Reclamation Costs and Regulation of Oil and Gas Development with Application to Wyoming

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Introduction

Boom and bust in Wyoming's energy sector is common and almost expected in the Rocky Mountain West's economy. However, the current energy boom in Wyoming has resulted in substantially more development than previous booms. For example, in the period 1988 to 1998 well counts grew at an annual average rate of 15 percent per year compared to 41 percent per year in the period 1998 to 2008.[2] As energy production increases there is growing concern about the pace of development and issues related to the reclamation of disturbed lands.

This study draws from a previous work by Andersen and Coupal (2009) that analyzed costs and policies that affect land reclamation decisions by oil and gas firms. We begin by providing a brief description of the current regulatory setting that governs the oil and gas industry in Wyoming and focus our attention on reclamation bonding requirements, which are intended to insure the proper reclamation of disturbed land. The most important issue affecting the decision to reclaim is the cost of reclaiming the disturbed land (although other factors such a clear reclamation guidelines and standards set by land management agencies are important as well). Therefore, we provide a detailed analysis of the cost of reclaiming orphaned wells in Wyoming using data provided by the Wyoming Oil and Gas Conservation Commission (WOGCC). The results are used to predict the current reclamation costs for Wyoming's oil and gas industry and to provide information on ways to improve the current bonding system.

As of 2009, there were more than 60,000 active oil and gas wells in the state operated by approximately 900 separate firms. This level of activity suggests that reclamation issues will become more important in the future as these wells are plugged and released or abandoned. Factors that become important in successful reclamation include the regulatory environment, industry structure, and environmental factors associated with the specific location of the field or well. Given the sheer number of wells and their distribution across varying ecological and precipitation regimes, as well as the sharp increase in development over the past decade, the structure and expectations of reclamation regulations becomes an important policy issue for State and Federal Agencies.

Regulatory Structure and Bonding Requirements

The Bureau of Land Management (BLM) is the main regulatory agency for oil and gas development on federal land. There are two aspects to the BLM's regulatory structure that are part of the reclamation decision and performance: the stated goals of reclamation and the

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[2] Authors calculations based on WOGCC data, available on line at http://wogcc.state.wy.us

bonding parameters. The BLM's land management objective over the years has been to reclaim up to the level that minimizes spillover damages on associated tracts. Reclamation in this federal regulation [43 CFR 23.3] is defined as follows:

> "…Reclamation means measures undertaken to bring about the necessary reconditioning or restoration of land or water that has been affected by exploration or mineral development, mining or onsite processing operations, and waste disposal, in ways which will prevent or control onsite and offsite damage to the environment."

The BLM focus was on minimizing off-site damages. The language in the rule under proposal now dramatically expands the scope of what is expected of reclamation (Lahti, 2009). The proposed rule focuses on both short term and long term goals, and establishes reconstruction of the previous ecosystem as priority:

> "Short term goal: immediately stabilize disturbed areas and provide conditions necessary to achieve the long term goal. Long term goal: facilitate eventual ecosystem reconstruction to maintain a safe and stable landscape and meet the desired outcomes of the land use plan." [Lahti, 2009]

The interesting difference is the reference to ecosystem parameters that existed before the development. This suggests a higher standard than the guidelines that governed previous operating procedures.

A second aspect of the existing regulation is the reclamation bond. An environmental bond represents a guarantee against the failure to cure environmental damage from mining (Webber, 1985). A study conducted by the Political Economy Research Center (Gerard, 2000) concluded that bonding "is a market-based enforcement mechanism that relies on financial incentives and reputation effects to deliver site reclamation at the lowest possible cost." Some of the potential advantages of reclamation bonds include increasing the probability of reclamation and regulatory flexibility in monitoring and enforcement activities. Bonding mechanisms also have inherent limitations such as the opportunity costs associated with investment of firm resources in bonds, administrative costs, and legal restrictions (Shogren, 1993).

Bonding can occur through various instruments: cash outlays, capital liens, or surety bond companies who pay the bond on promise that the reclamation will be completed by the oil and gas company. The latter approach allows companies to minimize cash outlays to cover bonds, and is a common practice in the industry. However, recent reports on the surety bond market suggest that a market approach to bonding may be limited (Kirschner and Grandy, 2002). Surety bonds are increasingly difficult to secure because of general market conditions and higher risk.

The current bonding requirements for oil and gas development depends on the type of land under development, with slightly different regulation covering federal land as opposed to state and private land. The Bureau of Land Management (BLM) has authority to require a bond under the Mineral Leasing Act (MLA), and the current fees range from $10,000 for a single lease that may cover multiple wells to $150,000 for a national blanket bond that covers all production activities (across state-lines) and often cover hundreds of wells under a single blanket bond. In addition, producers can apply for a blanket bond of only $25,000 to cover all the wells drilled within one state. In Wyoming, the WOGCC sets the bonding requirements for private lands and they are similar to the federal requirements although the WOGCC has recently made some changes to the rules including adding a fee for idle wells.[3]

The biggest weakness of the current bonding requirements is that they are not linked to production, but are instead a fixed cost that is essentially a sunk cost from the perspective of the operator. The bonding requirements are poorly designed, and the bond amounts posted are low relative to the cost of actually performing the reclamation, which is the subject of the remainder of this study. Given accurate reclamation cost estimates, appropriate bonding requirements can be established that fully account for the cost of reclamation.

Reclamation Costs for Orphaned Wells

The following analysis of the cost of reclaiming land disturbed by oil and gas development in Wyoming was conducted using data from the WOGCC.[4] The cost figures represent the actual costs incurred by WOGCC in the process of fully reclaiming a total of 48 separate locations on fee lands that included a total of 255 orphaned wells in Wyoming from 1997-2007.[5] As a starting point, Table 1 shows the actual cost, bond amount, and variance (difference between cost and bond) for the full set of 255 wells: 1) per foot of drilling depth; and 2) per well.

Table 1: Orphaned Oil & Gas Wells in Wyoming (1997-2007)

	Actual Cost	Bond	Variance
Per foot	$10.01	$1.59	$8.42
Per well	$27,555	$5,302	$22,253

Notes:
a. Averages from full database (48 locations and 255 wells).
b. Includes orphaned wells with no bond posted.

The actual cost of the full reclamation of the 255 wells was $10.01 per foot of well depth, and approximately $27,555 per well. The bond per foot of well depth was $1.59, and per well was $5,302. Part of the reason why the bond amount per foot of well depth and per well seems low is because the full sample includes some wells that had no bond posted, as their development likely pre-dated the bonding regulations. However, this gives a good indication of the variance that currently exists in Wyoming because there is a mix of older wells with no bond posted, and newer wells that are fully bonded. The existence of the older un-reclaimed wells with no bond posted places an added financial burden on the state, above and beyond insuring that funds are available in the future to reclaim current development.

[3] The WOGCC has the authority to set additional bonding requirements for State and fee lands, among which includes the option of imposing an additional fee of $10 per foot of drilling depth for idle wells. See WOGCC Rules and Statutes, revised Chapter 3, Section 4(c). Available on line http://wogcc.state.wy.us/rules-statutes.cfm?Skip='Y'.

[4] The data in this analysis were provided by Don Likwartz, *State Oil and Gas Supervisor*, WOGCC (Fall 2008).

[5] It is important to note that the funds for reclaiming orphaned wells in Wyoming come from a mill-levy paid by the oil and gas industry, and do not come from the general tax fund.

Table 2 shows descriptive statistics clustered by single and multiple well locations. The first thing to note is that on a depth-per-well basis, single-well locations are substantially deeper than multiple-well locations Single-well locations averaged 4,602 feet / well, and multiple-well locations averaged 2,038 feet / well. The average cost per foot of drilling depth is similar between single and multiple well locations; however, the cost per well is very different. The cost per well at multiple well locations was much less than single well locations ($13,681 and $35,880 respectively). The large difference in the cost per well is mostly a result of the fact that single well locations are on average deeper than the multiple well locations. Also, reclamation is a capital intensive process that requires moving heavy machinery to remote locations, and therefore it is likely cost effective to reclaim multiple wells at a given location, and this would imply a lower cost per well relative to single well locations. Finally, the variance between the bond and the reclamation cost was also much larger for single well locations. This is probably because single well locations tend to have lower bonding requirements and higher per well reclamation costs relative to multiple well locations.

Table 2: Orphaned Oil & Gas Wells in Wyoming 1997-2007 (Clustered by Single Well and Multiple Well Reclamation Sites)

	Single Well	Multiple Well	Difference
Number of wells	1	12.5	
Depth (feet)	4,602	35,751	
Depth per well (feet)	4,602	2,038	2,564
Total cost ($)	$35,880	$202,028	
Cost per foot ($)	$9.77	$10.41	-$0.64
Cost per well ($)	$35,880	$13,681	$22,199
Bond ($)	$5,733	$29,556	
Bond per foot ($)	$0.89	$2.77	-$1.88
Bond per well ($)	$5,733	$4,584	$1,150
Variance ($)	$31,695	$194,609	
Variance per well ($)	-$30,146	-$172,472	$142,326

Notes:

a. All figures are simple averages and include locations with no bond posted.
b. Single well averages include 30 observations (30 wells).
c. Multiple well averages include 18 observations with a total of 225 wells.

Our cost analysis also revealed a very strong relationship between the total drilling depth at any location and the total cost of reclamation. The simple correlation between these variables is 0.985. The strength of this correlation suggests one simple method for estimating the total outstanding reclamation bill for Wyoming's oil and gas industry. To do this we used additional data from WOGCC that includes most of the active wells in Wyoming, and wells that are inactive but un-reclaimed (or under-reclaimed). The data includes 60,403 active wells under various classifications.[6] The total drilling depth for all 60,403 wells is 260,819,811 feet. Recall that reclamation costs were $10.01 / foot in our orphaned well database. Using this estimate, we calculated the current potential total outstanding reclamation costs for Wyoming as: (260,819,811 cumulative feet of well depth)×($10.01 / foot) = $2.61 billion. It is important to note that we are not implying that the public will pay for this reclamation cost as most of these costs will be paid by legitimate oil and gas producers. However, the number is a good indication of the size of the reclamation task ahead.

Parametric Estimates of Reclamation Costs

In this section we specify a model of reclamation costs and obtain parametric estimates of costs using the WOGCC orphaned well data, as well as some additional data from the Bureau of Land Management (BLM).[7] The combination of the BLM and WOGCC data resulted in 67 orphaned well locations that were reclaimed in the period 1997 to 2007. We pooled all of the observations into a single database to obtain parametric estimates of reclamation costs.[8] Table 3 shows descriptive statistics for the variables in the regression analysis.

Table 3: Descriptive Statistics by Location of Orphaned Wells

Variable	*Mean*	*S.D. Mean*	*Min*	*Max*
Cost ($)	82,082	33,392	658	2,135,217
Depth (feet)	14,134	6,525	295	430,867
Cost per well ($/well)	30,340	7,134	569	428,656
Depth per well (feet/well)	4,220	419	148	14,824
Number of wells	4.18	1.37	1	57
Precipitation index	2.22	0.08	1	3

Source: WOGCC and BLM orphaned well database compiled by authors.
Notes:
a. Orphaned well locations include single and multiple well sites.
b. The total number of observations (locations) is $N = 67$.
c. The total number of wells in all locations is 280.
d. The precipitation index (P) is a 30-year average from 1971-2002, and is equal to 1 if $0 < P \leq 10$ inches, is equal to 2 if $10 < P \leq 25$ inches, and is equal to 3 if $P > 25$ inches of average annual precipitation.

[6] Most of the WOGCC data used in this study are available on line: http://wogcc.state.wy.us/. Note that the WOGCC database is constantly updated and our data represent most but not all of the current active wells.

[7] The BLM data include 19 orphaned well locations provided by the Cheyenne office.

The sample includes a total of 280 orphaned wells at 67 separate locations, for an average of 4.18 wells per location. The average cost of the locations is $80,082, and the average cost per well (among the locations) is $30,340. The average drilling depth per location is 14,134 feet, and the average depth per well is 4,220. The total drilling depth among all 67 locations is 946,978 feet.

In the following regression analysis we specify a 'Hedonic' cost function for reclamation, where the total cost of reclamation in each location is assumed to be a function of three primary attributes, the number of wells per location, the total drilling depth per location, and the 30-year average of annual precipitation at the location. The number of wells and the drilling depth are obvious factors affecting the total cost of reclamation at each location. The precipitation index was also included as an environmental control variable. The logic of including the precipitation index is that areas with higher average precipitation are likely to experience relatively more natural re-vegetation while a well is under production compared to arid areas, and this is hypothesized to reduce final reclamation costs. The estimating equation is specified as:

$$C_i = n_0 + n_1 W_i + n_2 D_i + n_3 P_i + n_i \quad (1)$$

Where for each location *i* = 1,2,…,67, C_i is the total cost of reclamation, W_i is the number of wells, D_i is the total drilling depth, P_i is the 30-year average of precipitation, and ε_i is an i.i.d. error term with zero mean and constant variance. Equation (1) was estimated using an Ordinary Least Squares (OLS) estimation procedure and the results are presented in Table 4.

Table 4: OLS Regression Results

Dependent variable = Total Cost	
Variable	*Coefficient* *(t-stat)*
Wells	1,560*
	(1.79)
Depth	4.80***
	(26.23)
Precipitation	-22,059**
	(-2.24)
Intercept	56,761**
	(2.48)
Goodness-of-fit	
Adjusted *R*-squared	0.9593

Notes:
a. Number of observations = 67.
b. Calculated *t*-statistics in parentheses.
c. *** denotes statistically significant at the 1% level, ** denotes statistically significant at the 5% level, and * denotes statistically significant at the 10% level.

The adjusted *R*-squared indicates that the independent variables jointly describe approximately 95 percent of total reclamation costs. The depth variable is highly significant and the wells variable is statistically significantly different from zero at the 10 percent level of significance. The precipitation variable and the intercept are also statistically significant at the 5 percent level.[9] Using the econometric results we obtained predicted costs for the current active wells in Wyoming based on the three key variables – number of wells, depth, and precipitation. The formula for the predicted cost, $\hat{C}_i$, of any location *i* is defined by Equation (2).

$$\hat{C}_i = 56761 + 1560 \times W_i + 4.80 \times D_i - 22059 \times P_i \qquad (2)$$

The results show that there is a substantial fixed cost equal to $56,761 for each reclamation location. However, because the data are organized by location (the cost estimates are by location not per well), some additional modifications are necessary to obtain a prediction of cost per well. From Table 3 we can see the average number of wells per location in this database is 4.18, implying a fixed cost of $13,584 per well.[10] The fixed costs are independent of the number of wells and drilling depth, and probably the largest fixed cost is related to road reclamation.

The variable costs of reclamation are related to the number of wells and total drilling depth per location. For each additional well drilled at a given location total costs increase by $1,560, and for each additional foot of drilling depth total costs increase by $4.80. Furthermore, reclamation costs are reduced in areas with higher precipitation. However, the interpretation of the estimated coefficient on precipitation is not as straightforward because the precipitation variable is not continuous (it is an indicator variable). The negative $22,059 estimate can be interpreted as a $22,059 reduction in the cost per location as we move from one precipitation classification to next. On a per well basis this is equal to $5,277.[11] The predicted cost, $\hat{C}_j$, for any well *j* is then given by Equation (3):

$$\hat{C}_j = \left(\frac{\hat{\beta}_0}{\bar{W}} + \hat{\beta}_1 \right) + \hat{\beta}_2 D_j + \frac{\hat{\beta}_3 P_j}{\bar{W}} \qquad (3)$$

Where $\bar{W}$ is the average number of wells per location. Note that in equation (3) we assume that the variable cost of an additional foot of drilling depth is the same as for Equation (1), but in Equation (3) the data are now on a per well basis as denoted by the subscript *j*. Predicted costs can then be calculated for any individual well using Equation (3) and the regression results

[9] We also conducted two diagnostic tests, including a Breusch-Pagan Test for heteroscedasticity, and a Ramsey RESET Test for omitted variables. The Breusch-Pagan Test indicated that we fail to reject the null hypothesis of constant variance and the Ramsey RESET Test indicated that we fail to reject the null hypothesis of no omitted variables.

[10] This estimate is $56,761 divided by the average number of wells per location = 4.18.

[11] This estimate is $22,059 divided by the average number of wells per location = 4.18.

$$\hat{C}_j = 15144 + 4.80 \times D_j - 5277 \times P_j \tag{4}$$

And the total predicted costs for any group of wells j = 1,2,…,J is:

$$\sum_{j=1}^{J} \hat{C}_j = J \times \left(\frac{\hat{\beta}_0}{\bar{W}} + \hat{\beta}_1 \right) + \hat{\beta}_2 \sum_{j=1}^{J} D_j + \hat{\beta}_3 \sum_{j=1}^{J} P_j \tag{5}$$

Plugging in our estimated coefficients we can calculate the total reclamation bill for Wyoming:

$$\sum_{j=1}^{J} \hat{C}_j = J \times 15144 + 4.80 \times \sum_{j=1}^{J} D_j - 5277 \times \sum_{j=1}^{J} P_j \tag{6}$$

Using Equations (4) and/or (6) we can obtain predicted cost estimates for reclaiming an individual well, an average well, and/or all active oil and gas wells in Wyoming. Evaluating Equation (6) at the means of the variables results in an estimated cost per well equal to $23,662. The 95 percent confidence interval for this estimate is $20,427 to $26,897, implying we can be 95 percent confident that this interval contains the true average cost of reclaiming a well in Wyoming. What is the total reclamation bill for the entire state? We can answer this two ways: 1) multiply the estimated average cost per well by the number of active wells; and 2) plug J, $\sum D_j$, and $\sum P_j$ directly into Equation (6) and evaluate. The number of active wells in our WOGCC database is 60,403. Using the first method we get ($23,662 per well) × (60,403 wells) = $1.43 billion. Method two results in a total reclamation cost of $1.46 billion.

Finally, within the WOGCC orphaned well database there is a subset of 25 fully bonded locations with data on the bond amount that was posted and ultimately forfeited to the WOGCC. The sample of 25 locations includes a total of 220 wells, and the average bond per well was equal to $10,180 Given this is a relatively small sample of wells, and the fact that the data only include State and fee lands (no federal lands), the statewide average of bond per well may be substantially different from this figure. However, if we extrapolate the $10,180 average bond per well to the entire state, this suggests an average bond variance equal to $13,482 per well, which is the difference between the predicted cost per well of $23,662 and the average bond per well of $10,180. Multiplied by 60,403 active wells this suggests a current shortfall of $814 million in the bond pool.

Conclusions

The full reclamation of land disturbed by oil and gas development is critical to the protection of Wyoming's natural heritage as well as to the long run viability of the oil and gas industry. If an environmental bonding requirement continues to be a part of the regulation that insures proper reclamation then a serious overhaul of the current system is warranted. We estimate the total cost of reclaiming all of the active wells in Wyoming is approximately 1.5 billion dollars.

The biggest weakness of the current bonding requirements is that they are not tied to production. This study has shown the strong link that exists between certain key production variables (such as drilling depth) and the cost of reclamation. Given accurate estimates of the cost of reclamation, an appropriate system of bonding requirements can be established that is linked to production and fully covers these costs. The most effective system would require a fixed bond amount per well plus an additional fee per foot of drilling depth, and this study provides estimates of these parameters.

In Section 2 we discussed the BLM's recent policy shift toward performance-based standards, and this is a move in the right direction. The final economic incentive that is required is to make defaulting on reclamation as costly as doing the actual reclamation.

References

Andersen, M.A. and R. Coupal. "Economic Issues and Policies Affecting Reclamation in Wyoming's Oil and Gas Industry," Paper presented at the 2009 National Meeting of the American Society of Mining and Reclamation, Billings, MT. *Revitalizing the Environment: Proven Solutions and Innovative Approaches* (June 2009).

Gerard, David. "The Law and Economics of Reclamation Bonds," *Resources Policy* 26 (2000).

Kirscher, S., and E.B. Grandy. "Mining and the Vanishing Surety Bond Market," *Natural Resources and Environment* 17(3) (2003).

Lahti, Thomas. "Wyoming Reclamation Policy," *Instruction Memorandum wy*-2009-022. Bureau of Land Management, Wyoming State Office (March 2009).

Shogren et al. "Limits to Environmental Bonds," *Ecological Economics* 8 (1993).

Sult, D. "The Effect of Coal Mining Bonding Systems on the Probability of Reclamation," *Unpublished PhD Dissertation*, Colorado School of Mines (2004).

United States Code of Federal Regulations. Title 43 SURFACE EXPLORATION, MINING AND RECLAMATION OF LANDS, Definitions Section 23.3.

Webber, B.S. "Promoting Economic Incentives for Environmental Protection in the Surface Mining Control and Reclamation Act of 1977: An Analysis of the Design and Implementation of Reclamation Performance Bonds," *Natural Resources Journal* 25 (1985)