This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-96SR18500 with the U. S. Department of Energy.

FINAL MANUSCRIPT

For the

World Water and Environmental Resources Congress 2004
American Society of Civil Engineers

Adaptations of the Purge Water Management System for Long-Term Groundwater Monitoring at Savannah River Site, South Carolina

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ACRONYM LIST

AWSA	Aqueous Waste Software Application
CERCLA	Comprehensive Environmental Response Compensation and Recovery Act
FFA	Federal Facility Agreement
gpm	gallons per minute
LLNL	Lawrence Livermore National Laboratory
NPL	National Priorities List
PWMS	Purge Water Management System
QED	QED MicroPurge™
RCRA	Resource Conservation and Recovery Act
SCDHEC	South Carolina Department of Health and Environmental Control
SGCP	Soil and Groundwater Closure Projects
SRS	Savannah River Site
USEPA	United States Environmental Protection Agency
USDOE	United States Department of Energy

1.0 INTRODUCTION

The Savannah River Site (SRS) is a United States Department of Energy (USDOE) facility in South Carolina that has operated for defense programs for over 50 years (Figure 1). The operations at SRS have resulted in contamination of the underlying groundwater. Soil and Groundwater Closure Projects (SGCP) is responsible for remediation of the groundwater.

The requirement for groundwater remediation is driven by two major federal statutes: the Resource Conservation and Recovery Act (RCRA), which establishes a system for tracking and managing hazardous wastes from generation to disposal; and the Comprehensive Environmental Response Compensation and Recovery Act (CERCLA), or Superfund, which addresses the protection and cleanup of the environment. RCRA requires corrective action for releases of hazardous waste from active or inactive waste units and treatment, storage, or disposal facilities. CERCLA maintains a National Priority List (NPL) of sites targeted for assessment and, if necessary, restoration. SRS was placed on this list on December 21, 1989. In addition to these two statutes, SRS waste unit remediation and closure is subject to the requirements of various settlement agreements, consent decrees, and a Federal Facility Agreement (FFA) with USDOE, United States Environmental Protection Agency (USEPA) Region IV, and South Carolina Department of Health and Environmental Control (SCDHEC). The FFA, effective August 16, 1993, specifies how SRS will address contamination or potential contamination at waste units in accordance with RCRA and CERCLA requirements. The FFA is required under CERCLA.

Remediation of groundwater and soil waste sites began in the early 1990s and continues at an aggressive pace with more than 60 percent of the 515 inactive waste sites in the cleanup program now complete or in remediation. To monitor the groundwater contamination and the effectiveness of remedial actions, over two thousand monitoring wells are in active operation (i.e., require quarterly or semi-annual sampling) at SRS. Most wells are expected to continue in operation for another 20 years. Required sample volumes can range from less than a liter to 10 liters. To support the long-term groundwater monitoring requirements of these wells, SRS actively seeks technologies that can maximize data acquisition and minimize costs. Toward this end, SRS has implemented the Purge Water Management System (PWMS). The key attribute of this system lies in its ability to reduce or eliminate the generation of purged groundwater, which is costly in terms of the time and management.

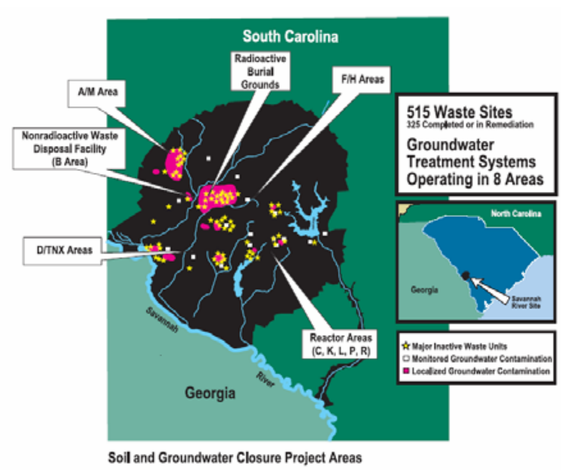

Figure 1. Savannah River Site Location

2.0 Description

Current groundwater sampling protocols at SRS require that monitoring wells be pumped or purged for at least two well volumes (i.e., the water volume contained in the well casing) before field parameter sampling begins. This practice ensures that a representative groundwater sample is obtained from the aquifer instead of the static turbid water within the well casing. Once the field parameters stabilize (i.e., the turbidity, specific conductance, pH and temperature remain constant), the protocol sample can be collected. This process typically results in three to four well volumes being purged. If the level of contamination in the groundwater exceeds the specified, health-based limits described in the *Investigation-Derived Waste Management P*lan, all purge water must be managed in accordance with SCDHEC regulations.

Originally, purged groundwater was managed by collection, transportation and treatment at permitted facilities on site. The PWMS was developed and implemented at SRS to create a system that was user-friendly and similar in operation to traditional sampling methods yet would eliminate the need to collect, transport, and treat purged groundwater. The system is a closed-loop aqueous system that extracts, temporarily stores, and returns groundwater to a well without significantly altering water quality. Because the purge water is returned to the well, no hazardous waste is generated. The PWMS is used in conjunction with current traditional sampling methods.

Several generations of PWMS designs have been developed to simplify the sampling process. Two adaptations of the PWMS are currently employed at SRS: the original "tank" unit and the "tankless" unit. The PWMS tank unit comprises a submersible pump, a groundwater supply/return line, and an above-ground tank (Figure 2 is a schematic of a tank unit). The groundwater is pumped through the supply/return line at a low flow rate between 0.5 and 1.5 gpm and is temporarily stored in the above-ground tank where the water is isolated from the atmosphere. Hollow plastic balls float on the surface of the stored water in the tank to isolate the purge water from the atmosphere although an air bladder is sometimes used for the same purpose.

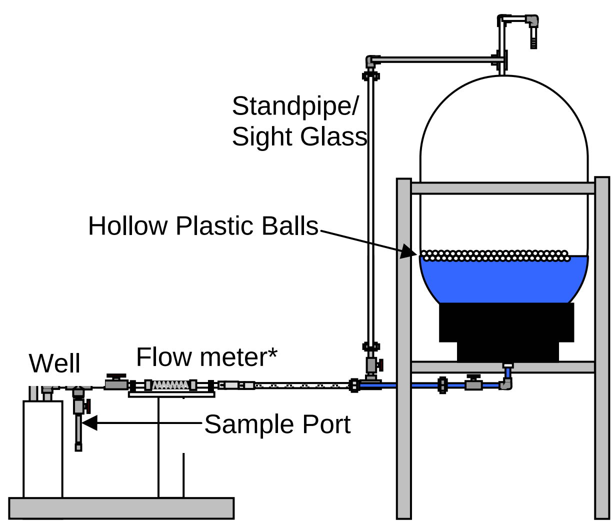

Figure 2. PWMS Tank Unit Schematic

After the protocol sample has been collected, the purged water is returned to the monitoring well. To date 120 wells have been fitted with the PWMS tank units at SRS.

The PWMS tankless unit is similar to the tank unit but with some variation. The unit comprises a submersible pump, a well packer, a supply line to the surface, and a return line (Figure 3 is a schematic of the tankless unit). The packer is inflated just above the well screen zone to isolate the aquifer water from the standing well water. The groundwater is pumped through the supply line, typically three to four well volumes, and is temporarily stored in the well casing above the inflated well packer. After purge water parameters have stabilized, a protocol groundwater sample is obtained from the well sampling port. The purge water that is held in isolation above the well packer is then returned to the aquifer when the well packer is deflated. The purge water is returned to the monitoring well via this closed loop non-contact system.

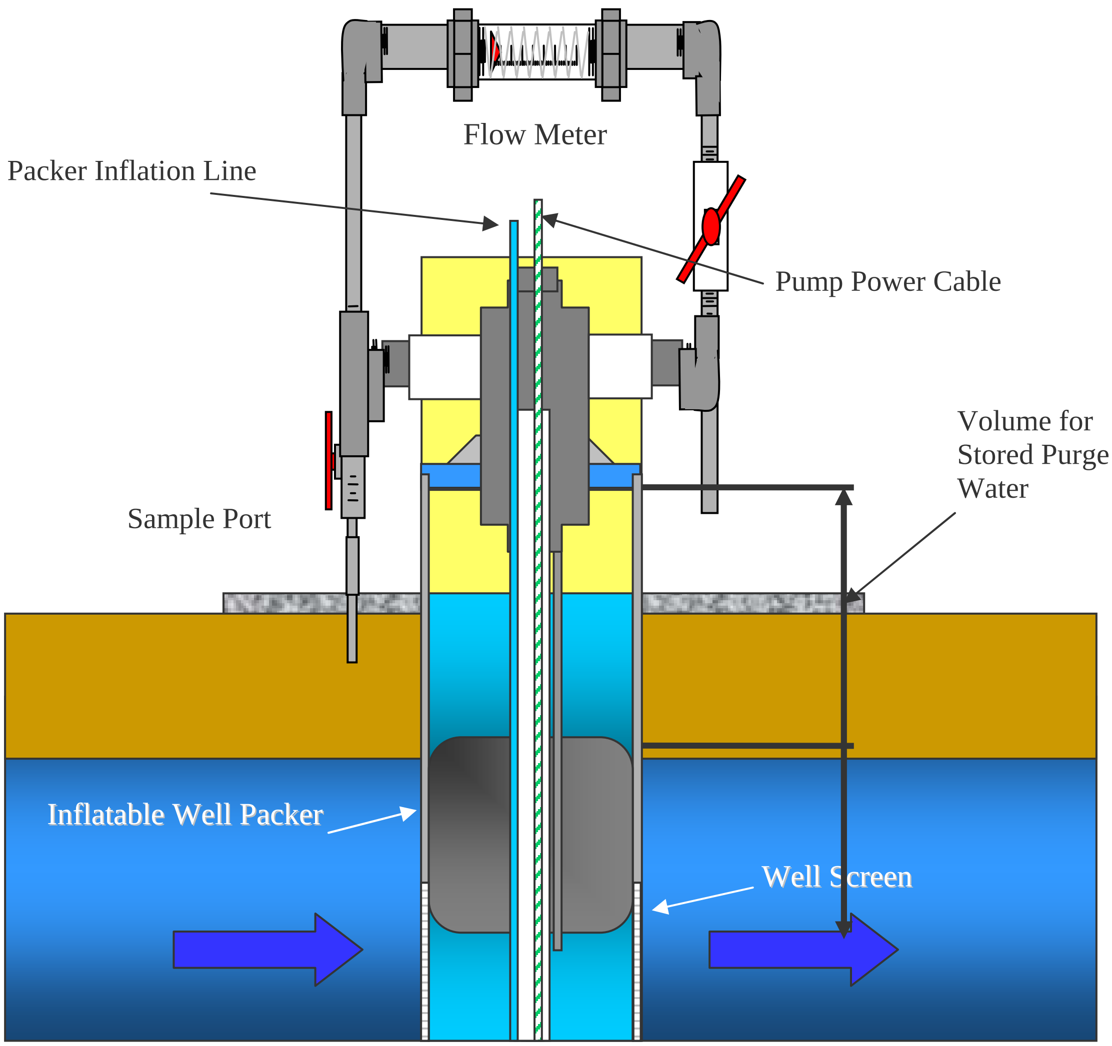

Figure 3. PWMS Tankless Schematic

Figures 4 and 5 show installed PWMS systems, both tank and tankless, at SRS.

Figure 4. PWMS Tank Unit

Figure 5. PWMS Tankless Unit Above-ground Portion

3.0 Evaluation Process

A series of pilot studies was conducted to demonstrate that both the PWMS tank and tankless units were technologically and regulatorily acceptable (i.e., groundwater sample quality was not altered), cost effective compared to original practices, easy to operate, and compared favorably with other purge water reduction methods. The studies included data collection, operational experience and field use of PWMS and other technologies.

Groundwater chemical analysis data was collected using the PWMS during the normal groundwater sampling process. The data was trended and compared to historical data to determine if the PWMS provided representative monitoring samples. Groundwater velocity data was collected using borehole dilution and tracer tests.

Operational experience was gained through a series of tests using the PWMS at both clean and contaminated groundwater wells. After successful testing, the PWMS was used during the normal groundwater sampling process. This experience led to development of several design enhancements that simplified operation and minimized the cost of fabrication, maintenance, and operation. These enhancements included the following:

- Single piping line for filling and draining the PWMS tank
- Hollow plastic balls to form the water/atmosphere barrier in the PWMS tank
- Standpipe for PWMS tank level indication
- Rotometer for the measurement of pumping flow rate
- Streamlined piping configuration for the tankless unit.

Field use and studies were used to evaluate the performance of other low purge water volume sampling methods such as EasyPump™ and QED MicroPurge™ systems. The EasyPump™ groundwater sampling technology developed at Lawrence Livermore National Laboratory (LLNL) provides a simple method for collecting a groundwater sample without generating purge water. The sampler consists of a cylindrical plastic bailer, 2 inches in diameter by 39 inches in length, with a small centrifugal pump and a small inflatable bladder. The sampler is lowered to below water level in the screen zone, and the pump is energized to allow sample collection. The single-speed pump fills the bladder and the bailer in less than a minute without disturbing sediment or increasing turbidity, after which the pump is de-energized, and the sampler is pulled from the well. The sample is then drained into a routine sample container.

The QED MicroPurge™ (QED) low-flow sampling system provides a method for taking a representative sample from the screen segment of a well and discharges only a small quantity of purge water. The QED is based on the following method: The bladder pump is placed in the screen segment of a well, and all connections are completed. The pump is started at the desired flow rate. A drawdown meter prevents the water level in the well from falling below a given level. A hand-held flow-through cell automatically monitors purge water quality indicator parameters and signals when the parameters stabilize. After stabilization, a sample is collected.

Comparisons between the four methods are shown in Table 1.

Table 1. Comparison of Low Purge Water Volume Sampling Methods

	PWMS Tank	**PWMS Tankless**	**EasyPump™**	**QED MicroPurge™**
Downhole Modifications	None	Complete Replacement	Complete Removal	Complete Replacement
Depth of Well Limit	None	~ 200 ft of water above packer	~ 200 ft	None
Sample Volume Limit	No limit	No limit	One liter	No limit. However, for low flow aquifers – time-consuming
Storage Capacity	Tank capacity	Well Casing capacity	N/A	N/A
Additional Operating Equipment	None	Air compressor	Controller	Controller, Flow-Through Cell, and Air Compressor
Waste Generated	None	None	Minimal. Tube volume not used for sample collection	Minimal purge water collected until groundwater stabilizes.
Level of Ops Training Req.	Least	3rd least	2nd least	Most

4.0 Technical concerns

Regardless of the method used to sample groundwater, obtaining representative samples is a primary concern. Suitability of the PWMS to collect representative samples, while allowing for the extraction and return of large volumes of purge water, is the chief issue to address for the successful demonstration of the technology. A successful application of the PWMS technology had to meet the following criteria:

- Groundwater sample chemistry must not be altered.
- An effective water/atmosphere interface barrier must be provided.
- A means to measure flow volume must be available.
- Water containment integrity must be maintained.
- Purge water volume must be minimized.

Groundwater sample chemistry unaltered: Since the purge water is returned to the well, water chemistry must be unaffected by the material used in the well and PWMS components. Great care was taken in the design and fabrication of the PWMS to ensure the groundwater chemistry was not affected. For example, in August and October 1999 special sampling events were conducted to determine whether elevated metals levels in PWMS effluent samples were attributable to the PWMS units. The primary sources of the metals were suspended particles resulting from natural aquifer materials and the dissolution of the metal components from well appliances (e.g., brass flow meters), which primarily contributed copper, lead, and zinc. Because of this finding, all metallic well components that could alter the water chemistry were replaced with polyvinyl chloride or stainless steel materials.

Effective water/atmosphere interface barrier: Because of the problems inherent in using a tank air bladder with a pressurized system to prevent water contact with the atmosphere, the use of hollow plastic balls was investigated as an alternative. Tests were conducted using a transparent mock-up tank. The tests established the following:

- Hollow plastic balls orient themselves in a hexagonal pattern as water is introduced into the tank
- The plastic balls spread out over the entire surface of the liquid.
- The plastic balls maintain surface coverage as the liquid level changes.
- The best surface coverage is achieved with two layers of 20-mm balls.
- Hollow plastic balls are equally as effective as a closed container in providing a barrier between liquid and air
- The hollow plastic ball technology simplifies maintenance of PWMS units.

Flow volume measurement: Storage capacity of the PWMS is limited and so accurate measurements of purge water volumes are required. To ensure this, several flow meters, including electronic and mechanical devices, were evaluated. When the tank bladder was eliminated, a tank standpipe was added. In the PWMS tankless units, an electronic water level measurement tape is used to indicate when the well casing has nearly reached capacity. Tests were performed to verify that flow measurements taken by a tank standpipe were equivalent to electronic and mechanical flow meters.

Water containment integrity: Purge water must be contained without leaking. Leakage could cause cross contamination of the surrounding vadose zone of the well or of an overlying aquifer or water table. Severe leaking could cause larger than necessary volumes to be purged, and the purge water could be recirculated into the system and prevent a representative sample of the aquifer from being taken. Since the PWMS tankless storage is below the ground surface, leakage tests are performed to verify leakage rates do not exceed one foot per ten minutes.

Minimize purge water volume: When the turbidity level in a well is minimized, the time required to stabilize the well is also minimized, decreasing purge water volumes. The following methods were used to reduce purge water volumes:

- Well Packer Installation – in the event of high static water levels, installing a well packer isolates the water column above the packer and allows only the water in the well screen area to be purged.

- Well Redevelopment – To minimize the duration of the purge, all wells are redeveloped to minimize the turbidity of the groundwater.

- Variable Speed Pump Installation - To preclude surging the well, variable speed pumps are installed in all the wells and flow rates are limited to 1.5 gpm maximum.

5.0 Applications

The following factors will determine whether a well is a suitable candidate for either a tank or tankless unit PWMS:

- Groundwater velocity and sample frequency
- Storage Capacity
- Purge Water Volumes

Groundwater velocity: Only wells finished in aquifers with sufficiently high groundwater velocities are suitable for PWMS use to ensure the returned water column in the well has time to clear the well area. This way the groundwater is not re-sampled and a representative groundwater sample is obtained. The mini-plume of returned water must migrate sufficiently far between sample events to avoid re-sampling during subsequent sampling events.

Screening calculations based on Darcy's Law are initially made to identify suitable candidate wells. Borehole dilution tracer and slug tests have been performed on several wells, and the original screening calculations have been validated. These tests will likely become the diagnostic tool used to identify PWMS candidate wells. To support the well identification process, a software program, AWSA, was developed to interface with the SRS groundwater database to extract the information needed to identify candidate wells. The typical information required to determine the suitability of a well for PWMS use includes the following: aquifer hydraulic conditions, historical purge volumes, well construction details, and contamination concentrations.

Storage Capacity: Adequate storage capacity is needed to ensure that the storage device, a tank or the well casing, can retain the entire purge water volume. Deeper wells with low static water level and small screen lengths provide the optimum conditions for the tankless unit; otherwise an adequately sized tank would be more appropriate. If storage capacity is exceeded, the excess purge water must be managed (i.e., containerized, transported, and treated or disposed).

Purge Water Volumes: Some wells may have large purge volumes due to high static water levels and to the length of time it takes for well parameters to stabilize (e.g., turbidity, pH, temperature and specific conductance.) A new PWMS tank design was developed to decrease the purge volume through use of a well packer. This design allows the water within the screen zone to be isolated from the standing water in the well above the well packer.

6.0 Regulatory Acceptance

SCDHEC regulatory acceptance was needed before SRS well sites deployed the PWMS. To gain acceptance, a series of pilot studies were conducted to test the efficacy of PWMS tank and tankless units at SRS and to demonstrate that the PWMS units would not alter the groundwater sample quality. SCDHEC was kept informed of all plans and progress of the demonstration through a series of meetings and reports.

The technical effectiveness of PWMS tank unit was demonstrated initially at a non-contaminated clean well. After gaining approval from SCDHEC, four contaminated wells were equipped with PWMS units in 1997 and a series of sampling events were conducted at each from 1997 to 1998. An additional twenty wells were later approved by the SCDHEC to be included in this pilot demonstration study.

Quarterly reports were submitted to SCDHEC throughout the demonstration phase to provide updates on the progress of the implementation of the PWMS deployment at the SRS. These reports provided data that supported the suitability of the PWMS to collect representative monitoring well samples. SCDHEC was informed of any modifications to the design of the units that had the potential to affect the integrity of the well samples (e.g., replacing the air bladder with hollow plastic balls).

After successfully demonstrating the effectiveness of the PWMS, SCDHEC approved full deployment of the PWMS tank units. After completion of the demonstration phase, the original four wells were approved for the demonstration of the PWMS tankless units. The demonstration phase of the PWMS tankless units followed the same approach as the PWMS tank units.

7.0 Material Costs and Process Cost Savings

Life cycle cost estimates have been developed for the PWMS deployment, which enables comparisons of costs for material, fabrication, installation, and operation of the well units to the original sampling practices. The comparisons reveal considerable cost and time savings attributable to elimination of many purge water management requirements.

The original sampling method of containerizing, transporting and treating the collected purge water incurred the following costs:

- Collection and transportation equipment – tanker trucks ($125K/20 years), water buffaloes, tractors, spare parts and other miscellaneous equipment.
- Transportation labor – truck drivers ($56K/year), driver training and certification, equipment training, standard operating procedures, facility-specific training
- Road maintenance for heavy traffic – wells are accessed via one-lane dirt roads

- Equipment Maintenance labor
- Waste Management Costs – staging areas, truck off loading
- Treatment costs – $0.89/gal non-rad (1999 costs) and $1.20 rad (1999 costs)

The PWMS eliminates the above costs but incurs the following costs:

- Design, material, fabrication, installation and testing of PWMS equipment
- Spare parts
- Maintenance to repair PWMS units
- Initial sampler training and oversight for PWMS equipment
- Minimal well head modifications

Both methods incur the following costs at approximately the same level:

- Sampler labor needed to obtain the groundwater samples.

Table 2. PWMS Expenditures By Contract

Sampling Method/ Manufacturer and Installer	2nd PWMS Tank Design - ATI	3rd PWMS Tank Design – Munns	4th PWMS Tank Design - ?	Original PWMS Tankless Design - ATI	Current PWMS Tankless Design - Brown Welding
Quantity	30/20	50	35	4	40
Material, Fabrication and Installation Cost	$10,659/ $10,809	$ 5,486	$2,000 (estimate)	$ 8,465	$ 4,300

Cost data for other comparable sampling methods

Approximate SRS material and fabrication costs (installation cost extra) – QED Micropurge™ $800 downhole equipment + installation and $12,000 controllers and other portable surface equipment that is used at all wells. Limitations – low flow aquifers and large sample volumes.

Approximate SRS material and fabrication costs (installation cost extra) - EZ Pump™ - $1,000 for one downhole tube assembly with controllers and other portable surface equipment. Limitations - shallow depth (i.e., depth of well < 200 ft), 2-inch diameter well, and small sample volumes (i.e., approximately 1.0 L).

8.0 Conclusion

Successful completion of the demonstration phases have shown that the current designs provide an efficient and cost-effective method for long-term monitoring. Table 3 compares the PWMS technology against the original (or baseline) method and lists the advantages of PWMS.

Table 3. A Comparison of Baseline vs. PWMS Sampling Methods

Feature	Baseline	PWMS Technology	Improvement / Advantage
Purge Water Containment	Purge water is containerized and stored	Purge water is collected in the PWMS tank	Containerization and storage areas are eliminated.
Purge Water Shipment	Purge water is collected in a Purge Water Tanker Truck or Water Buffalo.	Purge water is gravity drained back into well	Tanker truck and water buffaloes are eliminated.
Purge Water Treatment	Purge water is treated at an existing effluent treatment facility.	No treatment is needed. No waste is generated.	Existing treatment facility does not need to handle and treat frequent shipments of purge water.
Personnel	Personnel from other operating divisions (e.g., Transportation and Packaging, Effluent Treatment Facility, Health Protection) are required to support environmental sampling program.	Personnel from the environmental sampling program operate PWMS.	No need for outside organizations to support the environmental sampling program.
Scheduling	The regulatory driven schedule must be coordinated with other important schedules.	Sampling is scheduled internally.	No need to coordinate schedules with outside organizations.

Following successful demonstration of the PWMS technology, a 10-year full deployment schedule was developed. The schedule was later accelerated when DOE-HQ provided additional matching funding through their Accelerated Site Technology Deployment program, which will allow achievement in full deployment in four years. Currently, over 100 tank units and over 30 tankless units have been deployed at SRS. Funding at the present level would allow SRS to reach full deployment by 2006, which will ultimately include units at more than 500 wells.

ATTACHMENT A - DESIGN CHANGES

Elimination of the dual fluid lines (i.e., one line for influent and one line for effluent.) was made possible by eliminating the existing well pumps with foot valves.

Elimination of the tank air bladder. Purge water isolation: The original design uses an air bladder to fill the tank void space to prevent air contact with the purge water. The air bladder in the tank requires deflation to allow water to enter the tank and inflation to force all water out of the tank. Therefore, an air compressor, air pressure gauge, air injection and air release systems are needed. The air bladders were problematic maintenance items which required frequent replacement. In the enhanced design, the air barrier is provided by hollow plastic balls, which float on the water surface. Air is vented through a screened pipe vent at the top of the tank. Through testing it was shown that hollow plastic balls could supply a similar level of isolation from the atmosphere, which eliminated the need for a pressurized system which in turn allowed more enhancements.

Elimination of a pressurized system and air release valve. Since the system would no longer be pressurized, component pressure testing was eliminated. Prior to filling the tank, air no longer needed to be vented through an air release valve.

Elimination of electronic flow totalizers. Flow rate and volume measurement: Exact volume measurements of the water stored inside the tank is important to preclude overfilling the tank and potentially creating a spill. The original design required an electronic flow meter to indicate flow rate and total volume pumped. Therefore, portable power source and flow meter readout are needed to be brought to each unit. In the enhanced design, with the elimination of the backpressure created by the air bladder, tank volume can be measured using a calibrated standpipe. Flow rate can be measured by a rotometer.

The PWMS tankless units design was also enhanced. The enhanced design changes reduced the fabrication cost of the Tankless unit by nearly $2,000, compared to previous models. To date, the field tests show very positive results.

ATTACHMENT B – OTHER TECHNOLGIES EVALUATED

EasyPump™

The EasyPump™ groundwater sampling technology developed at Lawrence Livermore National Laboratory (LLNL) provides a simple method for collecting a groundwater sample. The sampler consists of a cylindrical plastic bailer, 2 inches in diameter by 1 meter in length, with a small centrifugal pump. The particular EasyPump™ model selected for deployment at SRS is designed for 2-inch monitoring wells and uses a small packer (Figure 1). The sampler is lowered to below water level in the screen zone, and the pump is energized to allow sample collection. The single-speed pump fills the bailer in less than a minute without disturbing sediment or increasing turbidity, after which the pump is deenergized and the sampler is pulled from the well. The sample is then drained into a routine sample container.

The EasyPump™ technology was implemented at the SRS in an initial test deployment at three groundwater monitoring wells (LFW 64D, LFW 65D, and LFW 67C) in the Sanitary Landfill at SRS. The following criteria were used to select the wells for demonstrating the EasyPump™ unit:

- shallow depth (i.e., depth of well < 100 ft),
- 2-inch diameter well, and
- requirement for relatively small sample volumes (i.e., approximately 1.0 L).

After three rounds of sampling using the EasyPump™ Sampling System at the three wells, the concentration trends for analytes in groundwater have been unaffected. Groundwater data from these sampling events indicate a successful deployment that generates high quality data. It is with this in mind that SRS plans to deploy this sampling system at four additional wells.

QED MicroPurge™

The QED MicroPurge™ (QED) low flow sampling system provides a method for taking a representative sample from the screen segment of a well while discharging only a small quantity of purge water. The QED is based on the following method: The bladder pump is placed in the screen segment of a well and all connections are completed. The pump is started at the desired flow rate. The equipment automatically monitors purge water quality indicator parameters and signals when the parameters stabilized. After stabilization, a sample is collected.

ATTACHMENT C – HOLLOW PLASTIC BALL EVALUATION

Effective water/atmosphere interface barrier: Because of the inherent problems of a pressurized system using a tank air bladder to preclude water contact with the atmosphere, an alternative was investigated using hollow plastic balls. The evaluation included to determine if:

- One layer of hollow plastic balls could arrange themselves to cover the calculated 91% of the surface area.

- Coverage could provide an effective barrier to reduce the transfer mechanism between liquid and atmosphere
    - Oxygen absorption reductions
    - Evaporation loss reductions
    - Heat loss reductions
    - The balls freely align as liquid levels rise and fall
    - Relatively maintenance free
    - Quick and simple to install

The test to simulate the action of the balls during filling and draining included the following:

- Mock-up tank configured to replicate current PWMS tanks
    - Diameter
    - Water inlet
    - Pumping rate

- Mock-up tank transparent to observe the simulation during tank filling and emptying (colored water to facilitate visual observations).

- Different simulations were conducted:
    - 1 and 2 layers of 20 mm balls
    - 2 layers of 20-mm balls and an additional 20% 10-mm balls
    - 1 layer 20-mm balls and 1 layer 10-mm balls

Results:

- Hollow plastic balls orient themselves in a hexagonal pattern as water is introduced into the tank
- The balls spread out over the entire surface of the liquid
- The balls maintain surface coverage as the liquid level changes
- Visual observations indicate best surface coverage is achieved with two layers of 20-mm balls

The test to simulate air/water interactions included the following:

Three (3) bucket test:

- Each bucket had 10 lbs of water (1.2 gallons) - Contents and buckets initially weighed
- Bucket #1 was sealed to the atmosphere
- Bucket #2 had two layers of twenty (20) mm balls
- Bucket #3 was open to atmosphere
- All buckets were weighed after 14 days and 18 days

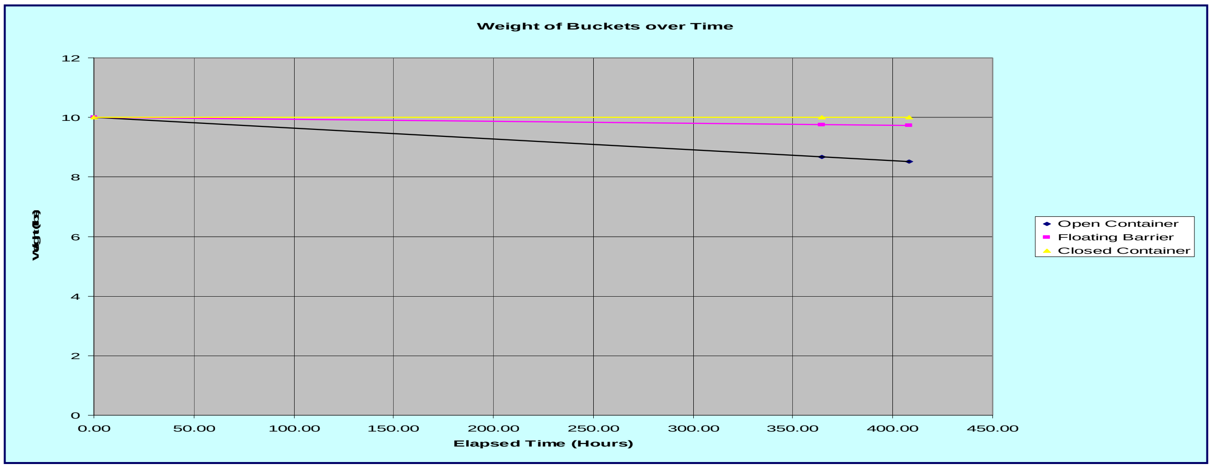

Chart C-1. Three Bucket Test

Data Summary:

A - Pre-stabilized Influent Purge Water Sample
B - Second Pre-stabilized Influent Purge Water Sample
I - Protocol Sample (Stabilized)
E - Returned Purge Water Sample (Effluent)

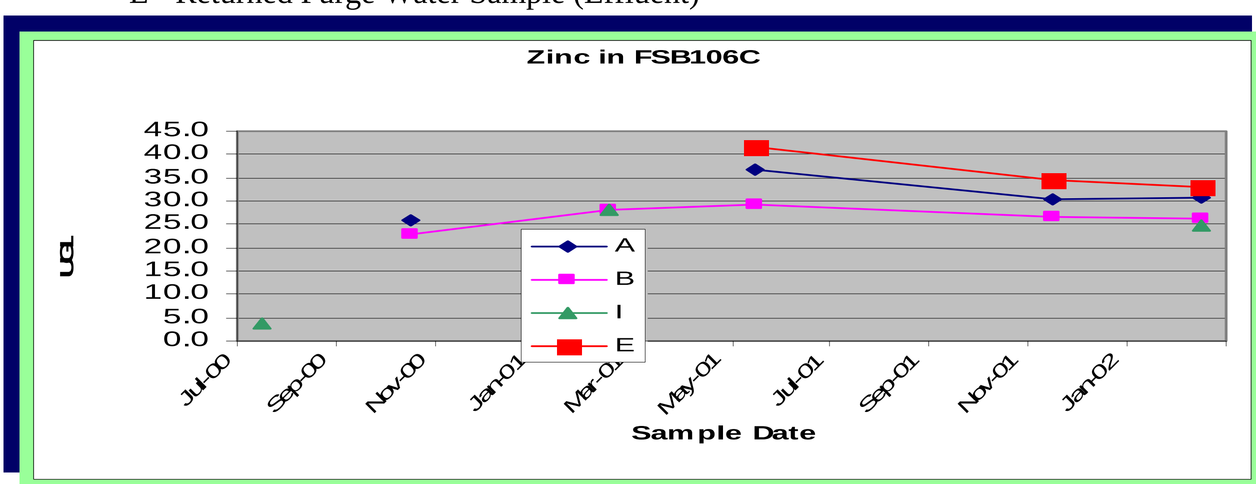

Chart C-2. Field Test for Floating barrier Design

Note: Impact of Hollow Plastic Ball Barrier determined by comparison of data trends between sample types and sampling events

Conclusions:

- Sample results indicated that hollow plastic balls are equally effective as a barrier between liquid and air to a closed container.
- Data trends show consistent relationships
- The hollow plastic ball technology provides a simplified cost effective sampling process for monitoring well applications
- The hollow plastic ball technology provides simplified maintenance of PWMS units

ATTACHMENT D – MISCELLANEOUS PICTURES

Original Purge Water Collection Methods

Figure D-1. Tanker Truck and Water Buffalo

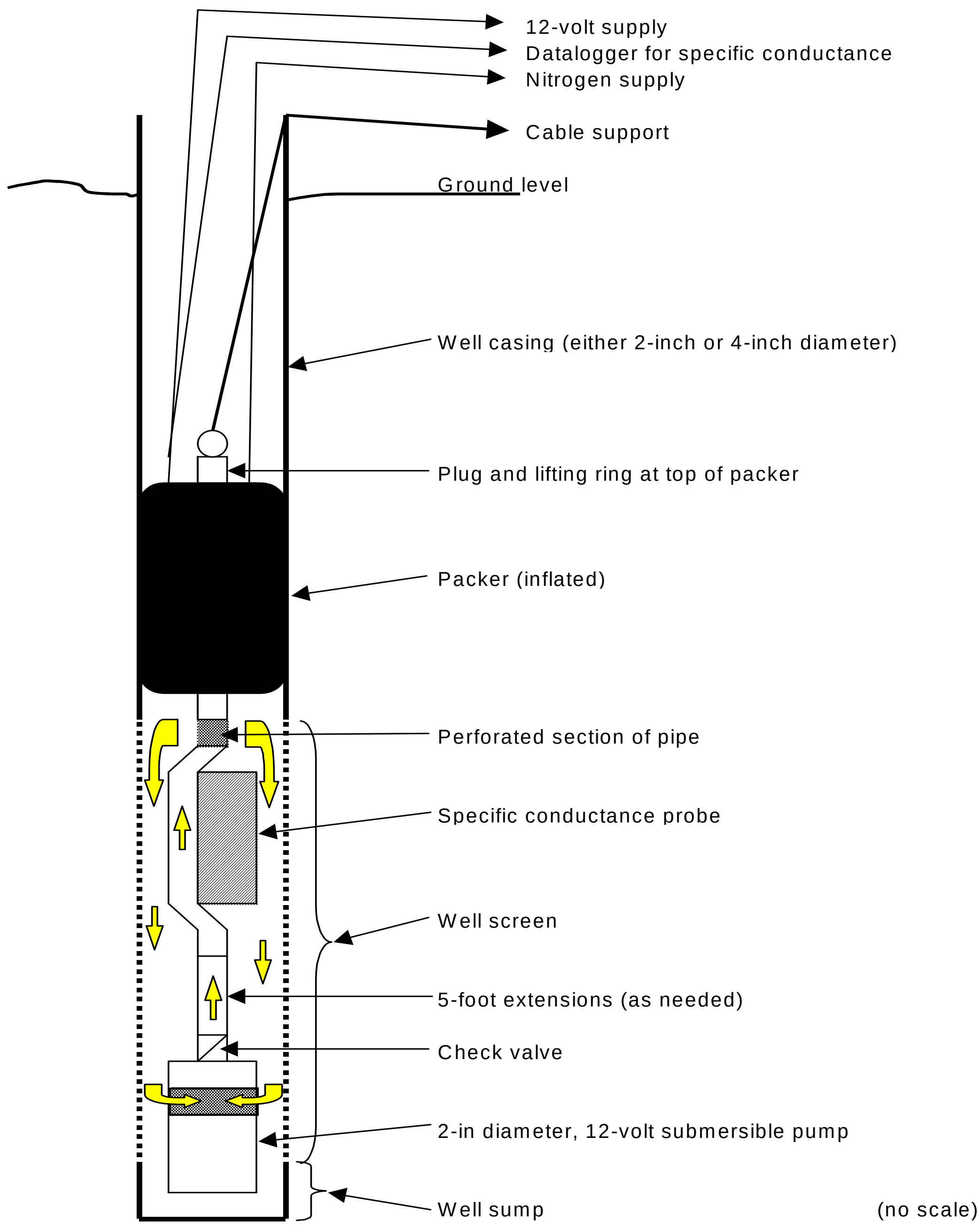

Figure D-2. Bore Hole Dilution Test Apparatus

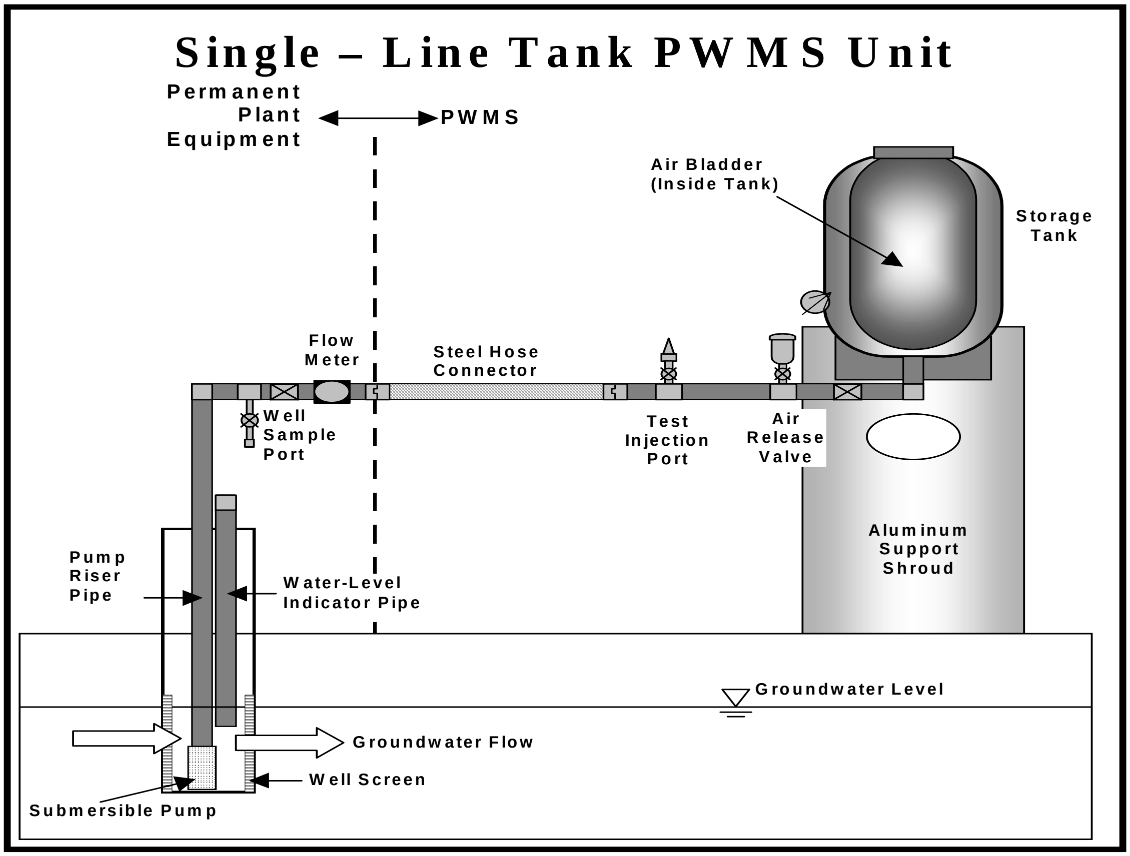

Figure D-3. 2nd Generation PWMS Design

Figure D-4 2nd Generation PWMS Design

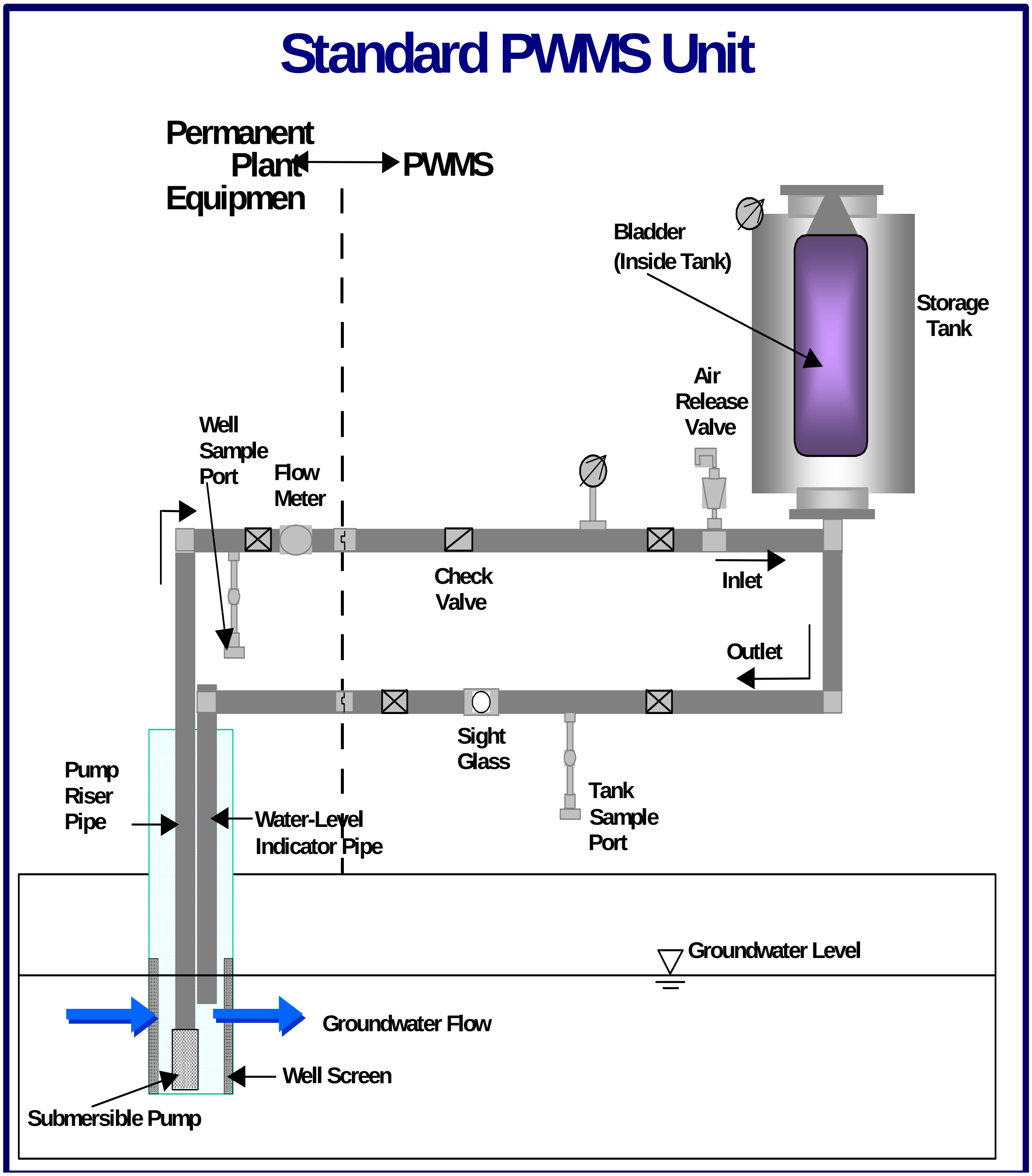

Figure D-4. PWMS Tank Demonstration Unit Design (2-line Piping)

Figure D-5. Original PWMS Demonstration Unit (2-line piping)