Assessing a Caltrans Reclaimed Wetland with Geographical Information Systems

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Abstract Wetland ecosystems are highly productive and vital to the environment due to the diversity of biological, physical and chemical attributes within each system. Unfortunately, loss of wetlands has been extensive since industrialized development began. In response to this, the government has instituted "No Net Loss" legislation to prevent further damage and restore previously damaged environments. The California State Department of Transportation (Caltrans) along with many other organizations have incorporated wetland creation, restoration and mitigation plans into their agenda. However, created wetlands have been criticized for being inadequate and ineffective in replacing the functionality of natural wetlands (Revkin, 2001). Despite the legal mandates designed to restore wetlands, the effectiveness of the legislation efforts has been difficult to gauge. More effective approaches to wetland management have been suggested and explored. (La Peyre et.al. 2001). One approach is the integration of Geographical Information Systems (GIS) with conventional wetland management methods to improve the speed of assessment (Wolfson et al., 2002). This case study of Caltrans' reclaimed wetland, Guadalcanal Village will have two main goals, to evaluate Caltrans' current vegetation assessment practice and to utilize and gauge aerial photography as an alternative method in vegetation assessment. The current state of the wetland's vegetation will also be appraised to determine if it meets the success criteria set by Caltrans. This study will examine the existing vegetation data available from Caltrans as well as the aerial photography and Arc View GIS and compare each source to the success criteria set by the mitigation plan. It is hypothesized that the current vegetation will not meet the success criteria and that utilizing aerial photography and GIS analysis to assess the wetland vegetative health is viable and will yield reliable data. While results suggest that according to Caltrans' method of vegetation assessment, the wetland site is meeting the success criteria, aerial photography data contradicts these results and shows that the wetland site does not meet the success criteria.

Introduction

The role a wetland can play is both vital and diverse. Wetland ecosystems are highly productive due to the diversity of biological, physical and chemical attributes while being home to numerous species of microbes, plants, insects, reptiles, amphibians and birds (EPA, 2002). High nutrient richness of wetlands allows for an abundance of the organisms at the base of the food web (EPA, 2002). Wetlands can also provide societal, recreational and cultural values, such as outlets for floodwaters, maintenance of water quality, aesthetics and more (US Army Corps of Engineers, 1995).

Unfortunately, the rate of loss of wetlands has been extensive. It is estimated that over half of the United States' wetland habitat has been dredged or converted to other uses. While major losses occurred in the 1970s, increased awareness has lead to more regulatory legislation. The loss of original wetlands is still occurring at an estimated rate of at least 100,000 acres a year in the United States with California suffering the greatest loss at 91% of its original wetlands already destroyed. In addition to losses, wetlands also suffer degradation both from human activities and natural causes (EPA, 2002).

The California State Department of Transportation (Caltrans) is under legal mandate to comply with all state and federal laws regarding wetlands and wetlands protection. These laws include the California Environmental Quality Act, National Environmental Policy Act, and sections 401 and 404 of the federal Clean Water Act established in 1972. (CEQA, 1970, NEPA, 1969 and CWA, 1972) In addition, section 10 of the Rivers and Harbors Act, and the President's Executive Order 11990 must be considered (Caltrans, 1997). Under these "No Net Loss" policies, all Caltrans projects that impact wetlands through disposal of dredged or fill material into wetlands and/or the paving over of wetlands must obtain federal and state permits. In order to obtain these permits, Caltrans must include a mitigation plan that details the compensation of the loss of the existing wetland. Compensation is mainly achieved through the creation of new wetlands (Wilson, 2002). The mitigation plan must replace at least 1.8 acres of wetlands for every 1-acre that the project destroys, as well as include a monitoring program to assess the functionality of the wetland (Revkin, 2001).

In response to legislation, Caltrans along with many other organizations have incorporated wetland creation, restoration and mitigation plans into their agendas. From 1982 to 1992 alone, a total of 768,700 acres of wetlands were gained as a result of restoration activities around the nation (EPA, 2002). While these statistics are impressive, created or artificial wetlands have been criticized for being inadequate and ineffective in compensating for the loss of natural wetlands (Revkin, 2001). One study that focused on compensatory wetland mitigation in the San Francisco Bay Area found that the majority of these wetlands cannot be classified as complete, active or successful (Campbell et al., 2002).

Despite legal mandates designed to save and manage wetlands, the effectiveness and outcomes of these legislation efforts have been difficult to gauge. With such aspects of wetland resource management as creation, impacts, and quality, a more progressive and rapid approach to wetland management is needed (La Peyre et.al. 2001). One alternative management approach that has been experimented with is the integration of geographical information systems (GIS) with conventional wetland management methods (Wolfson et al., 2002).

A study conducted in Michigan, USA, developed a wetlands information system for assessing wetland functions. They combined the standard National Wetlands Inventory codes, site visits, and GIS technology to define and assess the function and value of two-wetland site (Wolfson et al., 2002 and NWI, 2002).

This study examined Caltrans' current vegetation assessment practice and compared the current state of the reclaimed wetland to success criteria predetermined by Caltrans for the site. This study also explored the usage of aerial photography and GIS analysis as a possible alternative in assessing the vegetation of the wetland site. Assessments derived from aerial data were also compared to Caltrans' success criteria and from that, the usefulness of this alternative was examined.

Based on poor past records of wetlands mitigation successes (La Peyre et.al. 2001), The hypotheses for this study are that according to Caltrans' current vegetation assessment, the wetland site will not have met the success criteria and that aerial photography and GIS analysis will reveal the same conclusion. Also, aerial photography will prove useful in assessment of the wetland vegetation.

Methods

Study Site The study site will be a wetland reclaimed by Caltrans. It is Guadalcanal Tidal Marsh, located on Mare Island, CA. This site was chosen based on availability, accessibility and baseline data availability. See figure 1 (Bias et al., 2001).

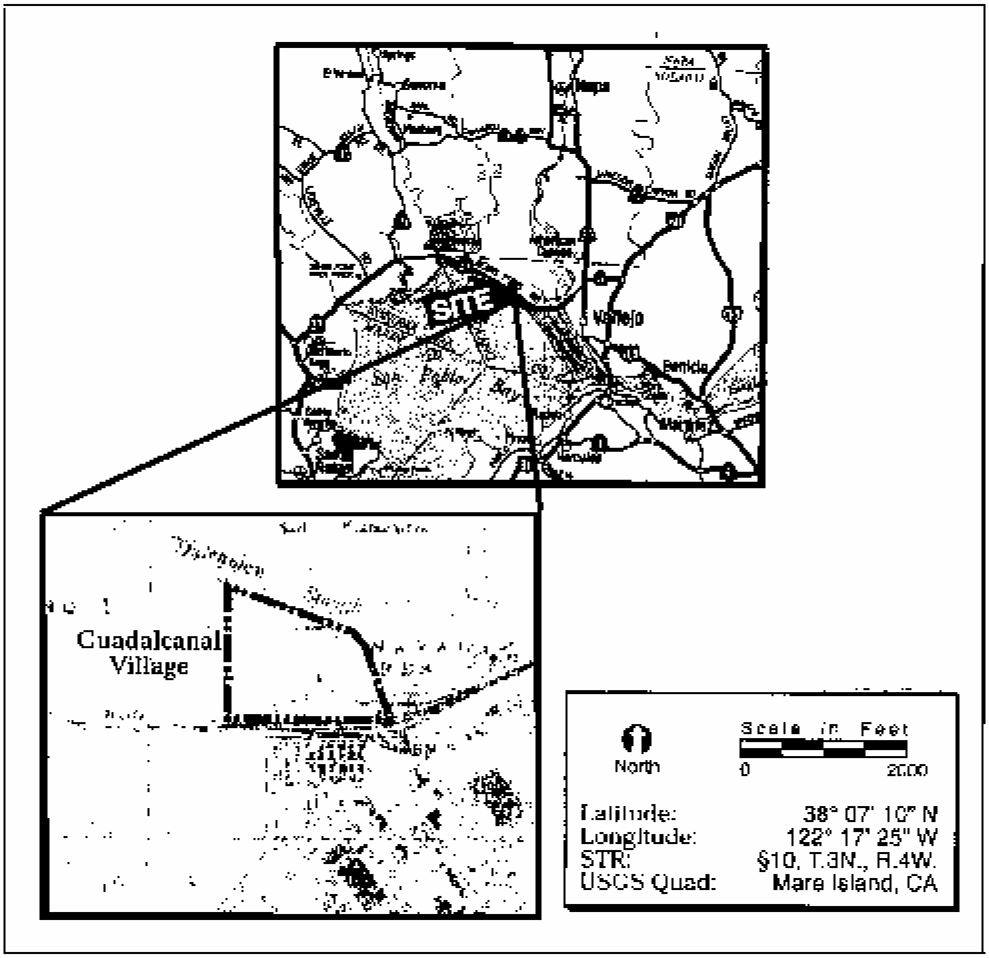

Figure 1: The study site is Guadalcanal Village right off of Hwy 37 in Vallejo, CA (Bias et al., 2001).

Data Sources The wetland vegetation data was derived from the ground sampling data that Caltrans has already compiled. The aerial photography and GIS data was derived from the National Wetland Inventory's digital maps and United States Geological Service's (USGS) aerial photographs.

Ground Sampling The data for vegetative ground samplings was taken by Caltrans. The vegetation was measured for species percent cover density measurements, height and frequency. The method that was employed by Caltrans used UTM gridlines to divide the site into 125 meter x 125 meter grids. The center of each square was determined using global positioning systems equipment. The line-intercept method was used in conjunction. Starting from the center point of each square, a 15 meter transect was extended in a randomly selected compass bearing. Vegetation species, number of plants, and stem height that occur along the transect will be recorded.

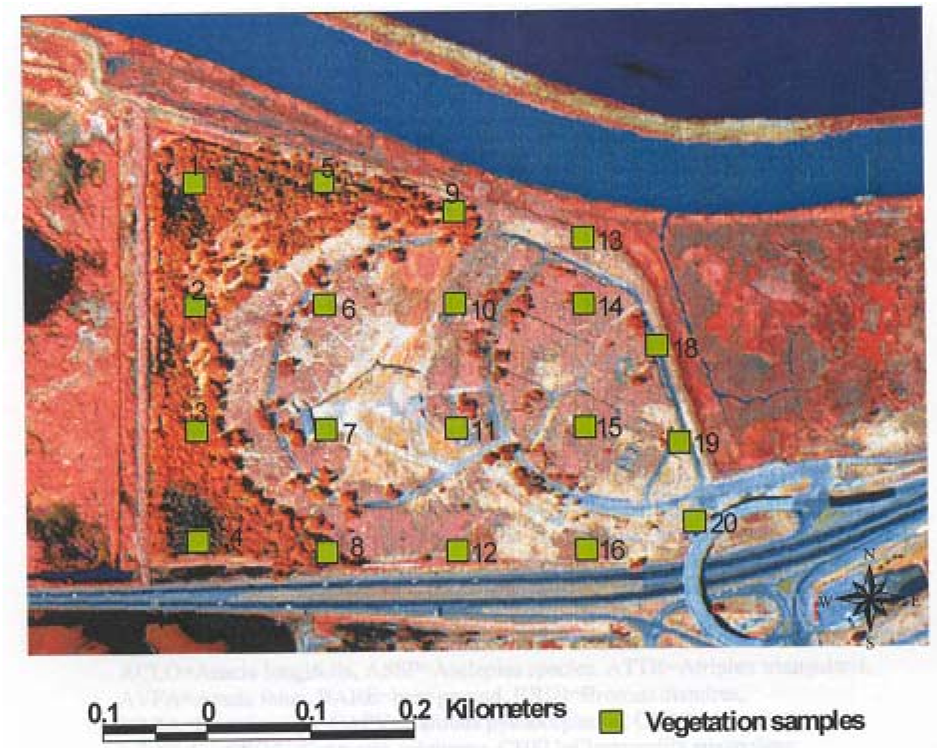

Figure 2: Vegetation ground sampling points (Caltrans, 1999).

Aerial Photography **A**ll the past aerial photographs taken of the site by the USGS were digitized. Existing digital maps of the site were also needed. Using Environmental Systems Research Institute's ArcView and Arc/Info GIS software, the digitized photos and digital maps were georeferenced to facilitate the necessary overlays. Georeferencing matches the photographs to its position on the earth. With the exact position of the site established, one can then overlay the grid used by Caltrans to divide the site into quadrats.

Using Nature Conservancy's National Wetland Vegetation Classification System standardized codes for classification of vegetation; the vegetation on the maps will be classified. One actual visit to the site was utilized to confirm homogeneity of the vegetation composition. Each habitat type was visited and surveyed with naked eye and/or binoculars. Homogeneity will be defined as an area that is dominated (>50% coverage) by a species of vegetation. After homogeneity is confirmed, polygons of homogenous vegetation will be drawn and the percent coverage of each species of vegetation present is determined.

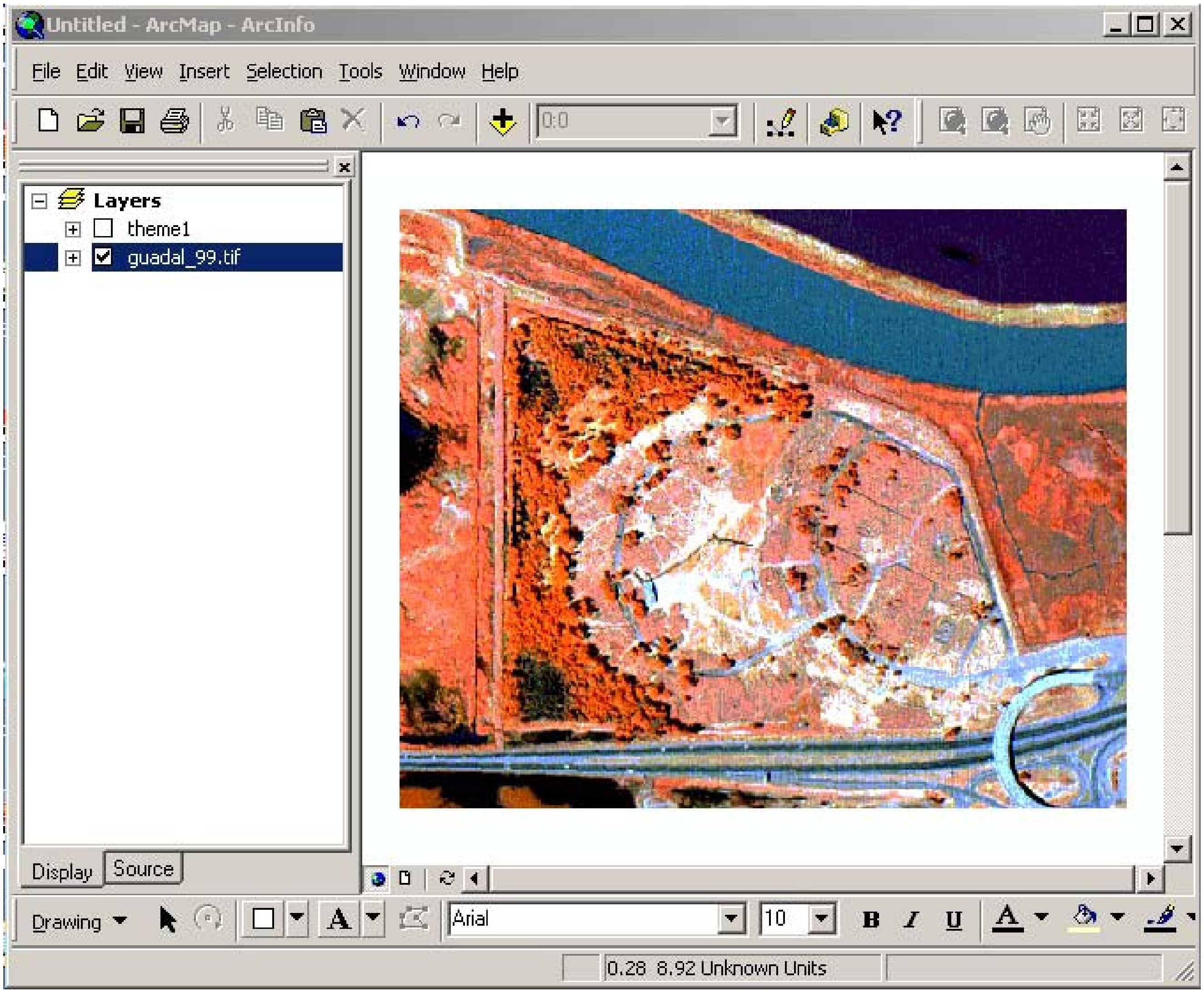

Figure 3: Screen capture of spring 1999 aerial photography in ArcMap before analysis.

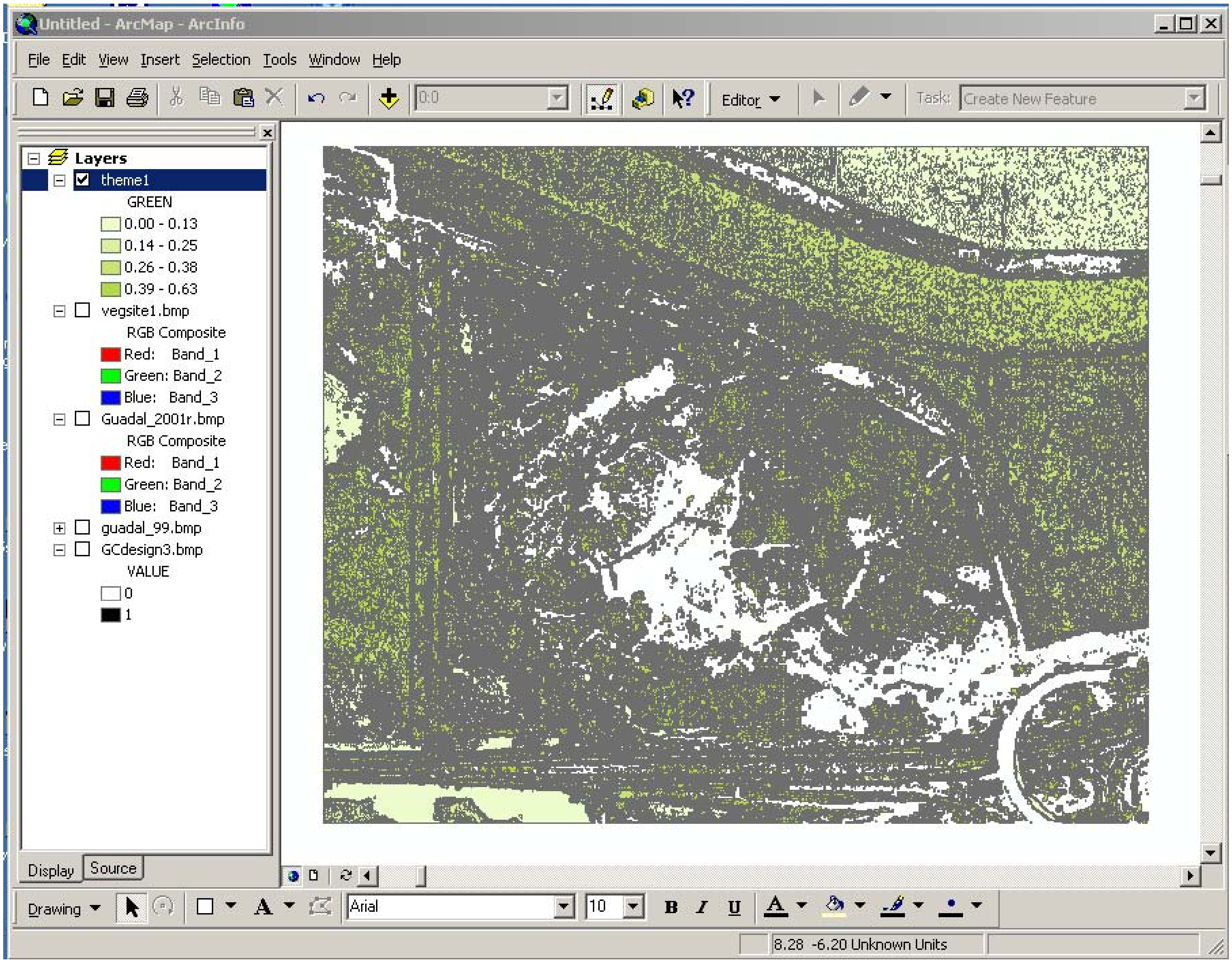

Figure 4: Screen capture of spring 1999 aerial photograph in ArcMap post analysis.

Statistical Techniques The percent coverage of vegetation obtained through ground sampling methods was compared to the success criteria. The percent coverage of vegetation derived from aerial photography and GIS analysis was also compared to the success criteria. The two vegetation sampling methods will then be compared based on how they each compared to the success criteria.

Results

The success criteria established by Caltrans for Guadalcanal Village is broken up by habitat types. These specific habitat types were determined by elevation and grading models at the time of mitigation plan design. The habitat types include low marsh, marsh plain, high marsh, gumplant, upland and grassland. This study will combine gumplant and grassland with upland. Each habitat type also has a targeted vegetation species as well as an associated success criterion in the form of percent vegetation cover. The success criteria are projected from year one to year seven, when the wetland site will be assumed to be mature, and the when vegetation should be stabilized. The success criteria is shown in Table 1.

Success Criteria		**Expected success**			
Habitat	**Propagule Type**	**Year 1**	**Year 3**	**Year 5**	**Year 7**
Low marsh - Cord Grass-Alkali bulrush	Natural colonization	Recruitment	Recruitment	50% stem density	90% stem density of reference area
Marsh plain - Pickleweed	Natural colonization	Recruitment	Recruitment	35% cover	75% cover of reference area
High marsh - Pickleweed, salt grass, mixed halophytes	Natural colonization	Recruitment	Recruitment	50% cover	75% cover of reference area
Gum plant	Nursery transplants	Plant	75% survival	Transplant producing seed	Recruits producing seed
Upland Buffer - Coyote brush, forbs, shrubs	Nursery transplants	Plant	50% survival	Transplant producing seed	New recruits
Grassland	Seed	Seed	75% cover	90% cover	90% cover

Table 1: Expected Success Criteria (Caltrans, 1995).

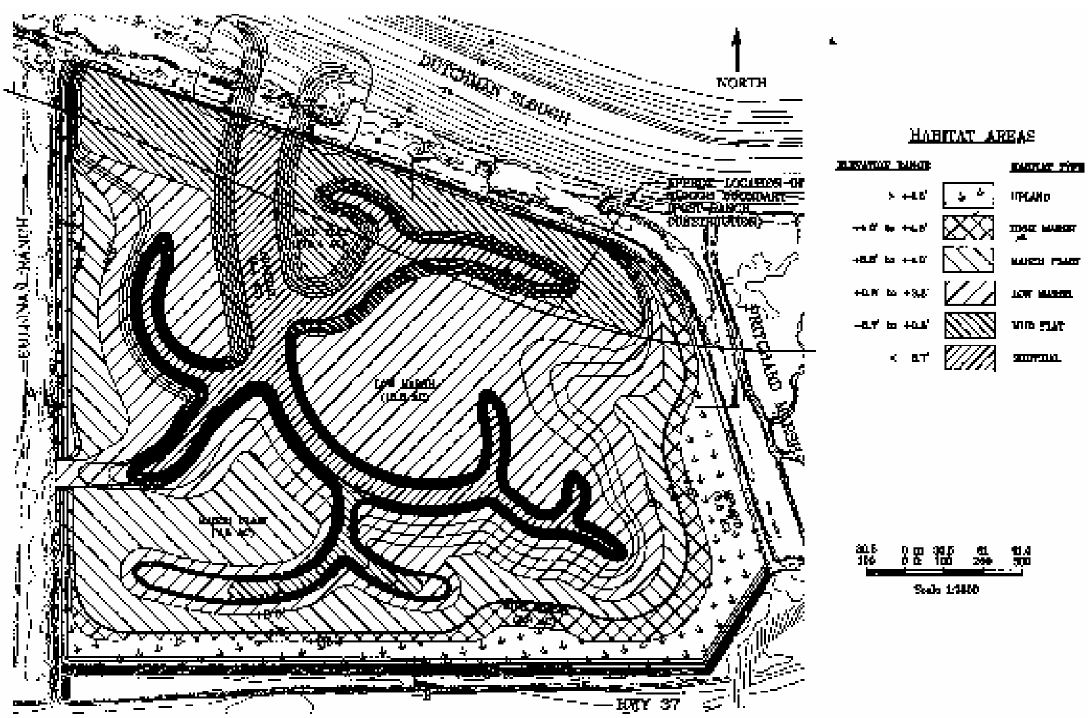

Figure 5: Habitat Types map (Caltrans, 1995).

Ground Sampling Compilation of the data isolating the percent coverage of vegetation species was necessary. Table 2 shows the type of vegetation cover and the percent coverage over the entire site. The data shown compares the Spring of 1999 before mitigation, to the Spring of 2002, three years post mitigation.

Gound Sampling Data		Spring 1999	Spring 2002
Marsh Zone	**Cover Type**	**Percent of site**	**Percent of site**
Upland	Buffer Plants	11	20
High Marsh	Pickleweed/ mixed halophytes	6	16.5
Marsh Plain	Pickleweed/ alkali bulrush	16	7
Low Marsh	Cord grass/ tules	37	14
Mudflat	Tules in upper portion	21	N/A
Subtidal		9	N/A
Mudflat/ Subtidal/Bare ground	N/A	N/A	42.5
TOTAL		100	100

Table 2: Vegetation percent over of the entire site for ground sampling (Caltrans, 1999, 2002).

Because the data provided by Caltrans was not categorized by habitat type, the vegetation data was not comparable to the success criteria, and reinterpretation was necessary. Using the habitat types boundary map and the raw data for each vegetation sample point, the existing raw was regrouped in more relevant values to the success criteria. This data is shown in Table 3.

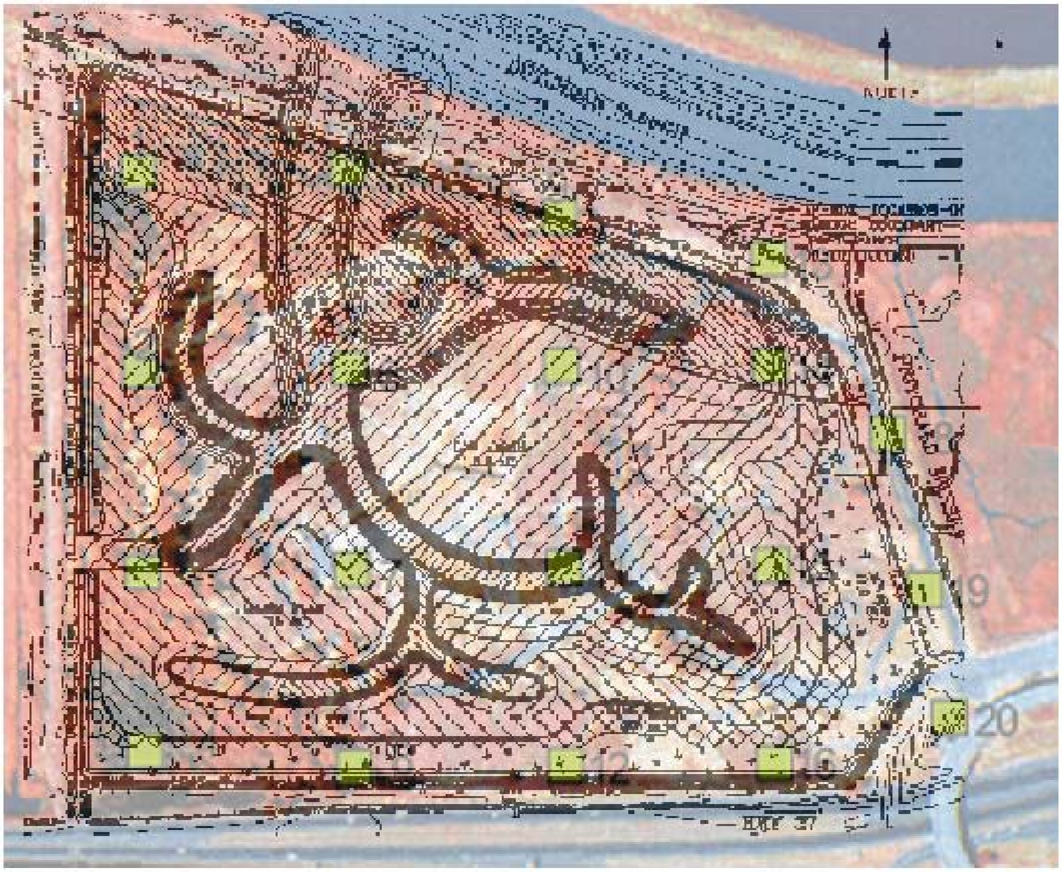

Figure 6: Habitat type overlaid upon vegetation sampling points.

Ground Sampling Data			Success Criteria	
Habitat Type	**1999 Spring Cover**	**2002 Spring Cover**	**Year 5**	**Year 7**
Upland	36%	80%	90% cover	90% cover
High Marsh	36%	75%	50% cover	75% cover of reference area
Marsh Plain	85.70%	45%	35% cover	75% cover of reference area
Low Marsh	77.50%	20%	50% stem density	90% stem density of reference area

Table 3: Reinterpreted ground sampling data compared to success criteria.

The vegetation coverage compared to the success criteria in Table 3 shows that high marsh and marsh plain areas have exceeded expectations, while upland and low marsh are deficient.

Aerial Photography and GIS The data derived from aerial photographs and GIS analysis is summarized in Table 4. This data describes the cover type and percent coverage of the entire site pre and post mitigation. This data, similar to the data from Table 2, is not comparable to the success criteria.

Aerial Photography Data	Spring 1999	Spring 2002
Cover Type	**Percent of site**	**Percent of site**
Grassland/ Mediterranean Barley/ Wild oats	47	4
Pickleweed/ Mixed Halophytes	32	10
Exotic/ Sweet Fennel	16	16
Cord grass	5	20
Bare Ground	0	50
TOTAL	100	100

Table 4: Vegetation percent coverage over the entire site from aerial photography.

Overlaying the habitat type boundary map over the aerial photographs and using GIS analysis yields the percent cover in each habitat type. The results are summarized in Table 5. This table compares the percent cover of vegetation with the success critera.

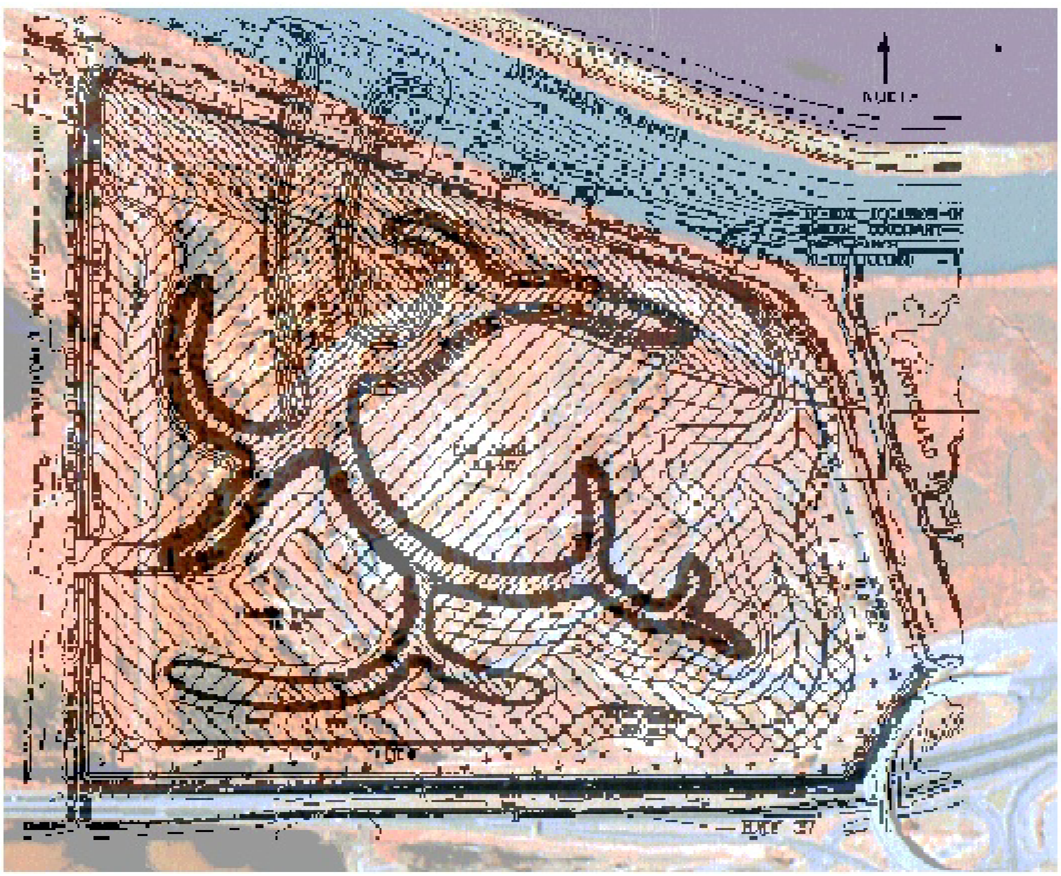

Figure 7: Habitat type map overlaid upon spring 1999 aerial photograph.

Aerial Photography Data			Success Criteria	
Habitat Type	1999 Spring Cover	2002 Spring Cover	Year 5	Year 7
Upland	23%	20%	90% cover	90% cover
High Marsh	18%	15%	50% cover	75% cover of reference area
Marsh Plain	89%	36%	35% cover	75% cover of reference area
Low Marsh	70%	80%	50% stem density	90% stem density of reference area

Table 5: Vegetation percent coverage by habitat types compared to success criteria for aerial photography.

The data in Table 5 shows that three habitat types do not meet the success criteria. They are upland, high marsh and marsh plain. However low marsh exceeds the success criteria.

Comparison The results from ground sampling and the results from aerial photography portray different results as illustrated in the Figure 8.

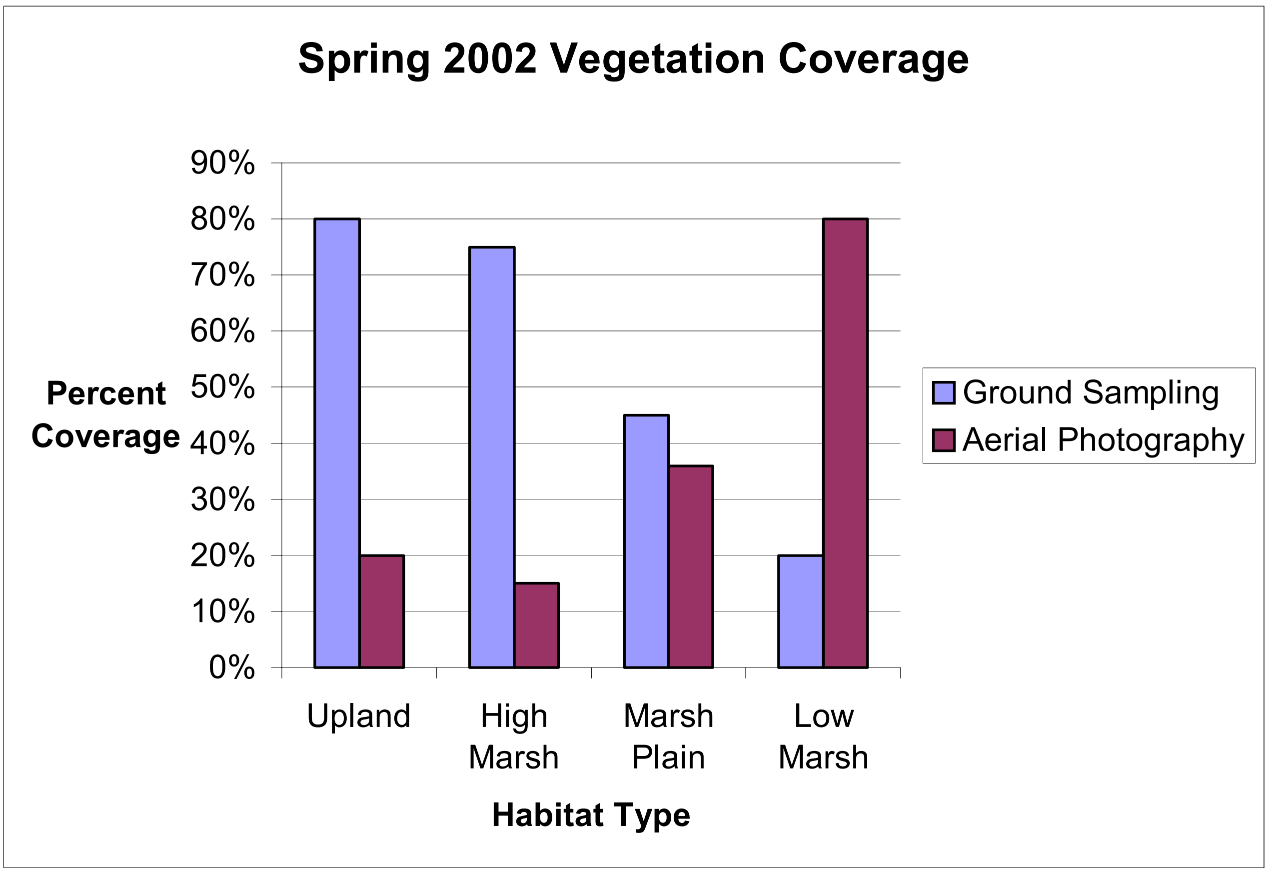

Figure 8: Spring 2002 vegetation coverage discrepancy between ground sampling and aerial photography.

Discussion

According to the data generated by Caltrans' current vegetation assessment method, the high marsh and marsh plain habitat types of the Guadalcanal Village wetland site meet the success criteria while the other two habitat types are slightly deficient. Since the wetland is about three years old now, even the deficient habitat types are doing fairly well. It can be concluded from the ground sampling data that Guadalcanal Village is in fact meeting its success criteria. However according to the data generated from aerial photography and GIS analysis, the vegetation on the wetland site is doing poorly. The only habitat type that is meeting the success criteria is the low marsh. This is completely contradictory to the ground sampling data.

In a side-by-side comparison of ground sampling and aerial photography as a method of vegetation assessment, each has its advantages and disadvantages. Ground sampling is widely regarded as accurate and has been the norm in wetland health assessment. Using ground sampling, there is greater resolution in species composition. However, the accuracy of this method is in question due to the assumption that the 15 meter transect assumes homogeneity across a 125m x 125m square. The labor intensiveness of this method as well as the time required poses other

The advantages to using aerial photography as a vegetation assessment method are that it is a quick and rough sketch of the vegetation. This method is easy to focus on the different habitat types of the wetland site. As well as being less labor intensive than the ground sampling method. A disadvantage is cost. Although cost is not a factor in this study, it is important to note that the ease and reduced time allocation is offset by the high cost of aerial photography flights. Many times though, aerial photography flights are done for hydrological and topological purposes and in these cases cost may not be an issue.

The results show that there is a discrepancy not only in vegetation coverage but also the amount of bare ground. There is more bare ground accounted for in aerial photography than in ground sampling. This could be due to the fact that with aerial photography there is a limit to the resolution and the vegetative covering did not register. While ground sampling can take into account budding or small vegetation

Other possibilities that explain large discrepancy in the vegetation cover results could be the confidence in the data generated. There was no statistical analysis performed on the data, therefore no confidence levels and error values were generated. Also, there is a large potential for error in both the ground sampling and the aerial photography methodologies because habitat boundary overlays were not exact.

Due to the large discrepancy between the ground sampling results, the more traditional and widely accepted method, and aerial photography, a possible conclusion is that aerial photography is not a valid method of vegetation assessment. However, because of other similar research, the case for the usage of aerial photography for vegetation assessment is strong. Thus, there is also a possibility that the methodology employed with the aerial photography was somehow flawed. While this is a possibility, it is highly doubtful due to a site visit and even just naked eye viewing of the aerial photography. It is a stretch to assume that upland is 80% covered as the ground sampling data suggests.

There is a possibility that the ground sampling method is also flawed or not representative of the vegetation cover. As mentioned above, the ground sampling method uses a 15m line transect in a random direction in the middle of a 125m x 125m square. Homogeneity is then assumed for the entire 15625m^2 area. This is small sample size to be assumed for the entire area. Also, the random direction chosen for the line transect might not be so random due to human error. Subconsciously, one might perform a line transect in the direction where all the vegetation is located.

Conclusion The existing ground sampling data suggests that the reclaimed Guadalcanal Village wetland site meets the success criteria established in 1995 by Caltrans. However, aerial photography and GIS analysis data suggests that this same wetland, Guadalcanal Village, does not meet the success criteria. The usage of aerial photography and GIS analysis also needs to be further explored and modified if it is to become a viable method in assessing wetland health through vegetation. Because there are advantages and disadvantages to both methods, it would be valuable to explore efficient ways to use both vegetation assessment methods in conjunction in order to maximize the advantages.

This study had many problems as well as limitations. The ground sampling data was not comparable to the success criteria; therefore it had to be reinterpreted using overlay of the habitat type map. This led to more sources of errors in the ground sampling data. With aerial photography and GIS analysis, there were many issues surrounding alignment of overlays as well as technical difficulties where the computer or program would crash.

The limitations of this study includes that it is a one-site case study. Also, this wetland site is relatively young at three years of age; this wetland might still be in a state of flux as it approaches its maturity at seven years. Additional site visits while conducting the aerial photography and GIS analysis would have been beneficial to the study. For further research is suggested that more site visits be incorporated into the aerial photography and GIS analysis methodology. Also, a methodology combining both methods would be valuable to explore

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