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TITLE: MONITORING OF COMPLIANCE IN AUSTRALIAN CONSERVATION CONTRACTS

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ABSTRACT:

Government and non-government conservation agencies have long-term goals and objectives to provide environmental services, such as conserving the biodiversity of Australian native vegetation. In addition to national parks and reserves, private lands are often included in conservation programs to achieve these objectives. Formal contracts are entered into between the private landholder and the conservation agency to provide environmental services, or more commonly to provide inputs that are likely to lead to environmental services. The paper examines the costs and benefits of monitoring these conservation contracts when biodiversity change is stochastic.

INTRODUCTION

In Australia, government and non-government conservation agencies have begun incorporating private lands into conservation programs primarily due to the high cost of establishing national parks and reserves (Figgis 2004). The land available to enter national parks and reserves will be insufficient for reserves alone to achieve the conservation agency's goals and objectives of biodiversity and environmental service provision into the future. The goals and objectives of government and non-government conservation agencies are diverse, but consistently include broad environmental aims which require long-term investment. For example, the *Australian Government Department of the Environment and Water Resources develops and implements national policy, programmes and legislation to ensure the protection, conservation and sustainable use of Australia's natural environment, water resources and cultural heritage* (DEWR 2007). The World Wide Fund for Nature state their mission is *to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature by: conserving the world's biological diversity; ensuring that the use of renewable natural resources is sustainable; and promoting the reduction of pollution and wasteful consumption* (WWF 2007). The broad, long-term nature of the goals and objectives of conservation agencies require them to make long-term investments in diverse conservation work.

Government and non-government conservation agencies have introduced a number of conservation schemes and programs designed to provide biodiversity and environmental services on private land through market- based instruments (Figgis

2004). Development of new conservation programs in Australia has progresses rapidly, with 19 pilot programs within the National Action Plan for Salinity and Water Quality alone (NAPSWQ 2008). In Western Australia, for example, landholders can receive a wide range of support for providing environmental services, including financial or labour assistance for conservation works, assistance entering into a covenant, as well as technical advice and training (Government of Western Australia 2004). Internationally, conservation programs have existed for much longer than Australian, . Mmost well known are the USA Conservation Reserve Program and the Wetlands Reserve Program (Hanrahan and Zinn 2005), and the UK Countryside Stewardship Scheme and Environmental Stewardship (NE 2006). Typically conservation schemes contract landholders to undertake actions which increase the probability of establishing or conserving a target vegetation community.

A conservation agency or their agent (regulator) who is paying landholders' compensation for retiring land and/or undertaking revegetation actions is expected to measure the output of the scheme by monitoring the actions of landholders and subsequent vegetation succession, as well as possibly taking action(s) based on this information. Based on the information from monitoring, the regulator may even alter or cease the contract with the landholder. The regulator must decide on the optimal frequency and accuracy of monitoring, as well as the subsequent action(s) to take.

The monitoring of conservation contract compliance by landholders and the environmental outcomes of contracts by regulators has received limited attention in the literature. Internationally, reviews of agri-environmental policy monitoring in the UK and elsewhere conclude that monitoring to assess ecosystem change incurs significant costs and is prone to inaccuracy in the form of mis-classifications of vegetation types (Hooper 1992; National Audit Office 1997; World Bank 1998). A wide variety of monitoring techniques are available to the regulator, each with a unique combination of accuracy, cost and ease of use, notable are satellite images such as Landsat, aerial photographs, and ground surveys. The USA Conservation Security Program takes the unusual approach of providing funds directly to farmers for undertaking recordkeeping, monitoring, and evaluation themselves (Farm Policy Team 2006).

The economics of environmental monitoring has its origins with Becker's (1968) model of crime and punishment which predicts that the decision to offend depends upon a comparison of the expected benefits with the expected costs (Heyes 2000). The economics of Becker 's model predicts that regulators will fix fines as high as possible, monitor infrequently to reduce costs (if fines are punitive) and always prosecute transgressors. Harrington (1988) uses a dynamic model from tax regulation (Greenberg 1984) to explain why the observed practices in air and water pollution monitoring are at odds with Becker's model. Harrington's (1988) highlights the facts that firms are rarely fined and fines are small, monitoring frequency is low, and yet most firms comply most of the time.

Environmental monitoring and decision making has also been covered within the adaptive control literature, reviewed by Walters and Holling (1990) and White (2000). However, this literature focuses on the control of state variables, such as biomass which can be represented by continuous variables;, for instance , see Williams' (1996) model of wildfowl harvesting. Operations research has approached monitoring as part of a general stochastic control literature, see , for instance, Bertsekas and Shreve (1978). The partially observed Markov decision process (POMDP) model (Monahan 1982; Smallwood and Sondik 1973) is a tractable approach to stochastic control when the states follow a Markov chain, but the decision maker is unable to observe the current state of the system. To date POMDP has had relatively few applications in environmental and natural resource economics, although the paper on salmon fishing by Lane (1989) is a notable exception.

In ecology, Markov chains have been used to represent vegetation successions (Barber 1978; Usher 1979) with methods for estimating transition probabilities from observations of the states of a system through time (Anderson and Goodman 1957). Recently ecologists used Markov chains to represent the stability of a heterogeneous ecosystem over time as well as space (Li 1995). More recent advances in the methodology have enabled the analysis of succession within various ecosystem types (Logofet and Korotkov 2002; Logofet and Lesnaya 2000; Plotnick and Gardner 2002; Tucker and Anand 2005), from grasslands (Balzter 2000; Somodi *et al.* 2004) to forests (Korotkov *et al.* 2001; Yemshanov and Perera 2002) and marine communities (Liu *et al.* 2006).

The monitoring problem described here differs from most previous contributions to the literature in two fundamental respects. First the variable monitored is a categorical variable classifying the state of the vegetation community into a finite number of classes. Most previous economic studies describe monitoring an emission variable where standards are in terms of quantities or concentrations. Secondly, the monitoring problem here is dynamic and extends from 2 periods up to potentially an infinite time horizon. Given this added complexity the strategic interaction between the firm and the regulator is not modelled explicitly, instead in the model it is characterised as 'nature' which determines if whether a conservation scheme succeeds or fails.

Most Australian market- based conservation contract schemes are in a trial stage and will require further development to meet the long-term and wide ranging goals of conservation agencies. Particularly, the monitoring and enforcement of the legal contract between the agency and the landholder to ensure the environmental objectives of the scheme are achieved requires further attention. At present, monitoring of the compliance and environmental outcomes of these schemes is primarily focused on efficient allocation mechanisms. The success of conservation schemes is generally measure by the quantity of inputs contracted to be supplied, rather than the quantity of inputs achieved or environmental services provided.

The aim of this paper is to use POMDP to explore the regulator's decision to enter into different types of conservation contracts with landholders, whether to monitor and, when monitoring occurs the regulator's response to the observation. The simplified case study investigates the regulator's decision to contract landholders to revegetate or maintain native vegetation for one year, and the use of monitoring of the vegetation succession to change the contract type or to withdraw from contract. The unit of analysis is an area of land which either had or has the potential to establish the target vegetation community. This analysis draws upon the ecology literature on how vegetation successions are modelled, the economic analysis of monitoring and irreversible environmental change and the operations research analysis of dynamic monitoring and control problems. Each of these strands is discussed. The next section introduces the POMDP model. Section 3 describes the case- study details for the conservation and restoration of Salmon Gum woodland in the Western Australian Wheatbelt and gives the POMDP results. Section 4 concludes.

METHODOLOGY

PARTIALLY OBSERVABLE MARKOV DECISION PROCESSES

A regulator wishes to maximise the private and public value of a piece of land where vegetation communities are described by *N* discrete states $s_i = 1, \ldots, N$. The vegetation community changes through time according to a Markov process and the (*NxN*) matrix of transition probabilities are a function of the level of conservation effort; for instance, for three vegetation states we have:

$$P(e_t) = \begin{bmatrix} p_{11}(e_t) & p_{12}(e_t) & p_{13}(e_t) \\ p_{21}(e_t) & p_{22}(e_t) & p_{23}(e_t) \\ p_{31}(e_t) & p_{32}(e_t) & p_{33}(e_t) \end{bmatrix} \qquad (1)$$

The elements $p_{ij}(e_t)$ give the probability of the land in state *i* being in state *j* after a single period *t*. Conservation effort, e_t, is a measure of resources allocated to conservation, in the example it is based on the work of Yates and Hobbs (1997) and Gibbons and Freudenberger (2006). The regulator offers a contract that stipulates conservation effort e_t. Conservation effort increases or decreases the probability of a transition to the target vegetation community.

The regulator has a prior probability of the current vegetation community being in a given state by the (*1xN*) vector π known in the POMDP literature as the *belief state*. For many ecosystems this is a realistic assumption: vegetation classifications are uncertain or the vegetation may be a mosaic of different vegetation classes. Often the high cost of a definitive vegetation survey means that conservation schemes are initialised with incomplete knowledge of the initial vegetation community across the whole area. The observation matrix, which is a function of monitoring effort u_t determines the accuracy of monitoring. For three states the *(NxN)* observation matrix is given by:

$$\Theta(u_t) = \begin{bmatrix} r_{11}(u_t) & r_{12}(u_t) & r_{13}(u_t) \\ r_{21}(u_t) & r_{22}(u_t) & r_{23}(u_t) \\ r_{31}(u_t) & r_{32}(u_t) & r_{33}(u_t) \end{bmatrix} \qquad (2)$$

where the element $r_{j\theta}(u_t)$ is the probability that if state θ is observed the vegetation at the end of period *t* is *j*. If $\Theta(u_t)$ is an identity matrix then monitoring is perfectly accurate; if it is uniform it is uninformative. Increased monitoring effort raises the probability of a correct observation.

Monitoring reduces the uncertainty about which state the land is in and updates the prior probability to a posterior probability by Bayes rule:

$$\pi_{jt} = \frac{\sum_i \pi_{it-1} p_{ij}(e_t) r_{j\theta}(u_t)}{\sum_{i,j} \pi_{it-1} p_{ij}(e_t) r_{j\theta}(u_t)} \tag{3}$$

The new belief state is a $1 \times N$ vector of probabilities. In vector form, (3) can be rewritten as:

$$\pi_t = T(\pi_{t-1} \mid e_t, u_t, \theta) \tag{4}$$

where *T(.)* is the belief transformation function. The belief state captures the history of all past observations and actions.

MONITORING COSTS

Heyes (2002) draws a useful distinction between inspecting an environmental variable which generates a noisy signal and an environmental audit which is definitive. Methods for monitoring vegetation community change range from low- cost remote sensing methods such as aerial photographs and satellite images, to relatively high- cost field surveys (World Bank 1998). We assume that from past 'ground truthing', these methods have established observation matrices. For instance remote sensing methods are known for relatively high probabilities of misclassification (Hooper 1992), while intensive field surveys are more accurate but more expensive.

We assume that the cost of monitoring depends on the observation matrix so the quasi-convex monitoring cost function $c^v(u_t)$ is at a maximum when $\Theta(u)$ is an identity matrix. That is, the state is observed with perfect accuracy, and $c^v(u_t) = 0$ when $u_t = 0$ and $\Theta(u)$ is a uniform matrix with all elements equal to 1/N.

THE REGULATOR'S PROBLEM

The regulator maximises the expected present-value of the welfare function in relation to conserving an area of land by choosing conservation effort and monitoring effort. The regulator's problem can be represented by the following POMDP problem represented in a mathematical programming problem

$$V[\pi_t] = \underset{wrt\ e_t, u_t}{Maximise} \sum_t \sum_i \pi_{it} [g_i(e_t) - c_i(e_t) - c^v(u_t)] \delta^t \tag{5a}$$

Subject to

$$\pi_t = T(\pi_{t-1} \mid e_t, u_t, \theta) \tag{5b}$$

$$\pi_0 = \tilde{\pi} \tag{5c}$$

The first term $g_i(e_t)$ in (5a) gives the non-market net benefits of vegetation community *i*. It is given as a function of e_t as conservation effort may enhance the benefits of a particular state. The term $c_i(e_t)$ gives the resource cost to the regulator/landholder of conservation effort in state e_t. Monitoring costs depend upon the monitoring effort and are given by $c^v(u_t)$. The term $\delta^t = 1/(1+g)^t$ is the discount factor which converts net benefits generated at time *t* to their present-value at *t=0*, *g* is the discount rate. Equation (5b) gives the updating equation for the belief state (4) and (5c) gives the belief state (prior probabilities of states) at the start of the planning horizon when t=0 as $\tilde{\pi}$. To simplify the notation in later sections we define net-benefit as

$$w_i(e_t, u_t) = g_i(e_t) - c_i(e_t) - c^v(u_t) \tag{6}$$

DYNAMIC OPTIMISATION

Unlike a Markov Decision Problem (MDP) which has a standard dynamic programming solution (Puterman, 1994), the solution to a POMDP problem is more difficult because the probability of the system being in a particular state depends upon past monitoring and the resulting observations. The original solution by Smallwood and Sondik (1973) introduces the notion of a *belief state* where the conventional states of MDP, namely s_i, are replaced by a *belief state* π_t which is the vector of probabilities of being in the states. The solution entails finding a set of actions which are optimal across the belief state (Cassandra 1995). In a simplified form the optimisation problem is to solve the following version of Bellman's equation:

$$V_t[\pi_t] = \underset{e_t, u_t}{\text{maximise}} \ \sum_{\text{i}} \pi_{it} \{ w_i(e_t, u_t) + \sum_j \sum_\theta p_{ij}(e_t) r_{j\theta}(u_t) V_{t+1}[T(\pi_t | e_t, u_t, \theta)] \}. \tag{7}$$

where $V_t(\pi_t)$ is the optimal value from optimizing across the time horizon from t to T starting in belief state π_t. The optimal value comprises two components. The first term is the expected immediate reward and the second term is the expected reward for the remaining periods. The term $p_{ij}(e_t) r_{j\theta}(u_t)$ gives the joint probability of observing state θ when the previous state is *i* and the current state *j*. Equation (7) is similar in construction to a standard stochastic dynamic programming model. The only difference is in the presence of the belief state. For instance if the initial state was known with certainty and there was no monitoring, optimization would proceed by maximizing the current net-benefit whilst accounting for the effect that the action has on the expected value across the remaining periods. This principle of optimality still holds in POMDP except it has to solve the problem for all possible belief states. This involves defining the optimal solution as a set of action vectors which are optimal in some belief state. This is illustrated and discussed in greater detail in the context of the case study.

Solving the dynamic optimization problem presented in Equation (7) is not trivial due to the problems of determining $V_t[\pi_t]$. However, if we restrict e_t and u_t to a discrete set of values we can make use of the result that $V_t[\pi_t]$ is always piecewise linear and convex (Smallwood and Sondik 1973). Thus a modified dynamic programming algorithm can determine $V_t[\pi_t]$ as a set of vectors generated from different actions. This allows us to rewrite (7) as:

$$V_t[\pi_t] = \underset{e_t, u_t}{\text{maximise}} \ \sum\nolimits_{\mathrm{i}} \pi_{it} \{ w_i(e_t, u_t) + \sum\nolimits_j \sum\nolimits_\theta p_{ij}(e_t) r_{j\theta}(u_t) \alpha_j^{\iota(\pi_t, e_t, u_t, \theta)}(t+1) \} \qquad (8)$$

where $\alpha_j^k(t)$ is a (1xN) policy vector which gives the expected payoff from an action across all the states. The superscript on the policy vector gives the optimal vector for a particular belief state and is formally defined as follows:

$$\iota(\pi_t, e_t, u_t, \theta) = \arg\max_k \left[\sum\nolimits_i \sum\nolimits_j \pi_{it} p_{ij}(e_t) r_{j\theta}(u_t) \alpha_j^k(t+1) \right] \qquad (9)$$

Tthat is, it selects the vector, by the superscript *k*, which gives the highest expected value for the belief state resulting from the prior probability, action and observation.

CASE STUDY

BACKGROUND

The Western Australian wheatbelt, and particularly the Northeastern Wheatbelt Regional Organisation of Councils (NEWROC), has received attention recently due to its agricultural and environmental importance. The area is of agricultural significance as well as having biodiversity that is under threat from salinity and large scale clearing. The NEWROC comprises the shires of Koorda, Mount Marshall, Mukinbudin, Nungarin, Trayning, Westonia and Wyalkatchem. The majority of the NEWROC (69%) is contained within the Land and Water Australia's Intensive Land-use Zone[1], with the remainder (31%) within the Extensive Land-use Zone. In 2002, 12% of NEWROC was remnant vegetation. Within each shire the area of remnant vegetation ranged from 5% in the south- west shire of Wyalkatchem to 21% in the eastern most shire of Westonia.

Yates and Hobbs (1997) detail the state of *Eucalyptus* woodlands in southeast and southwest Australia. Woodlands have been extensively cleared and much of them are badly degraded due to livestock grazing. Currently it is estimated that only 10% of *Eucalyptus loxophleba* (York gum) and 20% of *Eucalyptus salmonophloia/Eucalyptus salubris* (salmon gum/gimlet) woodlands remain. A similar situation exists on the east coast of Australia, where 0.01% of *eucalyptus albens* (white box) woodland remains relatively unmodified.

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[1] Intensive Land-use Zone: the area of Australia where intensive land use practices such as irrigated agriculture occur.

The removal of degrading factors such as grazing and weeds may be insufficient to restore the woodland, with revegetation action required. Yates and Hobbs (1997) go on to identify the stable woodland states that exist in *Eucalyptus salmonophloia* woodlands currently and the transitions required to shift the woodland areas from one state to another. Remnant vegetation in the NEWROC area is highly fragmented due to agricultural clearing, and degraded due to weeds, livestock grazing and firewood collection. Together with the impact of dryland salinity this means high levels of habitat loss, with the remaining vegetation severely degraded. The works required and probability of their success is largely determined by the current state of the woodland and its ability to shift to another state. The fencing of remnant vegetation to remove livestock and feral grazing may be insufficient to return a degraded woodland to an undegraded state. Extensive revegetation and weed control would likely be required to achieve this shift.

MARKOV CHAIN ESTIMATION

The states and transitions identified by Yates and Hobbs (1997) in salmon gum woodland are simplified to the diagram given in Figure 1 for this case study. Combining the characteristics detailed by Yates and Hobbs with aerial photography of the NEWROC gives 4 vegetation states; Undegraded Woodland, Degraded Woodland1, Degraded Woodland2 and Agricultural. Undegraded Woodland (Undegw) has an intact understory of shrubs, a layer of plant litter across the ground and good soil. Degraded Woodland1 (Degw1) is a remnant of native vegetation, where the vegetation quality is poor, with a few perennial understory species, a ground layer of annual weeds and compacted soil. Degraded Woodland2 (Degw2) is a remnant of native vegetation with clearing, likely by grazing or crop production, leaving only a mixture of endemic perennial grasses and annual weeds with a few trees. Agriculture (Agric) refers to a stable state of annual rotations of crop or livestock production on the land. Figure 2 gives an example of the classification of remnants in NEWROC into Undegw, Degw1, Degw2 and Agric.

The transition between vegetation states is unique for each action available to the regulator, Figure 1. In this case study the regulator can enter into (1) a contract for revegetation works as described by conservation schemes such as Auctions for Landscape Recovery in WA (Gole *et al.* 2005) (Reveg), (2) a contract for maintenance of existing remnant vegetation as described by Lockwood et al (2000) (Maintain), or (3) not enter into a contract, i.e. the status quo of voluntary revegetation works, grazing, etc. as the landholder desires (*No Contract*). Reveg requires the landholder to undertake a range of management actions to restore the land to a higher quality of remnant. This includes fencing the remnant, planting of woodland species, controlling weeds, rabbits and foxes and corridor construction. Maintain requires the landholder to fence large remnants but they are allowed limited grazing and collection of firewood or fence post timber in the area provided it is consistent with biodiversity conservation. *No Contract* refers to abandoning the remnant to the landholder's preference, or the status quo. Each action has an associated benefit and cost, and expected impact on the transition between vegetation states on the land. The action choice by the regulator changes the net benefit $w_i(e_t, u_t)$ by altering $g_i(e_t)$ and $c_i(e_t)$, detailed later. The transition probabilities for each action choice by the regulator and land type (Table 10) give the predicted start and end state of the land over 1 period, in this case annually. The transition probabilities are an average for the NEWROC, incorporating differences in topography, climate, landholder skill and landholder compliance across the region.

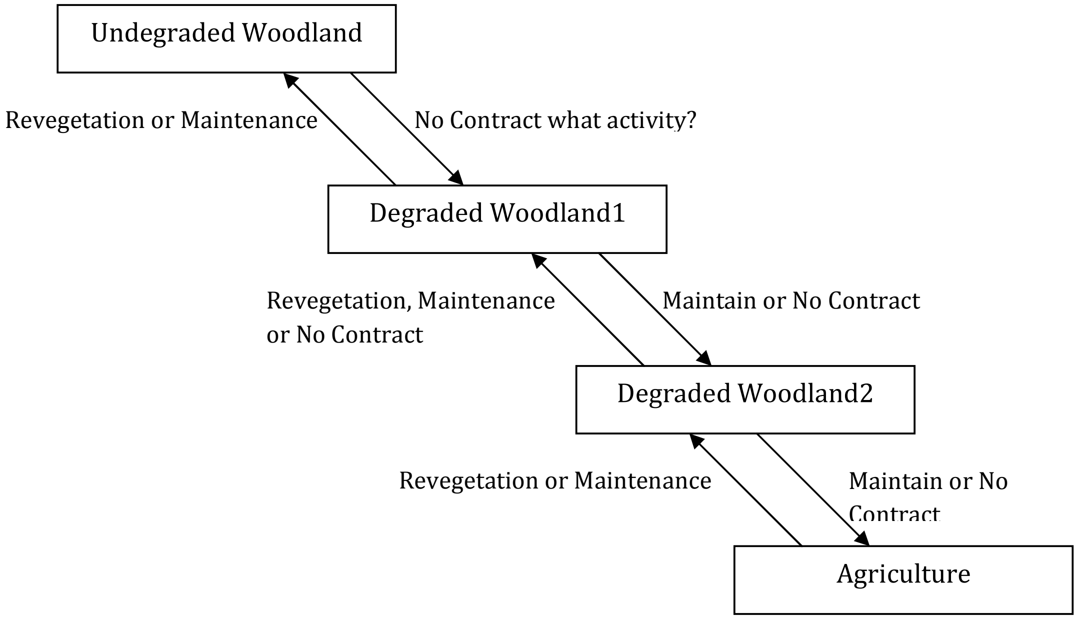

Figure 1 Transition and stable states of salmon gum woodland (based on Yates and Hobbs, 1997).

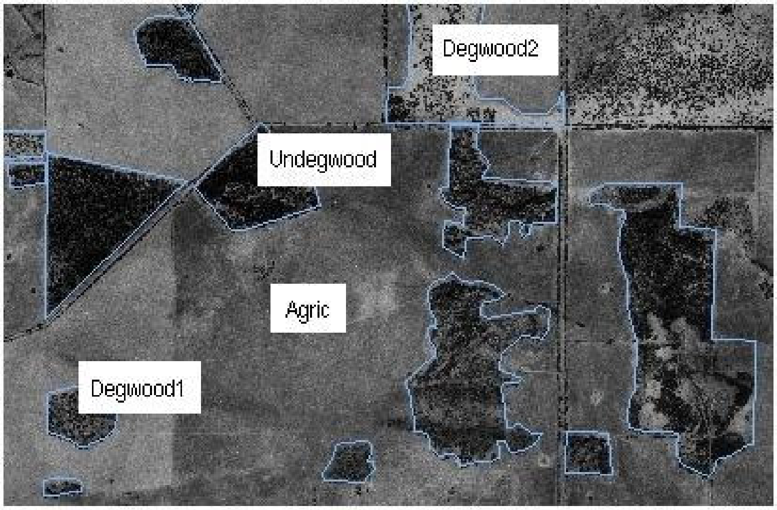

Figure 2 Example of classification of vegetation states of land in the NEWROC area.

Aerial photographs and Geographic Information System (GIS) data is analysed to determine the states, actions and transitions of the landscape over time in NEWROC. The steps in converting aerial photographs or GIS data into Markov transition probabilities include: (1) entering the images, (2) calibrating the classification system, (3) classifying the attributes of the images, (4) converting the attributes to states using principle components analysis, and (5) extracting the Markov transition probabilities. The transition probability matrix for the status quo (No Contract) was estimated from aerial photography of a subsection of NEWROC from 1962, 1972, 1984, 1996 and 2004. The transition probability matrix for *Reveg* and Maintain were estimated based on the matrix calculated for *No Contract* (Table 1).

To estimate the *No Contract* Markov transition probabilities the aerial photographs spatially rectified (georeferenced or orthorectified) to ensure accuracy of the landscape area topography and scale using ARC-GIS. The areas of remnant vegetation present in 1962 were identified and re-identified in each following photograph to observe their attributes such as colour, homogeneity of colour, if joined to another remnant. The remnant attributes were then evaluated using principle components analysis into the four vegetation states of Undegw, Degw1, Degw2 and Agric. The transitions between states for each vegetation remnant between photographs gave the longer term Markov chain transition probability matrix for the status quo (*No Contract*). The transition probabilities are converted from a longer time span to an annual basis using the techniques outlined in Craig and Sendi (2002).

TABLE 1 PROBABILITY OF TRANSITION BETWEEN STATES GIVEN SELECTED ACTION

No Contract

	Undeg	Degw1	Degw2	Agric
Undeg	0.9	0.0	0.0	0.1
Degw1	0.0	0.5	0.2	0.3
Degw2	0.0	0.0	0.9	0.1
Agric	0.0	0.0	0.0	1.0

Revegetation Contract

	Undeg	Degw1	Degw2	Agric
Undeg	1.0	0.0	0.0	0.0
Degw1	0.5	0.5	0.0	0.0
Degw2	0.1	0.5	0.4	0.0
Agric	0.1	0.4	0.4	0.1

Maintenance Contract

	Undeg	Degw1	Degw2	Agric
Undeg	1.0	0.0	0.0	0.0
Degw1	0.1	0.7	0.2	0.0
Degw2	0.0	0.1	0.8	0.1
Agric	0.0	0.0	0.0	1.0

The state of the land and choice of action and monitoring determine the net benefit to the regulator of the land for each period of the analysis. The cost of contracting land ($c_i(e_t)$) for revegetation (*Reveg*) is $86 per hectare per year (Gole *et al.* 2005), and maintenance of current vegetation (Maintain) is $42 per hectare per year (Lockwood *et al.* 2000). While not entering a contract (*No Contract*) does not incur a cost or provide a benefit to the regulator. Land being in the state of Undegw or Degw1 provides a benefit to wider society and the regulator, or non-market value. The community willingness to pay for remnant native woodland vegetation in the Murray catchment of New South Wales is used as an estimate of the benefit to wider society and regulator of salmon gum woodland in NEWROC ($g_i(e_t)$); $91 per hectare per year for Undeg and $46 per hectare per year for Degw1 (Lockwood *et al.* 2000). Monitoring the land to determine its current vegetation state requires engaging a local expert and is estimated to cost (c^m) $8 per hectare per year (Gole *et al.* 2005).

The regulator is able to engage an expert to monitor/assess the land and estimate its current state to inform their future decisions. The probability that this monitoring correctly estimates the current state of the land is given in Table 2. Without monitoring the regulator does not know what the state of the land is when deciding their action choice.. The combinations of conservation contract type and monitoring effort give six different action options for the regulator to choice from in total.

TABLE 2 OBSERVATION PROBABILITIES FOR NO CONTRACT, MAINTAIN AND REVEG.

	Undeg	Degw1	Degw2	Agric
Undeg	0.8	0.2	0	0
Degw1	0.1	0.8	0.1	0
Degw2	0	0.1	0.8	0.1
Agric	0	0	0.2	0.8

RESULTS

The POMDP analysis was run over a specified number of periods to compare the optimal contract type for the regulator and also whether they engage in monitoring, in both the short term and the longer term. A discount rate (g) of 5%, i.e. discount factor of $\delta = 0.95$, is assumed for all analysis.

THREE-PERIOD ANNUAL PLANNING HORIZON

Were the regulator's time horizon only 3 periods, or 3 years, the optimal action sequence for the regulator is either three periods of *No Contract*, or an initial period of *Reveg* and then *No Contract* for 2 years. The policy graph in Figure 3**Error! Reference source not found.** illustrates the sequence of actions (Action Set). The right had column gives the set of optimal actions for a 1-period problem, the next column the initial action of a 2-period time horizon and the left column the initial action in a 3 period time horizon. The 3 period Action Set beginning with *Reveg without Monitoring* (Action Set 0) is therefore made up of the optimal action of *Reveg without Monitoring* in the initial period and then the optimal action of a 2-period decision and a 1-period decision.

The optimal initial action and action sequence is determined by the regulator's belief about the initial state of the land. In the three period case were the regulator 100% certain the land was Agric the optimal sequence of actions is *No Contract* in the initial period and all following periods (Action Set 1, Table 3**Error! Reference source not found.**). If the regulator thought there was a 50% probability the land was Undegw and 50% it was Degw1 the benefit from Action Set 0 is 0.5*224+0.5*58=$141, and Action Set 1 $114, so Action Set 0 is optimal. The calculation of the net present value of Action Set 0 i.e. beginning with Reveg without Monitoring in Period 3, when the initial state of the land is Degw1 is detailed below for illustration;

NPV = Period t=1 + Period t=2 + Period t=3

= (0.5*-17.75+0.5*-40.50+0*-63.25+0*-63.25) +

0.95*(0.5*(0.9*91+0*68.25+0*45.5+0.1*45.5) + 0.5*(0*68.25+0.5*45.5+0.2*22.75+0.3*22.75) + 0*(0*45.5+0*22.75+0.9*0+0.1*0) + 0*(0*45.5+0*22.75+0*0+1.0*0)) +

0.95^2*(0.5*(0.9*(0.9*91+0*68.25+0*45.5+0.1*45.5) + 0*(0*68.25+0.5*45.5+0.2*22.75+0.3*22.75) + 0*(0*45.5+0*22.75+0.9*0+0.1*0) + 0.1*(0*45.5+0*22.75+0*0+1.0*0)) + 0.5*(0*(0.9*91+0*68.25+0*45.5+0.1*45.5) + 0.5*(0*68.25+0.5*45.5+0.2*22.75+0.3*22.75) + 0*(0*45.5+0*22.75+0.9*0+0.1*0) + 0*(0*45.5+0*22.75+0*0+1.0*0)) + 0*(0*(0.9*91+0*68.25+0*45.5+0.1*45.5) + 0*(0*68.25+0.5*45.5+0.2*22.75+0.3*22.75) + 0.9*(0*45.5+0*22.75+0.9*0+0.1*0) + 0.1*(0*45.5+0*22.75+0*0+1.0*0)) + 0*(0.1* (0.9*91+0*68.25+0*45.5+0.1*45.5) + 0*(0*68.25+0.5*45.5+0.2*22.75+0.3*22.75) + 0*(0*45.5+0*22.75+0.9*0+0.1*0) + 1.0*(0*45.5+0*22.75+0*0+1.0*0))).

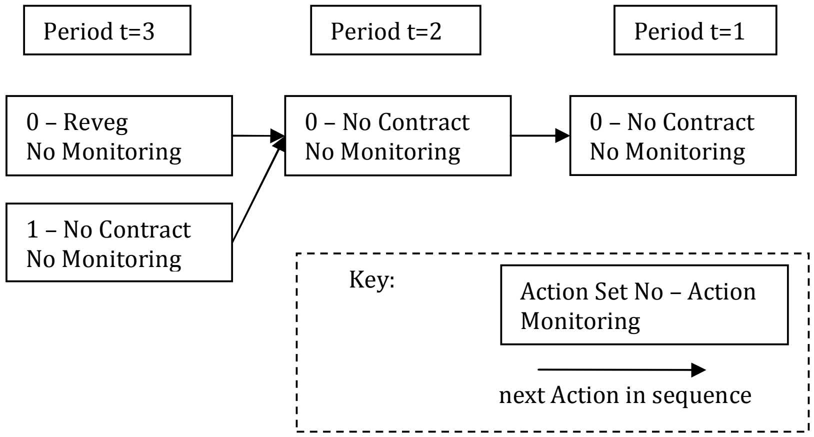

Figure 3 Policy graph for the regulator when the time horizon is 3 periods.

TABLE 3 NET BENEFIT OF ACTION SETS 0AND 1 FOR EACH INITIAL STATE OF THE LAND.

Action Set	1st period	2nd, 3rd period	Undegw	Degwood1	Degwood2	Agric
0	Reveg	No Contract	$157	**$71**	-$31	-$38
1	No Contract	No Contract	**$224**	$58	**$0**	**$0**

FIVE-PERIOD ANNUAL PLANNING HORIZON

Given a five- period time horizon, the regulator will engage in monitoring when there is uncertainty about the initial state of the being land Undeg, Degw1, Degw2 and/or Agric. Figure 4 shows how the regulator would undertake monitoring with Action Sets 0 and 1, both an initial period of *Reveg* followed by periods of *Reveg* or *No Contract* depending on the observed land type. Table 4 indicates that Action Set 3 is optimal when the land type is known to be Undgw, Degw2 or Agric. When the land type is known to be Degw1 the optimal Action Set is Action Set 1. Action Set 0 is optimal in situation such as when the probability of the land being Degw1 or Degw2 is 50:50. Action Set 2 is optimal in other situations again, such as when the probability of the land type being Undgw or Degw1 is 50:50.

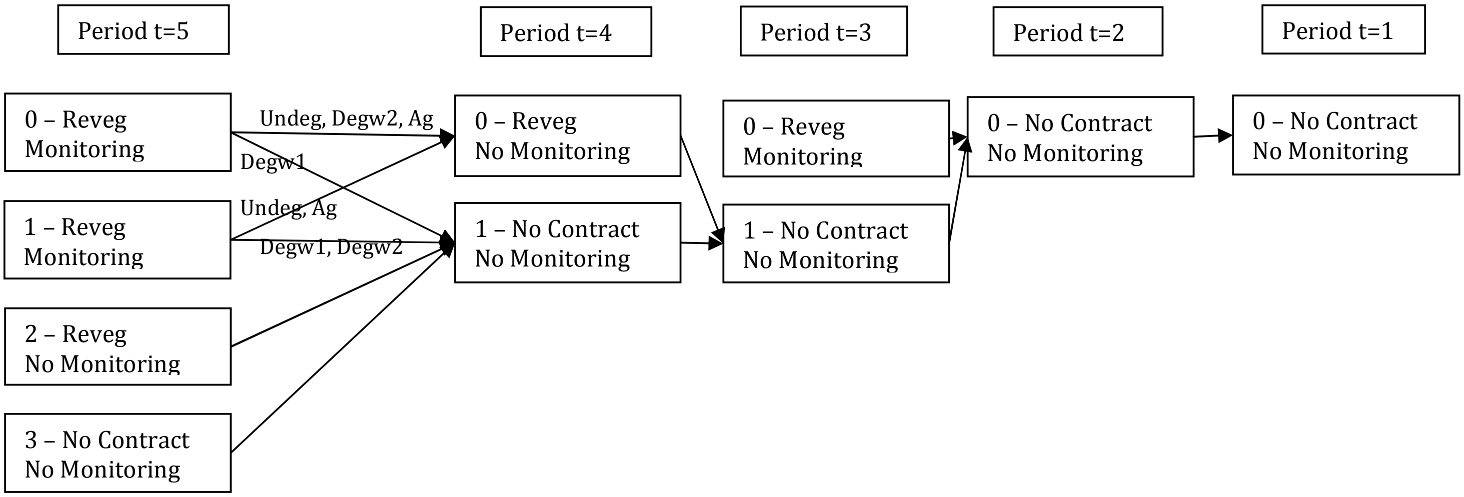

FIGURE 4 POLICY GRAPH FOR THE REGULATOR WHEN THE TIME HORIZON IS 5 PERIODS.

TABLE 4 NET BENEFIT RANGE OF ACTIONS 0 TO 3 DEPENDING ON THE INITIAL STATE OF THE LAND.

Action Set	Initial Action	Undegw	Degw1	Degw2	Agric
0	Reveg & Monitoring	$249	$135	-$8	-$19
1	Reveg & Monitoring	$249	**$137**	-$12	-$25
2	Reveg & No Monitoring	$269	$132	-$14	-$23
3	No Contract & No Monitoring	**$324**	$63	**$0**	**$0**

TEN-PERIOD ANNUAL PLANNING HORIZON

Continuing the analysis for a 10- period/year time horizon for the regulator further increases the number of Action Sets, to 40, with all combinations of *Reveg*, *Maintain* or *No Contract with* and *without Monitoring* being optimal in certain circumstances, except for *No Contract without Monitoring*. Table 5 gives the range of net benefits from each initial action in the 40 Action Sets. The full sequence of actions and net present value of the benefits are available in Appendix 1. When the initial land is predicted to be Undegw the optimal initial action is to *Reveg with or without monitoring*. For an expected initial state of Degw1 the optimal first action is *Reveg or Maintain with monitoring*. While a high probability of the land being Degw2 or Agric leads the regulator to *Reveg with Monitoring*. When the land type is uncertain *Maintain with monitoring* is preferred. The subsequent action(s) will vary depending on the predicted

TABLE 5 NET BENEFIT RANGE OF ACTIONS 0 TO 40 DEPENDING ON THE INITIAL STATE OF THE LAND.

1st period	Undegw	Degw1	Degw2	Agric
Reveg , No Monitoring	**$480**	$92	-$86	-$120
Reveg & Monitoring	$375-416	**$281-289**	**$115-127**	**$97-107**
Maintain, No Monitoring	**$474-480**	$94-115	-$61-72	-$82-68
Maintain & Monitoring	$416-463	**$184-289**	$59-115	$26-97
No Contract & Monitoring	$460-474	$114-184	$49-85	$26-68

DISCUSSION AND CONCLUSIONS

It is can be beneficial to government and non-government conservation agencies and/or their agents (regulators) to incorporate multiple contract types, and monitoring into conservation programs for native remnants. The value of multiple contract types and monitoring depends on the regulator's decision time horizon and the expected initial state of the vegetation. The case study shows a conservation agency only contracts for revegetation work when their decision time horizon is 3-periods or greater and the land type is expected to be partly degraded woodland. A short decision horizon with either quality woodland, very degraded woodland or agricultural lans means no conservation contract is entered into. The social cost from creating quality woodland outweighs the benefit of establishing it in very degraded bush or agricultural land. In land currently undegraded it is better to 'run down' the value of the land as the degradation does not substantially affect the social benefit from the woodland in the short-term.

With a longer decision horizon the analysis indicates conservation agencies should engage in a wider variety of conservation contracts, depending on the state of the land. In the medium to long-term, it is optimal for a regulator may contract land for revegetation work when the land is more likely to be degraded woodland or agricultural land, maintenance of the existing woodland is preferred when the initial land type is unknown, while not contract the land is optimal if there is a high probability the land is either undegraded woodland or agricultural. Monitoring is valuable to the regulator as it enables them to more efficiently contract degraded and agricultural land types. The increases in the average NPV from monitoring of conservation contracts to revegetate range from \$196 to \$219, and for a maintenance contract from \$71 to \$125, assuming a 10-period annual decision horizon. Monitoring is not beneficial when the initial land type is undegraded woodland as the contract type does not vary. The flexibility of contracting land for a variety of conservation works, and responding to information from monitoring, enables the conservation agency to respond opportunistically to vegetation succession over the longer term and thereby more efficiently achieve their goal of providing environmental services. This is particularly the case in situations where there is doubt about the current state of the land.

The analysis shows that undertaking monitoring and consequently altering the conservation contract as the vegetation changes may be valuable to conservation schemes. Conservation agencies or regulators with a very short-term planning horizon for decision making are less likely to benefit from monitoring the vegetation succession or the outcome of conservation contracts. The current trial conservation programs with short-term contracts would fall into this category. The case study supports the current practice of not monitoring short-term conservation contracts as monitoring is not optimal for any combination of the land type being undegraded or degraded woodland or agricultural when the contract is shorter than 5 years and contracts are negotiated annually. Future work will investigate the use of monitoring in longer-term contracts.

The POMDP framework presents a flexible approach to determine optimal actions where the stochastic process is represented by a Markov chain. Given the Smallwood and Sondik (1973) algorithm is reasonably robust and that Markov chains are familiar to ecologists as a method for modelling environmental change means that this approach has the potential to contribute to the analysis of monitoring systems and may lead to significant savings in monitoring costs. Currently monitoring is often undertaken as a matter of routine rather than relating monitoring to the actual predicted rates of vegetation change.

This paper has only presented a small set of results on the impact on optimal contract design and the use of monitoring of different assumptions. Further research will address the broader economic literature on monitoring, namely the incentives for compliance and cheating by landholders, and the enforcement and renegotiation strategies for the regulator.

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APPENDIX 1

Table 6details the optimal actions and their net present value given a 1-period to 10-period time horizon for the regulator. The initial column is the period in time the action is optimal for, with the Action Set and action named in columns 2 and 3. Columns 4 to 8 give the number of the Action Set to be taken in the following period depending on if monitoring has occurred and if so what was observed. For example, in period 6 for Action Set 4 the initial action is *Reveg with Monitoring*, were the regulator to monitor and observe Undegw or Agric land they would undertake Action Set 3 of time period 5 next (*No Contract without Monitoring*). If the regulator observed Degw1 they would undertake Action Set 2 of period 5 next (*Reveg without Monitoring*), but if they observed Degw2 the regulator would undertake Action Set 0 (*Reveg with monitoring*). The process would then be repeated as above for the actions undertaken in time period 5. The sequence of actions is combined with the probability of vegetation succession for each action and accuracy of monitoring from the transition probability matrix, as well as the benefit and costs of the action and land type, to give the net present value of each Action Set and land type in columns 9 to 12.

The Action Set number is underlined in Table 6 to indicate when an Action Set is not optimal as a subsequent Action Set, only as an initial action when the time horizon is equal to the time period. In the case of a 9 period time horizon there are 59 Action Sets that are optimal as initial actions but only 26 of these Aciton Sets are referenced as an action to follow from a 10 period Action Set. The extensive Action Set list is therefore not necessarily indicative of a large range of optimal actions in that period,when the decision time horizon is a longer time period.

TABLE 6 SEQUENCE OF ACTIONS AND NET PRESENT VALUE FOR A 1 TO 10-PERIOD TIME HORIZON.

t =	Action Set	Initial Action	No Monitor	Undegw	Degw1	Degw2	Agric	Undegw	Degw1	Degw2	Agric
1	0	No Contract, No Monitor	0					$169	$67	$0	$0
2	0	No Contract, No Monitor	0					$160	$50	$0	$0
3	0	Reveg, No Monitor	0					$157	$71	-$31	-$38
3	1	No Contract, No Monitor	0					$224	$58	$0	$0
4	0	Reveg, No Monitor	1					$217	$105	-$21	-$29
4	1	No Contract, No Monitor	1					$278	$62	$0	$0
5	0	Reveg & Monitor		1	0	1	1	$249	$135	-$8	-$19
5	1	Reveg & Monitor		1	0	0	1	$249	$137	-$12	-$25
5	2	Reveg, No Monitor	1					$269	$132	-$14	-$23
5	3	No Contract, No Monitor	1					$324	$63	$0	$0
6	0	Reveg, No Monitor	0					$242	$153	$15	-$2
6	1	Reveg, No Monitor	2					$260	$161	$13	-$4
6	2	Reveg & Monitor		3	1	0	3	$290	$171	$10	-$5
6	3	Reveg & Monitor		3	1	1	3	$290	$171	$8	-$7

6	4	Reveg & Monitor		3	2	0	3	$294	$171	$8	-$6
6	5	Reveg & Monitor		3	2	1	3	$294	$171	$7	-$8
6	6	Reveg, No Monitor	3					$313	$155	-$9	-$17
6	7	No Contract, No Monitor	3					$363	$64	$0	$0
7	0	Reveg, No Monitor	2					$281	$190	$42	$23
7	1	Reveg, No Monitor	4					$284	$192	$42	$23
7	2	Reveg & Monitor		7	4	0	0	$329	$204	$36	$18
7	3	Reveg & Monitor		7	5	0	0	$329	$204	$36	$18
7	4	Reveg & Monitor		7	5	1	0	$329	$205	$36	$18
7	5	Reveg & Monitor		7	5	2	0	$329	$205	$35	$17
7	6	Reveg & Monitor		7	5	3	0	$329	$205	$35	$17
7	7	Reveg & Monitor		7	5	5	0	$329	$205	$34	$16
7	8	Reveg & Monitor		7	6	2	0	$332	$201	$29	$12
7	9	Reveg & Monitor		7	6	3	0	$332	$201	$28	$12
7	10	Reveg & Monitor		7	6	5	0	$332	$201	$28	$11
7	11	Reveg, No Monitor	7					$350	$174	-$5	-$13
7	12	Maintain & Monitor		7	4	0	0	$373	$135	-$22	-$52
7	13	Maintain & Monitor		7	5	1	7	$373	$135	-$24	-$51
7	14	Maintain & Monitor		7	5	0	0	$373	$135	-$22	-$52
7	15	Maintain & Monitor		7	5	2	7	$373	$135	-$26	-$51
7	16	Maintain & Monitor		7	5	1	0	$373	$135	-$23	-$53
7	17	Maintain & Monitor		7	5	2	0	$373	$135	-$25	-$53
7	18	Maintain & Monitor		7	6	0	0	$376	$126	-$25	-$52
7	19	Maintain & Monitor		7	6	2	7	$376	$126	-$29	-$51
7	20	Maintain & Monitor		7	6	1	0	$376	$126	-$26	-$53
7	21	Maintain & Monitor		7	6	2	0	$376	$126	-$28	-$53
7	22	Maintain, No Monitor	7					$394	$78	-$34	-$42
7	23	No Contract, No Monitor	7					$397	$65	$0	$0
8	0	Reveg, No Monitor	4					$318	$224	$72	$52
8	1	Reveg, No Monitor	5					$318	$225	$72	$52
8	2	Reveg & Monitor		22	5	1	0	$359	$235	$65	$46
8	3	Reveg & Monitor		23	5	1	0	$361	$235	$64	$46
8	4	Reveg & Monitor		23	5	4	0	$361	$236	$63	$45
8	5	Reveg & Monitor		23	5	5	0	$361	$236	$63	$44
8	6	Reveg & Monitor		23	6	5	0	$361	$236	$63	$44
8	7	Reveg & Monitor		23	7	5	0	$361	$236	$63	$44
8	8	Reveg & Monitor		23	7	6	0	$361	$236	$63	$44
8	9	Reveg & Monitor		23	7	7	0	$361	$236	$62	$44
8	10	Maintain & Monitor		23	5	1	0	$405	$164	$4	-$28
8	11	Maintain & Monitor		23	8	1	0	$406	$161	$3	-$28
8	12	No Contract & Monitor		23	4	0	0	$409	$131	$30	$14
8	13	No Contract & Monitor		23	5	0	0	$409	$131	$30	$14
8	14	No Contract & Monitor		23	8	0	0	$409	$129	$29	$14
8	15	No Contract & Monitor		23	11	0	0	$412	$118	$26	$14

8	16	No Contract & Monitor		23	17	1	0	$416	$103	$25	$14
8	17	No Contract & Monitor		23	12	0	0	$416	$103	$25	$14
8	18	No Contract & Monitor		23	14	0	0	$416	$103	$25	$14
8	19	No Contract & Monitor		23	16	0	0	$416	$103	$25	$14
8	20	No Contract & Monitor		23	17	0	0	$416	$103	$25	$14
8	21	No Contract & Monitor		23	18	0	0	$417	$100	$25	$14
8	22	No Contract & Monitor		23	20	0	0	$417	$100	$25	$14
8	23	No Contract & Monitor		23	21	0	0	$417	$100	$24	$14
8	24	No Contract & Monitor		23	22	0	0	$420	$81	$24	$14
8	25	No Contract & Monitor		23	23	0	0	$420	$77	$27	$14
8	26	No Contract, No Monitor	23					$426	$65	$0	$0
8	27	Maintain, No Monitor	23					$426	$82	-$34	-$42
9	0	Reveg, No Monitor	3					$348	$254	$100	$80
9	1	Reveg & Monitor		27	6	1	0	$390	$263	$92	$74
9	2	Reveg & Monitor		27	6	1	1	$390	$263	$92	$74
9	3	Reveg & Monitor		27	7	1	0	$390	$263	$92	$74
9	4	Reveg & Monitor		27	7	1	1	$390	$263	$92	$74
9	5	Reveg & Monitor		27	7	2	0	$390	$264	$91	$72
9	6	Reveg & Monitor		27	7	2	1	$390	$264	$91	$72
9	7	Reveg & Monitor		27	7	3	0	$390	$264	$90	$72
9	8	Reveg & Monitor		27	7	3	1	$390	$264	$90	$72
9	9	Reveg & Monitor		27	7	4	0	$390	$264	$90	$72
9	10	Reveg & Monitor		27	7	4	1	$390	$264	$90	$72
9	11	Reveg & Monitor		27	7	5	0	$390	$264	$90	$72
9	12	Reveg & Monitor		27	7	5	1	$390	$264	$90	$72
9	13	Reveg & Monitor		27	7	6	0	$390	$264	$90	$72
9	14	Reveg & Monitor		27	7	6	1	$390	$264	$90	$72
9	15	Reveg & Monitor		27	8	6	0	$390	$264	$90	$72
9	16	Reveg & Monitor		27	8	6	1	$390	$264	$90	$72
9	17	Reveg & Monitor		27	8	7	0	$390	$264	$90	$72
9	18	Reveg & Monitor		27	8	7	1	$390	$264	$90	$72
9	19	Reveg & Monitor		27	9	7	0	$390	$264	$90	$72
9	20	Reveg & Monitor		27	9	7	1	$390	$264	$90	$72
9	21	Reveg & Monitor		27	9	9	1	$390	$264	$90	$72
9	22	Maintain & Monitor		27	5	1	0	$434	$192	$32	-$1
9	23	Maintain & Monitor		27	6	1	0	$434	$192	$32	-$1
9	24	Maintain & Monitor		27	5	1	1	$434	$192	$32	-$1
9	25	Maintain & Monitor		27	7	1	0	$434	$192	$32	-$1
9	26	Maintain & Monitor		27	6	1	1	$434	$192	$32	-$1
9	27	Maintain & Monitor		27	7	1	1	$434	$192	$32	-$1
9	28	No Contract & Monitor		27	3	1	0	$437	$158	$58	$41
9	29	No Contract & Monitor		27	4	1	0	$437	$159	$58	$41
9	30	No Contract & Monitor		27	5	1	0	$437	$159	$58	$41
9	31	No Contract & Monitor		27	6	1	0	$437	$159	$58	$41

9	32	No Contract & Monitor		27	7	1	0	$437	$159	$58	$41
9	33	No Contract & Monitor		27	6	0	0	$437	$159	$58	$41
9	34	No Contract & Monitor		27	7	0	0	$437	$159	$58	$41
9	35	Maintain & Monitor		27	10	1	0	$442	$153	$22	-$1
9	36	Maintain & Monitor		27	10	1	1	$442	$153	$22	-$1
9	37	No Contract & Monitor		27	10	1	0	$444	$130	$53	$41
9	38	No Contract & Monitor		27	10	0	0	$444	$130	$53	$41
9	39	No Contract & Monitor		27	11	1	0	$444	$129	$53	$41
9	40	No Contract & Monitor		27	11	0	0	$444	$129	$53	$41
9	41	No Contract & Monitor		27	13	1	0	$445	$118	$55	$41
9	42	No Contract & Monitor		27	14	1	0	$445	$117	$55	$41
9	43	No Contract & Monitor		27	17	1	0	$446	$107	$54	$41
9	44	No Contract & Monitor		27	18	1	0	$446	$107	$54	$41
9	45	No Contract & Monitor		27	19	1	0	$446	$107	$54	$41
9	46	No Contract & Monitor		27	18	0	0	$446	$107	$54	$41
9	47	No Contract & Monitor		27	19	0	0	$446	$107	$54	$41
9	48	No Contract & Monitor		27	21	1	0	$446	$106	$54	$41
9	49	No Contract & Monitor		27	22	1	0	$446	$106	$54	$41
9	50	No Contract & Monitor		27	21	0	0	$446	$106	$54	$41
9	51	No Contract & Monitor		27	22	0	0	$446	$106	$54	$41
9	52	No Contract & Monitor		27	25	1	0	$447	$97	$55	$41
9	53	No Contract & Monitor		27	25	0	0	$447	$97	$55	$41
9	54	No Contract & Monitor		27	26	1	0	$448	$92	$52	$41
9	55	No Contract & Monitor		27	26	0	0	$448	$92	$52	$41
9	56	No Contract & Monitor		27	27	1	0	$448	$98	$49	$41
9	57	No Contract & Monitor		27	27	0	0	$448	$98	$49	$41
9	58	Maintain, No Monitor	26					$454	$85	-$34	-$42
9	59	Maintain, No Monitor	27					$454	$90	-$61	-$82
10	0	Reveg, No Monitor	4					$480	$92	-$86	-$120
10	1	Reveg & Monitor		36	8	0	0	$375	$281	$127	$107
10	2	Reveg & Monitor		36	10	0	0	$407	$287	$120	$102
10	3	Reveg & Monitor		59	8	0	0	$407	$287	$120	$102
10	4	Reveg & Monitor		59	10	0	0	$416	$289	$118	$100
10	5	Reveg & Monitor		59	12	0	0	$416	$289	$118	$100
10	6	Reveg & Monitor		59	14	0	0	$416	$289	$118	$100
10	7	Reveg & Monitor		59	16	0	0	$416	$289	$118	$100
10	8	Reveg & Monitor		59	16	4	0	$416	$289	$118	$100
10	9	Reveg & Monitor		59	20	4	0	$416	$289	$116	$98
10	10	Reveg & Monitor		59	20	6	0	$416	$289	$116	$98
10	11	Reveg & Monitor		59	20	8	0	$416	$289	$116	$97
10	12	Reveg & Monitor		59	20	10	0	$416	$289	$116	$97
10	13	Reveg & Monitor		59	20	12	0	$416	$289	$115	$97
10	14	Reveg & Monitor		59	21	20	0	$416	$289	$115	$97
10	15	Reveg & Monitor		59	21	21	0	$416	$289	$115	$97

10	16	Maintain & Monitor		59	8	0	0	$416	$289	$115	$97
10	17	Maintain & Monitor		59	10	0	0	$460	$217	$59	$26
10	18	No Contract & Monitor		59	4	0	0	$460	$217	$59	$26
10	19	No Contract & Monitor		59	6	0	0	$463	$184	$85	$68
10	20	No Contract & Monitor		59	8	0	0	$463	$184	$85	$68
10	21	No Contract & Monitor		59	10	0	0	$463	$184	$85	$68
10	22	Maintain & Monitor		59	27	0	0	$463	$184	$85	$68
10	23	No Contract & Monitor		59	27	0	0	$468	$179	$49	$26
10	24	No Contract & Monitor		59	28	0	0	$471	$156	$80	$68
10	25	No Contract & Monitor		59	29	0	0	$471	$144	$82	$68
10	26	No Contract & Monitor		59	36	0	0	$471	$144	$82	$68
10	27	No Contract & Monitor		59	37	0	0	$472	$141	$79	$68
10	28	No Contract & Monitor		59	39	0	0	$472	$133	$81	$68
10	29	No Contract & Monitor		59	41	0	0	$473	$133	$81	$68
10	30	No Contract & Monitor		59	42	0	0	$473	$128	$82	$68
10	31	No Contract & Monitor		59	43	0	0	$473	$128	$82	$68
10	32	No Contract & Monitor		59	45	0	0	$473	$124	$81	$68
10	33	No Contract & Monitor		59	49	0	0	$473	$124	$81	$68
10	34	No Contract & Monitor		59	52	0	0	$473	$124	$81	$68
10	35	No Contract & Monitor		59	54	0	0	$473	$121	$81	$68
10	36	No Contract & Monitor		59	56	0	0	$473	$119	$81	$68
10	37	No Contract & Monitor		59	58	0	0	$473	$121	$81	$68
10	38	No Contract & Monitor		59	59	0	0	$474	$114	$74	$68
10	39	Maintain, No Monitor	58					$474	$115	$72	$68
10	40	Maintain, No Monitor	59					$480	$94	-$61	-$82