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Incorporating Pump-and-Treat Performance Assessment Into Hanford Remedy Documents

September 2017

MJ Truex
CD Johnson

U.S. DEPARTMENT OF
ENERGY

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Abstract

Performance assessment of a pump-and-treat (P&T) system to support a decision about whether it is appropriate to shut down the system can be facilitated by using a structured approach that includes consideration of decision elements. Decision elements involve assessment of contaminant concentrations and trends; contaminant mass discharge from source areas; the attenuation capacity of the aquifer; estimated future plume behavior; and P&T system design, operational, and cost information to identify an appropriate condition for transitioning from P&T remediation. It is also important to consider site-specific factors. Thus, P&T system performance assessment for the Hanford Site should be specific to the plumes, environmental setting, and design/operational approaches for Hanford Site P&T systems.

In fiscal year 2017, PNNL worked with 200-ZP-1 operable unit (OU) and 100-HR-3 OU staff in preparing OU documents associated with implementation of P&T remedies. In these efforts, elements of a structured approach to P&T decisions and Hanford-specific factors were incorporated into the documents. Because the 200-ZP-1 and 100-HR-3 OU documents were still in a draft stage at the time this report was written, the information provided here serves only as an example of how to map P&T decision elements to performance monitoring and work plans for P&T systems. Final remedy documentation for these OUs should be consulted for specific information on OU plans and activities.

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Acronyms and Abbreviations

AWLN	Automated Water Level Network
DOE	U.S. Department of Energy
DVZ-AFRI	Deep Vadose Zone – Applied Field Research Initiative
GALEN	**G**roundwater **A**na**L**ytics for **EN**vironment
MNA	monitored natural attenuation
P&T	pump-and-treat
PLATO	**PL**ume **A**nalysis **TO**ol
PMP	performance monitoring plan
PNNL	Pacific Northwest National Laboratory
QA	quality assurance
RAO	remedial action objective
RD/RAWP	remedial design/remedial action work plan
RPO	remedial process optimization
ROD	Record of Decision
SOCRATES	**S**uite **O**f **C**omprehensive **R**apid **A**nalysis **T**ools for **ES**timation
SPA	Single Page Application

Contents

1.0 Introduction

The U.S. Department of Energy (DOE) Hanford Site is applying pump-and-treat (P&T) remediation to control and diminish groundwater contaminant plumes. There are P&T systems in the 100 Areas (DOE 2015a) and 200 Area (DOE 2015b) currently operating to address aquifer contamination. Operational information for these systems is provided in annual summary reports (DOE 2015a,b). Groundwater monitoring information for the targeted plumes is compiled in the annual Hanford groundwater monitoring reports (http://www.hanford.gov/page.cfm/SoilGroundwaterAnnualReports). In the future, a remedial decision will be needed to transition from P&T to remediation closure or to another approach to complete remediation (e.g., transition to natural attenuation). The recent document *Performance Assessment for Pump-and-Treat Closure or Transition* (Truex et al. 2015) provides a structured approach to assess P&T systems and support remedy transition and closure decisions. The structured approach includes assessment of decision elements, including contaminant concentrations and trends, contaminant mass discharge from source areas, the attenuation capacity of the aquifer, estimated future plume behavior, and P&T system information (design, operations, and cost) to identify an appropriate condition for transitioning from P&T remediation.

An additional document (Truex and Johnson 2016) was published that identifies how elements of the *Performance Assessment for Pump-and-Treat Closure or Transition* document (Truex et al. 2015) can be applied for performance assessment specific to the plumes, environmental setting, and design/operational approaches for the Hanford Site P&T systems. The report was intended to be a resource to develop a performance assessment approach and exit strategy for each Hanford P&T system. The report focused on P&T assessment for transition to natural attenuation because 1) the 200-ZP-1 and 200-UP-1 operable unit (OU) P&T systems are part of remedies where transition to natural attenuation is identified in the Record of Decision (ROD) (EPA, DOE, and WDOE 2008, 2012) and 2) the 100 Area P&T systems target chromium plumes that are being diminished, receding from the river (DOE 2015a), and meeting aquifer concentration objectives that may allow for concentrations in the aquifer that are greater than the more-stringent river protection standards. Thus, for P&T applications at Hanford, it is anticipated that a key element of P&T performance assessment will be to determine when a P&T system can be shut down and transitioned to natural attenuation to meet the remedial action objectives (RAOs), with consideration of potential continued targeted treatment for areas of persistent contamination.

In fiscal year 2017, PNNL worked with 200-ZP-1 OU staff in revising the performance monitoring plan (PMP) (DOE/RL-2009-115) associated with the combined P&T/monitored natural attenuation (MNA) remedy. In this effort, elements of the P&T guidance (Truex et al. 2015) and Hanford-specific recommendations (Truex and Johnson 2016) were incorporated into the plan. The 200-ZP-1 OU performance monitoring plan update is still at a draft stage. Also in fiscal year 2017, PNNL staff worked with 100-HR-3 OU staff in preparing a decisional draft for the remedial design/remedial action work plan (RD/RAWP) that includes the design and implementation of P&T in the 100-HR-3 groundwater OU. The work plan includes a design and strategy for P&T implementation and closure that is consistent with the P&T guidance and Hanford-specific recommendations. The purpose of the material herein is to describe how the P&T guidance and Hanford-specific recommendation elements can be mapped to performance monitoring and work plans for P&T systems as a resource for future OU documents. Because the 200-ZP-1 and 100-HR-3 OU documents are still at a draft stage at the time of this report, final remedy documentation for these OUs should be consulted for specific information on OU plans and activities.

Section 2.0 of this document is a synopsis describing how the P&T guidance and Hanford-specific recommendations were incorporated into the 200-ZP-1 OU performance monitoring plan. Section 3.0 of this document is a synopsis describing how the P&T guidance and Hanford-specific recommendations were incorporated into the draft 100-HR-3 OU RD/RAWP. Section 4.0 discusses implications and additional considerations for P&T exit strategies.

2.0 Performance Monitoring and Remedy Management for the 200-ZP-1 Operable Unit

For the Central Plateau, transition from P&T to MNA was included in the ROD for the 200-ZP-1 OU (EPA, DOE, and WDOE 2008) with a transition timeframe identified as occurring after 25 years of P&T. Thus, the 200-ZP-1 OU P&T system will require management in the context of that transition and the identified RAOs. Additionally, performance assessment should include collecting information to 1) determine whether there are zones of persistent contamination that will affect reaching the transition goal, 2) guide P&T system remedial process optimization (RPO), or 3) potentially drive the need for a treatment technology other than P&T. These considerations are part of managing the remedy and therefore need to be included in the *Performance Monitoring Plan for the 200-ZP-1 Groundwater Operable Unit Remedial Action* (200-ZP-1 OU PMP; DOE/RL-2009-115). This section describes how these elements are incorporated into the 200-ZP-1 OU PMP consistent with the resources provided in the P&T guidance (Truex et al. 2015) and Hanford-specific recommendations (Truex and Johnson 2016).

2.1 Process and Decision Chart

Managing the 200-ZP-1 OU remedy requires operating, optimizing, and evaluating the progress of current remedy activities with respect to reaching P&T system performance goals that are consistent with meeting ROD RAO requirements. Management also includes planning for the full remediation process to reach RAOs and collecting data and information from current remedy activities that are relevant to support the decision regarding when it is appropriate to transition from P&T to MNA. Because several factors need to be considered for a multiple-step remedy, a process and decision chart is a useful tool to guide remedy performance assessment and management (Truex and Johnson 2016). Consistent with the Hanford-specific recommendations report (Truex and Johnson 2016), the 200-ZP-1 OU project team developed a process and decision chart relevant to the 200-ZP-1 OU remedy that 1) identifies the stages of remedy implementation; 2) includes monitoring, data analysis, reporting, and optimization actions; and 3) defines decisions associated with remedy management and transition to subsequent remedy stages.

The process and decision logic for the 200-ZP-1 OU PMP identifies the following primary stages of remediation: P&T System Operation; Evaluate P&T Shutdown; MNA; and Attainment. In this approach, the step of transitioning from P&T to MNA is identified as a specific stage, providing the opportunity to directly identify the approach and requirements for this process. Identifying all the remediation stages upfront also facilitates the planning of early data collection activities needed to support the later stages. Under each remediation stage, the process and decision chart includes activities and analyses under the following categories: monitor, calculate, predict, report, and optimize.

The first two categories, monitor and calculate, are foundations that feed subsequent activities. The “monitor” element is important to identifying the data inputs that are needed to support the other elements of the process and decision chart. The “calculate” element describes the data analyses conducted directly with the collected data to produce plots and calculated values that are diagnostic of remedy performance. For instance, for the P&T stage of the remedy, diagnostics include calculated items such as hydraulic capture, mass extracted, and plume volume for defined concentration contours. For the stage of transition from P&T to MNA, diagnostics include calculated items such as concentration trends and plume volume. Thus, each stage identifies diagnostic items that need to be calculated from the collected monitoring data.

The “predict” category of activities and analyses recognizes that predictive numerical simulation results underpin the remedy design and RPO, and set the performance expectations based on the design approach. Thus, monitoring results need to be compared to expectations from simulations as a key element of the performance assessment process. The “predict” category identifies the output of simulations that need to be generated to support these comparisons with monitoring data. Within this category, it is also recognized that as the P&T operational configuration evolves as part of RPO, the model may need to be updated.

The “report” category encompasses the synthesis of the data collection, analysis, and comparison to predictions. This category lists the questions and interpretation needed to support remedy management, with an important current part of this effort focused on assessing P&T progress toward goals and the subsequent transition to the MNA stage of the remedy. For the current P&T remedy stage, these interpretations also need to consider the impact of P&T facility operation and performance on meeting plume remediation goals. Thus, the “report” category identifies these elements and points to the *200 West Pump and Treat Operations and Maintenance Plan* (O&M Plan, DOE/RL-2009-124) as part of reporting to evaluate operating conditions, optimization, and performance issues that relate to plume remediation performance.

Based on interpretations in the “report” category, the “optimize” category identifies actions to optimize the remedy components (e.g., well network and pumping rates for the P&T stage) and monitoring (e.g., monitoring well network or sampling frequency), and/or consider whether elements such as hot spot treatment may be warranted. In addition, the “optimize” category recognizes that as data are collected and interpreted, the model may need to be updated to reflect this new information and provide a more defensible basis for RPO and predictions of future plume behavior.

A process and decision chart was developed for each remedy stage. Thus, a decision component is included that defines the decision needed at that stage of the remedy with respect to moving to the next stage or, in the last stage, when the remedy can be transitioned to closure.

2.2 Data and Modeling Analysis Approaches

The 200-ZP-1 OU groundwater plumes are large and complex. An effective design and predictive modeling approach has been developed by the 200-ZP-1 OU project team. This model, and associated data analyses, are incorporated into the process and decision chart as described above, in particular, under the calculate and predict elements for each remediation stage. The objectives for data and modeling analysis include both larger plume-scale objectives and local-scale performance objectives relevant to informing remedy management (Truex and Johnson 2016).

The Hanford-specific recommendation document (Truex and Johnson 2016) described the following plume-scale objectives and analyses that were mapped into the 200-ZP-1 OU PMP:

- Plume mapping – developing plume 2D and 3D contour “shells” that are tracked to evaluate plume dynamics in response to remediation
- Plume-scale mass and concentration trends – use of standard approaches to evaluate extraction and monitoring well data in terms of calculating changes in plume mass, mass extraction, and plume average concentration changes
- Plume attenuation analysis – use of plume-scale analysis to estimate the rate of attenuation of the plume, including use of predictive modeling to assess fate and transport of the plume
- Plume-scale threshold concentration analysis – evaluating plume fate and transport to identify plume concentration conditions at the end of P&T that are low enough that the plume can be attenuated to meet RAOs if P&T is terminated

The Hanford-specific recommendation document (Truex and Johnson 2016) described the following local-scale objectives and analyses that were mapped into the 200-ZP-1 OU PMP:

- Combined capture analysis and concentration trend data at individual wells – comparing predicted and measured responses at local regions of the aquifer to determine if the plume is behaving differently than expected and in a way that suggests either 1) a continuing source, 2) a different plume configuration than anticipated (e.g., plume hot spots), or 3) a need for optimizing pumping to improve capture within a local plume zone
- Rebound testing – use of standard approaches to evaluate extraction and monitoring well data in terms of calculating changes in plume mass, mass extraction, and plume average concentration changes

Plume-scale analyses focus on assessing the following performance elements, consistent with the approaches described in more detail in Truex and Johnson (2016). Hydraulic conditions (e.g., gradients and, for the P&T remedy stage, capture) coupled with plume-shell (contour interval zones) volume/area and plume-scale metrics like the 95% upper confidence limit concentration within plume shells serve multiple purposes. This information is an overall measure of plume diminishment during P&T and MNA stages of the remedy. The information is also important for transition from P&T to MNA because the plume characteristics at transition need to be quantified and used to evaluate whether the plume can be expected to attenuate within the time and attenuation zone (Truex et al. 2015) defined for the MNA remedy stage. Thus, plume-scale metrics of plume characteristics are a key part of data analysis. They also provide quantitative values that can be compared to expectations of plume conditions during the course of the remedy produced by predictive modeling. Plume mass and mass extraction (for the P&T remedy stage) are metrics that can be applied to track progress in diminishing the plume and can also be compared to predictive model estimates. These metrics are not directly related to plume size or concentrations, so they are helpful for nominal tracking of progress, but must be combined with plume distribution and concentration information to evaluate transition from P&T to MNA. For the P&T stage, and potentially during the 200-ZP-1 OU MNA stage, if the P&T continues to be used for treatment of water from other OUs, characteristics of the P&T effluent that is injected into the aquifer are an important part of assessment to track overall chemical and hydraulic impact on the aquifer from P&T operations.

Because the 200-ZP-1 OU P&T system receives inflow from other OUs, the P&T effluent may contain constituents that need to be tracked to ensure that water quality of the aquifer is not negatively impacted.

While the plume-scale metrics relate to many of the remedy management needs, local-scale analyses are also needed. In the 200-ZP-1 OU PMP, for the P&T remedy stage, measured individual-well capture zones, mass extracted, and contaminant concentration trends are collectively used for comparison to predicted behavior at the local scale. When measured metrics depart from predicted behavior, the data are used to determine RPO needs, provide input to quantification of continuing sources or persistent plume zone, refine plume concentration/mass estimates, or support evaluation of other potential remedial options to address localized areas not appropriately responding to P&T. For all stages of the remedy (e.g., P&T, transition, MNA, and attainment), individual well contaminant and other constituent trends are needed for direct comparison to goals for each stage and/or to the RAOs.

Also for the P&T stage, and potentially during the 200-ZP-1 OU MNA stage, if the P&T continues to be used for treatment of water from other OUs, P&T operational data are needed as input to the performance assessment. System extraction and injection flow rates and effluent characteristics are driving forces for plume dynamics. Therefore, these metrics need to be tracked and used in conjunction with the groundwater data described above for interpreting plume behavior over the course of the P&T remedy.

Data analysis for transition from P&T to MNA are associated with two assessment elements. Determining the appropriate transition time is based on evaluation of plume conditions with use of a model to predict whether the plume will attenuate within the time and attenuation zone (Truex et al. 2015) defined for the MNA remedy stage. Thus, as the transition time is approached, a series of predictive simulations needs to be applied to evaluate plume behavior and identify the appropriate plume condition for transition. While some general transition metrics can be set up front (e.g., diminishing plume mass by 95% and having concentrations below 100 µg/L), the distribution and location of the plume at the time transition is being considered need to be evaluated in the context of the attenuation rate and attenuation zone selected for the MNA stage of the remedy. As such, the decision is related to defining appropriate threshold concentration distributions that will allow MNA to meet the RAO (Truex and Johnson 2016). For the second assessment element, when P&T shutdown is contemplated based on plume concentrations, it is necessary to verify that the concentration observed during P&T will remain at or below targets for transition after the P&T system is shut down. Thus, rebound testing, where the P&T system is shut off for a specified period of time while concentrations are monitored, is an element of the transition assessment (Truex and Johnson 2016).

The above data and modeling analysis approaches are consistent with those described by Truex and Johnson (2016) associated with plume/source dynamic evaluation, continuing source evaluation, integration of capture zone and contaminant trend analysis, use of overall plume trends, and threshold analysis and rebound testing to support transition from P&T to MNA.

3.0 Remedial Design/Remedial Action Work Plan for the 100-HR-3 Operable Unit

For the 100 Areas, transition from P&T to MNA is not identified in remedy documents. However, P&T systems target chromium plumes that are being diminished and are receding away from the river (DOE 2015a) such that attenuation of a plume that meets aquifer concentration objectives may allow for concentrations in the aquifer that are greater than the more-stringent river protection standards. The 100-HR-3 OU P&T system RD/RAWP is being prepared and includes a design and strategy for P&T implementation and closure that is consistent with the P&T guidance (Truex et al. 2015) and Hanford-specific recommendations (Truex and Johnson 2016). This section describes how these elements are being incorporated into the draft 100-HR-3 OU RD/RAWP. Essentially, the same elements from the P&T guidance and Hanford-specific recommendations that were mapped to the 200-ZP-1 OU PMP were mapped to the 100-HR-3 OU RD/RAWP, but in a way that is consistent with the content of a work plan rather than a performance monitoring plan.

The following phases for cleanup are included in the draft RD/RAWP: P&T Operations, P&T Shutdown Evaluation, and RAO Attainment. For the 100-HR-3, the remedy includes treatment of the hexavalent chromium (Cr(VI)) plume in the unconfined aquifer, investigation of contamination in an underlying semi-confined aquifer within a different hydrogeologic unit (which may lead to additional remedy actions), and continued evaluation of secondary and ongoing sources (which may lead to additional remedy actions). The discussion herein focuses on the P&T system as applied to treatment of the Cr(VI) plume in the unconfined aquifer.

For the P&T Operations phase, the draft RD/RAWP calls for selecting and implementing a P&T well network for plume diminishment and river protection. Simulations of plume behavior and existing data from P&T operations inform the remedy design. The well network design focuses on capture of the plume to protect the river and diminish the inland plume. This design approach is consistent with setting up a situation where the P&T can be shut down with plume concentrations away from the river at concentrations that meet aquifer RAOs but that are higher than the river RAOs because attenuation of the plume will occur to maintain river RAOs over time. Performance monitoring will include wells along the river that demonstrate protectiveness (augmented by aquifer tube data), and inland wells monitoring plume dynamics as the plume is diminished and separated from the river. As the plume shrinks and performance wells are shifted inland, predictions of plume attenuation during remedy operation can be used to identify when and where cleanup can be achieved. Evaluation of the inland plume conditions, distance from the river at Cr(VI) concentrations above 10 µg/L, and attenuation will be used to identify P&T design targets that will define the exit strategy for P&T operations.

Because the plume conditions will be dynamic during P&T, the predicted transition conditions are estimated at the onset of the work plan effort and over time, as the plume is diminished and the transition time is approached. The simulations in the draft RD/RAWP identify plume conditions at the end of P&T operations that will meet the aquifer RAO (48 µg/L) and the river protection RAO (10 µg/L). The draft RD/RAWP also identifies monitoring and rebound testing that will be used for verification that the RAOs are met and maintained over time. Separating the plume from the river will maintain river protection while evaluating rebound effects as part of the P&T Shutdown Evaluation phase.

A monitoring network will be established to demonstrate performance and compare the measured concentrations to predicted concentration. The monitoring network will include wells to evaluate river protection (i.e., the performance wells closest to the river) downgradient of inland wells for performance monitoring. As necessary, targeted restarts of P&T could be instituted until conditions for full termination are reached. This verification monitoring and associated P&T rebound testing would then transition into compliance monitoring of the post-P&T RAO Attainment phase monitoring. This approach is consistent with the P&T guidance (Truex et al. 2015) and Hanford-specific recommendations (Truex and Johnson 2016), incorporating elements such as an attenuation zone, threshold concentration determination, comparison of monitoring data and predictive results, and application of verification monitoring.

Continuous performance monitoring during the P&T Operations phase is a component of the draft RD/RAWP and is consistent with the P&T guidance and Hanford-specific recommendations. Elements of the performance monitoring will include monitoring for contaminants of concern, water level, water quality constituents related to remedy performance, and P&T operational parameters related to plume objectives (e.g., injection flow rate). These data will be evaluated to quantify 1) how the remedy is affecting the plume dynamics (e.g., plume capture, mass extraction trends, and plume volume change trends) and 2) local conditions at individual monitoring and extraction wells (e.g., local hydraulic capture, trends in individual well concentration and mass extraction) for conditions and trends that can be interpreted to support RPO and to assess the potential for continuing sources.

Numerical simulations of plume-scale and individual well predicted performance will be conducted and updated as necessary for comparison to monitoring data. These evaluations will support analysis of remediation progress toward RAOs and to support RPO. For instance, performance monitoring of this type may show plume areas with persistent concentrations and areas of groundwater stagnation. Cyclic operation of the P&T system and realignment of wells may be used to target locations to enhance mass removal, enhance migration rates to extraction wells, eliminate stagnation zones, and expedite mass recovery.

This approach will compile information on P&T remedy performance to use in conjunction with an exit strategy as discussed above to determine when (all or part of) P&T should be terminated. For instance, targeted P&T rebound assessments and cyclic P&T operations may be applied based on plume responses, and may lead to partial shutdown for some plume zones of P&T or intensified P&T operations in other plume zones as part of RPO. This approach is consistent with the monitoring and performance assessment elements included in the 200-ZP-1 OU PMP. Thus, a similar PMP approach and related benefits for performance assessment and remedy management can be applied for the 100-HR-3 OU.

4.0 Discussion

In fiscal year 2017, PNNL worked with 200-ZP-1 OU and 100-HR-3 OU staff in preparing OU documents associated with implementation of P&T remedies. In these efforts, elements of the P&T guidance (Truex et al. 2015) and Hanford-specific recommendations (Truex and Johnson 2016) were incorporated into the draft OU documents. Because the 200-ZP-1 and 100-HR-3 OU documents were still at a draft stage at the time this report was written, information herein is provided as an example of the mapping of guidance elements to remedy transition and closure. Final remedy documentation for these OUs should be consulted for specific information on OU plans and activities.

The PMP effort for the 200-ZP-1 OU demonstrated several important aspects of defining monitoring and data analysis for a remedy to support managing the transition from P&T to MNA. The usefulness of a PMP is intended to be different than a sampling and analysis plan in that a PMP describes the data analysis, in addition to the data needs, that are required to support remedy management. Incorporating a decision chart approach provides a structure to 1) identify the stages of remedy implementation and specifically include transition from P&T to MNA; 2) include monitoring, data analysis, reporting, and optimization actions that provide the technical basis to support the transition; and 3) define decision steps associated with remedy management and transition. The decision elements described in the P&T guidance (Truex et al. 2015) can be inserted as elements in the decision chart. Thus, the decision chart should include 1) collecting data and analyzing contaminant trends relevant to performance assessment; 2) evaluating mass discharge and concentration data to identify potential persistent plume zones or continuing sources; 3) compiling information and applying modeling to interpret the attenuation capacity of the aquifer and the potential for natural attenuation to meet RAO as the plume changes in response to P&T; and 4) relating plume assessment to the P&T system configuration and operational conditions, which may need to change over time to optimize the ability of P&T to achieve a plume condition that is appropriate for transitioning to MNA. Use of rebound testing, as described in both the P&T guidance and Hanford-specific recommendation documents, is a key activity at the time of transition from P&T to MNA to verify that appropriateness of the transition timing.

The Hanford-specific recommendations (Truex and Johnson 2016) relate to the PMP decision chart through the inclusion of both plume-scale and local-scale metrics. In particular, Hanford OUs have the advantage of having well-developed predictive-modeling support. Thus, the plume-scale metrics of plume mass, volume, location, and concentration shells can be monitored and compared to simulation results as an important metric within the decision chart. In addition, the simulations provide local-scale expectations within individual extraction well capture zones that are important for assessing P&T performance and the potential presence of persistent plume zones or continuing sources. Finally, the predictive modeling supports defining the application of threshold concentration assessment and evaluation of expected future plume behavior described in both the P&T guidance and Hanford-specific recommendation documents. Thus, predictive assessment is an important element of a PMP to guide interpretation and support remedy management, especially in relation to P&T transition.

The RD/RAWP effort for the 100-HR-3 OU demonstrated how setting a P&T strategy at the work plan stage provides a structure for remedy implementation and management where near-term actions stay focused on the needs for meeting RAOs and providing the information needed to manage the near-term actions and the transition to subsequent remedy stages. The RD/RAWP is strengthened through use of predictive simulations to provide targets for the plume conditions that will meet both aquifer and river protection objectives, recognizing that plume concentrations in the aquifer may be above the river protection concentration standards outside the river protection compliance area. Application of threshold concentration assessment and evaluation of expected future plume behavior described in both the P&T guidance and Hanford-specific recommendation documents relates to this RD/RAWP content. The RD/RAWP also needs to set the stage for a PMP, as described above for the 200-ZP-1 OU. A key difference for the 100 Areas compared to the 200-ZP-1 OU is that MNA is not identified as a stage of the remedy after P&T. However, P&T systems need to target diminishing chromium plumes so that they recede from the river to create conditions where attenuation of the plume will meet aquifer concentration objectives and the more-stringent river protection standards at the location of the river (as defined by a compliance monitoring location). Thus, the PMP elements from the 200-ZP-1 OU are still relevant in terms of describing the process to collect and analyze data that defines plume conditions appropriate for P&T termination. As part of the remedy plan in the RD/RAWP, consistent with the PMP approach, clearly defining a rebound testing element is important to show how the timing of the transition will be managed and verified.

Implementing the PMP and RD/RAWP described in this report will require data analysis and interpretation to support remedy management decisions. The 200-ZP-1 OU and the 100-HR-3 OU have systems in place to support this type of data analysis, including appropriate numerical models. A suite of web-based analysis tools is being developed to enhance retrieval and analysis of water-level and plume data. Appendix A provides a synopsis of the status of these web tools at the time of this report.

5.0 Quality Assurance

The PNNL Quality Assurance (QA) Program is based upon the requirements as defined in DOE Order 414.1D, *Quality Assurance*, and 10 CFR 830, *Energy/Nuclear Safety Management*, Subpart A – Quality Assurance Requirements. PNNL has chosen to implement the following consensus standards in a graded approach:

- ASME NQA-1-2000, *Quality Assurance Requirements for Nuclear Facility Applications*, Part 1, Requirements for Quality Assurance Programs for Nuclear Facilities.
- ASME NQA-1-2000, Part II, Subpart 2.7, Quality Assurance Requirements for Computer Software for Nuclear Facility Applications, including problem reporting and corrective action.
- ASME NQA-1-2000, Part IV, Subpart 4.2, Guidance on Graded Application of Quality Assurance (QA) for Nuclear-Related Research and Development.

The procedures necessary to implement the requirements are documented through PNNL's "How Do I…? (HDI), a system for managing the delivery of laboratory-level policies, requirements and procedures.

The *DVZ-AFRI Quality Assurance Plan* (QA-DVZ-AFRI-001) is the minimum applicable QA document for DVZ-AFRI projects under the NQA-1 QA program. This QA Plan also conforms to the QA requirements of DOE Order 414.1D, *Quality Assurance*, and 10 CFR 830, Subpart A, *Quality Assurance Requirements*. The DVZ-AFRI is subject to the *Price Anderson Amendments Act*.

The implementation of the DVZ-AFRI quality assurance program is graded in accordance with NQA-1-2000, Part IV, Subpart 4.2, Guidance on Graded Application of Quality Assurance (QA) for Nuclear-Related Research and Development.

Three technology levels are defined for this DVZ-AFRI QA Program:

Basic Research consists of research tasks that are conducted to acquire and disseminate new scientific knowledge. During basic research, maximum flexibility is desired in order to allow the researcher the necessary latitude to conduct the research.

Applied Research consists of research tasks that acquire data and documentation necessary to assure satisfactory reproducibility of results. The emphasis during this stage of a research task is on achieving adequate documentation and controls necessary to be able to reproduce results.

Development Work consists of research tasks moving toward technology commercialization. These tasks still require a degree of flexibility and there is still a degree of uncertainty that exists in many cases. The role of quality on development work is to make sure that adequate controls to support movement into commercialization exist.

Research and Development Support Activities are those that are conventional and secondary in nature to the advancement of knowledge or development of technology, but allow the primary purpose of the work to be accomplished in a credible manner. An example of a support activity is controlling and maintaining documents and records. The level of quality for these activities is the same as for developmental work.

Within each technology level, the application process for QA controls is graded such that the level of analysis, extent of documentation, and degree of rigor of process control are applied commensurate with their significance, importance to safety, life cycle state of a facility or work, or programmatic mission. The work for this report was performed under the technology level of Development Work.

6.0 References

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Appendix A

Web-Based Water-Level and Plume Analysis Tool Status

Appendix A

Web-Based Water-Level and Plume Analysis Tool Status

The web-based water-level and plume tools are part of a suite of web-based tools. The following sections describe this tool suite at the time of this report.

A.1 SOCRATES (Suite Of Comprehensive Rapid Analysis Tools for EStimation)

SOCRATES is being developed as an NQA-1 web-based application that encapsulates the analytical approach and thought process of Pacific Northwest National Laboratory (PNNL) subject matter experts familiar with the Hanford Site. SOCRATES is a "living" body of research, essentially providing real-time interaction with scientific research and the end-users of study results to aid decision support for groundwater assessment and remediation activities.

- **SOCRATES.PNL.GOV** v 1.0 has been tested and released, and is currently available to users inside the PNNL network.
- **HTTPS://WWW.SOCRATES.PNNL.GOV** will be available outside PNNL network as of September 28, 2017, but will require authentication. PNNL is preparing a "soft release" externally with focus groups. Adaptations and code updates will be implemented based on initial feedback from focus group users, and the tool will be available without authentication in early FY18.

SOCRATES is developed on top of computational algorithms to support an end-to-end workflow. Distinguishing itself from "Data Access and Visualization" tools, SOCRATES provides an analytical framework for quantitative-based decision support relevant to mission objectives at the Hanford Site. Socrates embraces a fluid and modular framework, having separate functional components that meet very specific objectives.

SOCRATES is a Single Page Application (SPA), which is a fluid architectural and design approach that looks and feels more like "native" software (desktop – download and install), and less like web pages (Figure A.1). SOCRATES is the basic framework for a very modular design, meaning that new modules or applications can be imbedded and updated, without changing the design or interactive feeling of the application. In practical terms for code configuration management and updates, this means that code updates are a lower level of effort compared to the older convention of managing a series of different web pages. In an older paradigm, prior to SPA, each application was managed as a separate code base, each of which may have pointed to different code libraries.

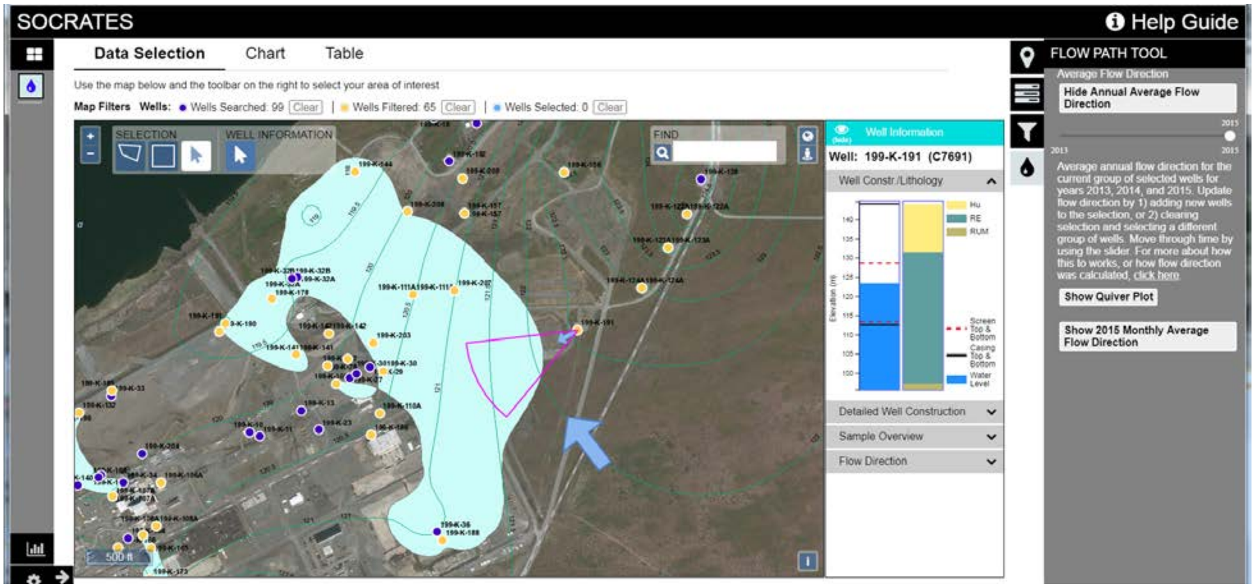

Figure A.1. Well pop-up information with relevant data, including well construction, derived nominal water level, and geology at well.

Modules planned within SOCRATES include GALEN (**G**roundwater **A**na**L**ytics for **EN**vironment) and PLATO (**PL**ume **A**nalysis **TO**ol), as described below.

A.2 GALEN (Groundwater AnaLytics for ENvironment)

The GALEN module (Figure A.2) ***functionality*** currently includes the following:

- Interactive groundwater flow direction at annual time intervals (2013 to 2015) based on Hanford Annual Groundwater Reports, and monthly time intervals based on PNNL groundwater elevation mapping
- Outlier analysis and data smoothing algorithms to highlight seasonal and annual trends in current and historical groundwater level data
- Data filtering by primary hydrogeologic unit, which accounts for well construction, screen interval, real-time nominal water level, and site-wide geologic framework

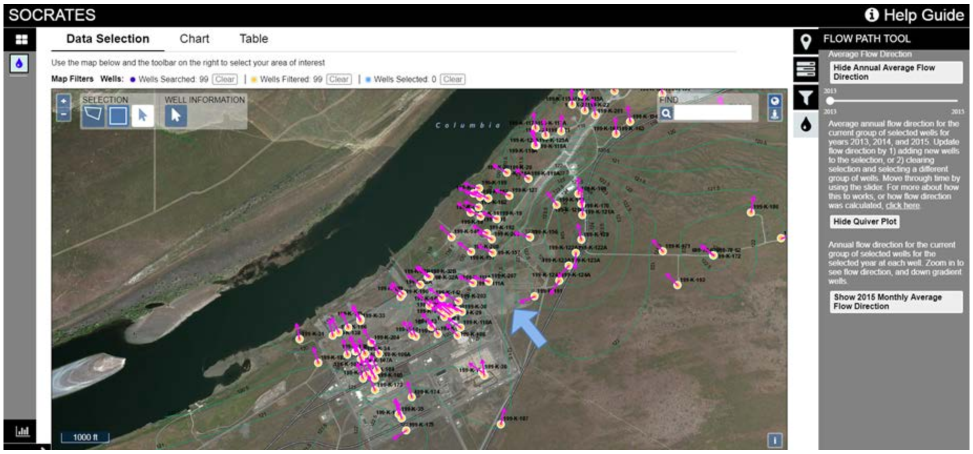

Figure A.2. Annual flow direction within area of selected wells, and quiver plots at each well. A slider bar in the right panel enables user to animate through time.

The GALEN module core data ***content and accessibility*** currently includes the following:

- Seamless use of the Automated Water Level Network (AWLN), manual measurements, and 300 Area network measurements, including data fusion and standardization of all sources of water level data
- All common GIS layers, hydrogeology by well, and most recent sample results for contaminants of potential concern

A.3 PLATO (PLume Analysis TOol)

The PLATO module (Figure A.2) ***functionality*** currently includes the following:

- Quantitative, defensible estimates of plume dynamics for pump-and-treat (P&T) performance assessment, as described in Truex and Johnson (2016)
  - Apply standard statistical methods and U.S. Environmental Protection Agency data analysis (EPA 2002) to quantify plume dynamics
    - Single-well rate of concentration change
    - Rate of change in average concentration (mass) of plume based on data from multiple wells
    - Change in concentration over time/distance between two wells on the same flow path
- Access to relevant data (e.g., Hanford Environmental Information System, AWLN, lithology)
- Easy-to-use, consistent, quality data analysis
  - Select wells that are relevant (spatially, hydrogeologically, temporally)
  - Simplify data processing steps (timeframes, aggregation)
  - Display information in a meaningful context on maps and plots
- Indication of monitoring approaches/locations needed for data analysis

A.4 References

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