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DEPARTMENT OF ENVIRONMENTAL PROTECTION

Oil and Gas Management

PIOGATECH Well Plugging Workshop: Well Plugging Regulatory Viewpoint

PIOGA®
Pennsylvania Independent Oil & Gas Association

April 25, 2019

A Note Regarding Terminology

The term “legacy wells” is used frequently throughout this presentation. The Crude Development Advisory Council (CDAC) has developed a working definition for this term: “any previously undiscovered, unregistered or unpermitted historical well. The status may be active, shut-in, abandoned, or plugged.” For this presentation, the term legacy wells is used to indicate all historically drilled wells that have been plugged or abandoned.

Discussion Outline

- A Brief Overview of the Legacy Well Story
- Review of Recent Critical Plugging Projects
- Ongoing Plugging Program Initiatives
  - Crude Development Advisory Council (CDAC) Updates
  - CDAC-Oil and Gas Technical Advisory Board (TAB) Plugging Workgroup
  - Research Partnerships
  - Program Improvement
- Environmental and Economic Liability Forecasting
  - Greenhouse Gas (GHG) Emission Footprint
  - Identifying At-risk Well Populations
  - Cost Modeling
  - Preventing Future Liability: The Arkansas Model
- Toward a Collaborative Future

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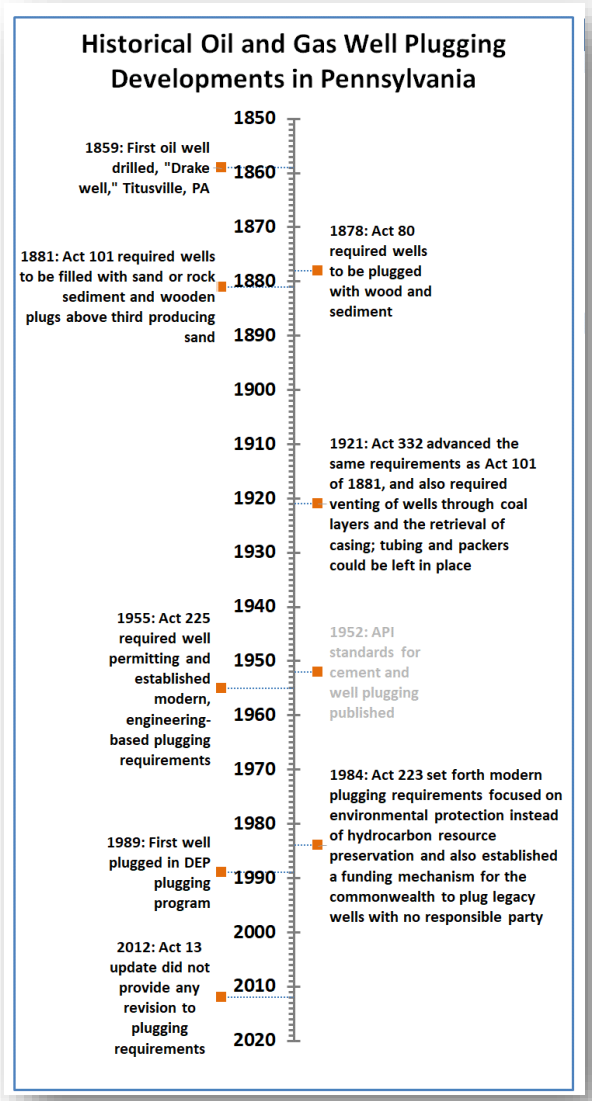
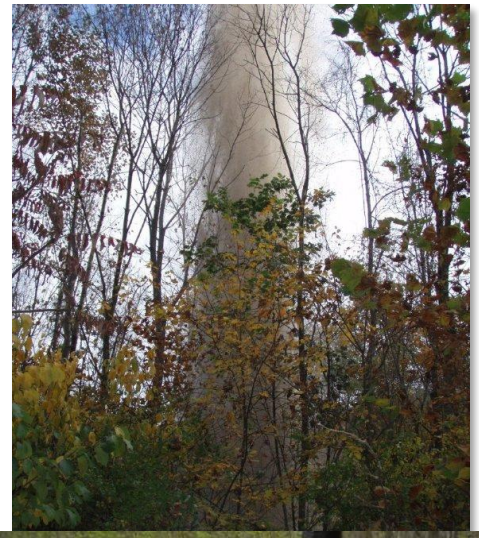
A Brief Overview of the Legacy Well Story

A Historical Perspective





A Brief Overview of the Legacy Well Story

Crunching the Numbers

- There are more than 8,000 wells in DEP's Orphan and Abandoned Well database. DEP has the statutory authority to plug these wells.
- Over the last four years, DEP has added 345 wells to its Orphan and Abandoned Well database.
- Over this same period, two operators with major holdings have abandoned almost 3,500 wells – since 1989, DEP has plugged a little over 3,000 wells.
- There are tens of thousands of producing conventional oil and gas wells that will eventually be candidates for plugging and many conventional operators face significant challenges in the current market.

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A Brief Overview of the Legacy Well Story

Crunching the Numbers

- Dilmore et al. (2015) and Engelder (2017) have estimated that somewhere between 330,000 and 350,000 wells were likely drilled in the commonwealth between 1859 and 2016. Kang et al.'s (2016) estimate more than doubles the upper end of this range.
- DEP and the industry have plugged 65,000 wells between 1910 and 2016, but many of these wells have not been decommissioned in accordance with current standards.
- Approximately 100,000 conventional wells are "active" and around 40,000 of these have never reported production. It is possible that the 40,000 wells will become future liabilities for the commonwealth.
- Conservatively, these studies and data suggest that there are likely at least 200,000 additional legacy wells, many of which will require plugging as they are discovered.

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A Brief Overview of the Legacy Well Story

Summary

- Regulatory requirements for well plugging have evolved over time. Wells plugged prior to modern plugging requirements may still pose a risk to public safety and the environment.
- Abandoned/orphan/improperly plugged wells can and have caused impacts to the environment and resulted in public safety concerns. Hundreds of thousands of legacy wells may yet be discovered.
- The longer an abandoned wells sits, the more likely it is going to cause a problem; and it is also more likely it will cost more money to decommission it.

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A Brief Overview of the Legacy Well Story

Summary

- Many marginal wells exist in Pennsylvania, and tens of thousands of them have no associated production records.
- Although the statutory changes associated with the Oil and Gas Act of 1984 that provided DEP legislative authority to address legacy wells and established a funding mechanism were well intentioned, there currently is no and there never has been a sustainable and reasonable mechanism for funding plugging of abandoned assets.

Review of Recent Critical Plugging Projects

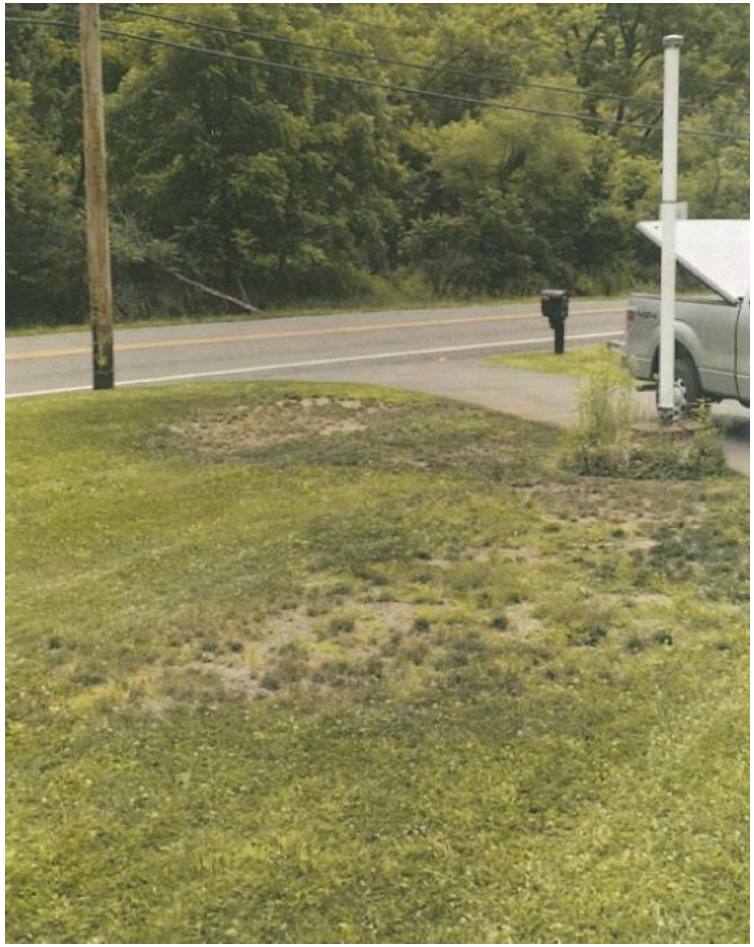
Addressing Emergencies

- DEP will continue to set funds aside for the execution of emergency contracts each year
- Protecting citizens of the commonwealth from imminent threats is a mission-critical objective
- Historically, the Plugging Program has set aside $200,000 annually for developing and executing emergency contracts – these include both well plugging and mitigation system/well venting projects
- Emergency contracts are classified as either “construction” or “mitigation” contracts
  - “Construction” emergency contracts involve well plugging and are administered by Construction Contracts
  - “Mitigation” emergency contracts involve well vents or stray gas migration mitigation systems and are administered by the Office of Oil and Gas Management – costs that exceed $10,000 must be approved by DGS

Review of Recent Critical Plugging Projects

Addressing Emergencies

- Antaki Well: $14,000 for stray gas mitigation system



Review of Recent Critical Plugging Projects

Addressing Emergencies

- Antaki Well: $14,000 for stray gas mitigation system

Review of Recent Critical Plugging Projects

Addressing Emergencies

- John Barron Well: $179,000 for flaring and plugging

Review of Recent Critical Plugging Projects

Addressing Emergencies

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Review of Recent Critical Plugging Projects

Addressing Emergencies

- John Barron Well: $179,000 for flaring and plugging

Review of Recent Critical Plugging Projects

Addressing Emergencies

- Monahan Well: $160,000 for plugging

Review of Recent Critical Plugging Projects

Addressing Emergencies

- Monahan Well: $160,000 for plugging

Review of Recent Critical Plugging Projects

Addressing Emergencies

- Since the projects reviewed on the previous slides, DEP has executed or is in the process of advancing three more projects classified as emergencies or critical for ensuring public safety – anticipated costs are $500,000
- Although further review of historical records is needed, a recent records audit by the agency has shown that DEP has spent upwards of $2 million in funding emergency projects dating back to 1986 and over $300,000 alone in the last two years
- At some of these locations, it is clearly less expensive to condemn and raze the property, and then restrict future development; but is that really a viable alternative?

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Ongoing Plugging Program Initiatives

CDAC Updates

- CFA OAWP Program Summary
  - Grant source: Act 13 Marcellus Legacy Fund
  - Eligible projects: well plugging/stray gas mitigation systems/well venting
  - Application period: February 1st – May 31st
  - Maximum grant level: $250,000 per project
  - Grant processing fee: $100
  - Applicant cost sharing: “eligible applicant shall provide easements and rights-of-way, and landowner commitments”
  - Grant period: up to 3 years with extensions available for good cause
  - For more information: https://dced.pa.gov/programs/orphan-abandoned-well-plugging-program-oawp/ and https://www.dep.pa.gov/Business/Energy/OilandGasPrograms/OilandGasMgmt/Pages/Abandoned-and-Orphan-Well-Program.aspx

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Ongoing Plugging Program Initiatives

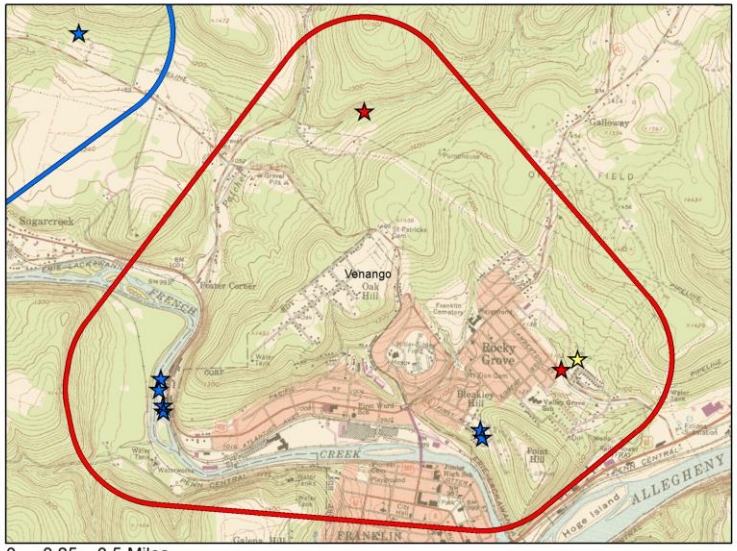
CDAC Updates

- Finding ways to improve access to existing sources of funding
  - Commonwealth Financing Authority (CFA) Orphan and Abandoned Well Plugging (OAWP) Program: Since inception in 2013, only $1.1 MM out of $103 MM (about 1%) in grants have been awarded for well plugging projects

Ongoing Plugging Program Initiatives

CDAC Updates

- Finding ways to improve access to existing sources of funding
  - DEP maintains a list of "shovel-ready" projects for interested grant applicants
  - Form more information: http://files.dep.state.pa.us/OilGas/BOGM/BOGMPortalFiles/AbandonedOrphanWells/Plugging_Projects_CFA_2_9_18.pdf



Plugging Project Name: 70L

Priority Ranking: 30 / 85
Opportunity Ranking: N/A
Number of Abandoned / Orphan Wells: 9
Estimated Number of Water Supplies: 30
Estimated Number of Residents: 2962
Environmental Justice Area: Yes
Project Value (Low): $88,012.29
Project Value (High): $174,085.29
High Resolution Cost Control: Yes
Congressional District:
Thompson, Glenn W. (5)
House District:
James, R. Lee (64)
Senate District:
Hutchinson, Scott E. (21)

Designated Use Streams (miles):

Cold Water Fishery: 1.5
Trout Stocking: 0
Warm Water Fishery: 9.9
High Quality: 0
Exceptional Value: 0

Recreational Areas (acres):

State or National Parks: 0
State or National Forest: 0
Fish and Game / State Game Lands: 0

Project Facts:

This project profile considers water resources, sensitive environments, recreational areas, and commonwealth residents in the vicinity of abandoned and orphan wells that DEP is responsible for plugging. These characteristics were used to rank this project relative to many other potential plugging projects throughout Pennsylvania. The project profile provides key statistics on the number of abandoned and orphan wells, water supplies, residents, legislative districts, stream miles, and recreational areas for the location. It also assigns a project value and assesses whether or not the location coincides with an Environmental Justice area. Project value information was developed in consideration of historical DEP plugging contract amounts. If the project falls in an area where DEP has completed a greater amount of prior work, the project is designated as having "High Resolution Cost Control."

Ongoing Plugging Program Initiatives

CDAC Updates

- CDAC members met with DCED leadership in March 2019 and several "Action Items" were established
  - DEP assessing orphan and abandoned wells to identify critical projects – plan to work out access issues and update well status/risk information for these wells
  - DCED willing to revisit grant cap amount of $250,000 – DEP is evaluating well cost data to propose a new cap
  - DEP working to better integrate Environmental Good Samaritan Act (EGSA) liability relief with CFA OAWP Program

Ongoing Plugging Program Initiatives

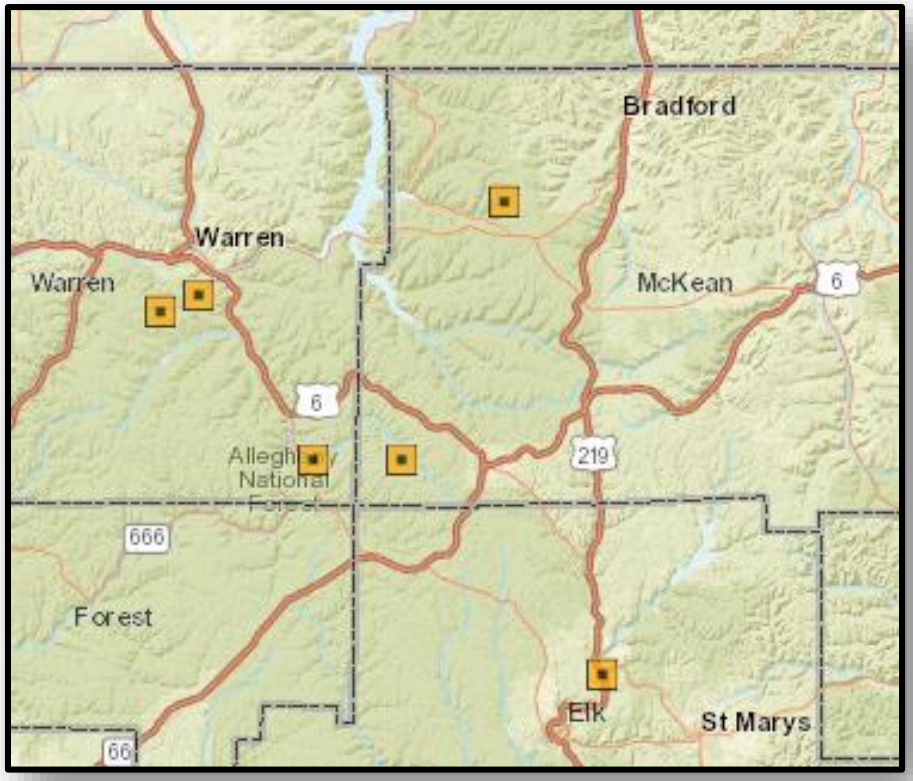
CDAC Updates

- Good Samaritan Project Highlights
  - EGSA provides liability relief for approved applicants conducting legacy well plugging
  - In many cases concerning legacy wells may have been identified, but they may not be high enough on DEP's priority list to advance agency plugging along the timelines of a development project considering current funding levels
  - DEP and CDAC have partnered to promote EGSA plugging and streamline the process as much as possible for legacy well plugging projects

Ongoing Plugging Program Initiatives

CDAC Updates

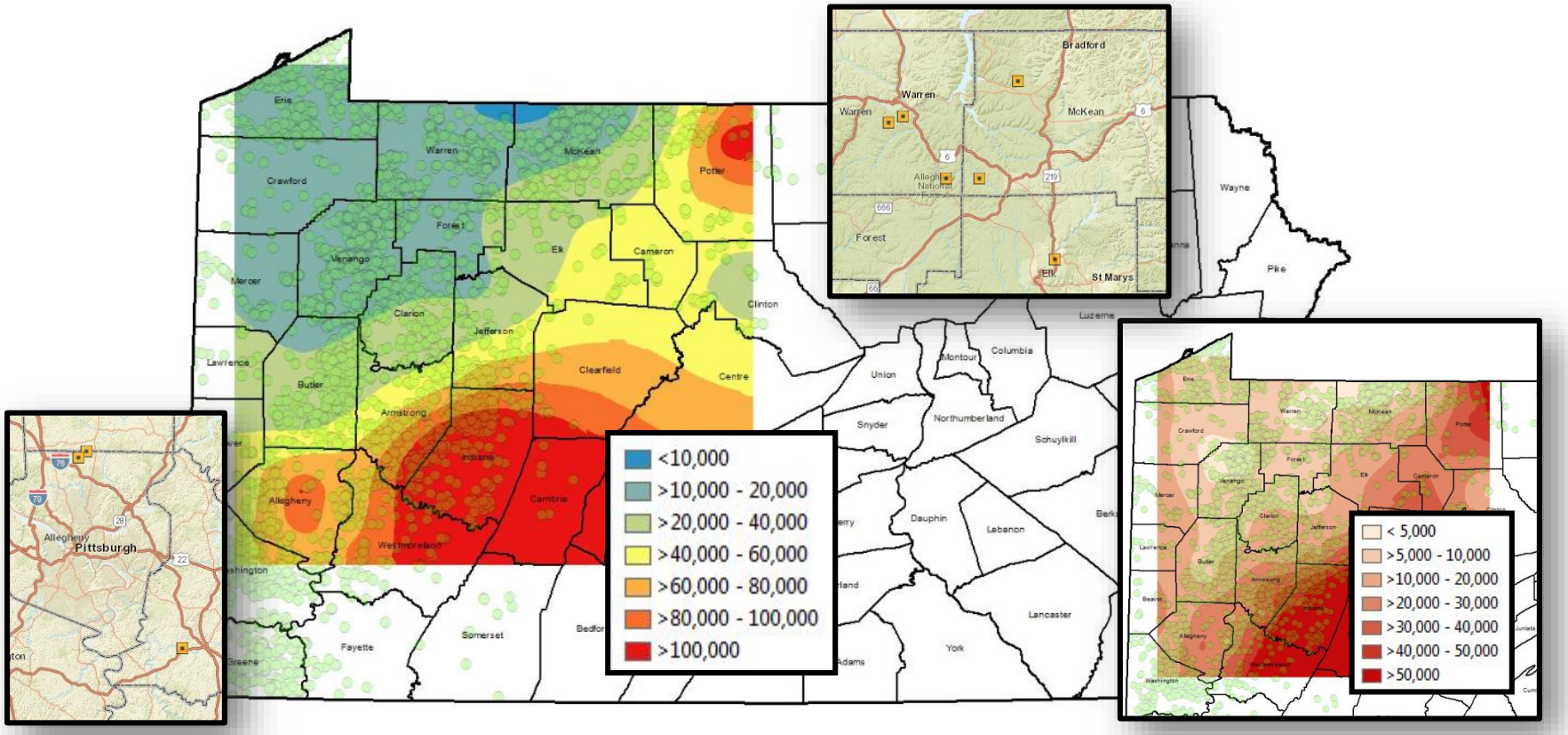
- Good Samaritan Project Highlights



Ongoing Plugging Program Initiatives

CDAC Updates

- Good Samaritan Project Highlights



Ongoing Plugging Program Initiatives

CDAC Updates

- Good Samaritan Project Highlights
  - Allowing redevelopment to continue at a pace driven by economic opportunities
  - Providing liability relief for developers
  - Protecting the environment and public safety
  - Extending DEP plugging resources and saving the agency a significant amount of money – cumulative project value estimated at $500,000
  - For more information: https://www.dep.pa.gov/Business/Energy/OilandGasPrograms/OilandGasMgmt/Pages/Abandoned-and-Orphan-Well-Program.aspx

Ongoing Plugging Program Initiatives

CDAC-TAB Plugging Workgroup

- Objective is to extend plugging resources for industry and the agency
  - Use existing regulatory process to increase plugging efficiency: policy interpretations and alternative methods
  - Facilitate more effective planning in advance of plugging projects and establish communication expectations during the project
  - Risk assess wells in a consistent manner to prioritize plugging
  - Facilitate research to better understand contributing factors when well plugs fail
  - Use assembled learnings to inform new regulations over the longer term

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Ongoing Plugging Program Initiatives

CDAC-TAB Plugging Workgroup

- Key Developments
  - Implemented new policy interpretation for pre-Act well plugging of wells with uncemented surface casing: http://files.dep.state.pa.us/OilGas/BOGM/BOGMPortalFiles/OilGasReports/Construction_Standards_FAQ/FAQ's/Pulling_Surface_Casing_FAQ_020190215.pdf

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Ongoing Plugging Program Initiatives

CDAC-TAB Plugging Workgroup

- Key Developments
  - Developed new risk-assessment process for prioritizing plugging at well sites that eliminates redundancy
  - Foundation for the risk-assessment process was established through a joint CDAC-DEP audit of the agency's well scoring system for legacy wells

Ongoing Plugging Program Initiatives

Research Partnerships

- McGill University
  - Kang et al. (2016) found a high occurrence of leaking abandoned and plugged wells
  - Isotopic signatures support deep, oil-associated origin
  - In some cases, gas was found to be flowing through the soil beyond the footprint of the outermost well casing
  - DEP is currently working to understand the construction and/or plugging details at the identified leaking wells

Ongoing Plugging Program Initiatives

Research Partnerships

- University of Pittsburgh
  - Pitt's Graduate School of Public and International Affairs (GSPIA) is conducting research on a number of oil and gas topics related to economic impact
  - Preliminary findings suggest that the presence of abandoned legacy wells may be deterring development, which ultimately has negative impacts on tax revenues for communities
  - The research group has also begun to evaluate bonding levels and liability potentially tied to wells where no production reports have been submitted
  - For more information: https://medium.com/@GSPIAe_eBlog

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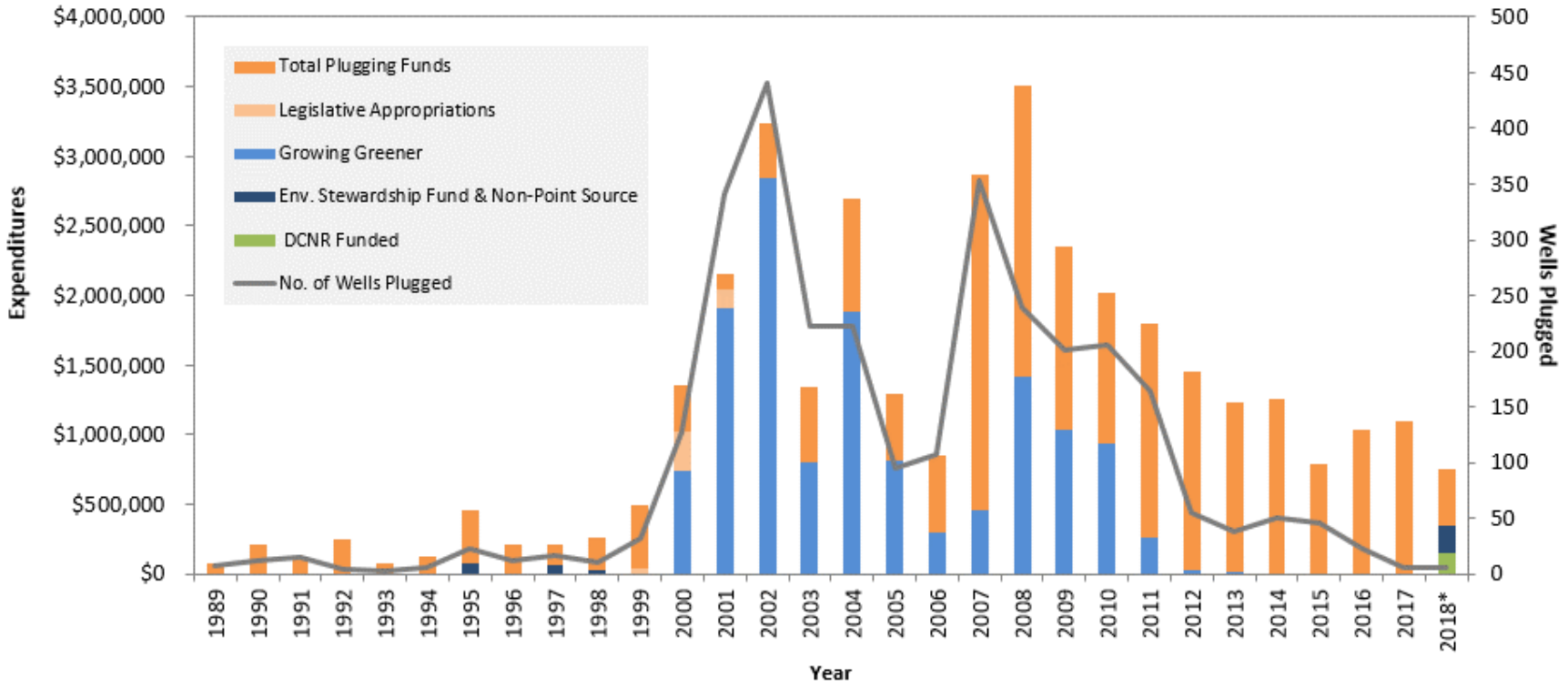
Ongoing Plugging Program Initiatives

Program Improvement

- DCNR, DEP Mining Program, and DEP Grants Center via Environmental Stewardship Fund (ESF) are contributing significantly to the program's funding options



Ongoing Plugging Program Initiatives

Program Improvement

- Website enhancements
- Social media utilization
- Appalachian basin partnerships
- Publication of new Technical Guidance Document for managing legacy well liability – expected release for public comment in second quarter, 2019
- Publication of legacy well integrity and emissions study in peer-reviewed journal – expected submission to journal for review in fourth quarter, 2019; for more information: https://gsa.confex.com/gsa/2017NE/webprogram/Paper290348.html

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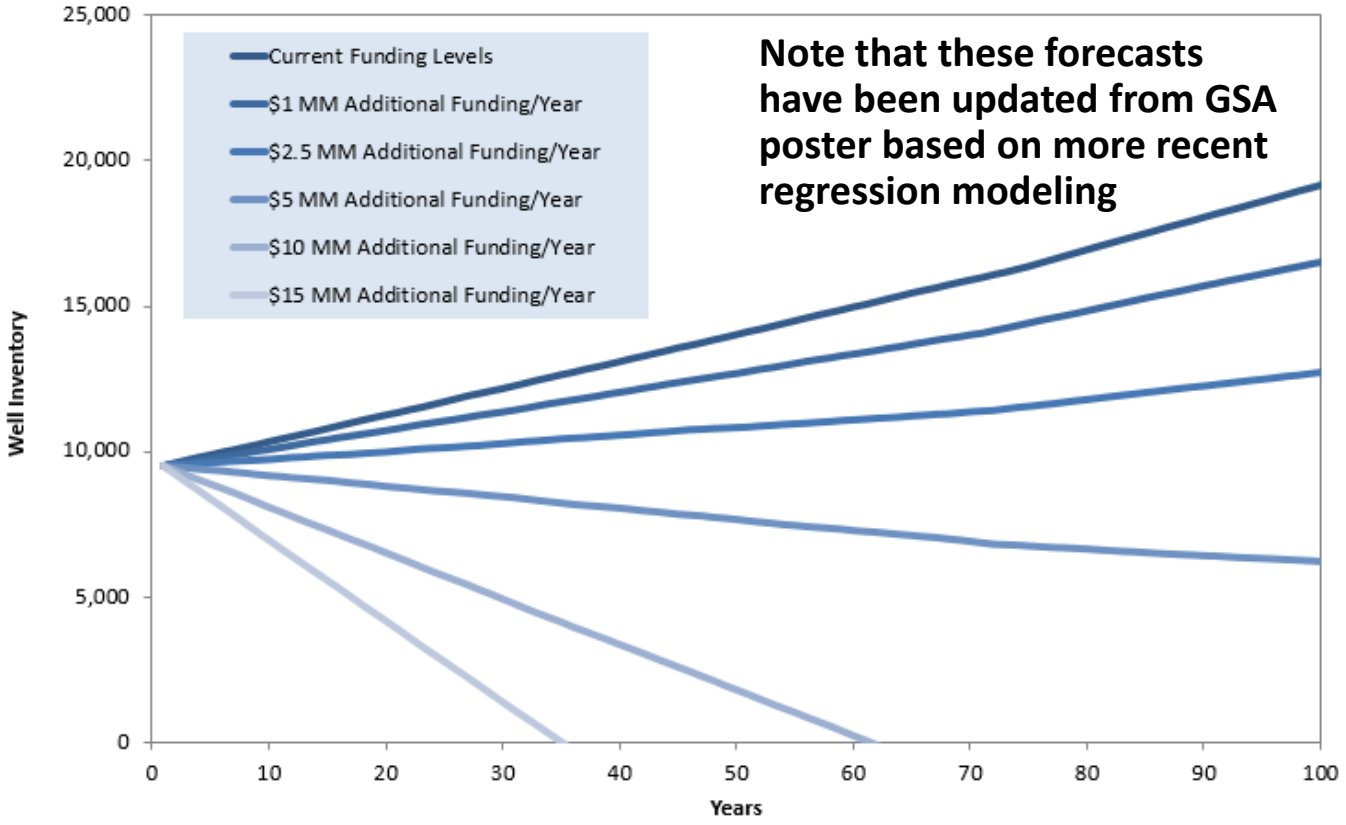
Ongoing Plugging Program Initiatives

Program Improvement

- Where does all this work leave us? Not close enough to a solution!



GHG Emission Footprint

- As part of DEP's planned publications, the agency anticipates developing legacy well emission estimates based on Kang et al.'s (2016) research in the commonwealth
- It is anticipated that emissions associated with known legacy wells could account for a significant fraction of the natural gas and oil systems emissions, which were estimated at almost 11 $MMTCO_2e$ by DEP in 2015

Environmental and Economic Liability Forecasting

GHG Emission Footprint

- Kang et al. (2016) developed several multiple regression models for estimating emissions
- Key predictor variables for Kang et al.'s (2016) L3 model include
  - Coal area (lower emission rates)
  - Plugging status (unplugged and plugged/vented wells have higher emission rates)
  - Well type (oil wells have lower emission rates)

Table S3. Multilinear regression analysis results: R^2 values, p-values, and variable coefficients.

	Model L6a	Model L6b	Model L6c	Model L3	Model N6b	Model N3
R^2 for model	0.39	0.44	0.26	0.43	0.20	0.20
p-value for model	8.1×10^{-7}	4.4×10^{-8}	8.0×10^{-4}	1.9×10^{-9}	0.011	0.0010
Variable Coefficients						
Intercept	2.54	2.84*	2.49	3.23***	18317	17159
d	0.00049	0.00039	-9.41×10^{-5}		-0.39	
C = coal area		-5.50***		-4.95***	-17384	-16486
C_1 = coal area			-1.12			
n_C	-1.39***					
P = unplugged	3.58***	3.99***	3.40**	3.94***	24107*	24711*
P = plugged/vented	9.60***	8.33***	7.00*	9.85***	67777*	67842**
W = Oil	-3.33*	-2.88*	-3.72*	-3.35***	-34302	-29930**
r_S	0.037	0.016	0.015		286	
r_U	-0.095	-0.087	0.053		-290	

Models L6a, L6b, L6c, and L3 are based on $\log \dot{m}$; while Models N6b and N3 are based on $\dot{m}$.
* p-values<0.05.
** p-values<0.01.
*** p-values<0.001.

Environmental and Economic Liability Forecasting

GHG Emission Footprint

- Why is Kang et al.'s (2016) L3 multiple regression model of most interest?
  - All predictor variables are statistically significant
  - It reasonably segregates the highest emitting wells from lower emitting wells

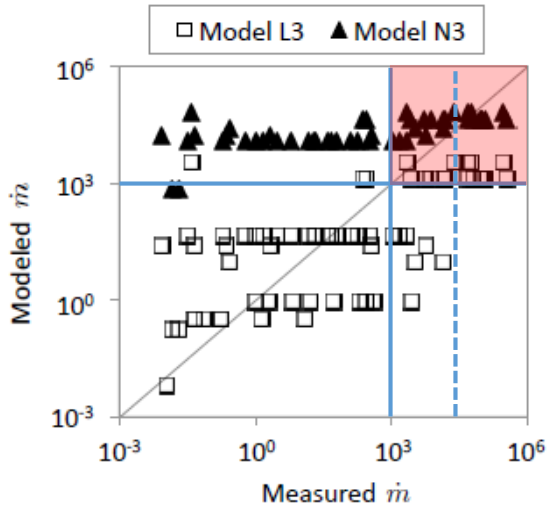


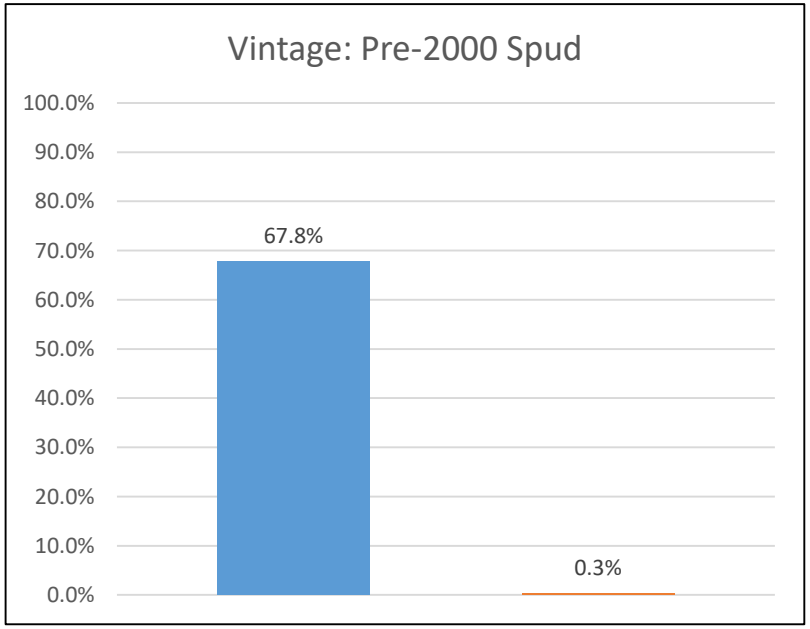
Fig. S6. Modeled and measured methane flow rates, $\dot{m}$ (mg hr^{-1} $well^{-1}$).

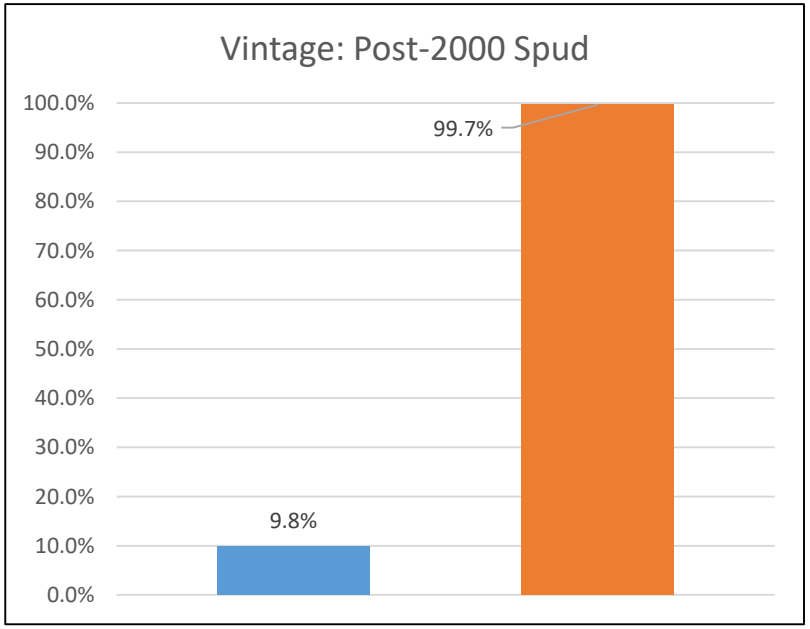
At-risk Well Populations

- DEP has recently begun mining its own datasets to develop tools for identifying “at-risk” well populations
- A clustering algorithm was used to assess conventional well production, waste and mechanical integrity assessment characteristics

At-risk Well Populations

- Well Vintage Characteristics

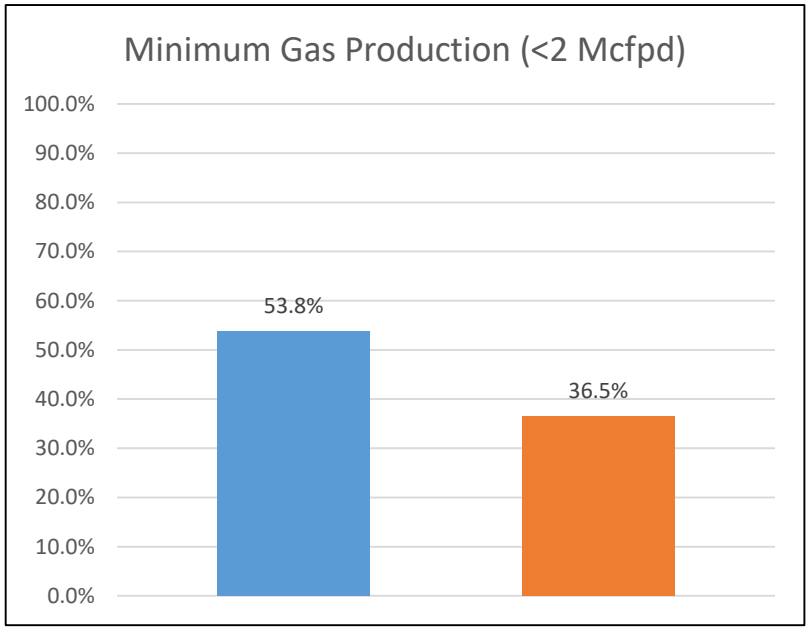


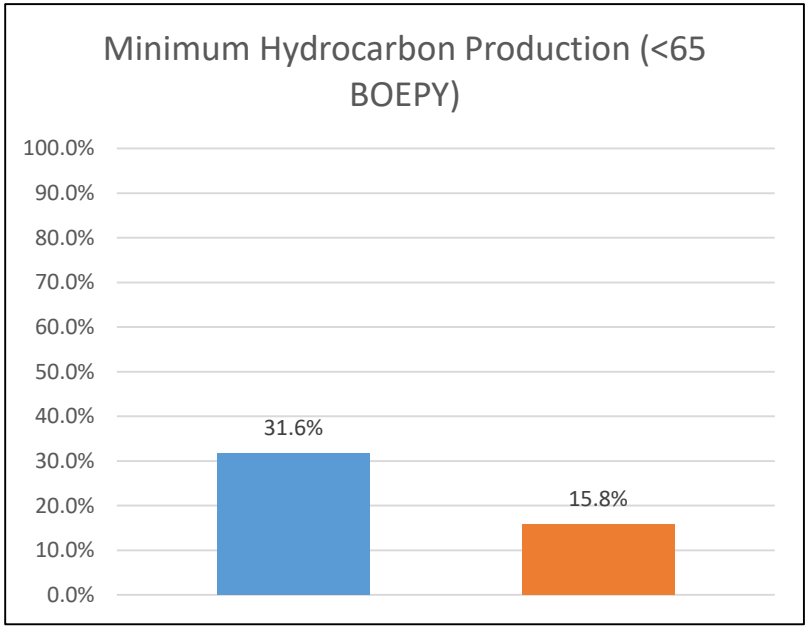


$N_{Cluster1}$ = 40,206 $N_{Cluster2}$ = 24,690

At-risk Well Populations

- Minimum Hydrocarbon Production



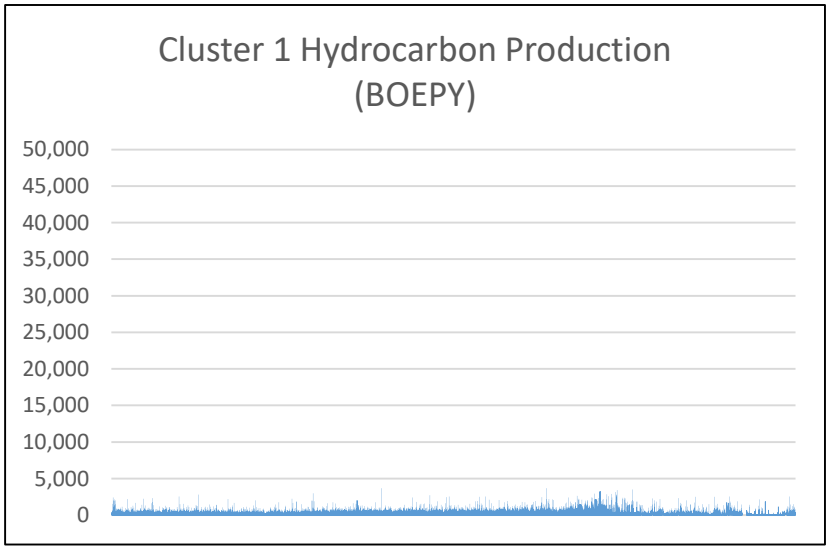


$N_{Cluster1}$ = 40,206 $N_{Cluster2}$ = 24,690

Environmental and Economic Liability Forecasting

At-risk Well Populations

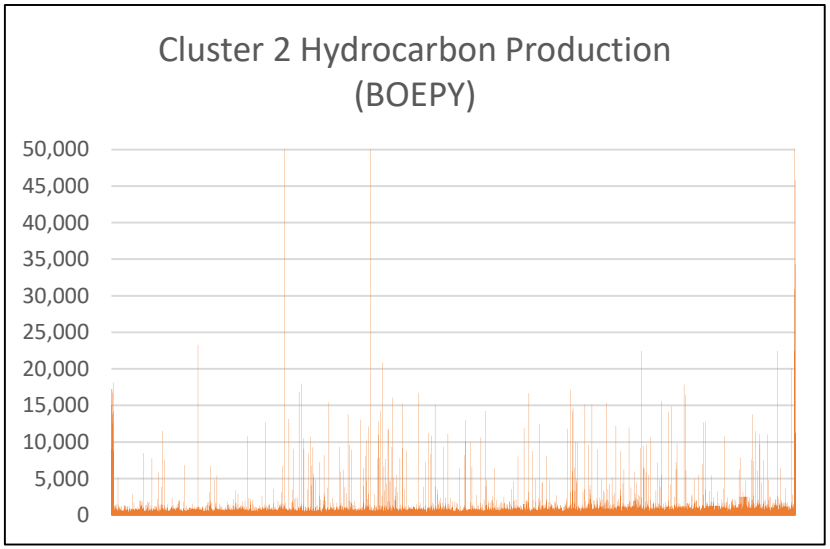
- Hydrocarbon Production (BOEPY)



$N_{Cluster1}$ = 40,206

$Mean_{Cluster\ 1}$ = 215

95% $UCL_{Cluster\ 1}$ = 217



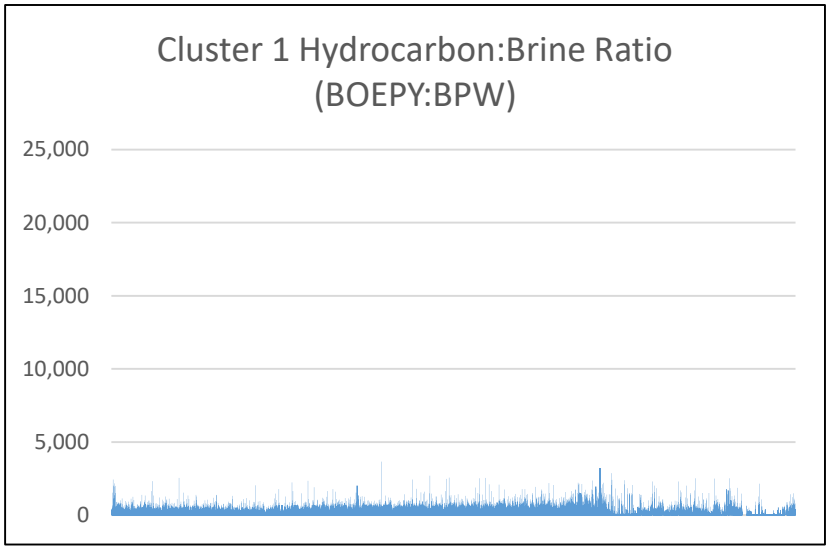
$N_{Cluster2}$ = 24,690

$Mean_{Cluster\ 1}$ = 470

95% $LCL_{Cluster\ 1}$ = 424

At-risk Well Populations

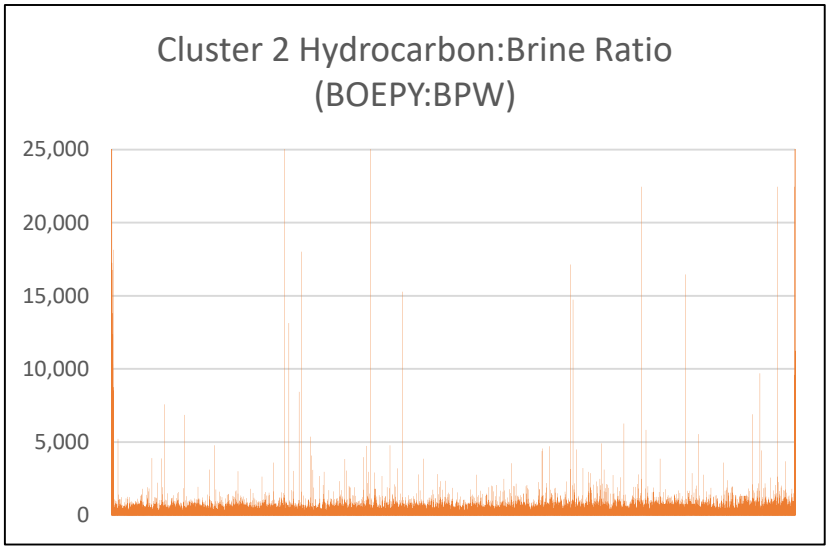
- Hydrocarbon:Brine Production (BOEPY:BPW)



$N_{Cluster1}$ = 40,206

$Mean_{Cluster\ 1}$ = 165

95% $UCL_{Cluster\ 1}$ = 167



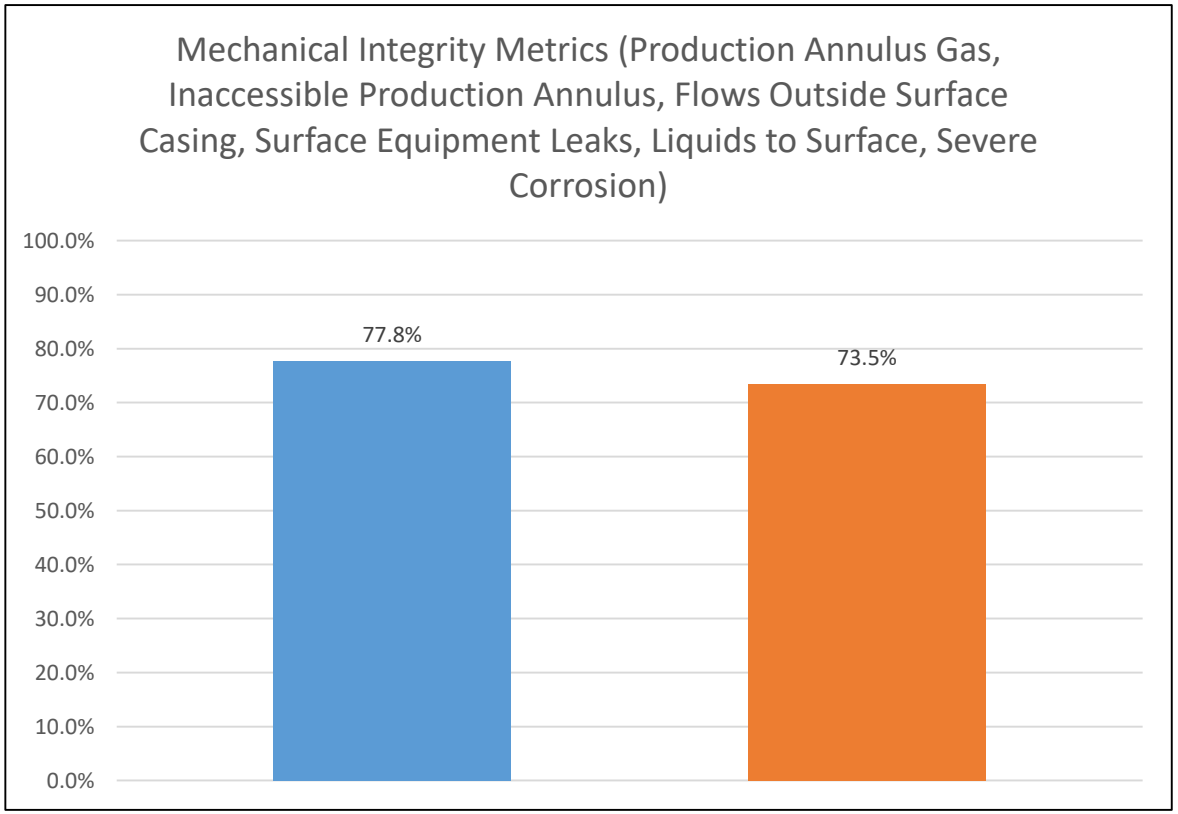
$N_{Cluster2}$ = 24,690

$Mean_{Cluster\ 1}$ = 294

95% $LCL_{Cluster\ 1}$ = 268

At-risk Well Populations

- Well Integrity Characteristics



$N_{Cluster1}$ = 40,206 $N_{Cluster2}$ = 24,690

At-risk Well Populations Summary

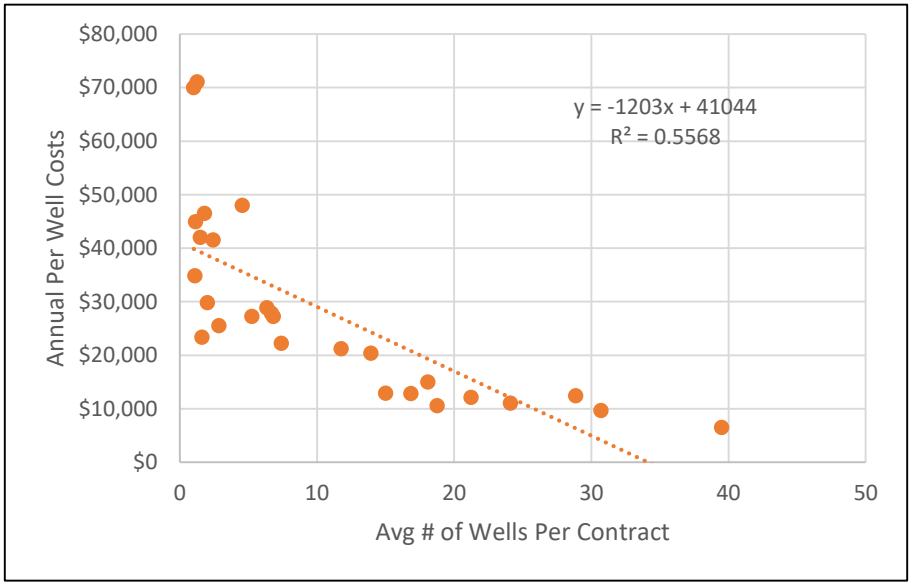
- Clustering algorithm groups older wells with lower hydrocarbon production and lower hydrocarbon-to-brine ratios together
- BOEPY and BOEPY:BPW mean differences appear to be statistically significant
- No appreciable difference in well integrity metrics has been noted between the two groups

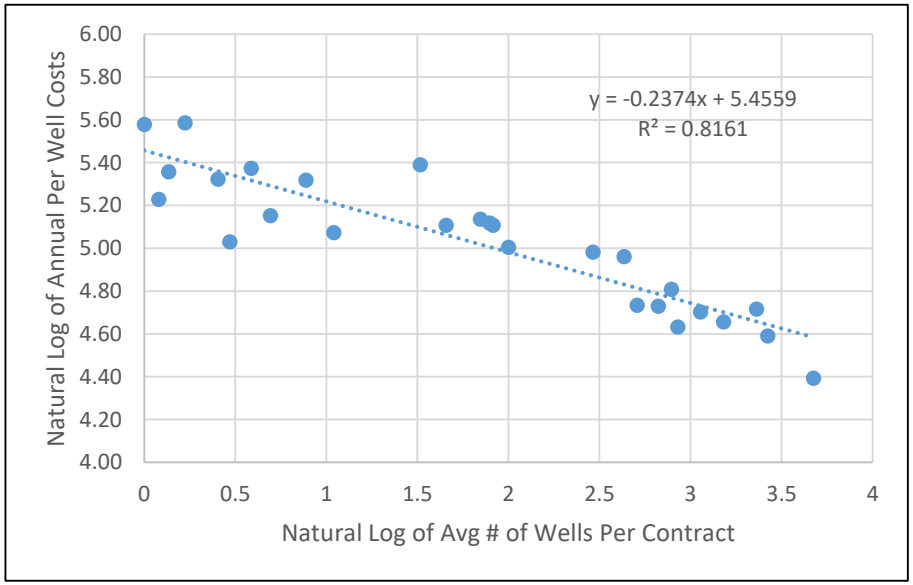
Cost Modeling

- As part of DEP's efforts to publish its well integrity and emissions study, updates to the agency's liability forecasting model are underway
  - Historical plugging cost database has been updated
  - Regression modeling has been used to derive average future well plugging costs

Cost Modeling

- Influence of number of wells per contract





Cost Modeling

- Influence of number of wells per contract

$$y_i = \beta_0 + \beta_1 x_1$$

where:

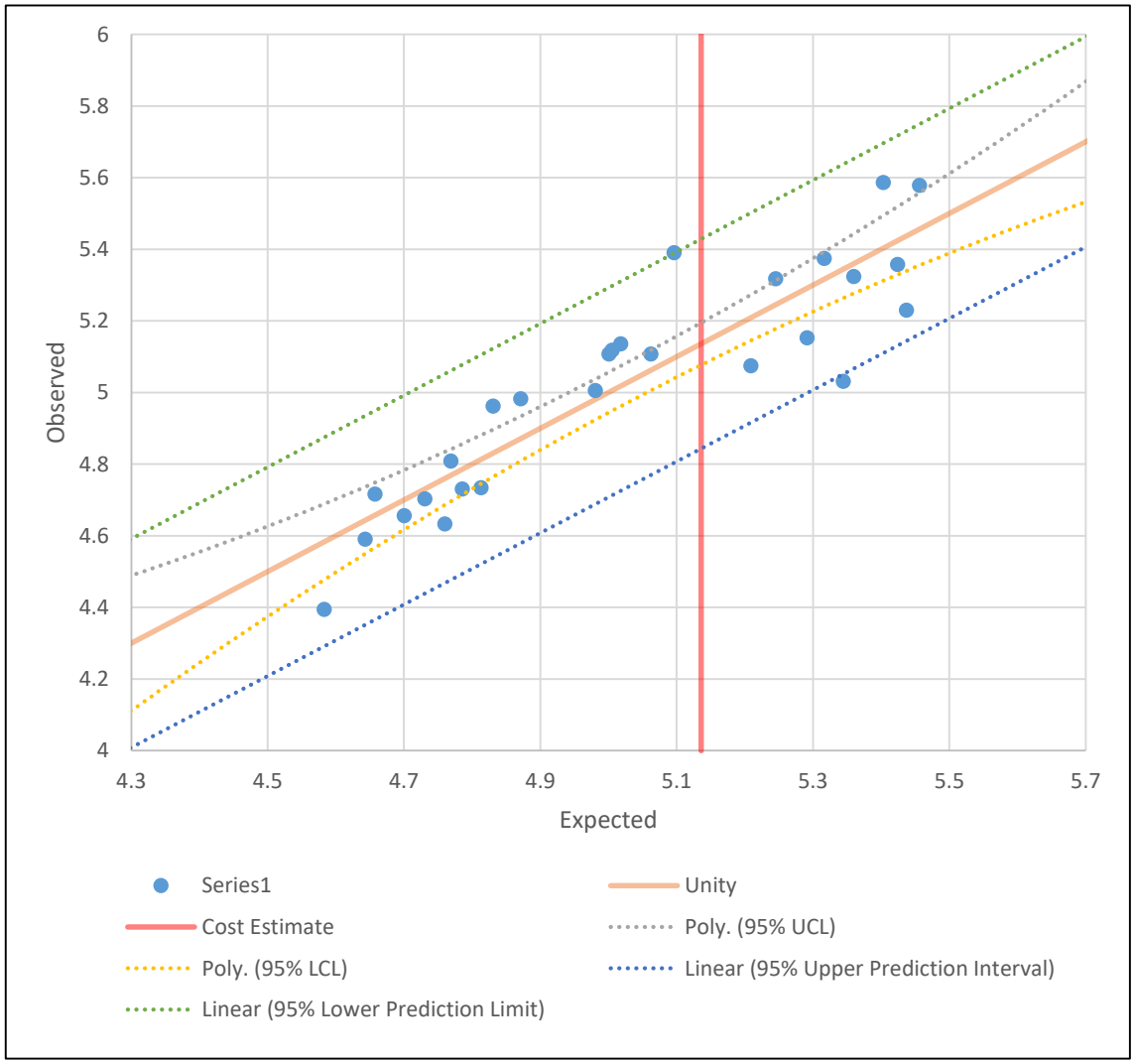
y_i = dependent variable (natural log of average annual per well costs)
β_0 = constant in the regression equation (5.456)
β_1 = coefficient for indepdent variable 1 (-0.237)
x_1 = independent variable (natural log of average number of wells per contract)

Cost Modeling

- By inputting a conservative value for the future anticipated number of wells per contract and modeling uncertainty, a useful future per-well cost estimate can be derived

Environmental and Economic Liability Forecasting

Cost Modeling

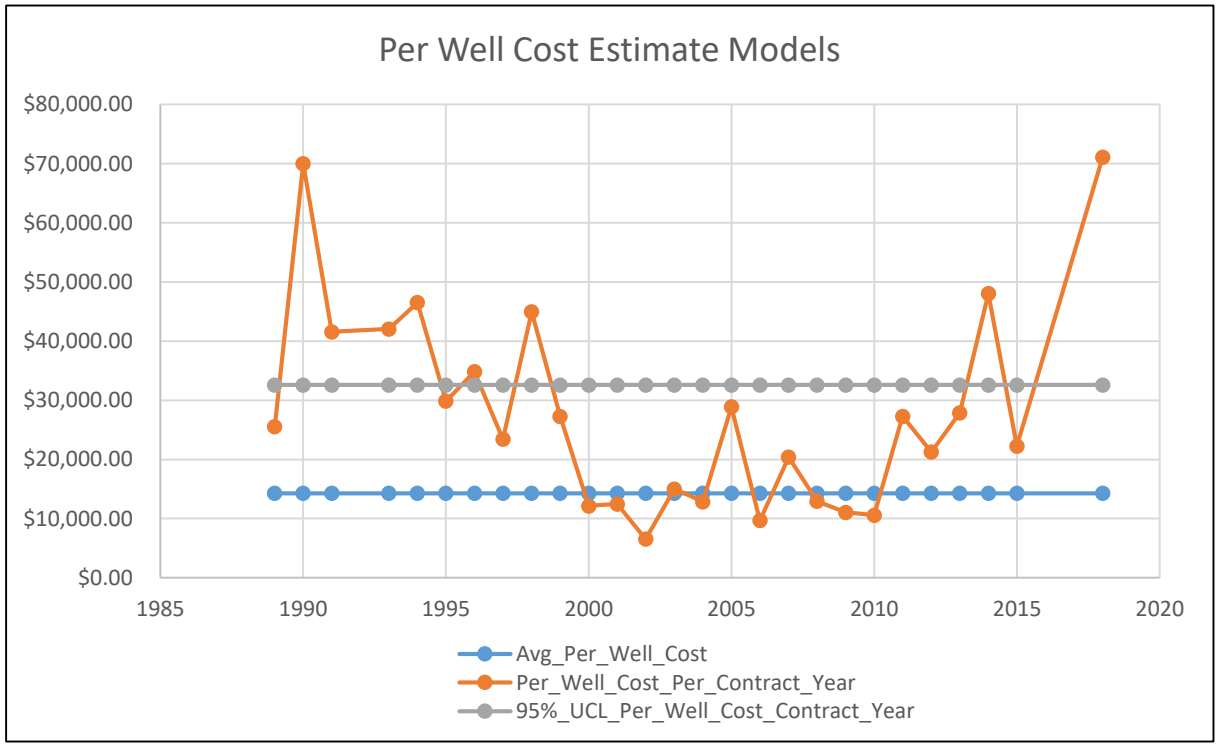


95% upper confidence limit per-well cost is estimated at approximately $33,000

Environmental and Economic Liability Forecasting

Cost Modeling

- Liability forecasting changes significantly based on per-well cost assumptions
- At $33,000 per well, DEP's plugging liability ranges somewhere between $280 MM (8,500 wells) and $6.6 B (200,000 wells)



Environmental and Economic Liability Forecasting

Preventing Future Liability: The Arkansas Model

- Modest annual operating fee for oil wells
- Site-specific per-well financial assurances for gas wells
- Pre-qualified plugging contractors
- Marginal-well definition and per-well financial assurances for transferred marginal assets
- Standardized per-well financial assurances for idle wells

RESULT: Arkansas has been able to decommission half of its legacy wells in half the time it has taken DEP to plug a quarter of its legacy wells

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Toward a Collaborative Future

Moving Forward

- All stakeholders must work to acknowledge the current state of conventional operations, legacy well liability, and environmental protection expectations in Pennsylvania – this can be done more effectively through collaboration than through unilateral actions
- Legacy wells are a liability, but they represent an economic opportunity, as well
- Multi-stakeholder efforts are resulting in the extension of plugging resources, but the work takes time and a firm commitment
- Failure to begin addressing this matter proactively has the potential to result in reactionary responses to anticipated future problems

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Oil and Gas Management

Thank You!
Questions?

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Many thanks to DEP Harrisburg Legacy Well Team Members (past and present): Harry Wise, Serena Oldhouser, Kevin Bogdan, Doug Catalano, Rick Swank, Bruce Jankura, Jim Braunns, Lindsay Byron, and Stew Beattie!

Find out more about DEP's Well Plugging Program