# Analysis of Conditions in Vegetation Parcel Blackrock 94

Staff Report Prepared by the
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## Executive Summary

In July 2007, the Technical Group received a letter from the California Native Plant Society (CNPS) stating that vegetation degradation was proceeding rapidly in vegetation parcel Blackrock 94 in the Thibaut-Sawmill wellfield. Based on an examination of vegetation and hydrologic data, the CNPS concluded that serious negative trends in ecosystem condition are occurring at Blackrock 94. The CNPS consequently recommended that pumping management in the area be altered to avoid an impact by reducing groundwater pumping at the Blackrock Fish Hatchery from its present level of about 12,000 acre-feet per year to 8,000 acre-feet per year. In response to this letter, the Technical Group agreed to examine the issue based on the Inyo-Los Angeles Long-Term Water Agreement's (LTWA) provisions for determination of a significant effect on the environment. The LTWA provides a three-step evaluation for determining whether an effect is significant. First, the effect must be measurable. Second, if an effect is measurable, its causes are evaluated as to whether the effect is attributable to LADWP groundwater pumping and/or a change in past surface water management practices. Third, if the effect is due to groundwater pumping and/or a change in past surface water management practices, its degree of significance is evaluated. This report is the Water Department's examination of whether a significant effect has occurred or is occurring in parcel Blackrock 94. This report evaluates conditions in Blackrock 94 according to the LTWA's three-step process for assessing measurability, attributability, and significance of change in the parcel.

This report focuses on evaluation of physical factors relevant to vegetation in the parcel: what are the conditions in the parcel, what has changed since the baseline vegetation mapping was done in 1986, what are probable causes of changes, what is the magnitude of change, and how changes in Blackrock 94 compare to other areas.

*Measurability of vegetation change*. Numerous sources of data, each of differing complexity and scale, were examined to assess whether a change in vegetation in Blackrock 94 can be detected: photo points at permanent transects, vegetation cover and composition from permanent transects, vegetation cover and composition measured at randomly located transects from 1991-2009 measured by Water Department staff, vegetation cover and composition measured at randomly located transects from 2004-2009 measured by LADWP and their consultants, and vegetation cover derived from satellite imagery. These multiple lines of evidence showed decreased live vegetation cover compared with baseline in 14 of 19 of years since 1991 and a decrease in grasses resulting in increased proportion of shrubs. These apparent changes in Blackrock 94 can be readily distinguished from conditions at a nearby permanent transect and vegetation parcel that experienced less severe water table decline, Blackrock 99. The Green Book requires that any small documentable changes in cover or composition be considered a measurable change. The analysis presented here meets that criterion; therefore, we conclude there has been a measurable change in vegetation condition in Blackrock 94.

*Attributability of vegetation change to water management*. The causes of the measurable vegetation change were assessed by examining the timing of vegetation changes in relationship to surface and groundwater management activities that could cause vegetation changes, primarily groundwater pumping and surface water use in the vicinity of Blackrock 94. Specific factors evaluated were groundwater pumping from wells at the Blackrock Fish Hatchery, groundwater pumping from other wells in the vicinity of the parcel, precipitation, surface water diversions and water spreading, shallow groundwater levels, and soil moisture storage in the plant root zone. To assess the relationship between vegetation cover and hydrology, vegetation cover derived from ground-based measurements was regressed against depth to water, and vegetation cover derived from satellite imagery was regressed against depth to water. To determine the relationship between community composition and hydrology, an ordination of vegetation community composition was regressed against depth to water and precipitation. The US Geological Survey groundwater model for Owens Valley was used to evaluate the causes of water table fluctuations at Blackrock 94. Factors not attributable to LADWP water management, such as precipitation, fire, grazing, were considered as well. Parcel Blackrock 99 is adjacent to Blackrock 94, but did not undergo vegetation or water table declines similar to Blackrock 94. Since precipitation was similar in these neighboring parcels, it is concluded that precipitation variability is not the cause of vegetation decreases and changes in Blackrock 94. Observations following the July 2007 fire which burned part of Blackrock 94 and most of Blackrock 99 indicate that grass recovered quickly and completely in areas where the grass root zone is replenished by groundwater, but recovery was slow or nonexistent in areas where the water table is too deep to replenish the root zone. No grazing information was available to the Water Department. These data and analyses indicate that:

- Groundwater pumping and episodic surface water spreading affect the water table at Blackrock 94. Pumping from wells at the Blackrock Fish Hatchery and other wells in Thibaut-Sawmill and Taboose-Aberdeen wellfields have affected the parcel. Surface water diversions to supply Eight-Mile Ranch and water spreading from Sawmill and Thibaut Creeks during high runoff have affected the parcel.

- Pumping induced declines in the water table correspond to decreased grass cover in Blackrock 94 where pumping has withdrawn the water table from the grass root zone. Groundwater depth is significantly (negatively) correlated with vegetation cover and composition in Blackrock 94.

- The effect of pumping on the water table is far greater than the effect of fluctuations in recharge.

- The earliest soil water measurements show that at two sites in Blackrock 94 the soil was dry by the early 1990's. Soil water at one site was replenished below about 2 m depth when the water table rose in the late 1990's. The soil at the other site remains dry, and the water level is still too deep to replenish soil water.

- There has been a statistically significant shift in vegetation from a grass dominated toward a shrub-dominated community.

- Comparison with a nearby parcel, Blackrock 99, which did not experience as severe and persistent water table, soil water, and vegetation decline indicate water table change is the primary driver of vegetation change in Blackrock 94.

- Because of their proximity, precipitation is similar in Blackrock 94 and 99. Contrasting changes in cover and composition between Blackrock 94 and 99 that are driven by precipitation and groundwater must be a result of fluctuations in DTW because precipitation is similar in the two parcels.

- Periodic fire is beneficial for grass-dominated communities where the water table is shallow enough to replenish the grass root zone. Areas where the water table is not accessible to the root zone will endure slower recovery and be prone to weed encroachment.

- Uncertainty exists as to the accuracy of the various sources of vegetation information, groundwater model results, and the degree to which baseline conditions were a result of water spreading within the parcel.

*Significance of impact*. The LTWA provides that the significance of an impact will be assessed by looking at a number of factors, listed below:

- <u>Size, location, and use of affected area.</u> The size of Blackrock 94 is 333 acres, it is within the Thibaut-Sawmill wellfield, seasonally grazed, recently partially burned, and traversed by US Highway 395. Impacts of this scale were deemed significant in the FEIR for the Water Agreement.

- <u>Degree of change in affected area.</u> Vegetation change in the parcel is measurable, constituting a decrease in vegetation cover of approximately one-third compared to baseline, and a statistically significant trend of increasing shrub proportion is present.

- <u>Permanency of change.</u> According to annual field measurements, vegetation cover has been statistically significantly below baseline levels 14 of 19 years over the period 1991-2009. According to cover measurements derived from satellite images, vegetation cover has been below baseline for all years since baseline surveys were done in 1986. The trend toward loss of grass cover and shrub encroachment may be reversible with a combination of fire to remove shrubs and water table conditions sufficiently high to provide water to the grass root zone.

- <u>Air quality.</u> There are no air quality data for Blackrock 94.

- <u>Affects on human health.</u> There is no indication that conditions in Blackrock 94 are affecting human health.

- <u>Cumulative impact.</u> A preliminary evaluation comparing vegetation cover in parcels potentially affected by pumping, or wellfield parcels, to parcels unaffected by pumping, or control parcels, shows that vegetation in wellfield parcels is generally below baseline measurements while cover in control parcels is generally above baseline cover. Wellfield parcel cover is negatively correlated with changes in DTW while control parcel cover is unaffected; indicating that groundwater management adversely affected wellfield parcels. Although this report does not exhaustively examine cumulative impacts, these results indicate that the decreases and changes documented here are not occurring in isolation.

- <u>Value of existing mitigation.</u> No specific mitigation project was identified in the 1991 FEIR for impacts to Blackrock 94. The 1991 FEIR identifies the LTWA's process for evaluating the measurability, attributability, and significance as the means of providing mitigation for impacts occurring under LTWA management.

- <u>Species of concern.</u> A stressed *Calochortus excavatus* population is located at TS2, but changes in this population have been erratic and appear associated with precipitation.

While the declaration of a significant impact is necessarily a subjective assessment, the LTWA provides a number of factors – some quantitative, some not - to evaluate when assessing the significance of an impact. Several of these factors indicate that a significant change is occurring in Blackrock 94 – the areal extent of the parcel is significant; the degree is important, change is persistent in time, and the impact to the parcel has not been mitigated**.** The significance of other factors such as human health effects, air quality impact, rare plants, and cumulative impacts are unknown or inconclusive.

*Conclusion.* The Water Department has evaluated conditions in vegetation parcel Blackrock 94 in accordance with the LTWA Section IV.B and Green Book Section I.C. Available factual and scientific data indicate a measurable vegetation change since baseline has occurred in Blackrock 94, both in terms of vegetation cover and species composition. These changes occurred between baseline and 1991 and have persisted in time. Vegetation composition has changed toward increasing shrub proportion and a decrease in grass cover. While the proportion of shrubs in Blackrock 94 has not yet caused the parcel to change from Type C to Type B vegetation, changes in species composition for perennial species suggest a change in Type is occurring. Parcel Blackrock 94 is currently Type C, but is changing to Type B. Vegetation decrease and change is primarily attributable to changes in water availability resulting from groundwater pumping and reduced surface water diversions into the vicinity of Blackrock 94. The factors prescribed in the LTWA and Green Book for assessing the significance of an impact were evaluated and indicate that a significant change is occurring in Blackrock 94. The terms of the LTWA require that such impacts be avoided or mitigated.

## Introduction

In July 2007, the Technical Group received a letter from the California Native Plant Society (CNPS) stating that vegetation degradation was proceeding rapidly in vegetation parcel Blackrock 94 in the Thibaut-Sawmill wellfield. Based on an examination of relevant vegetation and hydrologic data, the CNPS concluded that serious negative trends in ecosystem condition are occurring at Blackrock 94 and recommended that pumping management in the area be altered to avoid an impact.

The overall goal for managing the water resources within Inyo County under the Inyo/Los Angeles Long Term Water Agreement (LTWA) is to avoid certain described decreases and changes in vegetation and to cause no significant effect on the environment which cannot be acceptably mitigated while providing a reliable supply of water for export to Los Angeles and for use in Inyo County (LTWA Section III.A). More specifically, groundwater pumping and surface water will be managed: (1) to avoid causing significant decreases in live vegetation cover from conditions documented on maps based on vegetation measurements made in 1984 to 1987, (2) to avoid causing a significant amount of vegetation mapped and classified as Type B, C, or D to change to vegetation in a classification type which precedes it alphabetically, (3) to avoid causing other significant effects on the environment; and (4) in a manner consistent with State and Federal laws pertaining to rare and endangered species (Green Book, Section I.C.). Each LTWA baseline vegetation class, A, B, C, D, and E, is comprised of several vegetation communities defined in the Land Classification and Natural Community Descriptions for the Owens Valley (1987). Blackrock 94 is a 333 acre groundwater-dependent alkali meadow parcel located southwest of the Blackrock fish hatchery (Figure 1). Most meadows including Blackrock 94 were mapped and classified as Type C alkali meadow during the LTWA baseline vegetation inventory.

Methods to achieve the LTWA goals include monitoring, discretion vested in the Technical Group and Standing Committee to take actions to avoid or mitigate adverse impacts, provisions for automatic turning off wells, provisions for determining whether significant decreases or changes have occurred, and provisions for mitigation and dispute resolution (LTWA, Section II.A). Section I.C of the Green Book prescribes the process the Technical Group will follow to determine whether decreases and/or changes in the vegetation or other significant effects on the environment have occurred or are occurring in a given management area and to ascertain whether a change is significant and whether mitigation is necessary. To determine if a significant effect has occurred or is occurring, the Technical Group first shall evaluate the measurability of the effect; if the effect is measurable, the cause shall be evaluated; if the effect is attributable to LADWP water management, the significance of the effect will then be assessed. This report examines conditions in Blackrock 94 according to this three-step process.

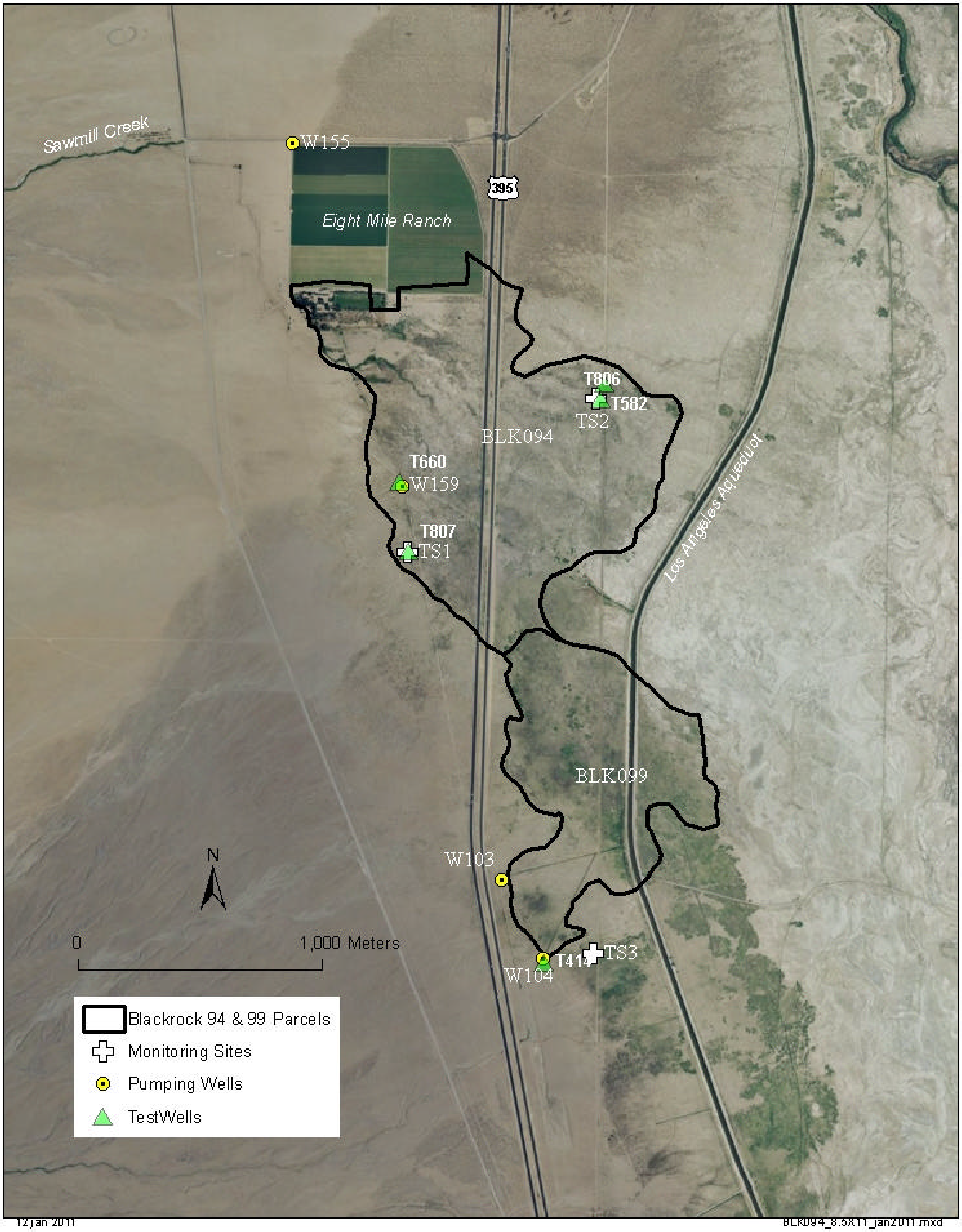



Figure 1. Map of the area surrounding vegetation parcel Blackrock 94 (BLK094) in the Thibaut-Sawmill wellfield.

## Measurability

The Green Book (Section I.C.1.a.) lists several factors and analyses that may be relevant to assess whether a measurable change has occurred or is occurring. The Green Book standard is that a determination of measurability will be made if any of the relevant factors considered indicate even a small change. Accordingly, multiple sets of monitoring results are presented in this report to assess whether a measurable change or decrease in vegetation has occurred or is occurring in Blackrock 94. Pertinent data include visual observations, monitoring data at permanent transects, parcel-scale vegetation monitoring, and remote sensing data.

### Vegetation cover and composition evaluation

Vegetation cover

Vegetation cover data are collected each year by Inyo County at permanent transects and at randomly located transects throughout the vegetation parcel. Field methods used for these monitoring programs are described in the Green Book and previous Inyo County reports (Manning, 1994; Manning 1997). Results of a LADWP monitoring program initiated in 2004 to assess vegetation conditions are also included in this report.

*Permanent transects*

Blackrock 94 contains two permanent transect monitoring sites, TS1 and TS2. Because only a single transect is completed at each site, it is not possible to infer parcel-level trends or to make a comparison with the LTWA baseline based solely on the monitoring site transect data. Factors such as elevation, depth to water, and soil type change across the parcel, and a single transect is not representative of the average or overall condition of the parcel. Additionally, observations at permanent monitoring sites may differ from the remainder of the parcel because cattle have been excluded from these transects since 1988 (except for intermittent periods when fences were down) while the remainder of the parcel has been grazed. Nevertheless, the examination of data collected along these transects is informative if due caution is exercised when interpreting the data.

Each year, the midsummer vegetation cover, leaf area index, and species composition are measured along the permanent transect using the point frame method (Green Book Sec. II, and references therein). The initial point frame data showed that species composition at TS1 and TS2 were similar; both transects were dominated by grass species (Figure 2). Cover has been less than the initial measurement at both transects every year except for three years at TS1 when a section of the transect was affected by water spreading. Between 1988 and 2009 grass cover decreased and shrub cover increased such that shrubs or weedy species were dominant at both sites.

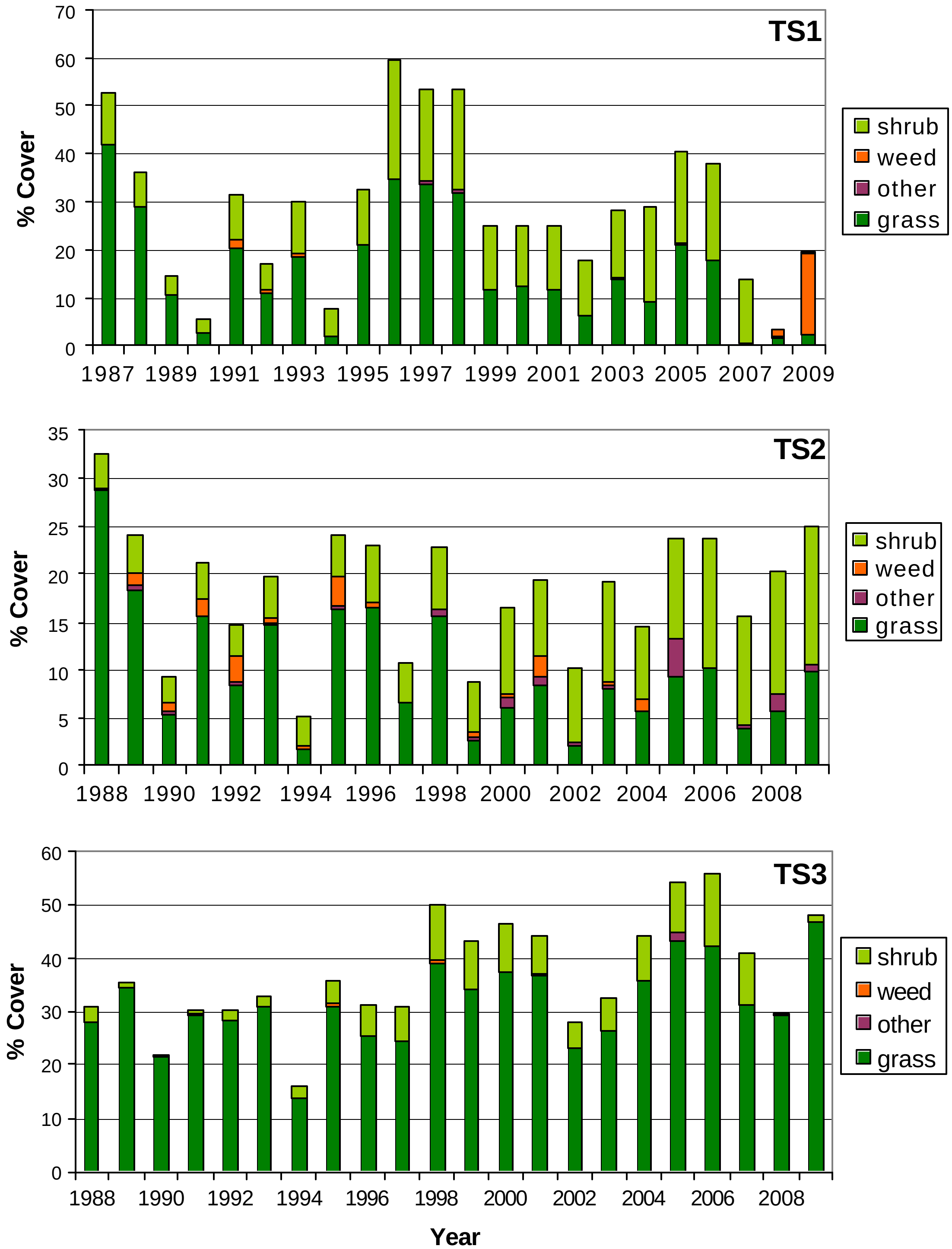



Figure 2. Vegetation cover by life form at TS1, TS2, and TS3 permanent transects. Wildfire burned the permanent monitoring sites TS1 and TS3 in Blackrock 94 in 2007 after these data were collected.

*Green Book Reinventory*

Vegetation cover data were collected at multiple randomly located transects within vegetation parcels to monitor parcel-scale vegetation change. The Green Book requires that vegetation monitoring be conducted to determine whether vegetation cover and composition have decreased or changed significantly due to affects of groundwater pumping (Green Book, Box I.C.1.a.ii.). Conditions documented during the baseline inventory completed between 1984-87 are the basis for comparison with subsequent years. According to the Green Book (Section II.A.1), the baseline inventory was conducted in the Blackrock area sometime during the first half of the growing season, March to June 1986, but the exact date Blackrock 94 was sampled is not known. The locations of the nine sampling transects completed in this parcel during the baseline inventory were not recorded; therefore, the exact transect locations cannot be revisited in later years. The sampling design of the Green Book monitoring program employs a widely used and standard sampling technique (Green Book, Box I.C.1.a.ii) and provides a valid sample of species cover and composition for the parcel for each year to compare with baseline values using statistical techniques.

Statistical tests are used to quantify whether differences between datasets are measureable. This is determined by calculating the probability that a difference between datasets is just due to chance. A low probability ($P$) suggests that the data being compared are very likely different. The threshold for statistical significance is selected by the analyst and is typically $P < 0.05$, meaning that there is only a 5% likelihood that the observed result is due to chance alone. The terms "statistically significant" or "significantly different" in this discussion pertain to the measurability of a change from baseline and are distinct from the assessment of whether a measureable change is environmentally significant or important.

Perennial species cover in Blackrock 94 has been monitored annually each summer from 1991 through 2009. Annual measurements of perennial cover were compared with the baseline data using a permutational Analysis of Variance, ANOVA (Anderson, 2001), which is robust to deviations from normality and less sensitive to equality of variance than traditional parametric tests, such as a parametric ANOVA or multiple t-tests. It is a robust non-parametric statistical tool that allows partitioning of variance similar to a traditional parametric Analysis of Variance (Anderson, 2001) using the program *NPMANOVA* (Anderson, 2005). It yields a 'pseudo' f-value (or t-value for pairwise comparisons) and an associated probability is generated using permutations of the data.

Baseline perennial cover for Blackrock 94 was 40.8% and was comprised primarily of native grass species (Figure 3a). Perennial cover has been statistically ($P \leq 0.05$) below baseline for 14 of 19 years since 1991 (1991-1996 and 2001-2008). Perennial cover was not statistically different from baseline for only five years (1997-2000). The 2007 reinventory data were collected before a fire burned a large part of the parcel in July, and potential influence from this fire is discussed in the 'Role of Other Factors' section below.

*LADWP Reinventory*

LADWP began a monitoring program in 2004 to assess conditions in the vegetation parcels. Inyo County obtained the LADWP data and a brief description of their sampling design and field procedures in 2010. LADWP stated their transect locations were selected randomly, but a written protocol for generating start points has not been provided. The same transect locations are revisited each year (within the accuracy of the GPS units used for navigation). In contrast, the Green Book reinventory randomly selects new transects each year. There are advantages and disadvantages of each procedure. LADWP field methods may also differ from Green Book reinventory methods. Because specifics of the baseline inventory methods are unavailable in the form of a written protocol, it is not possible to conclude which monitoring program provides a more valid comparison with baseline. Therefore, this report considers all data collected by the Green book reinventory as well as data collected by LADWP using the same statistical techniques.

Results of LADWP monitoring from 2004-2009 were similar to the Green Book results; perennial vegetation cover in Blackrock 94 has been lower than baseline measurements in all years inventoried, and statistically lower in three of six years ($P \leq 0.05$, Figure 3b).

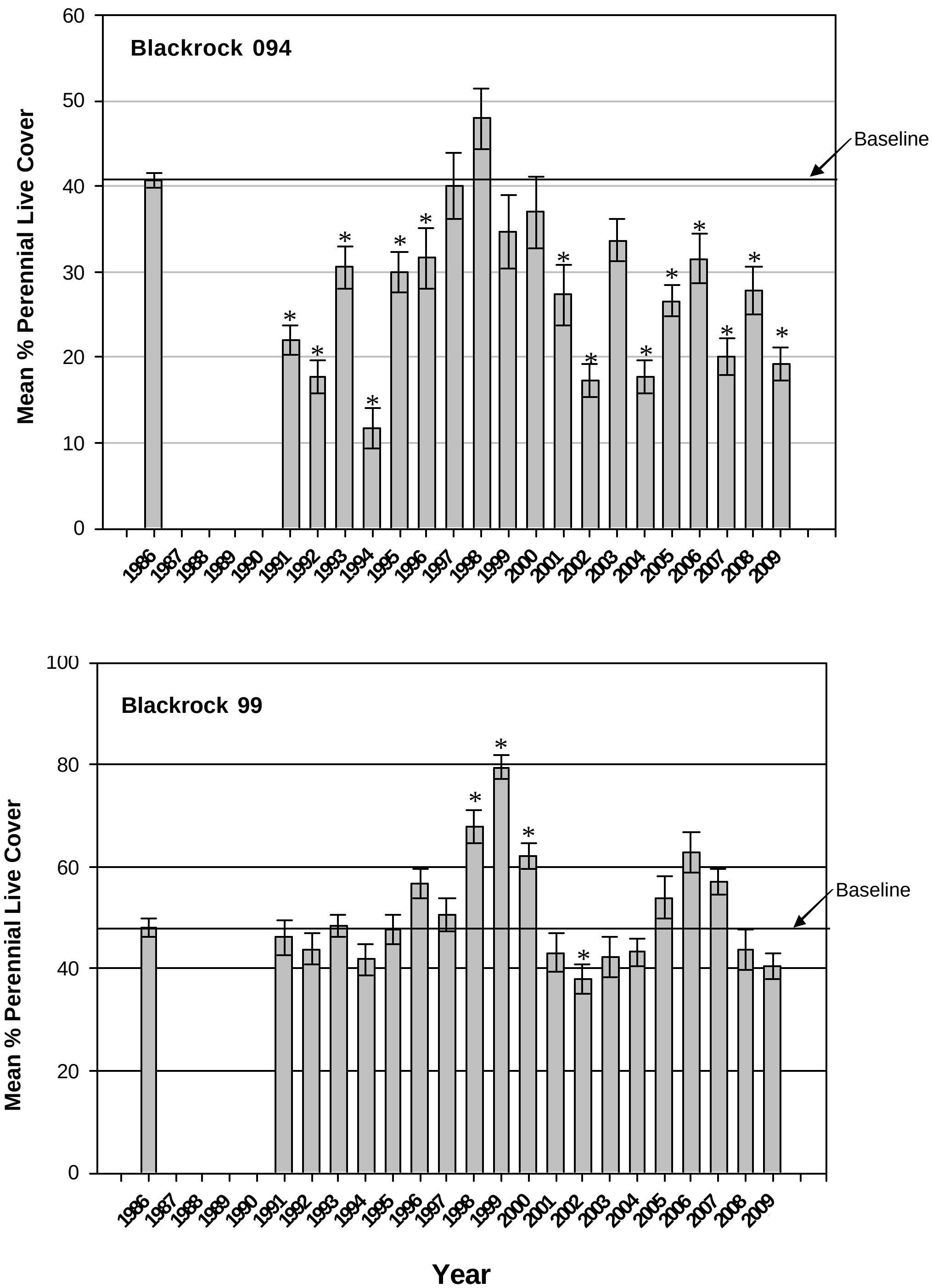



Figure 3a. Perennial cover measured in Blackrock 94 and Blackrock 99 by the Green Book line point monitoring program. Asterisks denote years where cover is statistically different from baseline ($P \leq 0.05$) using a permutational ANOVA. Horizontal line denotes baseline perennial cover.

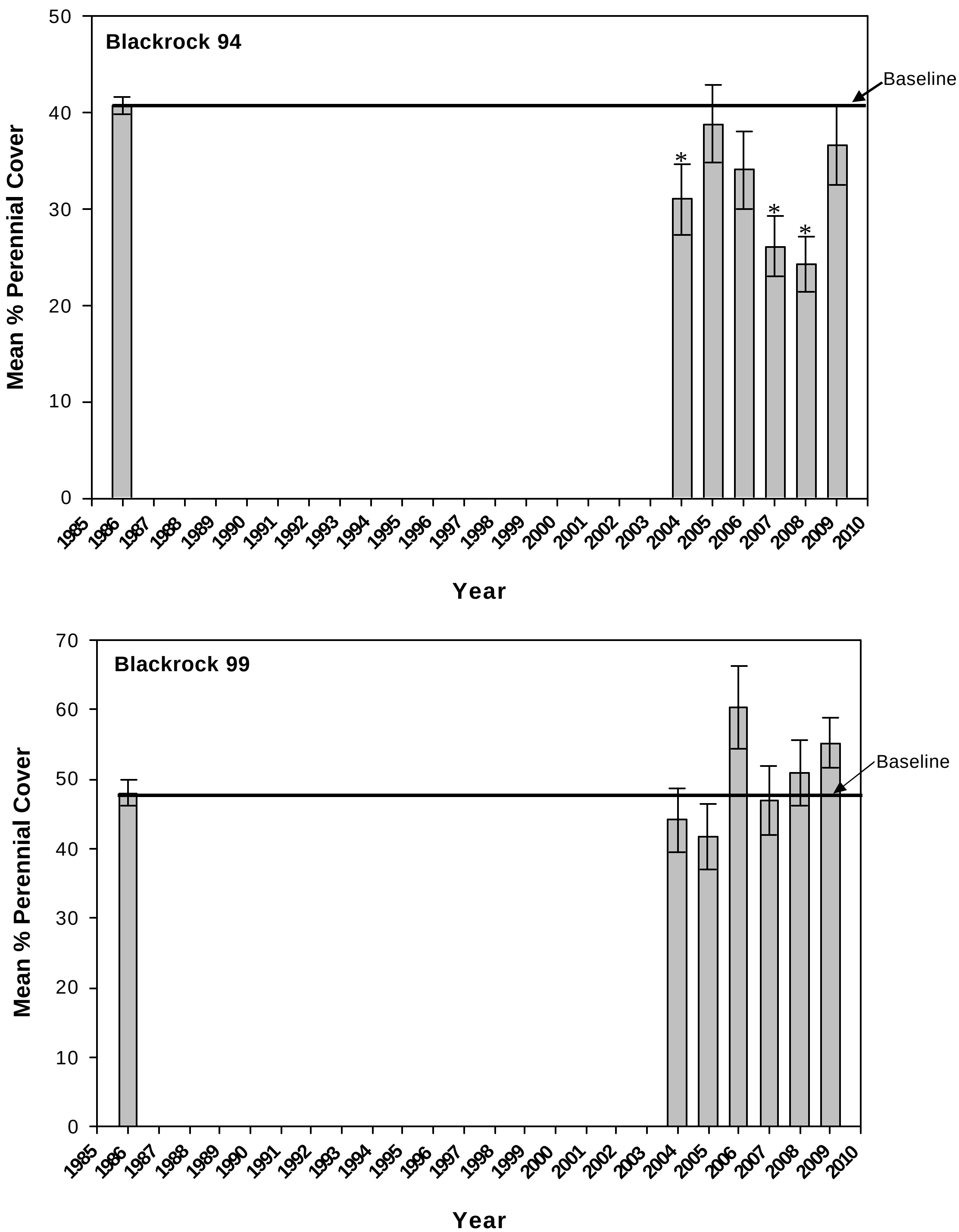



Figure 3b. Perennial cover measured in Blackrock 94 and Blackrock 99 by LADWP. Asterisks denote years where cover is statistically different from baseline ($P \leq 0.05$) using a permutational ANOVA. Horizontal line denotes baseline perennial cover. Error bars represent standard error of means.

Vegetation composition

Each year, approximately in mid summer, photos are taken from fixed end points on each permanent transect. Monitoring began at TS1 in 1987 and in 1988 at TS2. Paired photos from these transects taken in 1988 and 2007 are presented in Figures 4a and b (2008 monitoring occurred after the fire at TS1). An increase in shrubs and decrease in grass cover is evident at TS1 and TS2 from the photo comparison. Reliance on photo points is a valid monitoring technique, but they are not quantitative evidence for vegetation change. Quantitative monitoring results are discussed below.

Conversion from type C meadow to type B scrub is contrary to the LTWA goals and is therefore included in this analysis. Manning (2006) analyzed the raw baseline inventory data to determine a quantitative threshold between Type C and B vegetation classes. Using total cover rather than sum of grass and shrub cover provided a similar result, and was used in this report. In the LTWA baseline, parcels were classified as Type B when shrubs comprised 0.8 or more of the existing vegetation:

$$\frac{\text{shrub cover}}{(\text{total perennial cover})} \geq 0.8 \tag{1}$$

where all cover values are in percent. In the 1986 baseline inventory, the shrub proportion for Blackrock 94 was 0.26.

Shrub proportion in the first year of the reinventory, 1991, was nearly equal to the baseline value of 0.26. Shrub proportion has been gradually increasing from 1991 through 2009 ($r^2 = 0.675$, $P < 0.0001$, Figure 5a). During the same time period, grass proportion has been measurably decreasing ($r^2 = 0.62$, $P < 0.0001$, Figure 5b, and Figure 6). Both trends were statistically significant. The 2006 and 2007 reinventory data show Blackrock 94 shrub proportion reaches a high of 0.56 during the re-inventory period, and the 2009 data show a shrub proportion of 0.43, slightly lower due to the 2007 fire. Vegetation recovery following the fire is discussed below in the 'Role of Other Factors' section. The proportion of shrubs has therefore nearly doubled in Blackrock 94 over the 19 years of reinventory sampling. This change in proportion of shrub cover can be attributed to some combination of an increase in shrubs and a decrease in grasses. There has been little overall change in shrub cover between 1986 and 2007 (10.6% in 1986 vs. 8.3% in 2009). Rather, the large decrease in grass cover (29% in 1986 compared to 10% in 2009) accounts for much of the changing proportion of shrubs. Blackrock 94 shrub proportion has not crossed the 0.8 threshold, but this analysis demonstrates that the parcel was trending in that direction under the prevailing management before the fire in 2007, and this condition persists.


Figure 4a. Paired midsummer photos from transect TS1, 1988 and 2007. The 2007 photo was taken pre-fire.


Figure 4b. Paired midsummer photos from transect TS2, 1988 and 2007.


Figure 4c. Paired midsummer photos from transect TS3, 1988 and 2007. The 2007 photo was taken pre-fire.

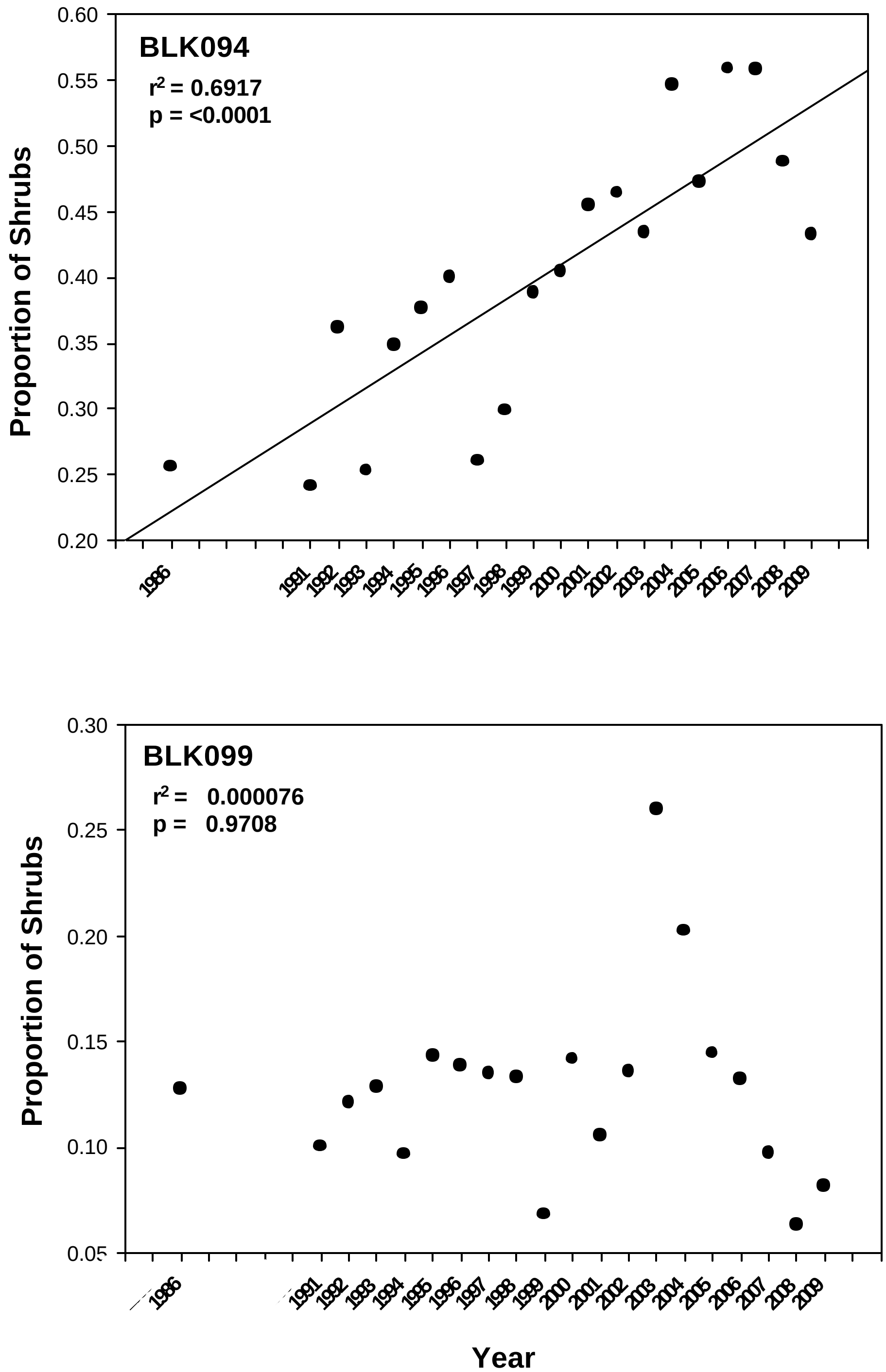
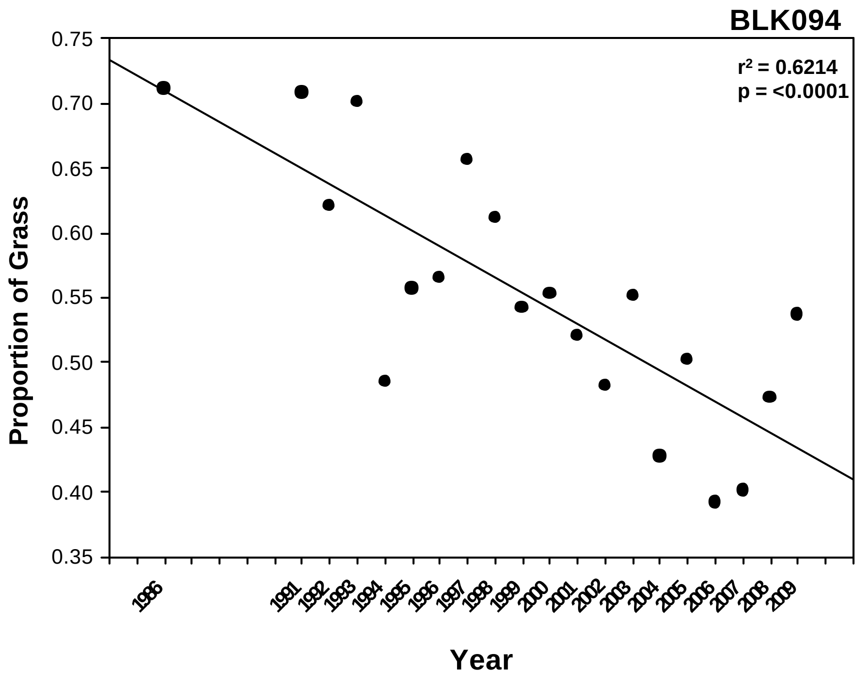



Figure 5a. Shrub proportion in Blackrock 94 (top graph) and 99 (bottom graph) measured by the Green Book line point monitoring program. Proportion of shrubs in Blackrock 94 has measurably increased since baseline (1986), while Blackrock 99 has not changed.



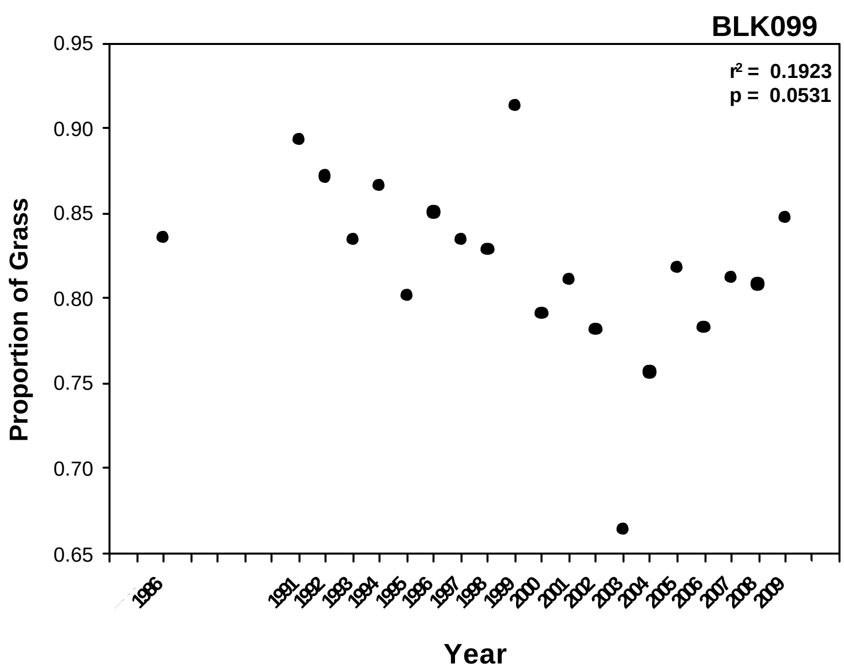
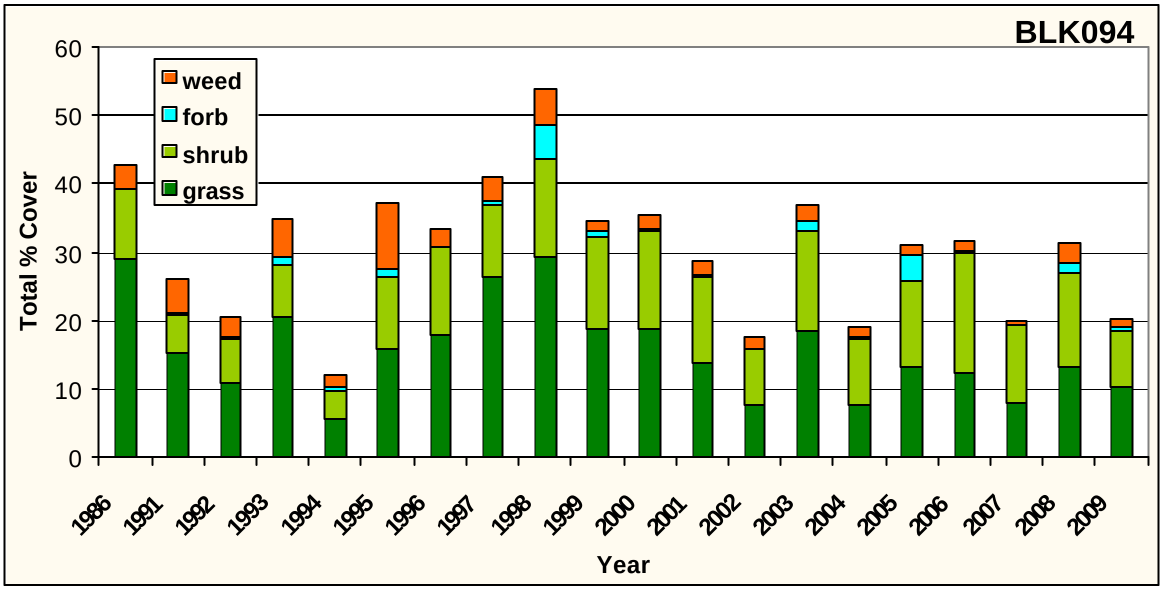




Figure 5b. Proportion of perennial grass in Blackrock 94 (top graph) and 99 (bottom graph) measured by the Green Book line point monitoring program. Grass proportion was calculated similar to shrub proportion in Equation 1. Proportion of grasses in Blackrock 94 has measurably decreased since baseline (1986), while Blackrock 99 has not changed.



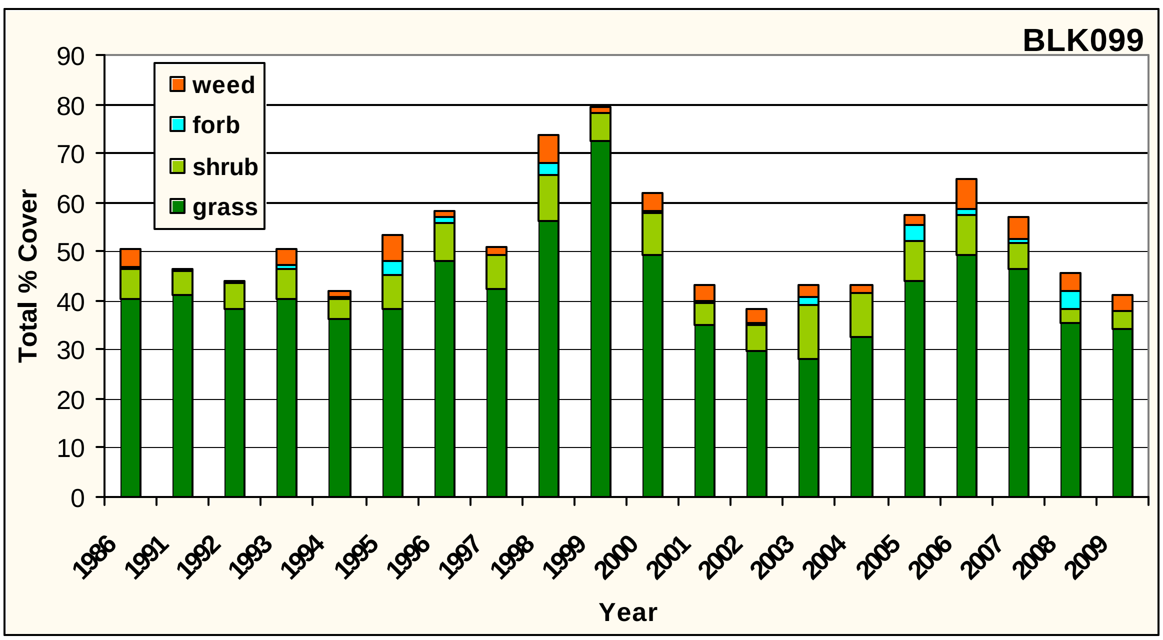




Figure 6. Vegetation cover by life form measured in Blackrock 94 (top graph) and Blackrock 99 (bottom graph) by the Green Book line point monitoring program.

Statistical analysis of species composition is complicated by the potentially large number of interacting variables to be considered (e.g., cover of species, type of species). The combination of ordination and permutational Multivariate Analysis of Variance (PERMANOVA) provide a means to illustrate and test whether statistically significant changes in the vegetation community have occurred. Non-Metric Multidimensional Scaling (NMDS) ordination permits the reduction of a complex multi-dimensional community dataset to a few dimensions by extracting gradients (axes) that explain most of the variability in the data (McCune and Grace 2002). For the case of vegetation community data, it allows visualization of the differences in species composition between transects in a parcel or differences within groups of parcels over time. Environmental variables such as depth to water estimates can be plotted on the ordination graph to show the association of the variable with the pattern of observed community composition. PERMANOVA is free from many of the formal assumptions of parametric statistical methods and therefore, is more appropriate for non-normal community datasets, which often contain multiple zero values (Anderson, 2001). We used the programs *NPMANOVA* and *PERMDISP* to evaluate statistical significance.

The perennial vegetation community in Blackrock 94 has changed measurably since baseline (*NPMANOVA* overall $P = 0.0002$, *PERMDISP* overall $P = 0.0002$). Each year's transect data from 1986-2009 (excluding 1987-1990) is represented by one point on the ordination diagram (Figure 7a). Years with similar vegetation community composition are located close to one another in the ordination diagram, while years with dissimilar composition are located far apart. In Blackrock 94, the baseline mean is on the edge of the cluster of re-inventory sample means in ordination space, which indicates a change in community composition from baseline. The final ordination represented 60% of the variation in the original distance matrix (Anderson 2001), which accounts for much of the variability in the raw data. Seven of 19 re-inventory years are similar to the baseline period (1995-2000, and 2003; $P = 0.0524$ for all pairwise comparisons, Table 1), while 12 years show a significantly different community composition from baseline ($P \leq 0.0178$ for all pairwise comparisons, Table 1). The change in community type is from a parcel dominated by grasses in 1986 to one dominated by shrubs for most years except 1995-2000 and 2003.

Three species were strongly correlated with ordination axis 1: *Artemisia tridenata, Atriplex lentiformis ssp. torreyi, Distichlis spicata* (r = 0.601, -0.512, and -0.534 respectively), while four species were strongly correlated with axis 2: *Artemisia tridentata, Distichlis spicata, Juncus balticus, and Sporobolis airoides* (r = 0.399, -0.435, -0.377, and –0.801). Axis 2 displays most of the variability between the baseline and subsequent reinventory years. Perennial grasses and rushes drive the spread of points to the negative end of the axis 2, and were the dominant species sampled during baseline, while shrubs drive the spread of transects to the positive end of the axis. *Sporobolis airoides* is most strongly correlated with axis 2 and is driving a large portion of the difference observed in community composition between baseline and subsequent re-inventory years.

Analysis of data collected by LADWP affirms the results demonstrated using the Green Book data, although the smaller sample size reduces confidence in the results. In Blackrock 94, all reinventory years (2004-2009) maintain a vegetation community composition that is significantly different from baseline. While the overall test is not significant, (*NPMANOVA* overall $P = 0.097$) all pairwise comparisons of the baseline year and all subsequent reinventory years are significant (all pairwise $P < 0.03$, *PERMDISP* overall $P < 0.004$, Figure 7c). All pairwise comparisons of reinventory years are not different from one another ($P > 0.17$). Because all reinventory years are not different from one another, this reduces the overall f-statistic, and increases the overall *P*-value. In addition, the smaller sample size (six reinventory years as opposed to 20 reinventory years) also reduces the power of the overall test to detect differences. Four species were positively correlated with axis 1: *Artemisia tridentata, Atriplex canescens, Ephedra nevadensis, and Psorothamnus polydenius* (r = 0.512, 0.491, 0.514, and 0.522), while three species were negatively correlated with axis 1: *Atriplex lentiformis ssp. torreyi, Distichlis spicata, and Sporobolis airoides* (r = -0.463, -0.468, and -0.587). Five species were positively correlated with axis 2: *Artemisia tridentata, Cynodon dactylon, Carex sp., Rosa woodsii, and Salix exigua* (r = 0.676, 0.555, 0.477, and 0.427), three of which were not recorded in the baseline sampling. Two species were negatively correlated with axis 2: *Atriplex lentiformis ssp. torreyi* and *Sporobolis airoides* (r = -0.521, and -0.327). Perennial grasses and one phreatophytic shrub dominate baseline community composition, while predominantly upland shrubs and an exotic perennial grass dominate the re-inventory community composition.

Three lines of evidence: repeated photo points, changes in shrub proportion over time and multivariate analyses of community composition, all show changes in species composition are occurring. In general, grasses are declining while shrubs are proportionally a greater component of the vegetation community, a trend, which if continued over time, may result in a change in vegetation type contrary with the goals of the LTWA. While the proportion of shrubs in Blackrock 94 has not yet caused the parcel to change to Type B vegetation status, when the entire plant community of 48 perennial species is considered, vegetation community composition has changed since baseline. Parcel Blackrock 94 is currently Type C, but is changing to Type B.

Table 1. Statistical difference in community composition between baseline and each subsequent year of sampling beginning in 1991 for Blackrock 94 using PERMANOVA. Asterisks denote years that were statistically different from baseline; all years except for 7 were statistically significantly different than the baseline sampling.

| Year Comparison | *t* | *P* | |
|---|---|---|---|
| Baseline (1986) vs. 1991 | 1.9802 | 0.0018 | * |
| Baseline (1986) vs. 1992 | 1.9210 | 0.0038 | * |
| Baseline (1986) vs. 1993 | 1.8662 | 0.0126 | * |
| Baseline (1986) vs. 1994 | 2.6945 | 0.0002 | * |
| Baseline (1986) vs. 1995 | 1.1771 | 0.2196 | |
| Baseline (1986) vs. 1996 | 1.1457 | 0.2474 | |
| Baseline (1986) vs. 1997 | 0.9042 | 0.5624 | |
| Baseline (1986) vs. 1998 | 1.2210 | 0.1878 | |
| Baseline (1986) vs. 1999 | 1.3955 | 0.0840 | |
| Baseline (1986) vs. 2000 | 1.5518 | 0.0524 | |
| Baseline (1986) vs. 2001 | 1.9210 | 0.0060 | * |
| Baseline (1986) vs. 2002 | 2.3175 | 0.0008 | * |
| Baseline (1986) vs. 2003 | 1.5113 | 0.0656 | |
| Baseline (1986) vs. 2004 | 1.9596 | 0.0034 | * |
| Baseline (1986) vs. 2005 | 1.8941 | 0.0178 | * |
| Baseline (1986) vs. 2006 | 1.9173 | 0.0110 | * |
| Baseline (1986) vs. 2007 | 2.2666 | 0.0040 | * |
| Baseline (1986) vs. 2008 | 1.8640 | 0.0098 | * |
| Baseline (1986) vs. 2009 | 2.0488 | 0.0056 | * |

Table 2. Statistical difference in community composition between baseline and each subsequent year of sampling beginning in 1991 for Blackrock 99 using PERMANOVA. Asterisks denote years that were statistically different from baseline; only 3 were statistically significantly different in community composition, while 16 years were not different.

| Year Comparison | *t* | *P* | |
|---|---|---|---|
| Baseline (1986) vs. 1991 | 1.9007 | 0.0118 | * |
| Baseline (1986) vs. 1992 | 0.9310 | 0.4964 | |
| Baseline (1986) vs. 1993 | 0.5413 | 0.8948 | |
| Baseline (1986) vs. 1994 | 1.0428 | 0.3692 | |
| Baseline (1986) vs. 1995 | 0.9348 | 0.4866 | |
| Baseline (1986) vs. 1996 | 1.0884 | 0.3114 | |
| Baseline (1986) vs. 1997 | 0.3920 | 0.9676 | |
| Baseline (1986) vs. 1998 | 1.3813 | 0.1154 | |
| Baseline (1986) vs. 1999 | 2.4723 | 0.0014 | * |
| Baseline (1986) vs. 2000 | 1.1456 | 0.2546 | |
| Baseline (1986) vs. 2001 | 0.8434 | 0.6118 | |
| Baseline (1986) vs. 2002 | 1.3801 | 0.0894 | |
| Baseline (1986) vs. 2003 | 1.1472 | 0.2484 | |
| Baseline (1986) vs. 2004 | 0.9333 | 0.5080 | |
| Baseline (1986) vs. 2005 | 0.7838 | 0.6564 | |
| Baseline (1986) vs. 2006 | 0.9144 | 0.5352 | |
| Baseline (1986) vs. 2007 | 1.1386 | 0.2662 | |
| Baseline (1986) vs. 2008 | 1.6897 | 0.0306 | * |
| Baseline (1986) vs. 2009 | 1.5126 | 0.0628 | |

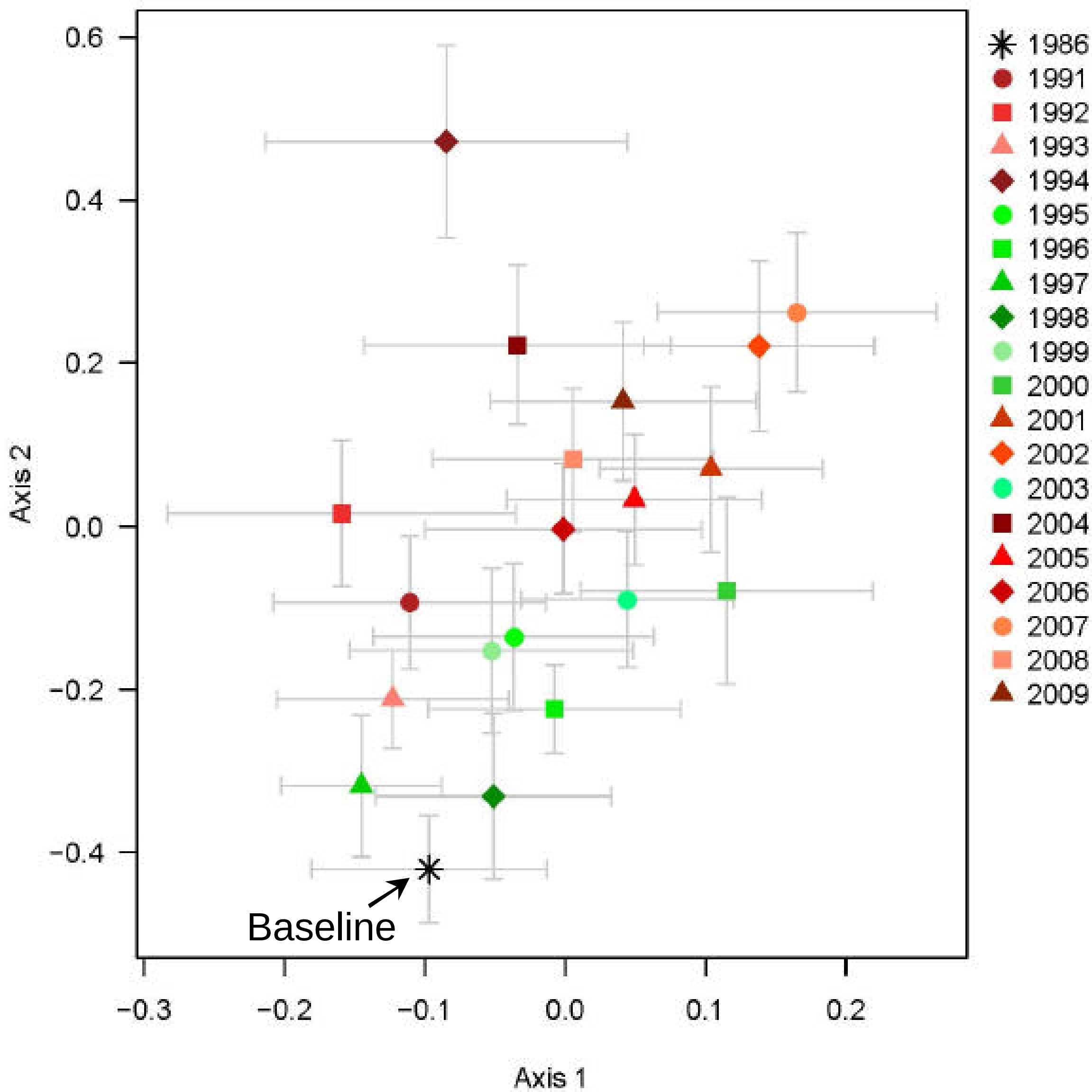



Figure 7a. NMDS Ordination of vegetation community composition in Blackrock 94 using data collected with the Green Book line point program. Each point represents the average location of transects for one year of sampling from the period 1986-2009 (excluding 1987-1990). Error bars represent the standard error of axis scores for all transects within each year. The baseline year is represented by an asterisk. In Blackrock 94, only seven years are not different from baseline (colored in shades of green) while 13 years have vegetation communities that are significantly different from the baseline period (colored in shades of red; See also Table 1). The baseline year is distant in ordination space to most re-visit years indicating dissimilarity in vegetation community composition (Stress = 18.19, $P$ = 0.0002). Ordination axes 1 and 2 represent 60% of the variation in the original distance matrix.

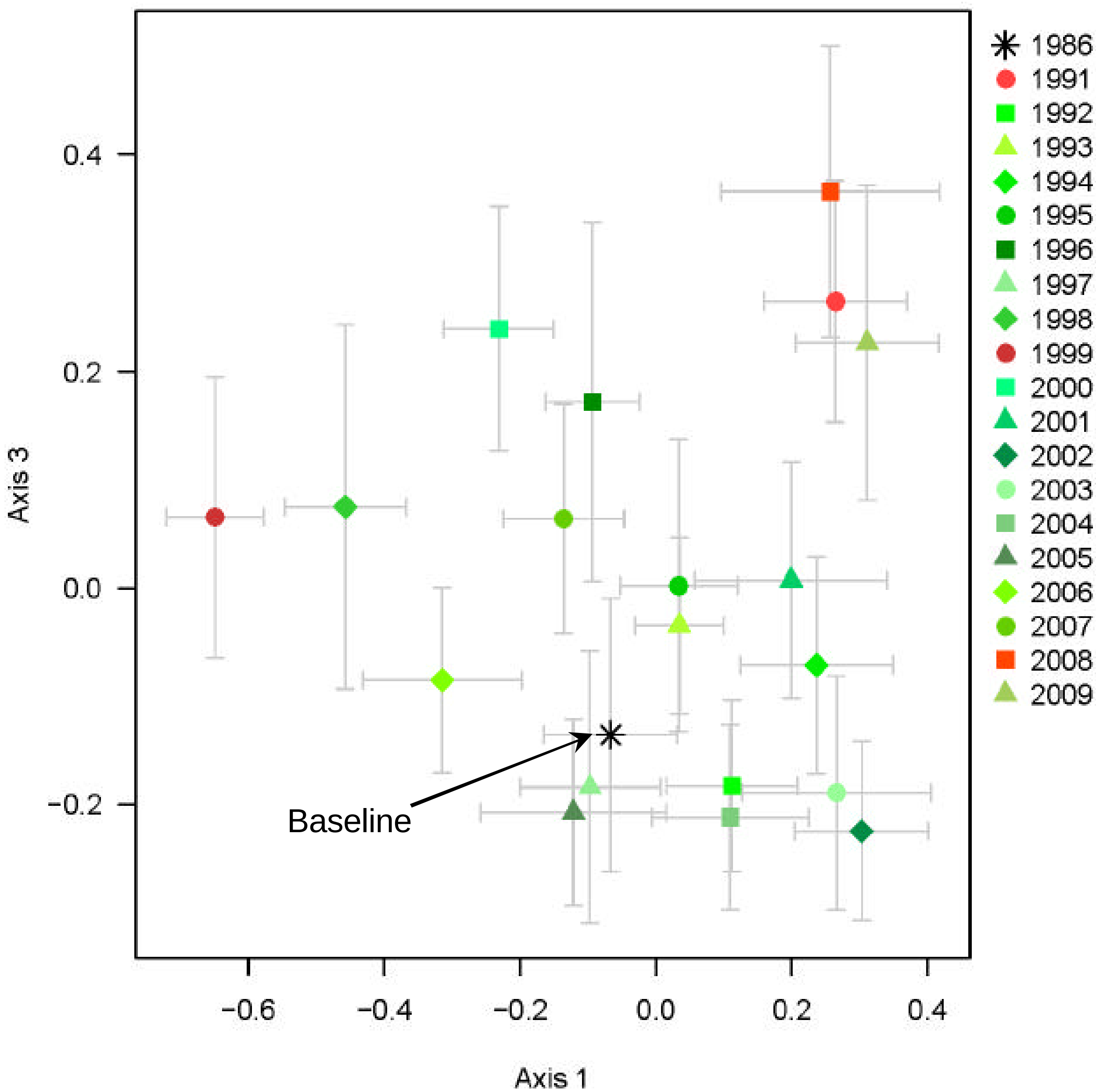



Figure 7b. NMDS Ordination of vegetation community composition in Blackrock 99 using data collected with the Green Book line point program. Thirteen years are not different from baseline (represented in shades of green) while only 6 years have vegetation communities that are statistically significantly different from baseline (represented in shades of red; See also Table 2). The baseline year is near most re-visit years indicating similarity in vegetation community composition (Stress = 13.63, *P* = 0.0002). Ordination axes 1 and 3 represent 64% of the variation in the original distance matrix.

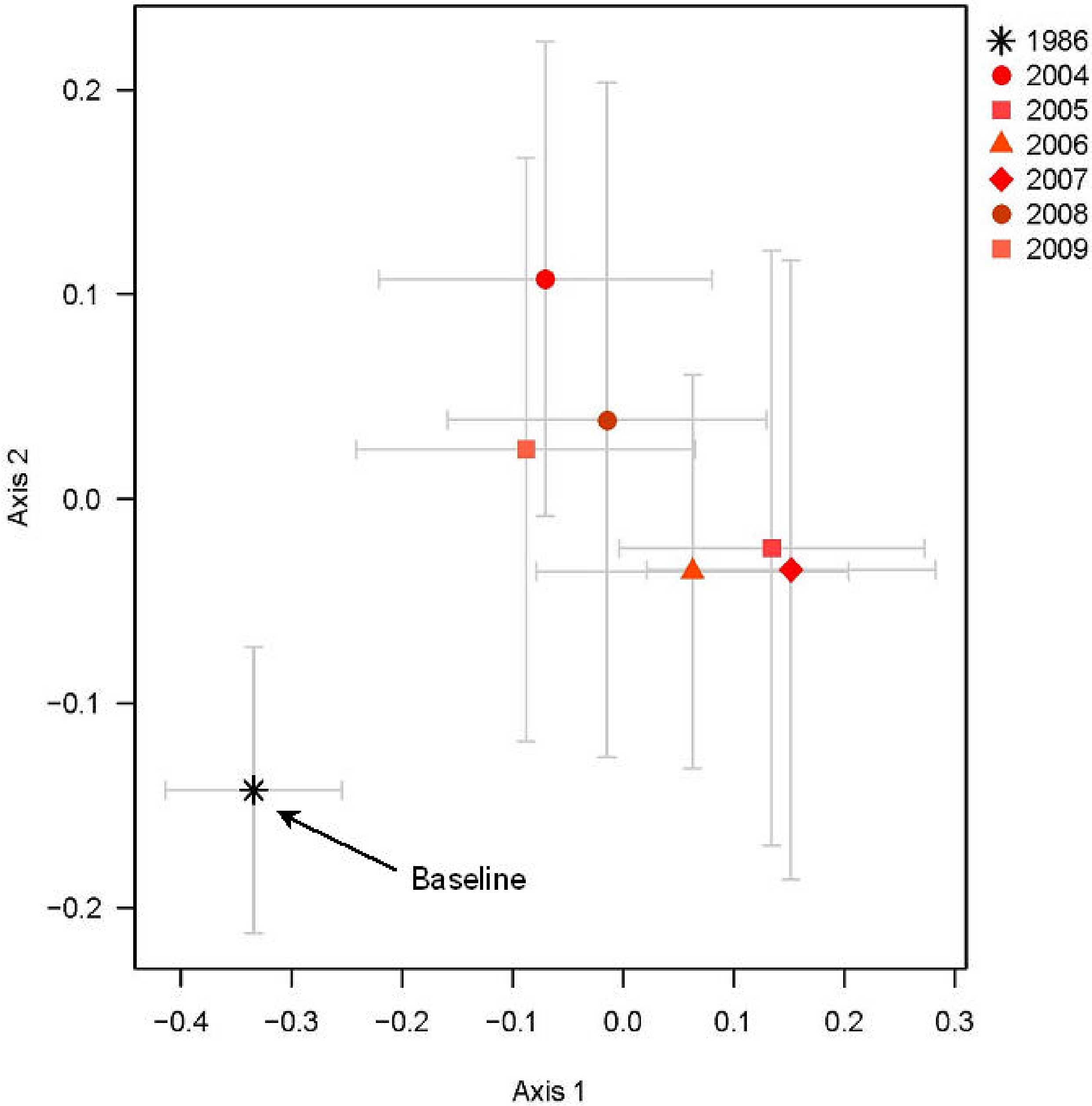



Figure 7c. NMDS Ordination of vegetation community composition in Blackrock 94 using data collected by LADWP. Each point represents the average position of transects for one year of sampling from the period 1986-2009 (excluding 1987-1990). Error bars represent the standard error of axis scores for all transects within each year. The baseline year is represented by an asterisk. In Blackrock 94, all years from 2004-2009 have vegetation communities that are significantly different from the baseline period (colored in shades of red). The baseline year is distant in ordination space to most other years indicating dissimilarity in vegetation community composition (Stress = 15.53, $P = 0.097$, pairwise $P < 0.03$).

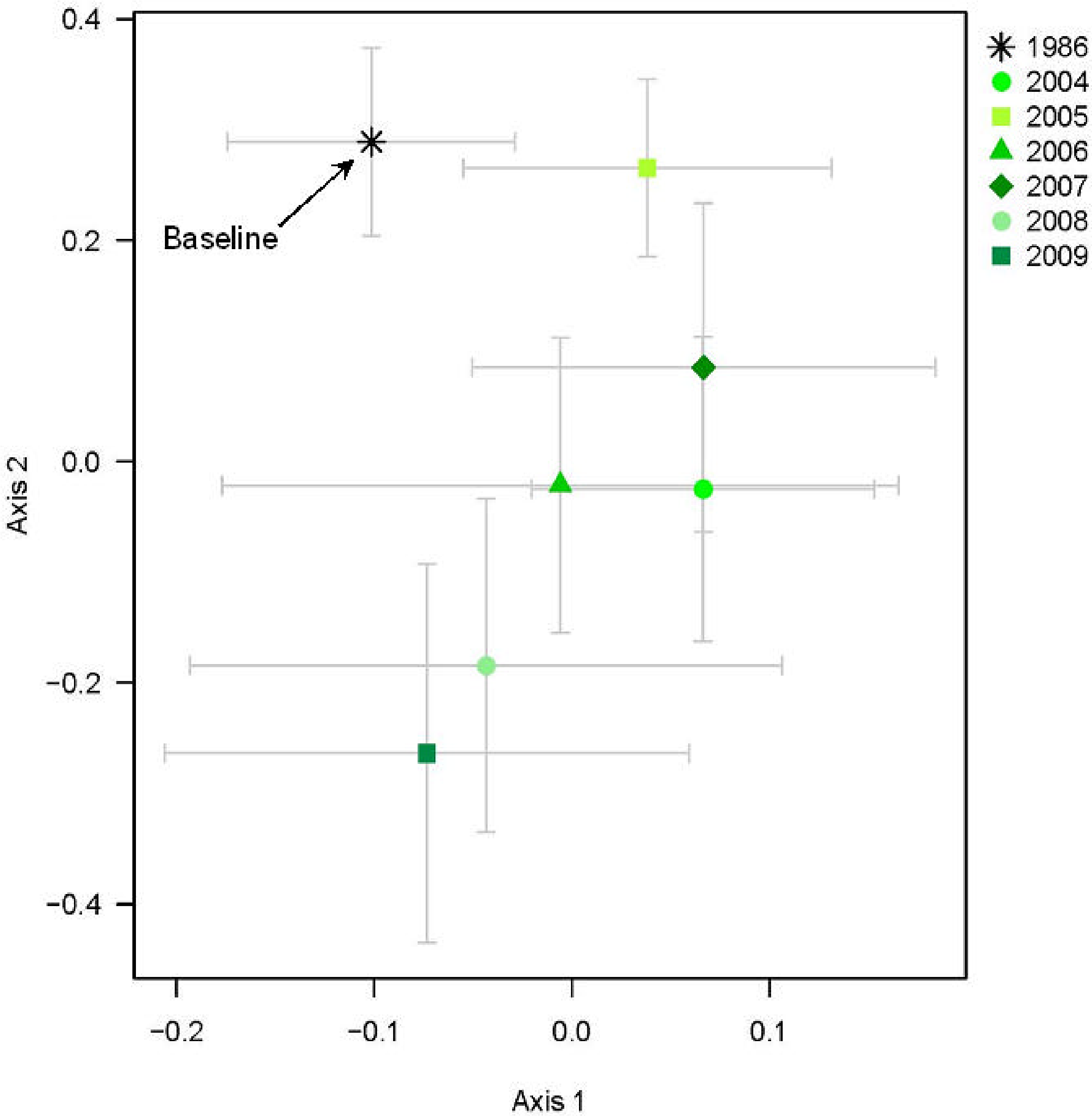



Figure 7d. NMDS Ordination of vegetation community composition in Blackrock 99 using data collected by LADWP. All years maintain vegetation communities that are not statistically significantly different from baseline (represented in shades of green). The baseline year is close in proximity to most re-visit years indicating similarity in vegetation community composition (Stress = 14.53, *P* = 0.21). Note: x-axis range is smaller than in Figure 7c.

**Vegetation cover and composition compared to control sites**

The permanent monitoring site TS3 and an adjacent meadow parcel Blackrock 99 were chosen for comparison with conditions in Blackrock 94, TS1 and TS2. These locations were chosen over control sites located east of the Los Angeles Aqueduct because of similar baseline vegetation, soil/landscape position, and proximity to Blackrock 94. Because of their close proximity, precipitation can reasonably be assumed to be similar, but the water table changes experienced since baseline have been substantially different. Blackrock 94, and monitoring sites TS1 and TS2 experienced greater and more persistent declines in water levels than at Blackrock 99 and TS3.

Vegetation Cover

Permanent monitoring site data depict vegetation cover generally below baseline for transects associated with Blackrock 94 (TS1 and TS2), and generally above baseline for the transect associated with Blackrock 99, TS3. In 1987, vegetation cover in TS1 was 53%, and has generally remained below this level in most of the 23 reinventory years, except three (1996-1998), and recently measured 19.7% cover in 2009. Likewise, TS2 cover measured 33% in 1988 and has remained below, that level for all 21 reinventory years, with 25% cover measured in 2009. In contrast vegetation cover at TS3 measured 31% in 1988 and has remained mostly at or above baseline with 48% cover recorded in 2009 (Figure 2).

Vegetation data recorded using the Green Book line point program for Blackrock 99 contrasts with conditions in Blackrock 94. Measurement and statistical methods were the same as for the analysis of reinventory data at Blackrock 94 described above. Baseline perennial cover was 48% (Figure 3a) for Blackrock 99, and composition of shrubs and grasses was similar to Blackrock 94 (Figure 6). Eighteen years of reinventory data show perennial cover statistically below baseline in only one year, 2002, compared with 14 years for Blackrock 94 (Figure 3a). Perennial cover was significantly higher than baseline in three years: 1998-2000; in contrast perennial cover has never been measurably higher than baseline in Blackrock 94. In all other years, perennial cover was not significantly different from baseline. In addition, LADWP data also provide consistent results with the Green Book program; vegetation cover in Blackrock 99 was not significantly different from baseline during any years from 2004-2009 ($P = 0.073$, Figure 3b).

Vegetation Composition

Shrub and grass composition at the three permanent monitoring sites were nearly indistinguishable from each other when monitoring began in 1988 (Figure 2). By 2007, the grass cover had decreased along TS1 and TS2, but grass cover at TS3 had changed little. Shrub cover increased along all three transects, but shrubs dominated TS1 and TS2 while TS3 was still dominated by grasses confirming the visual comparison depicted in the photos (Figure 4).

Proportion of shrubs and proportion of grasses have not changed statistically over time in BLK 99 according to reinventory data ($r^2$ = 0.00008, and r2 = 0.19, $P$ = 0.9708 and $P$ = 0.513 respectively, Figure 5a and b). Baseline shrub proportion was 0.13. Shrub proportion decreased in 1991 to 0.1, and in the years 2006 and 2007 when Blackrock 94 shows a high in shrub proportion, Blackrock 99 maintains a proportion of 0.13 and 0.1 respectively. Since 1991 shrub proportion has fluctuated higher and lower than the baseline level, but neither increasing nor decreasing trends are clearly demonstrated.

While the vegetation community composition in Blackrock 94 has changed, community composition in Blackrock 99 has remained relatively stable. Although the overall PERMANOVA indicates some years are different than baseline (*NPMANOVA P* = 0.0002; *PERMDISP P* > 0.008), only 3 of 19 years were different from baseline, while a much larger number, 16 of 19 years were similar to the baseline period (Table 2). The differences in overall community change (or lack thereof) between Blackrock 94 and 99 are illustrated in Figures 7a & 7b. Most Blackrock 99 re-inventory sample means surround the baseline year, indicating their similarity in community composition to baseline measurements; while in Blackrock 94, in most years the data were different from baseline. One species is strongly negatively correlated with axis 1: *Sporobolis airoides* (r = -0.769), and two species are strongly correlated with axis 3: *Distichlis spicata*, and *Sporobolis airoides* (r = 0.77, and -0.528 respectively, Figure 7b). Years when community composition is different than baseline have different proportions of *Distichlis spicata* and *Sporobolis airoides* cover, but the overall community composition is still generally not different. In addition, according to data provided by LADWP, the vegetation community in Blackrock 99 has not changed since baseline (*NPMANOVA* overall $P$ = 0.21, *PERMDISP* overall $P$ = 0.13, Figure 7d). The similarity in community composition of reinventory years to the baseline period is indicated by their proximity to the baseline year (note the differences in x-axis scale between Figures 7c and 7d).

In summary, available vegetation monitoring data demonstrate that vegetation trends for Blackrock 99 clearly differ from the decrease in total cover and grasses observed in Blackrock 94 since baseline period. The decrease in cover in Blackrock 94 greatly exceeded any minor declines in adjacent parcel Blackrock 99 and was more persistent. Composition of the vegetation community has changed in Blackrock 94. A decrease in grass cover (increasing shrub proportion) was observed in Blackrock 94 but no such trend was observed in Blackrock 99. The changes in overall plant community were measureable in Blackrock 94 and not measureable in Blackrock 99 using the Green Book data. Similar conclusions can be made for the LADWP data when the effect of the small sample size is taken into consideration.

**Remote sensing of Vegetation Cover**

Vegetation cover derived from remote sensing data provides another dataset to examine trends in vegetation condition in Blackrock 94. Landsat satellite data were processed using spectral mixture analysis (SMA) to measure average total green plant cover for the entire parcel (Elmore et al., 2000). The Landsat scenes were taken during late summer each year, 1986-2007. Generally the line point and remote sensing data show similar trends, but the absolute values of the two measurement techniques do not always agree. The line point data presented in this report depict perennial species cover to avoid fluctuations by weedy species that are largely driven by precipitation, whereas the satellite vegetation measurements include all species. To compensate, the late summer sampling period of the satellite data was chosen to reduce contribution from early season ephemeral species, but in wetter years, some summer annuals, (e.g. *Salasola* sp.) still can be green during late summer and detected in the satellite data. An important advantage of the remote sensing data is that the sampling date and spatial extent of the remote sensing cover measurements is known and is consistent throughout the monitoring period. Comparison between SMA data collected in the baseline year (1986) and in subsequent years is not subject to the uncertainty in replicating the baseline sampling methods; however, errors may still arise from co-registration of images, spectral calibration to ground points, error in the SMA model, and atmospheric corrections (Elmore et al., 2000).

SMA cover for Blackrock 94 was 46% in 1986, the year the parcel was mapped. Cover decreased to 38% in 1987 and has remained well below 30% in all subsequent years (Figure 8). Cover was close to zero for the parcel in late summer 2007 after the July fire when part of Blackrock 94 burned. Pre-fire, from 1988-2006, cover averaged 18%, less than half the 1986 value. The data suggest that cover decreased substantially soon after baseline measurements and has remained depressed. Minor increases in cover occurred in years with higher than average precipitation, but that factor alone has not promoted vegetation recovery to approach 1986 values.

SMA measurements in Blackrock 94 and 99 both show a steady decrease in cover from 1986 to 1990 (Figure 8). The decrease in cover between the years 1986 and 1990 relative to 1986 cover was much greater at Blackrock 94 than at Blackrock 99 (0.73 vs. 0.39). In subsequent years, the decrease in cover relative to 1986 at Blackrock 94 was consistently greater than at Blackrock 99, averaging 0.63 and 0.34 respectively. Where the line point data for Blackrock 94 show a degree of recovery in 1998, the SMA data show no such recovery.

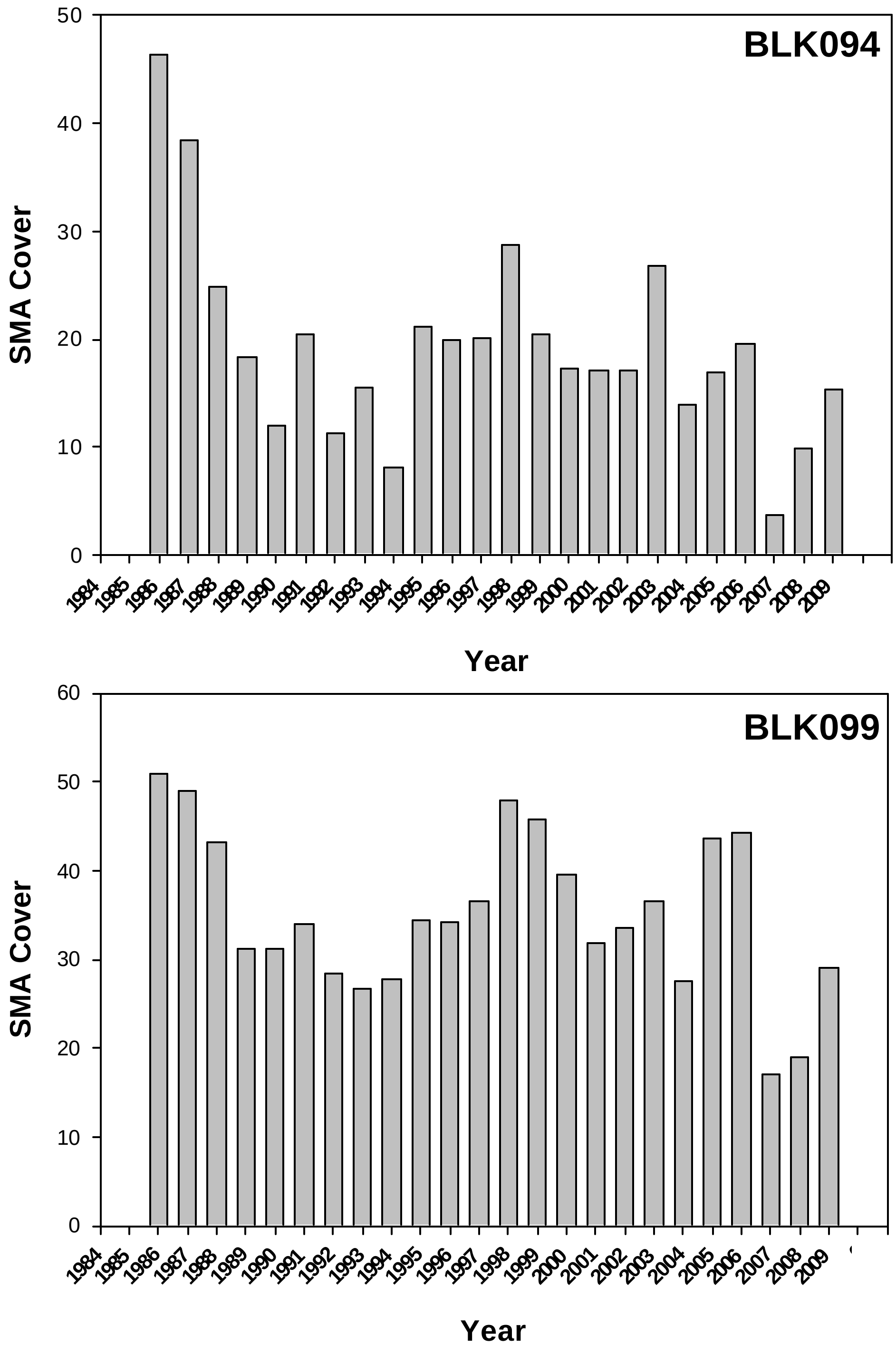



Figure 8. Total vegetation cover measured in Blackrock 94 (top graph) and Blackrock 99 (bottom graph) by SMA.  Remote sensing data in 2007 collected after the parcels burned in July.

**Comparison of dead/alive ratio**

This comparison is listed in the Green Book as a possible analysis of vegetation conditions to document if a measurable change has occurred or is occurring. We are not aware of any existing data that could be used to perform this analysis.

**Summary of measurability analysis**

Four monitoring programs of differing complexity and scale were examined to assess whether a change in vegetation in Blackrock 94 can be detected: photo points, permanent transects, reinventory results, and remote sensing. Multiple lines of evidence from all the monitoring programs at Blackrock 94 documented decreased live vegetation cover compared with baseline in the majority of years and a decrease in grasses resulting in increased proportion of shrubs. Perennial parcel cover has been statistically below baseline for 14 of 19 years since 1991according to Green Book data. Vegetation community composition in Blackrock 94 has been significantly different than the baseline measurements 84% of the 19-year reinventory period, likely due to a shift in proportion of shrubs as compared with grasses. Similar data provided by LADWP agree with these findings both with respect to vegetation cover and composition of perennial species. Apparent changes in Blackrock 94 can be readily distinguished from conditions at a nearby permanent transect and vegetation parcel that experienced less severe water table decline, Blackrock 99. We conclude that a change in vegetation cover in Blackrock 94 has occurred and is persistent. Likewise, changes in vegetation composition are measureable and that a change from Type C vegetation to Type B vegetation is occurring in Blackrock 94. The Green Book allows that any small documentable changes in cover or composition can be considered a measurable change. The analysis presented here meets that criterion. The possible causes of the measurable changes are assessed in the following section.

## Attributability

The causes of the measurable vegetation change were assessed by examining the timing of vegetation changes with respect to surface and groundwater management that could be responsible for these changes. Data for some potential variables (e.g. grazing management, insect herbivory, fungal blight) to analyze suggested by the Green Book are not available at the Water Department and cannot be included in this analysis. The Technical Group may be able to complete an analysis of those variables.

**Groundwater Pumping and Surface Water**

<u>Groundwater Pumping</u>

Groundwater wells in the Thibaut-Sawmill and Taboose Aberdeen wellfields near Blackrock 94 are shown on Figure 9. Thibaut-Sawmill pumping history is presented in Figure 10a. Runoff year pumping totals from 1973 to 1986 (baseline year) averaged approximately 12,000 acre-feet. Wellfield pumping increased during 1987 to1992 (average >19,000 ac-ft) with three consecutive years near the wellfield maximum from 1987 to 1989. Since 1993, pumping has been less variable, averaging 13,556 ac-feet. The majority of pumping in this wellfield from 1972 to present has been to supply the Blackrock Fish Hatchery from wells W351 and W356 (W356 primarily was used in the 1980's). Pumping from wells W106, W109, W110, W111, W114, and W370 in the Taboose-Aberdeen wellfield (Figure 9b) to the north also may affect Blackrock 94 albeit to a lesser degree than Thibaut-Sawmill wells. Southern Taboose-Aberdeen wellfield pumping from 1973 to 1986 averaged approximately 5200 acre-feet. Like the Thibaut-Sawmill wellfield, pumping in 1987-88 approached the maximum capacity for the southern Taboose-Aberdeen wells. Pumping from this set of wells essentially ceased in 1992 (Figure 10b).

Surface Water History and Runoff

An approximate water balance of surface water uses and losses on the alluvial fans and valley floor immediately west (upgradient) of Blackrock 94 can be used as an indicator of recharge to this portion of the Thibaut-Sawmill wellfield (Figure 11). The northwestern edge of Blackrock 94 borders Eight Mile Ranch, an irrigated lease on LADWP land. Irrigation water is supplied to the ranch from Sawmill creek. Creek flows at the base of the mountains, pumping, and return flows to the LAA are monitored. Uses and losses are the amount of surface water that is used for irrigation, water spreading, or percolates into the subsurface through stream channels and conveyances, which can be estimated from,

$$\text{Uses and losses} = (\text{STAID 78} + \text{W155} + \text{W159}) - \text{STAID 38} \tag{2}$$

where: STAID 78 is Sawmill Creek at the base of the mountains flow, W denotes pumping well, and STAID 38 is Sawmill Creek return flow to LAA. The baseline year was preceded by three years of high runoff, which translated into higher uses and losses west of Blackrock 94. In the wet years 1983 to 1986, before and during baseline, the average annual uses and losses were 3,463ac-ft/year. In subsequent years, annual uses and losses typically varied between 1,200 and 2,000 ac-ft/year. The wettest four-year period since baseline was 1995-1999 during which uses and losses averaged 2,697 ac-ft/year, less than the mid 1980's.

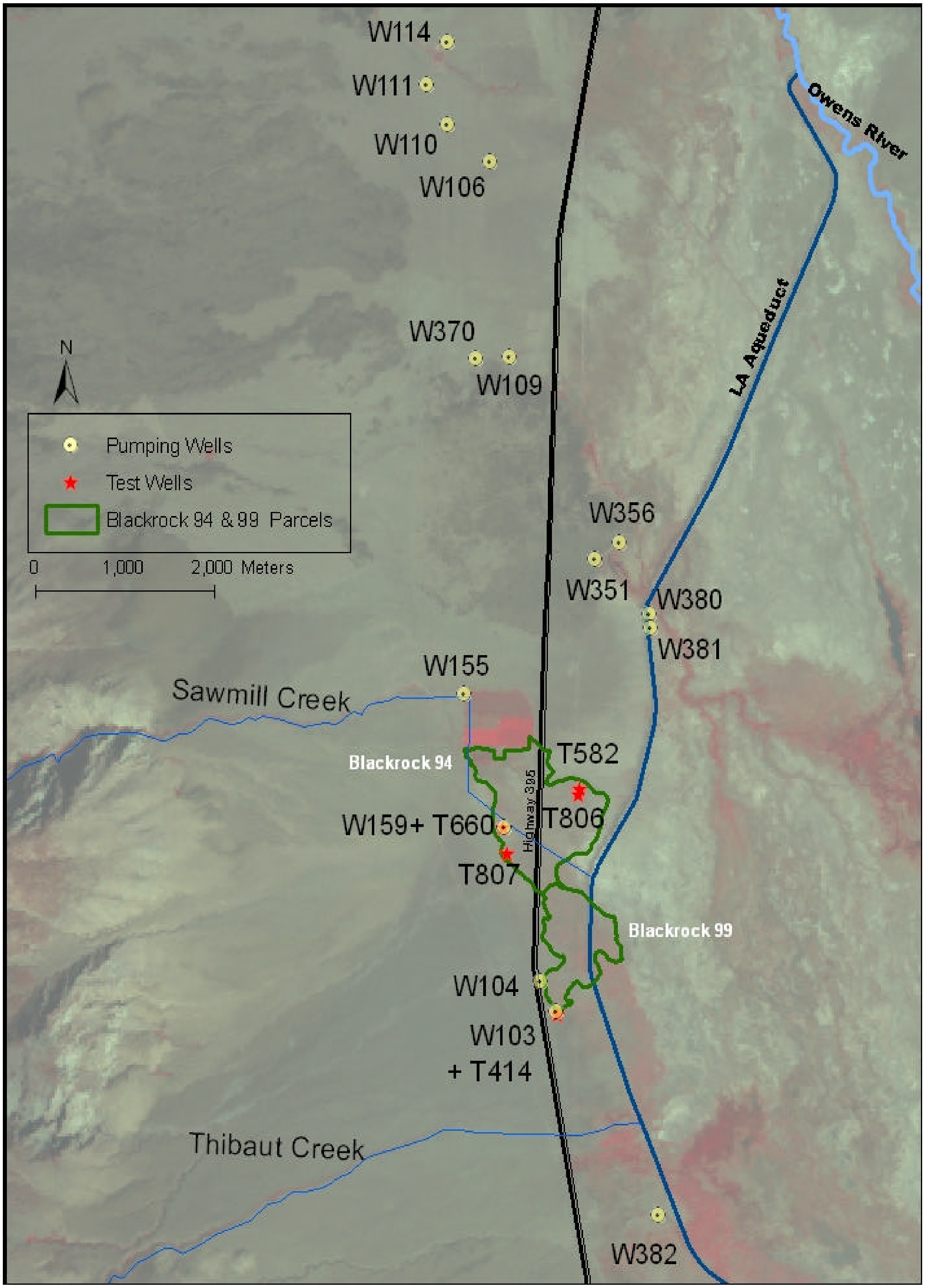



Figure 9. Location of pumping wells and creeks near Blackrock 94.

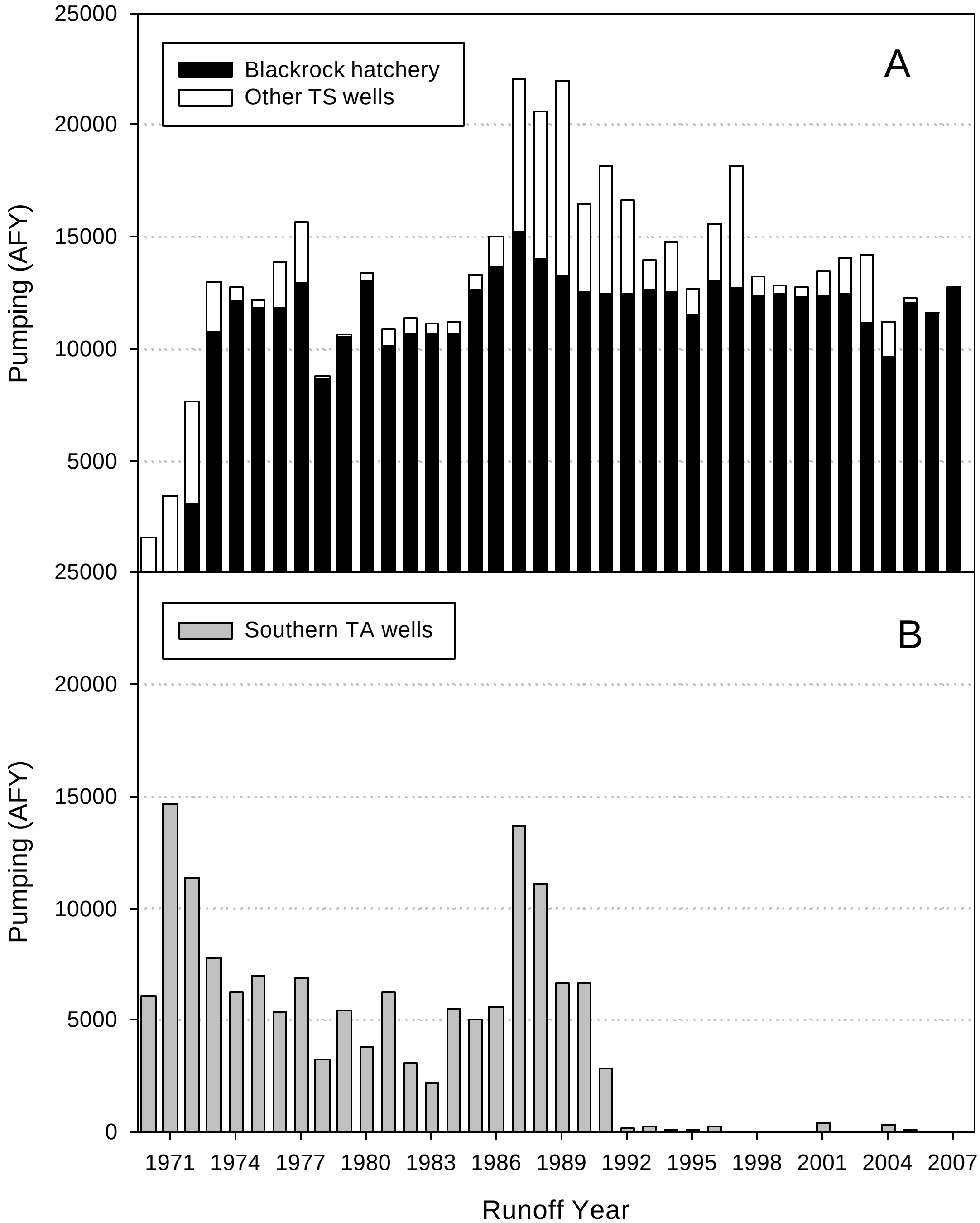



Figure 10a and b. History of pumping in the Thibaut-Sawmill (A) and southern Taboose-Aberdeen (B) wellfields. Taboose-Aberdeen pumping included wells: W106, W109, W110, W111, W114, and W370. Wellfield modeling indicated these wells could have a small effect on water levels under Blackrock 94. Values are in ac-ft per runoff year (April 1- March 31).

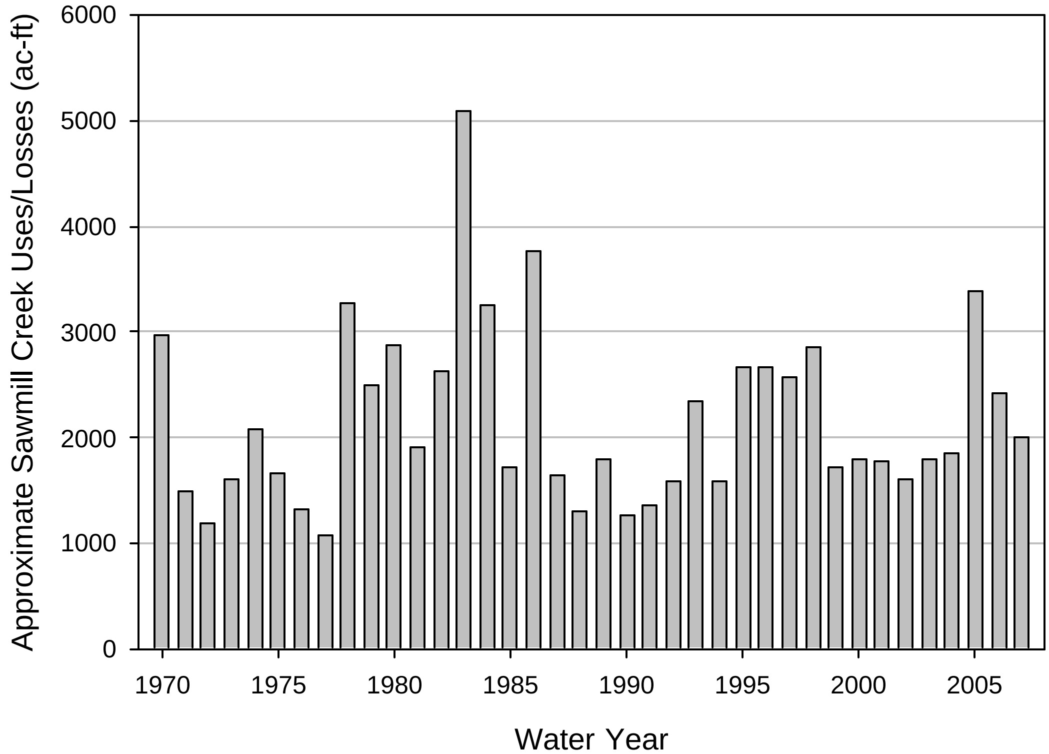



Figure 11. History of uses and losses from Sawmill Creek 1970 to 2007 calculated using Equation 2.

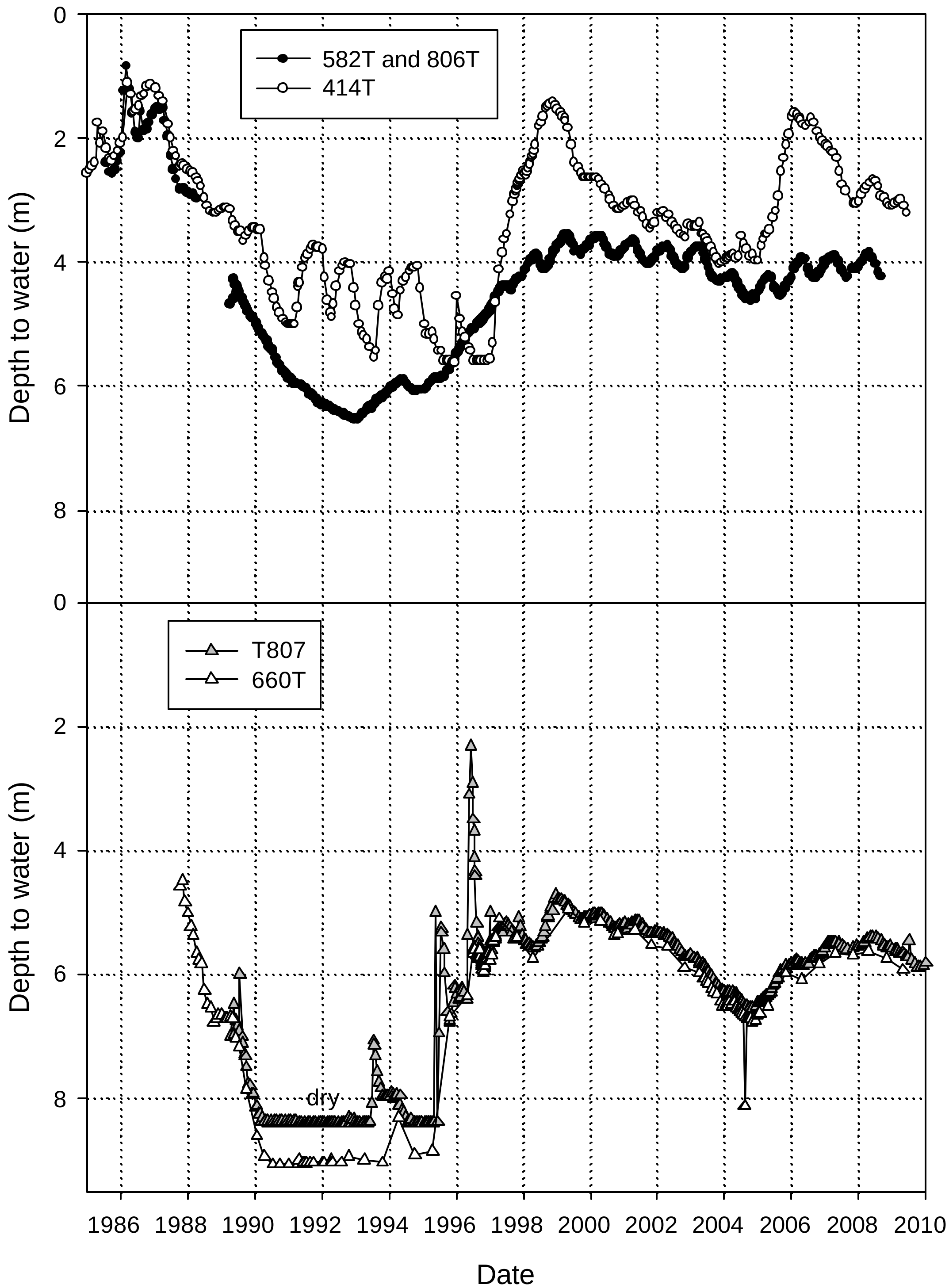



Figure 12. Hydrographs of the water table in and near Blackrock 94 and 99. The dry measurements shown for T660 and T807 are at the bottom of the well.

## Water Table Conditions

Hydrographs of depth to the water table for several test wells in and near Blackrock 94 are presented in Figure 12. Well 414T is near the southern edge of Blackrock 99 (near TS3). Wells 582T and 806T are shallow test wells separated horizontally by 195 feet. Together the pair essentially constitute a single hydrograph for water table fluctuations at TS2. Similarly, 660T and 807T are both located near the western edge of Blackrock 94 and their hydrographs overlap. Water levels in test wells were relatively high from 1985-87. Water levels declined and remained lowered until the early 1990's when water tables slowly began to rise, peaking in 1999. Water levels have since declined or remained relatively stable. Test well data from permanent monitoring sites suggest that water levels had probably dropped below the reach of grass roots by 1990, if not sooner at TS1, TS2 and TS3. The water table returned to the grass root zone by 1999 at TS3, indicated by 414T, but it did not return to the grass root zone at TS1 (660T and T807) or TS2 (582T and 806T). Water spreading is evident in the hydrographs as rapidly rising and falling spikes, e.g., T807 in 1993, 1995, and 1996.

Water levels vary across Blackrock 94, and test wells only provide point-scale information. Because it is not possible to monitor all locations, water levels beneath the parcel were estimated from existing test well data using a standard method of interpolating spatially distributed environmental data called kriging (Harrington and Howard, 2000). The analysis is completed using test well data collected in April of each year when measurements for all test wells in the valley are available. From the kriging output, average water levels beneath a parcel can be calculated and a parcel hydrograph produced (Figure 13). Average water table depth beneath Blackrock 94 was less than 2 m in 1986 and then declined below 6 m by 1990. By the late 1990s, Blackrock 94 water levels had risen to the highest point since the baseline period, but still averaged approximately 4 m. In contrast, average water level also declined in Blackrock 99, but it remained above 3 m. Water supplied by capillarity was potentially within reach of grass roots and well within reach of shrub roots in Blackrock 99 since the baseline period.

## Soil water conditions

Soil water monitoring at permanent monitoring sites TS1 and TS2, both within Blackrock 94 parcel boundaries, began in late 1988 using psychrometers. The psychrometer measurements were restricted to depths above 1.5m and often were not reliable, but those data can discriminate wet from dry soil. At TS1, soil above 1.5 m encompassing most of the grass root zone (approximately 2-2.5 m) was very dry by mid 1989. Soil water at TS2 also was low, and it varied little for several years except after rain or snow. These observations indicate that for most of the period 1988-90, soil water in much of the grass root zone was scarce for plant use.

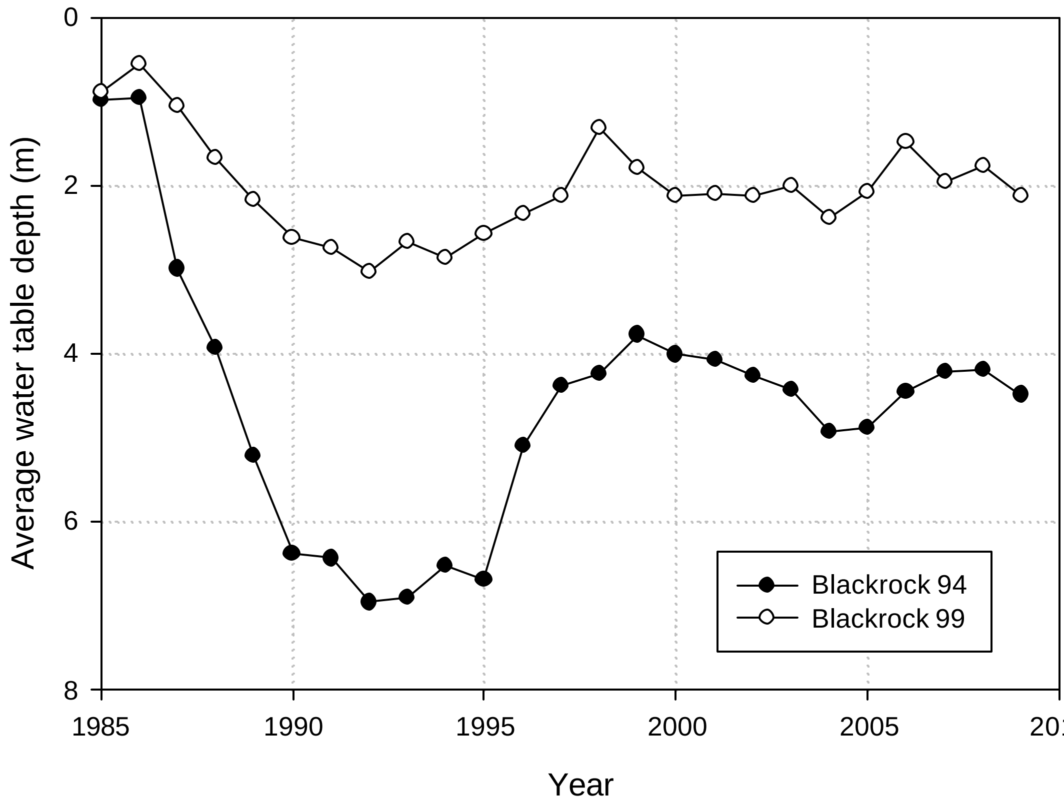



Figure 13. Average water table depth in Blackrock 94 and Blackrock 99 calculated using ordinary kriging.

A separate soil water monitoring program using a neutron probe instrument was begun in 1990, and the methods and number of monitoring locations were revised in 1995. The data collected before 1995 are approximate values, but they are adequate to judge whether the soil was dry or wet and also to detect wetting or drying trends. Monitoring extended to about 4 m depth allowing measurement of water content changes due to water table fluctuations.

The soil at TS1 was dry to 4 m depth by November 1990 (Figure 14a). Estimates of plant-limiting water content range between 2-12% (volume basis) for the sandy to clay loam soil textures at the sites. Small amounts of plant water uptake of stored soil water between 2.3-3.3 m continued until 1994. There is no evidence of groundwater reaching above 4 m until water spreading temporarily raised the water table in 1995 and 1996. Plants gradually took up soil water replenished at that time during the next couple of summers. Except for the two spreading episodes in 1995 and 1996, groundwater has not replenished the soil above 2 m and rarely even above 3 m since monitoring began.

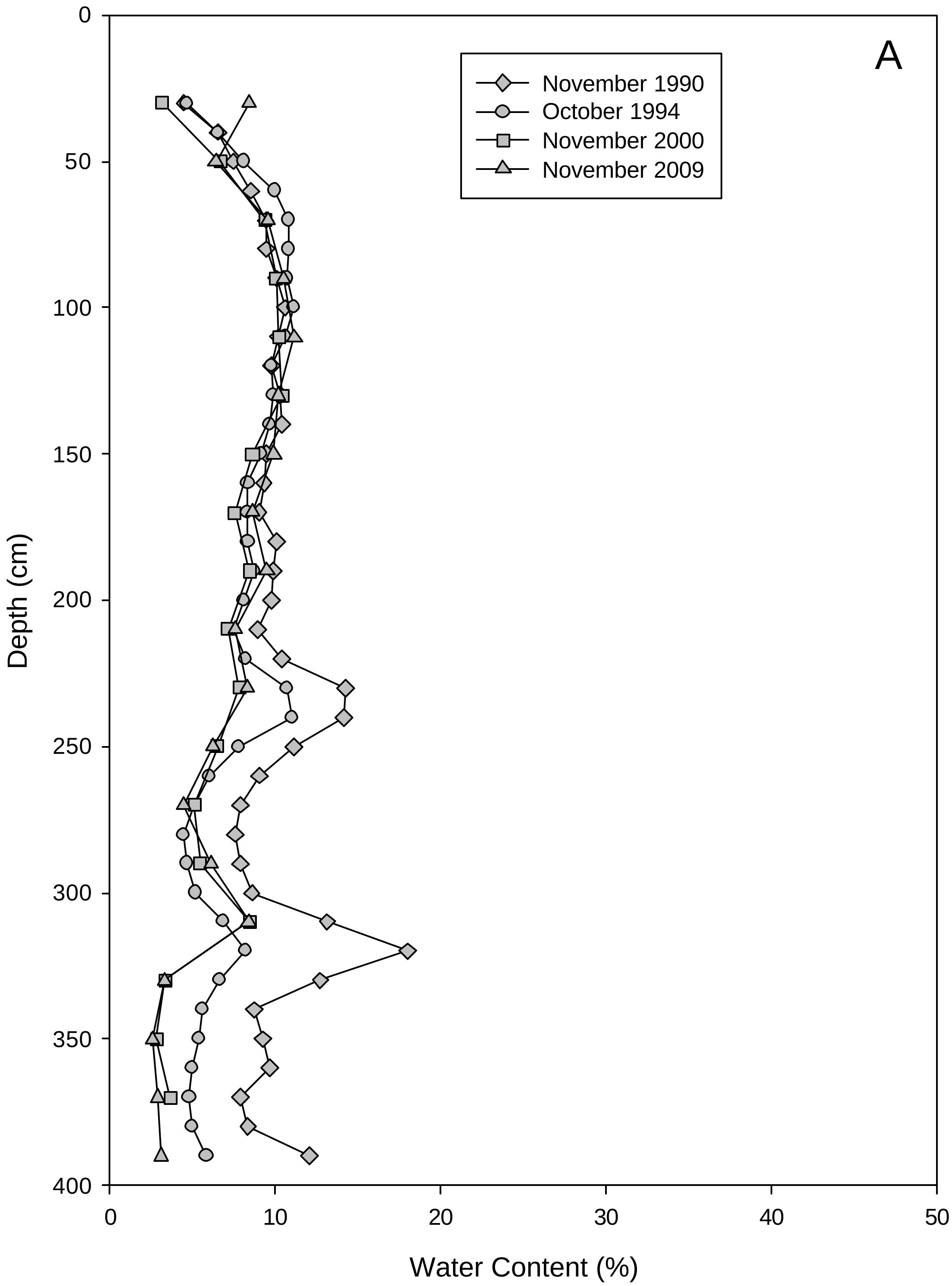



Figure 14a. Examples of four soil water profiles from tube 1 at monitoring site TS1.

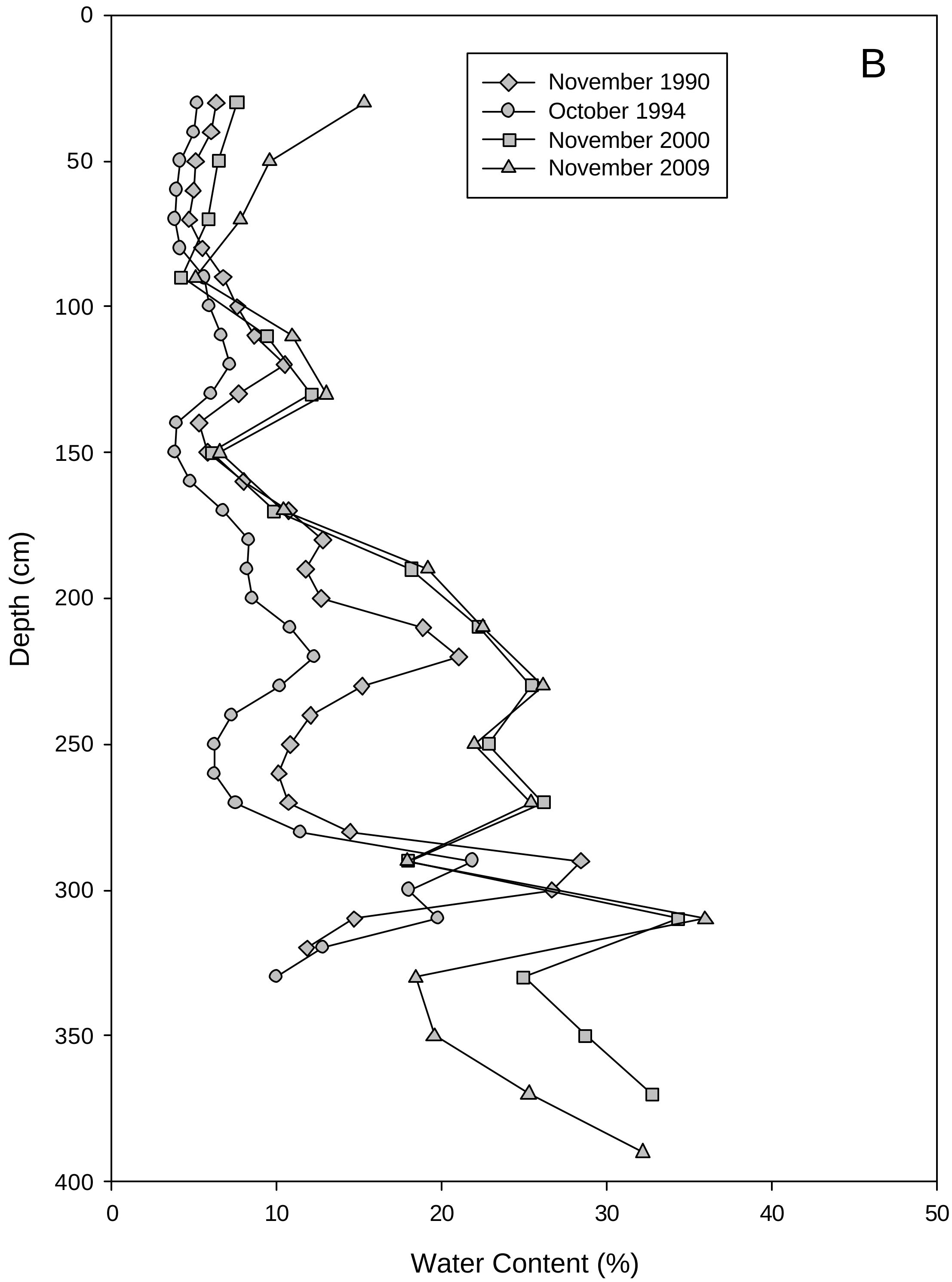



Figure 14b. Examples of four soil water profiles from tube 1 at monitoring site TS2.

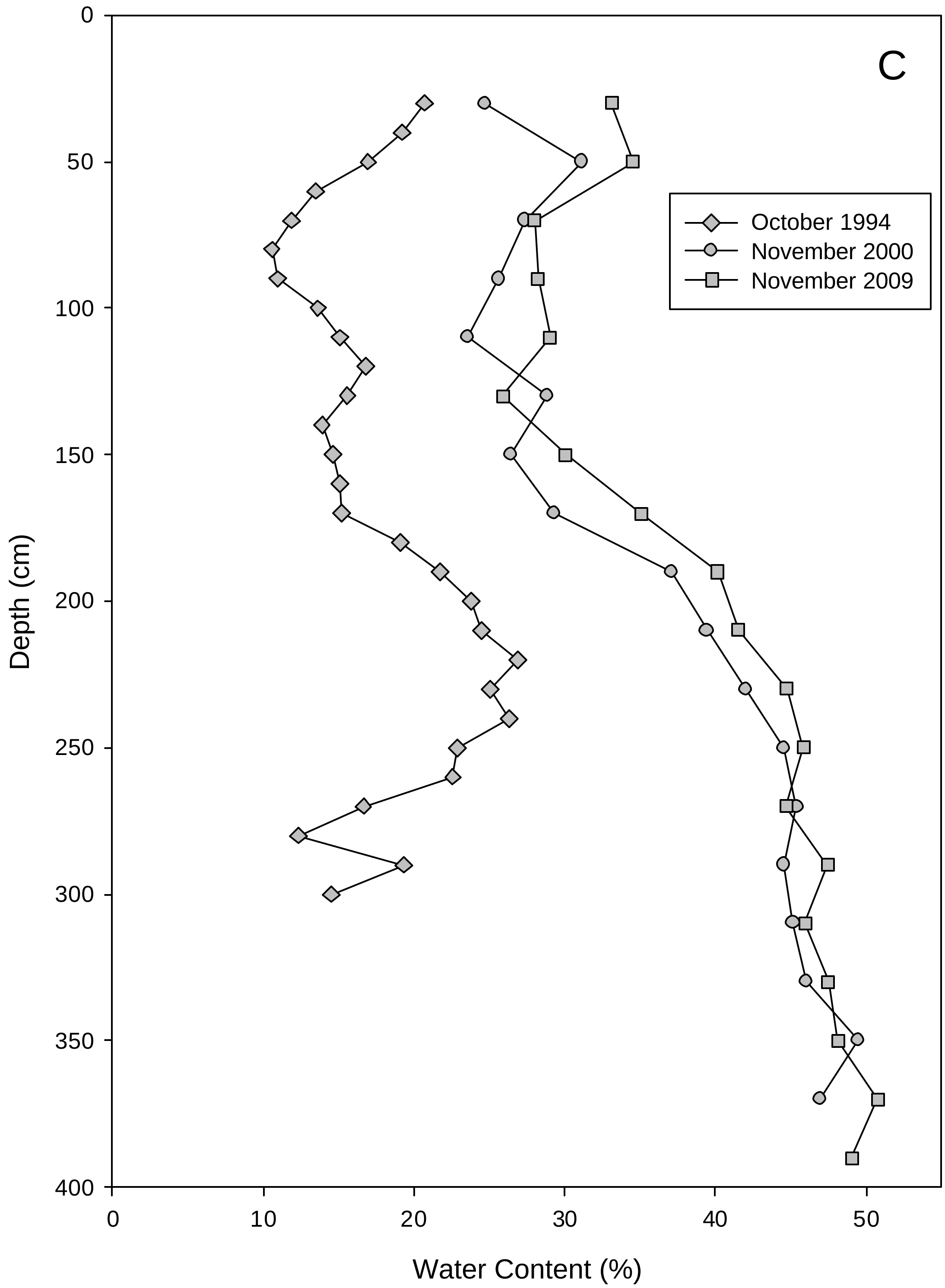



Figure 14c. Examples of three soil water profiles from tube 1 at monitoring site TS3. Monitoring at this site using the neutron probe did not begin until 1994.

The soil at TS2 was dry by 1990 with gradual plant water uptake observable below 1.7 m continuing until 1994 (Figure 14b). Soil water above 4m changed little until the water table was shallow enough to replenish soil water in 1999. Between 1999 and 2005, groundwater replenished soil water only below 2 m and usually only below 3 m. Since 2005, the water table has been shallow enough to wet the soil slightly to 1.9 to 2.5m depth depending on location along the transect.

For comparison, the soil at TS3 has been much wetter than at TS1 and TS2 since monitoring began in 1989 using all measurement methods, and the soil water content above 2 m has remained coupled with water table fluctuations (Figure 14c).

**Comparison of Water Table and Vegetation Cover**

Changes in water table depth and concurrent vegetation change can be examined by comparing spatially extensive measurements of vegetation cover and groundwater depth (Appendix A). The maps in Appendix A show either vegetation cover or change in cover and DTW each year from conditions that existed in 1986 when the vegetation baseline map was completed. Vegetation cover was estimated from SMA satellite results and DTW interpolated by ordinary kriging.

The first map in Appendix A shows vegetation cover in most of Blackrock 94 was between 15 and 75% in 1986. The water table depth of was 2.1 m or shallower in April 1986, just slightly below the approximate grass root zone (2 m), but it began to decline precipitously in 1987 with the western portion of the parcel experiencing the greatest decline. By 1990 the water table under Blackrock 94 had declined by more than 3 m under the entire parcel. As the water levels declined, vegetation cover progressively declined from the northwest towards the southeast across the parcel. Areas with severe decline in cover (greater than 50%) in Blackrock 94 were evident where drawdown exceeded 5m during the dry years 1990, 1992, and 1994. Water tables began to rise in 1994 due to higher recharge and reduced pumping (Figure 13), and by 1999 water levels were the highest observed since baseline. Since that time, water levels fluctuated 2-4 m below 1986 levels, and cover in most of the parcel remained below baseline.

Two areas of Blackrock 94 were affected by site-specific land management that is not fully reflected in the interpolated water table map. First, the brief rise in the water table in 1995 and 1996 (Figure 12) due to spreading in the southwestern corner of the parcel was not reflected in the annual kriging results. (The overall rising trend during the period is reflected, however). Second, vegetation did not decrease to the same degree along the northwest corner of Blackrock 94 where ranch tailwater was spread. Increases in vegetation cover and water table in both areas was short-lived and the spatial extent limited so that overall parcel cover and DTW remained below baseline during these events.

Water levels and cover in 1986 in Blackrock 99 were similar to Blackrock 94. Between 1986 and 1990, however, only the northwest portion of the parcel experienced water table decline greater than 3 m. This area also exhibited the greatest decrease in vegetation cover during the period. The eastern portion of the parcel experienced water table declines of less than 2 m, and the water table remained near the grass root zone. In this area, vegetation decreased less than 10% or even exceeded 1986 levels. Overall, Blackrock 99 experienced smaller water table declines, over a smaller area, and for a shorter period than Blackrock 94. Accordingly, vegetation cover decreased less and has approached baseline levels in 1999, and 2005-06.

Correlation of vegetation change with groundwater level and precipitation

Because of their close proximity, winter precipitation can reasonably be assumed to be similar in Blackrock 94 and 99. Vegetation cover and composition in 1986 during the baseline mapping were similar in both parcels. Blackrock 94 perennial cover measured 41%, and was composed of 29% grasses, 11% shrubs and 1% perennial herbs. Blackrock 99 perennial cover measured 48%, and was composed of 40% grasses, 6% shrubs and 2% perennial herbs. DTW in 1986 under Blackrock 94 was 0.96m and was 0.56m under Blackrock 99, well within the rooting depth of species occurring in the parcels. Both Blackrock 94 and 99 were mapped as groundwater dependant alkali meadows during baseline, and given the similarity in initial DTW, vegetation cover, and composition they would be expected to respond similarly to precipitation fluctuations if groundwater levels remained constant.

Because Blackrock 99 and Blackrock 94 were mapped as groundwater dependent alkali meadows during the baseline mapping, vegetation cover and species community are also expected to respond to variation in depth to groundwater. Winter precipitation is particularly important for perennial desert species and these communities would be expected to respond to precipitation fluctuations. Precipitation was measured by LADWP at Independence, Ca. The data from this location were chosen because they included the baseline period, and precipitation totals were highly correlated with measurements collected in Blackrock 94 by Inyo County from 1993 to 2009. First, we examined the effect of variation in depth to groundwater on mean perennial live cover in Blackrock 94. Perennial vegetation as measured using the line point program in Blackrock 94 is negatively affected by the large fluctuations in groundwater depth ($r^2$ = 0.24, $P$ = 0.027, Figure 15). In contrast, perennial live cover in Blackrock 99 is not affected by the smaller variation in groundwater depth present under that parcel ($r^2$ = 0.14, $P$ = 0.105, Figure 15).

The relationship between vegetation cover and water table depth (DTW) was also evaluated using simple linear regression of SMA measurements and average water table depth from the kriging analysis. These data are available each year from 1986 to 2009 and they are the most spatially extensive datasets to evaluate conditions across the entire parcel, and the same method is employed during the entire time period. For the entire time period, Blackrock 94 SMA cover was significantly correlated with DTW ($r^2$ = 0.40, $P$ = 0.0009, Figure 16). Since baseline, vegetation cover and DTW in Blackrock 99 are also significantly correlated ($r^2$=0.40, $P$ = 0.0009).

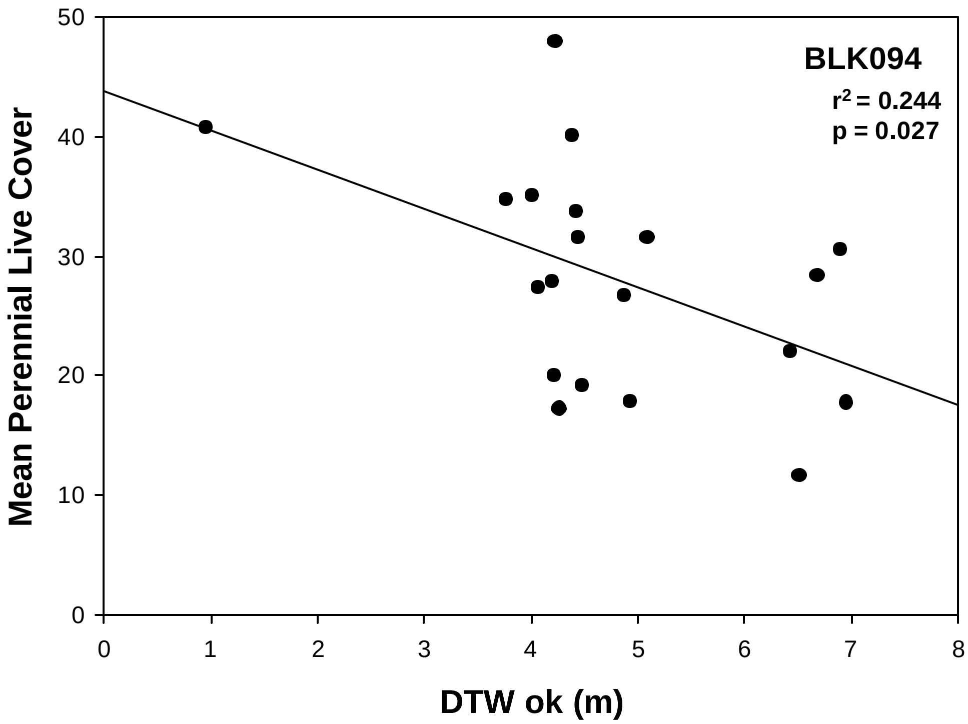
Regressions between Green Book line point cover and winter precipitation in Blackrock 94 suggest precipitation also contributes to fluctuations in cover ($r^2$ =0.34, $P$ = 0.007). However, using SMA measurements, precipitation is only marginally correlated with winter precipitation ($r^2$ =0.17, $P$ = 0.047). Vegetation conditions in nearby parcel Blackrock 99, with similar rainfall, were uncorrelated with winter precipitation using both Green book line point data and SMA measurements because plant roots were almost always in contact with a shallow water table ($r^2$ =0.00002 and 0.08, $P$ = 0.98 and 0.17 respectively for LPT and SMA). This suggests variation in precipitation alone is not the primary factor resulting in the measurable vegetation decrease in Blackrock 94. Significant correlations between perennial cover and both DTW and precipitation in Blackrock 94 reflect its more water-limited status compared to Blackrock 99.

To determine the relative effect of water-year precipitation versus depth to groundwater (DTW) on perennial vegetation in Blackrock 94, a Multiple Linear Regression of both live cover from the Green Book program and SMA data were conducted against DTW and precipitation. Significant relationships were found between cover and both DTW and precipitation, but the results were inconsistent between the two data sets as to what was the predominant factor. The line point dataset suggests that water year precipitation is a more important predictor of perennial vegetation than depth to ground water ($r^2$ = 0.18, and 0.43 respectively for DTW and precipitation, $P$ = 0.01 and $P$ =0.001) however the SMA data suggest that depth to ground water is a more robust predictor ($r^2$ = 0.40, and 0.15 respectively for DTW and precipitation $P$ = 0.0006 and $P$ =0.02). The SMA dataset contains a more complete time record; the line point data may have missed an important period of vegetation response to declining DTW during 1987, 1988, and 1989. This data gap may explain the discrepancy in results between the two datasets. In addition, soil water from precipitation is exhausted by mid-summer, so vegetation cover imaged in late August to September may not detect cover fluctuations driven by precipitation. In contrast, late June line point data may be capturing increased cover supplied by precipitation.

Environmental gradients that may be driving observed vegetation community patterns were analyzed using a combination of NMDS and linear regression using the Green Book re-inventory data. According to a multiple linear regression of NMDS axis scores and both groundwater estimates and winter precipitation, 16% of the variation in vegetation community composition in Blackrock 94 can be explained by depth to groundwater, and only 9% is explained by winter precipitation ($P$ = 0.001 respectively, Figure 17a). Years with deep groundwater are also those that show vegetation communities that are most distant in ordination space, and therefore different than the baseline period (Figure 17a). According to data collected by LADWP, the vegetation composition in Blackrock 94 is correlated with depth to groundwater, but not with precipitation ($r^2$ = 0.14 and $r^2$ = 0.0046, $P$ = 0.001 and $P$ = 0.774 respectively; Figure 17c), consistent with previous studies showing that shallow groundwater is important to maintaining groundwater dependent alkali meadow communities (Sorensen et. al., 1991).

In contrast, variation in groundwater is only marginally correlated with community composition in Blackrock 99, and winter precipitation is not correlated ($r^2$

=0.0205 and 0.0038, *P* = 0.014 and 0.457 respectively, Figure 17b). Because this parcel maintains a consistently shallower groundwater table than Blackrock 94, vegetation communities similar to baseline are sustained, and variation in groundwater level does not explain variation in vegetation community composition. This result is consistent with the data collected by LADWP from 2004-2009. Both depth to ground water and winter precipitation are not correlated with the ordination ($r^2$ =0.0308 and 0.0346, *P* = 0.199 and 0.172 for DTW and winter precipitation respectively).



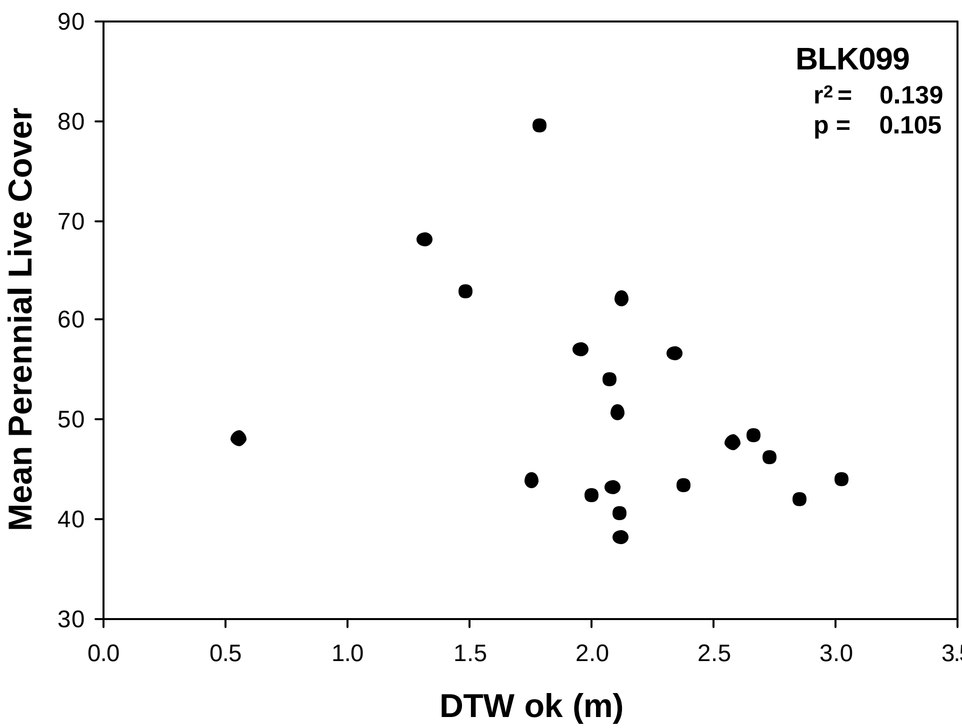




Figure 15. Regressions of mean perennial vegetation cover, measured by the Green Book program in Blackrock 94 (top) and Blackrock 99 (bottom). Larger variation in DTW in Blackrock 94 is correlated with vegetation cover, while smaller variation in DTW in Blackrock 99 results in no correlation of DTW and cover.

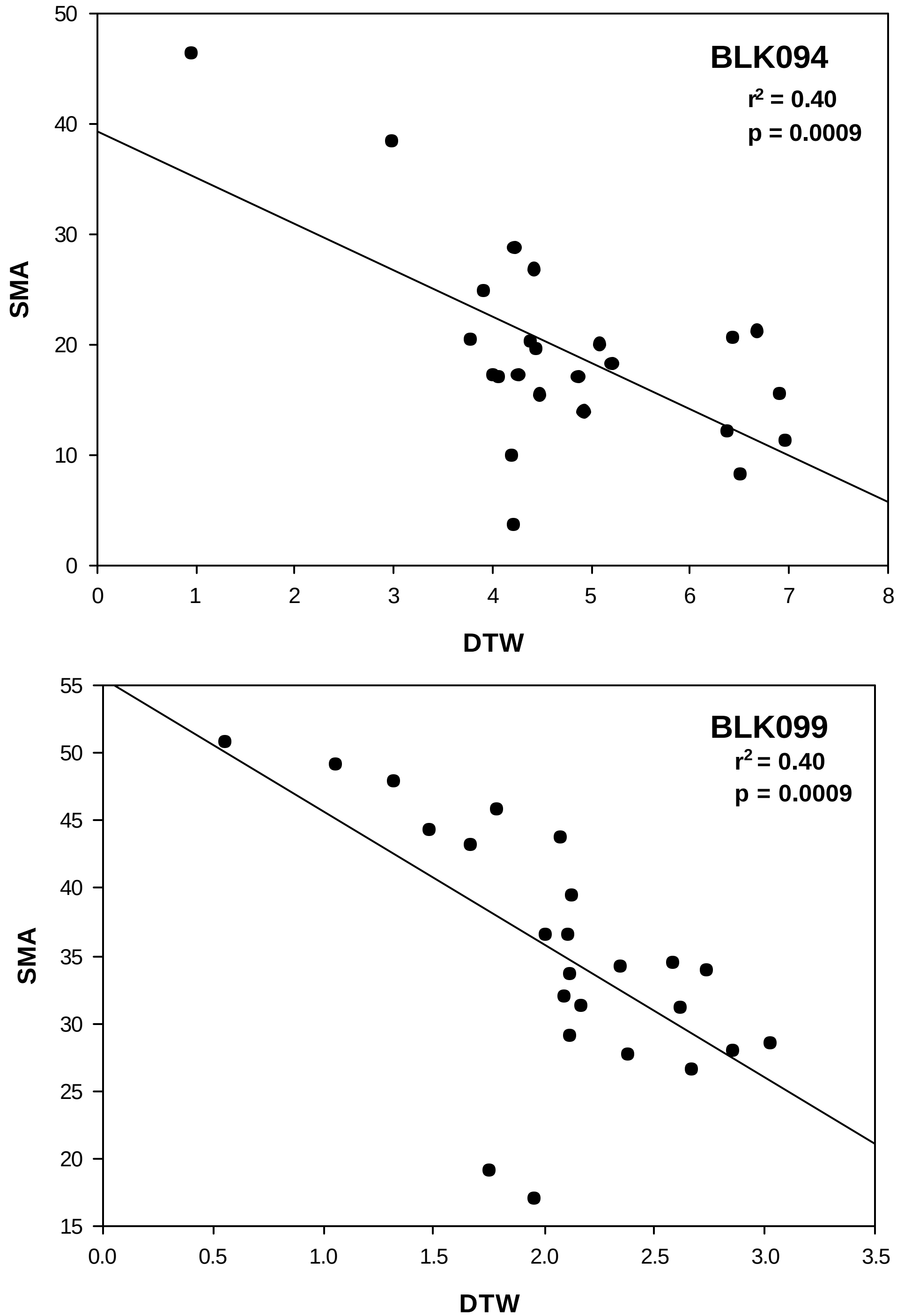



Figure 16. SMA Cover regressed against depth to groundwater (DTW) derived using kriging interpolation.

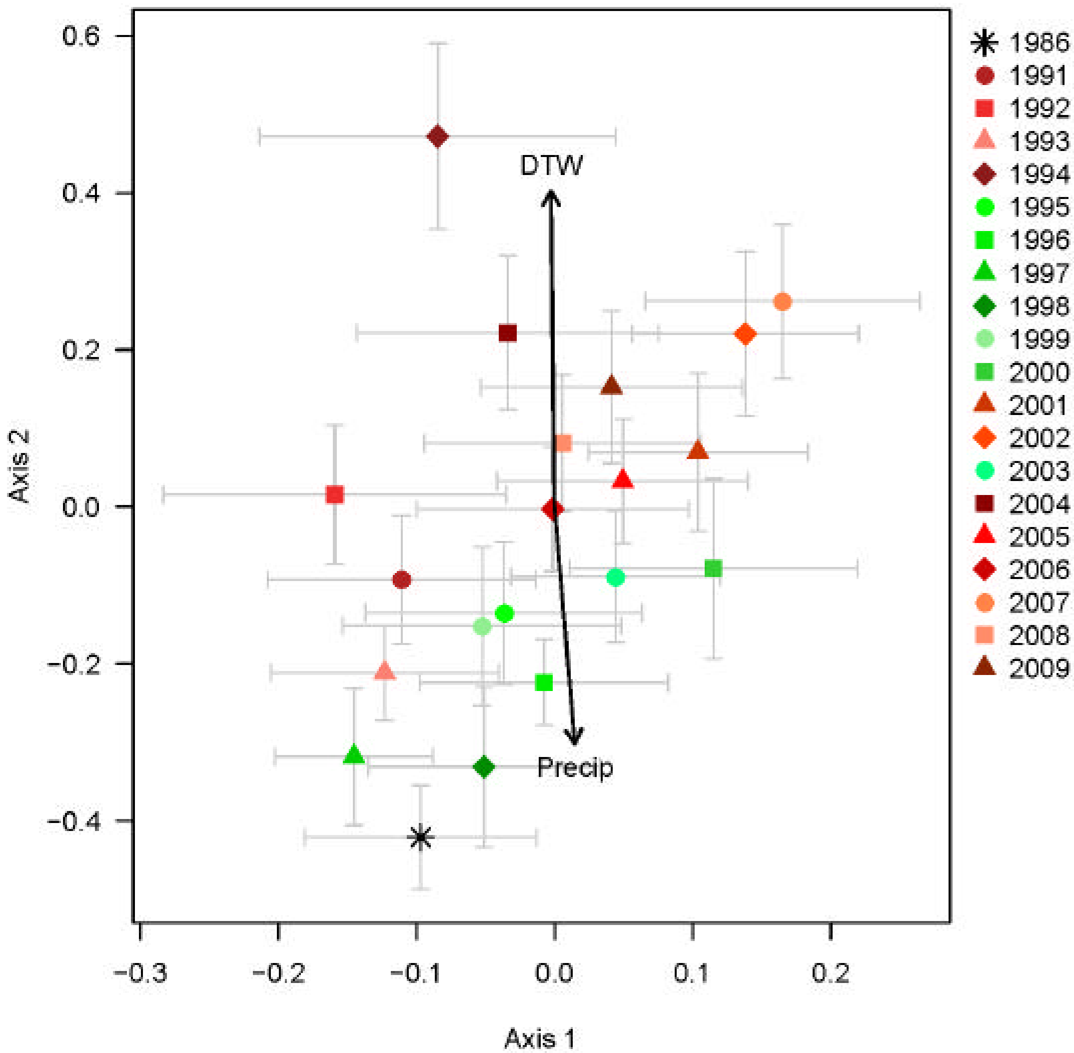



Figure 17a. Joint plot depicting NMDS Ordination of vegetation community composition regressed against depth to groundwater and winter precipitation in Blackrock 94. Each point represents the average location (in ordination space) of transects for each year of sampling from the period 1986, and 1991-2009. Error bars represent the standard error of axis scores for all transects within each year. The baseline year is represented by an asterisk. Vectors point in the direction of increasing environmental gradients, depth to groundwater (*DTW*) and winter precipitation (*Precip*). Fluctuations in depth to water explain more of the changes in vegetation community composition than variation in precipitation.

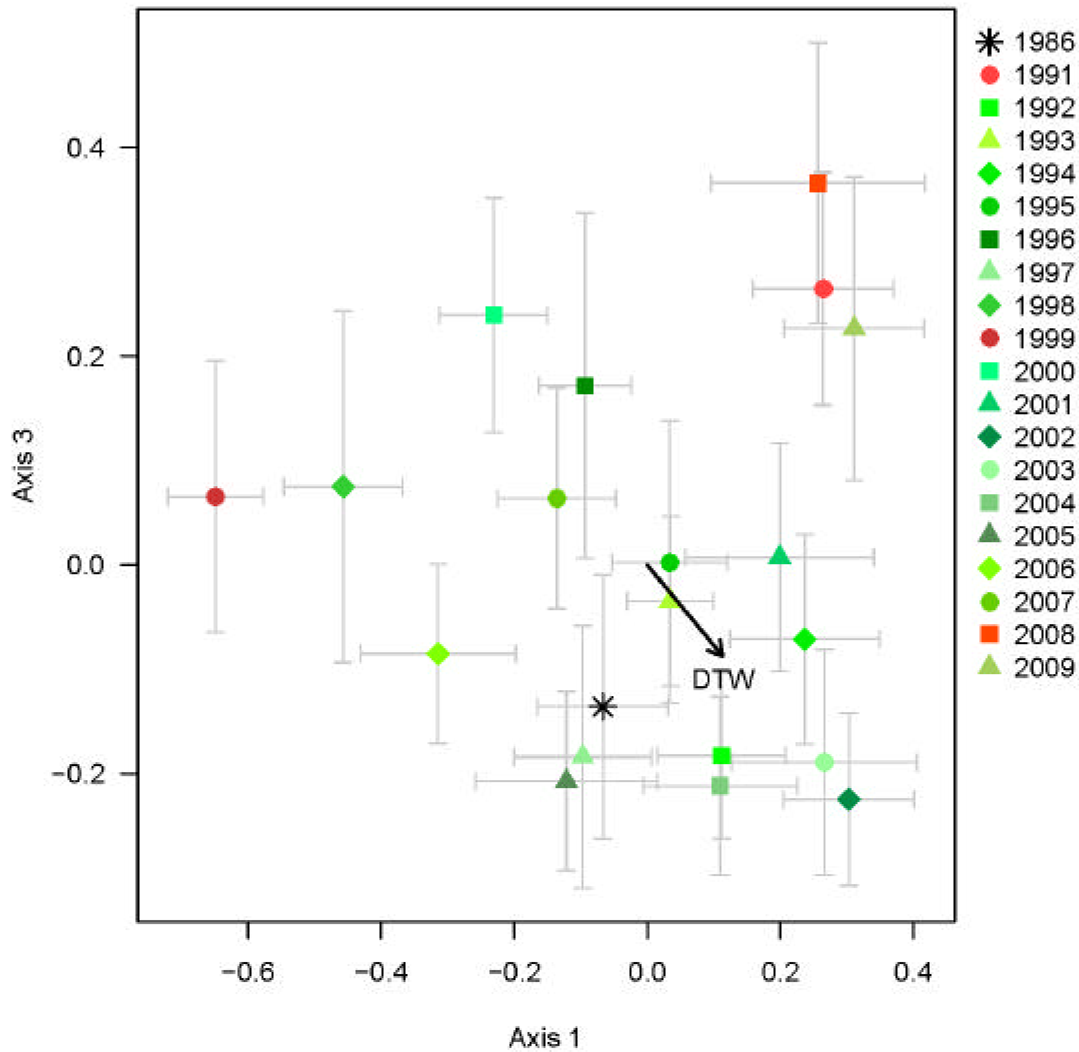



Figure 17b. Joint plot depicting the NMDS Ordination of vegetation community composition regressed against depth to groundwater and winter precipitation in Blackrock 99. Each point represents the average location of transects (in ordination space) for each year of sampling from the period 1986, and 1991-2009. Error bars represent the standard error of axis scores for all transects within each year. The baseline year is represented by an asterisk. Vectors point in the direction of increasing environmental gradients, depth to groundwater (*DTW*). Although the vector points in the direction of increasing groundwater depth, the fluctuations are not great enough to explain changes in vegetation community composition. Variation in precipitation did not explain changes in composition.

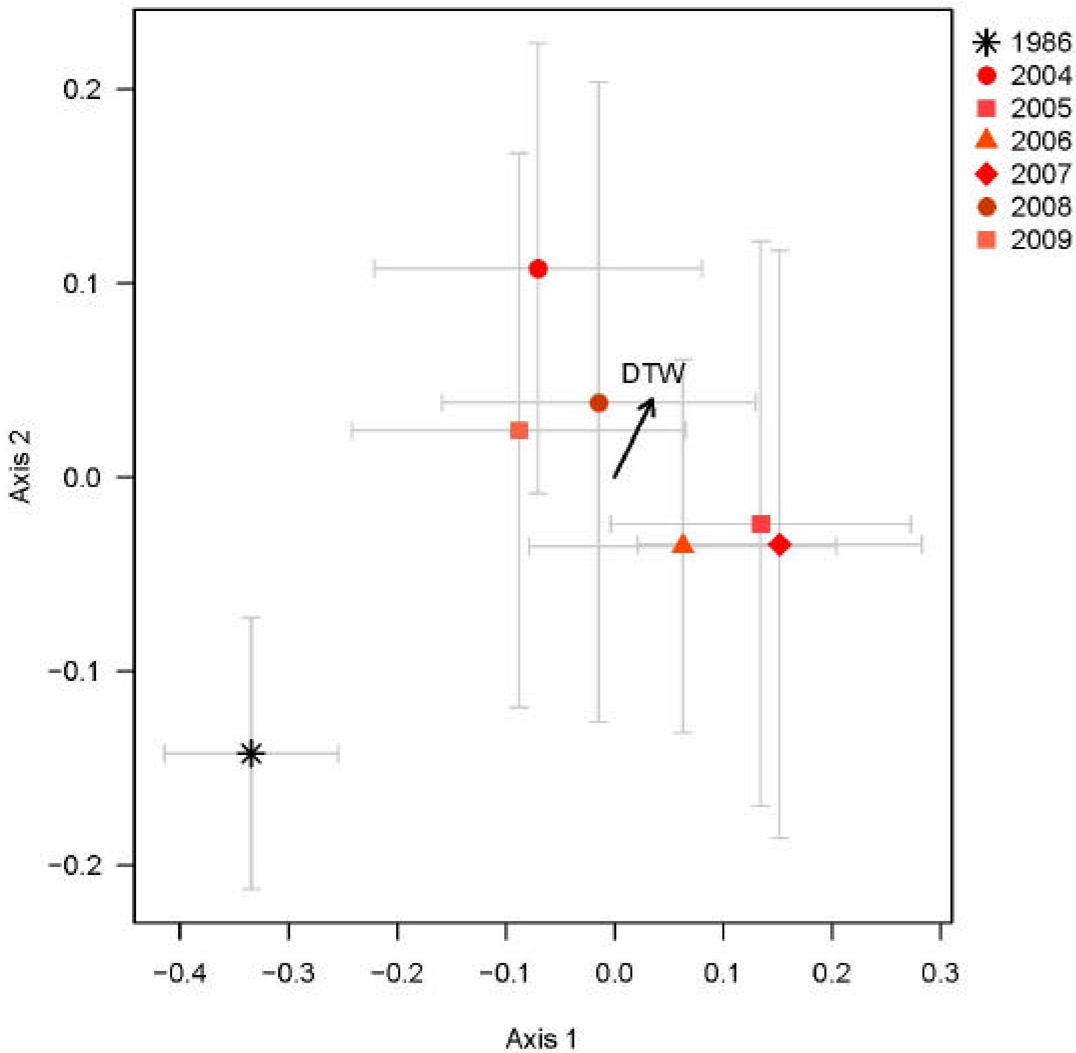



Figure 17c. Joint plot depicting the NMDS Ordination of data collected by LADWP in Blackrock 94. Depth to groundwater was correlated with community composition similar to the result using the Green Book reinventory data. All reinventory years maintain deeper groundwater and are significantly different from baseline ($r^2$ = 0.14, *P* = 0.001). Winter precipitation was not significantly correlated with this ordination. ($r^2$ = 0.0046, *P* = 0.774).

**Causes of water table fluctuations**

In order to determine the relative effects on Blackrock 94 of recharge, pumping from wells at the Blackrock Hatchery, and pumping from other LADWP wells, four scenarios were modeled using the USGS regional groundwater flow model for the Owens Valley (Danskin, 1998). The four scenarios were:

1. Actual pumping. This scenario simulates pumping and recharge as historically occurred. This scenario serves as a standard case to which the following scenarios can be compared.
2. Hatchery pumping only. In this scenario, the only wells pumping are W351 and W356, the two wells supplying the Blackrock Fish Hatchery, pumped in the amounts that they were actually pumped. Recharge was simulated as it historically occurred. This scenario simulates water table changes due to wells at the hatchery without the additional pumping stress of other LADWP wells.
3. No hatchery pumping. In this scenario, pumping is simulated as it actually occurred, except without pumping from wells W351 and W356. This scenario simulates water table changes due to non-hatchery wells.
4. No pumping. In this scenario, no wells are pumped. It simulates how the water table would have fluctuated in the absence of any pumping. Water table fluctuations in this simulation are driven by primarily by fluctuations in recharge. It should be noted that the groundwater model is not equipped to reproduce localized short-lived spreading events.

These scenarios are for comparative purposes. Differences in the effect of each scenario allow the relative importance of various factors to be evaluated. Figures 18 and 19 show the results for the four scenarios described above for monitoring sites TS1 and TS2, respectively. The simulated hydrographs at these two sites located on the eastern and western edge of Blackrock 94 exhibited similar patterns suggesting they adequately represent simulated trends over time at the parcel. The actual pumping scenario shows a period of drawdown from 1971 to 1978, followed by recovery to the mid-1980's, followed by drawdown from 1987 to 1992, followed by a period of recovery to 2001, followed by a slight decline and recovery. The other three scenarios show similar patterns over time, but are offset upwards indicating a higher water table, as would be expected from lower pumping amounts in each simulation compared to what was actually pumped. The hatchery-only and no-hatchery scenarios result in hydrographs roughly midway between the no-pumping and actual pumping scenarios. The no-pumping scenario results in a water table close to the average pre-1970 water table.

Comparison of the actual pumping and no pumping scenarios at both sites shows that after 1970, water tables declined substantially due to pumping, and by the mid-1980s baseline period, pumping had lowered the water table about 6 ft. Under historical pumping, the decline in the water table from 1987 to 1992 was about 13.5 ft at both sites, whereas with no pumping it would have declined about 3-4 ft due to drought, indicating

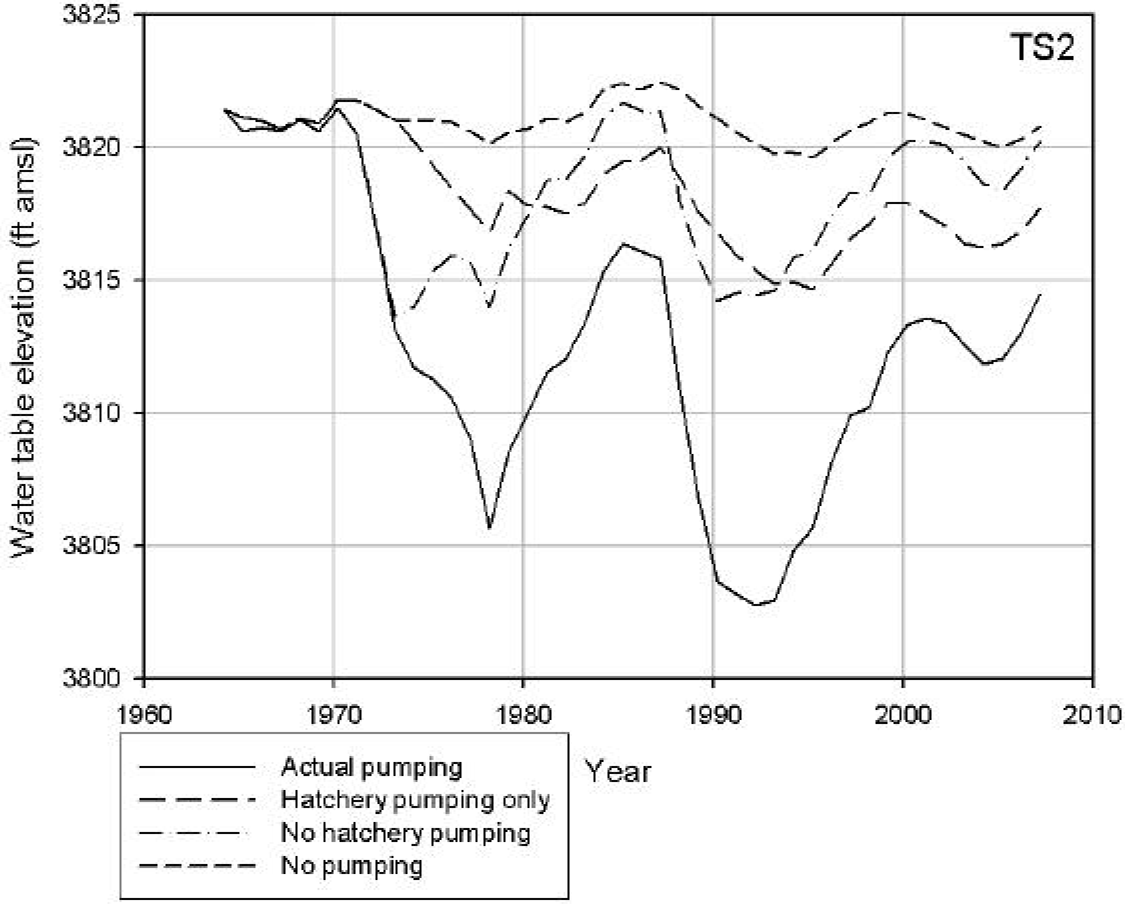



Figure 18. Water table hydrographs for monitoring site TS2. See text for description of the four pumping scenarios modeled. Ground surface is at 3826.4 ft amsl.

that the majority of drawdown from 1987 to 1992, about 10 ft, was caused by pumping from both hatchery and non-hatchery wells. Water tables in 2007 were about 2 ft below mid-1980s levels for all four scenarios. Water table levels in 2007 for the no-hatchery scenario are only 0.5-1.0 ft below the no pumping scenario, because very little non-hatchery pumping has occurred in the vicinity of Blackrock 94 since 1993.

These results indicate that high runoff and recharge conditions during the mid-1980s baseline period resulted in relatively high water tables at that time, consistent with the high surface water uses and losses in the mid-1980's shown in Figure 11. High uses and losses from the surface water system result in increased recharge to the groundwater system. Even without any pumping, 2007 water tables would be slightly below baseline levels. However, the combination of pumping from both hatchery and non-hatchery wells was the largest factor contributing to the water table decline in the 1970's and from 1987 to 1992. Since 1993, pumping from non-hatchery wells has

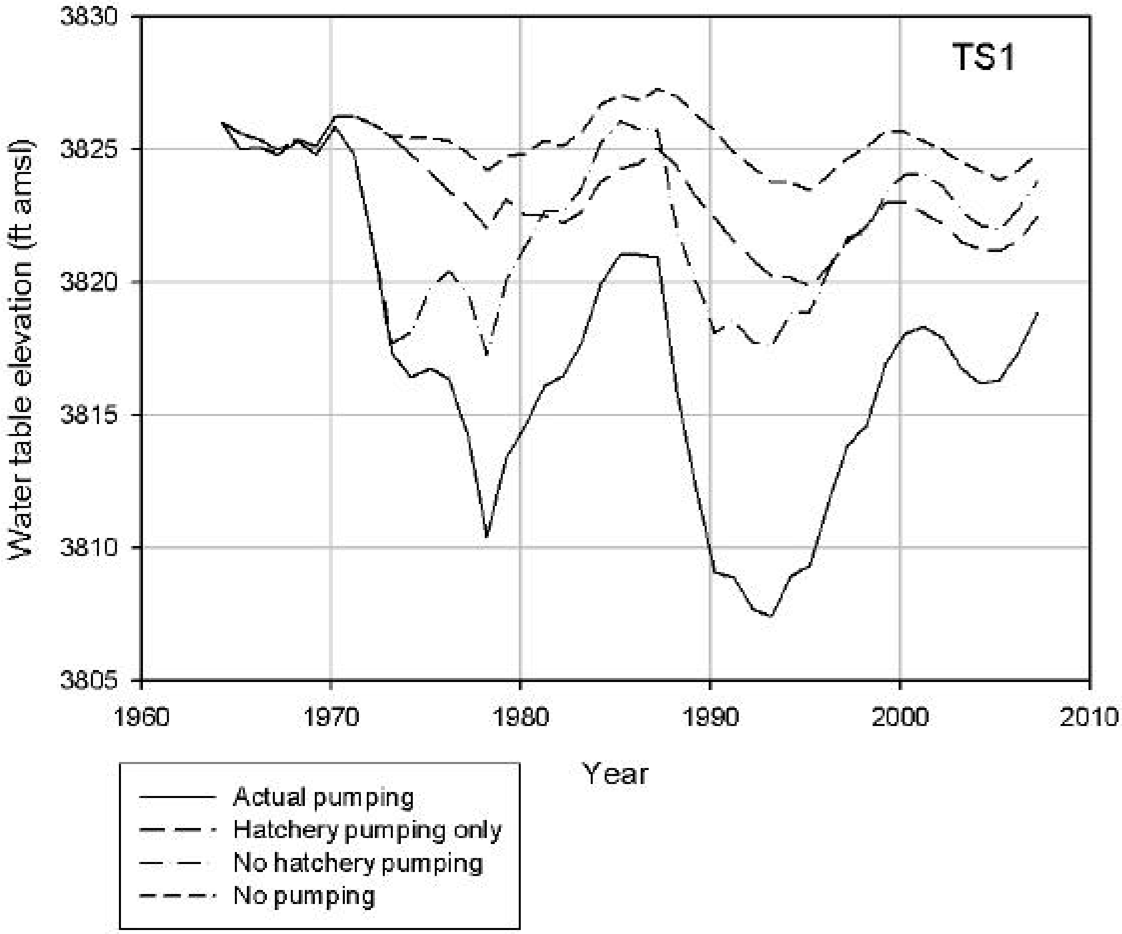



Figure 19. Water table hydrographs for monitoring site TS1. See text for description of the four pumping scenarios modeled. Ground surface elevation is 3842.2 ft amsl.

been limited and the 2007 simulated water levels in the non-hatchery pumping scenario and the no pumping scenario are approximately the same. It is apparent that water tables in the parcel remain impacted by pumping (actual vs. no pumping scenarios) and that raising the water levels to baseline levels or above could be accomplished by a reduction in pumping from wells W351 and W356. However, it is also apparent that the water table would be a few feet below baseline levels solely due to recharge fluctuations, as shown by the no-pumping scenario.

**Role of other factors**

The Green Book lists several other factors to be considered in the attributability analysis, ostensibly to more clearly ascribe the observed vegetation change to one or more specific causes. Other factors include precipitation, grazing, plant disease, wet/dry cycles, wildfire, and vehicle traffic. Unfortunately, quantitative data do not exist to

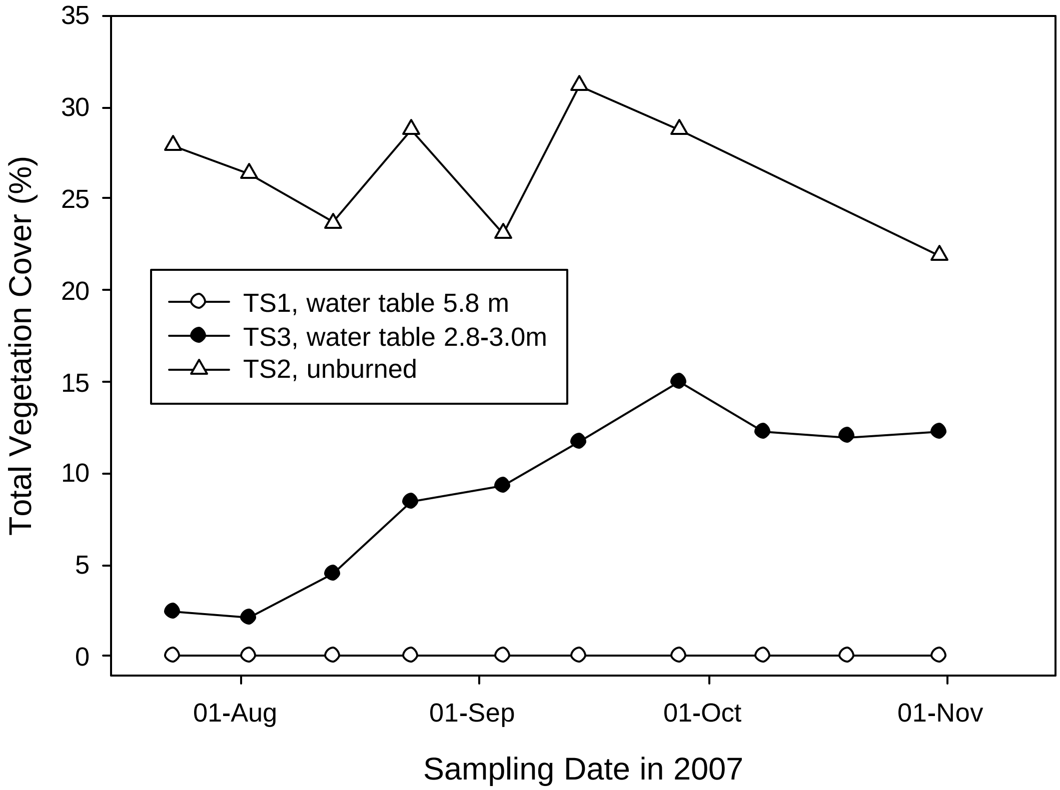



Figure 20. Vegetation cover at permanent monitoring site TS1, TS2, and TS3 following the July 2007 wildfire. Fire burned through sites TS1 and TS3 but not through TS2.

permit evaluation of most of these factors. Information regarding historical grazing management in this area is not available to the Water Department.

In July 2007 fire burned through portions of Blackrock 94 and 99. Vegetation response following the fire differed greatly between TS1 and TS3, the two monitoring sites that burned (Figures 20 and 21). Within days following the fire, perennial native grasses sprouted at TS3. The grass grew vigorously and flowered before the growing season ended in October. In contrast, no grass sprouted along the permanent transect at TS1, and no live hits were recorded along the transect during the remainder of the growing season. As shown in Figure 21, in the summer of 2009, TS3 was dominated by native perennial grasses while TS1 was dominated by an annual exotic weed, *Salsola tragus*. Where the water table is present near the grass root zone, the 2007 fire may support meadow persistence, i.e. promote grasses and slow the increase in shrubs, but fire may hasten the conversion to shrub community in areas like portions of Blackrock 94 where the water table is below the grass roots and the soil is largely barren after the fire. Fire has historically affected Blackrock 94; the 2007 fire was preceded by a fire in the 1970 that affected the parcel.

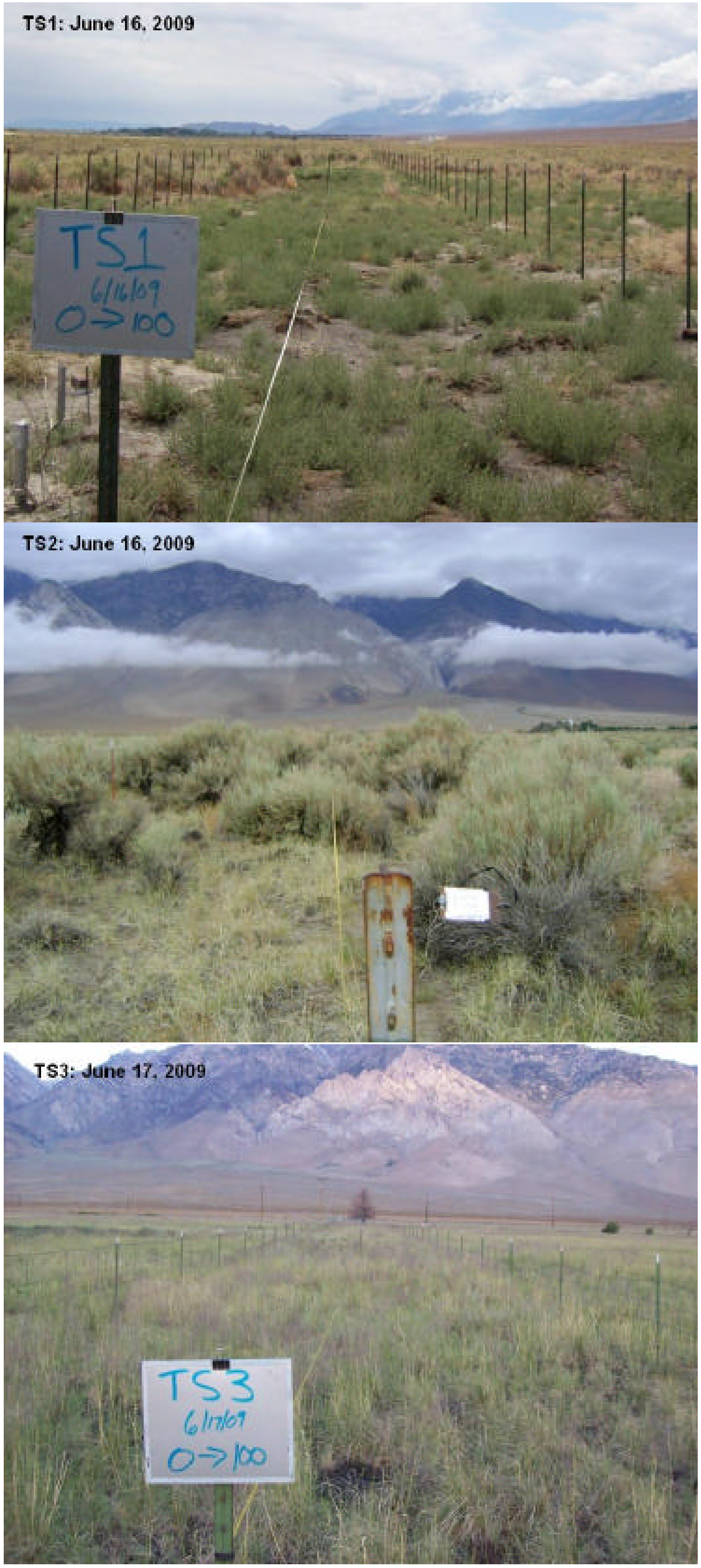



Figure 21. Midsummer 2009 photographs of monitoring sites TS1, TS2, and TS3.

### Summary of attributability analysis

Groundwater modeling shows that the water table at Blackrock 94 was affected by pumping from both hatchery and non-hatchery wells, particularly during the period from 1987-1990. Hydrographs of monitoring wells and remote sensing imagery show that the parcel has been affected by episodic water spreading during periods of high runoff. The relative effect of pumping is greater than the effect of fluctuations in recharge. However, according to the groundwater model, recharge fluctuations are sufficient to explain current deviations from baseline depth to water. Differences between baseline and current depth to water observed in monitoring wells near Blackrock 94 are greater than those produced by the model (Figures 12 and 13).

The earliest soil water measurements show that at two sites in Blackrock 94 the soil was dry by the early 1990's. Soil water at one site (TS2) was replenished below about 2 m depth when the water table rose in the late 1990's. The soil at the other site (TS1) remains dry, and the water level is still too deep to replenish soil water.

Pumping induced declines in the water table 1987-1990 corresponded to decreases vegetation cover and a change in species composition. In Blackrock 94, where pumping has withdrawn the water table from the grass root zone, grass cover has diminished. Groundwater depth is significantly negatively correlated with vegetation cover and species composition in Blackrock 94, because the variation in groundwater is large enough to cause changes in vegetation response. The vegetation community response to groundwater depth is similar when a dataset provided by LADWP is analyzed. The line point and SMA vegetation data both suggest that Blackrock 94 cover responds to both DTW and precipitation, but differ as to which was the predominant factor driving fluctuations in vegetation cover. Comparison with a nearby parcel, Blackrock 99, which did not experience as severe and persistent water table, soil water or vegetation decline suggest pumping and a decrease in recharge were the factors largely responsible for the decrease from baseline vegetation conditions and change in plant composition at Blackrock 94. Contrasting changes in cover and composition between the two parcels that are driven by precipitation and groundwater must be a result of fluctuations in DTW because precipitation is similar in these two adjacent parcels.

## Significance

The LTWA (Section IV.B) and Green Book (I.C.1.c) list a number of criteria to guide the Technical Group in assessing the significance of an impact. The LTWA provides these factors to be considered by the Technical Group: the size, location, and use of the affected area; the degree of the decrease, change or effect within the affected area; the permanency of the decrease, change or effect; whether the decrease, change, or effect causes a violation of air quality standards; whether the decrease, change, or effect affects human health; available factual and scientific data; whether effects of the decrease, change, or effect are limited, but the incremental effects are substantial when viewed in connection with decreases or changes in other areas that are attributable to water management practices by LADWP; and enhancement and mitigation projects that have been implemented by LADWP. The Green Book reiterates the criteria from the LTWA, and adds that the impact on rare or endangered species and on other vegetation of concern should be considered. In the preceding sections concerning measurability and attributability of effects in Blackrock 94, much attention is given to factual and scientific data relating to conditions in the parcel. Each of the other factors is considered below.

**Size, location, and use of affected area**

The size of the area in question is 333 ac. It is located approximately 2 miles south of the Blackrock Fish Hatchery, spanning Highway 395 and is seasonally grazed. The parcel burned in 2007 and part of the parcel has been graded and paved to widen the highway. The 1991 Final Environmental Impact Report for the operation of the second Los Angeles Aqueduct (FEIR, Los Angeles and Inyo County, 1991) identifies numerous significant impacts to vegetation due to groundwater pumping. Several of the specific impacts identified are on a scale similar to that of parcel Blackrock 94. Impact 10-11 identified 655 acres of vegetation die-off and mitigated for this by irrigating the affected area. Impact 10-12 identified approximately 300 acres of impacted vegetation due to pumping wells W385 and W386, and mitigated for the impact by revegetation, water spreading, and cessation of pumping. Impact 10-13 identified that groundwater pumping affected approximately 60 acres in the Symmes-Shepherd wellfield, with mitigation comprising revegetation and water spreading as necessary. Impact 10-14 identified that groundwater affected spring flow and vegetation at spring vents in an area less than 100 acres, and various off-site mitigations were undertaken. Impact 10-18 identified vegetation decrease and change on approximately 640 acres in Laws, which was mitigated by 140 acres of revegetation and 541 acres of irrigation.

These affects and mitigations documented in the FEIR indicate that impacts to areas of vegetation of similar size to parcel Blackrock 94 were considered significant in the FEIR, and a variety of strategies and actions were implemented to mitigate for the impacts.

**Degree of change in affected area**

Baseline perennial cover measured 41%, while, on average, parcel cover from 1991-2009 was 27% (Figure 3a). This represents a 1/3 decrease in cover on average, while in the same period, Blackrock 99 has increased in cover. The decrease in vegetation cover is persistent, occurring in 14 of 19 years since the Green Book monitoring program began in 1991. Grass cover has decreased, while shrub cover is has changed little resulting in an increasing proportion of shrubs (Figures 5a and b, Figure 6). Changes in vegetation community composition suggest a transition from Type C to Type B vegetation is occurring in Blackrock 94 (Figures 7a and 17a). Such a decrease and change is contrary to the goals of the LTWA.

**Permanency of change in affected area**

Vegetation monitoring indicates that Blackrock 94 has been persistently below baseline levels since 1991 and has experienced a decrease in grass cover resulting in an increase in the proportion of shrubs in the parcel (Figure 5a and b). This shift from meadow to scrub vegetation represents a degradation in grazing and habitat value and is contrary to LTWA goals. The change may be ameliorated with favorable hydrologic conditions and management to reduce shrubs.

**Air quality**

There are no air quality data for this specific site.

**Species of concern and Other vegetation**

*Calochortus excavatus* or Inyo County star tulip is endemic to Inyo and Mono counties and grows in alkali meadow habitat. *C. excavatus* is classified as CNPS List 1B.1: seriously endangered in California. In 1995, a senesced *C. excavatus* plant was discovered on the TS2 permanent monitoring site transect in June. Only the dried remnants of the plant remained in 1996, and no other *C. excavatus* plants were observed. In 1997 the area was searched in early May, the typical peak flowering time for this species, and seven senesced plants were found. Following the relatively wet winter of 1998, the site was visited in late April and a thorough search of the area was conducted.

Sixteen plants were mapped to enable monitoring in subsequent years. By June, only three were reproductive, and most of the plants had senesced. The same day a newly-observed population of *C. excavatus*, located about 1 mile south of TS2 near monitoring well T581 was visited. A brief walk through the area revealed about 50 robust flowering and fruiting *C. excavatus* individuals. Inyo County has continued to monitor both populations. At TS2, the 16 mapped locations are checked for plant presence/condition, and the general area is searched for any other *C. excavatus* individuals. Typically, in dry years, either no plants are found, or a few senescent leaves are found (Table 1). No new *C. excavatus* have been found at TS2. At the T581 site, individual plants are not mapped for permanent monitoring, but the area is searched during peak flowering time. Plants are flagged and counted, population phenology is assessed, and notes are recorded on site conditions. Since monitoring began at T581, plants have been found in the original footprint of the population as well as the surrounding area. In some years, hundreds of individuals are counted. Plant condition has been noted as good to robust, and high percentages of the plants observed have been reproductive. Overall, the rare plant data are insufficient to document any trend or impact related to LADWP surface water or groundwater management.

Table 1. *Calochortus excavatus* monitoring results for TS2 and T581 populations. Information presented includes monitoring year, date, number of green, number of flowering or fruiting plants observed. Depth to groundwater (DTW) data for TS2 are from test well T806. Sixteen actual plant (bulb) locations are checked each year at TS2 (see text). At T581, the extent of the population is searched each year.

| | TS2 | | | T581 | | |
|---|---|---|---|---|---|---|
| **Year** | **vegetative** | **flowering/ fruiting** | **DTW (m)** | **vegetative** | **flowering/ fruiting** | **DTW (m)** |
| 1997 | 7 | 0 | 4.1 | - | - | 1.9 |
| 1998 | 14 | 2 | 3.8 | 0 | ~50 | 1.1 |
| 1999 | 2 | 0 | 3.9 | - | - | 1.8 |
| 2000 | 0 | 0 | 4.0 | 25 | 5 | 2.1 |
| 2001 | 4 | 0 | 4.0 | 61 | 20 | 2.1 |
| 2002 | 1 | 0 | 4.1 | 72 | 24 | 2.1 |
| 2003 | 5 | 1 | 4.5 | 139 | 155 | 2.0 |
| 2004 | 0 | 0 | 4.5 | 47 | 33 | 2.2 |
| 2005 | 7 | 1 | 4.2 | 80 | 210 | 1.6 |
| 2006 | 6 | 2 | 4.2 | 22 | 398 | 1.5 |
| 2007 | 1 | 0 | 4.2 | 34 | 42 | 2.0 |
| 2008 | 3 | 5 | 4.3 | 61 | 111 | 1.9 |
| 2009 | 1 | 0 | 4.3 | 7 | 16 | 2.0 |

**Affects on human health**

There is no indication that the condition of the parcel is affecting human health. .

**Cumulative impact**

In order to describe valley-wide cumulative impacts, we define two types of vegetation parcels, 'control' and 'wellfield' parcels. Control parcels are defined as such because they are not affected by groundwater pumping; these parcels are generally located distant from pumping wells. In contrast, wellfield parcels show a reduction in groundwater below the parcel as a result of groundwater pumping. This category was determined using both groundwater modeling and interpolation of DTW measurements using kriging. According to groundwater modeling, all control parcels in this analysis were located outside the 10ft drawdown contour surrounding pumping wells shown on LTWA baseline maps. In addition, where the kriging data are reliable, under control parcels the water table did not decline more than 1m between the years 1987 and 1988-1992, a period of heavy pumping. All other parcels were considered wellfield parcels.

The vegetation degradation measurable in Blackrock 94 has not occurred in isolation. Since monitoring began in 1991, 26 parcels have been sampled each year encompassing a total of 3936 acres. Because a larger number of parcels (n = 45, 5445 acres) has been sampled since 1992, the analysis of cumulative impacts in the Owens

Valley were based on that set of parcels. There was a significant interaction between time and parcel type (i.e. control or wellfield, $P < 0.0001$) according to repeated measures multivariate analysis of variance (MANOVA) suggesting control parcels behave differently than wellfield parcels with respect to time (Figure 22). Further, pairwise testing using the set of parcels sampled each year from 1992-2009, following an Analysis of Variance (ANOVA) using Tukey's Honestly Significant Difference (HSD) shows that wellfield parcels were generally below baseline while controls were generally above ($P < 0.05$, Figure 23). Tukey's HSD was chosen because it controls the alpha or significance level when multiple pairwise comparisons are tested. Permutational ANOVA could be used, but Tukey's HSD is a slightly more conservative (less likely to falsely identify a significant change). Regardless, the results generated with permutational ANOVA were generally consistent with those presented in this report.

Finally, a regression of all wellfield parcel cover against depth to groundwater under these parcels is significant (Figure 24a and b, $r^2 = 0.236$ and $r^2 = 0.236$ for the 1991-2009 and 1992-2009 set of parcels respectively and $P < 0.0001$ for both regressions). Because wellfield parcels are consistently below baseline measurements, and groundwater fluctuation is significantly correlated with cover in wellfield parcels, the impact in Blackrock 94 is similar to other affected wellfield parcels in the Owens Valley. While controls generally show no correlation between cover and DTW, like we observed in Blackrock 99.

Evaluation of the significance of the change in vegetation valley-wide is beyond the scope and purpose of this report, however, the results presented here indicate that the documented decreases and changes affecting Blackrock 94 are not occurring in isolation. We recommend the Technical Group develop an approach to adhere to the LTWA language requiring that significant impacts be assessed on a case-by-case basis.

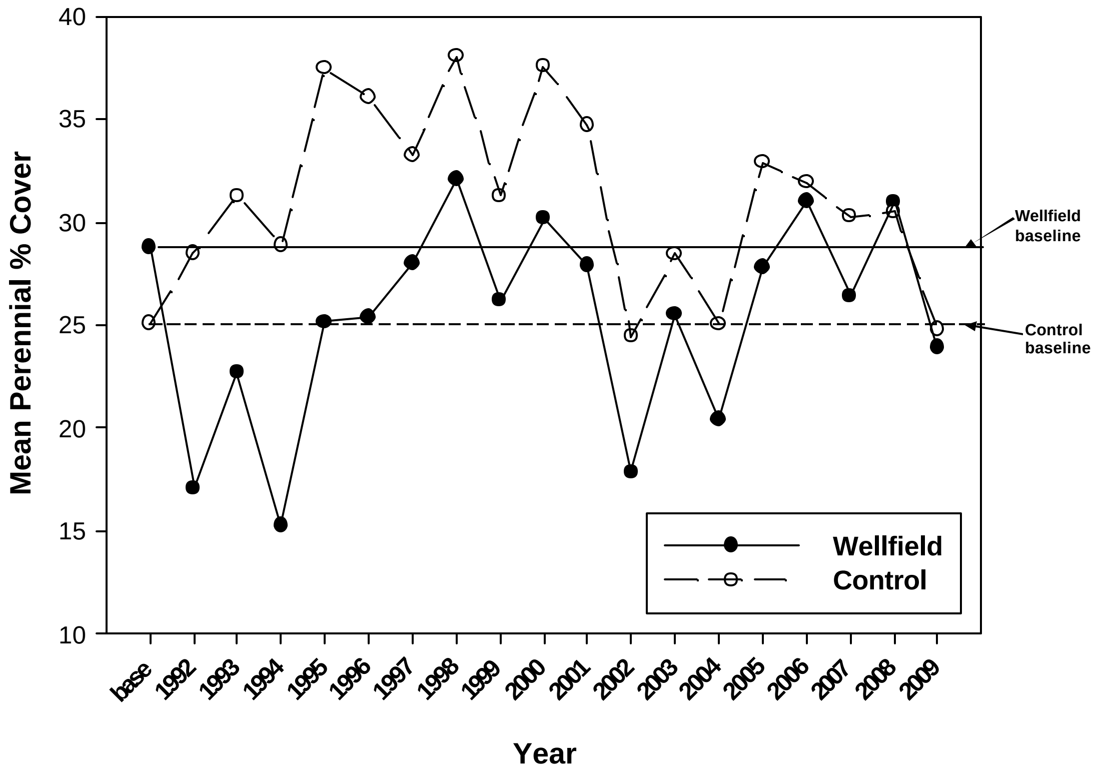



Figure 22. Repeated Measures MANOVA analysis of parcels sampled from the period 1992-2009 (n = 45). The interaction of time and parcel type (factor) is significant, indicating that control parcels behave differently than wellfield parcels with respect to time ($P < 0.0001$). Mean wellfield parcel percent cover is below baseline for most of the years since baseline measurements, while mean control parcel cover has been above baseline during the same period.

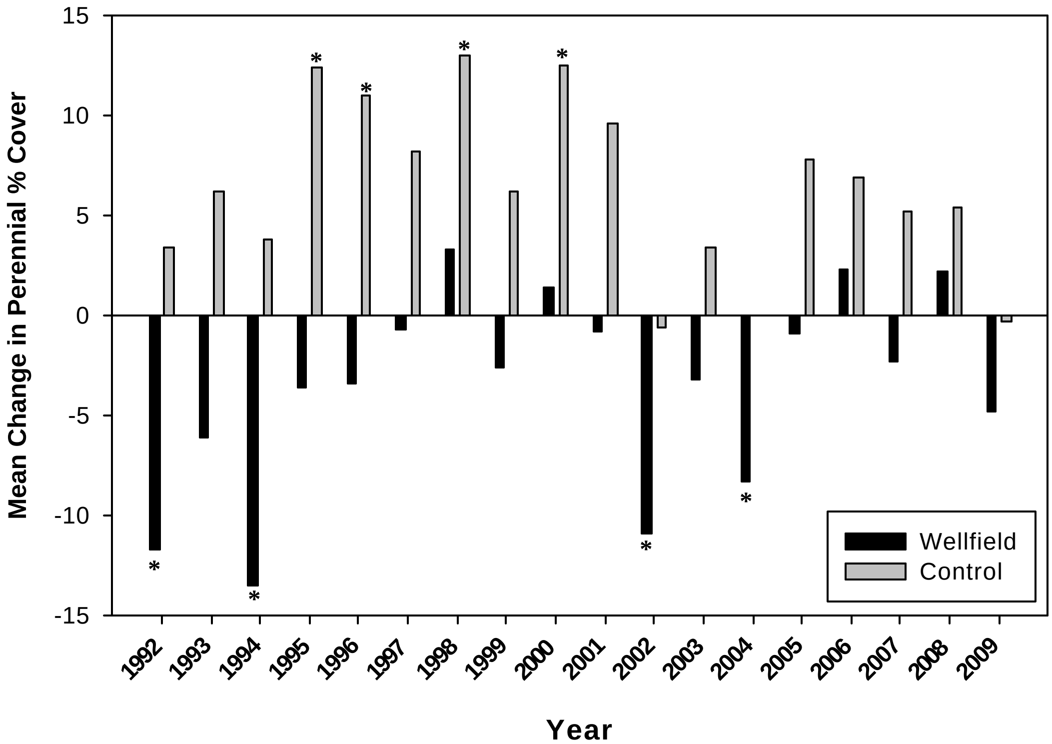



Figure 23. Change in vegetation cover compared to baseline for wellfield parcels measured by the Green Book line point program for the subset of wellfield parcels visited every year since 1992 (n = 45). Asterisks denote instances where change in mean cover was significantly different from zero ($P \leq 0.05$, ANOVA with Tukey's HSD).

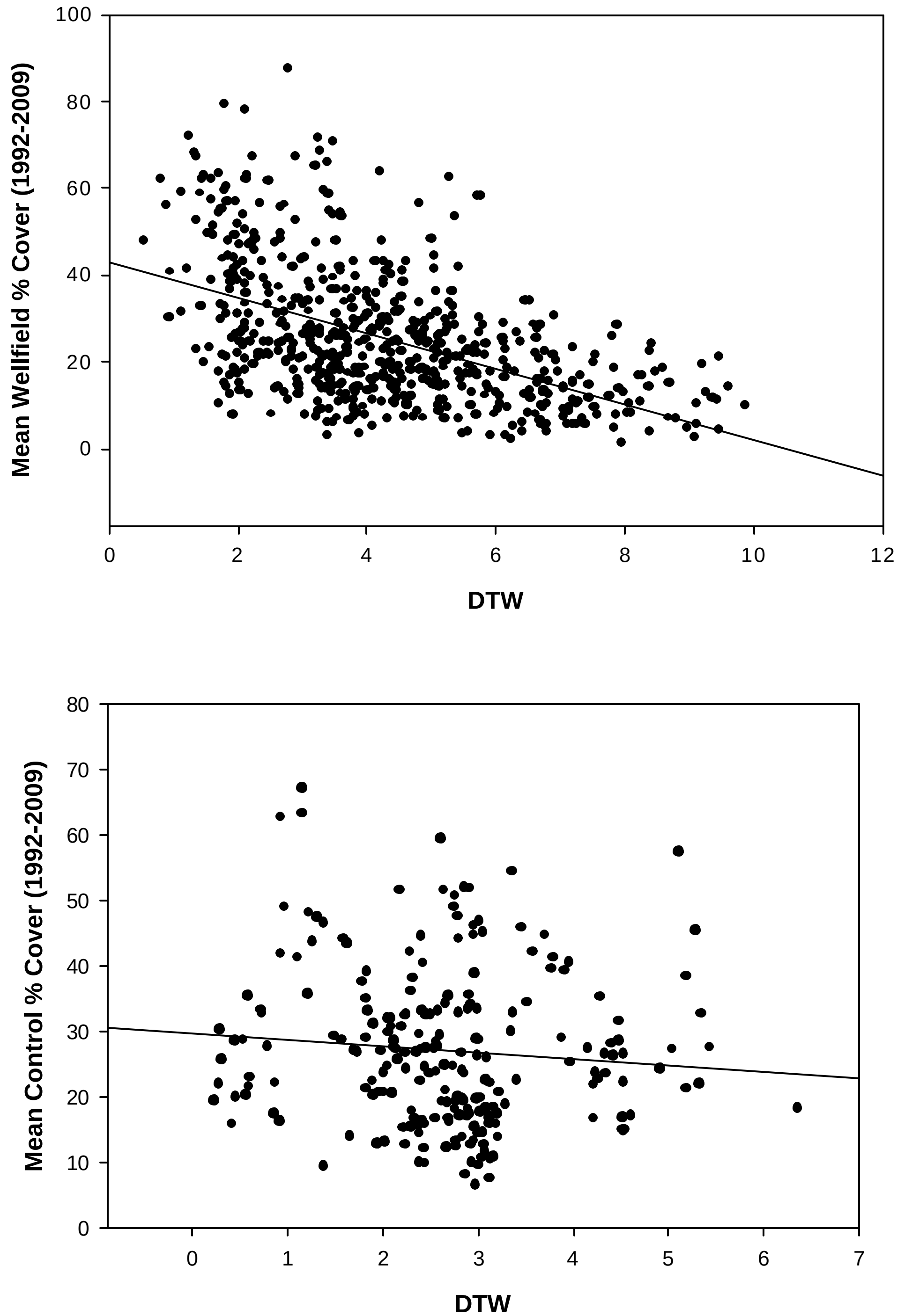



Figure 24a and b. Mean wellfield (top) and control (bottom) parcel cover regressed against average parcel depth to groundwater (DTW) for the set of parcels reinventoried each year between 1992 and 2009 ($n_W$ = 32 and $n_C$ = 13). As DTW increases in wellfield parcels, vegetation cover decreases ($r^2$ = 0.236, $P$ < 0.0001), while no relationship is found between control parcels and observed changes in depth to groundwater ($r^2$ = 0.008, $P$ = 0.17).

**Value of existing EM and mitigation projects**

The effects discussed above in Blackrock 94 were not identified in the 1991 FEIR and have not been mitigated by any project currently completed or planned as part of the Agreement, MOU, or 1991 FEIR.

In 1991 FEIR Chapter 10 (Vegetation), Impact 10-14 identified that "*Increased groundwater pumping has reduced or eliminated flows from Fish Springs, Big and Little Seeley Springs, Hines Spring, Big and Little Blackrock Springs, and Reinhackle Spring. This has caused significant adverse impacts to vegetation at several of these springs.*" Impacts identified at Big and Little Blackrock Springs are elimination of spring flow, elimination of riparian and emergent vegetation, and reduction in pond area. The impacts that have occurred or are occurring at Blackrock 94 – type change from type C to type B and loss of cover in an alkali meadow – differ distinctly from the loss of riparian, marsh, and pond habitat identified in Impact 10-14. Impact 10-14 relates to losses of vegetation and habitat near the Big and Little Blackrock Springs spring vents that depend directly on the spring outflow, whereas Blackrock 94 is a groundwater dependent meadow 1.3 – 2.3 miles from the former vent of Big Blackrock Spring. Mitigation Measure 10-14 identifies the Lower Owens River Project and the production of fish at Blackrock Hatchery as mitigation for Impact 10-14; however, because Impact 10-14 differs from the impacts to Blackrock 94, Mitigation Measure 10-14 does not mitigate for vegetation decreases and changes at Blackrock 94. Mitigation Measure 10-14, states "*…not all springs and associated riparian and meadow vegetation will receive on-site mitigation…*" The distance between Big Blackrock Spring and Blackrock 94 is sufficiently large – over one mile – that the alkali meadow vegetation comprising Blackrock 94 cannot be considered "associated" with the spring. Mitigation Measure 10-14 states "*the area of riparian and meadow vegetation that has been lost and will not be restored because of the elimination of spring flow due to groundwater pumping is estimated to be less than 100 acres.*" Vegetation parcel Blackrock 94 is an additional 332 acres that has not been mitigated for in the FEIR.

The FEIR discusses monitoring and mitigating future impacts, such as those discussed in the report, and identifies the LTWA process for evaluating and mitigating future impacts as a mitigation measure. This mitigation measure is described in the FEIR on pages 10-69 – 10-70, where it is stated:

> *As described throughout this impact section, decreases and changes in Owens Valley vegetation have occurred since operations to supply the second aqueduct commenced. Many on-site and compensatory mitigation measures are discussed in this section. However, the Agreement itself serves as a Valley-wide mitigation measure. As stated in Chapter 9 – Water Resources, because of an extremely wet period between 1982 and 1986, the water table recovered to pre-1970 levels in all areas of the Valley except around the Fish Springs and Blackrock fish hatcheries and in portions of the Laws area. During this same period, because of high runoff, precipitation, and the restored water tables, vegetation recovered to its greatest vigor since 1970. Under the provisions of the Agreement, the goal is to*

> *manage groundwater and surface water to avoid significant decreases and changes from these vegetation conditions; therefore, these provisions of the Agreement are themselves a mitigation measure.*

Thus, the FEIR anticipated that impacts not mitigated by specific mitigation measures would be avoided or provided with additional mitigation. In terms of how to evaluate whether an impact has occurred, the FEIR (p 10-59) provides that:

> *The goals of the Agreement are to manage Owens Valley groundwater and surface water resources to avoid significant decreases in the live cover of groundwater dependent vegetation (management Types B, C, and D), and to avoid a change of a significant amount of such vegetation from one management type to vegetation in another management type which precedes it alphabetically. The vegetation conditions documented during the 1984-87 vegetation inventory serve as the base for comparison for determining whether decreases and changes have occurred.*

The FEIR anticipated that the Technical Group would exercise its responsibility to evaluate impacts during the implementation of the LTWA by comparing current conditions with conditions documented during the period 1984-87.

W351 and W356 are exempt from well turn-off provisions and are not linked to vegetation monitoring sites. However, neither section IV.B of the LTWA nor the mitigations of the FEIR provide that significant impacts from exempt wells need not be mitigated. Green Book section I.B.2 requires that:

> *If it is established that there has been a significant decrease in live vegetation cover, or a significant amount of vegetation has changed from one vegetation classification to a lower classification, or any other significant effect on the environment has occurred, then any such significant impact will be mitigated as soon as a reasonable and feasible mitigation plan is developed.*

The forgoing provides that any significant impact from LADWP water management will be mitigated, regardless of whether the well causing the impact is exempted from the well turn-off provisions of the LTWA.

**Summary of Significance Analysis**

While the declaration of a significant impact is necessarily a subjective assessment, the LTWA provides a number of factors – some quantitative, some qualitative - to evaluate when assessing the significance of an impact. Several of these factors indicate that a significant change is occurring in Blackrock 94 – the areal extent of the parcel is significant; the degree of change is significant, change is persistent in time, and the impact to the parcel has not been mitigated. Although this report does not examine cumulative impacts exhaustively, the results presented here indicate that the decreases and changes documented here are not occurring in isolation. The significance of other factors such as human health effects, air quality impact, and rare plants are unknown or inconclusive. In total, these impacts are significant.

## Conclusions

The Water Department has evaluated conditions in vegetation parcel Blackrock 94 in accordance with the LTWA Section IV.B and Green Book Section I.C. Available factual and scientific data indicate a measurable vegetation change since baseline has occurred in Blackrock 94, both in terms of vegetation cover and species composition. These changes occurred between baseline and 1991 and have persisted in time. Vegetation composition has changed toward increasing shrub proportion and a decrease in grass cover. While the proportion of shrubs in Blackrock 94 has not yet caused the parcel to change from Type C to Type B vegetation status, changes in species composition suggest a change in Type is occurring. Parcel Blackrock 94 is currently Type C, but is changing to Type B. Vegetation degradation is primarily attributable to changes in water availability resulting from groundwater pumping and reduced surface water diversions into the vicinity of Blackrock 94. The factors prescribed in the LTWA and Green Book for assessing the significance of an impact were evaluated and indicate that a significant change is occurring in Blackrock 94. The terms of the LTWA require that such impacts be avoided or mitigated.

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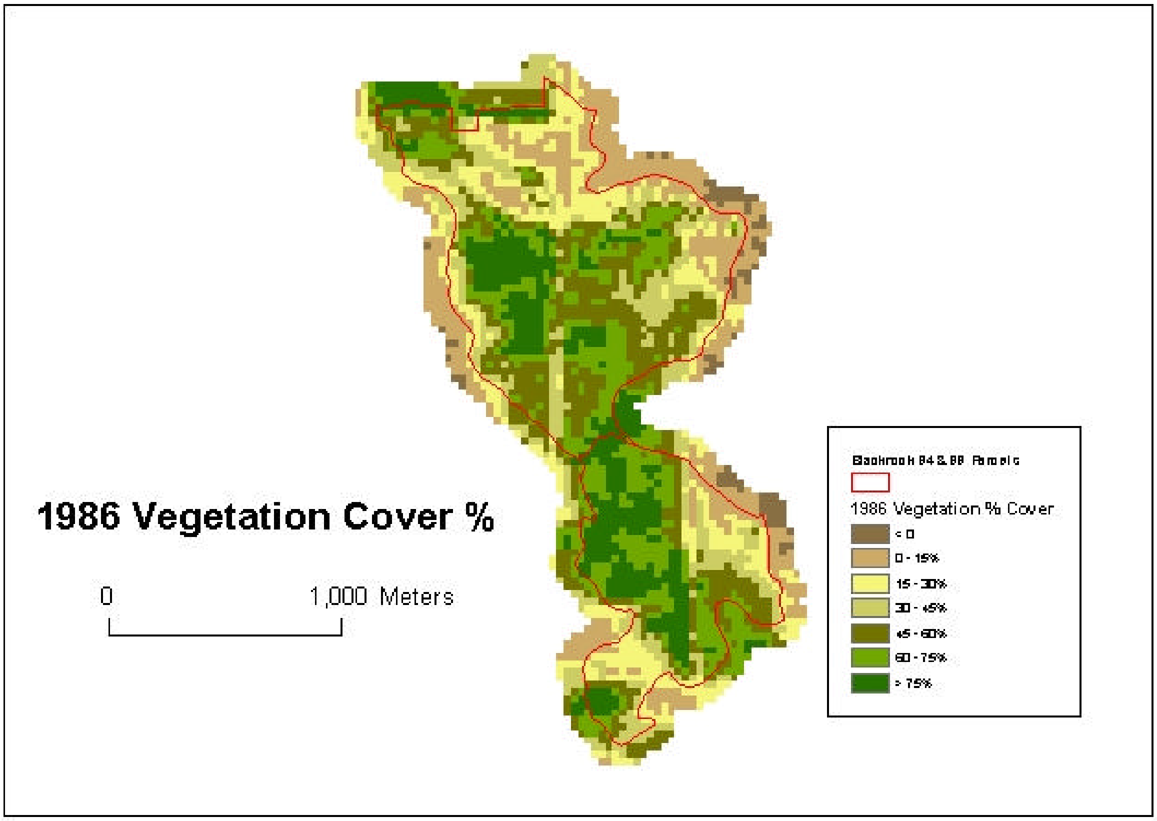
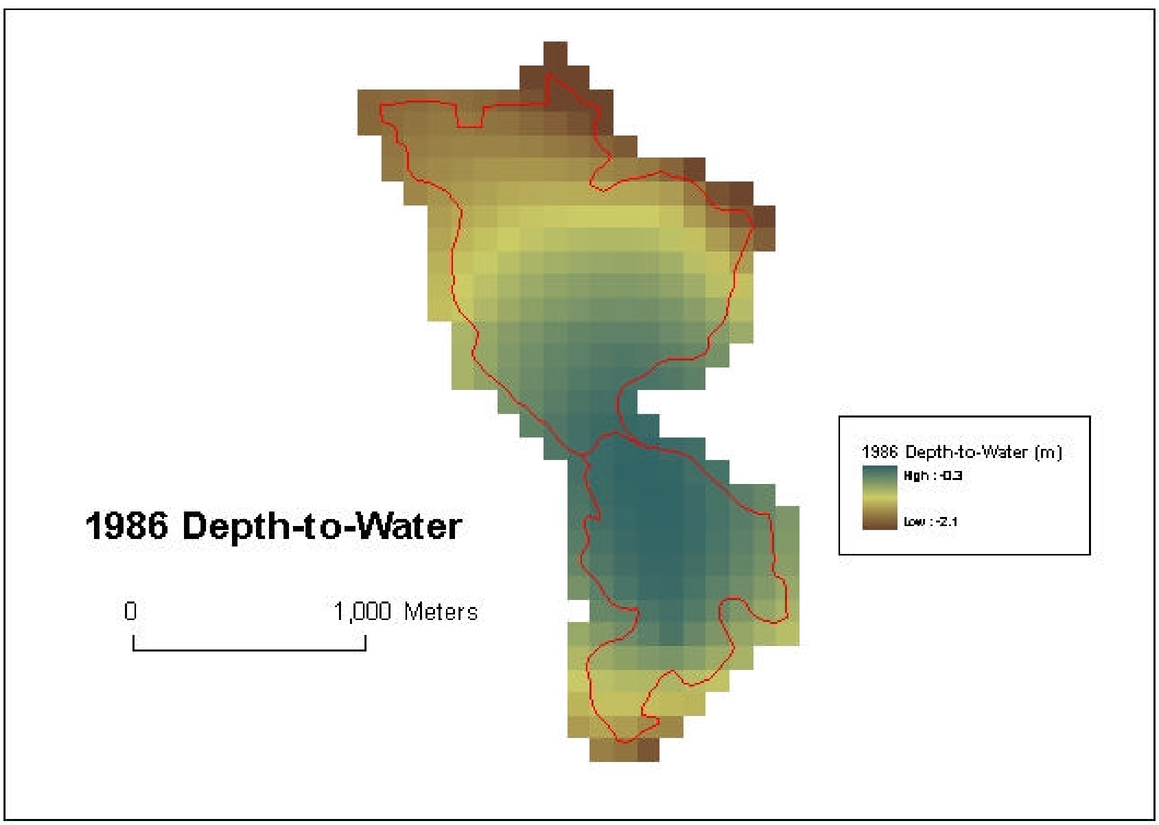
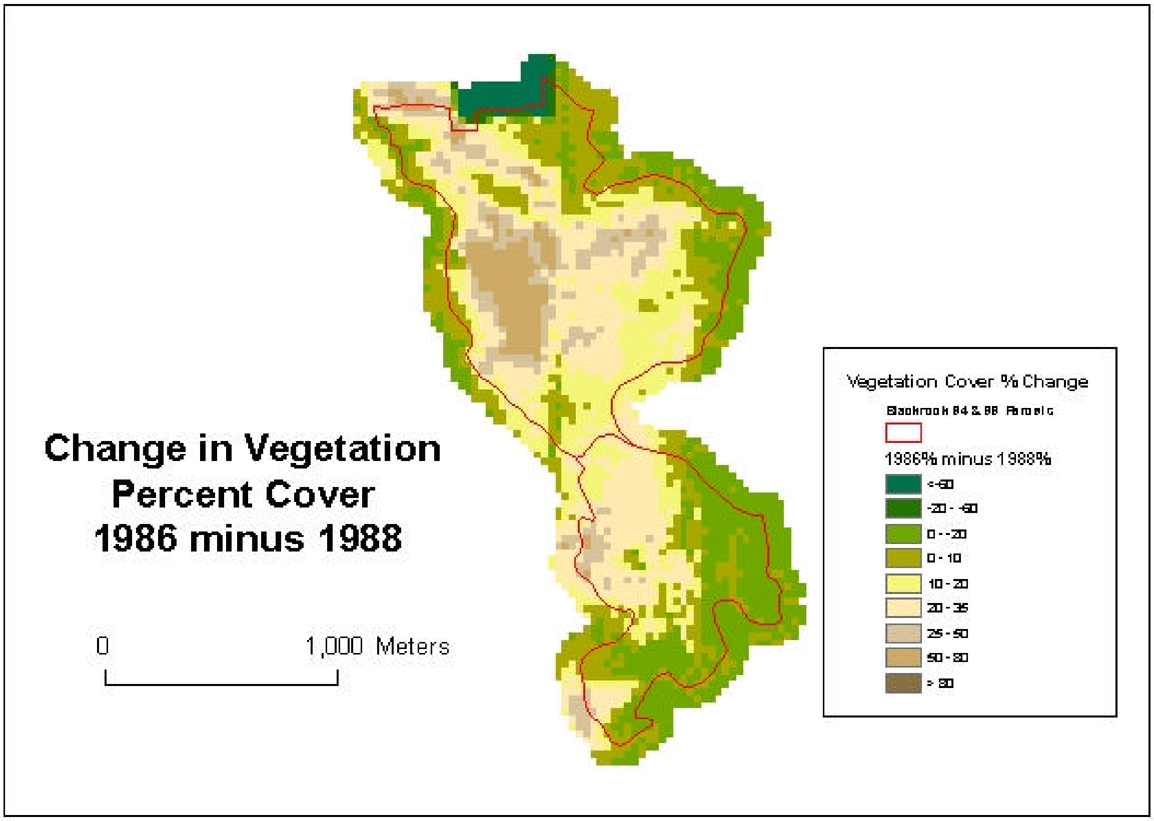
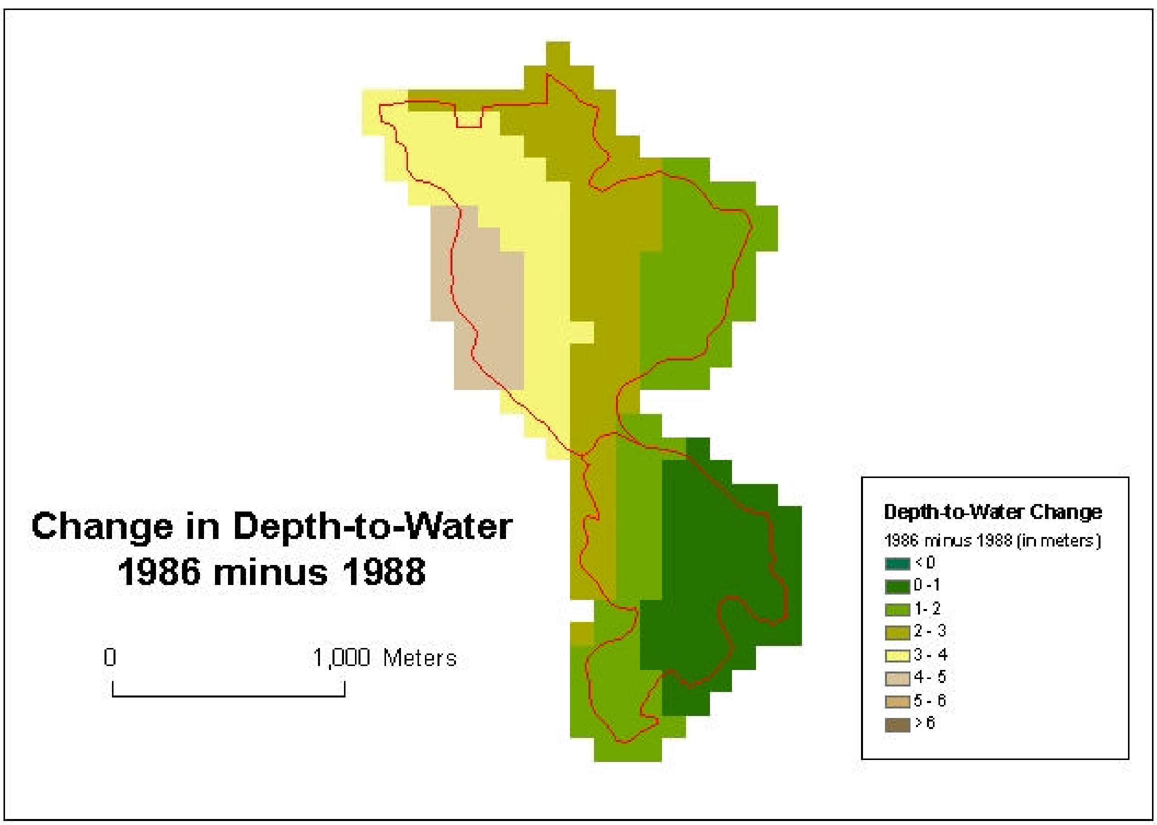
## Appendix A

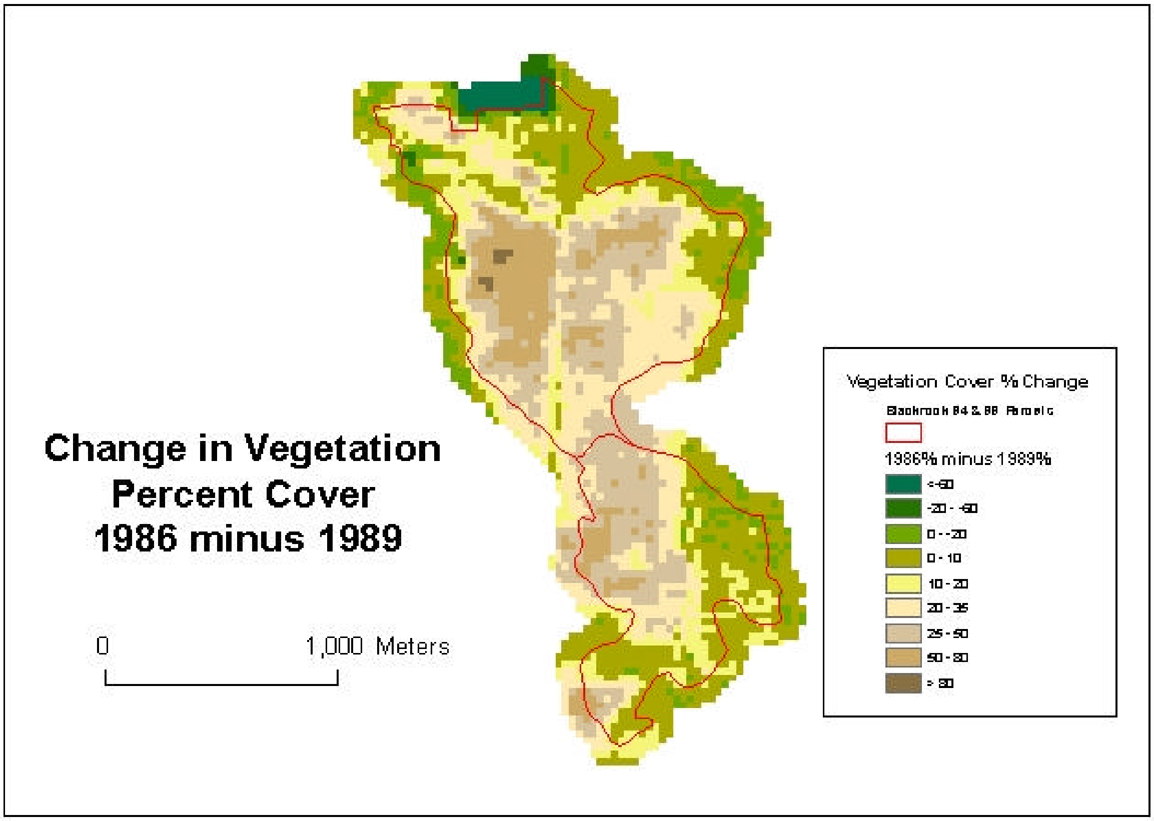
Maps of change in vegetation cover and depth to water (DTW) from baseline for parcels Blackrock 94 and 99 for each year 1986-2009. The top map shows the change in total vegetation cover measured using SMA satellite data between 1986 when the baseline vegetation was mapped and each year until 2009. Positive values of change reflect a decline in vegetation cover. The bottom map shows the change in DTW estimated using ordinary kriging between 1986 and each year until 2009. Positive values of change reflect a decline in the water table. The methods to derive the cover and DTW values are described in the report.


1986 Vegetation Cover %
0
1,000 Meters
1986 Vegetation % Cover
< 0
0 - 15%
15 - 30%
30 - 45%
45 - 60%
60 - 75%
> 75%

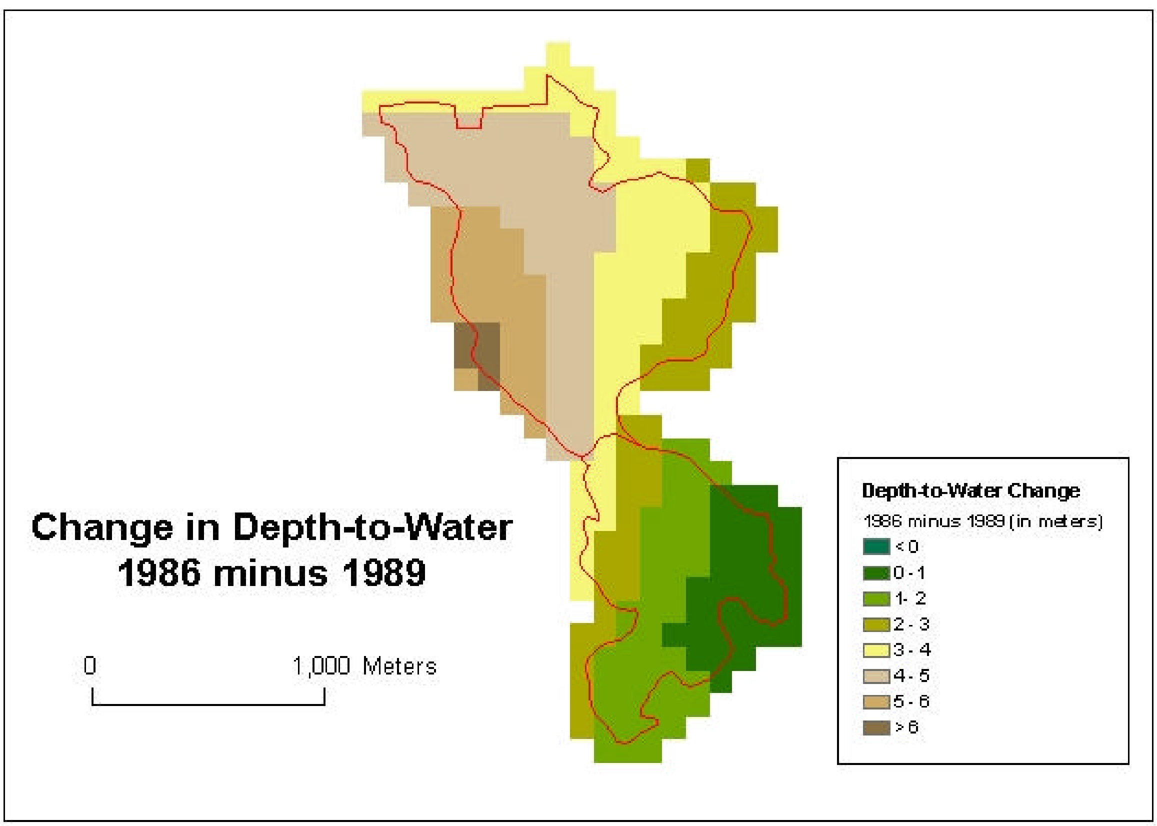

1986 Depth-to-Water
0
1,000 Meters
1986 Depth-to-Water (m)
High : -0.3
Low : -2.1


Change in Vegetation
Percent Cover
1986 minus 1988
0
1,000 Meters
Vegetation Cover % Change
1986% minus 1988%
< -60
-20 - -60
0 - -20
0 - 10
10 - 20
20 - 35
35 - 50
50 - 80
> 80

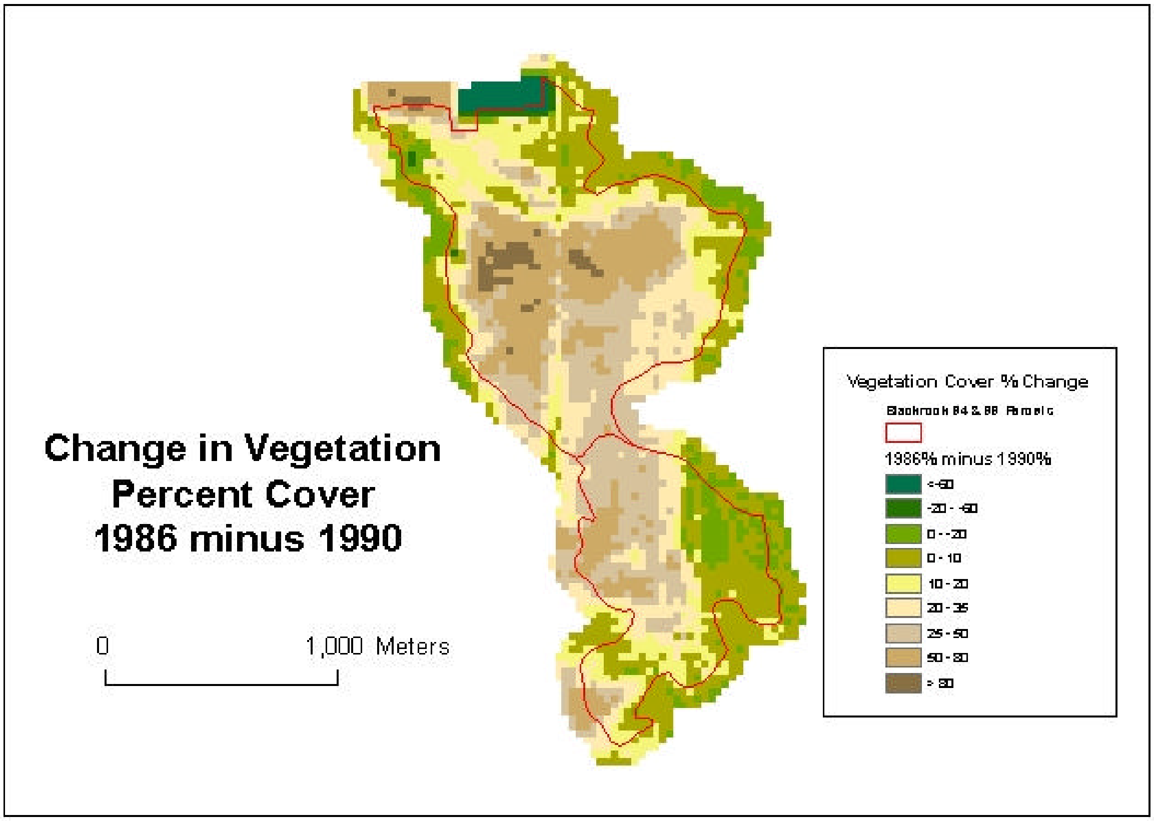

Change in Depth-to-Water
1986 minus 1988
0
1,000 Meters
Depth-to-Water Change
1986 minus 1988 (in meters)
< 0
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
5 - 6
> 6



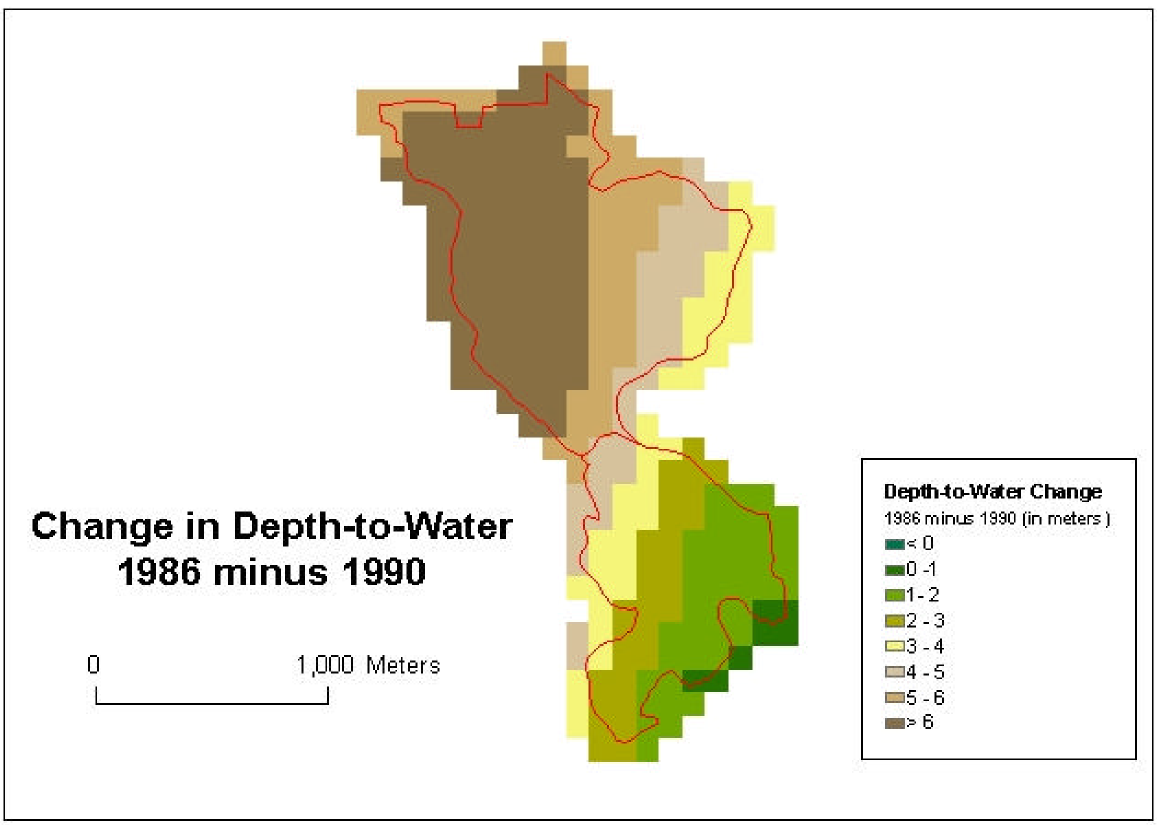
Change in Vegetation Percent Cover 1986 minus 1989
0
1,000 Meters
Vegetation Cover % Change
1986% minus 1989%
< -60
-20 - -60
0 - -20
0 - 10
10 - 20
20 - 35
25 - 50
50 - 80
> 80

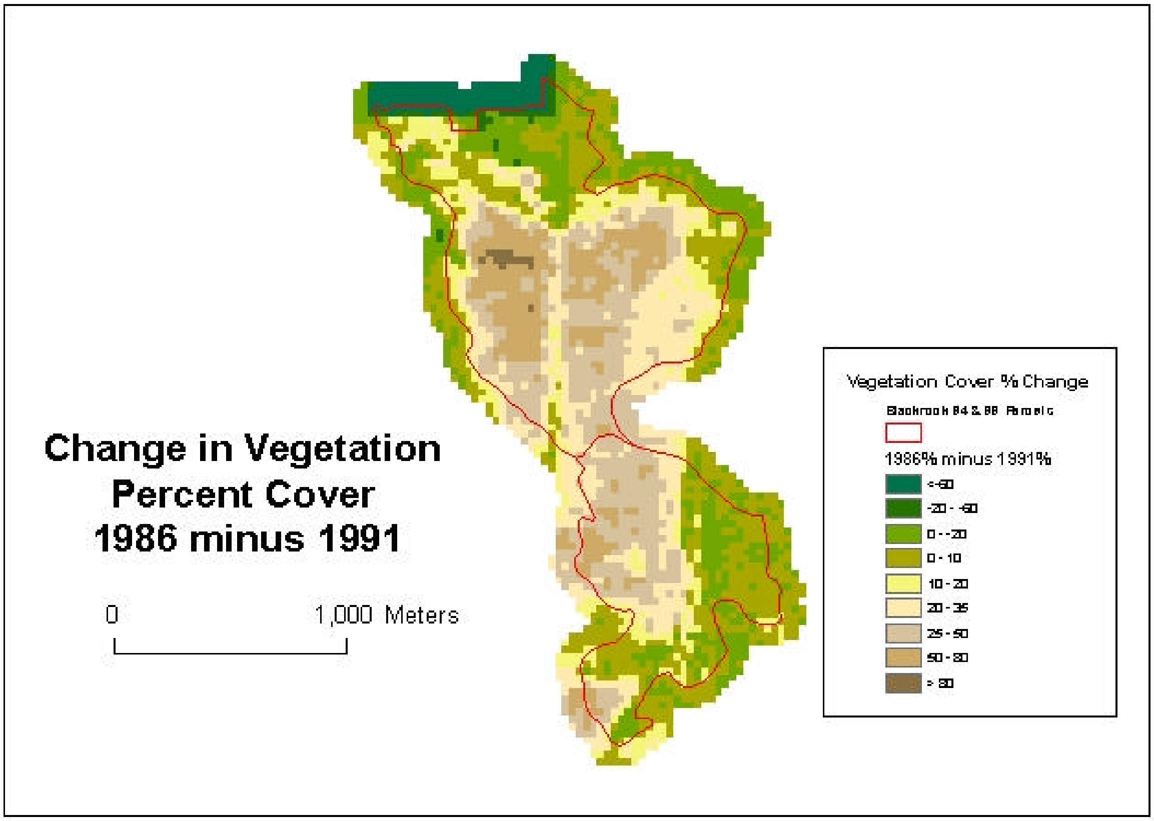
Change in Depth-to-Water 1986 minus 1989
0
1,000 Meters
Depth-to-Water Change
1986 minus 1989 (in meters)
< 0
0 - 1
1- 2
2 - 3
3 - 4
4 - 5
5 - 6
> 6

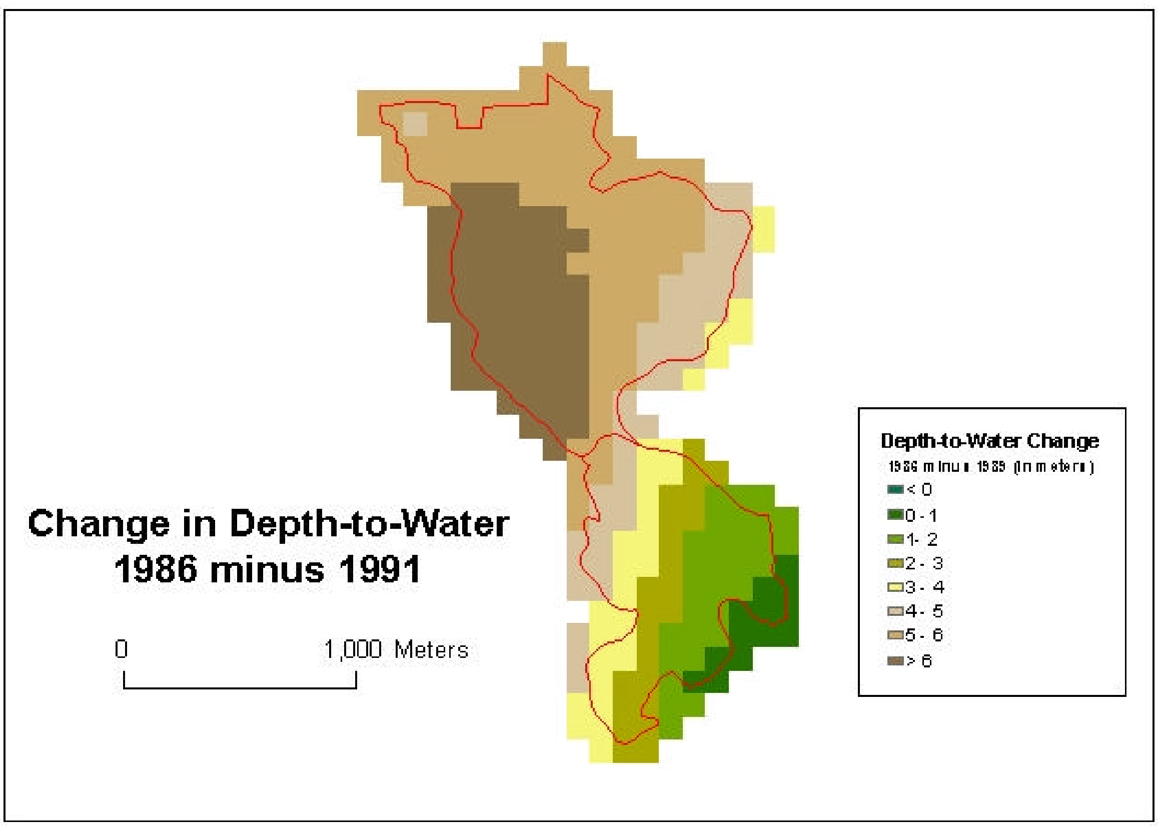


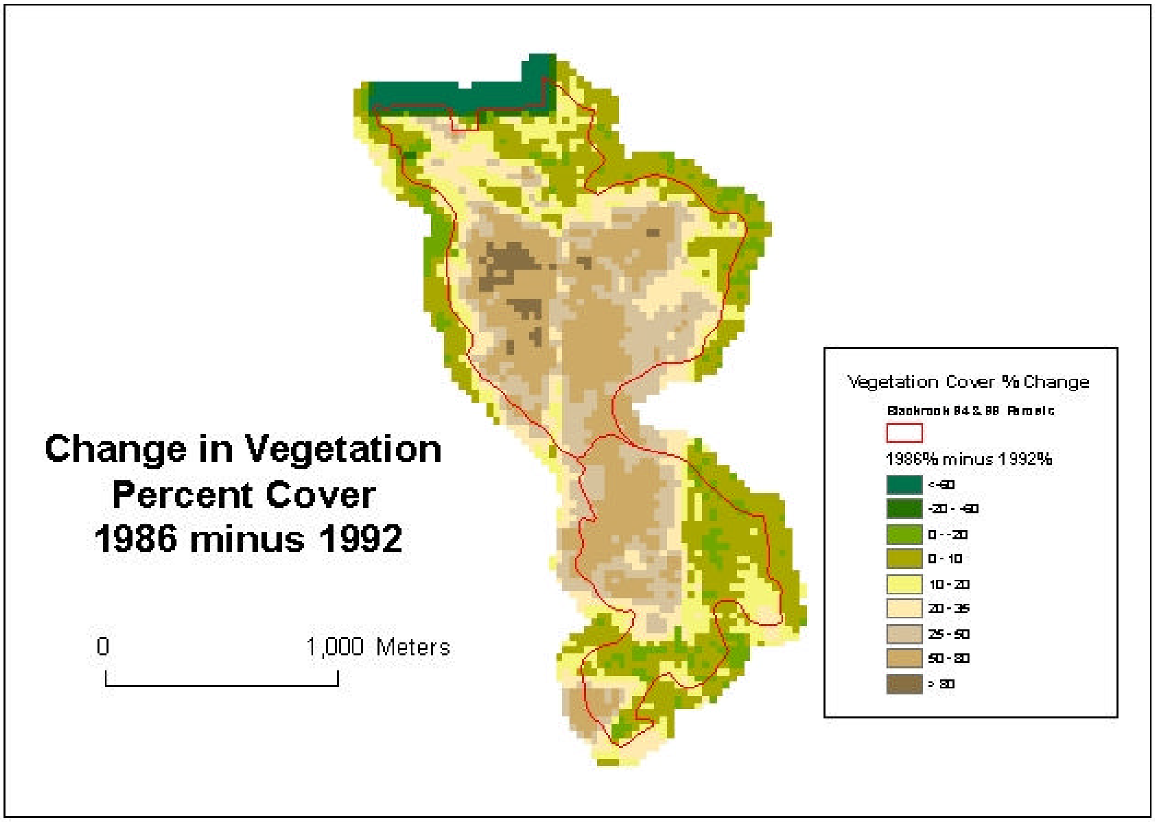
Change in Vegetation Percent Cover 1986 minus 1990
0
1,000 Meters
Vegetation Cover % Change
1986% minus 1990%
< -60
-20 - -60
0 - -20
0 - 10
10 - 20
20 - 35
25 - 50
50 - 80
> 80

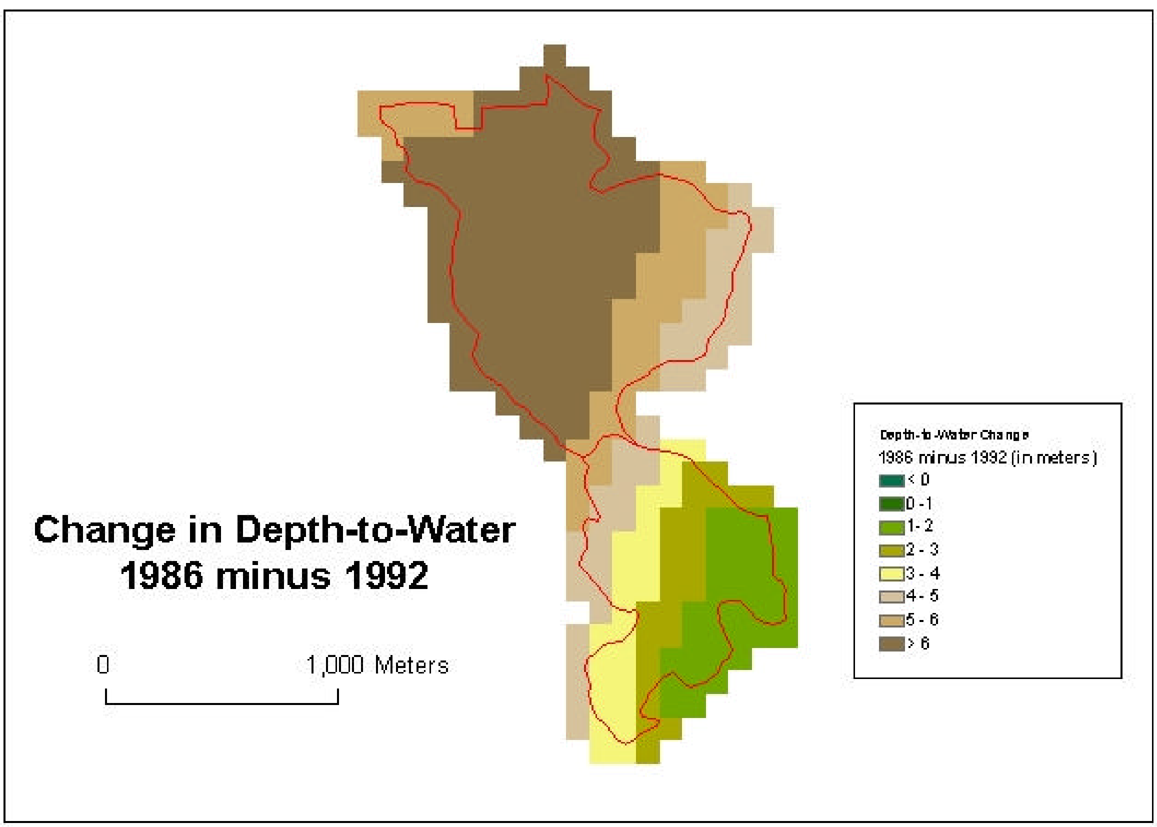
Change in Depth-to-Water 1986 minus 1990
0
1,000 Meters
Depth-to-Water Change
1986 minus 1990 (in meters)
< 0
0 -1
1 - 2
2 - 3
3 - 4
4 - 5
5 - 6
> 6


Change in Vegetation
Percent Cover
1986 minus 1991
0
1,000 Meters
Vegetation Cover % Change
1986% minus 1991%
<-60
-20 - -60
0 - -20
0 - 10
10 - 20
20 - 35
25 - 50
50 - 80
> 80

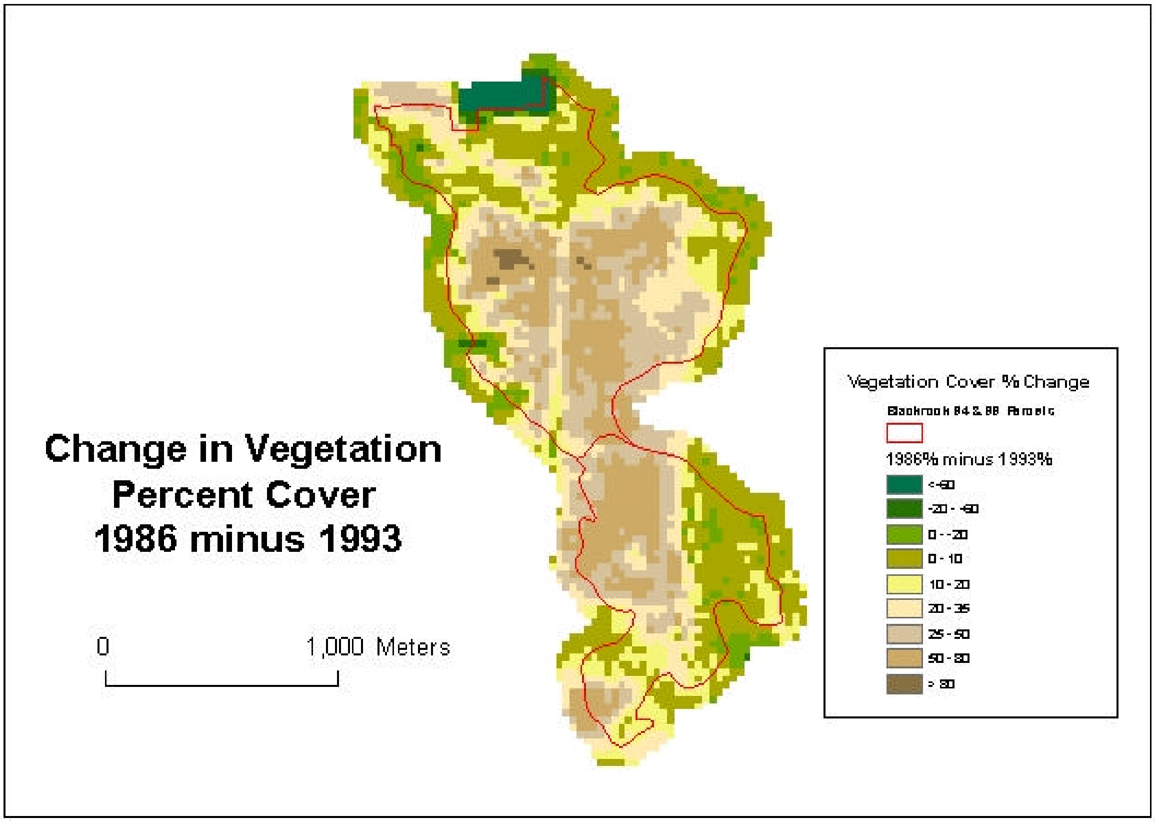

Change in Depth-to-Water
1986 minus 1991
0
1,000 Meters
Depth-to-Water Change
< 0
0 - 1
1- 2
2 - 3
3 - 4
4 - 5
5 - 6
> 6

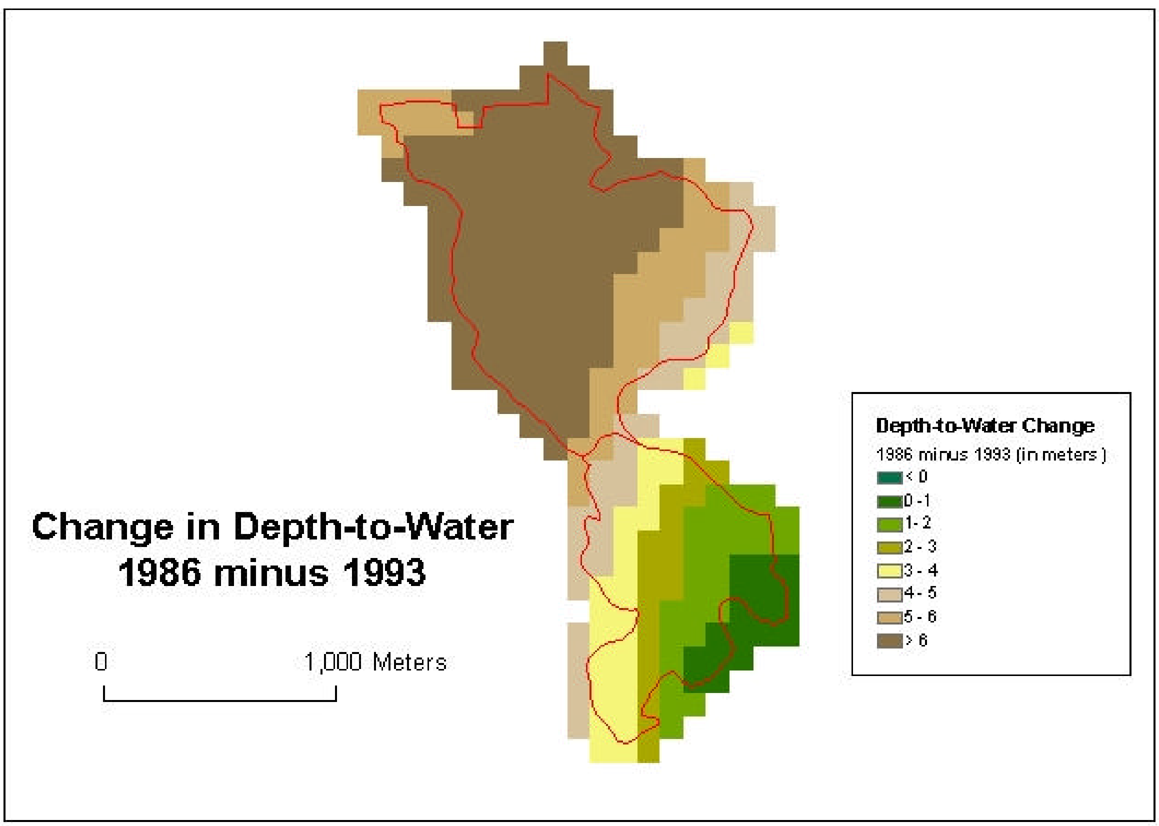


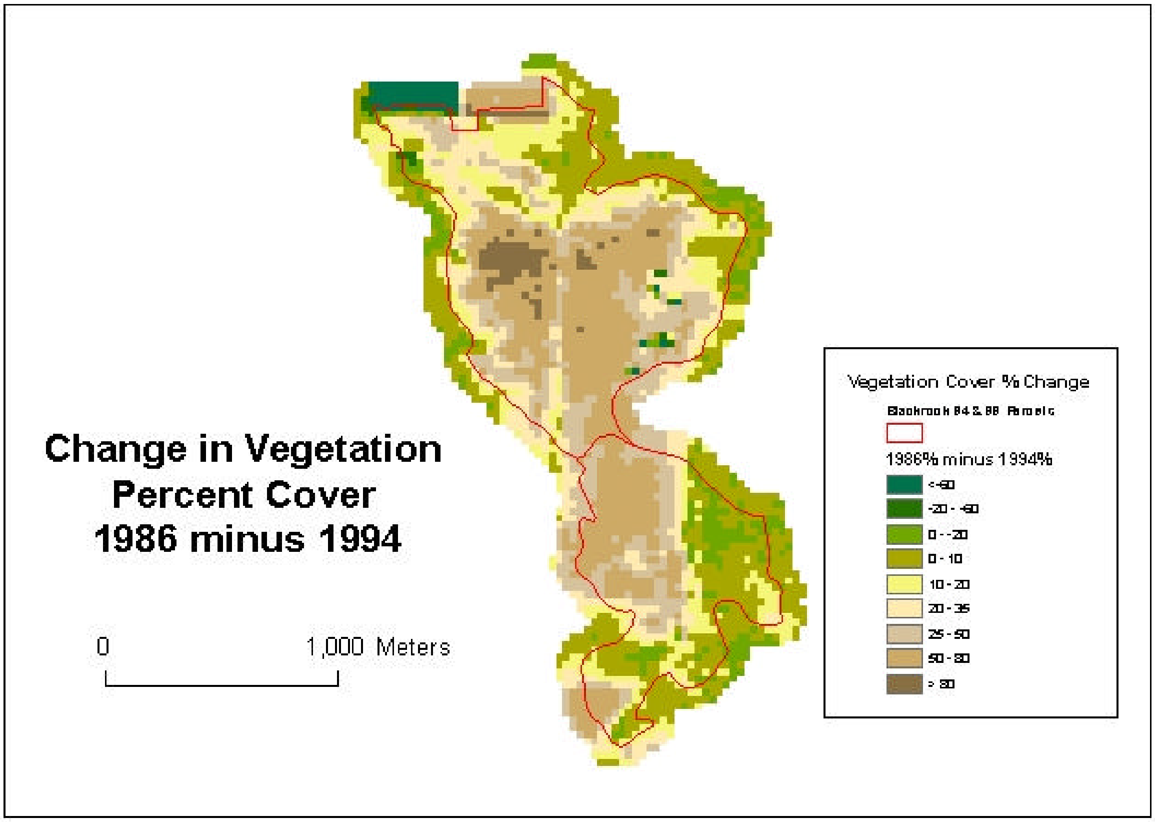
Change in Vegetation
Percent Cover
1986 minus 1992
0
1,000 Meters
Vegetation Cover % Change
1986% minus 1992%
< -40
-20 - -40
0 - -20
0 - 10
10 - 20
20 - 35
25 - 50
50 - 80
> 80

Change in Depth-to-Water
1986 minus 1992
0
1,000 Meters
Depth-to-Water Change
1986 minus 1992 (in meters)
< 0
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
5 - 6
> 6


Change in Vegetation
Percent Cover
1986 minus 1993
0
1,000 Meters
Vegetation Cover % Change
1986% minus 1993%
< -40
-20 - -40
0 - -20
0 - 10
10 - 20
20 - 35
25 - 50
50 - 80
> 80


Change in Depth-to-Water
1986 minus 1993
0
1,000 Meters
Depth-to-Water Change
1986 minus 1993 (in meters )
< 0
0 - 1
1- 2
2 - 3
3 - 4
4 - 5
5 - 6
> 6


Change in Vegetation
Percent Cover
1986 minus 1994
0
1,000 Meters
Vegetation Cover % Change
1986% minus 1994%
< -40
-20 - -40
0 - -20
0 - 10
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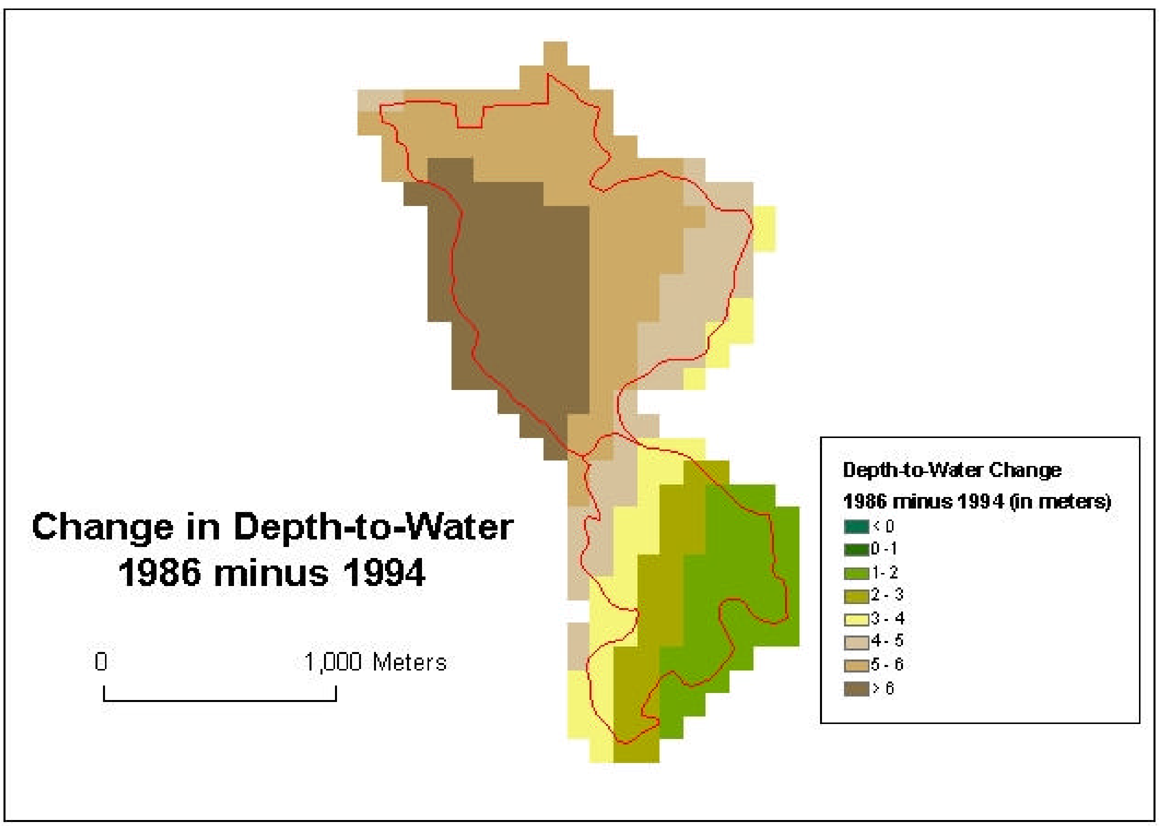
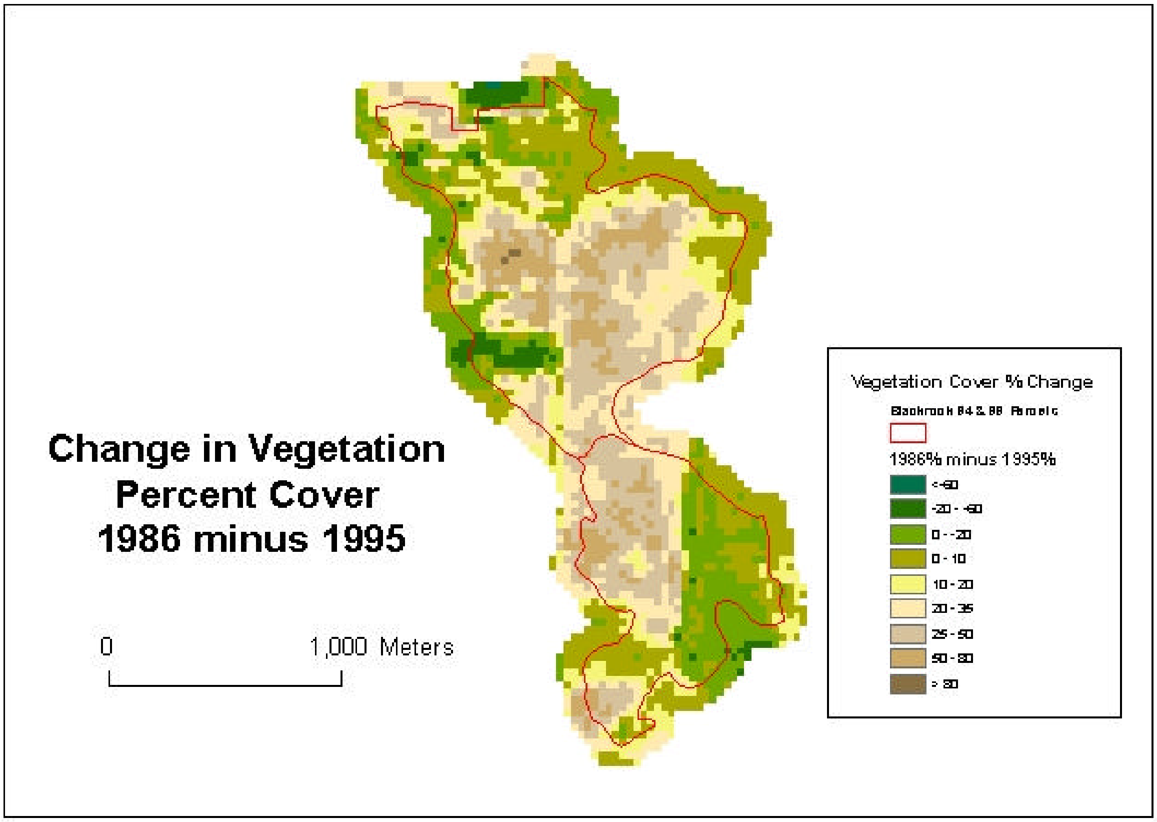
20 - 35
25 - 50
50 - 80
> 80


Change in Depth-to-Water
1986 minus 1994
0
1,000 Meters
Depth-to-Water Change
1986 minus 1994 (in meters)
< 0
0 - 1
1- 2
2 - 3
3 - 4
4 - 5
5 - 6
> 6


Change in Vegetation
Percent Cover
1986 minus 1995
0
1,000 Meters
Vegetation Cover % Change
1986% minus 1995%
<-40
-20 - -40
0 - -20
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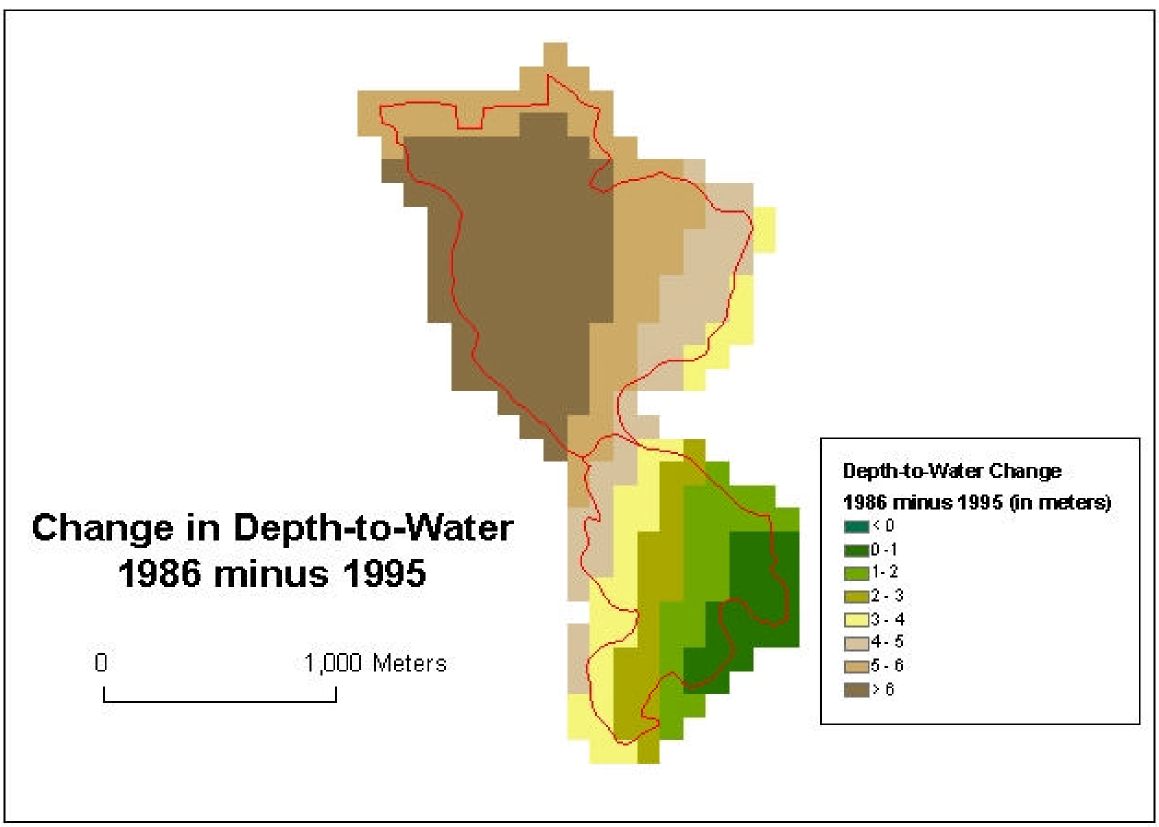
25 - 50
50 - 80
> 80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1986 minus 1995
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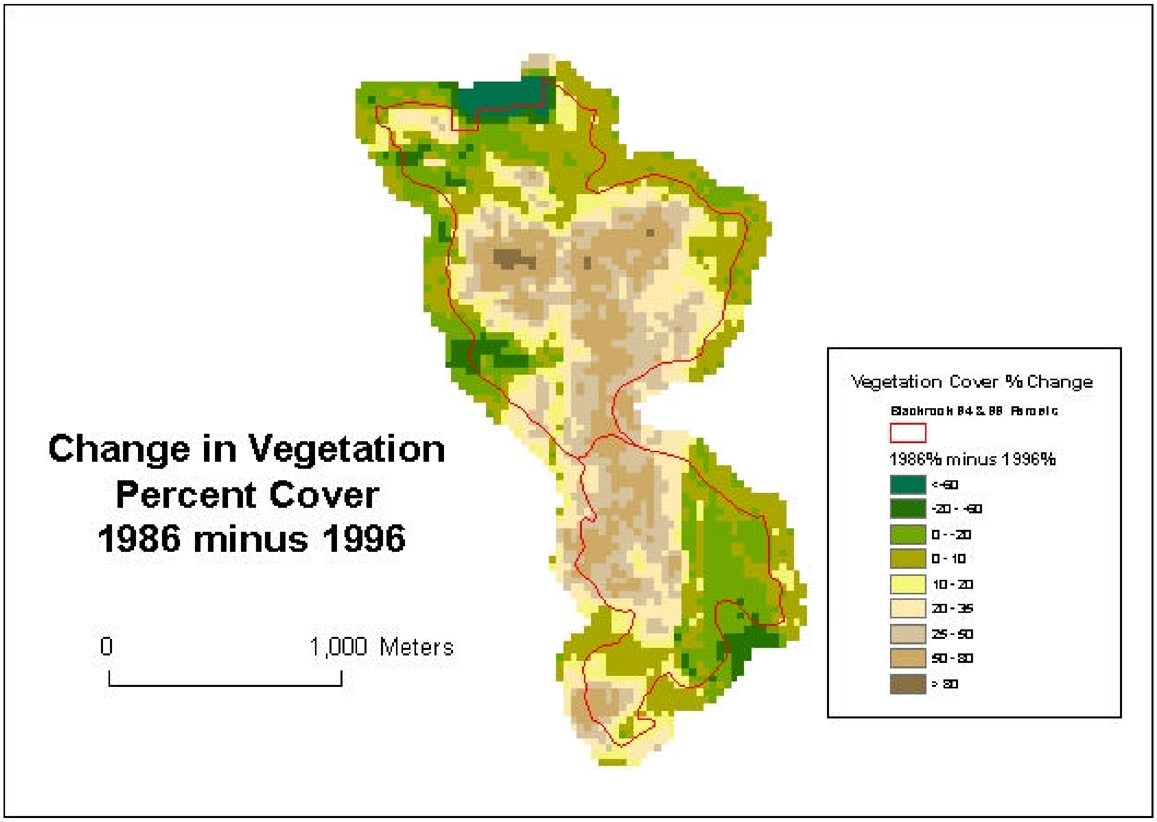
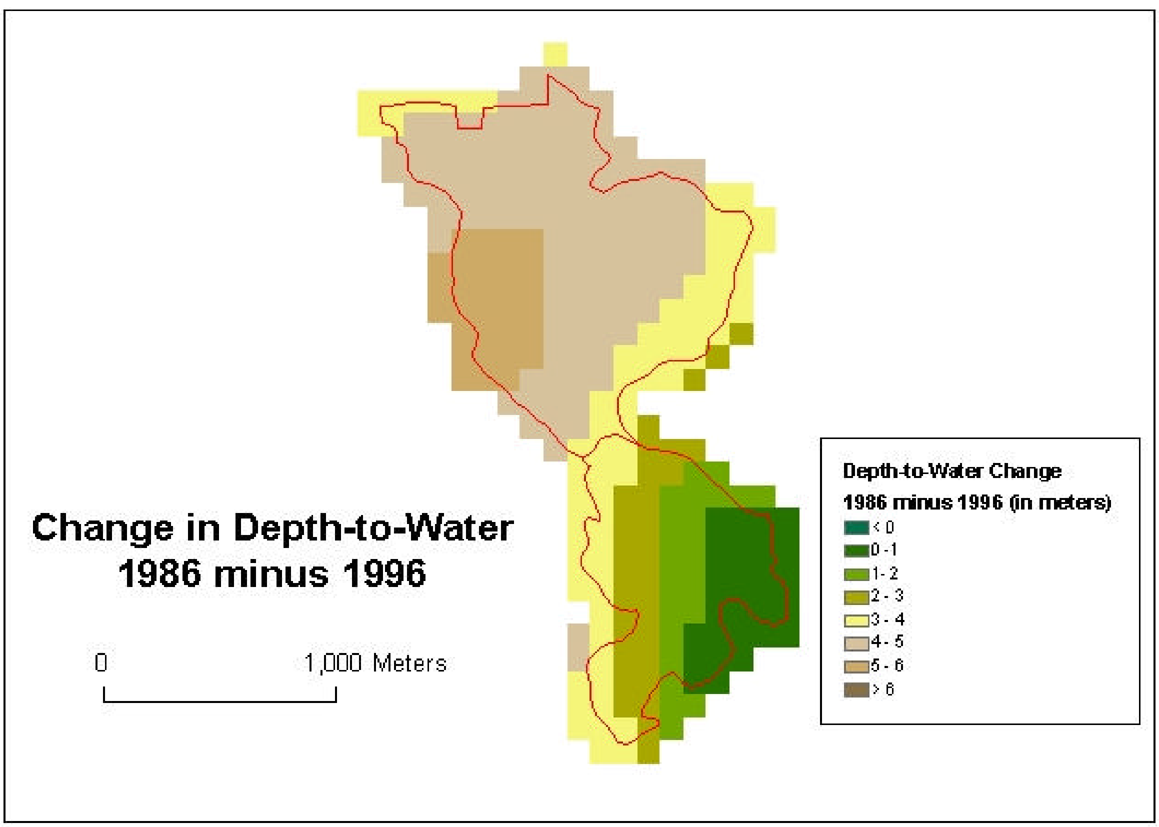
1,000 Meters
Depth-to-Water Change
1986 minus 1995 (in meters)
< 0
0 - 1
1- 2
2 - 3
3 - 4
4 - 5
5 - 6
> 6


Change in Vegetation
Percent Cover
1986 minus 1996
0
1,000 Meters
Vegetation Cover % Change
1986% minus 1996%
< -40
-20 - -40
0 - -20
0 - 10
10 - 20
20 - 35
25 - 50
50 - 80
> 80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1986 minus 1996
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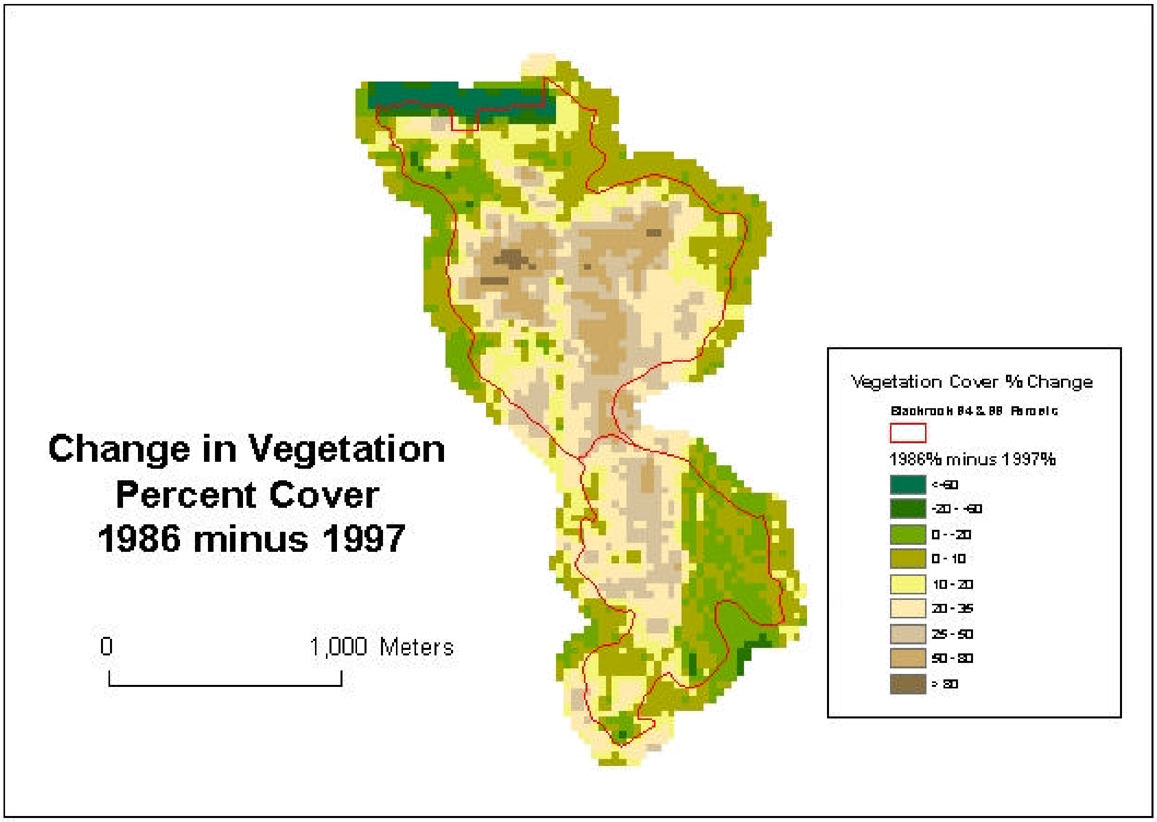
1,000 Meters
Depth-to-Water Change
1986 minus 1996 (in meters)
< 0
0 - 1
1- 2
2 - 3
3 - 4
4 - 5
5 - 6
> 6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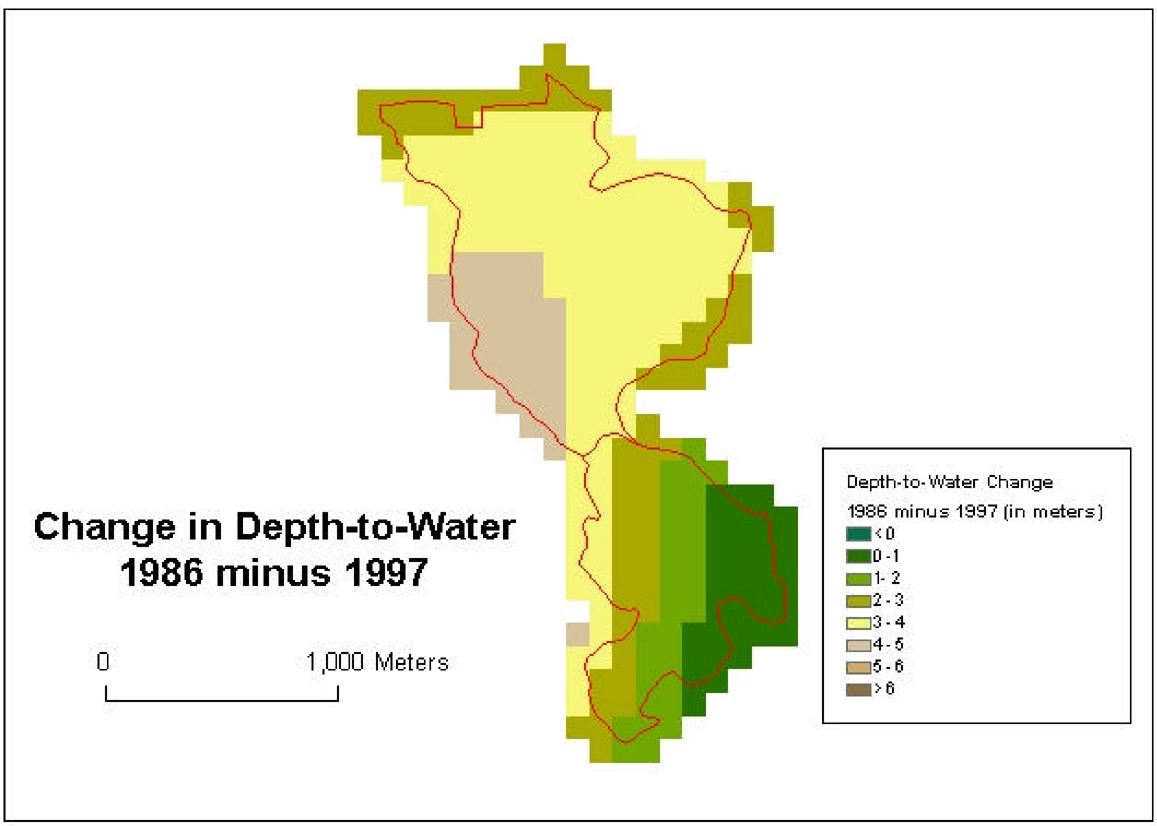
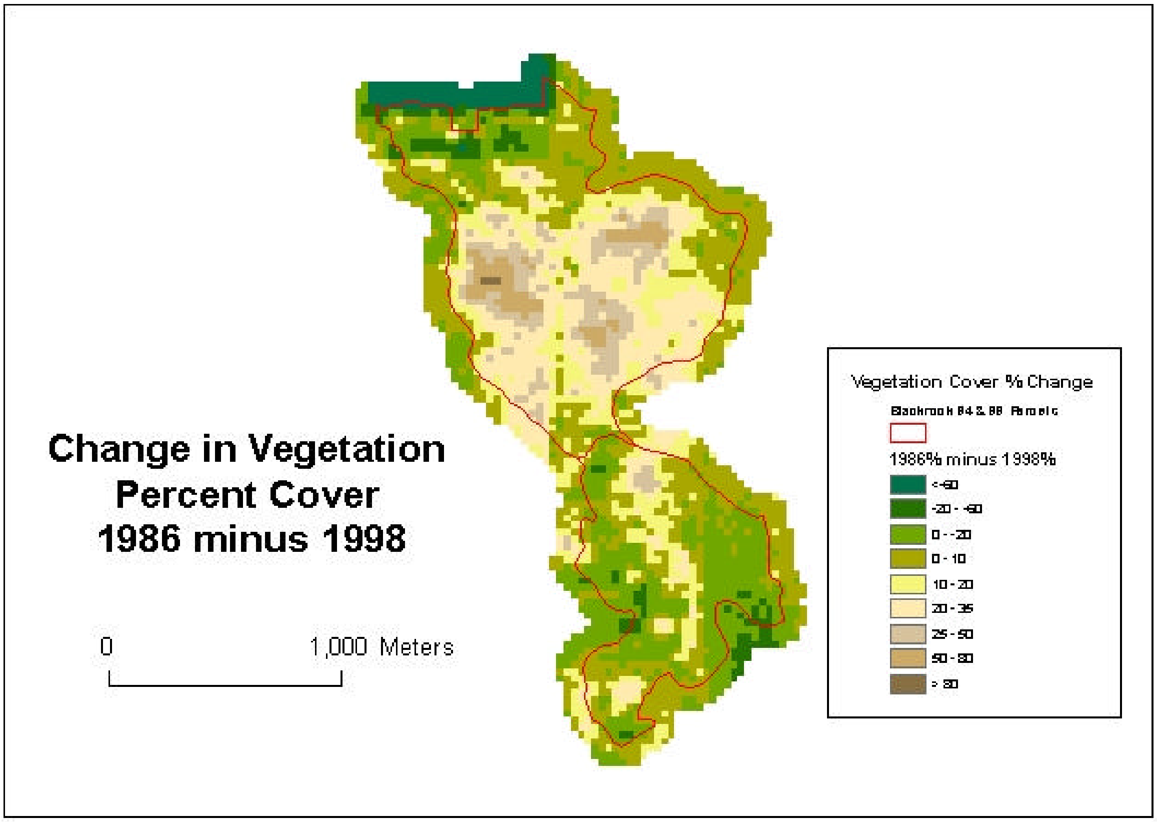
Percent Cover
1986 minus 1997
0
1,000 Meters
Vegetation Cover % Change
1986% minus 1997%
0 - 10
10 - 20
20 - 35


Change in Depth-to-Water
1986 minus 1997
0
1,000 Meters
Depth-to-Water Change
1986 minus 1997 (in meters)
< 0
0 - 1
1- 2
2 - 3
3 - 4
4 - 5
5 - 6
> 6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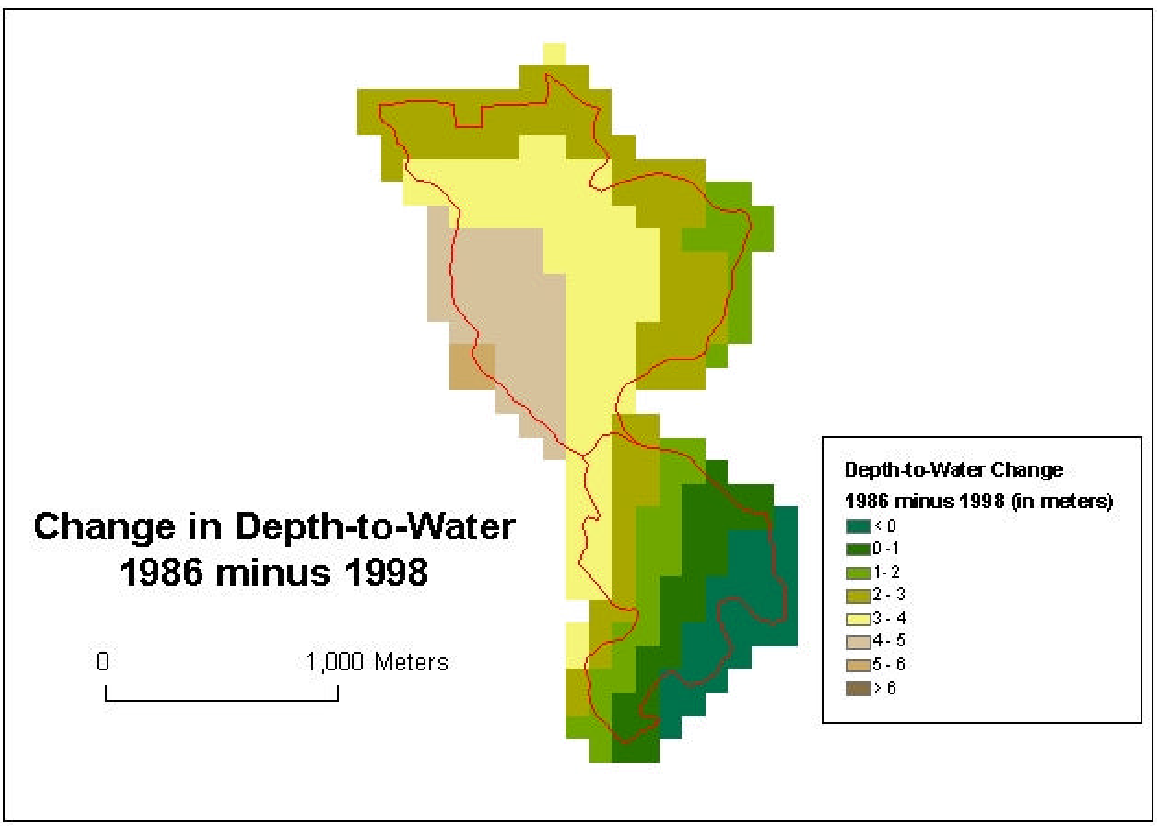
Percent Cover
1986 minus 1998
0
1,000 Meters
Vegetation Cover % Change
1986% minus 1998%
0 - -20
0 - 10
10 - 20
20 - 35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1986 minus 1998
0
1,000 Meters
Depth-to-Water Change
1986 minus 1998 (in meters)
< 0
0 - 1
1 - 2
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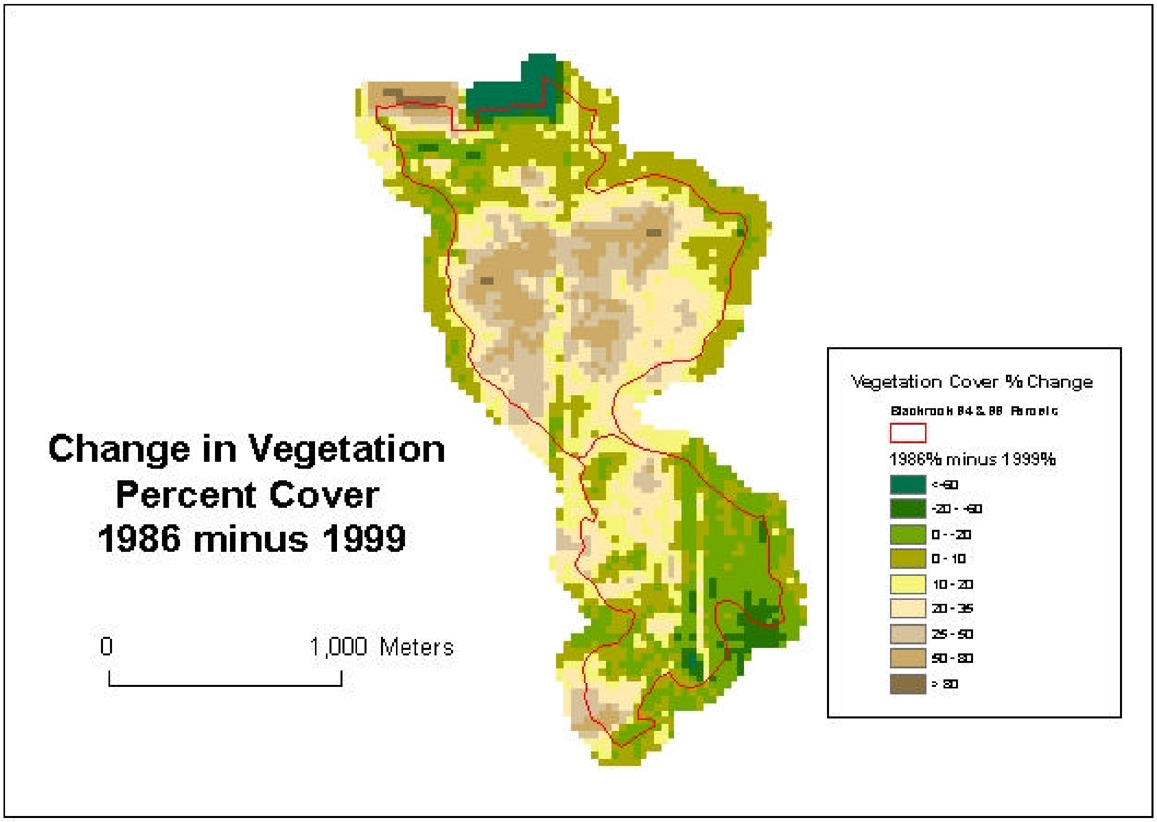
4 - 5
5 - 6
> 6


Change in Vegetation
Percent Cover
1986 minus 1999
0
1,000 Meters
Vegetation Cover % Change
1986% minus 1999%
< -40
-20 - -40
0 - -20
0 - 10
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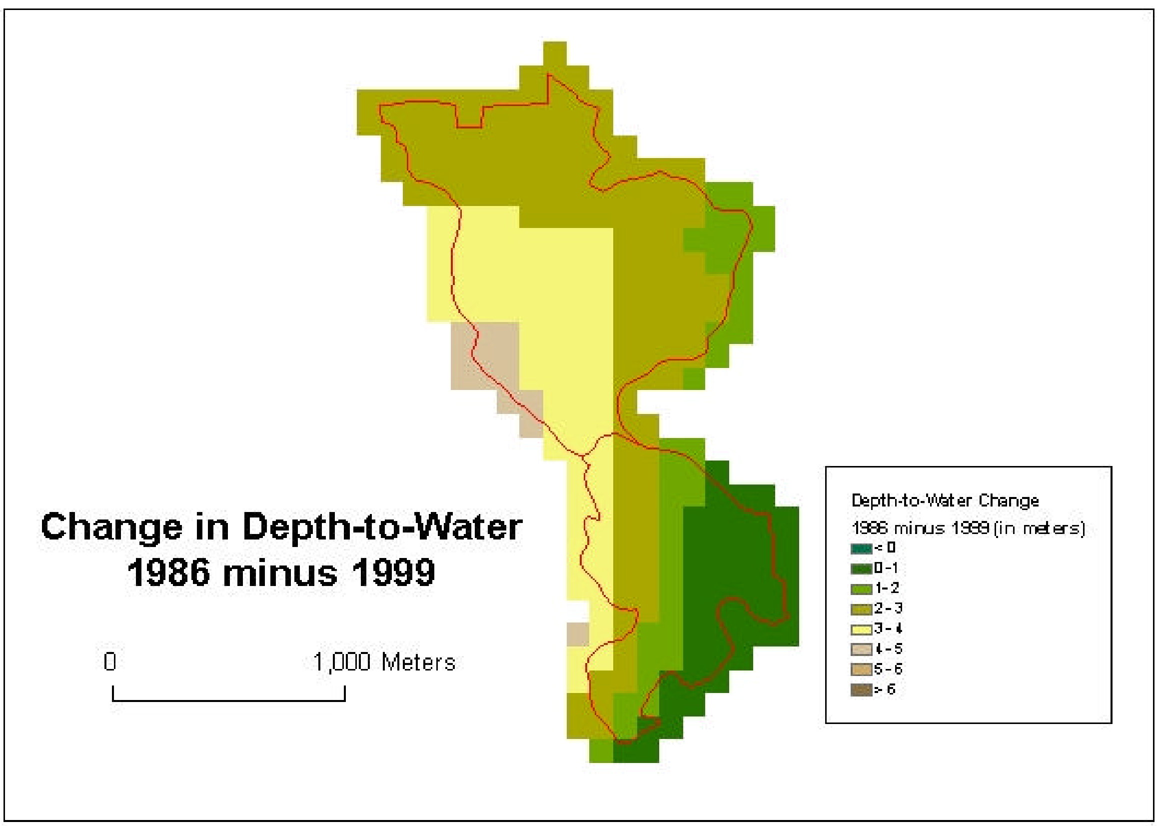
20 - 35
25 - 50
50 - 80
> 80


Change in Depth-to-Water
1986 minus 1999
0
1,000 Meters
Depth-to-Water Change
1986 minus 1999 (in meters)
< 0
0 - 1
1 - 2
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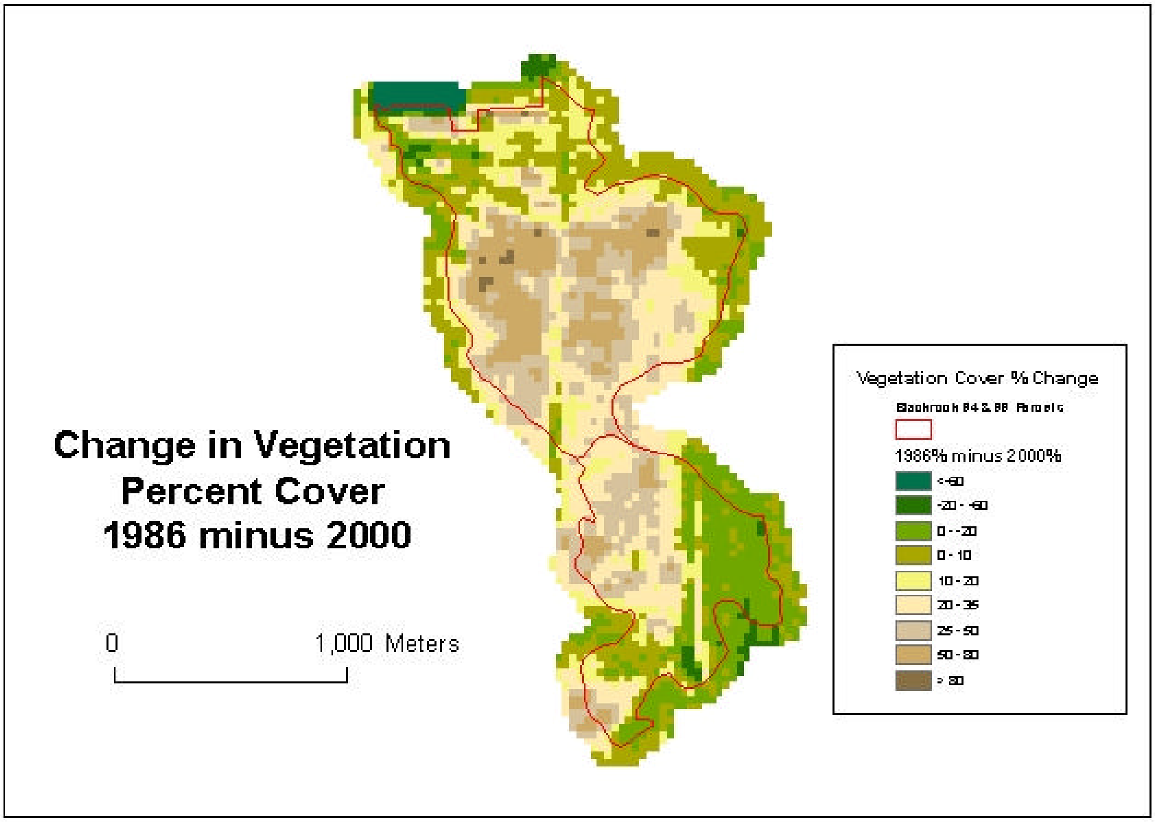
4 - 5
5 - 6
> 6


Change in Vegetation
Percent Cover
1986 minus 2000
0
1,000 Meters
Vegetation Cover % Change
1986% minus 2000%
< -40
-20 - -40
0 - -20
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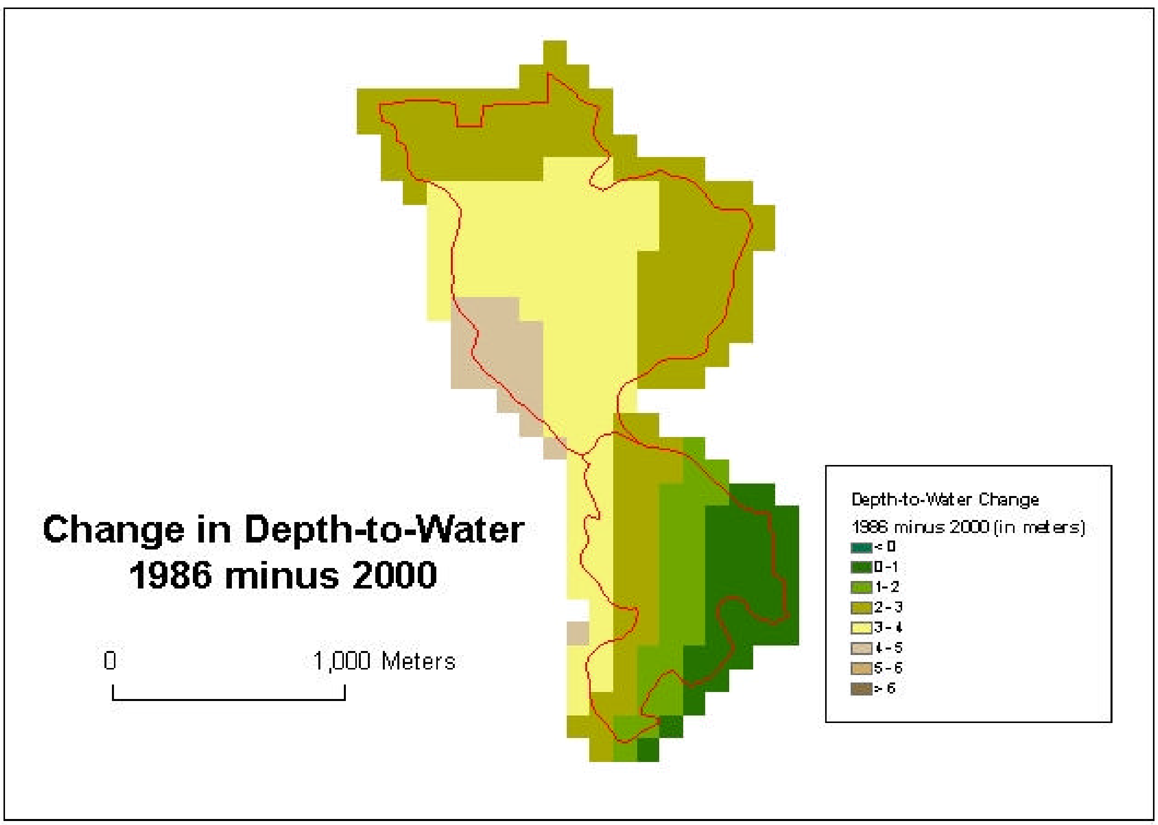
20 - 35
25 - 50
50 - 80
> 80


Change in Depth-to-Water
1986 minus 2000
0
1,000 Meters
Depth-to-Water Change
1986 minus 2000 (in meters)
< 0
0 - 1
1 - 2
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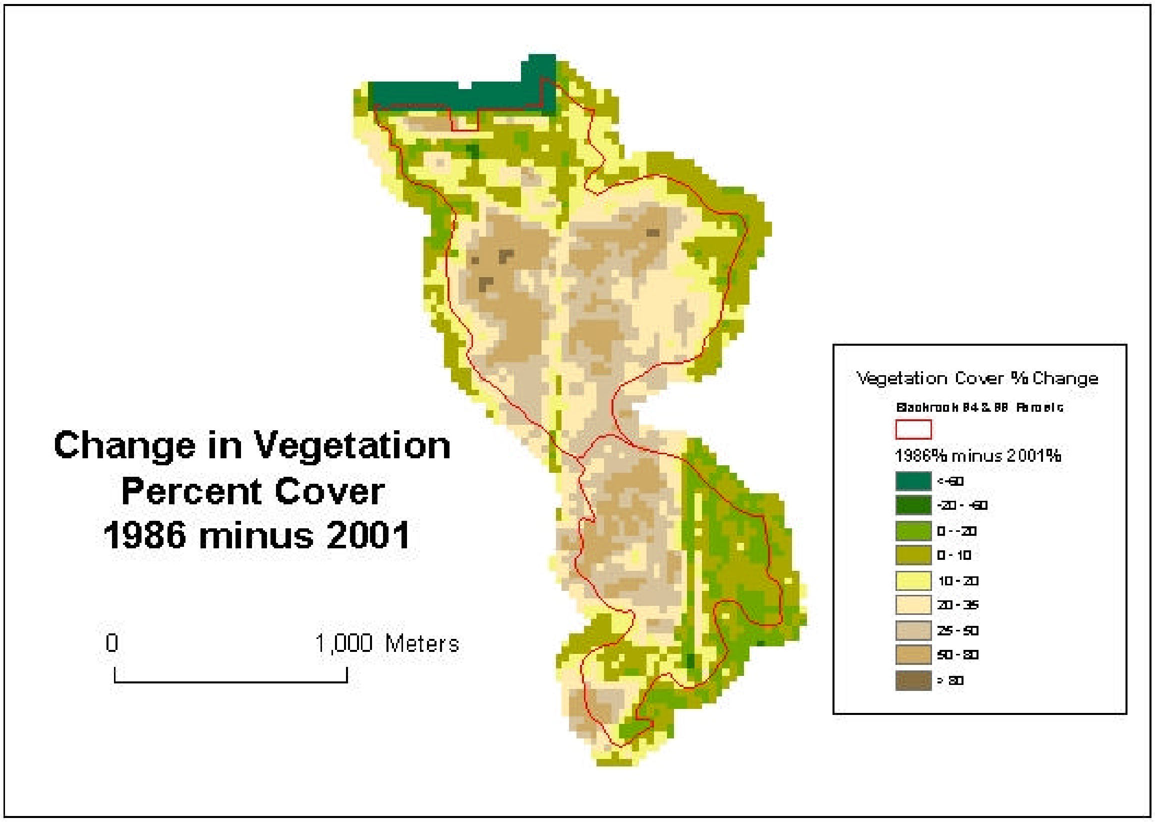
3 - 4
4 - 5
5 - 6
> 6


Change in Vegetation Percent Cover 1986 minus 2001
0
1,000 Meters
Vegetation Cover % Change
1986% minus 2001%
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-20 - -40
0 - -20
0 - 10
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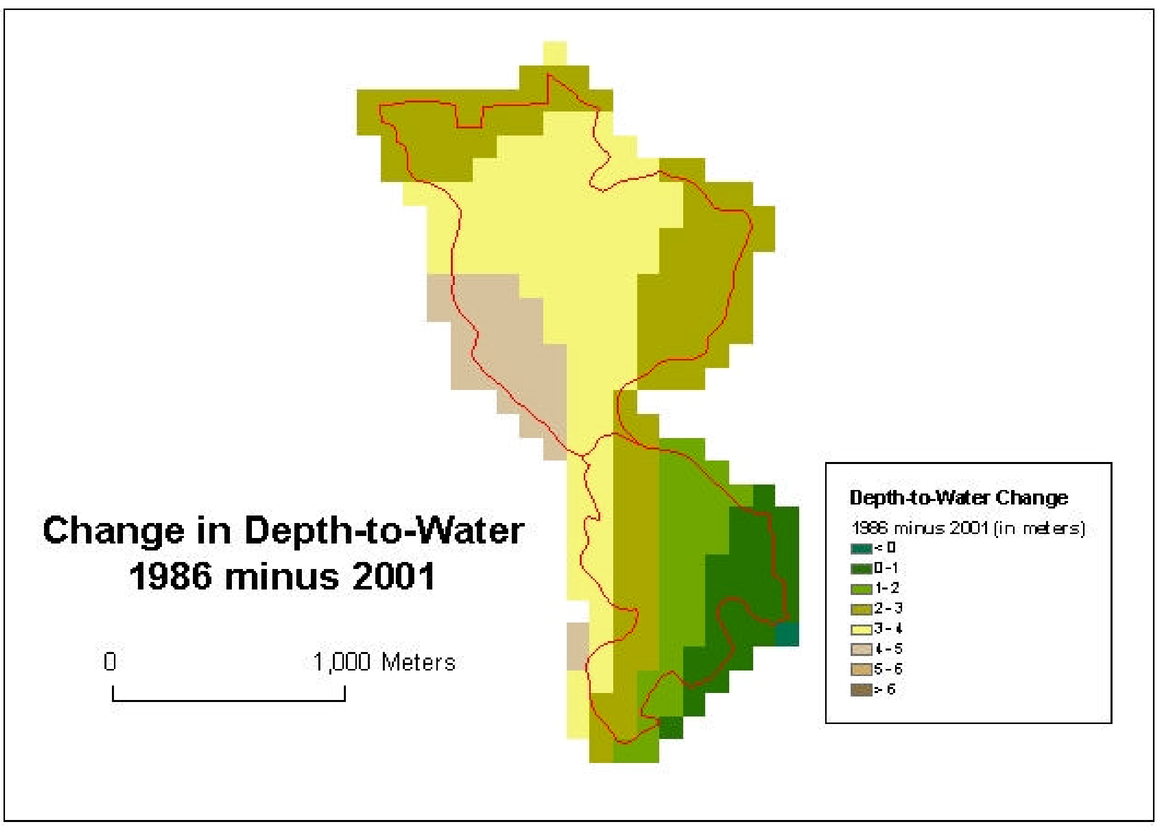
25 - 50
50 - 80
> 80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0
1,000 Meters
Depth-to-Water Change
1986 minus 2001 (in meters)
< 0
0 - 1
1 - 2
2 - 3
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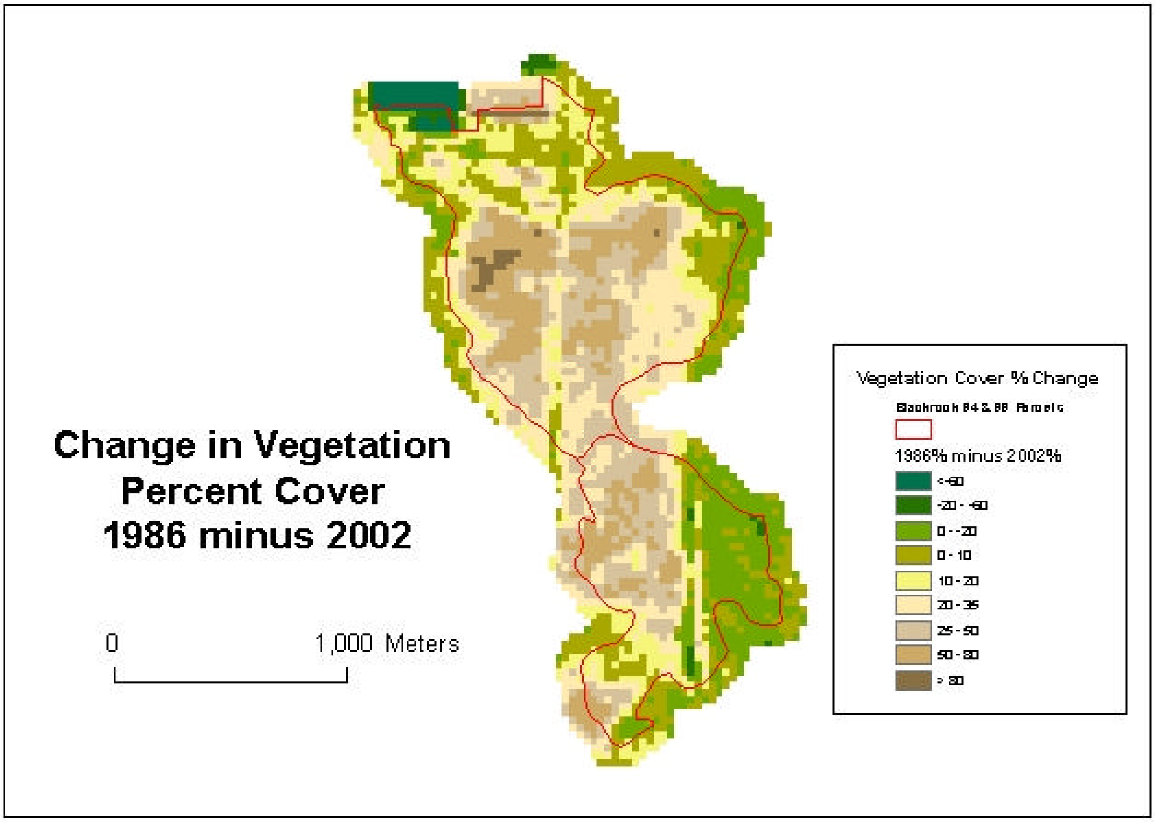
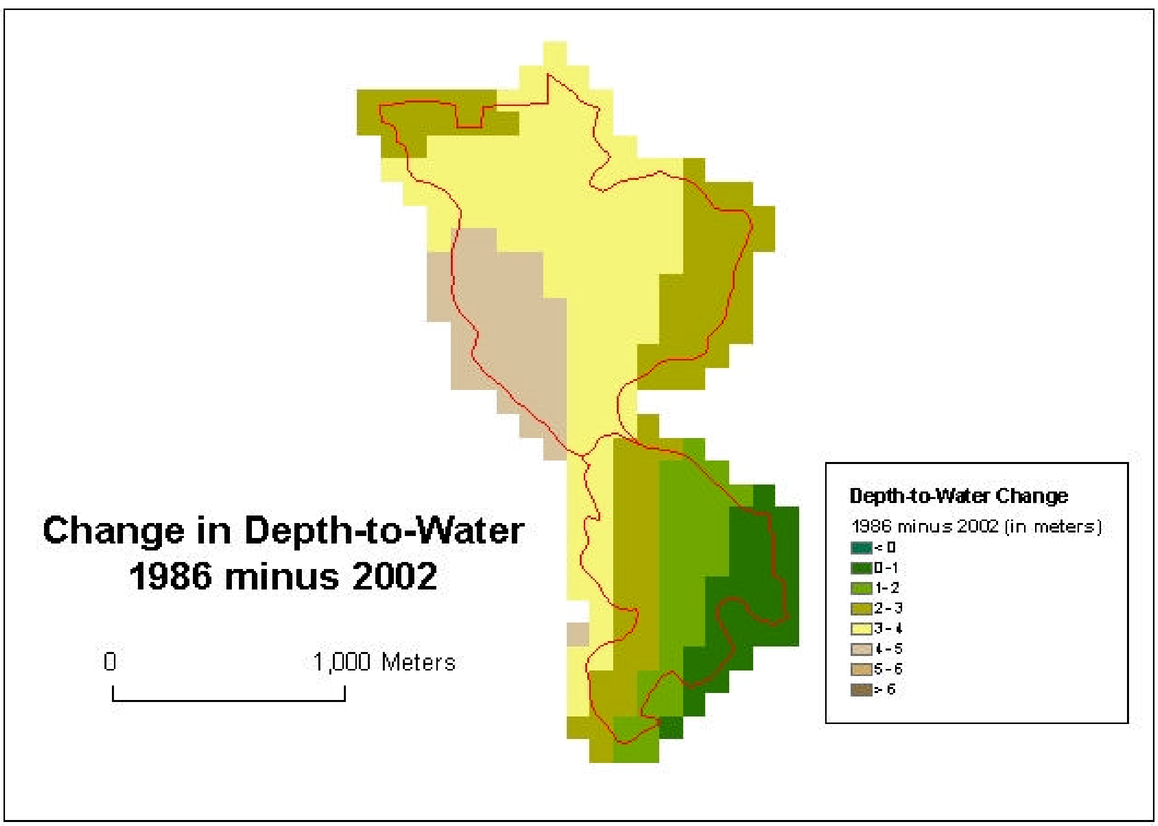
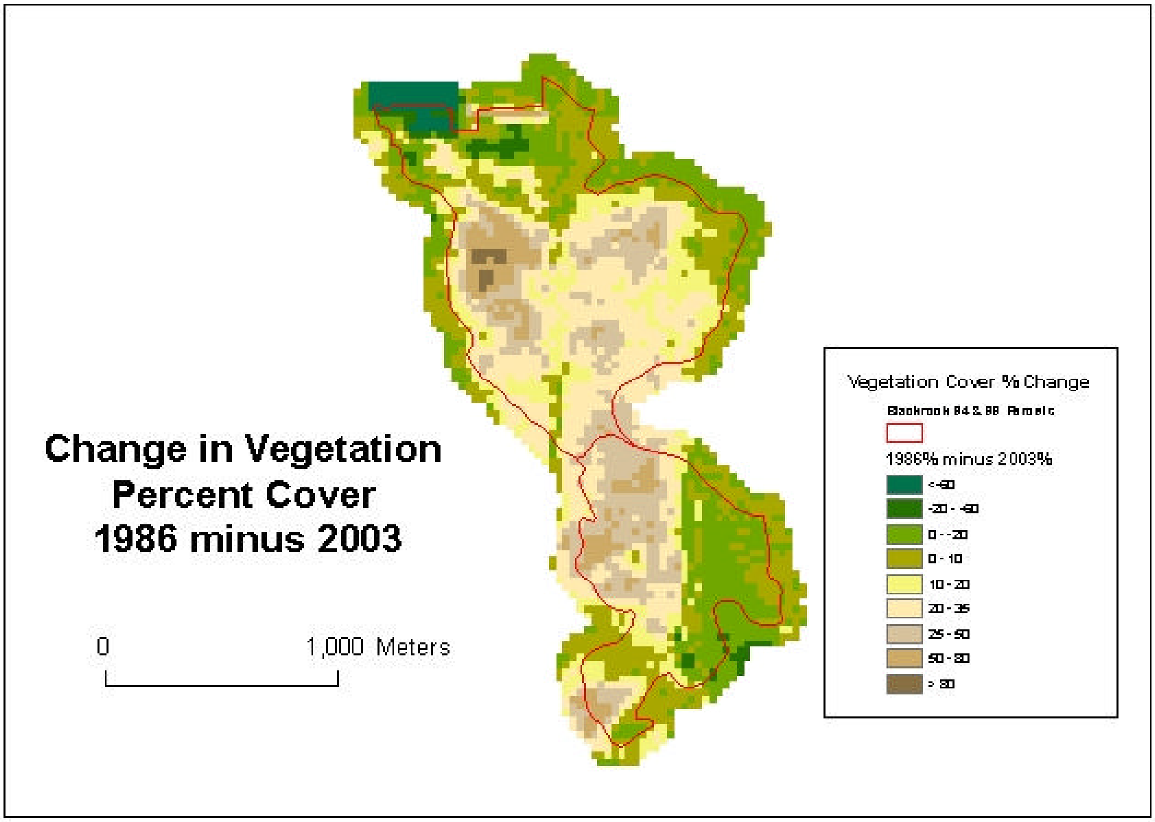
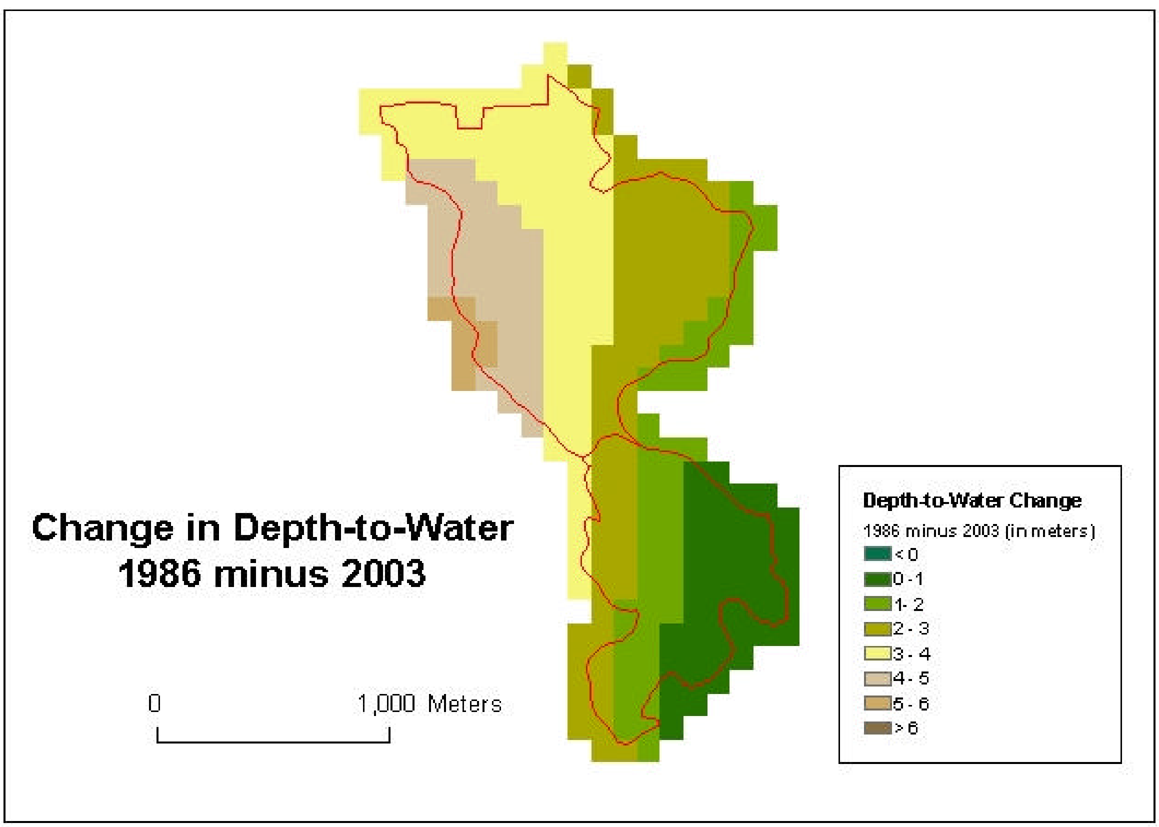
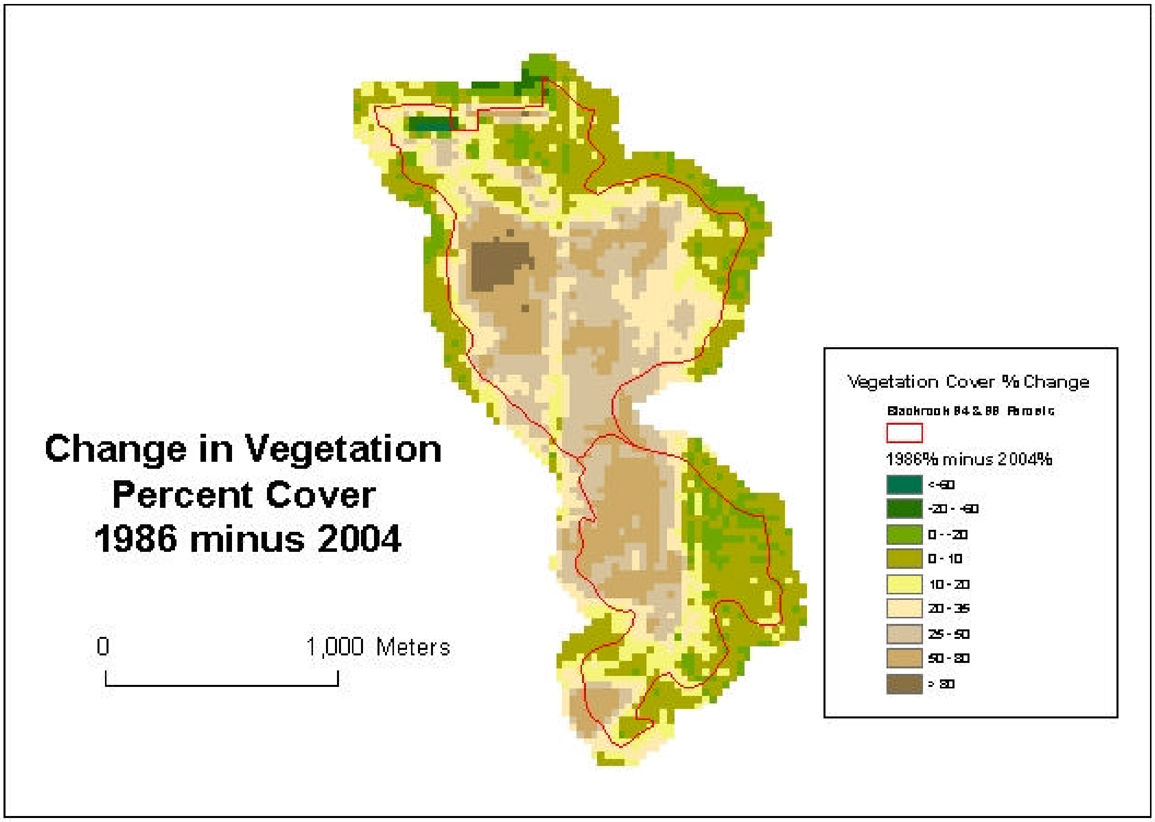
4 - 5
5 - 6
> 6

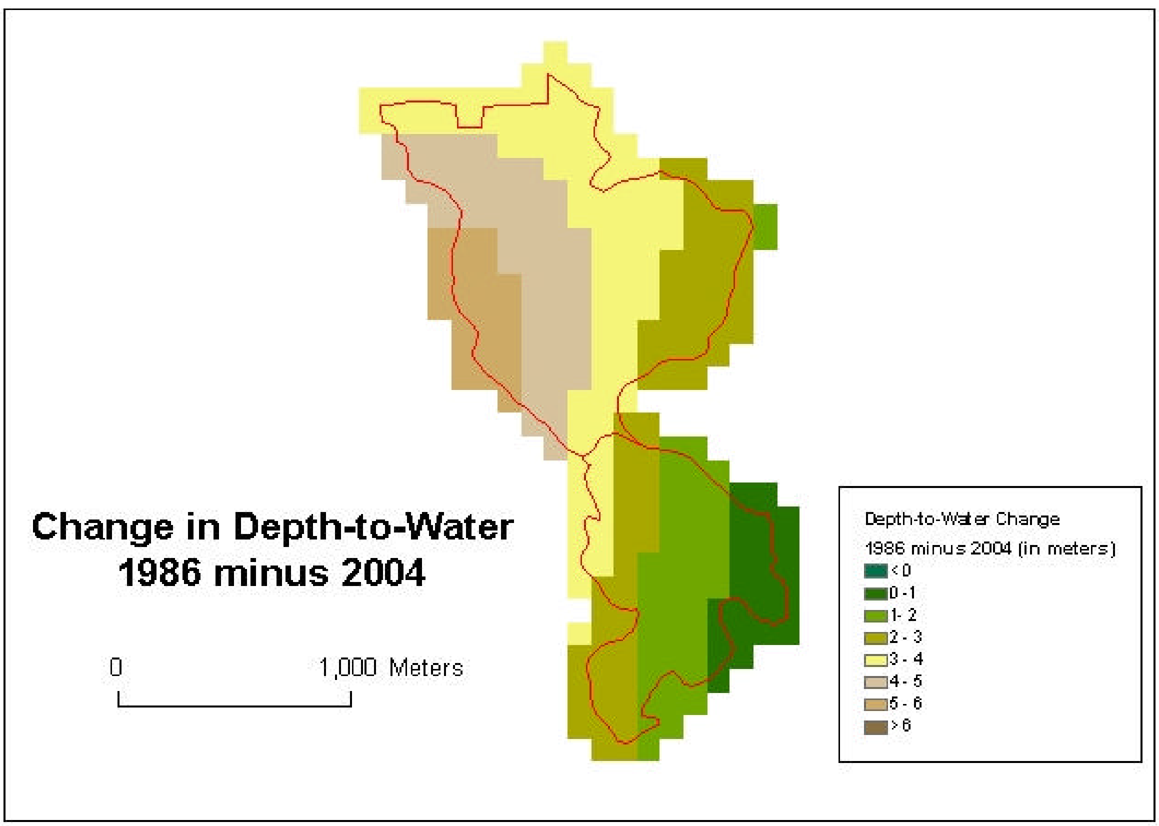

Change in Vegetation
Percent Cover
1986 minus 2002
0
1,000 Meters
Vegetation Cover % Change
1986% minus 2002%
< -40
-20 - -40
0 - -20
0 - 10
10 - 20
20 - 35
25 - 50
50 - 80
> 80

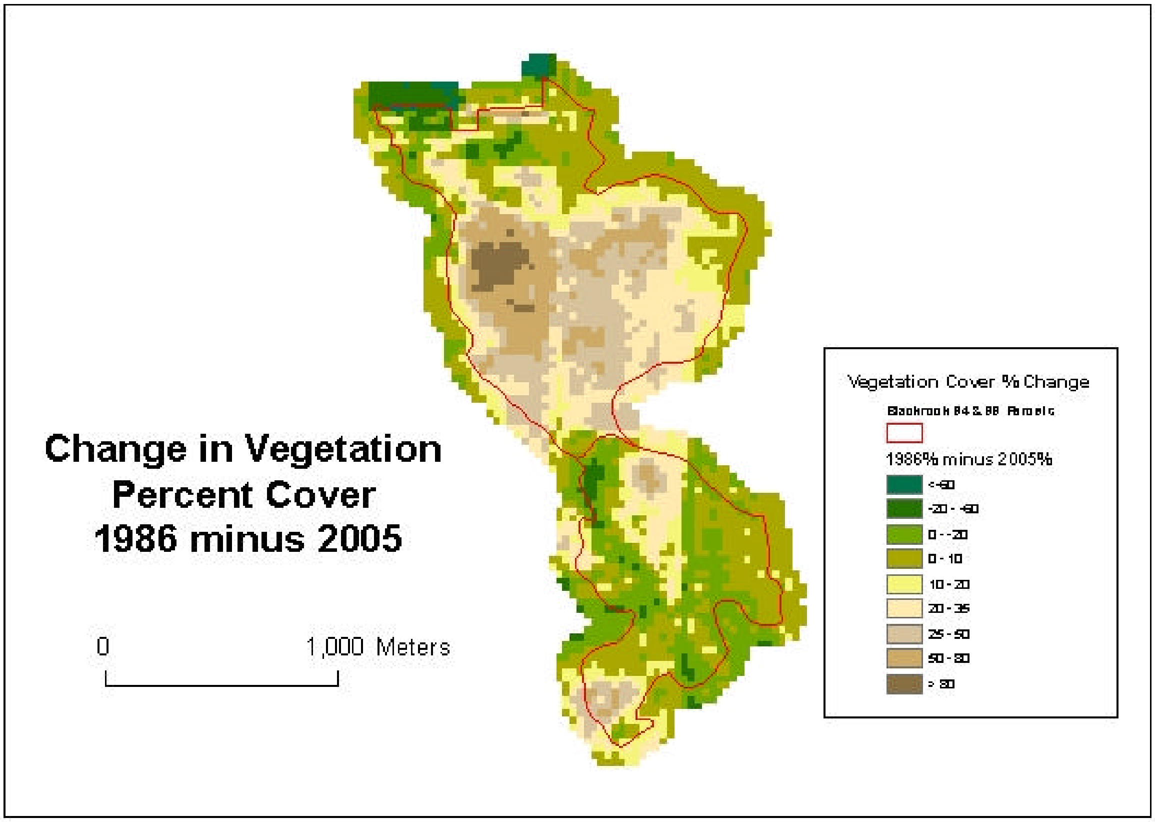

Change in Depth-to-Water
1986 minus 2002
0
1,000 Meters
Depth-to-Water Change
1986 minus 2002 (in meters)
< 0
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
5 - 6
> 6


Change in Vegetation
Percent Cover
1986 minus 2003
0
1,000 Meters
Vegetation Cover % Change
1986% minus 2003%
0 - -20
0 - 10
10 - 20
20 - 35
25 - 50
50 - 80
> 80

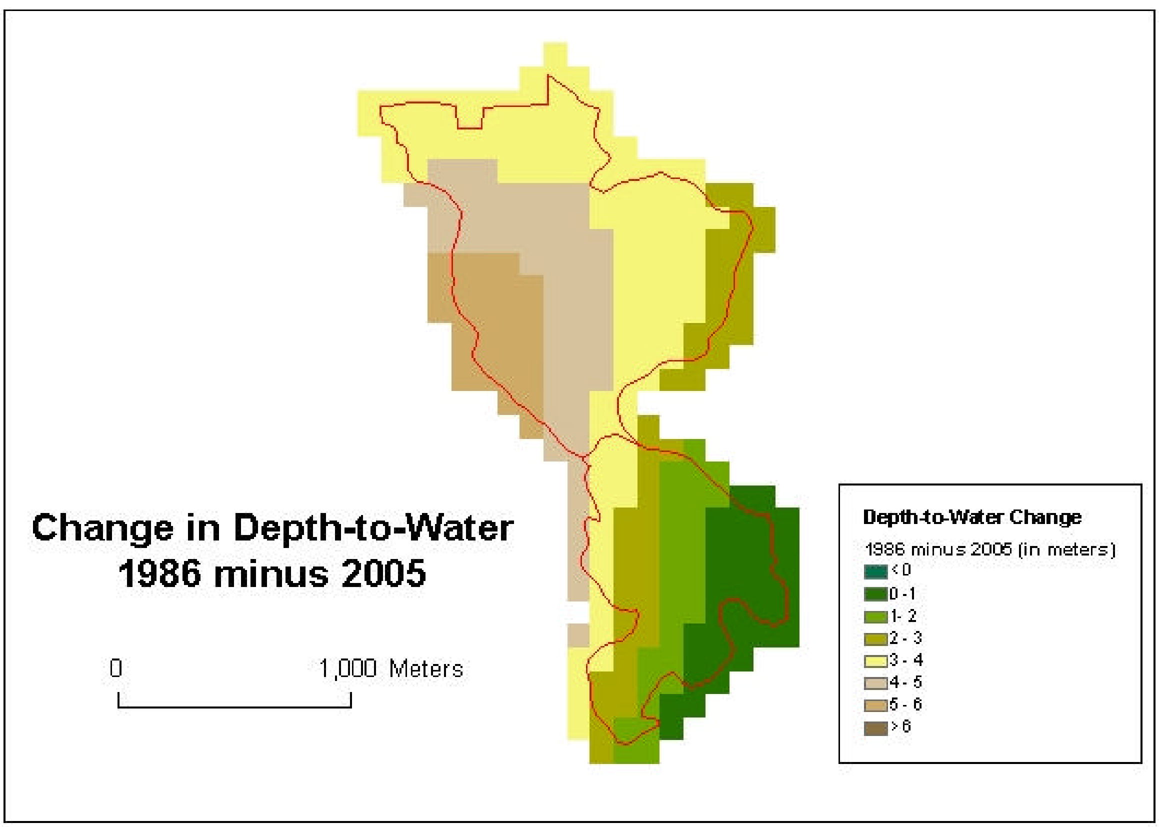

Change in Depth-to-Water
1986 minus 2003
0
1,000 Meters
Depth-to-Water Change
1986 minus 2003 (in meters)
< 0
0 - 1
1- 2
2 - 3
3 - 4
4 - 5
5 - 6
> 6


Change in Vegetation Percent Cover 1986 minus 2004
0
1,000 Meters
Vegetation Cover % Change
1986% minus 2004%
< -40
-20 - -40
0 - -20
0 - 10
10 - 20
20 - 35
25 - 50
50 - 80
> 80

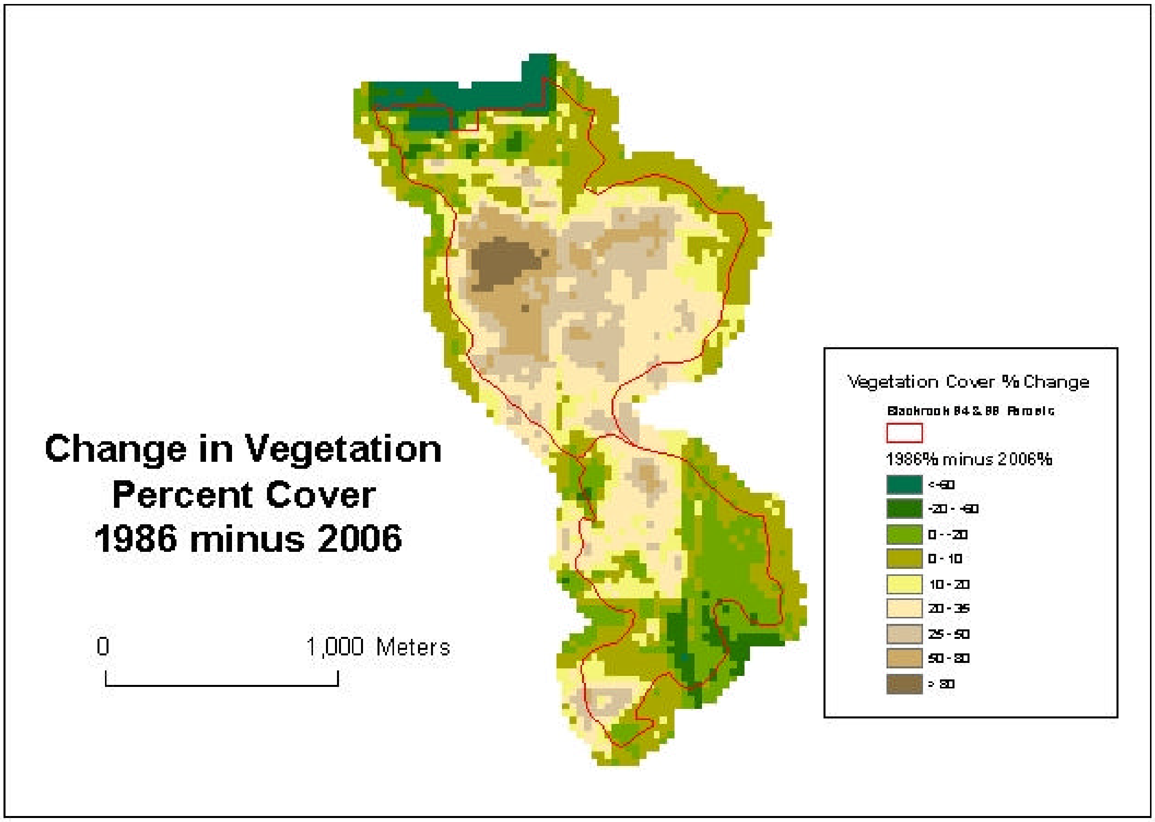

Change in Depth-to-Water 1986 minus 2004
0
1,000 Meters
Depth-to-Water Change
1986 minus 2004 (in meters)
< 0
0 - 1
1- 2
2 - 3
3 - 4
4 - 5
5 - 6
> 6

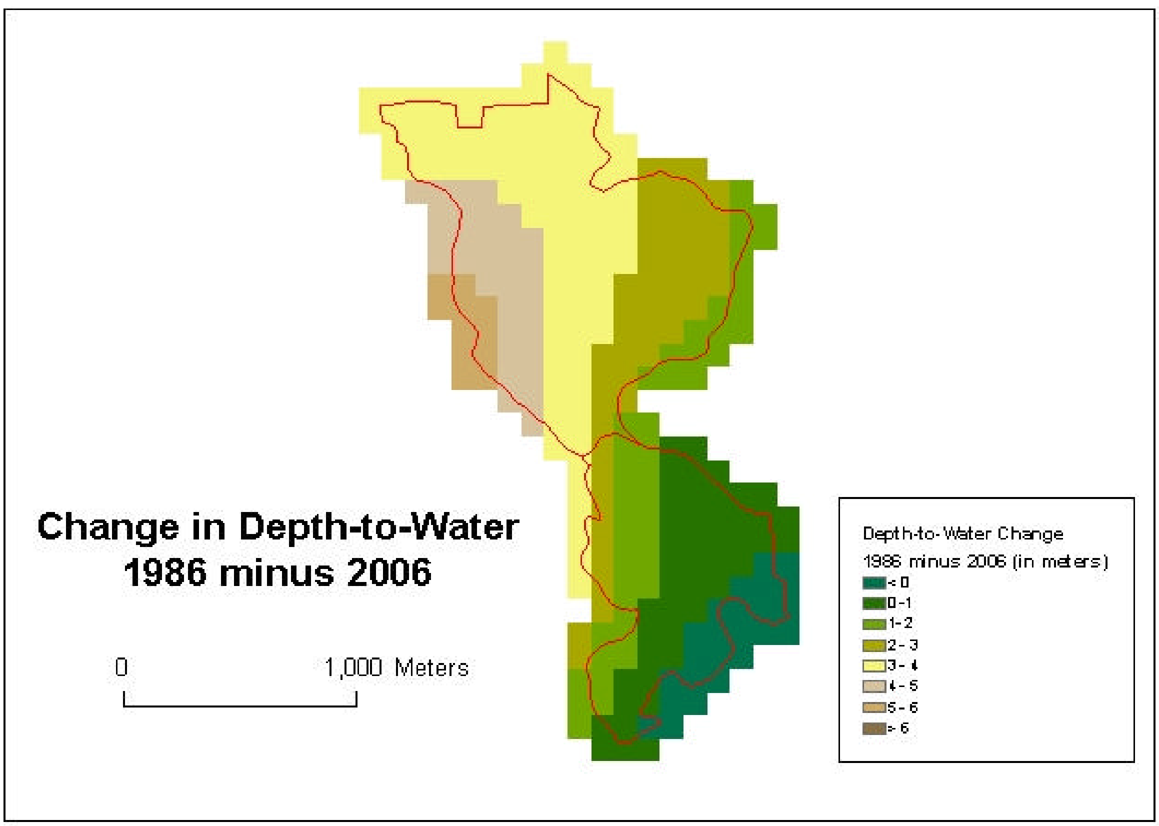


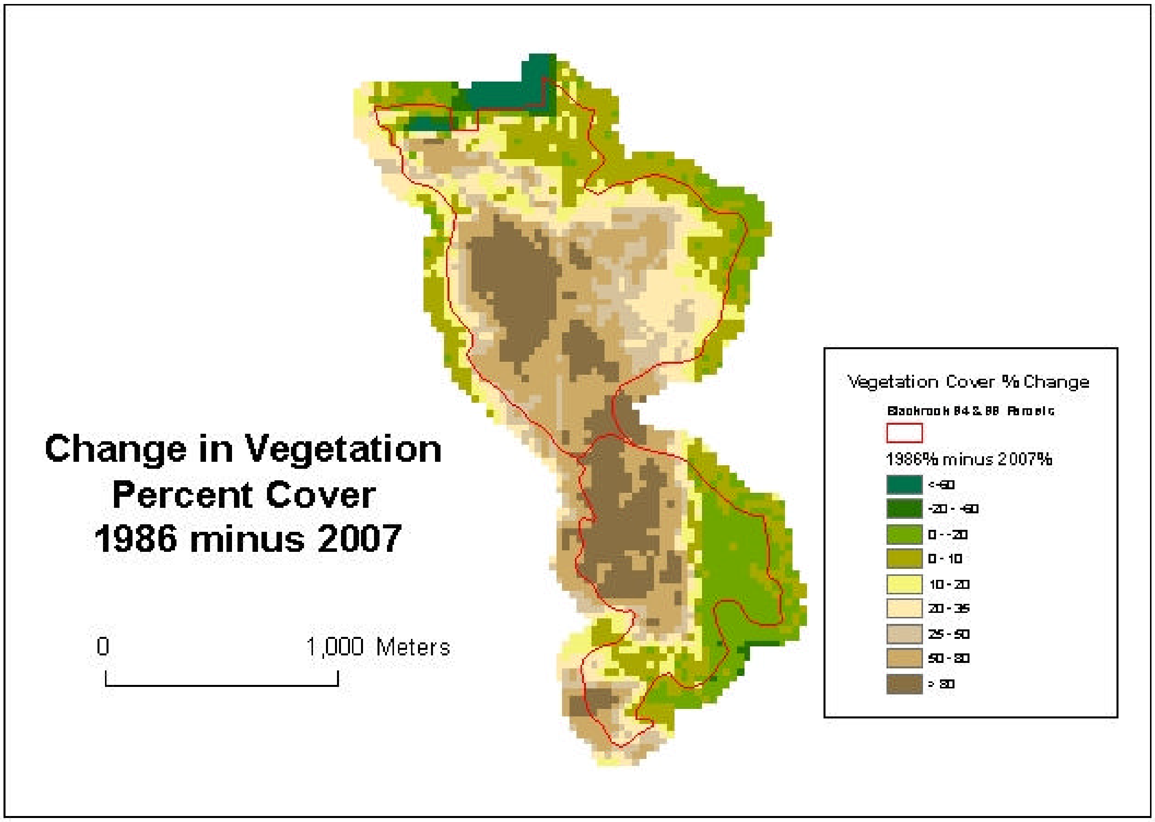
Change in Vegetation Percent Cover 1986 minus 2005
0
1,000 Meters
Vegetation Cover % Change
1986% minus 2005%
<-50
-20 - -50
0 - -20
0 - 10
10 - 20
20 - 35
25 - 50
50 - 80
> 80

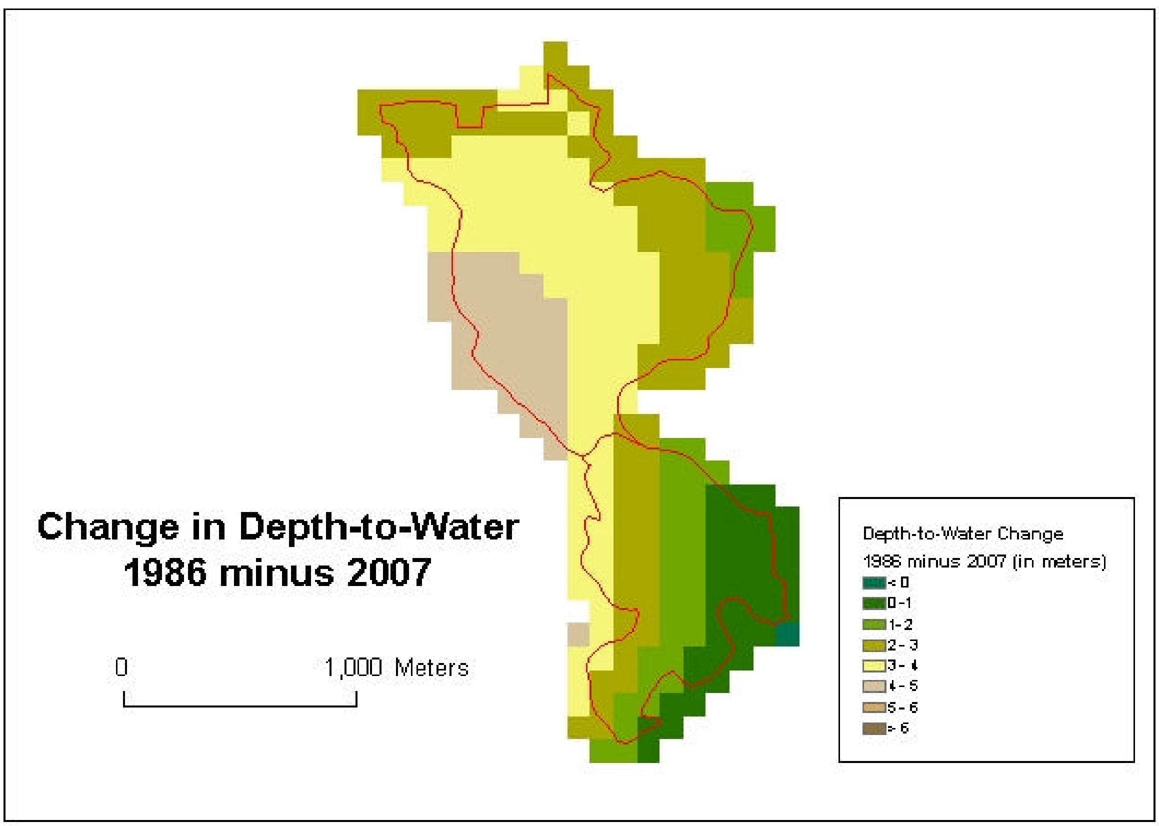



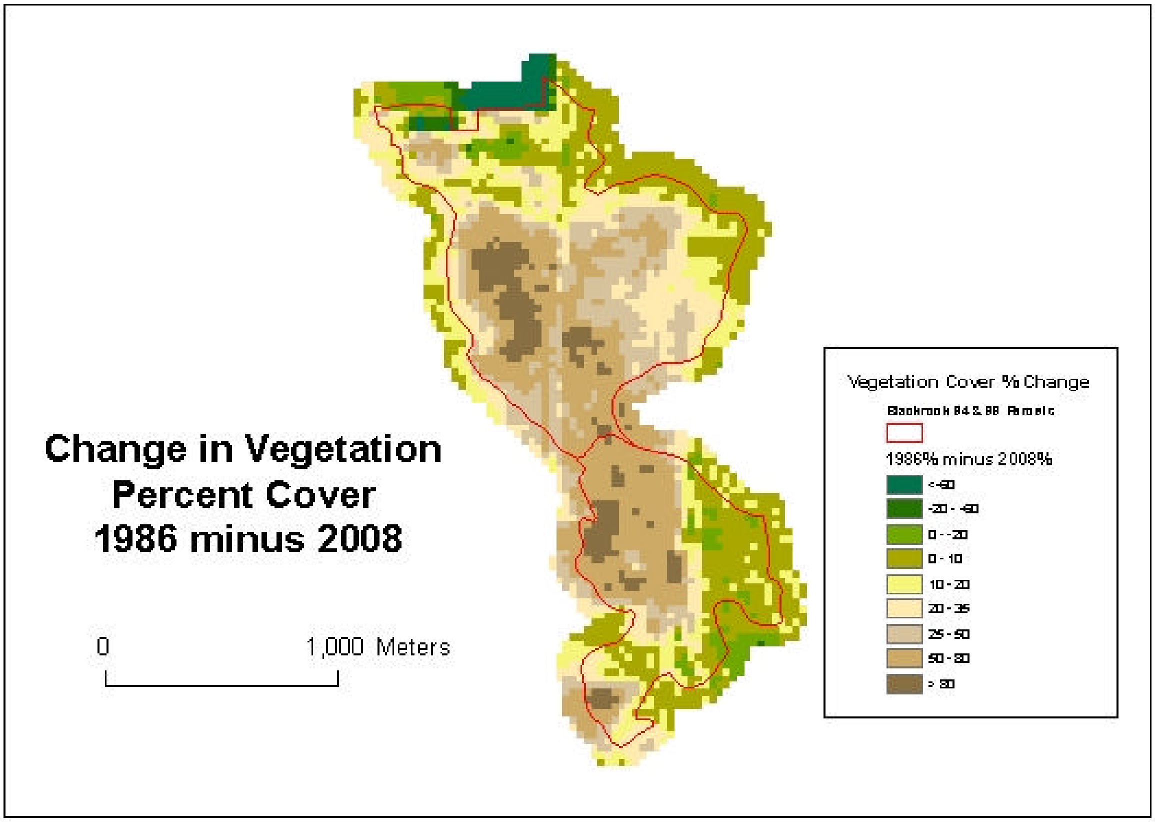
Change in Depth-to-Water 1986 minus 2005
0
1,000 Meters
Depth-to-Water Change
1986 minus 2005 (in meters)
< 0
0 - 1
1- 2
2 - 3
3 - 4
4 - 5
5 - 6
> 6

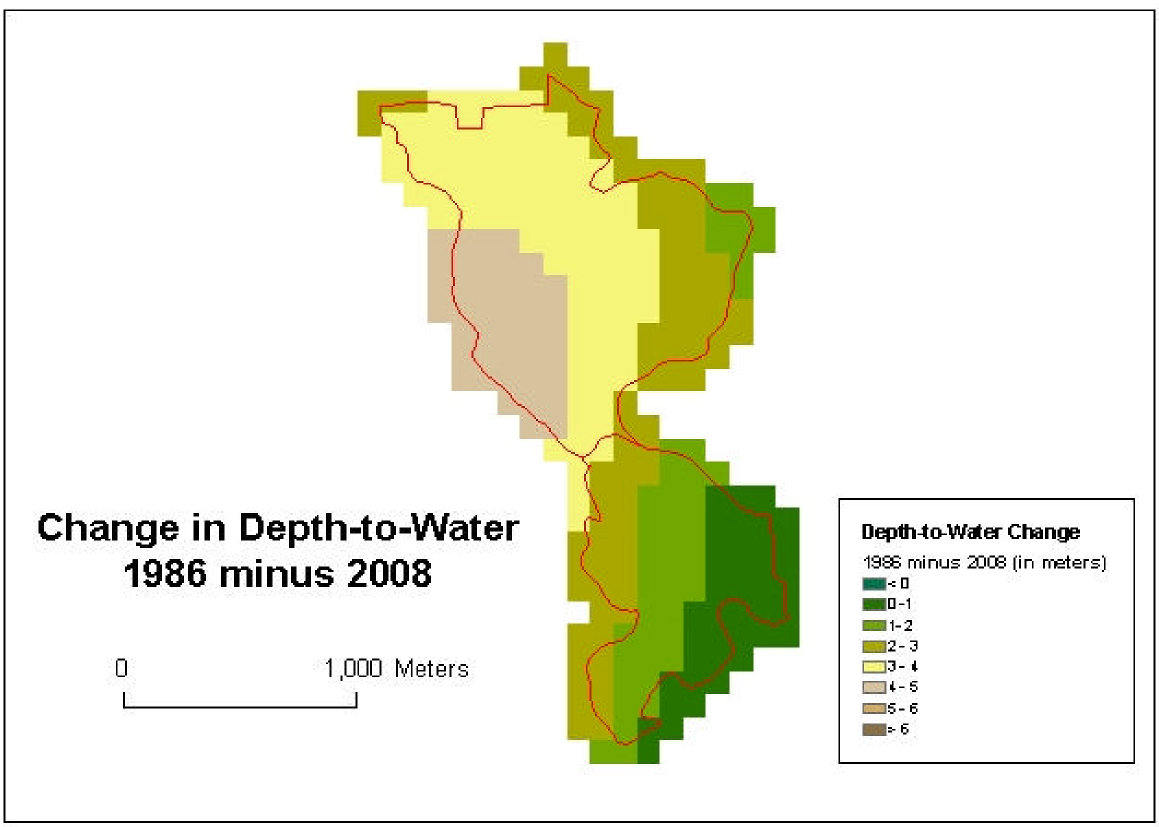

Change in Vegetation
Percent Cover
1986 minus 2006
0
1,000 Meters
Vegetation Cover % Change
1986% minus 2006%
< -40
-20 - -40
0 - -20
0 - 10
10 - 20
20 - 35
35 - 50
50 - 80
> 80

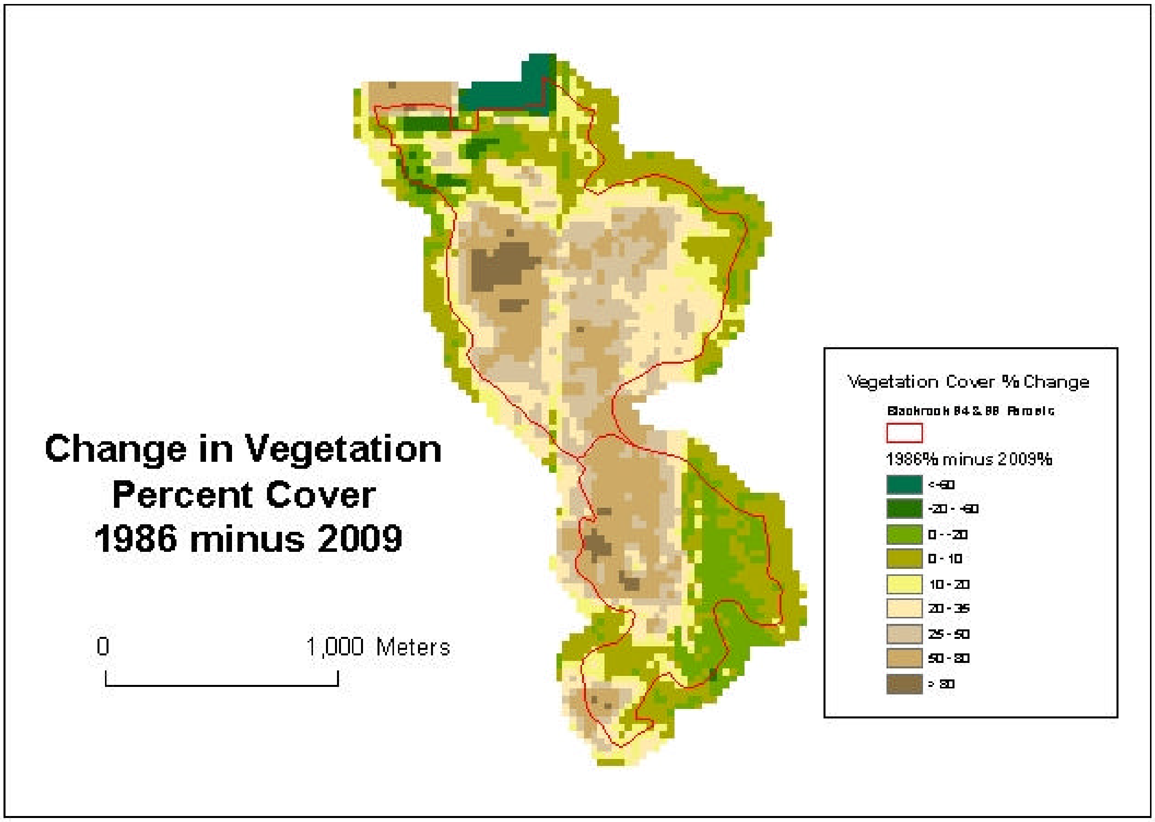

Change in Depth-to-Water
1986 minus 2006
0
1,000 Meters
Depth-to-Water Change
1986 minus 2006 (in meters)
< 0
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
5 - 6
> 6

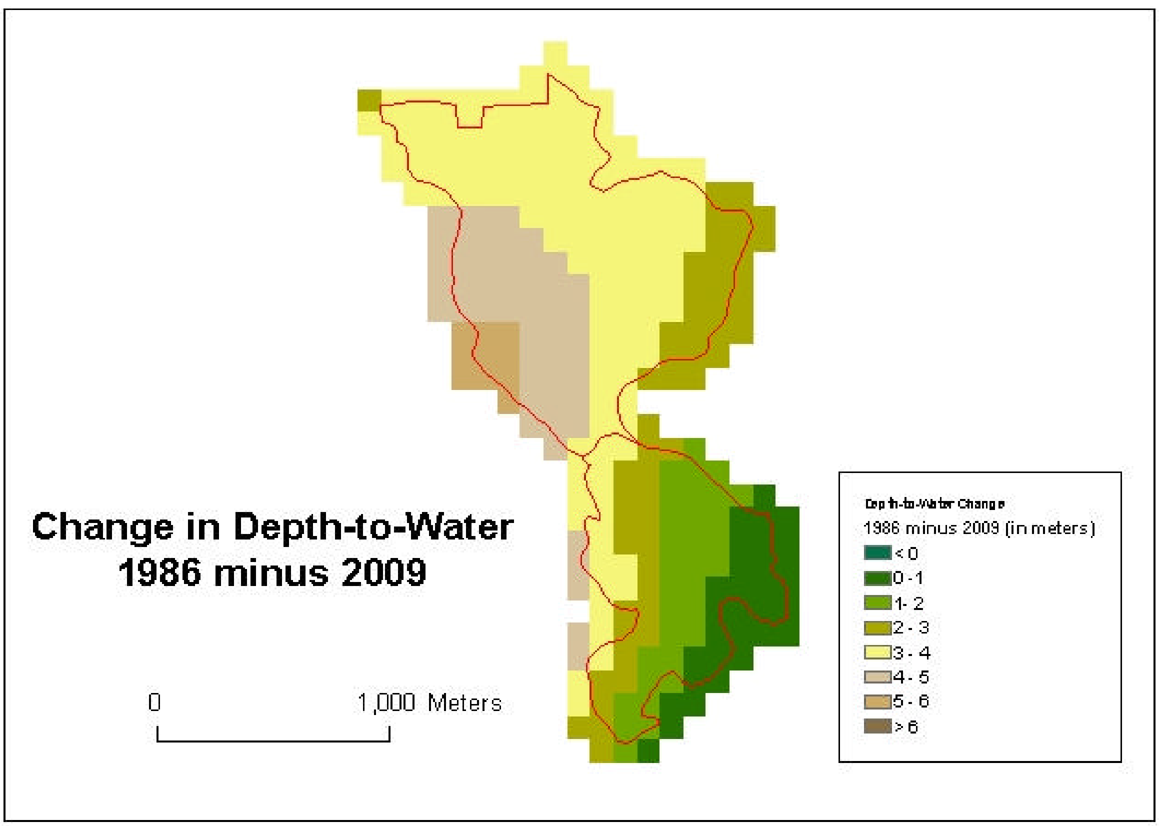

Change in Vegetation
Percent Cover
1986 minus 2007
0
1,000 Meters
Vegetation Cover % Change
1986% minus 2007%
< -40
-20 - -40
0 - -20
0 - 10
10 - 20
20 - 35
25 - 50
50 - 80
> 80


Change in Depth-to-Water
1986 minus 2007
0
1,000 Meters
Depth-to-Water Change
1986 minus 2007 (in meters)
< 0
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
5 - 6
> 6


Change in Vegetation
Percent Cover
1986 minus 2008
0
1,000 Meters
Vegetation Cover % Change
1986% minus 2008%
< -40
-20 - -40
0 - -20
0 - 10
10 - 20
20 - 35
25 - 50
50 - 80
> 80


Change in Depth-to-Water
1986 minus 2008
0
1,000 Meters
Depth-to-Water Change
1986 minus 2008 (in meters)
< 0
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
5 - 6
> 6


Change in Vegetation
Percent Cover
1986 minus 2009
0
1,000 Meters
Vegetation Cover % Change
1986% minus 2009%
< -40
-20 - -40
0 - -20
0 - 10
10 - 20
20 - 35
25 - 50
50 - 80
> 80


Change in Depth-to-Water
1986 minus 2009
0
1,000 Meters
Depth-to-Water Change
1986 minus 2009 (in meters)
< 0
0 - 1
1- 2
2 - 3
3 - 4
4 - 5
5 - 6
> 6