July 2003

Contractual Difficulties in Environmental Management and the Protection of Biodiversity: The Case of Conservation and Mitigation Banking

Paul Hallwood
University of Connecticut

CONTRACTUAL DIFFICULTIES IN ENVIRONMENTAL MANAGEMENT AND THE PROTECTION OF BIODIVERSITY: THE CASE OF CONSERVATION AND MITIGATION BANKING

Paul Hallwood
Professor of Economics
University of Connecticut

Correspondence to:
Professor Paul Hallwood
31 Sterling City Road,
LYME,
CT 06371.

Abstract: This paper offers a principal-agent model of feasible private contracting in mitigation and conservation banking aimed at the protection of natural habitat and bio-diversity of US wetlands and uplands. It is shown that while it is straightforward to design an incentive contract, such a contract may not achieve the federally mandated objective of *no net loss* of habitat. This is because the minimum payment required as an economic incentive to private agents may be greater than what they should receive for the habitat values that they actually created in the field. This possible problem is shown to derive from nonconvexity in the production possibility set between the biological value of land as natural habitat and in non-habitat uses such as in urban development. The paper concludes with a consideration of several institutional devises that may promote the convergence of private contracting and the attainment of *no net loss*. These include the payment of subsidies, greater accuracy in the identification of actual quality by the principal, and the use of several incentive alignment devises.

Journal of Economic Literature: 721, 722.

Key words: biodiversity, conservation banks, environmental management, incentive contracts, mitigation banks, sustainable development.

July 2003

CONTRACTUAL DIFFICULTIES IN ENVIRONMENTAL MANAGEMENT AND THE PROTECTION OF BIODIVERSITY: THE CASE OF CONSERVATION AND MITIGATION BANKING

Abstract: This paper offers a principal-agent model of feasible private contracting in mitigation and conservation banking aimed at the protection of natural habitat and bio-diversity of US wetlands and uplands. It is shown that while it is straightforward to design an incentive contract, such a contract may not achieve the federally mandated objective of *no net loss* of habitat. This is because the minimum payment required as an economic incentive to private agents may be greater than what they should receive for the habitat values that they actually created in the field. This possible problem is shown to derive from nonconvexity in the production possibility set between the biological value of land as natural habitat and in non-habitat uses such as in urban development. The paper concludes with a consideration of several institutional devises that may promote the convergence of private contracting and the attainment of *no net loss*. These include the payment of subsidies, greater accuracy in the identification of actual quality by the principal, and the use of several incentive alignment devises.

Mitigation and conservation banking are institutional initiatives aimed at, respectively, wetland and upland environmental management with the objectives of promoting environmental sustainability and biodiversity of natural habitats. However, mitigation and conservation banking is sometimes criticized for failing in these objectives, rather, causing the over-development by property developers of natural habitats without adequate replacement by reconstructed habitat from derelict land.[1] This paper investigates certain aspects of this too frequent failure from the perspective of a principal-agent asymmetric information model.

[1] By 'derelict land' is meant land currently offering low biological and nonbiological values. Such land includes abandoned industrial land, lands taken over by invasive species, or areas of wetland or upland cut off from an integrated productive environment by linear developments such as roads, bridges and railways.

The requirement to mitigate damage to natural habitats is governed by several federal statutes and regulations.[2] Thus, when a developer is required to mitigate the impact of property development on natural habitats it may do so itself - either on-site or off-site. However, as a property developer is unlikely to be a specialist in mitigation, its costs may be higher than when a specialist in habitat reconstruction performs mitigation.[3] Thus, the development of private mitigation and conservation banking over the last twenty years or so is a response to cost differences between developers and bankers - with a consequent social surplus derived from trading in mitigation credits and the equation of marginal costs of mitigation. As such, the social value of mitigation and conservation banking is derived in much the same way as many other private institutions trading in pollution permits of various types: viz.: the equation of the marginal costs of abatement between polluters.[4]

The institutional details of mitigation and conservation banking are described *inter alia* in Bonnie (1999), Castelle *et al*. (1992), Federal Register (1995), Sheahan (2001), Wheeler and Strock (1995) and Weems and Canter (1995). Our focus is on the award of mitigation credits by a regulatory agency (the *Army Corp or Engineers* or the US Fish and Wildlife

[2] The relevant legislation is contained in section 404 of the *Clean Water Act*, section 10 of the *Rivers and Harbors Act* and in the wetland conservation provisions of the *Food Security Act.* The practice of mitigation banking is systematized in the *Federal Guidance for the Establishment, Use and Operation of Mitigation Banks* (1995) issued under the signatures of five assistant secretaries in the Departments of Agriculture, Interior and Commerce, the Army and the Environmental Protection Agency. Conservation banking is promoted under the *Endangered Species Act* and is operated by the US Fish and Wildlife Service.

[3] Sheahan (2001, page 22) offers evidence on the high failure rate of on-site mitigation by non-specialists.

[4] While US laws require the mitigation of impacts, the growth of private (or, 'entrepreneurial') mitigation and conservation banking developed without legislation of details (Sheahan, 2001). Relevant details developed 'on the go' that are important here include the definition of the 'commodity' unit traded as mitigation 'credits', the exact moment when these credits are to be awarded to a mitigation or conservation bank for habitat restoration, and how 'quality' is to be measured and compared between a natural habitat that is being destroyed and a reconstructed habitat for which it mitigates.

Service), hereafter *'the principal'*, to a mitigation or conservation bank, hereafter '*the agent'*, for the physical restoration work that it has performed on a particular site.

Several important points about mitigation or conservation credits should be emphasized at the outset. First, the number of credits awarded by the principal is supposed to reflect the quality of reconstructed habitat in comparison with natural habitat. The *mitigation replacement ratio* would be 1:1 if the quality of reconstructed habitat matched that of the natural habitat it was replacing. The use of an appropriately calculated mitigation replacement ratio is crucial under the *Federal Guidance* (1995) policy of *no net loss* of habitat. Awarding too many credits for low quality reconstructed habitat would thwart this objective.[5] Secondly, investment in the restoration of otherwise derelict land into *sustainable-quality* restored habitat requires costly investment. As agents have a good degree of control over the level of these expenditures the quality of a reconstructed habitat is a choice variable.[6] Thirdly, the sustainable-quality of restored habitat soon after restoration is difficult even for teams of experts employed by the principal to observe. The reason why seemingly premature judgments of quality are made by principals is so that the agent can obtain a return on its investment through the award of credits in a

---

[5] Principals are aware of this issue: in California replacement ratios vary from 1:1 to 4:1, in Maine 1:1 to 8:1, and in New Jersey 1:1 to 7:1 (Castelle *et al*, 1992). A 4:1 ratio means that four credits in a bank are required to substitute for one credit of natural habitat. The reason for a ratio greater than unity is the perceived lower quality of reconstructed habitat. The mitigation ratio would be *less* than unity when reconstructed habitat is of better quality than destroyed natural habitat. Typically this can occur when mitigation is of several small, isolated, natural habitats that are consolidated into a large mitigation tract. Since failure of mitigation banking to achieve *no net loss* is frequently stated, the emphasis of this paper is on situations where the mitigation ratio is greater than unity. However, the consolidation benefit of mitigation banking should not be ignored in a wider assessment of the institution.

[6] . That quality is a choice variable is implied in the following statement by three biologists: "There is no recipe for restoration that will work at all sites. The success of tidal marsh restoration efforts depends heavily on the extent to which the designer understands the site and the materials being utilized during construction. Projects need well-defined objectives and attention paid to detail. Site morphology, substrate

timely manner. These are later sold to companies that are destroying a natural habitat that, under permit, are required to mitigate damages.[7]

The success of mitigation for destroyed natural habitat has been questioned. In an extensive review Castelle *et al* (1992) found that "follow-up studies indicate that the average rate of compliance with permit conditions was 50%. Common problems include inadequate design; failure to implement the design; lack of proper supervision; site infestation by exotic species; grazing by geese or other animals; destruction by floods, erosion, fires, or other catastrophic events; failure to adequately maintain water levels; and failure to protect projects from on-site and off-site impacts such as sediments, toxics, and off-road vehicles" (Castelle *et al*, 1992, page i). Moreover, Harrison (1995) points out that mitigation banks often put little effort into reconstruction projects, and Kukoy and Canter (1995) assert that non-compliance with Section 404 permit requirements was quite widespread.

While there may be several explanations for quality failures, the focus here is on the existence of asymmetric information between principals and agents. As it is an agent that works on a daily basis reconstructing a habitat, it will be more familiar than the principal with key characteristics of a site - such as the condition of the many determinants of its hydrology that are critical in the health of reconstructed wetlands (e.g. Montalto *et al*,

---

transmissivity, and porosity all have the potential to make or break a project, and should therefore be considered carefully in design development" (Montalto, Steenhuis and Parlange, 2002, page 46).

[7] The profitability of mitigation banking is not generally known. However, it has been estimated that the cost of wetland restoration varies between $25,000 and $130,000 per acre while credits have sold for as much as $250,000 per acre in New Jersey (*The Economist*, August 10th, 2000).

2002). It is the agent, therefore, that has the clearest idea of what types and levels of expenditure are actually needed to reconstruct a sustainable high quality habitat.

Although we are assuming asymmetric information consider for a moment the situation of fully symmetric information. At the point in time of the award of credits, based on its observation of the quality of the finished 'product', the principal awards either a high or low number of credits to the agent, respectively, F* and R*. If it sees high quality, Q^H, it awards the full number of credits, F*. If it sees low quality, Q_L, it awards a reduced number of credits, R*. Alternatively, with full information, the principal could base its award on an observation of the level of investment by the agent. Schematically,

C_N gives Q^H and is awarded with F*
C_S gives Q_L and is awarded with R*

where C_N is the high 'no shirking' level of investment by the agent and C_S is the lower 'shirking' level of investment. However, sustainable quality is *not* observable until many years after the time of the credit-award. The agent knows this and therefore has an opportunity to fool the principal. The agent can benefit by incurring only low costs for the possible award of the high number of credits.

The award of credits is actually made on the basis of two other observations by the principal - of the agent's *actual* spending on habitat reconstruction, C, and on a *premature* observation of sustainable-quality, Q. Thus,

C gives Q which in the long-run yields Q^H or Q_L

Accordingly, the principal's observation of Q does not entirely discriminate between Q^H and Q_L. Nor is observation of actual investment in habitat reconstruction, C, a perfect predictor of Q^H or Q_L. Thus, the principal does not know whether C_N or C_S was invested - even though it observes C - and so cannot use C_N and C_S as proxies for Q^H or Q_L.

Since the principal faces a problem of asymmetric information it draws up an incentive contract with the agent awarding F* or R* credits on the basis of its (imperfect) observation of quality. The full number of credits, F*, is awarded for reconstructed habitat that is judged to be of equal biological value to that of natural habitat of equal acreage. The lower level of credits, R*, is awarded if lower quality is (imperfectly) observed.

Having defined the principal-agent problem of interest, the rest of this paper proceeds as follows. Section 2, defines the contractually feasible set of F* and R* that will both induce an agent to participate in mitigation or conservation banking and give it the incentive to choose the high level of investment that produces the high sustainable-quality reconstructed habitat. However, it is argued in section 3 that such a contract may not attain the federally mandated aim of *no net loss* of natural habitat because of objective conditions in the field. As is explained below, these have to do with nonconvexity in the production possibility set between the value of a tract of land as undisturbed natural habitat and in its best non-habitat uses. Section 4 discusses various reliefs to problems of private contracting in habitat restoration. Conclusions are drawn in section 5.

2: Feasible contracts

A mitigation bank's net payoff measured in credits awarded by the principal for developing a given tract of reconstructed wetland depends on the number of credits awarded less the cost of creating those credits. A mitigation bank can try to maximize the option value of a tract assuming that quality is perfectly observable by the principal (as in the model of Fernandez and Karp, 1998). Alternatively, because it is in fact difficult for the principal to measure quality, the agent might reduce the level of investment in quality-enhancement so lowering its costs, hoping that the principal will not notice the lower quality. This is a classic principal-agent problem that derives from the difficulty of the principal observing true quality.

A mitigation bank's expected payoff from "shirking" on the level of investment, $E(\Pi_S)$, measured in credits is:

$$E(\Pi_S) = pF + (1 - p)R - C_S \tag{1}$$

where p is the probability of low-quality *not* being detected when quality is in fact low, F is the full number of credits awarded for high quality, $(1 - p)$ is the probability of low quality being detected by the principal, R is the reduced number of credits awarded for lower quality, and C_S is the cost of investing in the tract (again measured in credits) [8] when the low level of effort is applied by a mitigation bank.

The level of C_S is determined by a minimum set of "gardening" inputs that the agent reasons must be seen to be done, even though it may know that expenditure at the high

[8] The cost of investment in a tract measured in credits is simply the dollar cost divided by market price of a credit.

level C_N is really necessary to achieve Q^H. Furthermore, it is assumed that $C_S \geq C_M$ where C_M is the minimum level of investment determined by the principal and stated (either explicitly or implicitly) in the contract.[9]

The expected payoff from not shirking, $E(\Pi_N)$, is:

$$E(\Pi_N) = (1 - q)F + qR - C_N \qquad (2)$$

where q is the probability of high quality *not* being detected when in fact quality is high, and C_N is the cost of creating high quality reconstructed habitat, $C_N > C_S$. If the principal wants the agent to invest in high quality it must set $E(\Pi_N) = U$, where U is the return on comparable investments outside of mitigation banking. This is the participation constraint.

The, incentive compatibility condition, whereby the mitigation bank chooses to invest in high quality is $E(\Pi_N) \geq E(\Pi_S)$. Or,

$$(1 - q)F + qR - C_N \geq pF + (1 - p)R - C_S \qquad (3)$$

This rearranges to:

$$F - R \geq \frac{C_N - C_S}{1-(p+q)} \qquad (4)$$

That is, the difference in credits awarded in the contract for high and low quality reconstructed habitat, F - R, must be equal to or greater than the (mistake) adjusted difference in costs. Notice that the larger is the propensity to make mistakes - measured by p + q, the greater must be the contractual difference between F and R. If this

[9] In practice the agent may require the agent to increase expenditure on inputs are work progresses. Hey and Philippi (1999) have a good description of this in the case of wetland mitigation in the Florida Keys.

inequality is reversed the agent has an incentive not to invest in high quality reconstruction.

Further insights can be gained by graphing the participation and incentive compatibility constraints. The participation constraint assuming competitive conditions is derived from equation (2)

$$E(\Pi_N) = (1 - q)F + qR = U + C_N \qquad (5)$$

where

$$U = C_N K \qquad (6)$$

and K is the rate of return on capital in a comparable risk class outside of mitigation banking.

On rearrangement the participation constraint is:

$$F = \frac{U + C_N}{(1-q)} - \frac{q}{1-q}R \qquad (7)$$

This is graphed in figure 1.

The incentive compatibility constraint once again is $E(\Pi_N) \geq E(\Pi_S)$, which on rearrangement of equation (3), and again assuming competitive conditions, becomes:

$$F = \frac{C_N - C_S}{1-(p+q)} + R \qquad (8)$$

where the first term on the right-hand side is a constant. The incentive compatibility constraint is also drawn in figure 1.

Both constraints are simultaneously fulfilled in the area on or above the heavy lines drawn in figure 1. If the contract between the principal and the agent states that F and R falls in this area for, respectively, high and low quality, the agent will want both to participate and to aim to produce high quality reconstructed habitat.[10]

3: Objective constraints in nature

A crucial issue is whether the combination F* R* offered in a contract is necessarily consistent with the policy of *no net loss*. An important consideration here is how many credits, $\underline{R}$, are actually created with the low-expenditure level, C_S, as an objective fact? More particularly, we are interested in the *objective constraint* (F*$\underline{R}$) so that it can be compared with the *contractual constraint* (F*R*). As is shown below, a private contract may not be consistent with the policy of *no net loss*.

According to the opinion of experts, the biological value of a contiguous tract of land in many habitat functions increase rapidly as the area of land under consideration increases in size.[11] The implication of this observation is that the production possibility set on contiguous land between its biological use as natural habitat and other uses - such as in urban development - is nonconvex. Such possible non-convexity is implied in, for

[10] If the principal was a profit maximizer and competitive conditions were assumed, all the principal needs to offer the agent is the combination F*R*. However, the assumption is that the principal aims for *no net loss* project by project. In this case any contract in the area above the heavy lines should suit the principal.

[11] Wetland habitat and biotic valuation by experts can use the Delphi method of scoring the many characteristics of a wetland on a scale of 0 to 1 and then combining the individual scores into a weighted average quality index. Mitsch and Gosselink (2000, pages 591-96) point out. that several quality assessment methods exist including the Habitat Evaluation Procedure used by the US Fish and Wildlife Service, the Wetland Evaluation Technique used for a time by the US Army Corps of Engineers, and the recently developed hydrogeomorphic classification. These authors also observe that economic valuation of wetlands depends, *inter alia*, on the correct identification of habitat, biotic and other physical characteristics.

example, NRC (1992) that suggests that habitat and species diversity on wetland increases disproportionately with wetland acreage. In addition, federal government agencies recognize the ecological advantage of large over small acreages of restored wetlands (Federal Register, 1995). Thus, "it may be more advantageous for maintaining the integrity of the aquatic ecosystem to consolidate compensatory mitigation into a single large parcel or contiguous parcels when ecologically appropriate" (page 58,605). The implication is that the ecological value of a single large habitat acreage is more than n times the value of n separate acreages each $1/n^{th}$ the size.[12]

Figure 2 shows a production possibility set on a given acreage W_1, of natural habitat. Initially all of this acreage is natural habitat with a biological value of OA.[13] However, as acres are sequentially moved over to non-habitat uses the value of the acreage as natural habitat falls rapidly.

The nonconvexity in the production possibility set of figure 2 is reflected in figure 3. Thus, the *marginal* cost in terms of lost biological or economic value of sequentially converting a natural habitat property of W_1 acres to another use *falls* as the amount of it withdrawn from natural habitat rises. Hence, the *total* cost function in the upper part of the figure is convex.

[12] At the theoretical level Baumol and Bradford (1972) and Helfand and Rubin (1994) argue that if technical external diseconomies from one good onto the other are strong enough, the production possibility set will be nonconvex. For example, it could be that building only a few houses on a tract of natural habitat destroys the remainder as, say, a bird nesting habitat. The declining (in absolute value) slope of the production possibility frontier in figure 2 indicates that the marginal social cost of residential use is falling.
[13] Proportionality between biological and economic values is assumed.

Nonconvexity in the production sets between natural habitat and non-habitat uses also implies that the *marginal* benefit of moving contiguous derelict land into natural habitat uses rises as the amount of land sequentially moved over increases. Hence, the *total* benefit function (TB_{CN}) in the lower part of figure 3 increases at an increasing rate. For example, the second one-acre of created wetland has a greater biological value than the first one-acre when it is added to the first one-acre, the third acre more the second (making three acres), and so on. While there must be some limit to this process, it is assumed that the amount of derelict land at some locality available for moving over into mitigation acreage is not at this limit. In fact, it is assumed that there is a maximum of W_1 acres of derelict land available.[14]

Figure 3 indicates that if W_1 units of existing natural habitat is moved to other uses, the total cost in terms of lost natural habitat biological services is OA. However, assuming quality equivalence (i.e., the high quality commensurate with expenditure C_N), if W_1 acres of derelict land is turned into reconstructed habitat an equivalent value, 0B, is created. Equally, assuming for simplicity that one-acre is worth one credit, then W_1 acres of reconstructed habitat is worth F* credits.

However, what is the equivalency - measured in credits - when low quality reconstructed habitat (commensurate with the low level of expenditure C_S) is used to replace high valued natural habitat?

[14] These assumptions about the productivity of converted land imply that the acreage of contiguous land in a conservation or mitigation bank should be as large as possible. This is consistent with expert opinion

In figure 4 the total benefit function TB^{Cs} is closer to the x-axis than is TB^{CN} because of the lower level of expenditure by the agent.[15] In this case, the objective of *no net loss* implies that more than W_1 acres of reconstructed habitat are needed to offset the loss of W_1 acres of natural habitat. In fact, W_2 acres of newly created habitat balance W_1 acres of lost natural habitat.

Alternatively, if W_1 acres are all that is available in a particular mitigation or conservation bank, that bank can compensate for only W_3 lost acres of natural habitat. That is, the value of the reconstructed habitat (W_1C) is equal to the value of only W_3 acres (= $\underline{R}$ credits) of natural habitat lost (where $W_1C = W_3D$).

Notice that in this case - where the value of created habitat is less than the value of natural habitat - there is a large disparity in the compensation ratio. In figure 4 inspection shows that this is about 8 acres of created habitat substituting for only one acre of natural habitat. Equivalently, each acre of reconstructed habitat is worth only $1/8^{th}$ of a credit. Thus, from figure 4, the objective payoffs for high quality and low quality reconstructed habitat are determined as, respectively, F* and $\underline{R}$.

There remains the issue of the comparison between the *objective* and *contractual* payoff ratios. It will be recalled that the combination F*R* simultaneously fulfills the participation and incentive alignment constraints. However, as has just been

---

cited earlier

[15] If reconstructed habitat is inherently less productive than natural habitat - which could well be the case in the field - the TB functions will be even closer to the x-axis. This will worsen the problems discussed below.

demonstrated, the objective tradeoff is the combination $F^*\underline{R}$. It may turn out that $F^*\underline{R}$ does not simultaneously fulfill the two constraints. In which case either private contracting is not possible, or, the objective of *no net loss* will be frustrated.

Thus, suppose that C_S has to be large in order to produce even low quality habitat on a tract of unpromising derelict land. But that nonconvexity in the production possibility set is so severe that such low quality replaces very little natural habitat. That is, C_S produces $\underline{R}$, but $\underline{R} < R^*$ (where R^* is the lowest acceptable payment given the agent's cost conditions C_N and C_S).

The objective equilibrium might fall in any of the four areas marked G, H, I, J in figure 1. Whether the conditions for the simultaneous fulfillment of private contracting and *no net loss* are fulfilled are described in table 1.

TABLE 1: THE OBJECTIVE CONSTRAINT($F^*\underline{R}$) AND THE FEASIBILITY OF PRIVATE CONTRACTING

Area in figure 1	Incentive compatibility	Participation constraint fulfilled	Private contract consistent with *no net loss*
G	Yes	Yes	Yes
H	No	Yes	No
I	No	No	No
J	Yes	No	No

As can be seen in table 1 only if $F^*\underline{R}$ lies in area G (including on the heavy lines) is a private contract consistent with *no net loss*. In all other areas a private contract offering $F^*\underline{R}$ is not consistent with *no net loss*. Thus, in area H the incentive compatibility constraint is not fulfilled and the agent chooses the low level of expenditure on inputs, C_S, with resulting low quality. As a result $\underline{R} < F^*$ - where $\underline{R}$ is the return to the low level of investment and F* is the loss on the associated destroyed natural habitat.[16] In areas I and J the participation constraint is not fulfilled and an agent offered F*$\underline{R}$ would choose not to participate in a private contractual relationship.

Looked at differently, suppose that the principal offers the contract F*R* no matter what - so ensuring that the agent participates. Unfortunately the incentive compatibility constraint is not met in areas H and I so the agent will deliver only $\underline{R}$. In area J the agent has incentive compatibility so would try to supply F*. However, as the participation constraint is not fulfilled, private contracting is frustrated.

4: Institutional supports

The foregoing discussion indicates that private sector mitigation and conservation banking are not necessarily viable institutions under certain biological conditions in the field. In particular, strong nonconvexity in the production possibility set between the value of a tract of natural habitat in this use and in nonhabitat uses militates against private contracting achieving *no net loss.*

However, this is not the end of the story as certain steps may be taken to improve the prospects of successful private mitigation and conservation banking.

First, looking back to table 1, in area J the alignment of the objective payoffs F* and $\underline{R}$ is such that if a private contract offered F*R* incentive compatibility would be achieved.

[16] Without incentive compatibly the agent will supply $\underline{R}$ which with a nonconvex production possibility set can never be large enough to equal F*.

The agent would strive to supply sustainable high quality reconstructed habitat. The problem is that this will not happen because the agent will not want to participate. However the participation constraint might be fulfilled on the payment of the subsidy to the agent. Thus, equation 7 becomes:

$$F = \frac{U + C_N - S}{(1-q)} - \frac{q}{1-q}R \qquad (7a)$$

where S is the subsidy. The effect of the subsidy is to shift the participation constraint towards the x-axis, so shrinking area J - where private contracting is not feasible, and increasing area G where it is feasible.

Secondly the area of feasible contracting can be increased by reducing the size of p and q - where it will be recalled, p is the probability of the principal mistaking low quality for high quality, and q is the probability of mistaking high quality for low quality. Lower p and q move both the participation constraint and incentive compatibility constraint, respectively equations (7) and (8), closer to the x-axis in figure 1. The result is that the area of feasible contracting, G, is enlarged at the expense of the other areas.

Two factors that can aid a principal in reducing its propensity to make mistakes (p + q) are closer monitoring and better science. Closer monitoring of agents' investments in habitat reconstruction should help in reducing mistakes. For example, closer monitoring can help a principal discriminate between knowing whether a particular investment has been executed and when it has been executed well.

Improved scientific knowledge of the practice of habitat reconstruction should also better inform the principal in its judgement of the link between investment by the agent and ultimate impact on sustainable quality. For example, improved scientific knowledge may help to discriminate between those 'gardening techniques" that work well and those that don't.[17]

Another factor that can improve the efficacy of private mitigation and conservation banking if when the agent wishes to create a good reputation for turning out high quality reconstructed habitat. Our earlier discussion was implicitly constructed as a one off game between the principal and the agent. However, in a repeated game the incentive for the agent to supply low quality, Q_L, with low investment, C_S, is likely to be reduced.

Still other devices have been suggested to achieve incentive alignment - including the posting of bonds by agents, and the sequencing of credit awards over a longer timeframe. These too may work to achieve incentive alignment, but it is worth mentioning, by raising agent's costs such devises may breach the participation constraint.

5: Conclusions

This paper discusses contractual difficulties in private sector contracting for habitat replacement aimed at creating sustainable habitat and bio-diversity. The paper describes the nature of the principal-agent problem as stemming from two sources. First, a principal's inability to discriminate between high or low effort as applied by the agent, and, secondly, its inability to observe the exact quality of reconstructed habitat at the time of payment (where payment is in the form of the award of credits that the agent can later sell).

Moreover, it is argued that the existence of asymmetric information is not an insufferable problem as it is feasible to design an incentive contract between the principal and the agent that could achieve the stated Federal policy of *no net loss* of habitat - whereby natural habitat destroyed is balanced by restored habitat on otherwise derelict land.

However, it is argued that the private contracting of habitat restoration to mitigation or conservation banks using incentive contracts may not achieve *no net loss* because it is not possible to write an appropriate contract. The root of this problem lies with nonconvexity in the production possibility sets between the value of land in biological uses as natural habitat and in non-habitat uses such as urban development. It can be that the difference in biological value created on reconstructed habitat and that on destroyed on natural habitat is so great that an incentive contract cannot be written so as to fulfill the participation constraint given an agent's minimum investment costs.

The paper concludes with some suggestions for improving the effectiveness of private contracting in the maintenance of the scale and diversity of habitat under the *no net loss* objective. These include the use of subsidies, greater accuracy in the judgment of quality

---

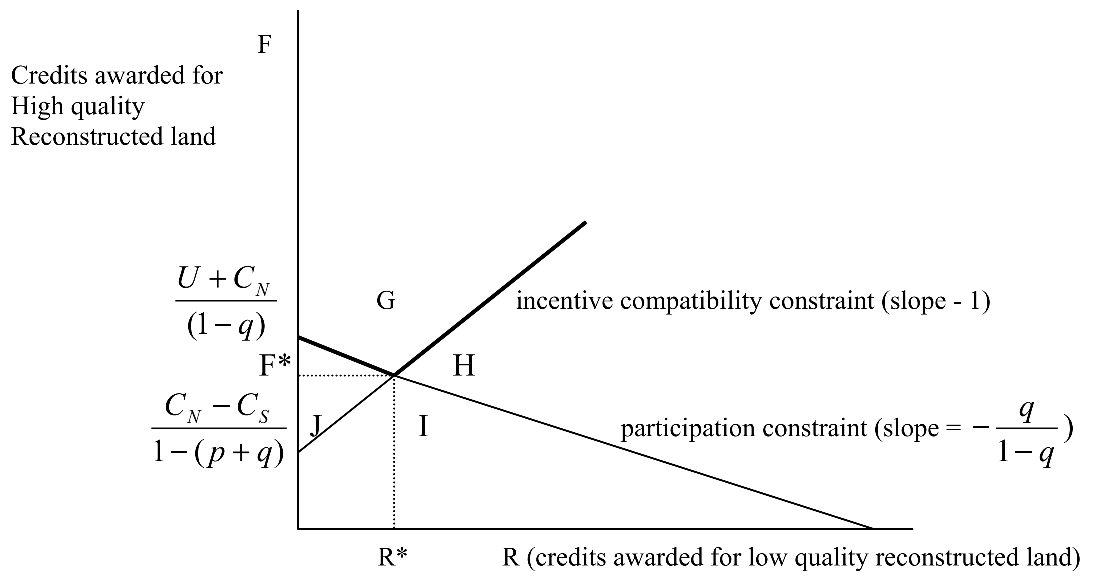
[17] Hey and Philippi (1999) describe trial and error in ascertaining the best way to restore seagrass beds. Initial replanting by scuba divers largely failed, and it was discovered that what really mattered was the

of reconstructed habitat on the part of the principal, and the use of devises such as the posting of bonds and the sequencing of credit 'payments' as actual quality becomes observable.

---

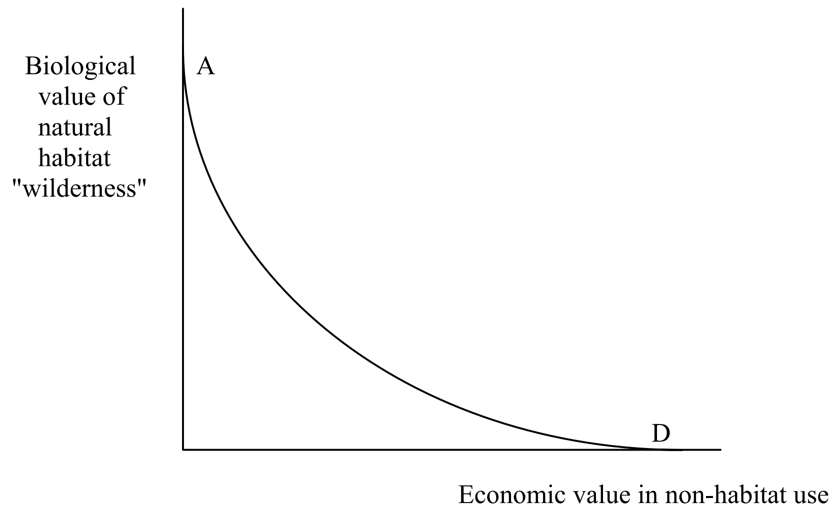
creation of appropriate subsea conditions in which the grasses would repopulate themselves.

Figure 1: Feasible contracts



….

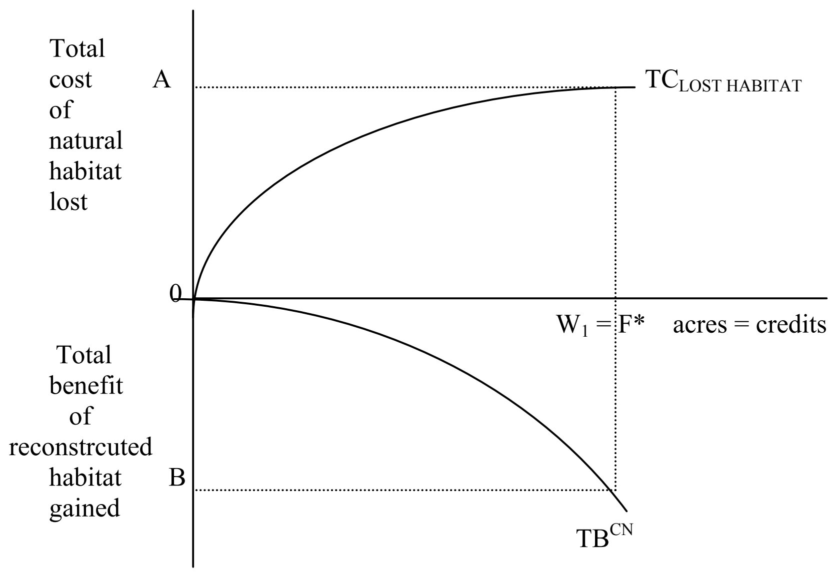
Figure 2 : A nonconvex production set between natural habitat and non-natural habitat biological values on a given acreage of land



..

…

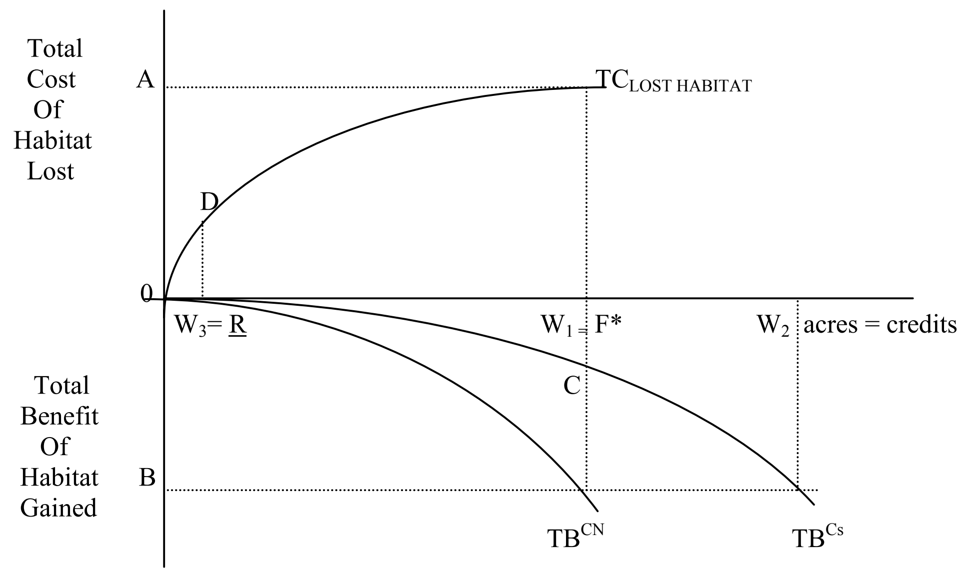
Figure 3 : No Net Loss of Habitat Services.



..

.

Figure 4: Created habitat less productive than natural habitat



..

References

Baumol, W.J. and Bradford, D.F. (1972), "Detrimental Externalities and Non-Convexity of the Production Set", *Economica*, 39, May, 160-76.

Bonnie, R. (1999), "Endangered Species Mitigation Banking: Promoting Recovery Through Habitat Conservation Planning Under the Endangered Species Act", *The Science of the Total Environment*, volume 240 (issues 1-3), 11-19.

Castelle, A.J.C. *et al*, (1992), "Wetland Mitigation Replacement Ratios: Defining Equivalency". Adolfson Associates Inc., for Shorelands and Coastal Zone Management Program, Washing Department of Ecology, Olympia, WA. *Publication number 92-08*.

Federal Register (1995), Federal Guidance for the Establishment, Use and Operation of Mitigation Banks, 60 (228), November 28th, 58,605-58,614.

Fernandez, L. and Karp L. (1998), "Restoring Wetlands Through Wetlands Mitigation Banks", *Environmental and Resource Economics*, 12, 323-344.

Harrison, W. (1995), "Can You Bank on Wetland Mitigation? New Developments in Wetland Mitigation Banks", University of Mississippi Law Center, *Water Log* 15 (1), 10-11.

Helfand, G.E. and Rubin, J. (1994), "Spreading versus Concentrating Damages: Environmental Policy in the Presence of Nonconvexities", *Journal of Environmental Economics and Management*, 27, 84-91.

Hey, D. and Philippe, N.S. (1999), *A Case for Wetland Restoration*, John Wiley and Sons Inc., New York.

Kukoy, S.J. and Canter, L.W. (1995), ""Mitigation Banking as a Tool for Improving Wetland Preservation via Section 404 of the Clean Water Act", *Environmental Protection*, 17 (4), 301-08.

Mitsch, W.J. and Gosselink, J.G. (2000), *Wetlands*, John Wiley and Sons Inc. New York.

Montalto, F.A., Steenhuis, T. and Parlange, J.Y. (2002), "The Restoration of Tidal Marsh Hydrology". In C.A. Brebbia (editor), *Coastal Environment: Environmental Problems in Coastal Regions IV*, WIT Press, Boston.

National Research Council (1992), *Restoration of Aquatic Ecosystems*, National Academy Press, Washington DC.

Sheahan, M. (2001), "Credit for Conservation: A report on conservation banking and mitigation banking in the USA, and its applicability to New South Wales", Volume I: Report. The Winston Churchill Memorial Trust of Australia.

Weems, W.A. and Canter, L.W. (1995), "Planning and Operation Guidelines for Mitigation Banking for Wetland Impacts", *Environmental Impact Assessment Review*, 15, 197-218.

Wheeler, D.P. and Strock, J.M. (1995), "Official Policy on Conservation Banks", California, Environmental Protection Agency, April 7th.