Passive Groundwater (GW) Sampling: Effective Tools to Transition Your Program

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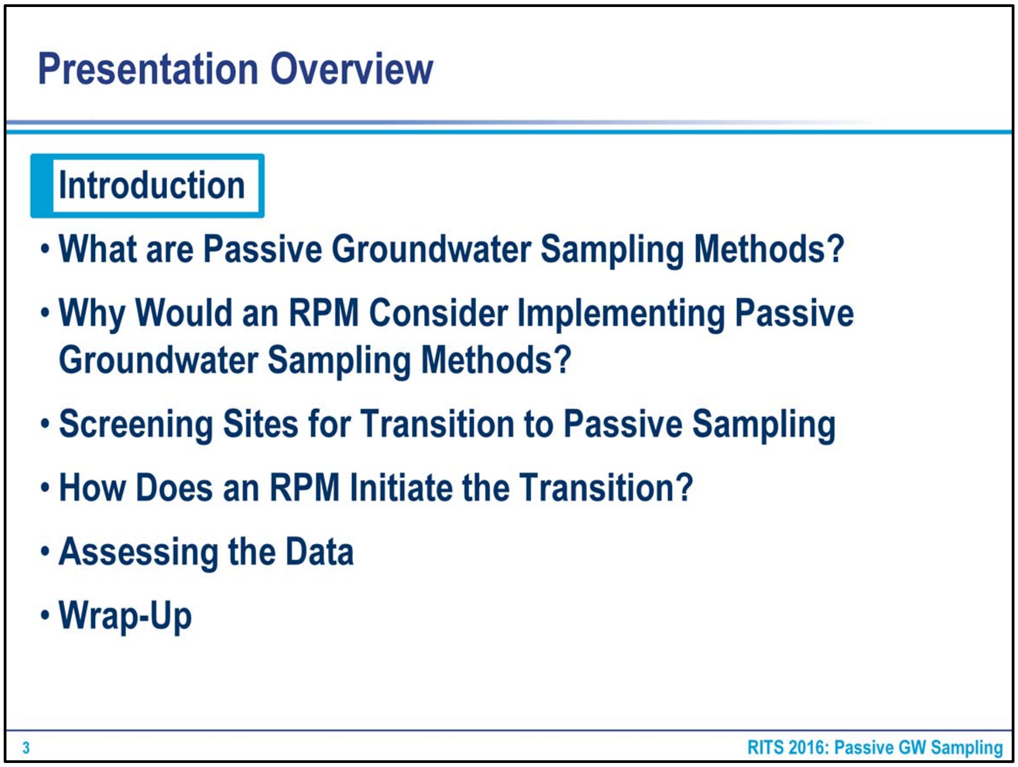


This presentation focuses on the implementation and transiting of groundwater sampling programs to passive sampling. It specifically addresses the issues associated with long-terms groundwater sampling programs, although it can also be applied to short-term sampling programs and one-off events.

Since passive sampler technologies for groundwater monitoring first started to gain traction in the late 2000s they have been the subject of numerous studies and data collection efforts, in particular, since the last RITS presentation in 2013 and publication of ITRC guidance documents in 2006 and 2007 a number of large datasets and statistical comparisons have been completed which have begun to influence implementation processes. In addition, a greater understanding of the sources of variability in broader groundwater sampling programs, regardless of sampling method, as allowed passive sampling data to be reviewed in the context of inherent variability.

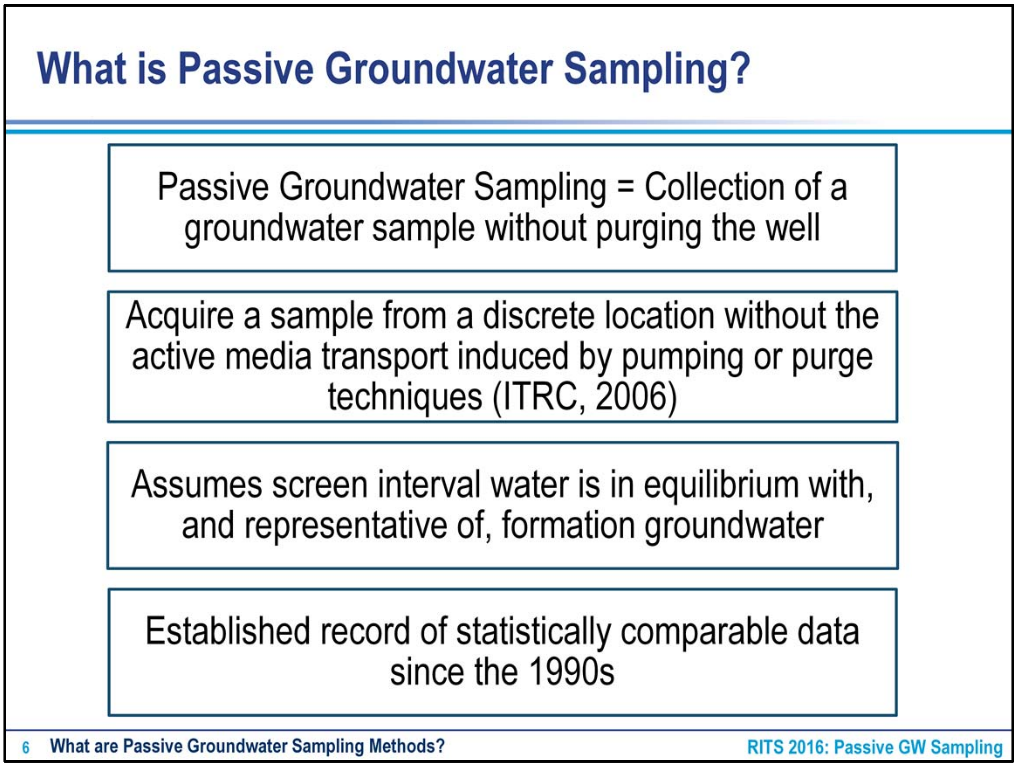
The information contained in these slides will build on the 2013 RITS presentation as well as internal and external guidance documents and literature, to provide an updated status of the technology which includes recent relevant studies and details on how to implement a transition to passive samplers. Significant details on each sampler type as well as their individual pros and cons and specifics can be easily accessed elsewhere, and at the references and resources shown in later slides (Slides 12-13) and are not the focus of this presentation.

Introduction and Objectives

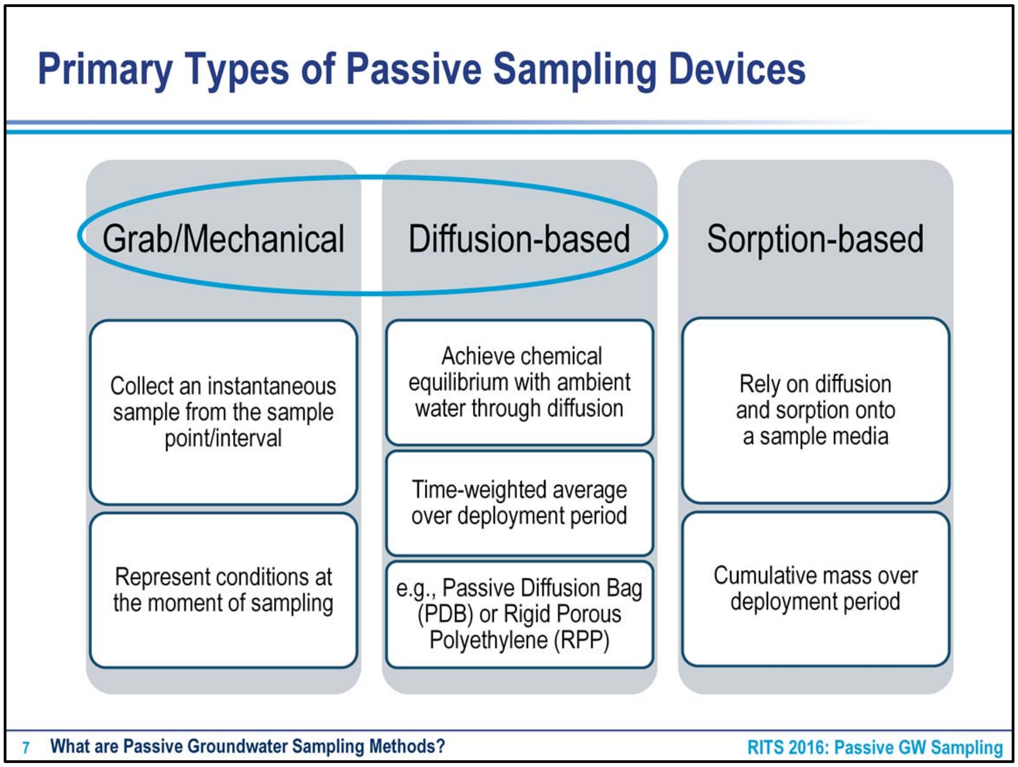
- Passive groundwater sampling is becoming increasingly accepted by regulatory agencies
- Numerous studies now exist to support that passive methods collect comparable data to traditional sampling methods
- Information in this presentation is intended to support RPMs with implementing a passive GW sampling program
  - Examples and case studies through each stage of implementation to analysis of the data are provided
  - Expand on prior presentations and fact sheets, including the 2013 RITS presentation Passive Sampling Techniques for Groundwater and Sediment Sites

Presentation Overview

- Introduction
- **What are Passive Groundwater Sampling Methods?**
- Why Would an RPM Consider Implementing Passive Groundwater Sampling Methods?
- Screening Sites for Transition to Passive Sampling
- How Does an RPM Initiate the Transition?
- Assessing the Data
- Wrap-Up



The key assumption behind passive groundwater sampling methods is that water inside the screen interval is representative ambient groundwater. This assumption based on the fact that the wellbore hydraulic conductivity is higher than that of the surrounding formation in almost all geologic settings. This allows groundwater to easily move into and toward the well and constantly flushes the open interval of the well in what is essentially a natural purging effect that has been demonstrated in numerous studies and models. A similar principal also forms the basis of low-flow sampling methods. This natural purging effect results in water quality within the well screen that is representative of the formation surrounding the well, without the need for additional purging.



Each of the three primary types of passive sampling devices generate different types of data. Key take-away: Each sampler category and device type fundamentally collects different types of data, which can correlate, but not always due to these fundamental differences. The examples shown are intended to support an understanding of what each type of sampler is and are not a recommendation or endorsement of a particular sampler. Other examples of samplers are shown in the ITRC guidance documents (2006, 2007) and the past RITS presentation (2013) referenced on Slides 12 through 14.

The sorption-based samplers can provide an indication of mass-flux, but do not yield a concentration-based result, which is what we are typically interested during long-term monitoring programs, as such, this presentation is focused on grab/mechanical and diffusion based samplers.

Grab/mechanical samplers, provide a sample representative of the concentrations in the formation at the time of sampling, however, these samplers do collect different data.

Diffusion-based samplers collect a time-weighted average concentration, which can correlate to an instantaneous sample assuming minimal temporal changes over the equilibration period. Depending on the length of the sampler, they can be representative of discreet zones within the screen, or an average over the screen interval, for longer samplers.

Passive/Polyethylene Diffusion Bags (PDBs)

- Established method for select VOCs
- Can be placed in series/depth specific profiling
- Can provide 200 to 350 mL (per ~4 feet) of sampling in a 2-inch well
- Semi-permeable membrane filled with deionized (DI) water, through which VOCs permeate
  - Limited analytes: Not appropriate for metals, inorganics, and large or polar organic compounds
- Variable diffusion rates; equilibrium important
- Simple to install, low capital costs

Source: ITRC 2006

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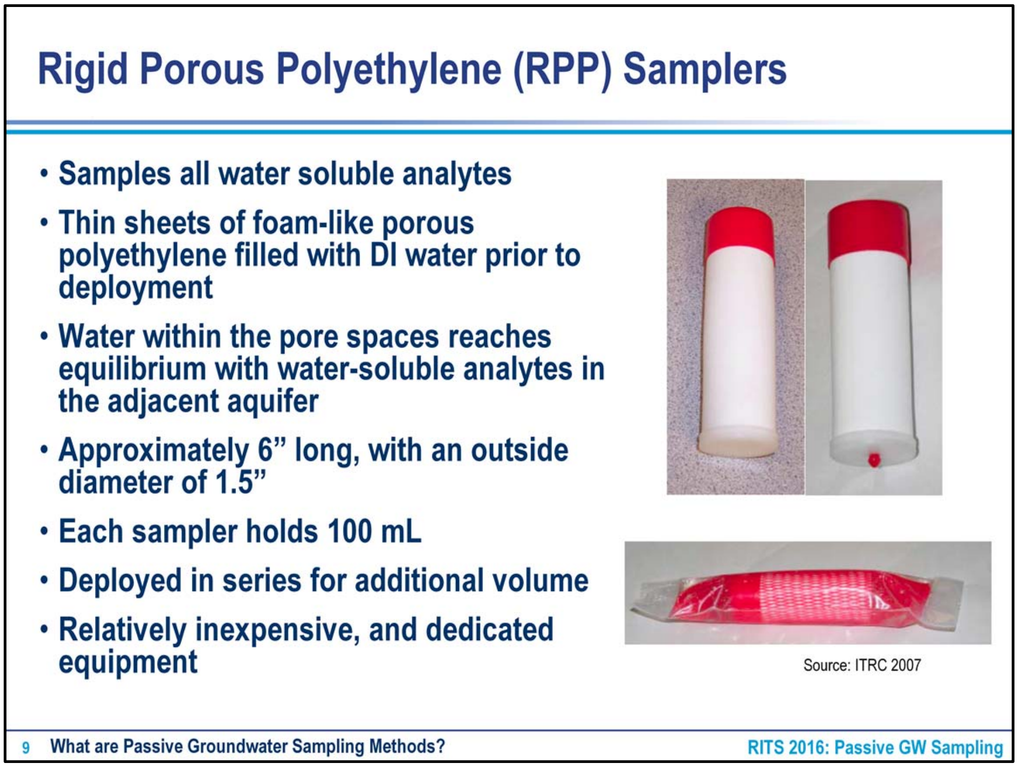
A typical passive diffusion bag consists of a low-density polyethylene tube, closed at both ends, containing deionized water positioned by attachment to a weighted line. The PDB is left in the well for a period of time to equilibrate. There are two equilibration factors relating to passive samplers, which are termed here: hydraulic equilibrium and chemical equilibration. The hydraulic equilibration applies to all downhole passive samplers and is the time taken for the environmental disturbance created by sampler deployment to return to ambient conditions, this is dependent on the rate of recharge of a well and is often rapid, particularly if low volumes of water are disturbed/displaced. The chemical equilibration applies to diffusion based samplers only and is the time for deionized water to reach chemical equilibrium with the ambient groundwater quality. This is governed by the type of compound being sampled and water temperature and typically is taken as 2 weeks, although it can be much shorter.

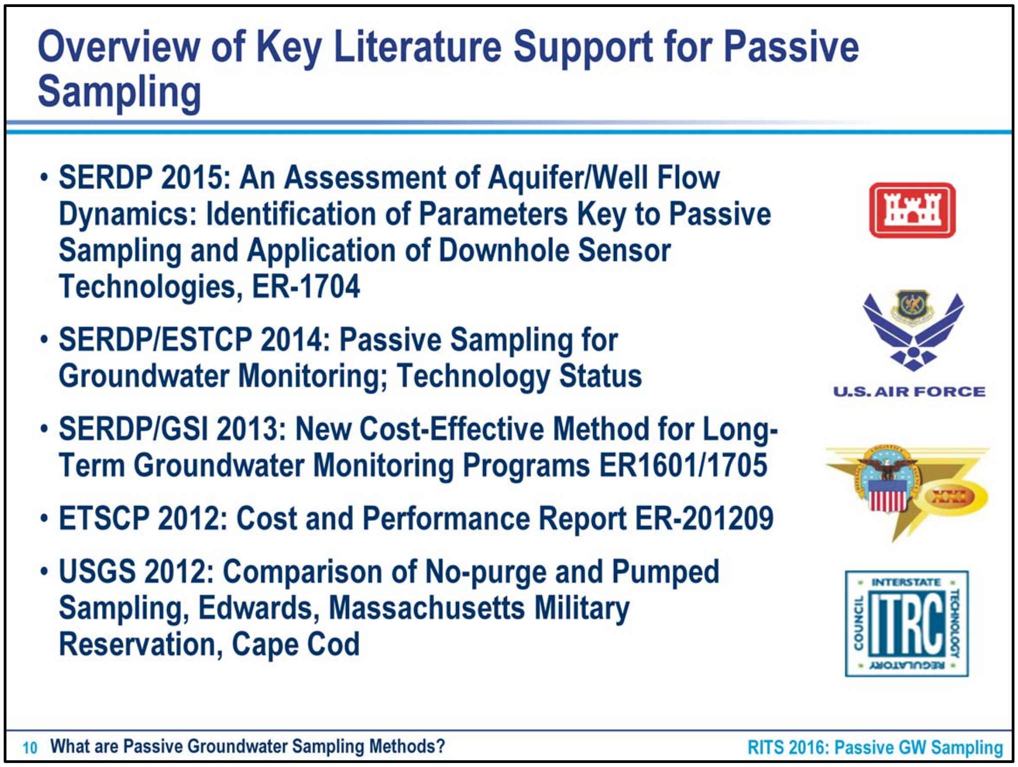
PDBs can be created to different lengths, typically between 1-2 feet long for ease of deployment and for minimal VOC requirements, however, the standard USGS samplers is 45 cm (3.75 ft) and holds 300 mL in a 2 inch well.

Diffusion is straight molecular diffusion (e.g., molecule in air, molecule in water, etc.). Permeation through a membrane has both solubility and diffusion considerations. In the PDB context, the analyte must first dissolve in the PDB (solubility) and then diffuse through it (diffusion). So, in actuality compounds permeate into the PDB, rather than diffuse.



The RPP is filled with deionized water and capped at either end and placed inside a mesh lined for deployment. Constituents diffuse into the porous material and equilibrate with water within the pore spaces of the sample.

While they are suitable for most constituents, additional equilibration timeframes have been noted for some less-soluble VOCs and SVOCs. They must be stored and shipped fully immersed in deionized water and are not suitable for wells smaller than 2” in diameters. They may have some additional complications for SVOCs, as described in the ITRC 2007 guidance documents.



There are a number of documents that already exist which establish the validity of these methods. A few of these documents are summarized above and in the list below. The intent of this presentation and the strategy of implementation described here in is to build of the already established literature.

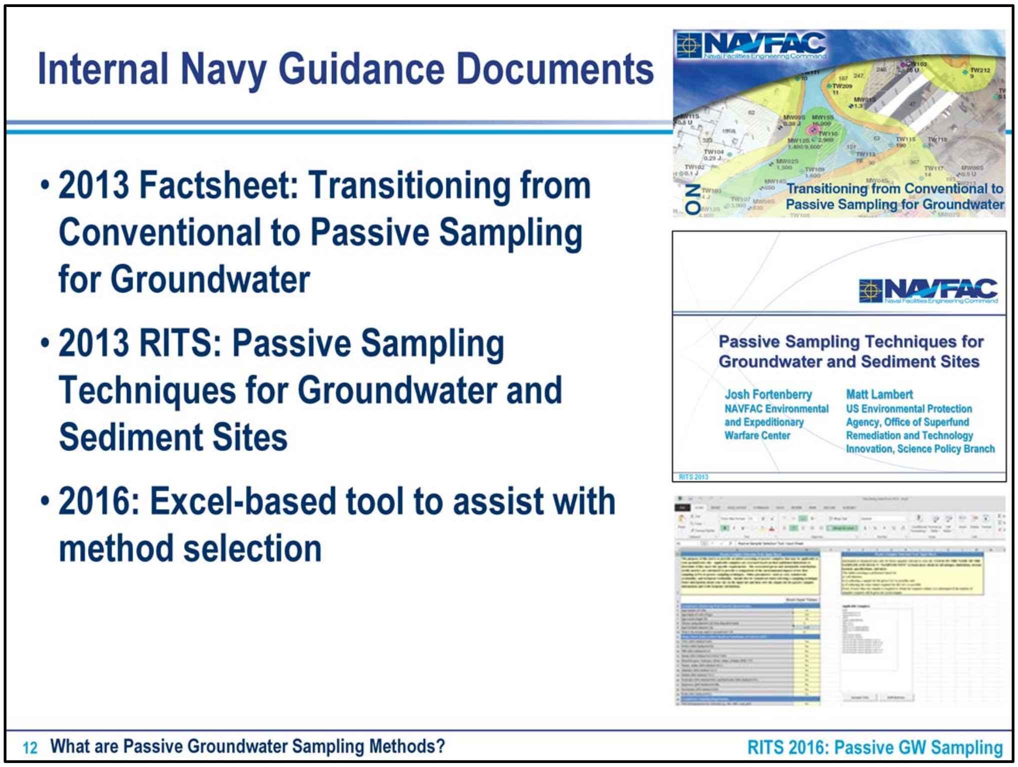
Additional relevant information includes, but is not limited to:
ASTM Standard D7929-14: Standard Guide for Selection of Passive Techniques for Sampling Groundwater Monitoring Wells
SERDP (2013), Improved Understanding of Sources of Variability in Groundwater Sampling for Long-Term Monitoring Programs, by GSI Environmental, February 2013, SERDP Project ER-1705
ITRC (2004) Technical and Regulatory Guidance for Using Polyethylene Diffusion Bag Samplers to Monitor Volatile Organic Compounds in Groundwater, February 2004
AFCEE/ERS 2003: Comprehensive Results Report for PDBS Demonstration - 14 DoD sites

2016 – Internal Draft Stage – EPA is completing a Technical Memorandum on the “Process for Evaluation of Sampling Methods for Groundwater” including transitioning from active to passive sampling

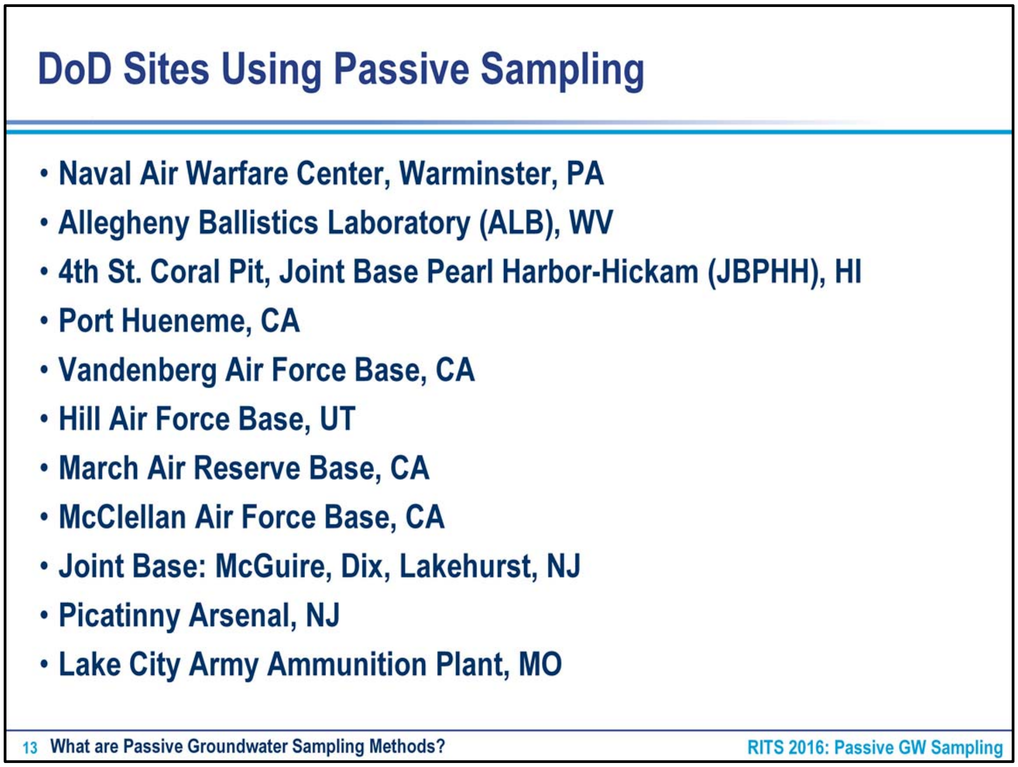
- Focus San Fernando Valley Superfund Site

Overview of Key Literature Support for Passive Sampling (cont.)

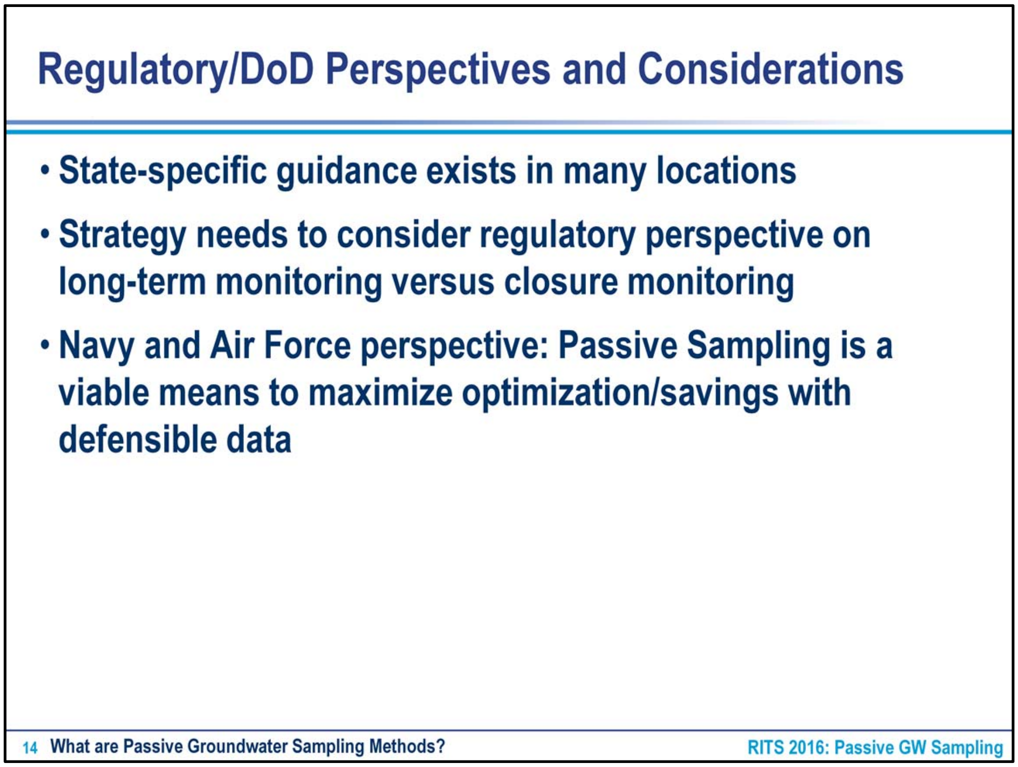
- ITRC 2007: Protocol for the Use of Five Passive Samplers to Sample for a Variety of Contaminants in Groundwater
- ITRC 2006: Technology Overview of Passive Samplers
- USACE/AFCEE/AFRPA/DLA 2005: Results Report Demonstration of No-Purge Groundwater Sampling Devices at Former McClellan AFB
- ITRC: 2004: Technical and regulatory guidance for using PDBs to monitor VOCs in groundwater
- USACE 2002: Study of Five Discrete Interval-Type Groundwater Sampling Devices



In addition to numerous external documents, there are a number of internal Navy tools that address the use of passive groundwater sampling. These are generally consistent with the information in this presentation and where discrepancies exist they are related to changes in thinking and new data since their publication. For instance, the 2013 Factsheet: Transitioning from Conventional to Passive Sampling for Groundwater states a side-by-side comparative study will be a feature of any transition, however, recently some sites have made the transition to passive sampling with out a side-by-side comparison study. Where this is possible it is largely due to positive regulatory experiences in those regions in combination with other comparative studies in similar settings or with similar technologies, and a good understanding of sources of variability.



As an example, the following is a list of Department of Defense sites which had transitioned to some form of passive sampling device as of January 2016. This may not be an exhaustive list, but the number of sites establishes a track record of support for implementation of passive sampling at Department of Defense sites, and provides a dataset that can be leveraged during implementation at your site.

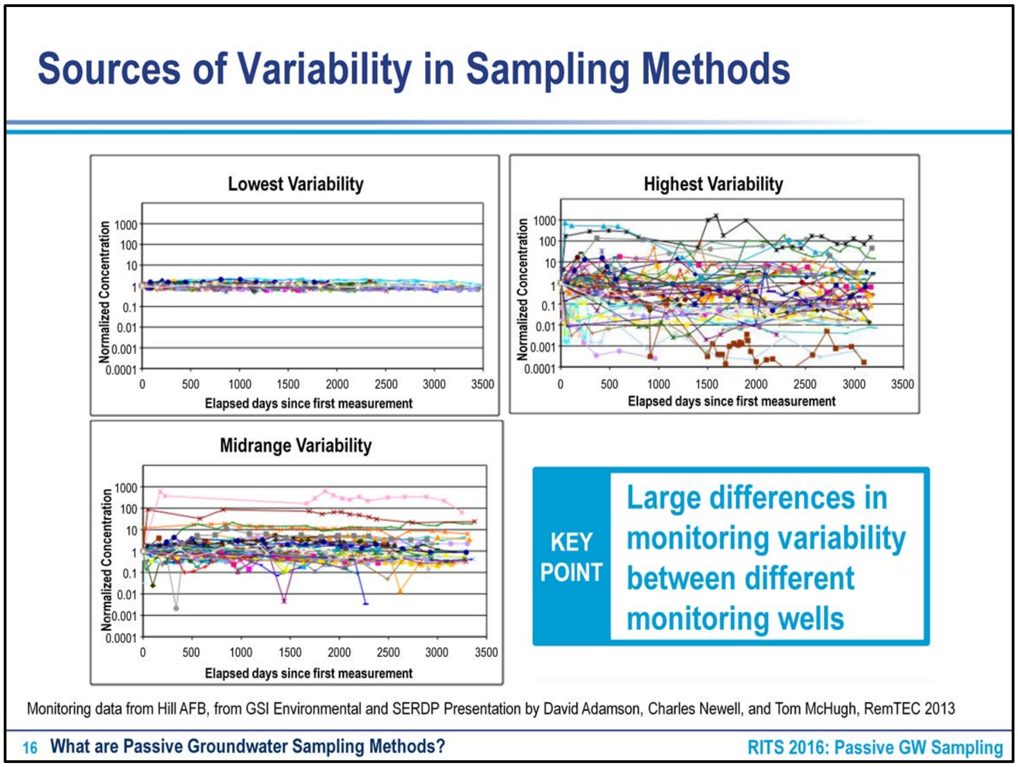


State-specific guidance for implementation and transitions does exist, however, this is not present in all states and the documentation and regulatory requirements for your location and regulatory framework should be carefully reviewed. Implementation of passive sampling devices has been successfully completed even in locations where formal guidance does not exists, and a lack of formal guidance for these technologies does not preclude their implementation. For instance, Hill Air Force Base in Utah has successfully transitioned in the absence of specific regulatory guidance.

EPA support for passive sampling varies from region to region and regulator to regulator. While some regions, e.g., Region 2 and Region 5 are very familiar with passive sampling devices, others, e.g., Region 3 are less familiar and my be more conservative. Overall, regulatory approval is obtained on a site-by-site basis, and while numerous EPA documents discuss passive sampling devices, there is no specific or overarching guidance.

Question Time

- Up Next: Sources of Variability in Sampling Methods
- Before we go…. What questions do you have on passive sampler types or general information?

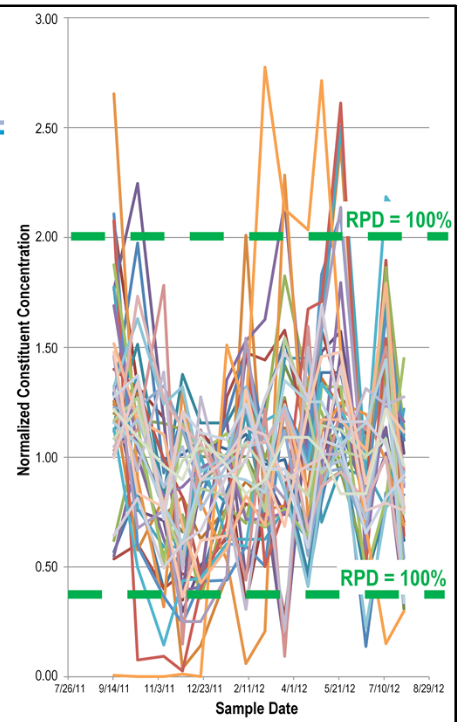


As mentioned in the introductory slides one of the major contributors to the acceptance of passive sampling methods is a body of data which demonstrates comparability, as well as large-data studies on the variability inherent to all groundwater sampling data. One detailed study which expressly discusses these sources of variability is the SERDP 2013 Report, Improved Understanding of Sources of Variability in Groundwater Sampling for Long-Term Monitoring Programs, by GSI Environmental, February 2013, SERDP Project ER-1705. This data was also presented at the RemTEC Conference in Westminster Colorado, in March 2013

As seen in this slide, monitoring wells have inherent variability with time, with some locations exhibiting very low variability and others very high, even when sampled using consistent methods. Understanding the drivers for the sources of variability and determining which category the monitoring wells at your site fit in to can help set expectations for data collected using passive sampling methods versus other traditional methods at your site.

Sources of Variability in Sampling Methods (cont.)

- 8 monitoring wells at Hill AFB
- 5 sampling methods each well (x3 events)
  - Low-flow to parameter stability
  - Low-flow to 24 L
  - No-purge low-flow without mixing
  - No-purge with Snap®
  - No-purge low-flow with mixing
- Inherent short-term variability in all methods



Monitoring data from Hill AFB, from GSI Environmental and SERDP Presentation by, David Adamson, Charles Newell and Tom McHugh, RemTEC, 2013

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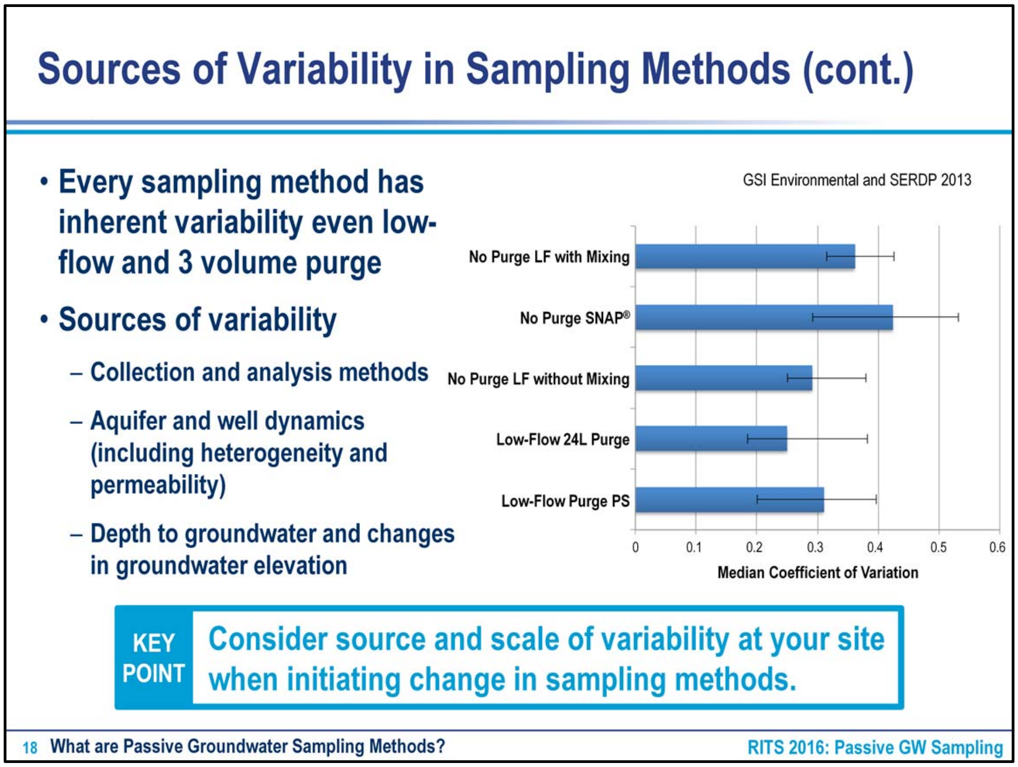
The data shown in the figure on this slide was generated by collecting data from 8 monitoring wells, using 5 different methods, for 3 event, 23 days apart. The data was analyzed for benzene, ethylbenzene, vinyl chloride, chlorobenzene and 1,1-dichloroethane at each well. The individual concentrations measurements were normalized by diving by the average of the 15 concentrations measurements for the 5 sampling methods for that constituent/well pair.

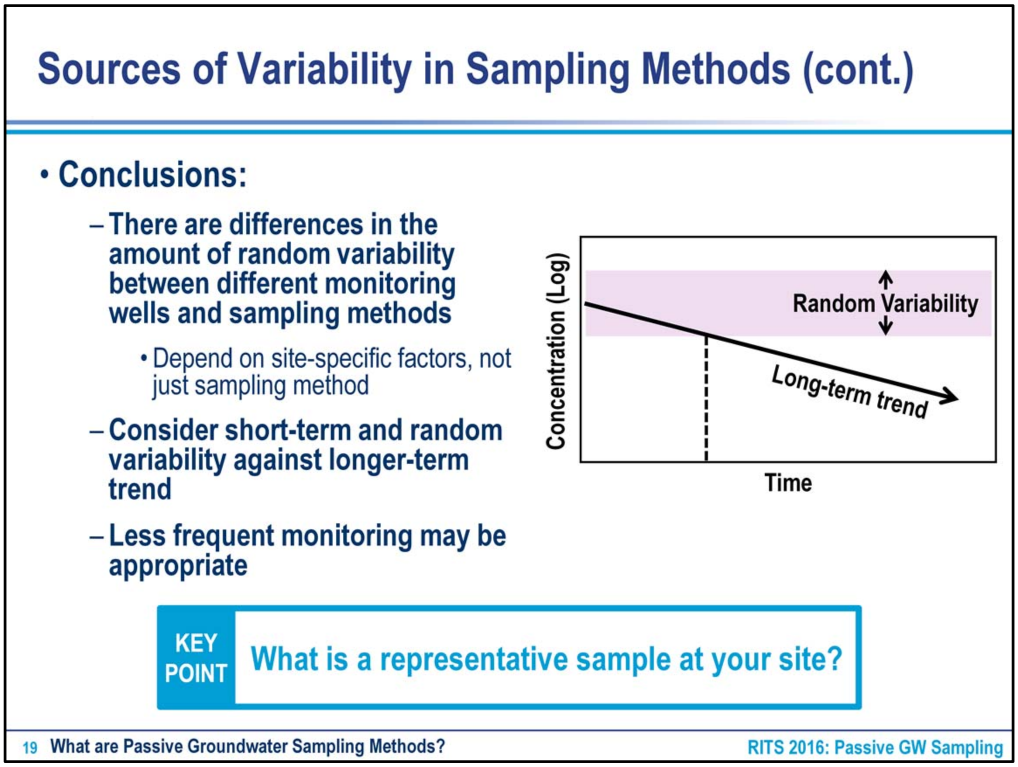
The lines corresponding to relative percentage differences (RPDs) of 100% are shown to illustrate that variability inherent to individual well/constituent pairs with time is often greater than 100%.

The figure illustrates that constituent concentrations measured over this time period were highly variable (see Figures 5.1 and 5.2). For individual constituents in individual wells (e.g., benzene in MW-04), the median ratio of the maximum measured concentration to the minimum measured concentration from the 15 sampling events was 4.4. For nine of the 40 constituent/well pairs, this ratio was greater than 10 and the largest ratio was 2,000. There was no clear pattern to the changes in constituent concentration over time and changes in constituent concentration from one sample event to the next were not highly correlated within individual wells or for individual constituents.



As part of the SERDP and GSI 2013 work the capacity for minor modifications to existing groundwater sampling method to result in a measurable reduction in the variability in the data was reviewed. The figure above was generated by calculating the coefficient of variation (CV) defined as the standard deviation divided by the mean) and the 95% confidence interval for the median CV for each set of time-series data shown on the previous slide. The data indicated similar variability for all sample methods. These results indicated that Snap Samplers® had the highest statistical variability with the other methods having similar variability.

They key point, is that every sampling method has a source of variability, some of this is related to sampling method, and some is not. There is no correct method for every well. The change in sampling method will affect variability, but the absolute change in concentration may also be effected by other factors.



Because so many factors influence variability at a given monitoring well, and the degree of variability can vary even within monitoring wells at a particular site, it is important to have a good understanding of sources, drivers and magnitude of variability at your site in order to put the data in context of broader trends and inherent variability. Groundwater sampling methods are not always the primary source of variability at a monitoring well. The magnitude of inherent natural and temporal variability should be considered and used to define appropriate ranges in data when making remedial decisions, including modifications to sampling methods.

In many cases it is not the sampling method itself which is generating variability, but the way that the selected method interacts with the specific characteristics of the well and surrounding aquifer. For instance, we should consider scenarios such as does purging mobilize constituents in high K zones that passive methods do not? Changing the basis of the method, changes the interaction between sampling technique and aquifer and well properties, and can result in differences in measured concentrations, and it is up to us as practitioners to look into the source of that change and decide what is the best, most representative method to use for our specific scenario.

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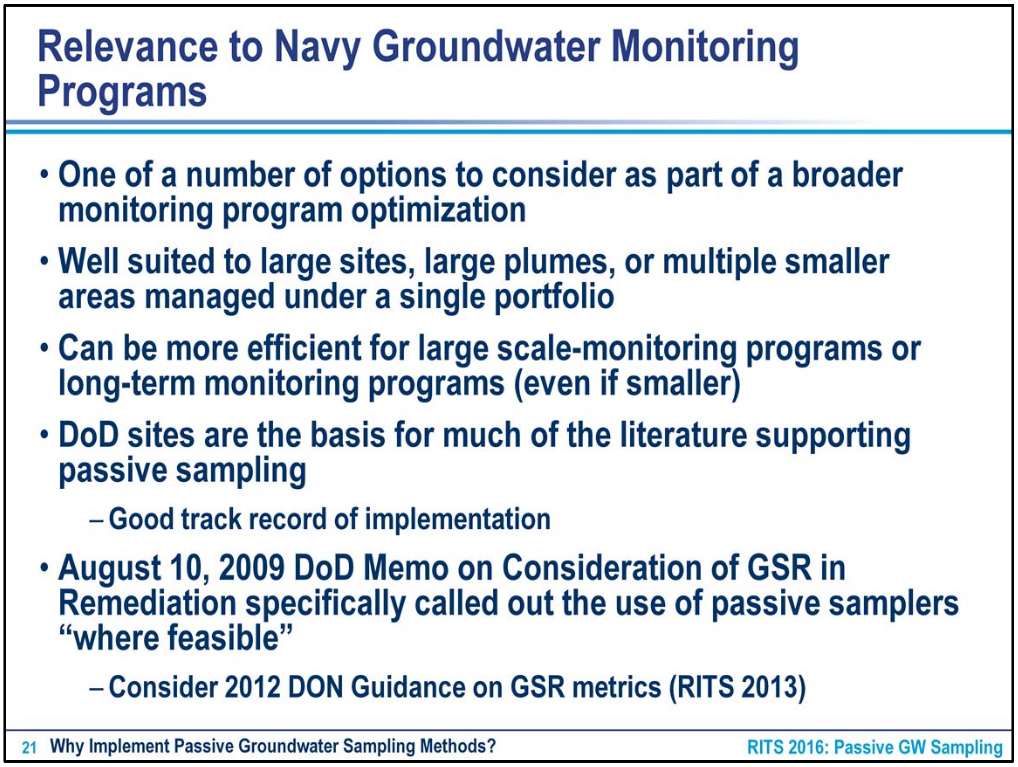
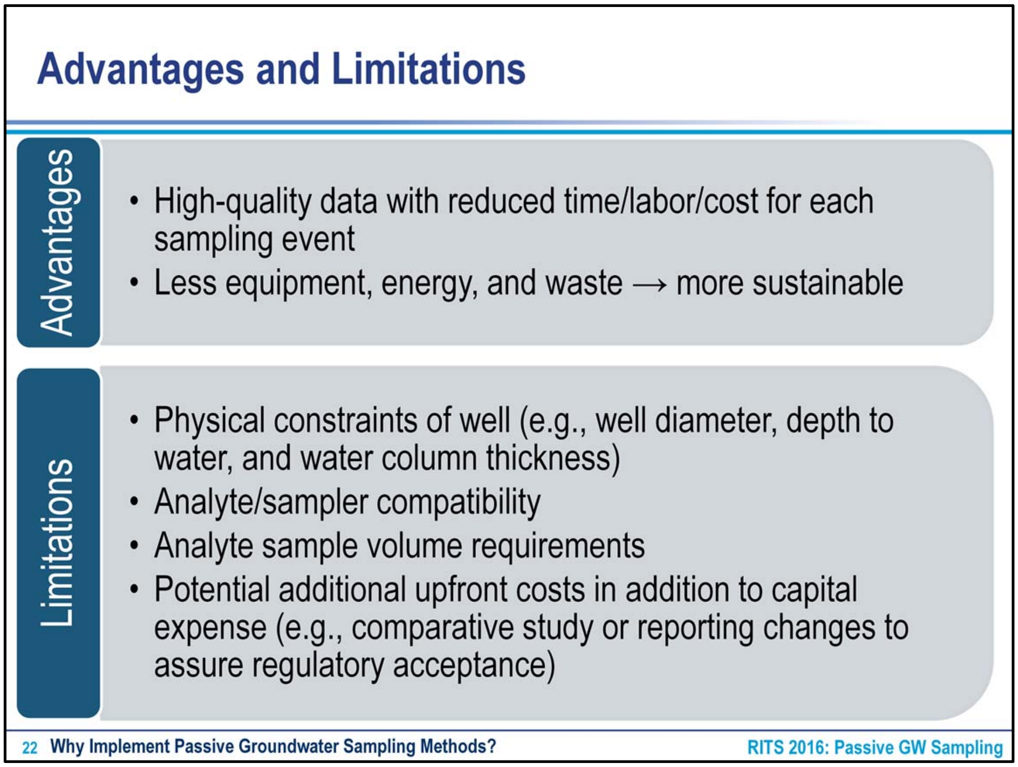


Passive groundwater sampling methods are one of a number of cost-saving options that can be implemented as part of a broader monitoring program optimization strategy. There are a variety of reasons to implement passive sampling techniques, but typically they are most relevant for long-term monitoring programs. They are applicable to both large and small sites, although different implementation strategies and methods may apply depending on the size, scale and sampling frequency at your site, and all these factors should be considered in the screening and selection process, discussed in subsequent slides.

There are specific metrics relating to GSR and passive sampling which are detailed in the August 2009 Memorandum on Consideration of GSR in Remediation (EO 13423), 2012 DON Guidance on Green and Sustainable Remediation and also in the 2013 RITS presentation: Passive Sampling Techniques for Groundwater and Sediment.



Each passive sampling device has specific advantages and limitations which make them applicable under different scenarios, but at a high level, a general overview of the pros and cons for passive sampling are provided in this table. The limitations drive the suitability and ability to implement passive sampling or specific types of samplers at your site. These points are expanded upon in the RITS 2013 presentation: Sampling Techniques for Groundwater and Sediment, Slides 12-13 and detailed expressly for various sampling devices in the ITRC 2006 and 2007 guidance documents referenced on Slide 13 of this presentation.

Cost Considerations

- Passive sampling cheaper on a per well basis
- Actual and total sampling costs will vary on a site-specific basis
- Consider the costs of a transition
  - Vary on a site-by-site basis
  - Dependent on details of the transition

Method	Per Well Cost ($)
Traditional 3-Volume Purge	310
Low-Flow Purge	280
RPP	104
PDB	68

From RITS 2013, original source USACE and AFCEE, 2005

Question Time

- Up Next: How to Screen, Implement, and Analyze Data for your Transition
- Before we go…. What questions do you have on why to implement passive sampling?

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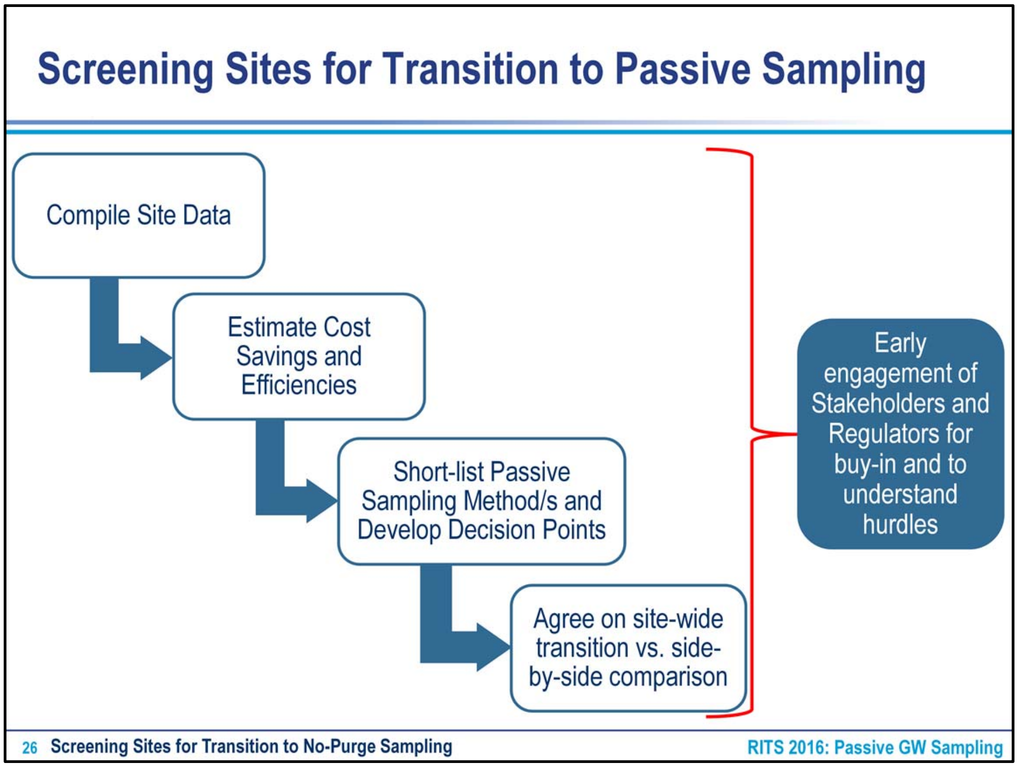
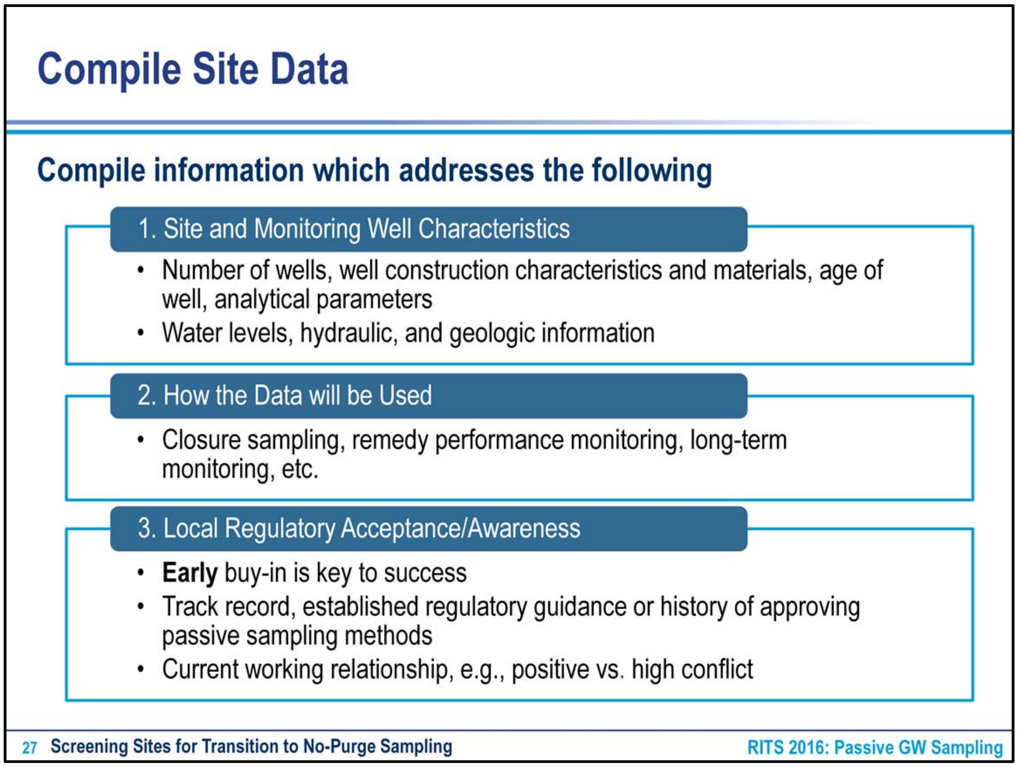


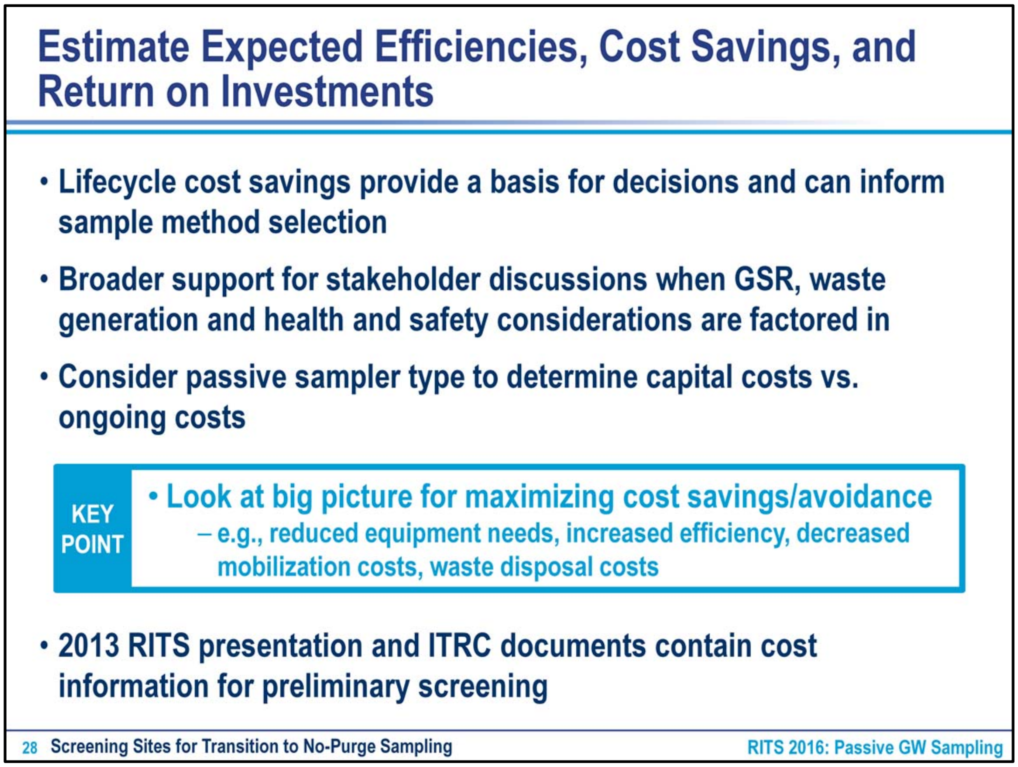
When we first begin to consider transitioning our sites to passive sampling, there are a number of steps to consider which will help streamline the process, and provide an understanding the types of sampling methods that are suitable as well as determine the benefits of changing sampling methods. Early engagement of stakeholders and regulators can not only help inform the data needs and decisions made at each of these steps, but allows opinions to be voiced and concerns addressed early in the process. In fact, understanding regulatory perspectives for your specific site is an important part of Step 1-Compiling the Site Data, and can significantly streamline future discussions.

1. Begin to collect the data which will enable you to screen and select appropriate methods and inform the decisions throughout the rest of the transition
2. Start to estimate cost savings and efficiencies to better understand if these technologies are going to work at your site
3. Begin to short-list appropriate methods and determine which factors will affect the final selection of methods and result in specific actions. The internal Navy Passive Sampling Selection tool can be useful at this step.
4. Begin discussions relating to inherent variability at the site, to determine if a side-by-side comparative study is required, or is required at all monitoring wells. This may be a significant factor in refining costs and developing an implementation plan and can be important to establish upfront.



Monitoring Well Characteristics

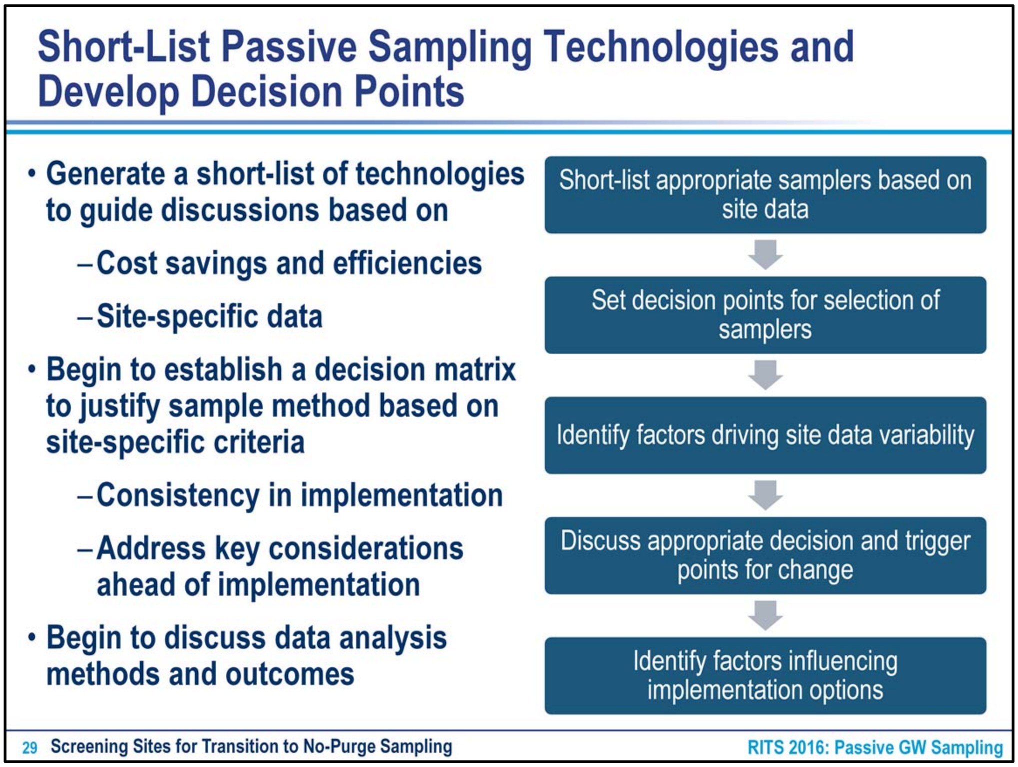
- Don’t forget to consider:
  - Age of well (issues with well deterioration)
  - Steel wells (effects of corrosion)



A cost-benefit analysis and initial quantification of expected savings can be a key factor in driving the decision to move to passive sampling, and justifying any capital expense to do so. At different sites, reductions in different areas may be more important than others, for instance, the relative importance in reductions in health and safety, carbon footprint, or simply fewer dollars spent may drive difference choices and selection of one method over another.

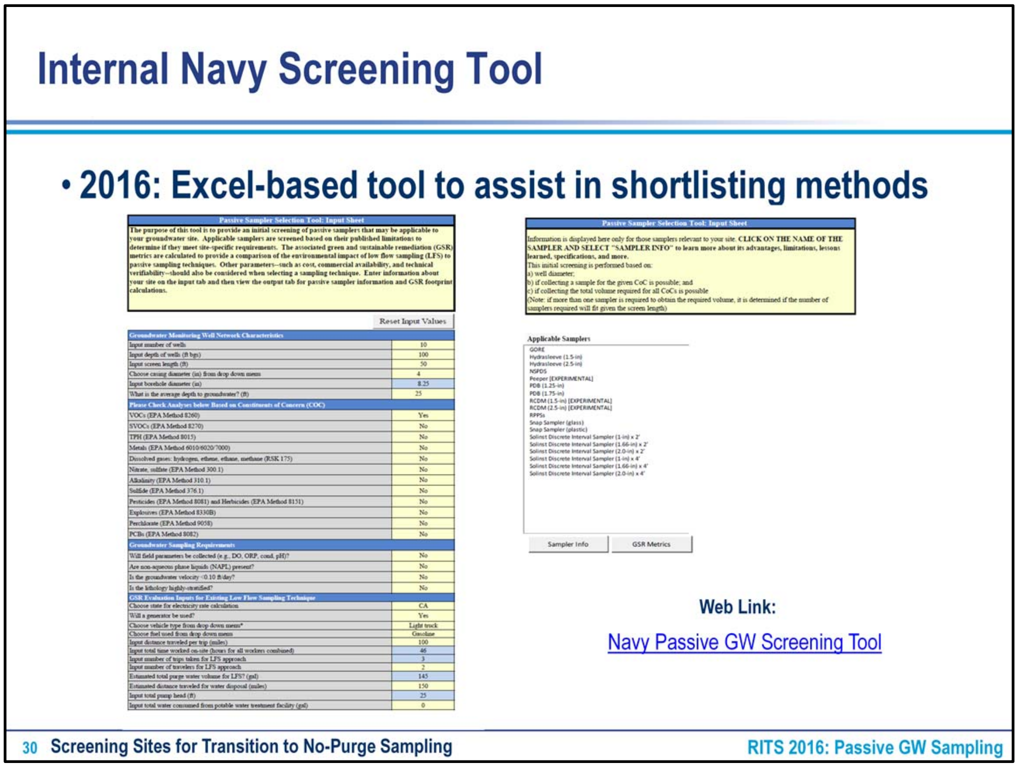
Different methods may have different cost savings and decision trigger points. Having an understanding of cost drivers for each method will feed into determination of which method is appropriate.

An important lesson learned, is don’t just look at big picture costs, for instance reduced equipment needs, reduced sampling time, a reduction in the volumes of waste generated. There can be significant savings to be realized in other logistical areas, such as simplified mobilization processes and the capacity to use smaller vehicles given reduced equipment needs.

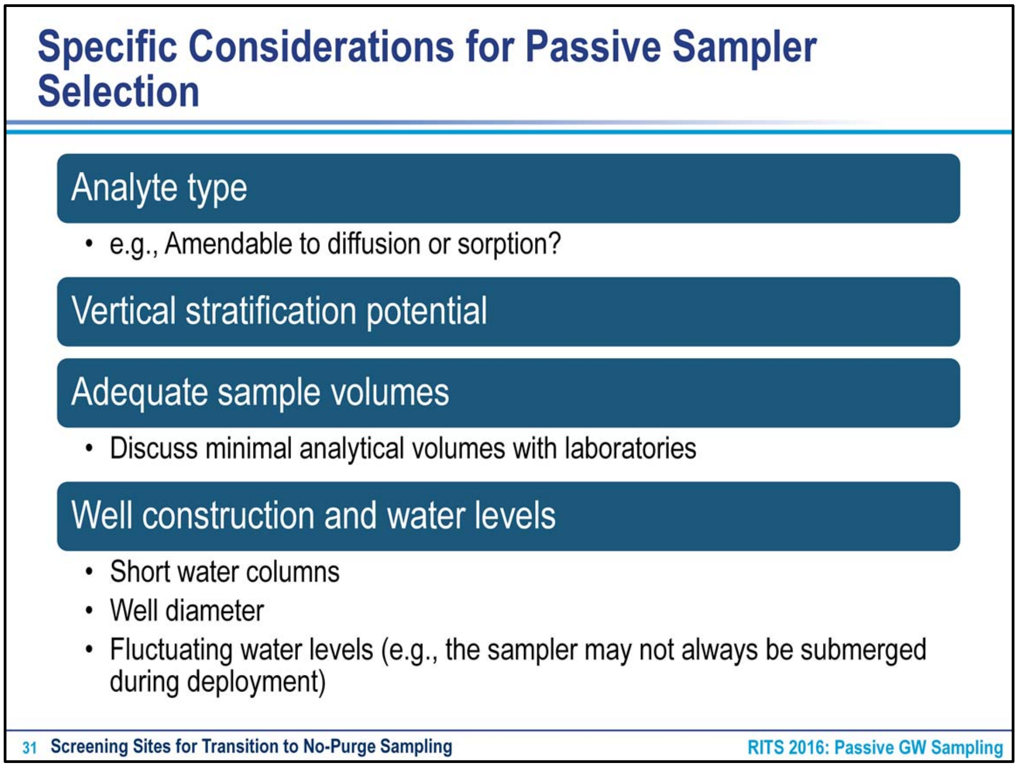


This slide describes an internal thought process and high level overview of steps which may assist in identifying stages, and decision points to inform the development of a strategy which can be communicated to regulators and assist in staging implementation.

Thinking through these factors initially will help with development of a sampling method selection matrix, particularly for complex sites where more than 1 type of monitoring well is present. Before a sampling method can be selected, some understanding of the relevant site characteristics which will drive selection of that method is key. This informs not just estimates of cost savings but just as importantly, creates a consistent implementation framework that allows key considerations to be identified and addressed ahead of time. When considering decision points, an initial understanding of the data analysis requirements should be included.

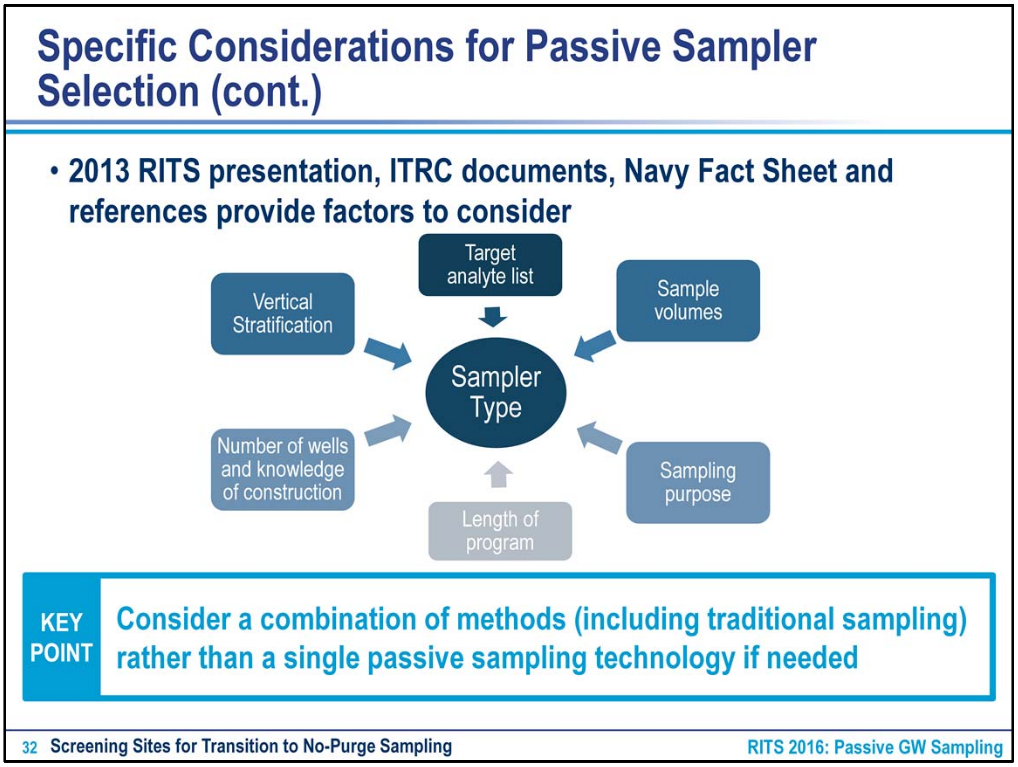


The Navy has an excel based tool which can be used during this initial selection process. In this tool the general, or average properties for site monitoring wells can be entered and a list of potentially appropriate passive sampling methods is generated for consideration.



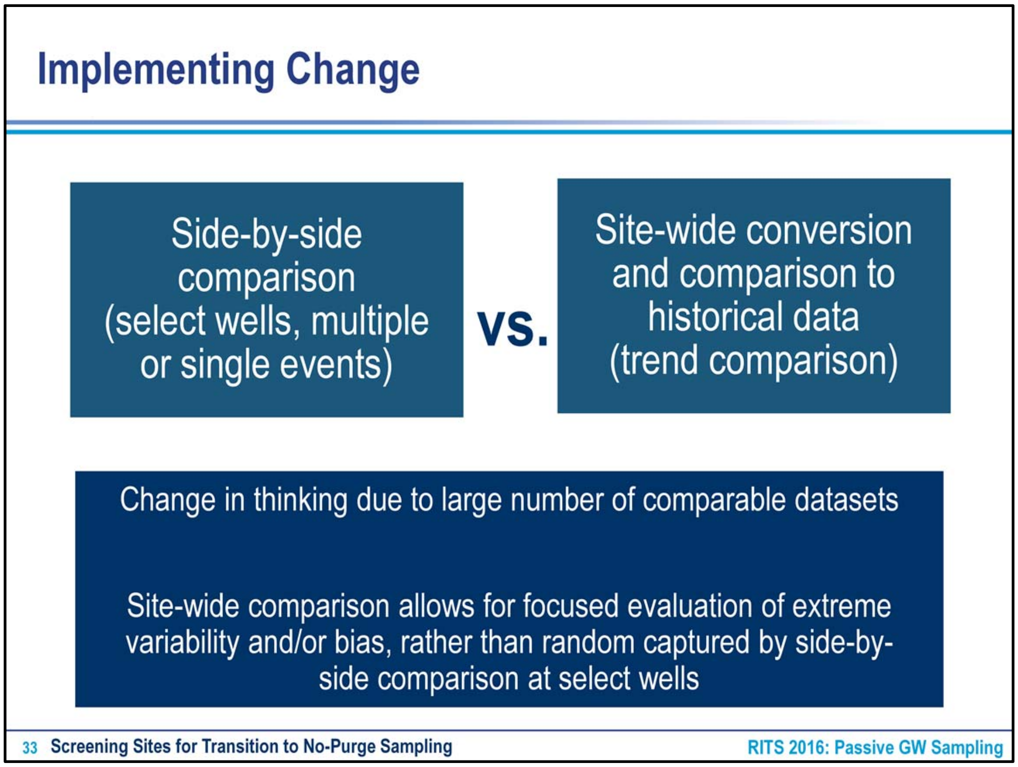
This slide details some of the physical considerations which will form the sample selection decision matrix for your site. There may be others, depending on the conditions at your site.

Of particular importance is the analyte – for instance PDBs are not suitable for all analytes, as well as the potential to obtain the required analytical volumes using the desired sampling method.



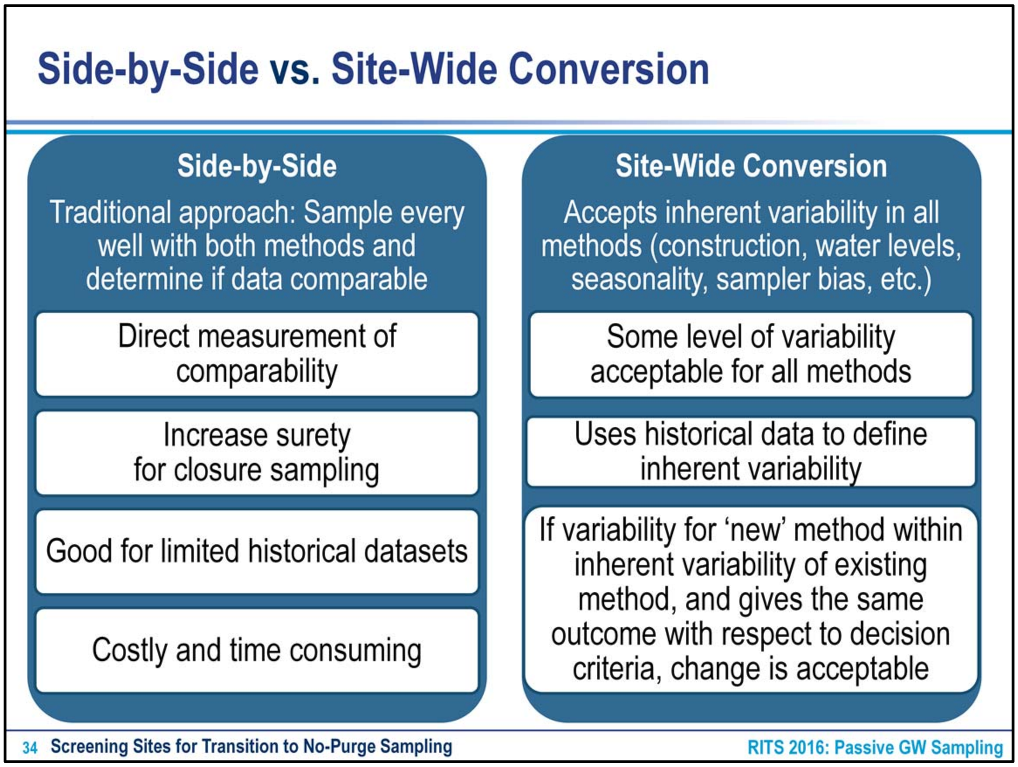
There are a variety physical factors which should be considered when determining which passive sampling method is appropriate for monitoring wells at your site. These are discussed extensive detail many of the documents referenced on Slides 12 and 14 of this presentation.

If a site has multiple different types of monitoring wells, in terms of construction, analytes assessed, water levels, or monitoring purpose, consider a strategy which allows for a combination of passive sampling devices to be implemented. This was the case for Vandenberg Air Force Base, where a combination of samplers was implemented depending on well properties and characteristics.



When beginning to discuss how to implement the change, agreement on the comparative study requirements can be a key factor and may affect cost assumption for your site. It has historically been assumed that a side-by-side comparative study is a requirement of any change to passive sampling methods, however, at some sites a side-side-study has not been required. For instance at Vandenberg Air Force Base and McGuire-Dixon-Lakehurst Joint Base a comparison of passive sampling methods to historical data was sufficient. Similarly, at some UST sites there has been successful transition to passive sampling methods without any requirement to demonstrate comparability at all, either using side-by-side studies or a comparison to historical data. This shift in approach from what was the norm a few years ago has been driven primarily by wider use of the technology, which has lead to a greater number of supporting comparative studies already in existence, and more familiarity and confidence in methods from regulators.

Both methods have their pros and cons, and in some scenarios, one may be better than the other, however, for large-scale, portfolio wide, long-term monitoring approaches it is recommended that the first option be a comparison to historical data. This not only will reduce implementation costs, but allows site-wide trends to be discovered, and does not focus at variability within individual wells. In some cases, a compromise could be a limited side-by-side comparison at wells which are of key remedial or regulatory importance may be appropriate in lieu of a large-scale side-by-side comparison.



As mentioned on the prior slides, both methods have their pros and cons, some of which are described above. During the transition stage, it is up to each RPM to decide which method will best suit their site and needs, and agree with regulators on that method. As mentioned earlier, there is a preference in an immediate site-wide conversion with a comparison to historical data as this generates additional cost savings. However, there may still be some push back on this from regulators in spite of successful implementations at other sties. In these case, we would recommend offering a limited side-by-side comparative study rather than a comprehensive study as a first option.

Side-by-Side Comparison: Navy Case Studies

Naval Air Warfare Center, Warminster, PA (large dataset)	
• PDB samplers vs. 3-purge volume sampling • 3 sites, stacked samplers, 3 per well • COCs: PCE, TCE, and CCl_4	• Good correlation (r-Value 0.86 and 0.87) • PDB samplers deployed at 2 of 3 sites • >25% reduction in LTM costs
Allegheny Ballistics Laboratory (ALB), WV	
• Passive sampler (LDPE) vs. Low Flow Purge • 27% monitoring wells tested • COCs: TCE, DCE, VC	• Strong linear correlation • Concluded passive sampling is acceptable
Joint Base Pearl Harbor-Hickam (JBPHH), HI (limited dataset)	
• PDB samplers vs. Low Flow Purge • Limited, 1 site, 2 rounds, 6 wells • COCs: Metals and VOCs	• Poor correlation As (R^2 = 0.955 & 0.3414) • VOCs NDs, Cu, Ni, Zn no clear trend • Not applied due to low concentrations & poor correlation
Port Hueneme, CA (limited dataset)	
• 12 location at 2 depths • COCs: TCE, DCE, BTEX, MTBE	• Good correlation (R^2 = 0.9979)

35 Assessing the Data

RITS 2016: Passive GW Sampling

Lessons Learned

- Actual cost savings may differ from expected savings
  - These vary with site and implementation considerations
  - Total labor hours, access, travel, and other logistical costs can play a significant role
- Consider changing site conditions
  - e.g., Low or variable water levels
    - Sufficient volume present for sampling during initial screening but not for subsequent events

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Lessons Learned (cont.)

- Examples of variation in savings
  - Difficult to conduct comparisons by well due to a wide range of assumptions (sampling cost only vs. sampling program costs)
  - Actual costs savings are difficult to calculate due to performance based remediation (PBR) contracts
  - These bases transitioned over to PBR between 2011 to 2014

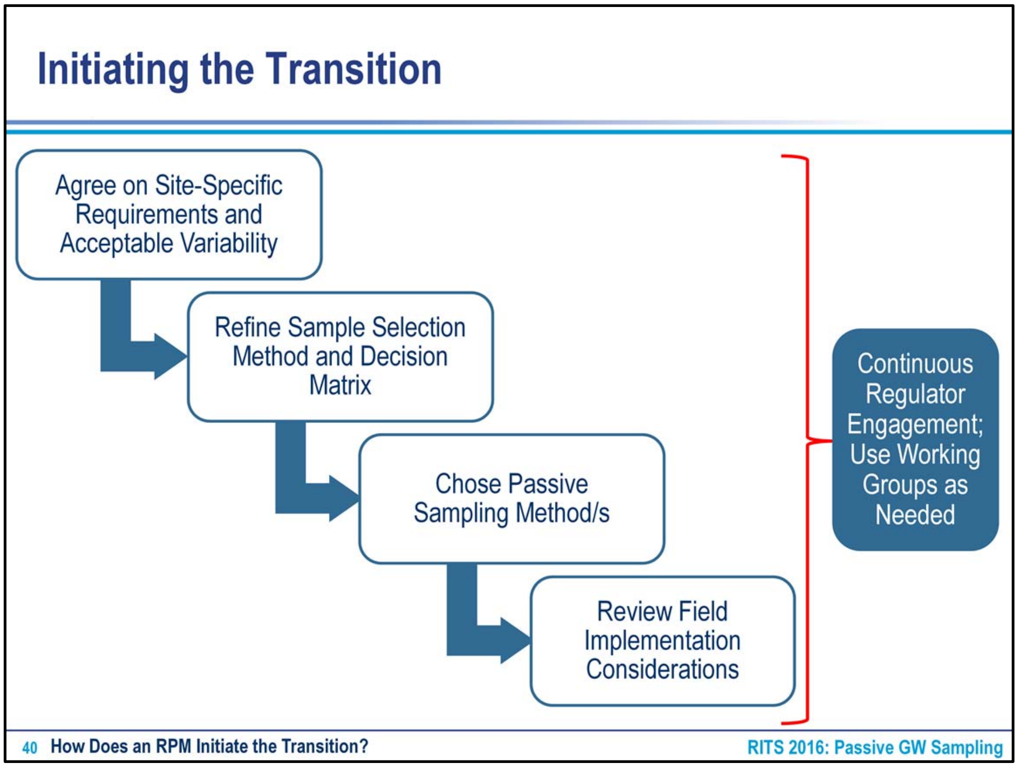
Air Force Programs	Percent (%) Reduction
March AFB (2008)	
- Planned	~ 50 %
- Actual	Not Verified
Hill AFB (2010)	
- Planned	70% HS 50% SS
- Actual	60%
Vandenberg AFB (2015)	
- Planned	40%
- Actual (short-term)	20%

Lessons Learned (cont.)

- Active remediation or short timeframes to closure
  - i.e., limited time for return on investment to recoup transition management costs
- Consider timeframes to implement change and influencing factors
  - Regulatory environment, project remedial drivers, other site activities

Presentation Overview

- Introduction
- What are Passive Groundwater Sampling Methods?
- Why Would an RPM Consider Implementing Passive Groundwater Sampling Methods?
- Screening Sites for Transition to Passive Sampling
- **How Does an RPM Initiate the Transition?**
  - **Integrated Case Study – Vandenberg AFB**
- Assessing the Data
- Wrap-Up

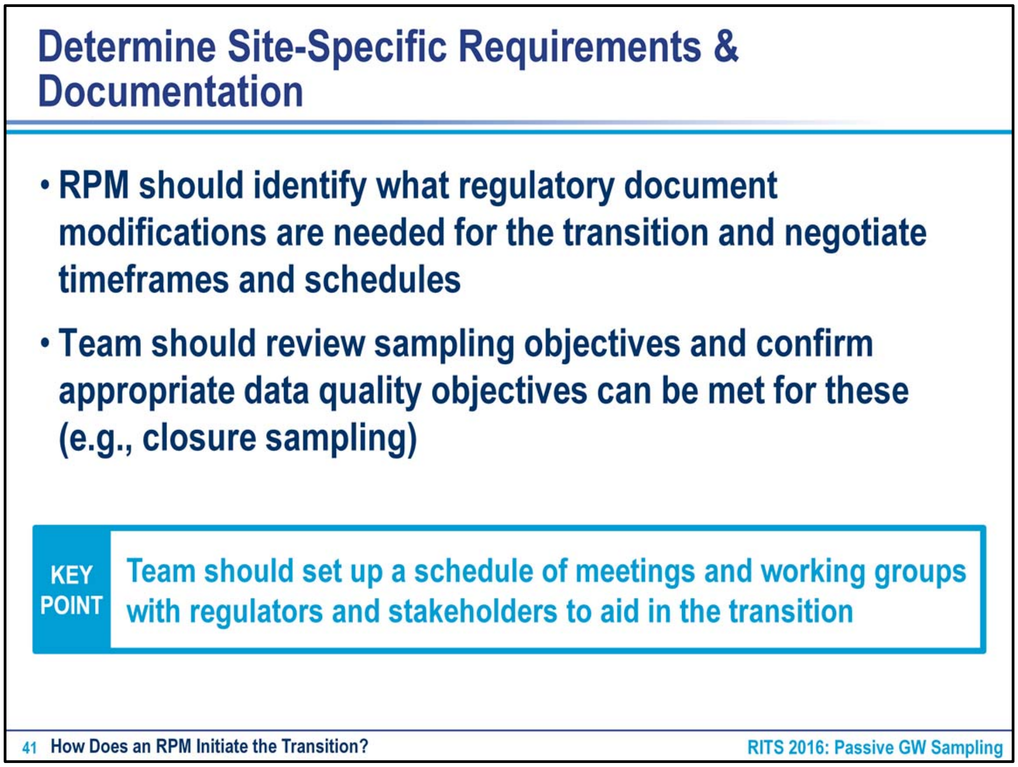


Once a general framework and strategic understanding of the need for a change to passive sampling and the process by which it will be implemented has been agree and decided upon, the next phase is to begin to initiate the specific details of the strategy. Throughout this whole process, regulatory involvement can streamline and avoid issues down the track.

1. Key to this is defining and understanding upfront the degree of variability likely to be excepted at the site, and the factors governing that variability. In addition to this, the requirements of r documentation and other factors should be reviewed.

2. and 3. The preliminary well and site characteristics used to shortlist potential sampling methods should then be used to refined and develop a sample selection method which allows a comprehensive, consistent framework for application, which can then be applied to individual wells.

4. Finally, the field considerations should be reviewed, these include training needs, logistical issues, and any field documentation like SOPs.

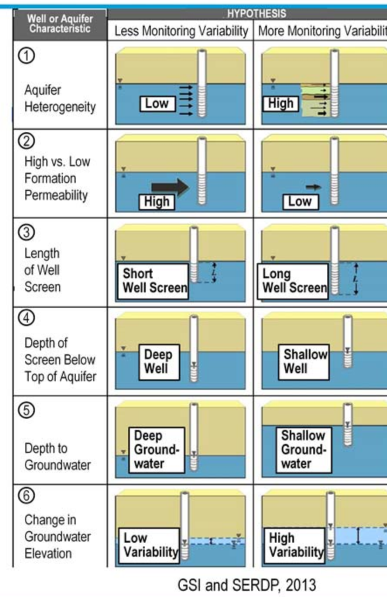


Each site will have specific document requirements that should be reviewed early in the implementation process and updated as needed. If these require regulatory approval, or changes are significant, this step can take some time and this should be considered during planning. For instance. ROD modifications may be required for some sites. When making changes to documents, or generating new documents relating to passive sampling it is very important to make these and any decision documents as flexible as possible to account for future changes and make this step more efficient in the future.

An implementation schedule at this stage can also be helpful.

Agree on Appropriate Variability

- **What criteria define a representative sample?**
  - **Dependent on site inherent variability, regardless of sample method**
  - **Recall SERDP 2013 study (Slides 18-21)**
- **Relative percentage difference (RPD) calculations can be used as a screening tool, but more robust methods may be better**
  - **RPD developed to test the integrity of laboratory variability not in-well variability**
- **Agreed range of acceptable variability should consider at a minimum:**
  - **Project DQOs, concentrations, current/planned remediation, seasonal and in-well variability, and analytical methods**



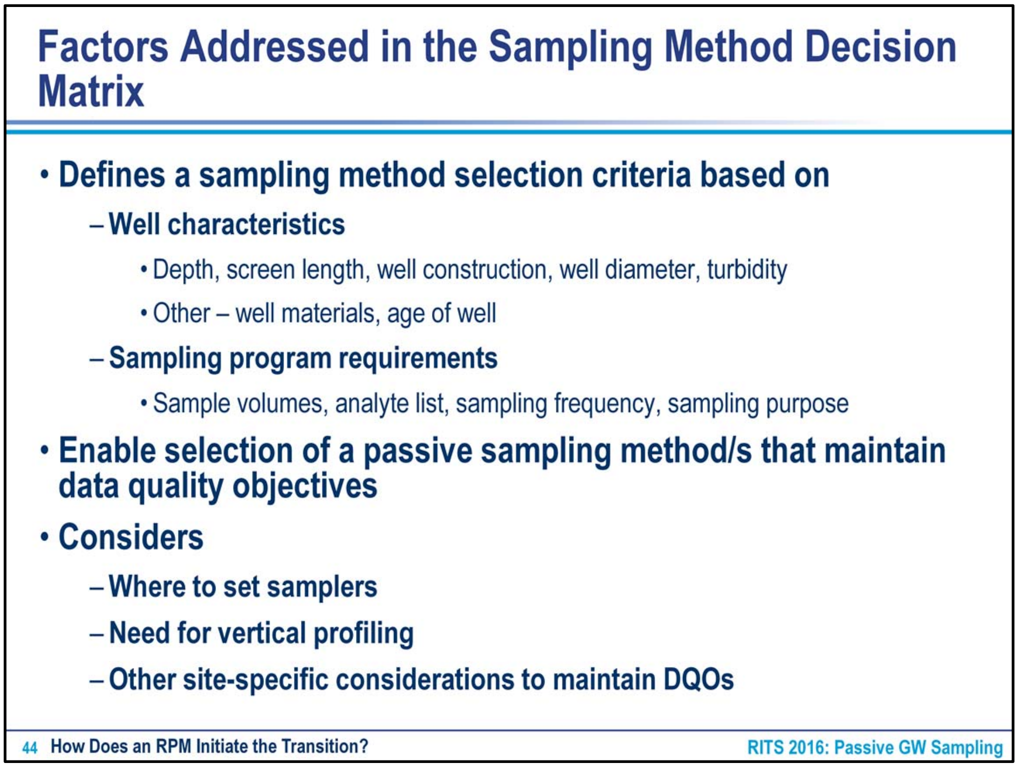
GSI and SERDP, 2013

42 How Does an RPM Initiate the Transition? RITS 2016: Passive GW Sampling

Deciding on, illustrating and discussing ranges of variability and drivers that already exist at the site under the current sampling regime is important in setting expectations at your site and developing decision and trigger points. This will be further illustrated in the data analysis section using an example from Vandenberg Air Force Base.

Expand and Refine Sampling Method Decision Matrix

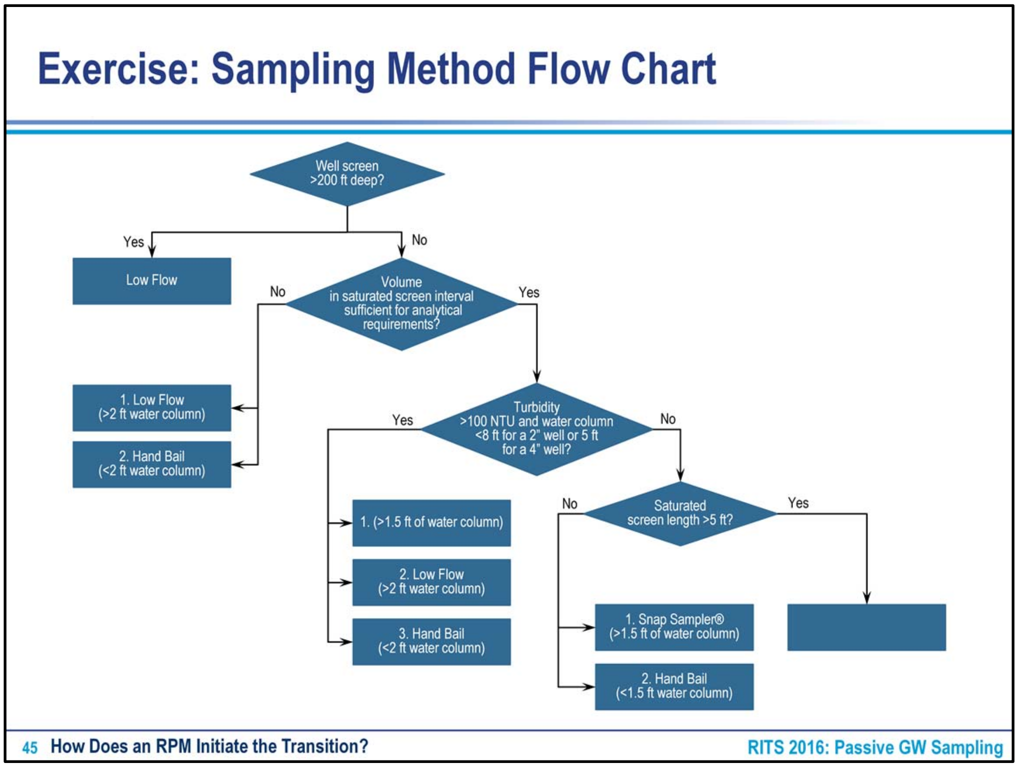
- Provides an agreed, established framework to confirm an appropriate passive sampling method for each well
- Particularly useful when a range of sampling methods are being used
- Get buy-in from stakeholders early in the process using working groups as needed
- Allows for real-time modification
  - When needed, based on changing site conditions
  - e.g., analyte lists changing, changing groundwater levels, changing concentrations, change in sampling program purpose



Recommendation:

Consider expanding the flow chart and decision matrix to consider other well characteristics like:

- well construction materials (steel vs. PVC)
- age of well
- etc.

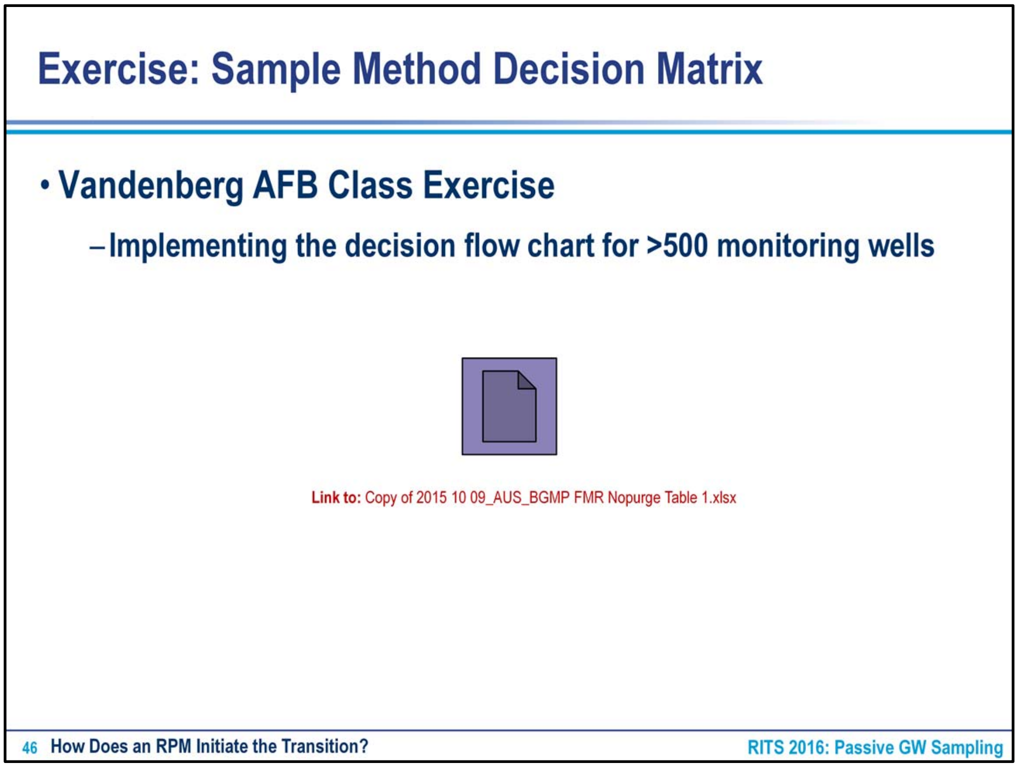


This is an example from Vandenberg Air Force Base of a sample method flow chart which was used to define an appropriate sample method at each well. The site was complex, with a variety of different well types and with four sampling methods implemented, however, this framework allowed a consistent basis, was agreed upon by all stakeholders, and can be applied whenever conditions at the site change without the need for additional discussions.

Recommendation:

Consider expanding the flow chart and decision matrix to consider other well characteristics like:

- well construction materials (steel vs. PVC)
- age of well
- etc.



Recommendation:

Consider expanding the flow chart and decision matrix to consider other well characteristics like:

- well construction materials (steel vs. PVC)
- age of well
- etc.

Field Implementation Considerations

- Cost-effective deployment methods and strategies
  - Consider deploying samplers at the prior sampling event
- Deployment timeframes
  - How long does the sampler need to be in the well before retrieval?
- Lessons learned
  - Experience and training of deployment staff
  - Account for other site activities
    - e.g., pilot tests

Lessons Learned: Actual vs. Planned Deployment

- **Depending on selection criteria and site drivers, actual methods differ from planned**
  - **At Vandenberg AFB, drought conditions and declining water levels drove in-field changes**
- **Develop an adaptive program, be prepared to make changes during deployment and provide field staff with guidelines to manage change**

Method	Planned Sampling Method (Wells)	Actual Sampling Method (Wells)
Low Flow/ System Port	86	99
Hand Bail	70	77

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One of the major lessons learned, which highlighted the importance of an agreed framework and decision matrix or flow chart was the need for infield changes due to differences between the expected and actual well characteristics and use. At Vandenberg, many of these changes were driven by water level decreases between sampling events. The matrix and training allowed the field team to make changes during the implementation easily and in and consistent manner.

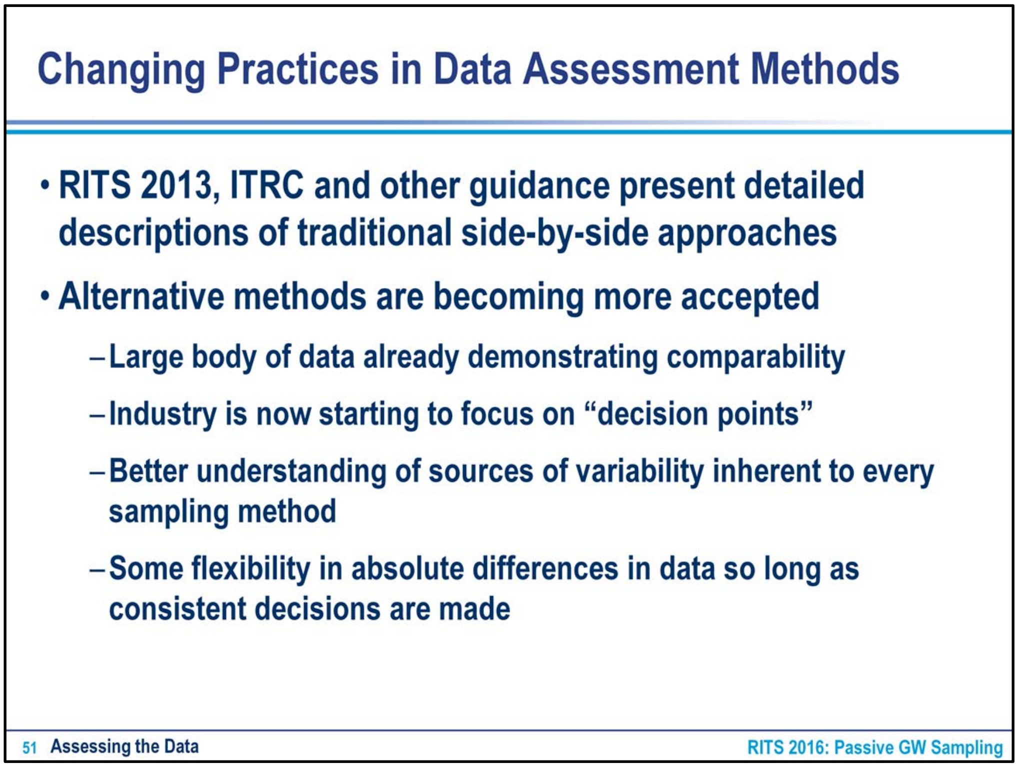
Question Time

- Up Next: Analyzing the Data
- Before we go…. What questions do you have on the screening and transition process?

49 How Does an RPM Initiate the Transition? RITS 2016: Passive GW Sampling

Presentation Overview

- Introduction
- What are Passive Groundwater Sampling Methods?
- Why Would an RPM Consider Implementing Passive Groundwater Sampling Methods?
- Screening Sites for Transition to Passive Sampling
- How Does an RPM Initiate the Transition?
- Assessing the Data
  - Case Studies
- Wrap-Up



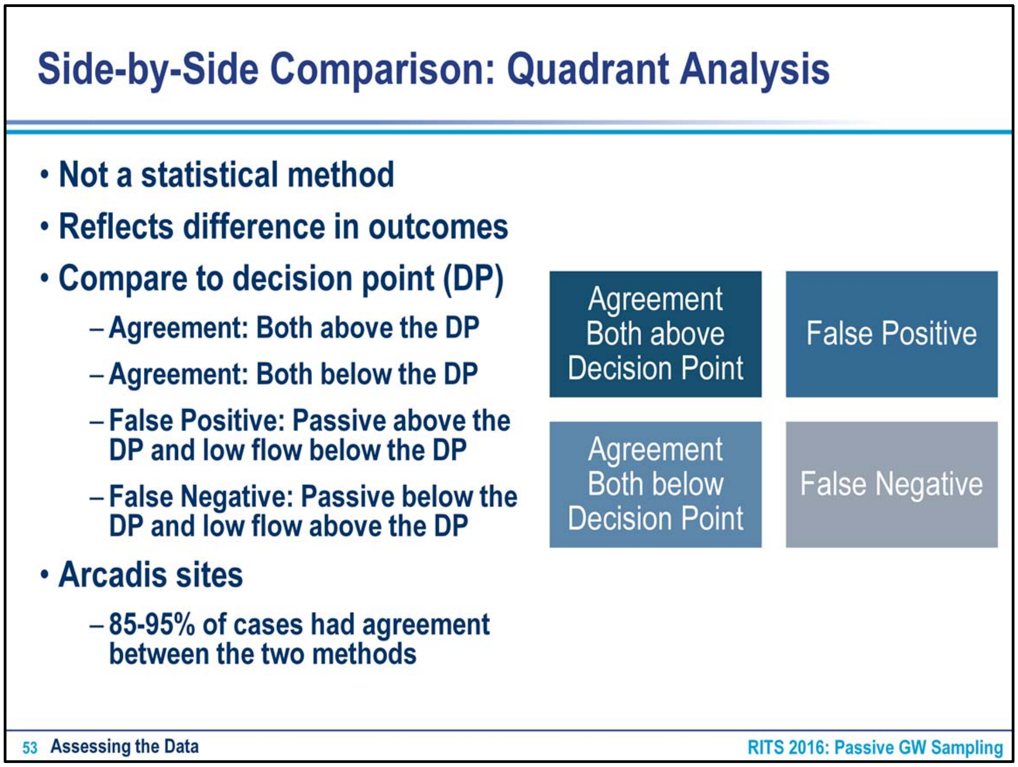
As mentioned earlier there has been some success in moving away from side-by-side comparison studies during conversion, and much of this is based on a better understanding of the sources of variability in sampling methods, as well as the significant body of data demonstrating comparability that already exists. Another important point is the focus on "decision points" in the sense of specifically understanding how the data will be used to make remedial or closure decisions and does variability change what would be done at a site.

The next few slides provide a short overview of traditional side-by-side evaluations, which are detailed in other guidance documents, and then illustrates an alternative approach for use when a paired dataset has not been collected, illustrated via an example of data from Vandenberg Air Force Base as well as the results of a more detailed paired study from Hill Air Force Base.

Side-by-Side Comparison: Statistical Methods

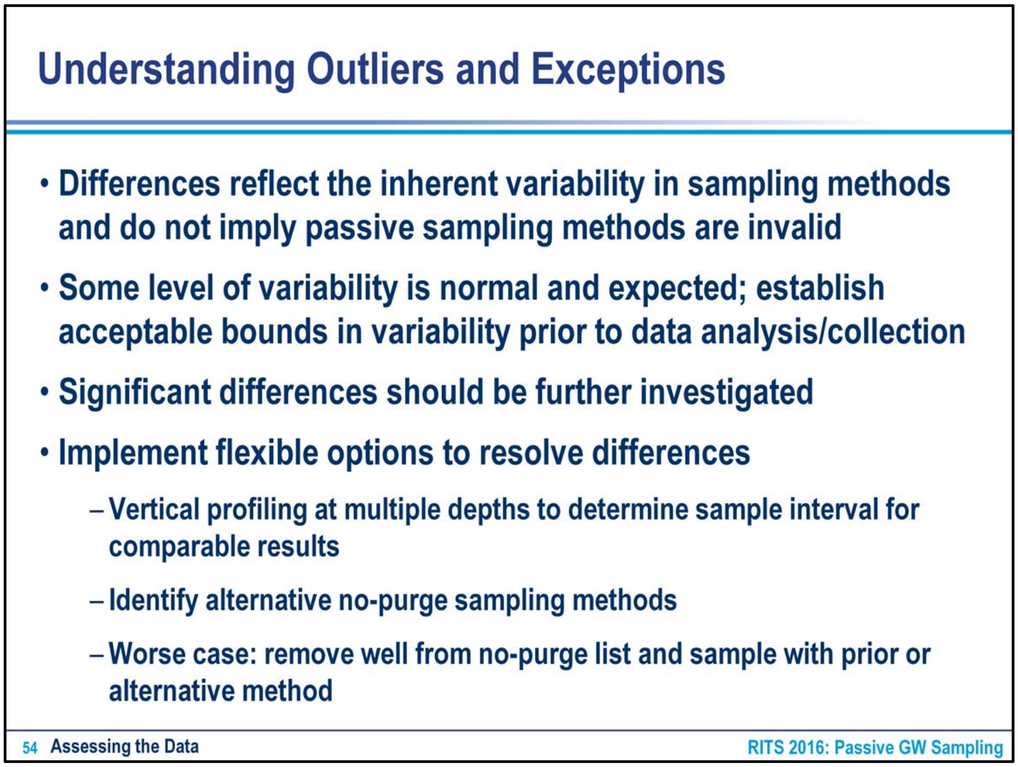
- Traditional approaches
  - Relative percentage differences
  - Paired t-tests
  - Wilcoxon test
  - Sign test
  - Linear regressions
  - Complex assessments
  - Differences between sampling methods are expected

KEY POINT Better question: How do those inherent differences affect remedial/compliance decisions?

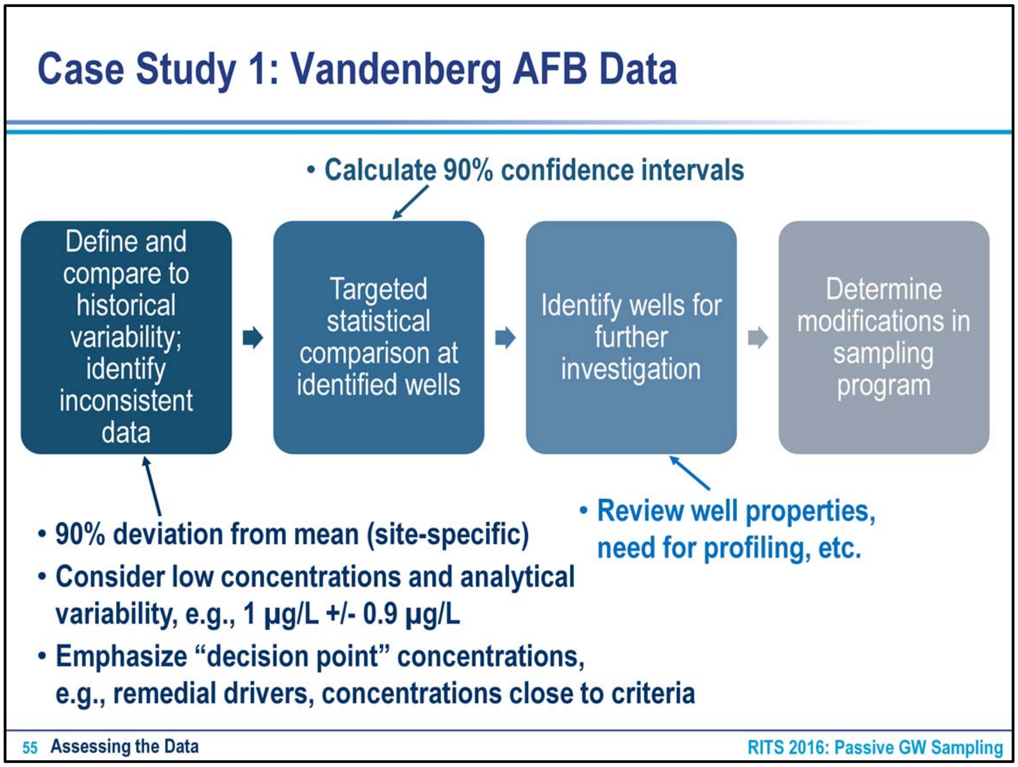


Here, for side-by-side/paired datasets rather than a traditional statistically comparison the data was divided in to 4 categories, hence the working name “Quadrant analysis”. For the two “Agreement” categories, same decision would be made regardless of the absolute value of the data. For the remaining two categories a different decision would be made.

What we are seeing is that the degree of variability introduced by a change in sampling method is not significant enough in most cases to affect remedial decisions.
This type of analysis may not be suitable for all sites, but it definitely worth considering as an option over statistical methods and when deciding if the degree of variability observed is acceptable.



When reviewing the data it is important to put it in the context of variability and decision points, and accept that some level of variability is normal in any sampling method. Where there is significant variability that is outside the range of expected, these should be looked at in more detail.

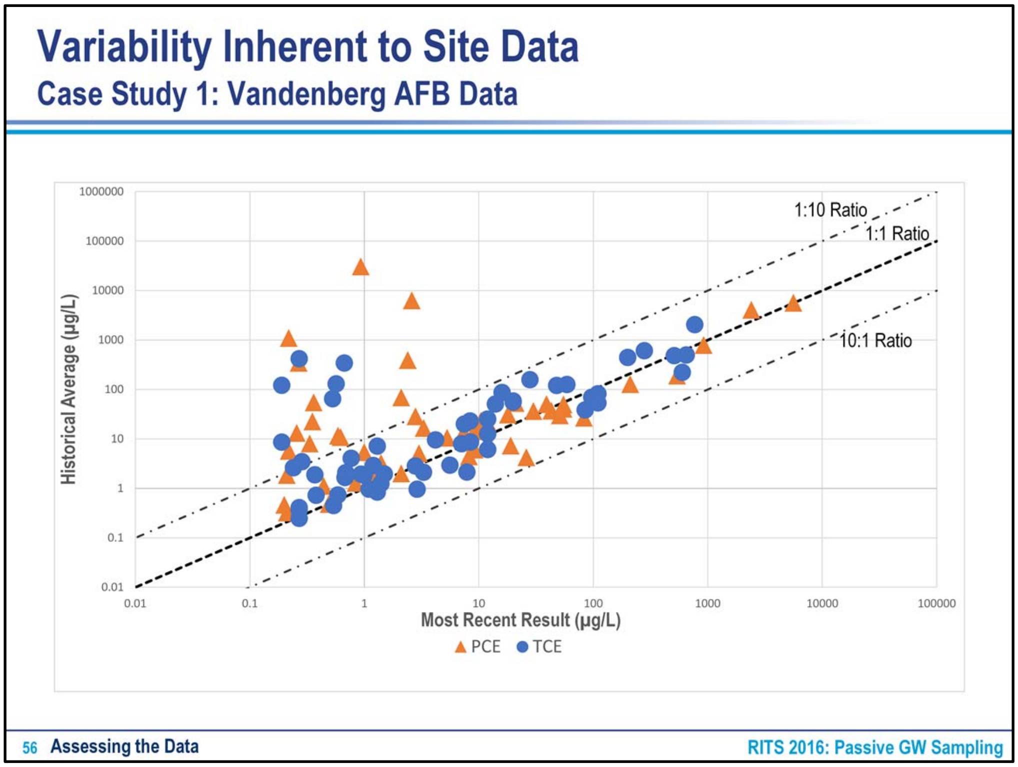


This slide describes the process by which data was analyzed for Vandenberg Air Force base, where an immediate site-wide switch to passive sampling as implemented without a side-by-side paired comparative study.

First, the range in historical variability was identified. In this evaluation, a 90% deviation from the mean represents a range consistent with the inherent variability under a single sampling method for a given site. Then the passive sampler data was compared to the historical data to identify wells which fell outside of accepted side-wide variability ranges for further evaluation. Lower concentrations, close to the analytical detection limit were expected to have higher variability, and variability around decision point concentrations were given priority and less flexibility in the range of variability to avoid making decisions which would incorrectly affect remedial strategy.

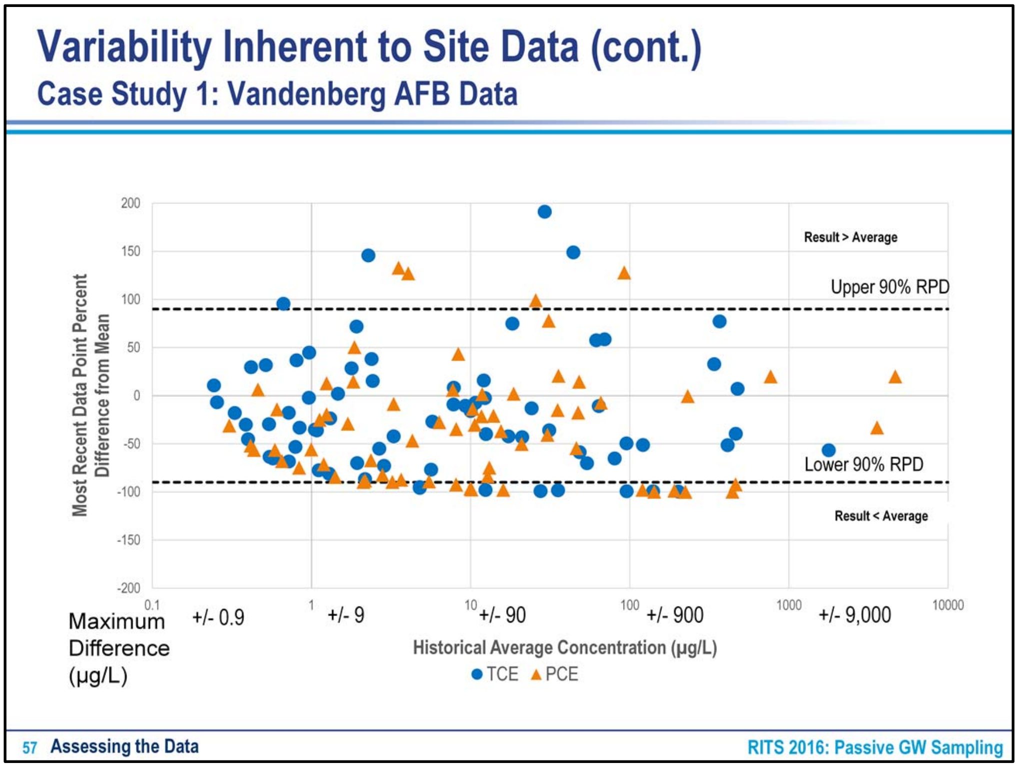
Where wells were not inside the bounds of reasonable, historical variability for the site, they were subject to additional statistical evaluation using more robust methods and plotting the data within 90% confidence intervals for the historical data. This allowed wells where trends were resulting in variability in passive sampling methods to be identified.

Where wells were not inline within historical variability at individual wells, they were investigated further, and a strategy for modification of the sampling method, or further monitoring, as needed, developed.



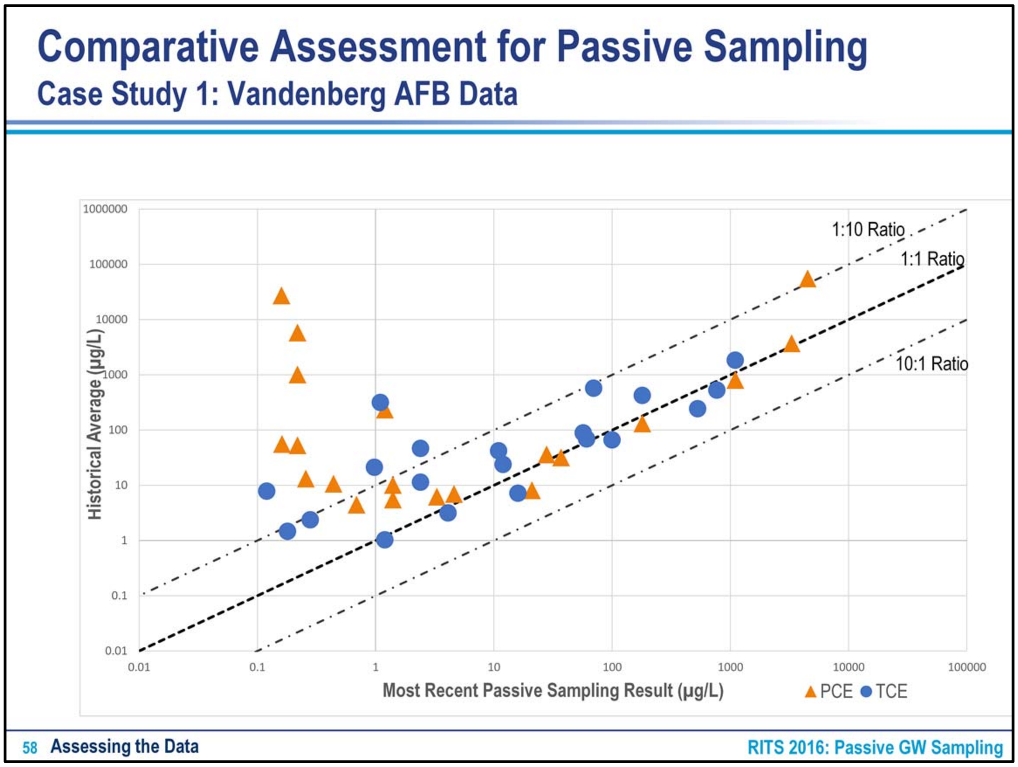
Here we are looking at a comparison of the historical average to the most recent data point, collected under the same sampling methods. Generally, the results lie on a 1:1 line, indicating the most recent data is comparable to the historical average, however, there is some obvious variability, particularly in the lower concentration data, close to analytical detection limits.

This type of comparison helps define the inherent variability within a site. The data shown is for the most recent comprehensive basewide sampling event.

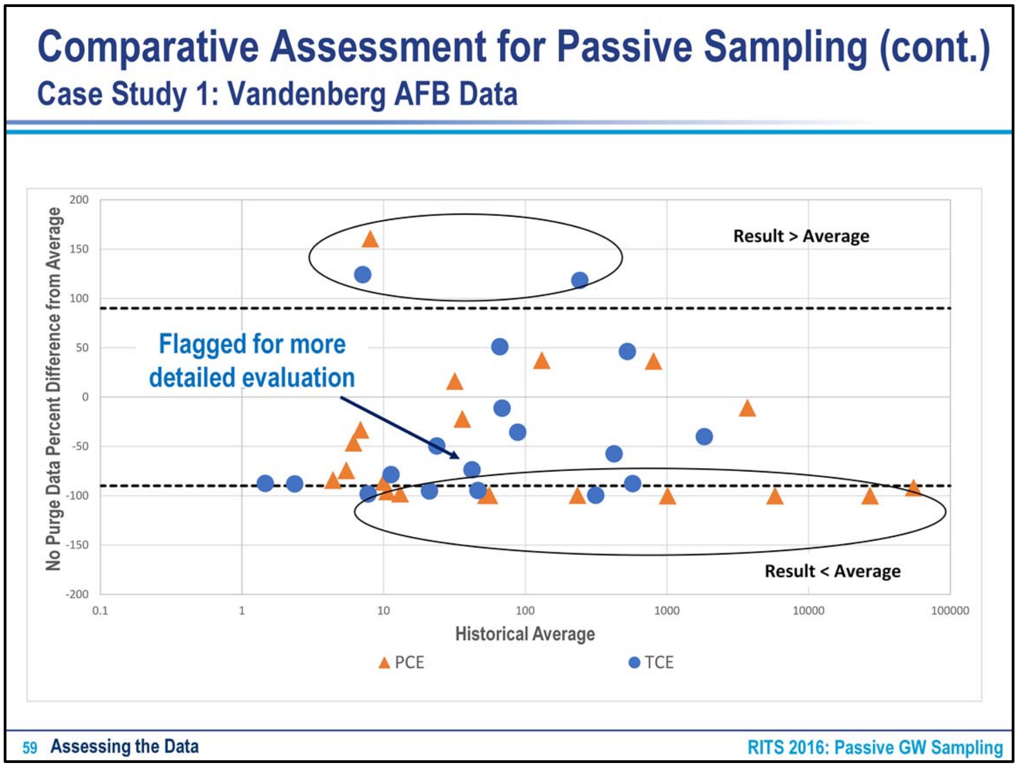


Similarly, here we are looking at the degree of variability in the RPD between the most recent data point, and the historical average. We can see that most of the variability at the site, when the same sampling method is used, is defined by the 90% upper and lower RPD lines. However, even in this instance, where there is no variability between sample methods, some data lie outside of these lines. These tended to be related to wells with large inherent variability and/or areas where active remediation and decreasing trends were observed.

The data shown is for the most recent comprehensive basewide sampling event.

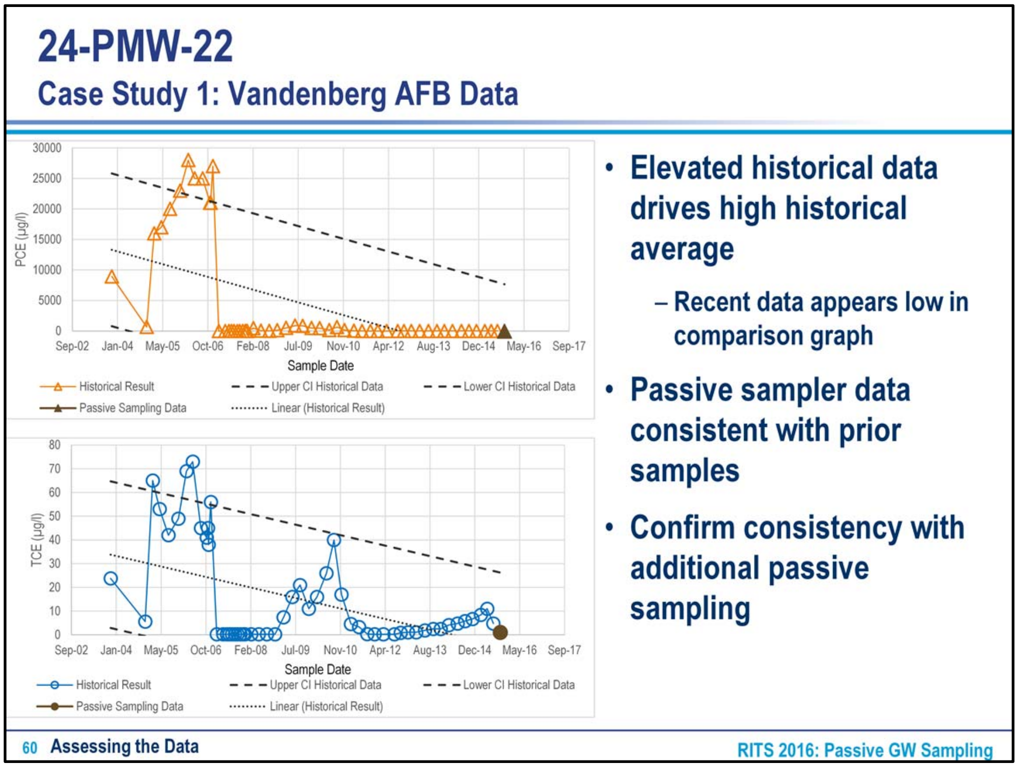


This data is from the first passive sampling event at site in the basewide monitoring program. The number of samples is fewer than was presented in previous slides (4th quarter as opposed to a more comprehensive 1st quarter event). It appears that there are a number of samples which are lower than the historical average, but many of the samples collected via passive sampling methods fall within the same range of variability as for traditional sampling methods.

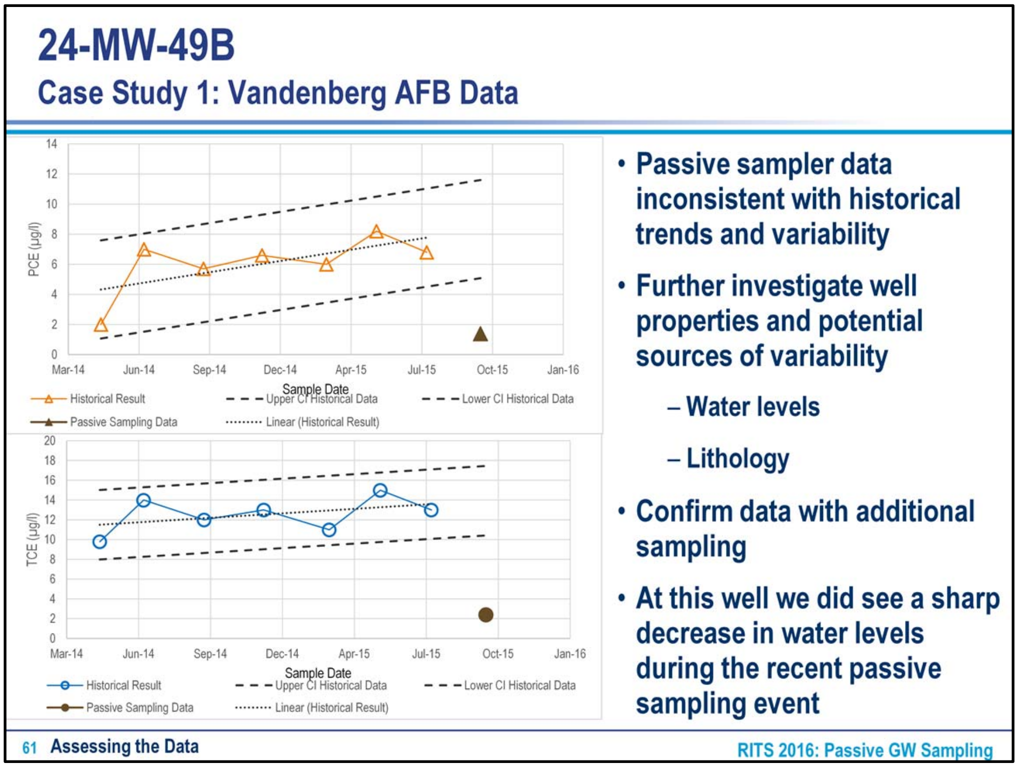


This data is from the first passive sampling event. The number of samples is fewer than was presented in previous slides (4th quarter as opposed to a more comprehensive 1st quarter event). It appears that there are a number of samples which are lower than the historical average, but many of the samples collected via passive sampling methods fall within the same range of variability as for traditional sampling methods.

The data shown that lay outside of the bounds were flagged for a more detailed evaluation. What was found, was that in the majority of cases, this bias low was a result of overall decreasing trends at these locations, as discussed in subsequent slides.



Examples of the additional evaluation completed at two monitoring wells for PCE and TCE is shown here. Other monitoring wells outside the range of typical site variability went through the same process.



Examples of the additional evaluation completed at two monitoring wells for PCE and TCE is shown here. Other monitoring wells outside the range of typical site variability went through the same process.

Preliminary Conclusions

Case Study 1: Vandenberg AFB Data

- One Sampling Event Currently Evaluated
- Data for most analytes comparable between passive sampling and traditional sampling methods
- Where data outside of the range of site variability, in most cases, attributed to decreasing trends or fluctuating water levels
- Where concentrations appear different, and can not be explained by site conditions, continue to monitor to confirm passive sampler data, then assess method suitability

Question Time

- Up Next: Wrap-Up
- Before we go…. What questions do you have on the data analysis and case studies?

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Presentation Overview

- Introduction
- What are Passive Groundwater Sampling Methods?
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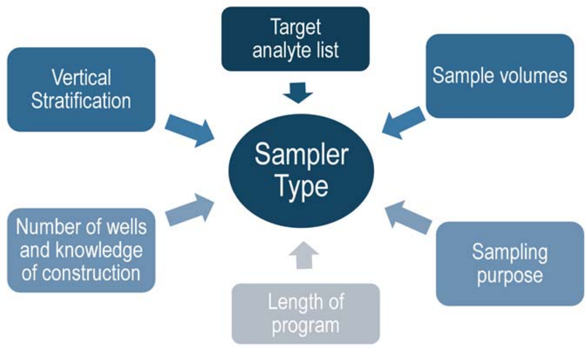
- Assessing the Data
- **Wrap-Up**

Key Points and Take-Away Messages for RPMs

- Passive groundwater sampling is one option for part of a broader optimization strategy
- Multiple accepted options for passive samplers
- Use decision criteria to select the best method for each site



Key Points and Take-Away Messages for RPMs (cont.)

- Large number of accepted and reputable studies on which to base transition decisions
  - More widely accepted and fewer barriers to implementation
  - Side-by-side comparisons are not always needed
- Some degree of variability is acceptable and expected for all sampling methods
  - Establish how much variability is acceptable early
  - Determine how the degree of variability influences remedial decisions
  - Determine regulatory impact and perspective

Key Points and Take-Away Messages for RPMs (cont.)

- Engage regulators early
- Define decision points and sampling method selection criteria upfront
- Negotiate with stakeholders to develop decision matrices to implement flexible and adaptable monitoring programs and data and analysis methods
- Actual savings may differ from estimated savings
  - Do not look simply at capital and ongoing costs
  - Labor, access, travel, and other logistical costs can play a significant role