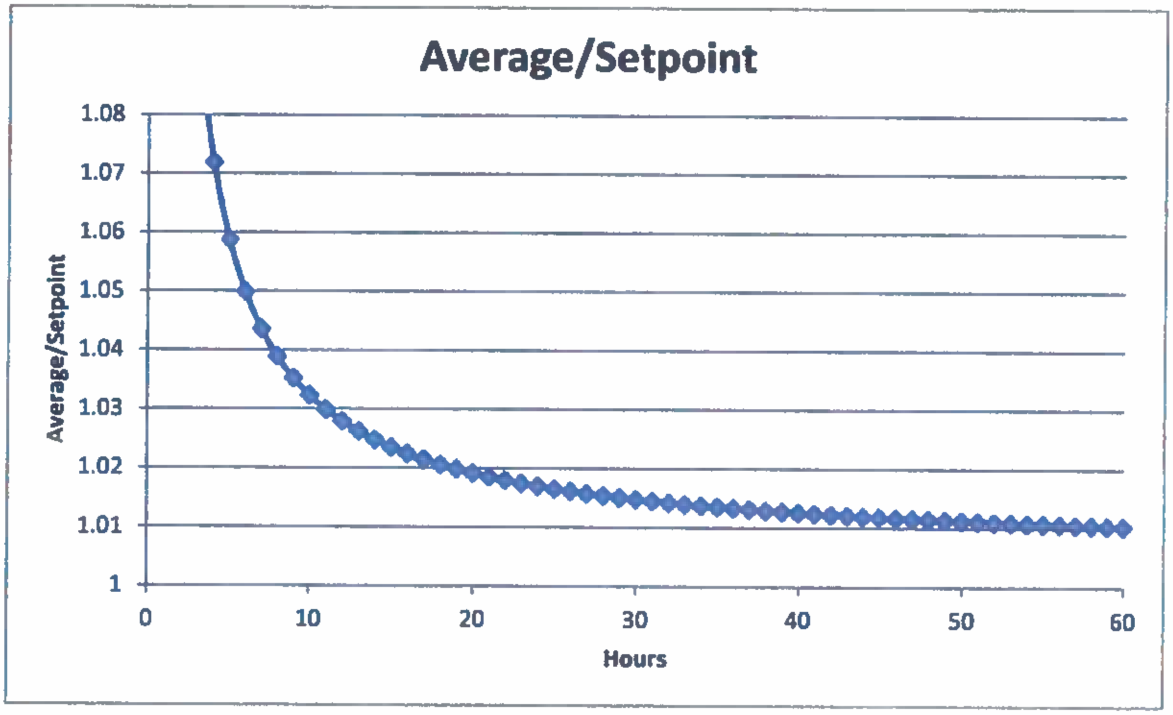
These figures show the water to premix ratio during the entire process run at the Saltstone facility both before and after the ELAWD project. In conclusion the water to premix ratio is above the set point of 0.60 during startup and shutdown, but is close to the set point during steady state. The average water to premix ratio is increased post-ELAWD which is expected due to the increased flushing volumes. The average water to premix ratio is also shown to get exponentially closer to the setpoint value with only a 1% difference at close to 60 hours continuous processing.

Figure 3: Graph of Height Poured into SDU 2 During Post-ELAWD Processing



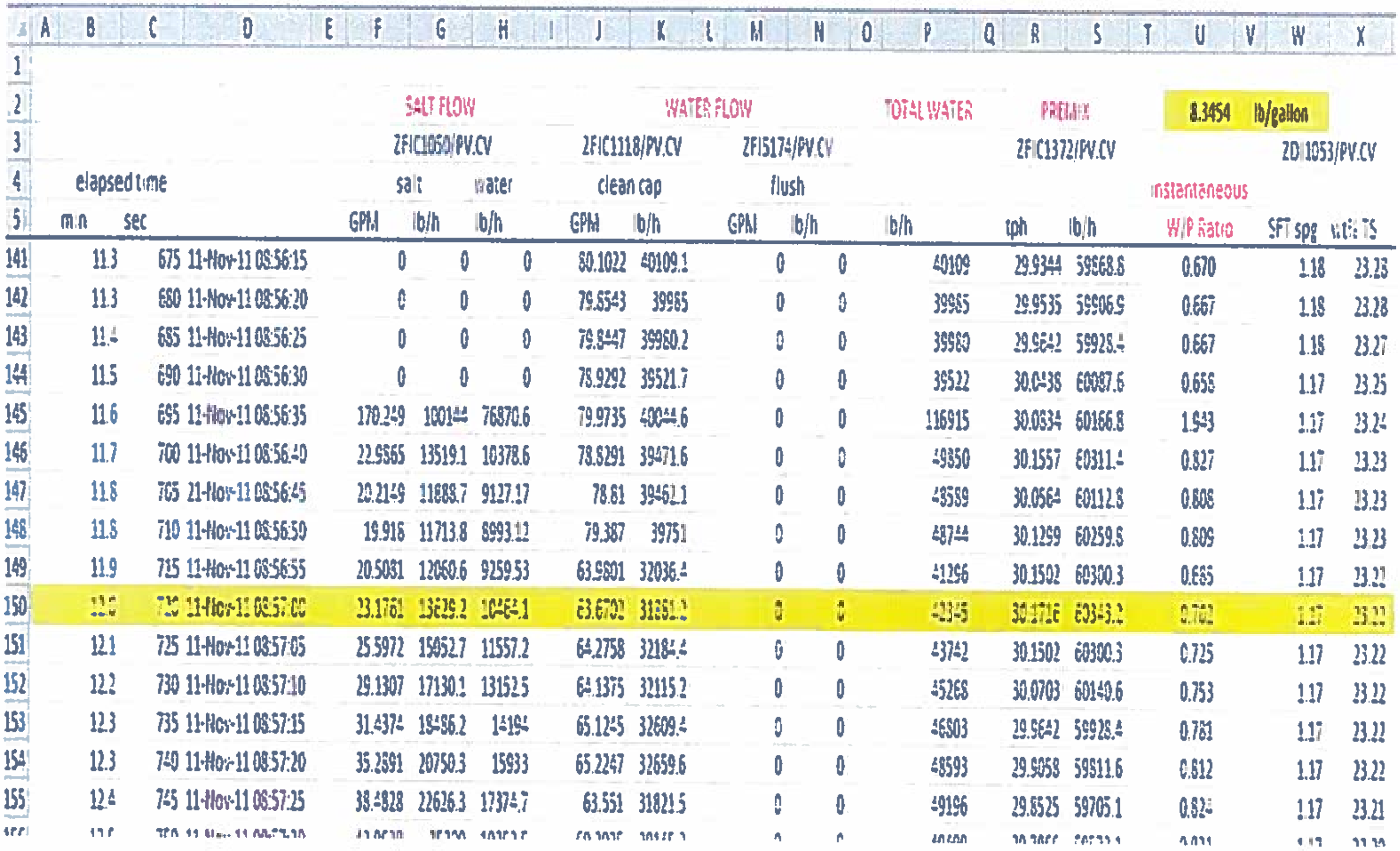
The graph depicted below is a representation of the data calculated using Equations 39 and 40 (zoomed view).

Figure 4. Hypothetical Extended Processing Average Divided by Setpoint Graph



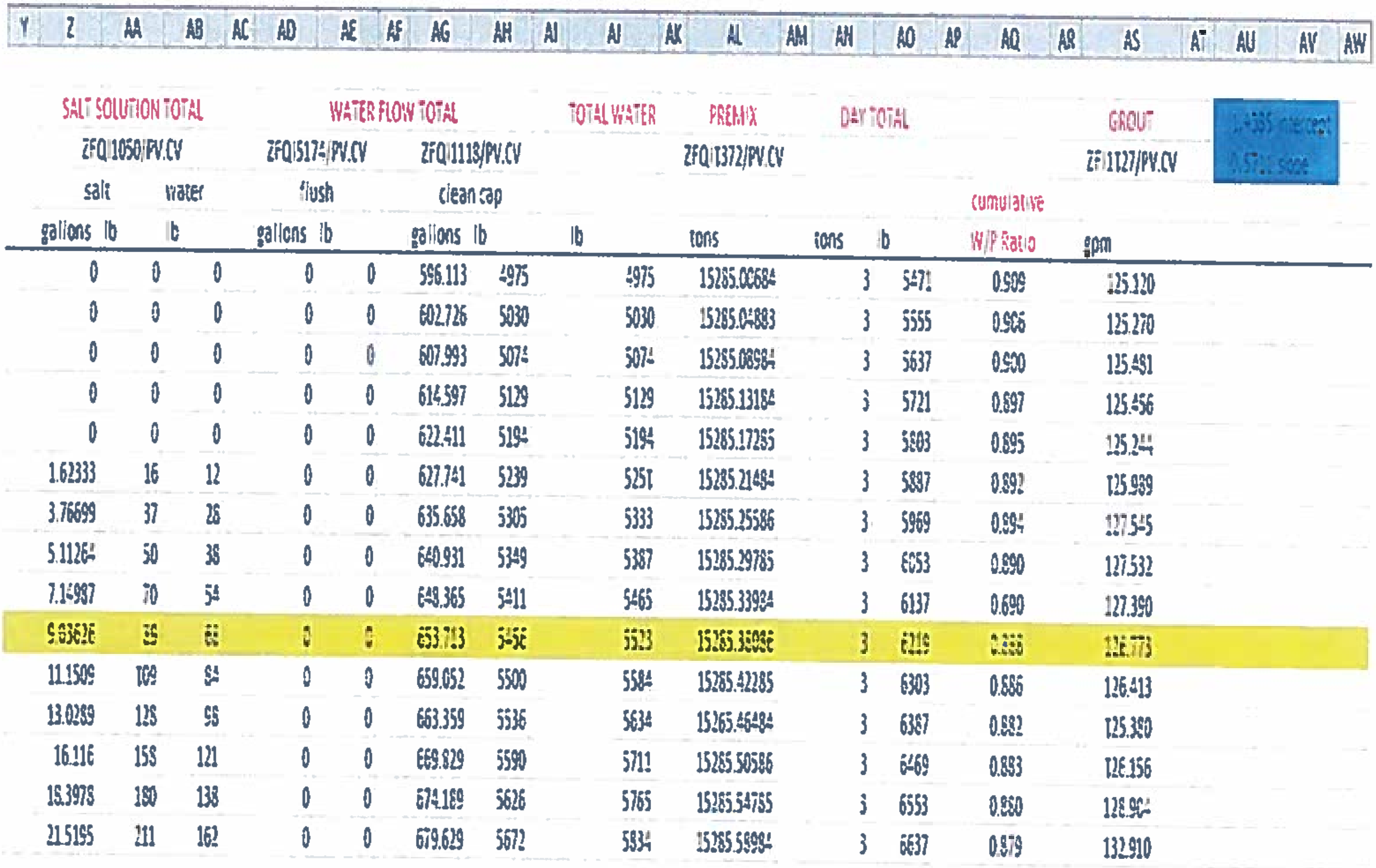
Appendix

Table 4a. Excel Spreadsheet Used to Determine Results Bar Graph



	B	C	D	F	G	H	J	K	M	N	P	R	S	U	W	X
1																
2					SALT FLOW			WATER FLOW			TOTAL WATER	PREMIX		8.3454	lb/gallon	
3					ZFIC1050/PV.CV		ZFIC1118/PV.CV		ZFI5174/PV.CV			ZFIC1372/PV.CV			ZDI1053/PV.CV	
4	elapsed time				salt	water	clean cap		flush					instantaneous		
5	min	sec		GPM	lb/h	lb/h	GPM	lb/h	GPM	lb/h	lb/h	tph	lb/h	W/P Ratio	SFT spg	wt% TS
141	11.3	675	11-Nov-11 08:56:15	0	0	0	80.1022	40109.1	0	0	40109	29.9344	59868.8	0.670	1.18	23.23
142	11.3	680	11-Nov-11 08:56:20	0	0	0	79.8543	39985	0	0	39985	29.9535	59906.9	0.667	1.18	23.28
143	11.4	685	11-Nov-11 08:56:25	0	0	0	79.8447	39980.2	0	0	39980	29.9642	59928.4	0.667	1.18	23.27
144	11.5	690	11-Nov-11 08:56:30	0	0	0	78.9292	39521.7	0	0	39522	30.0438	60087.6	0.658	1.17	23.25
145	11.6	695	11-Nov-11 08:56:35	170.249	100144	76870.6	79.9735	40044.6	0	0	116915	30.0834	60166.8	1.943	1.17	23.24
146	11.7	700	11-Nov-11 08:56:40	22.9865	13519.1	10378.6	78.8291	39471.6	0	0	49850	30.1557	60311.4	0.827	1.17	23.23
147	11.8	705	11-Nov-11 08:56:45	20.2149	11888.7	9127.17	78.81	39462.1	0	0	48589	30.0564	60112.8	0.808	1.17	23.23
148	11.8	710	11-Nov-11 08:56:50	19.916	11713.8	8993.12	79.387	39751	0	0	48744	30.1299	60259.8	0.809	1.17	23.23
149	11.9	715	11-Nov-11 08:56:55	20.5031	12060.6	9259.53	63.9801	32036.4	0	0	41296	30.1502	60300.3	0.685	1.17	23.21
150	12.0	720	11-Nov-11 08:57:00	23.1781	13629.2	10464.1	63.6702	31881.2	0	0	42345	30.1716	60343.2	0.702	1.17	23.22
151	12.1	725	11-Nov-11 08:57:05	25.5972	15052.7	11557.2	64.2758	32184.4	0	0	43742	30.1502	60300.3	0.725	1.17	23.22
152	12.2	730	11-Nov-11 08:57:10	29.1307	17130.1	13152.5	64.1375	32115.2	0	0	45268	30.0703	60140.6	0.753	1.17	23.22
153	12.3	735	11-Nov-11 08:57:15	31.4374	18486.2	14194	65.1245	32609.4	0	0	46803	29.9642	59928.4	0.781	1.17	23.22
154	12.3	740	11-Nov-11 08:57:20	35.2891	20750.3	15933	65.2247	32659.6	0	0	48593	29.9058	59811.6	0.812	1.17	23.22
155	12.4	745	11-Nov-11 08:57:25	38.4828	22626.3	17374.7	63.551	31821.5	0	0	49196	29.8525	59705.1	0.824	1.17	23.21

Table 4b. Excel Spreadsheet Used to Determine Results Bar Graph



SALT SOLUTION TOTAL			WATER FLOW TOTAL				TOTAL WATER	PREMIX	DAY TOTAL			GROUT
ZFQI1050/PV.CV			ZFQI5174/PV.CV		ZFQI1118/PV.CV			ZFQI1372/PV.CV				ZFI1127/PV.CV
salt		water	flush		clean cap						cumulative	
gallons	lb	lb	gallons	lb	gallons	lb	lb	tons	tons	lb	W/P Ratio	gpm
0	0	0	0	0	596.113	4975	4975	15285.00684	3	5471	0.909	125.120
0	0	0	0	0	602.726	5030	5030	15285.04883	3	5555	0.906	125.270
0	0	0	0	0	607.993	5074	5074	15285.08984	3	5637	0.900	125.491
0	0	0	0	0	614.597	5129	5129	15285.13184	3	5721	0.897	125.456
0	0	0	0	0	622.411	5194	5194	15285.17285	3	5803	0.895	125.244
1.62333	16	12	0	0	627.741	5239	5251	15285.21484	3	5887	0.892	125.939
3.76699	37	28	0	0	635.658	5305	5333	15285.25586	3	5969	0.894	127.545
5.11264	50	38	0	0	640.931	5349	5387	15285.29785	3	6053	0.890	127.532
7.14987	70	54	0	0	648.365	5411	5465	15285.33984	3	6137	0.690	127.390
9.63626	89	66	0	0	653.713	5456	5523	15285.38086	3	6219	0.888	126.773
11.1509	109	84	0	0	659.052	5500	5584	15285.42285	3	6303	0.886	126.413
13.0289	128	98	0	0	663.359	5536	5634	15265.46484	3	6387	0.882	125.390
16.116	158	121	0	0	669.829	5590	5711	15285.50586	3	6469	0.883	126.156
18.3978	180	138	0	0	674.189	5626	5765	15285.54785	3	6553	0.880	128.904
21.5195	211	162	0	0	679.629	5672	5834	15285.58984	3	6637	0.879	132.910

Table 5: Targeted Set Points of Water to Premix Ratio

Run Dates	Production Cell	W/P Ratio	Specified SFT SPG
11/11/2011	B	0.59	1.2
10/16/2011	B	0.59	1.2
8/26/2011	B	0.59	1.2
3/31/2011	J	0.60	1.19
6/19/2010	L	0.60	1.16
9/6/2012	2B	0.59	1.2
9/7/2012	2B	0.59	1.2
9/8/2012	2B	0.59	1.2
9/10/2012	2B	0.59	1.2
9/16/2012	2B	0.59	1.2