Voluntary Cleanup Programs for Brownfield Sites: A Theoretical Analysis

Thomas P. Lyon
University of Michigan
Ross School of Business
tplyon@bus.umich.edu

Haitao Yin
University of Michigan
Erb Institute for Global Sustainable Enterprise
haitaoy@umich.edu

Allen Blackman
Resources for the Future
Washington, DC
blackman@rff.org

Kris Wernstedt
Virginia Tech.
Urban Affairs and Planning
krisw@vt.edu

Draft: October 28, 2008

Acknowledgements. We gratefully acknowledge the U.S. Environmental Protection Agency STAR Program (Grant No. 83215401) for providing funding for this research.

**Voluntary Cleanup Programs for Brownfield Sites:
A Theoretical Analysis**

ABSTRACT

We develop a model of state voluntary cleanup programs (VCPs) that treats them as negotiated agreements, but within a context where the background "regulatory threat" is highly contingent on particular *status quo* conditions. We consider three possible *status quo* situations: (i) the site owner would develop the site taking into account the risk of liability from a lawsuit, (ii) the site owner would mothball the site, and (iii) the site owner would be forced into a mandatory cleanup program. We showed that if a VCP is implemented, then by its nature as a voluntary and negotiated agreement, it makes both site owners and regulators better off. Furthermore, the VCP is an effective device for increasing the number of contaminated sites that are remediated and placed back on the market. However, there is no guarantee that a VCP induces an increase in mitigation activity, and no guarantee that it moves mitigation activity closer to the socially optimal level.

1. Introduction

There are thousands of properties in the U.S. that are contaminated with various forms of toxic pollutants; these sites are popularly known as "brownfields." The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA or commonly known as Superfund Act) was enacted by Congress on December 11, 1980, in the wake of the Love Canal incident, in an attempt to protect the public from toxic pollution. Some 317 sites have been cleaned up via the program, but over 1,200 sites remain on the Superfund National Priority List. In addition, thousands of other contaminated sites are not on the Priority List.

The Superfund Act and its amendments imposed "joint and several" liability, which made those people and companies who currently own or operate hazardous waste sites among the parties liable for the costs of cleanup, even if they did not contribute to the contamination (*hereafter, we refer to this as the " private approach"*). The chilling effect of the Superfund's joint and several liability provisions on corporate transactions of historically contaminated sites, and its sometimes perverse incentives for cleanup of such sites has been widely recognized.[1] Because of these concerns, some researchers have suggested that the public purse should be used to cover liability due to historical contamination (*hereafter, the "public approach"*) (Boyd and Kunreuther, 1997). Indeed, Superfund includes some public funds for site cleanup. However, the effectiveness of this approach is directly determined by the availability of public funds.

[1] Congress, recognizing the chilling effect the Superfund's retrospective liability provisions could have on corporate transactions, expressly authorized parties to protect themselves by means of contractual contribution and indemnification. 42 U.S.C.A. § 9613(f).

Either the private or public approach for dealing with Brownfield liability could result in a backlog of hazardous sites that cannot be redeveloped and reused in as timely a fashion as socially desired. For the private approach, firms do not want to purchase and develop brownfield sites for fear of potential liability. With regard to the public approach, government agencies simply do not have enough resources to clean up the contaminated sites. In search of a better solution, states have developed Voluntary Cleanup Programs (VCPs) to allow motivated parties to move ahead at their own pace to investigate and remediate their sites. In return, they obtain a Certification of Completion or No Further Action that certifies that the property has been cleaned up to standards acceptable to state governments and therefore are freed from the liability from future state actions.

This approach represents a new solution for environmental liability through a public-private partnership. Developers or site owners initiate a cleanup plan. Public agencies make sure that the plan is adequate for protecting the environment, based on which the private parties are freed from future liability. This type of private-public approach is not unique to brownfield cleanup programs. One example is the Habitat Conservation Plan (HCP) under the Endangered Species Act (ESA). The ESA of 1973 prohibited the “take” of any endangered species and defined “take” very broadly. This exacted a heavy toll on the commercial value of private land, as it increases the risk that private landowners will be held liable. In 1982, Congress amended the ESA to include a HCP provision. Under this system, private land owners develop a HCP and upon approval, landowners will obtain authorization of the “incidental taking” of listed species. Similar to brownfield VCPs, a HCP provides an opportunity for public and private parties to interact and devise a plan that is good for both environmental protection and business interests.

Although programs like VCP and HCP have become increasingly popular[2] (Bartsch, Anderson and Dorfman, 1999), the theoretical basis for these programs remains largely unexplored. This paper is an effort to forge a better understanding of how these programs work in the context of brownfield voluntary cleanup programs. To do so, we develop a theoretical model that combines insights from the literature on voluntary environmental agreements (Lyon and Maxwell, 2004) with insights from the literature on regulation and liability as policy instruments to encourage optimal precautions by entities engaged in hazardous activities (Shavell, 1984).

The remainder of the paper is organized as follows. Section 2 briefly reviews the relevant literature. Section 3 presents a simple model of brownfield hazards and mitigation, and establishes as a benchmark the socially optimal level of mitigation. Section 4 considers the level of mitigation under legal liability alone, while section 5 studies mitigation levels under a mandatory cleanup program, and section 6 does the same for a voluntary cleanup program. Section 7 concludes and offers some policy recommendations.

2. Literature Review

Our work lies at the intersection of the literature on voluntary environmental agreements and the literature on tort liability's effects on incentives for care, so we review both of these literatures here.

[2] http://www.epa.gov/swerosps/bf/stcntct.htm

The literature on voluntary environmental agreements usually recognizes three categories: unilateral agreements, negotiated agreements, and public voluntary agreements. The first category comprises industry self-regulation, that is, agreements among industry members that do not involve direct negotiations with government. Maxwell, Lyon and Hackett (2000) present a model of this phenomenon, and show that industry self-regulation of pollution can be effective in preempting legislative threats, and can improve social welfare in the process. The second type of agreement involves negotiations between industry and government. Segerson and Miceli (1998) develop a model of such agreements, and show that both industry and regulators can benefit from preempting legislation that would be costly to enforce. In contrast, the third type of voluntary agreement is very different, and is typically initiated by government in the absence of serious legislative threats. Public voluntary agreements generally offer firms technical assistance and positive publicity to encourage them to reduce emissions. Lyon and Maxwell (2003) model such agreements, and show that they are weak tools relative to environmental taxation, and only become attractive when political pressure prevents regulators from imposing more stringent policies.

Because tort liability appears central to the incentives created by VCPs, we draw from the literature in law and economics that explores the relative merits of regulation and liability as alternative tools for reducing risks. Shavell (1984) offers a seminal analysis of the difference between liability and regulation. He shows that liability is inefficient because of injurers' limited liability, while regulation is inefficient because it imposes a "one size fits all" solution when injurers' optimal precautions should vary with the risks they pose. As a result, he concludes that the joint use of regulation and liability is generally advantageous for society. Beard (1990) finds that when care is pecuniary and strict liability is imposed without any *ex ante* regulation, a potential injurer may take either too much or too little care. Kolstad, Ulen and Johnson (1990) show that when the two instruments are used jointly, and there is uncertainty in enforcement, it is efficient to set the safety standard below the level of precaution that would be called for if the standard were used alone. Segerson (1993) shows that efficiency in land-use transactions depends delicately on how the probabilities that buyer and seller are judgment-proof (i.e., bankrupt and hence subject to limited liability) change with a transaction. Pitchford (1995) shows that, with judgment-proof firms and non-contractible precaution, increasing the liability of outsider creditors such as lenders could result in a higher accident probability and reduced social welfare.

Schmitz (2000) uses Shavell's basic model, and shows that if punitive damages are used (i.e., liability is greater than the harm done), and all injurers have the same wealth, then it is never optimal to use both regulation and liability. However, if injurers differ in their wealth constraints, then it is optimal to use a combination of *ex ante* regulation and *ex post* liability. Hiriart, Martimort and Pouyet (2004) show that the social optimum can be obtained through regulation alone if the regulator can verify the site owner's level of mitigation ex ante, and can offer the site owner a menu of incentive contracts. If the mitigation level is unverifiable, however, then the first-best cannot be obtained.

Another strand of the literature studies the effect of alternative liability rules on transactions in the real estate market. Boyd, Harrington, and Macauley (1996) identify two potential sources of inefficiency. First, there may be information asymmetries between buyers and sellers of potentially polluted property, which can create a "lemons market" for brownfields. Second, since the likelihood of detection increases with a property's sale, owners of polluted property may have an incentive to withhold it from the market. Segerson (1993) shows that incentives for abatement are generally enhanced by joint and several liability. Chang and Sigman (2005), however, identify an additional effect: joint and several liability can have a chilling effect on transactions of brownfields, since a property transaction may increase the total liability to which the site is exposed.

3. The Basic Model

To the best of our knowledge, there has been no formal economic modeling of brownfield voluntary cleanup programs (VCPs). Nor do such programs fit neatly within the normal categories of voluntary agreements as outlined in the literature review. They are not unilateral agreements, since government is intimately involved. They are not typical negotiated agreements, since there is no legislative threat hanging over owners of brownfield sites.[3] They bear some resemblance to public voluntary agreements, but the inducement offered by the regulator is a reduction in the risk of liability, rather than technical assistance. The approach we take here is to lay out a simple model of VCPs as voluntary agreements, built on a foundation from the law and economics of accidents and precaution.

We turn now to the elements of our model. Define

h: Total harm from contamination
h_e: External harm from contamination, $h_e<h$
m: Mitigation

[3] Indeed, VCPs are often thought to have arisen in response to the excessive stringency of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), also known as Superfund, which induces firms to let brownfield sites lie undeveloped rather than develop them and risk liability.

1-m: Probability of harm *h*
V: Value of the property if developed
C(m): Mitigation cost
q: Probability that site owners are held liable for the damages.
y : Wealth that is exposed to liability

We assume *C'(m)>0, C''(m)>0.* We also assume there is a distribution of sites with varying levels of potential harm, so that $h \in [0, \bar{h}]$ and is distributed with density *f(h)*.

We use $L(y,h,V,m)$ to denote the potential liability a site owner may bear, where

$$L(y,h,V,m) = \min\{h, y+V-C(m)\} = \begin{cases} h & \text{if } h \le y+V-C(m) \\ y+V-C(m) & \text{if } h > y+V-C(m) \end{cases}$$

It is worth highlighting that our model differs in several respects from much of the previous literature. First, in our model, precaution (mitigation effort) is verifiable, like Beard (1990) but unlike Pitchford (1996). We believe this is consistent with the fact that state governments typically oversee the mitigation plans of participants in VCPs, and more realistic than assuming that mitigation projects simply take the form of unverifiable "effort." Second, like Chang and Sigman (2005), we consider the possibility of "mothballing" – that is, some sites that would be developed without joint and several liability are withheld from the market because selling them would generate a negative payoff for the seller.[4] Third, because of the importance of mothballing for brownfield sites, we distinguish "internal" harm from "external" harm. The former only results if a site is developed and put to use; the latter can occur even if the site is mothballed. For example, the proverbial case of children eating contaminated dirt at a day-care center

[4] In Pitchford (1996), a similar case likely occurs – that is, increasing lender's liability would drive bad firms out of market – but it is not pursued.

would be an "internal" harm, while groundwater contamination on neighboring properties would be an "external" harm.

We begin our analysis by establishing several the following welfare benchmark.

The socially optimal level of mitigation

This is the solution to the problem

$$\max W(h,m) = V - C(m) - [1-m]h \,.$$

Thus, the socially optimal level of mitigation m^* can be characterized simply by:

$$-C'(m^*) + h = 0 \qquad (1)$$

3. The Level of Mitigation under Liability Alone

We turn now to the site owner's decision under a pure liability regime. We assume that if the site owner decides to mothball a site, he undertakes zero mitigation and obtains zero utility. Equivalently, we can assume that the likelihood that a suit is brought against a site owner is negligible when he mothballs his site.[5] In addition, we assume that if the site owner sells the site, then his proceeds from the sale, V, become part of the assets which are at stake in the event of a lawsuit. Similarly, the pecuniary costs of mitigation are deducted from the owner's assets.

The site owner's problem is to

$$\max \quad V - C(m^L) - q[1-m^L]\min\{h, y + V - C(m^L)\}$$

$$\textit{subject to } V - C(m^L) - q[1-m^L]\min\{h, y + V - C(m^L)\} > 0$$

Clearly, the first-order condition depends upon whether or not $y + V - C(\hat{m}_B^L) < h$.

---

[5] Part of the reason for making this assumption is technical: if we assume otherwise, we need to deal with two reservation utilities – one for the case of bankruptcy and another for solvency – which would complicate the analysis without adding much additional insight.

Thus, we consider the two possible cases in turn. We let the subscript B denote the bankruptcy case, in which the harm is greater than the site owner's assets, and the subscript NB denote the case in which there is no bankruptcy.

Case (i): $y+V-C(\widehat{m}_B^L)<h$**.** In this case, the mitigation level is defined by first-order condition

$$C'(\widehat{m}_B^L)[1-q(1-\widehat{m}_B^L)]-q[y+V-C(\widehat{m}_B^L)]=0 \quad (4)$$

The owner's utility is $V-C(\widehat{m}_B^L)-q(1-\widehat{m}_B^L)[y+V-C(\widehat{m}_B^L)]$. He will mothball the site if

$V-C(\widehat{m}_B^L)-q(1-\widehat{m}_B^L)[y+V-C(\widehat{m}_B^L)]\leq 0$.

Case (ii): $y+V-C(\widehat{m}_B^L)>h$. In this case, the mitigation level is defined by first-order condition

$$C'(\widehat{m}_{NB}^L)-qh=0 \quad (5)$$

The owner's utility is $V-C(\widehat{m}_{NB}^L)-q(1-\widehat{m}_{NB}^L)h$. He will mothball the site if

$V-C(\widehat{m}_{NB}^L)-q(1-\widehat{m}_{NB}^L)h\leq 0$.

Before proceeding to develop propositions, we present three lemmas that provide useful background results..

Lemma 1: When $y+V-C(\widehat{m}_B^L)>h$, it must be true that $y+V-C(\widehat{m}_{NB}^L)>h$.

Proof: It is sufficient to prove $\widehat{m}_B^L>\widehat{m}_{NB}^L$ when $y+V-C(\widehat{m}_B^L)>h$. From (2), we have $C'(\widehat{m}_B^L)=\dfrac{q[y+V-C(\widehat{m}_B^L)]}{1-q(1-\widehat{m}_B^L)}$. From (3), we have $C'(\widehat{m}_{NB}^L)=qh$. Because $y+V-C(\widehat{m}_B^L)>h$, it is easy to see $C'(\widehat{m}_B^L)>C'(\widehat{m}_{NB}^L)\Leftrightarrow \widehat{m}_B^L>\widehat{m}_{NB}^L$. Q.E.D.

We turn now to characterizing the behavior of site owners under a pure liability regime.

Lemma 2: Sites are more likely to be developed if they are of large value or if the probability of a lawsuit is low.

Proof: Straightforward differentiation shows that $V - C(\widehat{m}_B^L) - q(1-\widehat{m}_B^L)[y + V - C(\widehat{m}_B^L)]$ and $V - C(\widehat{m}_{NB}^L) - q(1-\widehat{m}_{NB}^L)h$ are both increasing functions of V and decreasing functions of q.

Lemma 3: Site owners undertake more mitigation when they have greater assets, the site is more valuable, and when the probability of a lawsuit is higher.

Proof: By implicitly differentiating equation (4), we see that $\partial \widehat{m}_B^L / \partial y > 0$, $\partial \widehat{m}_B^L / \partial V > 0$ and $\partial \widehat{m}_B^L / \partial q > 0$. Q.E.D.

From the perspective of social welfare, we want to compare the mitigation level in a pure liability regime as defined in (4) & (5) and the socially optimal level of mitigation as defined in (1).

Proposition 1: (i) when $y + V - C(\widehat{m}_B^L) < h$, the mitigation level could be lower or higher than socially optimal level. Under-mitigation is more likely to happen when the site owner's assets are smaller, the site is less valuable, and when the probability of a lawsuit is smaller. (ii) When $y + V - C(\widehat{m}_B^L) > h$, the mitigation level is lower than socially optimal level.

Proof: (i) Both $\widehat{m}_B^L > m^*$ and $\widehat{m}_B^L > m^*$ could be possible. To see this, define $Y(m) = -C'(m) + h$. We know that $Y(m^*) = 0$ by definition. However,

$$Y(\widehat{m}_B^L) = -C'(\widehat{m}_B^L) + h = -\frac{q[y + V - C(\widehat{m}_B^L)]}{[1 - q(1-\widehat{m}_B^L)]} + h$$ could be greater or smaller than zero.

(ii) To see that $\widehat{m}_{NB}^L < m^*$, it is sufficient to observe that $C'(\widehat{m}_{NB}^L) = qh < h = C'(m^*)$

Q.E.D.

The Proposition shows that it is uncertain in general whether a pure liability regime produces more or less mitigation than is socially optimal. True, the social marginal benefit of mitigation exceeds the site owner's private marginal benefits at all levels of mitigation, that is, $q[y+V-C(\widehat{m}_B^L)]<h$. This reflects both the possibility that the site owner will escape liability altogether, as well as the fact that limited liability shields him from bearing the full social cost of the harm he imposes. However, it is also true that the site owner's private marginal cost of mitigation is less than that of society, that is, $C'(\widehat{m}_B^L)[1-q(1-\widehat{m}_B^L)]<C'(\widehat{m}_B^L)$. This is because part of the firm's mitigation cost goes unpaid for in the event the firm goes bankrupt, a result similar to that of Beard (1990). Over-mitigation is more likely when q is larger and the site owner's assets are pretty close to actual harm.

4. The Mandatory Clean-up Program

For simplicity, we model state-sponsored mandatory cleanup programs as requiring "cleanup to background levels," that is, requiring $m^M = 1$, so that contamination is completely cleaned up. This comports with the thrust of CERCLA, which was to induce site owners to fully remediate the contamination on their properties. The site owner's utility under such a program is $V^M = V - C(1)$.

The state agency charged with running such a program will undoubtedly have resource constraints, and hence will not be able to force all contaminated sites into the program. Instead, it is likely to test them with the intention of focusing first on the most highly contaminated sites. Thus, suppose the regulator has a budget *B* and that the transaction cost the regulator must incur for putting a site through the mandatory program is T^M. Suppose also that the regulator desires to maximize harm reduction subject to his budget constraint, i.e.

$$\max \int_{\hat{h}}^{\bar{h}} hf(h)dh$$

subject to the constraint that

$$\int_{\hat{h}}^{\bar{h}} T^M f(h)dh \leq B .$$

The solution to the problem involves requiring sites to join the mandatory program if $h \geq \hat{h} \equiv F^{-1}(1 - B / T^M)$. Thus, firms with $h \geq \hat{h}$ join the mandatory program and earn $V - C(1)$, and firms with $h < \hat{h}$ select a mitigation level $\widehat{m}_B^L$ or $\widehat{m}_{NB}^L$ based on the liability concerns explained above.

5. The Level of Mitigation under a VCP

We now turn to modeling a VCP. For simplicity, we assume that the VCP allows for bargaining between the site owner and the regulator. In exchange for implementing an agreed mitigation level m^v, the site owner obtains a certificate of "No Further Action" (NFA) which shields him (or a future purchaser) from state-initiated liability lawsuits in the future.[6] This freedom from liability is very similar to what happens under a pure regulation regime in the papers by Shavell (1984) and Schmitz (2000), but here the regulation is tailored to a site's particular case, rather than imposing a "one size fits all" policy on all site owners, which is the prime inefficiency associated with regulation.

The mitigation level under a voluntary program, m^v, is determined through a Nash bargaining game. There are three cases to consider, depending upon what the site owner's *status quo* point would otherwise be: (A) the site owner develops the site subject

[6] In practice, an NFA letter cannot shield a site owner from citizen-initiated liability suits. However, the number of such suits is relatively small, so in the interest of clarity and simplicity we assume that only the state initiates liability suits.

to the risk of a future lawsuit, (B) the site owner mothballs the site, and (C) the site owner would otherwise be sent to the state's mandatory cleanup program.

Case A: Site owner would otherwise develop the site under liability

The regulator is only interested in maximizing environmental benefits. His utility depends simply upon whether the VCP induces greater mitigation than the status quo:

If site owner joins VCP: $-(1-m^v)E(h)$

If not: $-(1-\widehat{m}^L)E(h)$

The site owner's payoff depends upon whether he goes bankrupt or not, so we consider two cases separately.

(i) $y+V-C(\widehat{m}_B^L)<h$

In this case, the site owner's utility is:

If joining VCP: $V-C(m^v)-T^v(h)$

If not: $V-C(\widehat{m}_B^L)-q(1-\widehat{m}_B^L)[y+V-C(\widehat{m}_B^L)]$;

The Nash Bargaining equilibrium is then determined by the program:

$$\max\{-C(m^v)-T^v(h)+C(\widehat{m}_B^L)+q(1-\widehat{m}_B^L)[y+V-C(\widehat{m}_B^L)]\}*\{-(1-m^v)E(h)+(1-\widehat{m}_B^L)E(h)\}$$

The first-order condition is:

$$-C'(\widehat{m}^v)(\widehat{m}^v-\widehat{m}_B^L)-C(\widehat{m}^v)-T^v(h)+C(\widehat{m}_B^L)+q[1-\widehat{m}_B^L][y+V-C(\widehat{m}_B^L)]=0$$

Case (ii) $y+V-C(\widehat{m}_B^L)>h$

In this case, the site owner's utility is:

If joining VCP: $V-C(m^v)-T^v(h)$

If not: $V-C(\widehat{m}_{NB}^L)-q(1-\widehat{m}_{NB}^L)h$.

The Nash Bargaining equilibrium is thus defined by

$$\max\{-C(m^v)-T^v(h)+C(\widehat{m}_{NB}^L)+q(1-\widehat{m}_{NB}^L)h]\}*\{-(1-m^v)E(h)+(1-\widehat{m}_{NB}^L)E(h)\}.$$

The first-order condition for the problem is:

$$-C'(\widehat{m}^v)(\widehat{m}^v - \widehat{m}^L_{NB}) - C(\widehat{m}^v) - T^v(h) + C(\widehat{m}^L_{NB}) + q[1-\widehat{m}^L_{NB}]h = 0.$$

Using this formulation, we have the following proposition.

Proposition 2: (a) The site owner will participate in a VCP if and only if the transaction cost for participation is lower than his expected liability; (b) When the site owner participates in a VCP, the mitigation level is higher than that induced by pure liability; (c) $\widehat{m}^v$ could be larger or smaller than m^*. In the case of over-mitigation with liability, the VCP will exacerbate the over-mitigation. In the case of under-mitigation with liability, the VCP will push the level of mitigation towards the socially optimal level.

Proof: We construct the proof first for case (i); the logic is virtually the same for case (ii).
Parts (a) & (b):
Let $H(m) = -C'(m)(m - \widehat{m}^L_B) - C(m) - T^v(h) + C(\widehat{m}^L_B) + q[1-\widehat{m}^L_B][y + V - C(\widehat{m}^L_B)]$.
We know that $H(\widehat{m}^v) = 0$ and $H(\widehat{m}^L_B) = q[1-\widehat{m}^L_B][y + V - C(\widehat{m}^L_B)] - T(h)$. Therefore,
$\widehat{m}^v > \widehat{m}^L_B \Leftrightarrow q[1-\widehat{m}^L_B][y + V - C(\widehat{m}^L_B)] - T(h) > 0$. The site owner will participate in the VCP if $V - C(m^v) - T^v(h) - [V - C(\widehat{m}^L_B) - q(1-\widehat{m}^L_B)[y + V - C(\widehat{m}^L_B)]]$>0. Of course,
$V - C(m^v) - T^v(h) - [V - C(\widehat{m}^L_B) - q(1-\widehat{m}^L_B)[y + V - C(\widehat{m}^L_B)]] = C'(\widehat{m}^v)(\widehat{m}^v - \widehat{m}^L_B)$,
so the site owner will participate if and only if $C'(\widehat{m}^v)(\widehat{m}^v - \widehat{m}^L_B)$>0
$\Leftrightarrow q[1-\widehat{m}^L_B][y + V - C(\widehat{m}^L_B)] - T(h) > 0$.

Part (c):
$$H(m^*) = -C'(m^*)(m^* - \widehat{m}^L_B) - C(m^*) - T^v(h) + C(\widehat{m}^L_B) + q[1-\widehat{m}^L_B][y + V - C(\widehat{m}^L_B)]$$
$$= -h(m^* - \widehat{m}^L_B) - C(m^*) - T^v(h) + C(\widehat{m}^L_B) + q[1-\widehat{m}^L_B][y + V - C(\widehat{m}^L_B)]$$
Then $\widehat{m}^v > m^* \Leftrightarrow H(m^*) > 0$. This is more likely if q is larger. Q.E.D.

One interesting special case is when transaction costs are zero. In this case, the site owner will surely participate in the VCP and will implement a higher level of mitigation than he would if he had not joined the program. More generally, the VCP represents a Pareto improvement. Site owners can always choose not to participate and obtain the utility they would expect under joint-and-several liability. Regulators can always obtain a mitigation level greater than $\hat{m}^{JSL}$. Thus, both parties find the VCP attractive.

Case B: The site owner would otherwise mothball the site

In this case, the site owner's utility is:

If joining VCP: $V - C(m^v) - T^v(h)$
If not: 0.

The regulator's utility is:

If site owner joins VCP: $-(1-m^v)E(h)$
If not: $-E(h_e)$

The Nash Bargaining equilibrium is defined by:

$$\max[V - C(m^v) - T^v(h)]*[-(1-m^v)E(h) + E(h_e)]$$

The first-order condition characterizing the equilibrium is:

$$[V - C(\hat{m}^v) - T^v(h)]E(h) + [-C'(\hat{m}^v)]*[-(1-\hat{m}^v)E(h) + E(h_e)] = 0$$

We characterize the outcome of the VCP under these conditions in the following proposition.

Proposition 3: If a site owner would mothball his site otherwise, then the availability of a VCP will induce him to develop his site if there exists a value of $\hat{m}^v$ that satisfies $1 - \frac{E(h_e)}{E(h)} < \hat{m}^v < C^{-1}(V - T^v(h))$. The required mitigation level from the voluntary program increases with the external environmental harm from the site and with the site's property value.

Proof: From the first-order condition for the bargaining equilibrium, we have

$$V - C(\hat{m}^v) - T^v(h) = \frac{C'(\hat{m}^v)*[-(1-\hat{m}^v)E(h) + E(h_e)]}{E(h)}$$

The site owner will participate in the VCP if

$$V - C(\widehat{m}^v) - T^v(h) = \frac{C'(\widehat{m}^v)*[-(1-\widehat{m}^v)E(h) + E(h_e)]}{E(h)} > 0.$$

This expression can be rewritten as $1 - \frac{E(h_e)}{E(h)} < \widehat{m}^v < C^{-1}(V - T^v(h))$.

If there exists a value of $\widehat{m}^v$ that satisfies the condition above, then a VCP will be implemented and both site owners and regulators are better off. If not, the site owner reverts to the *status quo*, that is, mothballing.

Case C: The site owner would otherwise be in the mandatory program

In this case, the site owner's utility is:

If joining VCP: $V - C(m^v) - T^v(h)$
If being forced into MP: $V - C(1)$

The regulator's utility is
:
If site owner joins VCP: $-(1-m^v)E(h)$
If the site owner is in the MP: $-T^M(h)$

The Nash Bargaining equilibrium is defined by:

$$\max[V - C(m^v) - T^v(h) - V + C(1)]*[-(1-m^v)E(h) + T^M(h)]$$

and has first-order condition:

$$[-C(\widehat{m}^v) - T^v(h) + C(1)]E(h) + [-C'(\widehat{m}^v)]*[-(1-\widehat{m}^v)E(h) + T^M(h)] = 0$$

Proposition 4: If a site owner would be sent to the mandatory program otherwise, then the availability of a VCP will induce him to develop his site through the VCP if there exists a value of $\widehat{m}^v$ that satisfies $1 - \frac{T^M(h)}{E(h)} < \widehat{m}^v < C^{-1}[C(1) - T^v(h)]$.

Proof: From the first-order condition, we have

$$-(1-\widehat{m}^{v})E(h)+T^{M}(h)=\frac{[-C(\widehat{m}^{v})-T^{v}(h)+C(1)]E(h)}{C'(\widehat{m}^{v})}>0.$$

This can be restated as $1-\frac{T^{M}(h)}{E(h)}<\widehat{m}^{v}<C^{-1}[C(1)-T^{v}(h)]$.

If there exists a value of $\widehat{m}^{v}$ that satisfies the condition in the Proposition, then a VCP is implemented and both site owners and regulators are better off. If not, regulators will force the site owner to enter mandatory program. The larger is $T^{M}(h)$ and the smaller is $T^{v}(h)$, the larger is the set of parameter values for which such a case occurs.

In summary, if a VCP is implemented, then by its nature as a voluntary and negotiated agreement, it makes both site owners and regulators better off. Whether it induces an increase in mitigation activity, and whether it moves the mitigation level closer to the optimal level, cannot be answered in general.

6. Conclusions

We have developed a model of voluntary cleanup programs (VCPs) that treats them as negotiated agreements, but within a context where the "regulatory threat" that lurks in the background is highly contingent on particular *status quo* conditions. We considered three possible *status quo* situations: (i) the site owner would develop the site taking into account the risk of liability from a lawsuit, (ii) the site owner would mothball the site, and (iii) the site owner would be forced into a mandatory cleanup program.

We showed that the level of mitigation that occurs under a pure liability regime may be either too low or too high from a social perspective. All site owners have an incentive to underinvest in mitigation, since there is always a chance they will not be held liable for their actions anyway. However, site owners with few assets and low-value properties have a countervailing incentive to overinvest, because when they go bankrupt their debts are forgiven, and a portion of their mitigation costs is effectively offloaded onto the public.

Mothballing a site is a common outcome under joint and several liability, and results in underinvestment in mitigation and also a failure to put a site back into economically beneficial use.

In contrast, when the site is forced into a mandatory cleanup program, it must comply with the requirement to eliminate all contamination on its site, which is generally inefficient from an economic perspective. Hence, the mandatory program typically involves overinvestment in mitigation. Nevertheless, an environmental regulator concerned only with environmental outcomes prefers this outcome, since such a regulator does not value the economic costs associated with the cleanup.

The effects of a VCP depend greatly on the status quo conditions that apply to the particular firm negotiating a VCP. In case (i), the VCP induces greater mitigation, although it is possible the level of mitigation could be too high from a social perspective. In case (ii), the VCP may, but need not, induce the firm to shift from mothballing to site development. The required mitigation level from the voluntary program increases with the external environmental harm from the site and with the site's property value. Finally, in case (iii), if the VCP is utilized, it induces less mitigation than would the mandatory program, but more than makes up for this in terms of reduced transaction costs.

Overall, then, we showed that if a VCP is implemented, then by its nature as a voluntary and negotiated agreement, it makes both site owners and regulators better off.

Furthermore, the VCP is an effective device for increasing the number of contaminated sites that are remediated and placed back on the market. However, there is no guarantee that a VCP induces an increase in mitigation activity, and no guarantee that it moves mitigation activity closer to the socially optimal level.

References

Beard, T. Randolph (1990), Bankruptcy and Care Choice, *The RAND Journal of Economics*, Vol. 21, No. 4, pp. 626-634.

Boyd, James, Winston Harrington, and Molley K. Macauley. 1996. "The Effects of Environmental Liability on Industrial Real Estate Development", *Journal of Real Estate Finance and Economics*, 12:37-58.

Chang, Howard F. and Hilary Sigman. 2000. "Incentives to Settle under Joint and Several Liability: An Empirical Analysis of Superfund Litigation", *The Journal of Legal Studies*, Vol. 29, No. 1. pp. 205-236.

Chang, Howard and Hilary Sigman. 2005. "The Effect of Joint and Several Liability under Superfund on Brownfields," Institute for Law and Economics Research Paper No. 05-21, University of Pennsylvania.

Dana, David A. 2005. "State Roles in U.S. Environmental Law and Policy," 14 *New York University Environmental Law Journal*, 86.

Hiriart, Yolande, David Martimort and Jerome Pouyet. 2004. "On the Optimal Use of Ex Ante Regulation and Ex Post Liability," *Economics Letters* 84: 231-235.

Kolstad, Charles D., Ulen, Thomas S., and Johnson Gary V. (1990). "Ex Post Liability for Harm vs. Ex Ante Safety Regulation: Substitutes or Complements?," *American Economic Review* 80: 888—901.

Pitchford, Rohan. 1995. "How Liable Should a Lender Be? The Case of Judgment-Proof Firms and Environmental Risk". *The American Economic Review*, Vol. 85, No. 5 pp. 1171-1186.

Schmitz, Patrick W. 2000. "On the Joint Use of Liability and Regulation," *International Review of Law and Economics*, 20: 371-382.

Segerson, Kathleen. 1993. "Liability Transfers: An Economic Assessment of Buyer and Lender Liability," *Journal of Environmental Economics and Management*, 25 pp. 46-63.

Segerson, Kathleen. 1994. "Property Transfers and Environmental Pollution: Incentive Effects of Alternative Policies," *Land Economics*, Vol. 70, No. 3. pp. 261-272.

Shavell, Steven. 1984. "A Model of the Optimal Use of Liability and Safety Regulation," *Rand Journal of Economics* 15: 271—280.

Spier, Kathryn E. 1994. "A Note on Joint and Several Liability: Insolvency, Settlement, and Incentives". *The Journal of Legal Studies*, Vol. 23, No. 1, Economic Analysis of Civil Procedure, pp. 559-568.

Tietenberg, Tom H. "Indivisible Toxic Torts: The Economics of Joint and Several Liability", *Land Economics*, Vol. 65, No. 4. pp. 305-319.