Owens Valley Vegetation Conditions 2010

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Abstract

One goal of the Long Term Water Agreement is to manage ground and surface water pumping while maintaining healthy groundwater-dependent vegetation communities found on the floor of the Owens Valley. Each year the Inyo County Water Department monitors a subset of vegetation parcels within the Owens Valley to ensure the goals of the Agreement are met. This report addressed two main questions regarding vegetation conditions; changes among groups of parcels with respect to the effects of groundwater and precipitation on vegetation cover and composition valley-wide, and cover decreases or changes over time within particular vegetation parcels. Over time, wellfield parcels have been below baseline measurements while control parcels are above or have maintained baseline cover. In alkali meadows, decreases in perennial cover correspond with deepening water tables. The 2010 reinventory data show that several parcels affected by groundwater pumping are below their baseline measurements. In the Laws wellfield, perennial cover is below baseline in 78% of wellfield parcels, and in 65% of parcels overall. Alkali meadows, commonly found in the valley, comprise only 0.1% of the state's vegetation community types; this rarity elevates the need to conserve their ecological integrity. Recovery of water tables in the Owens Valley is necessary to recover and maintain groundwater dependent meadows in the Owens Valley.

Introduction

To determine whether the goals of the Long Term Water Agreement (LTWA) are met, the Inyo County Water Department monitors vegetation conditions on an annual basis in the Owens Valley. The goals of this monitoring, according to the technical appendix to the LTWA (the Green Book), are to detect any "significant decreases and changes in Owens Valley vegetation from conditions documented in 1984 to 1987". Vegetation conditions, i.e. live cover and community type, documented during the 1984-87 mapping effort were adopted as the baseline conditions to be compared with each annual reinventory according to the LTWA. These baseline measurements are referred to as the 'baseline'.

The Green Book details the decreases and changes in vegetation that must be avoided according to vegetation community types. Baseline vegetation communities that required more moisture for evapotranspiration than was provided by precipitation were classified as groundwater-dependent communities and were given specific protections. These phreatophytic communities are dependent on shallow groundwater for moisture, particularly in years with low rainfall or runoff (Sorensen et al., 1991; Steinwand, et al., 2006). For these parcels, according to the Green Book, "the goal is to manage groundwater pumping and surface water management practices so as to avoid causing significant decreases in live vegetation cover" and to prevent a significant amount of vegetation from changing to a drier vegetation community type. A large proportion of these groundwater-dependent parcels were mapped during baseline as alkali meadows (61%) and the Agreement seeks to prevent these meadows from changing to shrub-dominated communities. Considering the rarity of the alkali meadow community type in

the state of California, alkali meadow comprises 0.1% of the vegetation community types (calculated from: Davis et al., 1998); this is a particularly important goal.

To evaluate the effects of water pumping on Owens Valley vegetation, data were analyzed at two scales, among- and within-parcels. We addressed three questions at the among (grouped) parcel scale: (1) whether cover in groups of parcels has changed over time as a result of groundwater management; (2) whether shrub and grass cover have changed over time; (3) whether observed changes in alkali meadow cover can be explained by changes in DTW or precipitation. Two main questions were addressed at the within-parcel scale: (1) whether changes in perennial vegetation cover have occurred over the twenty-year reinventory period, and (2) if observed changes in vegetation cover can be attributed to changes in depth to water (DTW) or precipitation.

Methods

Study Site—

The Owens Valley is located entirely within Inyo County, east of the Sierra Nevada and bounded by the White Mountains to the east. Runoff from the Sierra Nevada supplies a shallow groundwater basin that has historically supported phreatophytic vegetation communities including alkali, Nevada saltbush and rabbitbrush meadows. Perennial grasses have dominated the alkali meadow vegetation communities, while shrubs and grasses co-dominate mixed meadows (Manning, 1997).

Vegetation Sampling—

Using the Greenbook line point protocol, ICWD sampled 105 parcels of the 2126 vegetation parcels and 223,168 acres mapped during baseline in the summer of 2010 (Table 1). The average size of a vegetation parcel was approximately 88 acres (range 13-565 acres) for a total of 9273 acres sampled. A criterion for parcel selection was described in previous Inyo County reports (Manning, 1994). Approximately 19 to 41 random transects were sampled in each vegetation parcel. Transect start locations were generated using ArcView 3.3 software (ESRI , 1992-2002; Jabis, 2010). Estimates of perennial vegetation cover using Spectral Mixture Analysis (SMA) were generated by Dr. Andrew Elmore using satellite imagery for the time period from 1985 to 2010 (Elmore et al., 2001).

Table 1. Parcels sampled in 2010, listed by wellfield and control status. Columns indicate; wellfield or control status, *W/C*; plant community type based on Holland (1986), *Plant Community*; presence of baseline transect data, *BaseTransData*; presence of Greenbook line point data during the entire time period from 1992-2010, *LPT'92-2010*; and presence of line point data during the complete time period from 1991-2010, *LPT'91-2010*.

	Parcel	W/C	Plant Community	BaseTransData	LPT'92-2010	LPT'91-2010
1	BGP019	C	Rush/Sedge Meadow	Y		
2	BGP031	C	Alkali Meadow	Y	Y	
3	BGP047	C	Alkali Meadow	Y		
4	BIS055	C	Alkali Meadow	Y		
5	BLK115	C	Alkali Meadow	Y	Y	
6	FSL187	C	Alkali Meadow	Y	Y	
7	IND067	C	Nevada Saltbush Meadow	Y		
8	IND096	C	Nevada Saltbush Scrub	Y	Y	Y
9	IND119	C	Alkali Meadow	Y		
10	IND122	C	Nevada Saltbush Scrub	Y		
11	IND151	C	Alkali Meadow	Y		
12	IND163	C	Alkali Meadow	Y	Y	Y
13	LNP018	C	Alkali Meadow	Y	Y	
14	LNP019	C	Nevada Saltbush Scrub	Y		
15	LNP050	C	Alkali Meadow	Y		
16	LNP095	C	Alkali Meadow	Y		
17	MAN014	C	Nevada Saltbush Meadow	Y		
18	MAN060	C	Alkali Meadow	Y	Y	
19	PLC024	C	Alkali Meadow	Y	Y	
20	PLC028	C	Alkali Meadow	Y		
21	PLC056	C	Rabbitbrush Meadow	Y		
22	PLC059	C	Nevada Saltbush Scrub	Y		
23	PLC072	C	Rabbitbrush Scrub	Y		
24	PLC088	C	Alkali Meadow	Y		
25	PLC092	C	Rabbitbrush Scrub	Y		
26	PLC097	C	Alkali Meadow	Y		
27	PLC106	C	Rabbitbrush Meadow		Y	Y
28	PLC121	C	Alkali Meadow	Y	Y	
29	PLC136	C	Alkali Meadow	Y		
30	PLC137	C	Rabbitbrush Meadow	Y		
31	PLC144	C	Alkali Meadow	Y		
32	PLC223	C	Alkali Meadow	Y	Y	Y
33	UNW029	C	Alkali Meadow	Y	Y	
34	UNW031	C	Rush/Sedge Meadow	Y		
35	UNW039	C	Nevada Saltbush Scrub	Y	Y	Y
36	UNW079	C	Nevada Saltbush Meadow	Y		
37	BGP086	W	Alkali Meadow	Y		
38	BGP154	W	Nevada Saltbush Meadow	Y	Y	Y
39	BGP157	W	Rabbitbrush Scrub	Y		
40	BGP162	W	Nevada Saltbush Scrub	Y	Y	Y

	PCL	W/C	Plant Community	BaseTransData	LPT'92-2010	LPT'91-2010
41	BIS085	W	Rabbitbrush Meadow	Y		
42	BLK002	W	Rabbitbrush Scrub	Y		
43	BLK009	W	Alkali Meadow	Y	Y	Y
44	BLK016	W	Alkali Meadow	Y	Y	Y
45	BLK021	W	Nevada Saltbush Scrub	Y		
46	BLK024	W	Nevada Saltbush Meadow	Y	Y	Y
47	BLK033	W	Alkali Meadow	Y	Y	
48	BLK039	W	Alkali Meadow	Y	Y	
49	BLK044	W	Rabbitbrush Meadow		Y	Y
50	BLK069	W	Desert Sink Scrub		Y	Y
51	BLK074	W	Nevada Saltbush Scrub		Y	
52	BLK075	W	Alkali Meadow	Y	Y	
53	BLK077	W	Desert Sink Scrub	Y		
54	BLK093	W	Alkali Meadow	Y		
55	BLK094	W	Alkali Meadow	Y	Y	Y
56	BLK099	W	Alkali Meadow	Y	Y	Y
57	BLK142	W	Alkali Meadow	Y		
58	BLK143	W	Alkali Meadow	Y		
59	FSL053	W	Alkali Meadow	Y		
60	FSL064	W	Alkali Meadow	Y		
61	FSL065	W	Alkali Meadow	Y		
62	FSL116	W	Alkali Meadow	Y		
63	FSL120	W	Alkali Meadow	Y		
64	FSL123	W	Alkali Meadow	Y		
65	FSP004	W	Rabbitbrush Meadow	Y		
66	FSP006	W	Alkali Meadow		Y	Y
67	IND011	W	Alkali Meadow	Y	Y	
68	IND019	W	Alkali Meadow	Y		
69	IND024	W	Alkali Meadow	Y		
70	IND026	W	Alkali Meadow	Y		
71	IND029	W	Alkali Meadow	Y		
72	IND035	W	Alkali Meadow	Y	Y	
73	IND106	W	Nevada Saltbush Scrub		Y	Y
74	IND111	W	Nevada Saltbush Meadow	Y	Y	Y
75	IND132	W	Nevada Saltbush Scrub		Y	Y
76	IND133	W	Nevada Saltbush Scrub			
77	IND139	W	Nevada Saltbush Meadow	Y	Y	Y
78	IND205	W	Alkali Meadow			
79	IND231	W	Nevada Saltbush Scrub		Y	Y
80	LAW030	W	Alkali Meadow	Y		
81	LAW035	W	Alkali Meadow	Y		
82	LAW043	W	Rush/Sedge Meadow	Y		
83	LAW052	W	Alkali Meadow	Y		
84	LAW062	W	Rabbitbrush Meadow	Y		
85	LAW063	W	Desert Greasewood Scrub	Y	Y	Y
86	LAW065	W	Alkali Meadow	Y	Y	

	PCL	W/C	Plant Community	BaseTransData	LPT'92-2010	LPT'91-2010
87	LAW070	W	Rush/Sedge Meadow	Y		
88	LAW072	W	Alkali Meadow	Y		
89	LAW078	W	Alkali Meadow	Y		
90	LAW082	W	Rabbitbrush Meadow	Y		
91	LAW085	W	Alkali Meadow		Y	Y
92	LAW107	W	Alkali Meadow	Y	Y	
93	LAW112	W	Nevada Saltbush Meadow	Y		
94	LAW120	W	Alkali Meadow	Y	Y	Y
95	LAW122	W	Alkali Meadow	Y	Y	
96	LAW137	W	Rabbitbrush Meadow	Y		
97	LNP045	W	Nevada Saltbush Meadow	Y		
98	MAN006	W	Alkali Meadow	Y	Y	
99	MAN007	W	Nevada Saltbush Scrub	Y	Y	Y
100	MAN037	W	Nevada Saltbush Scrub	Y	Y	Y
101	TIN028	W	Desert Greasewood Scrub	Y	Y	Y
102	TIN050	W	Alkali Meadow	Y		
103	TIN053	W	Alkali Meadow	Y		
104	TIN064	W	Alkali Meadow	Y		
105	TIN068	W	Alkali Meadow	Y	Y	

Covariates –

Depth to water (DTW) measurements were generated using ordinary kriging based on test wells located throughout the Owens Valley (Harrington and Howard 2000; Harrington, 2003). Precipitation measurements were collected by LADWP at six weather stations: Bishop Yard, Big Pine Yard, Tinemaha Reservoir, Independence Yard, Alabama Gates, and the Lone Pine yard. These gauges were chosen because they provide a complete record from the baseline sampling through the present (see Jabis, 2010 for selection details).

Control vs Wellfield Designations—

We classified parcels according to the level of water table drawdown to evaluate the effects of groundwater pumping on vegetation. The water table underneath 'control' parcels are largely unaffected by groundwater pumping while 'wellfield' parcels have experienced pumping-induced drawdown during the monitoring period. To classify parcels, the level of drawdown sustained by the parcel during heaviest period of pumping (1988-1990) was used. Two water table estimation methods were used to evaluate the level of drawdown; ordinary (OK) kriging of measured water levels since baseline and the groundwater modeling results shown on the baseline maps (Danskin 1998; LTWA Exhibit A: Management Maps; Harrington and Howard 2000; Harrington, 2003). Parcels with greater than 1m drawdown of the water table using kriged depth to water (DTW) estimates during the period 1987-1993 and within the modeled 10ft drawdown contour were classified as wellfield parcels. The modeled drawdown contour alone was used if the parcel had a surface water feature nearby; for example, a canal, river, or other adjacent ground water source, or if kriged DTW estimates were not reliable. Unreliable DTW estimates are a result of inadequate test well coverage near vegetation parcels,

which results in inaccurate water table interpolation (see Harrington, 2003 for details). Parcels designated as controls experienced less than 1m drawdown according to kriged estimates between the time period 1987-1993 and were outside of the modeled 10ft drawdown contour. If water table estimates using kriging were not reliable, the 10m drawdown contour alone was used. Control parcels located within the 10ft drawdown contour were buffered by a surface water source, i.e. a canal, sewer pond, creek, river or by a ground water seepage source which would moderate potential drawdown.

Statistical Analysis—
Among-Parcel—

We addressed four questions with respect to the control and wellfield parcel groups. We first assessed whether groups of parcels changed over the entire time period time with respect to groundwater management using wellfield and control groups. Second, we compared differences between baseline and 2010 for the wellfield and control groups using two datasets. Third, we evaluated whether shrub and grass cover have changed over time with respect to groundwater management using wellfield and control groups using two datasets. Finally, we assessed whether observed changes in alkali meadow wellfield or control parcel cover can be predicted by changes in DTW or precipitation.

To assess whether wellfield parcels differ from control parcels over time, a repeated measures MANOVA was used for the set of parcels that have been sampled each year between 1992-2010 (n = 45), and for alkali meadows sampled during this period (n = 27). A repeated measures MANOVA was chosen for two reasons; it allows testing of all years simultaneously because it controls the family-wise error rate (to prevent the rejection of a true null hypothesis of no difference) and it accounts for the dependence of subjects between years (to prevent the violation of statistical independence). It is therefore an extension of the paired t-test for multiple years and subjects. The number of parcels sampled each year has varied for a number of reasons including staffing and available technology. Analyzing the complete dataset (all parcels sampled in any given year) confounds the evaluation of the effects of DTW fluctuations on cover with the effects of varying the sample size. The set of parcels sampled each year from 1992-2010 was chosen because the sample size (n = 45) is greater than the set of parcels sampled each year from 1991-2010 (n = 21). This consistently sampled set of parcels will hereafter be referred to as the 'rarefied' (or reduced) set.

To visualize the difference in perennial cover between each reinventory year and baseline measurements for the rarefied set of parcels, annual cover measurements for each parcel were graphed (Figure 2). To analyze perennial cover changes between baseline and 2010 for the rarefied set (n = 45) of wellfield and control parcels, a paired t-test was performed in JMP 8.0 (JMP, 1989-2007). A paired t-test was used because it is designed to assess differences between two time-periods. Similarly, to assess changes in perennial cover for all parcels sampled in 2010 that have baseline transect data, hereafter referred to as '2010 parcels' (n = 94), a paired t-test was performed to compare wellfield and control perennial cover in 2010 with mean baseline perennial cover.

To examine changes in mean perennial cover by lifeform (grass, herb, or shrub) perennial cover was graphed for each year between 1992 and 2010 using the rarefied set of parcels (n = 45). This was followed with a paired t-test of perennial grass cover between baseline and 2010 for the same set of parcels with a complete time record. Regressions of shrub and grass cover over time were also performed on the rarefied dataset for wellfield and control groups. Mean perennial cover was also graphed by lifeform for 2010 parcels (n = 94) to view potential changes in cover and community type at a valley-wide scale, and followed by a paired t-test of baseline perennial grass cover by parcel type (wellfield or control). Finally a regression of mean shrub cover against time was analyzed for the rarefied set of wellfield and control parcels (n_T = 36: n_W = 24, n_C = 12 for the wellfield and control groups respectively).

To assess whether observed changes in vegetation cover in alkali meadows can be predicted by fluctuations in DTW or precipitation, simple linear regressions of wellfield and control cover were performed against DTW and precipitation (both water year and winter). These tests were performed on all alkali meadows with at least a 10-year line point sampling record. To determine which of the two moisture sources was a better predictor of vegetation cover, a multiple linear regression was performed on alkali meadow wellfield and control parcels against DTW and winter precipitation. Only parcels with reliable DTW estimates were used (n_W = 231, and n_C = 106 data points from n_W =15, and n_C = 8 parcels for wellfield and control groups respectively).

Within-Parcel—

Two main questions were addressed at the individual parcel scale; whether changes in vegetation cover have occurred over time and whether any observed changes in vegetation cover can be attributed to changes in depth to groundwater or precipitation. To test whether a single parcel's vegetation cover changed over time, a weighted ANOVA was performed followed by Dunnett's test to compare each year to baseline measurements in *R* (2011). A weighted ANOVA was chosen because of heterogeneous levels of variation in vegetation cover between baseline and reinventory, while the Dunnett's pairwise test controls the alpha level when multiple comparisons are employed (Zar, 1999). Results of these tests on 2010 parcels were also mapped according to three categories: significantly below baseline, no difference from baseline, and significantly above baseline in 2010.

To determine whether observed changes in vegetation cover can be predicted by changes in depth to groundwater or precipitation, simple linear regressions of perennial cover against DTW and precipitation (winter and water-year) were performed for each parcel with at least 10 years of line-point data. If both simple linear regressions were significant, a multiple linear regression of cover against DTW and winter precipitation was completed. Only parcels with reliable DTW estimates were used. A total of 44 parcels have both 10 years of line-point data and reliable DTW estimates (Table 2).

Results

Cover Changes—

Wellfield vs Control—

Wellfield and control parcels behaved differently during the 18-year monitoring period. Perennial cover in the rarefied set of wellfield parcels (n = 32) was below baseline while control parcels (n = 13) were above their baseline measurements (Figure 1a, n = 45, $P = 0.0032$, repeated measures MANOVA). The magnitude of difference between mean cover in control and wellfield parcels has decreased over time. For alkali meadow parcels sampled each year during this same time period (1992-2010), the general pattern is the same; however, the difference between wellfield (n = 17) and control (n = 10) parcels and their baseline was not significant (Figure 1b, n = 27, $P = 0.2235$).

Differences between baseline and reinventory perennial cover for the rarefied dataset are displayed in Figure 2 according to wellfield or control status. In 2010, mean perennial cover in rarefied wellfield parcels (n = 32) was 29%; 0.2% above average baseline and control cover was 27%; 1.4% above baseline. These changes were not significant in 2010 according to a paired t-test (Figure 2, $P = 0.90$, and $P = 0.54$ for wellfield and control parcels respectively). For the 2010 parcel set (n = 94), mean perennial cover in wellfield parcels was 28.6%; 6% below average baseline and control cover was 31%; 0.6% above baseline. Wellfields (n = 59) were significantly lower than baseline in 2010 (Figure 5a, $P = 0.008$), while control (n = 35) cover was not different than baseline (Figure 5b, $P = 0.79$) according to paired t-tests.

Individual Parcels by Wellfield—

A visual inspection of individual parcel results reveals decreases in perennial cover compared to baseline readings in several parcels. See Appendix 1 for graphs of Greenbook line point vegetation cover (where available), SMA cover, and hydrographs depicting groundwater levels beneath vegetation parcels during the time period 1985-2010. See Appendix 2 for a map of parcels color-coded by statistical significance in 2010. Parcel changes were assessed by wellfield to identify areas that may require management adjustments or potential mitigation. The Laws area contained the most parcels with perennial cover significantly lower than baseline measurements. In 11 of 17 Laws parcels, perennial cover has been consistently below baseline during all, or a majority of the reinventory period from 1991 to 2010, and these decreases appear to be vary with similar changes in groundwater levels. These parcels include: LAW035, LAW043, LAW052, LAW062, LAW063, LAW065, LAW070, LAW072, LAW078, LAW082, LAW085. In two Bishop parcels, FSL120 and PLC106, cover has been lower than baseline in the past several years, but the decreases do not appear to be related to changes in groundwater levels. Similarly, in two Big Pine parcels, changes in cover do not appear to be due to changes in groundwater (BGP019 and FSP006). In BGP162 and BGP047, it is unclear whether significantly reduced cover is correlated with changes in DTW. In the Taboose-Aberdeen wellfield, in parcel BLK009, decreased perennial cover appears to be related to a lowered groundwater table from the late 1980's to the mid 1990s, while it is unclear whether significantly decreased cover in BLK021 and BLK033 are due to changes in DTW. Two parcels in the Thibaut-Sawmill (TS) wellfield show

decreased cover, but it is unclear whether these changes are due to fluctuations in groundwater, BLK075 and IND026. However, in two parcels in the TS wellfield, BLK077 and BLK094, significant decreases in cover appear related to lowering of the water table. In the Independence-Oak wellfield, significantly decreased perennial cover in IND119 appears to be related to changes in groundwater depth. This control parcel was affected by water spreading in the mid-1980s. In the Symmes-Shepard, Bairs-Georges and Lone Pine wellfields, it is unclear whether decreased cover in six parcels (IND139, MAN007, MAN014, MAN037, LNP045, and LNP050) is related to changes in groundwater availability.

Composition Changes—

Changes in lifeform are occurring according to analyses completed using both the rarefied (n = 45) and the 2010 parcel set (n = 94). According to the rarefied set of parcels, wellfield grass cover has decreased significantly between baseline and 2010, while no change has occurred in control parcels (Figure 3, $P = 0.0086$ and $P = 0.84$ respectively, paired t-test). Using the 2010 parcel set, wellfield perennial grass cover in 2010 is significantly lower than baseline, while in control parcels grass cover has not changed ($P = 0.0001$, and $P = 0.14$ respectively). According to regression, perennial shrub cover has increased over the time period 1992-2010 in the rarefied set of wellfield parcels (Figure 4, n = 24, $r^2 = 0.25$, $P = 0.0246$), but did not change in control parcels ($r^2 = 0.00$, $P = 0.91$). However, regression also indicates that grass cover did not change over time in either rarefied wellfield or control parcels ($r^2 = 0.004$, $P = 0.79$, and $r^2 = 0.056$, $P = 0.313$ respectively).

Driving Factors—

Alkali Meadow: Wellfield vs Control—

Changes in depth to groundwater were negatively correlated with changes in alkali meadow wellfield perennial cover while no correlation was found in control parcels (Figure 6, n = 231, $r^2 = 0.34$, $P = 0.0001$ for wellfields; and n = 106, $r^2 = 0.0004$, $P = 0.84$; for control parcels). No correlation was found between precipitation and wellfield alkali meadow cover (n = 231, $r^2 = 0.0004$, $P = 0.75$). However there was a slight positive correlation between alkali meadow control cover and precipitation (n = 106, $r^2 = 0.06$, $P = 0.0095$).

Individual Parcels—

Following analysis of cover changes over time, we assessed whether any observed changes in parcel-scale vegetation cover could be directly attributed to changes in depth to groundwater or precipitation. Results of simple linear regressions at the parcel scale are listed in Table 2, for parcels with reliable DTW estimates. In 41% of control parcels and 40% of wellfield parcels with at least 10 years of data, changes in DTW and cover were correlated. The Laws wellfield responded most significantly to changes in groundwater availability; 78% of wellfield parcels declined in cover in response to reduced groundwater levels. Fewer parcels responded to changes in precipitation than to changes in DTW; 16% of control parcels and 26% of wellfield parcels were correlated with precipitation.

Table 2. Results of both simple and multiple linear regression (MLR) analysis of mean perennial cover regressed against depth to groundwater, winter precipitation, and water year precipitation for parcels sampled each year from 1992-2010 with reliable DTW estimates. Bold text indicate significant regressions at the $\alpha = 0.05$ level (*r2* and *P* values are given); where two regressions are significant in the MLR, shading indicates the predictor that demonstrates a stronger correlation with perennial cover; where both columns are shaded, both predictors have an equal effect.

		Cover x DTW		Cover x Winter Precip		Cover x WY Precip		MLR: Cover x DTW and Winter Precip			
C/W	Parcel	*r^2*	*P*	*r^2*	*P*	*r^2*	*P*	dtw *r^2*	dtw *P*	precip *r^2*	precip *P*
C	BGP031	**0.41**	**0.0023**	0.03	0.4344	0.06	0.3034	**0.44**	**0.0019**	0.09	0.2244
C	BGP047	**0.54**	**0.0011**	0.1	0.2285	0.13	0.1712	**0.56**	**0.0013**	0.13	0.181
C	BIS055	**0.4**	**0.0262**	0.11	0.2939	0.14	0.2356	**0.67**	**0.0022**	**0.5**	**0.0148**
C	BLK115	0.13	0.1224	0.01	0.7504	0.03	0.4498	0.13	0.1222	0.01	0.6285
C	IND064	0.05	0.5065	**0.69**	**0.0008**	**0.72**	**0.0005**	**0.47**	**0.0198**	**0.83**	**0.0001**
C	IND067	0.07	0.37	**0.32**	**0.0343**	**0.51**	**0.0044**	0.21	0.1149	**0.43**	**0.0156**
C	IND119	**0.25**	**0.0425**	0.22	0.0577	0.21	0.0635	**0.45**	**0.0045**	**0.43**	**0.0058**
C	PLC106	0.03	0.4178	0	0.937	0	0.9054	0.04	0.4272	0	0.9014
C	PLC113	0.14	0.2789	0.03	0.6316	0.05	0.542	0.15	0.3056	0.03	0.6303
C	UNW029	0.02	0.6003	0.13	0.1162	0.15	0.0964	0	0.8744	0.12	0.148
C	UNW039	**0.41**	**0.0018**	0	0.912	0	0.8219	**0.41**	**0.0023**	0.01	0.7322
C	UNW079	0.04	0.4379	0.03	0.4727	0	0.9188	0.07	0.3171	0.06	0.3375
W	BGP154	**0.61**	**0**	0	0.7751	0.02	0.5182	**0.69**	**0**	0.19	0.0561
W	BGP157	0	0.9659	0.01	0.7231	0	0.8317	0	0.9266	0.01	0.7274
W	BIS085	0.21	0.1331	0.06	0.4542	0.1	0.3238	0.29	0.0903	0.15	0.2454
W	BLK009	**0.22**	**0.0308**	**0.26**	**0.0178**	**0.32**	**0.0076**	**0.35**	**0.0061**	**0.38**	**0.0037**
W	BLK016	**0.51**	**0.0003**	0.01	0.6881	0	0.7701	**0.52**	**0.0003**	0.03	0.4371
W	BLK021	0.01	0.6792	**0.46**	**0.0027**	**0.48**	**0.0019**	0.01	0.7315	**0.46**	**0.0039**
W	BLK069	0.05	0.314	0.13	0.1096	0.17	0.0633	0.04	0.4048	0.12	0.1419
W	BLK074	0.03	0.4355	**0.26**	**0.0215**	**0.32**	**0.0091**	0.04	0.4238	**0.26**	**0.0246**
W	BLK077	0.24	0.1098	0.27	0.0821	0.3	0.0669	0.27	0.0983	0.31	0.0759
W	BLK094	**0.24**	**0.0228**	**0.34**	**0.0058**	**0.43**	**0.0013**	**0.32**	**0.01**	**0.4**	**0.0028**
W	BLK099	0.14	0.0912	0	0.9911	0	0.8041	0.16	0.084	0.02	0.5925
W	FSL065	0.06	0.3445	0	0.7942	0.01	0.7272	0.06	0.3607	0	0.7963
W	FSP004	0.2	0.0855	0	0.9072	0	0.9505	0.22	0.0783	0.03	0.542
W	FSP006	0.04	0.4166	**0.39**	**0.0023**	**0.47**	**0.0006**	0.16	0.0792	**0.47**	**0.0008**
W	IND011	**0.22**	**0.0375**	0.04	0.3772	0.06	0.3146	**0.24**	**0.0352**	0.06	0.2965
W	IND019	**0.57**	**0.0019**	0	0.9651	0	0.8311	**0.57**	**0.0029**	0	0.8218
W	IND029	0.09	0.3744	0.34	0.0583	0.29	0.0882	0.09	0.3898	**0.35**	**0.0733**
W	IND106	0.04	0.4019	**0.29**	**0.0118**	**0.28**	**0.0146**	0	0.8058	**0.27**	**0.0202**
W	IND111	**0.4**	**0.002**	0.12	0.1174	0.16	0.073	**0.62**	**0**	**0.44**	**0.0014**
W	IND132	**0.21**	**0.0363**	**0.24**	**0.025**	**0.23**	**0.0271**	**0.6**	**0.0001**	**0.61**	**0**
W	IND133	0.15	0.2084	**0.36**	**0.0393**	0.3	0.0628	0.05	0.5262	0.28	0.0951
W	LAW052	**0.48**	**0.0028**	0.18	0.1067	0.19	0.0907	**0.62**	**0.0005**	**0.39**	**0.0132**
W	LAW062	**0.49**	**0.0013**	0.01	0.7177	0.02	0.548	**0.52**	**0.001**	0.08	0.2745
W	LAW063	**0.71**	**0**	0	0.8779	0	0.8372	**0.78**	**0**	**0.23**	**0.0307**
W	LAW065	**0.5**	**0.0005**	0.02	0.5836	0.02	0.5102	**0.67**	**0**	**0.35**	**0.0071**
W	LAW078	**0.75**	**0**	0	0.9509	0	0.9527	**0.76**	**0**	0.02	0.6039
W	LAW082	0.2	0.0822	0.15	0.1434	0.14	0.1467	**0.28**	**0.0432**	0.23	0.0704
W	LAW107	**0.66**	**0**	0.04	0.4062	0.04	0.3907	**0.65**	**0**	0.02	0.5352
W	LAW112	0.15	0.1116	0.01	0.709	0	0.8138	0.18	0.0933	0.04	0.4469
W	LAW120	**0.33**	**0.0061**	0	0.984	0	0.8089	**0.35**	**0.0065**	0.02	0.5748
W	MAN006	0.06	0.3107	0.02	0.5191	0.03	0.4635	0.08	0.237	0.05	0.3649
W	MAN007	0.11	0.149	**0.26**	**0.0194**	**0.26**	**0.019**	**0.36**	**0.0054**	**0.46**	**0.0009**

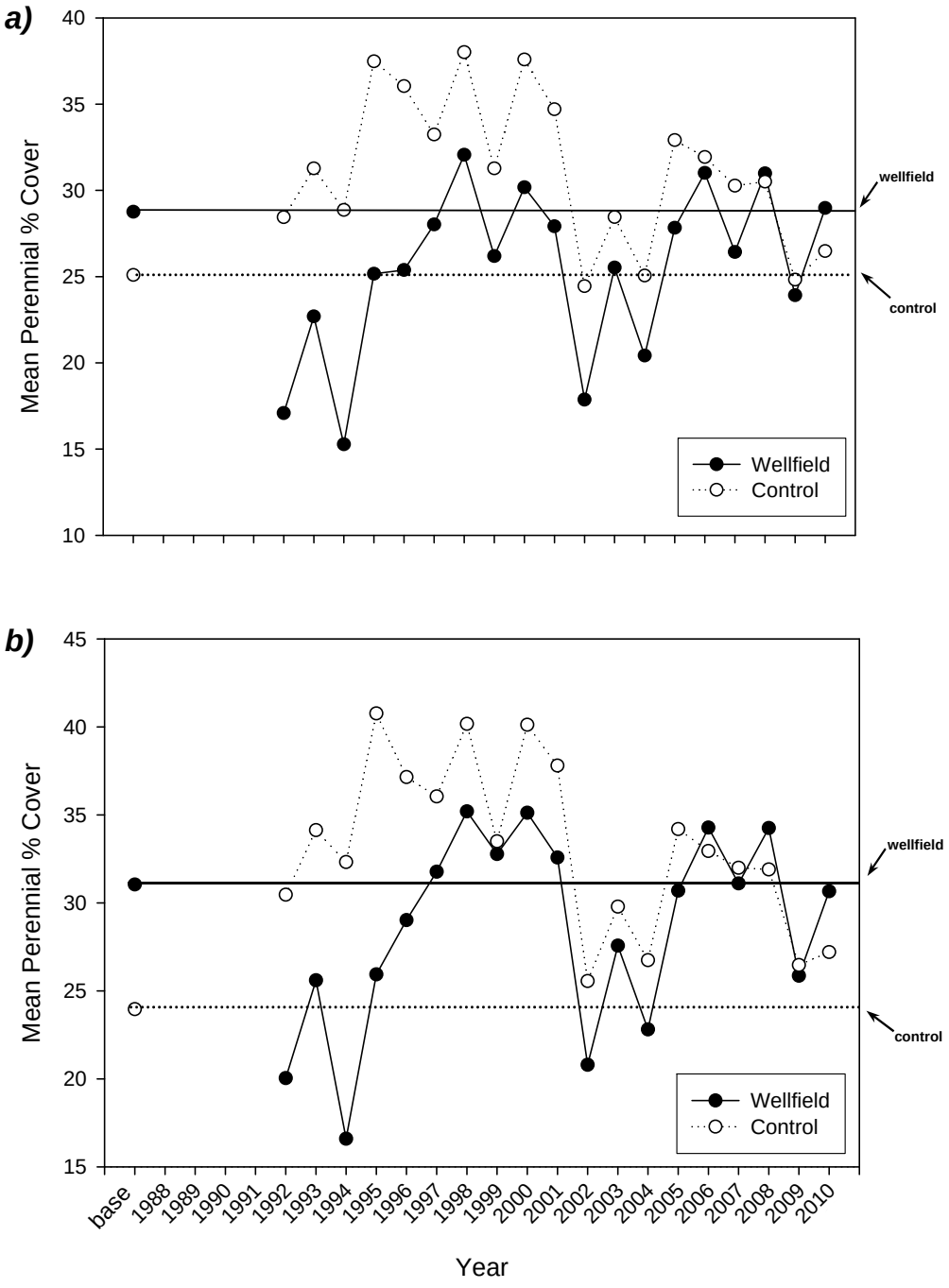


Figure 1. Repeated measures MANOVA results; *a)* parcels sampled each year between 1992 and 2010 (n = 45); wellfield parcel perennial cover is significantly below its baseline while control parcel cover is above baseline measurements ($P = 0.0032$). For *b)* Alkali meadow parcels sampled each year from 1992-2010 (n = 27), the general pattern is the same, however, no difference over time between wellfield or control baseline and reinventory cover was found ($P = 0.2235$).

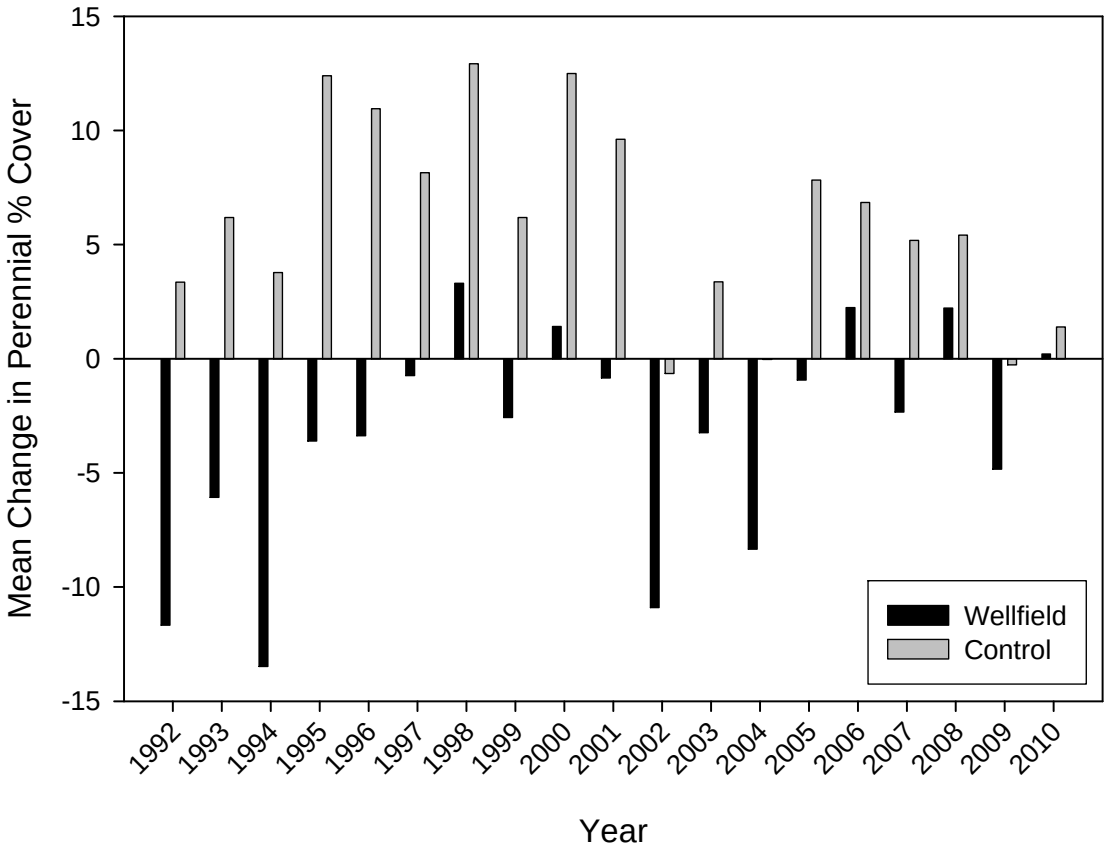


Figure 2. The difference in mean perennial cover between baseline and each reinventory year for the set of parcels sampled each year between 1992 and 2010. Mean wellfield and control cover are not significantly different than baseline in 2010 for this set of parcels ($P = 0.90$, and $P = 0.54$).

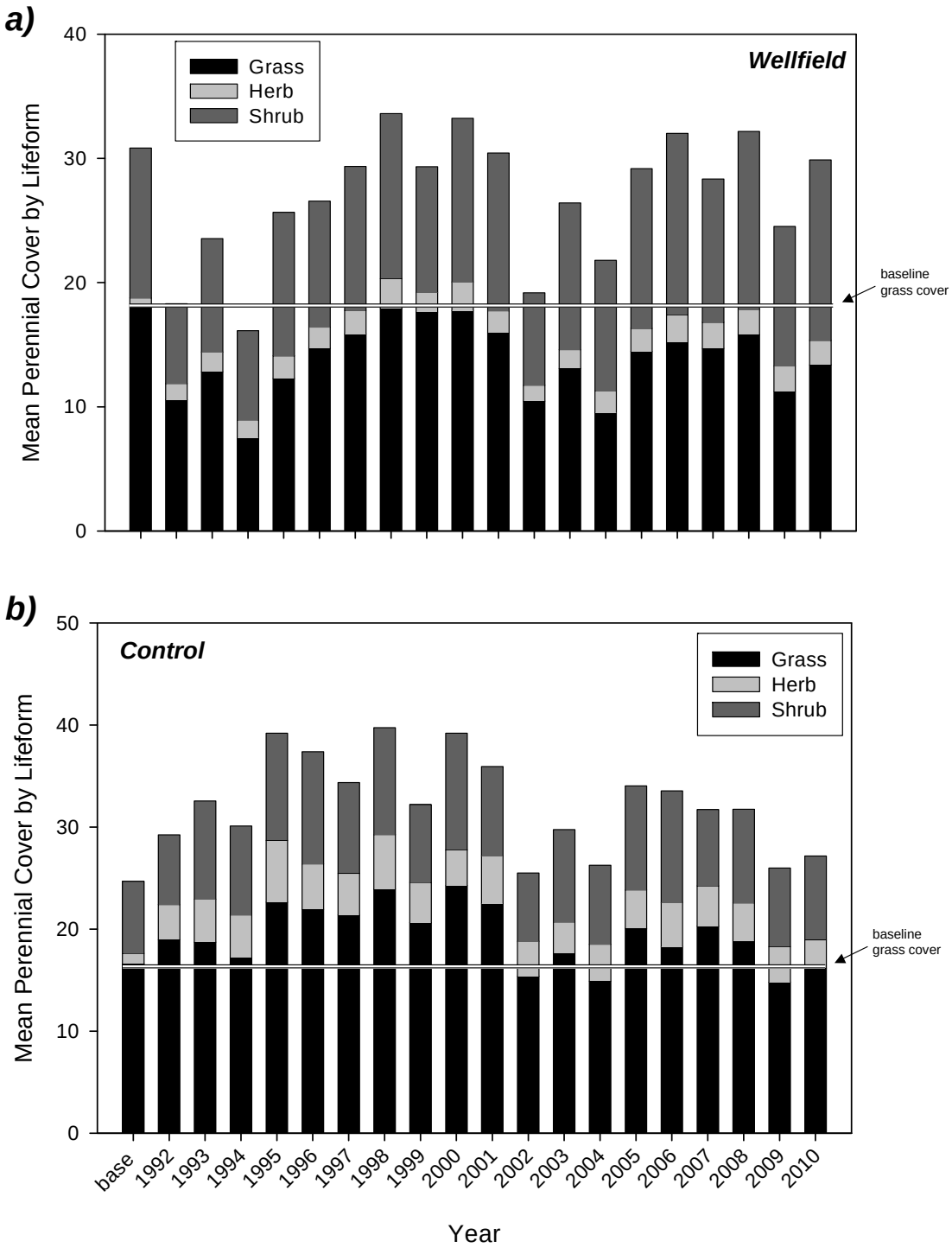


Figure 3. Mean perennial cover by lifeform for the set of parcels sampled each year between 1992 and 2010. In *a)* a significant decrease in grass cover is apparent in wellfield parcels, while in *b)* no change in grass cover is apparent in control parcels (P = 0.0086 and P = 0.84 respectively).

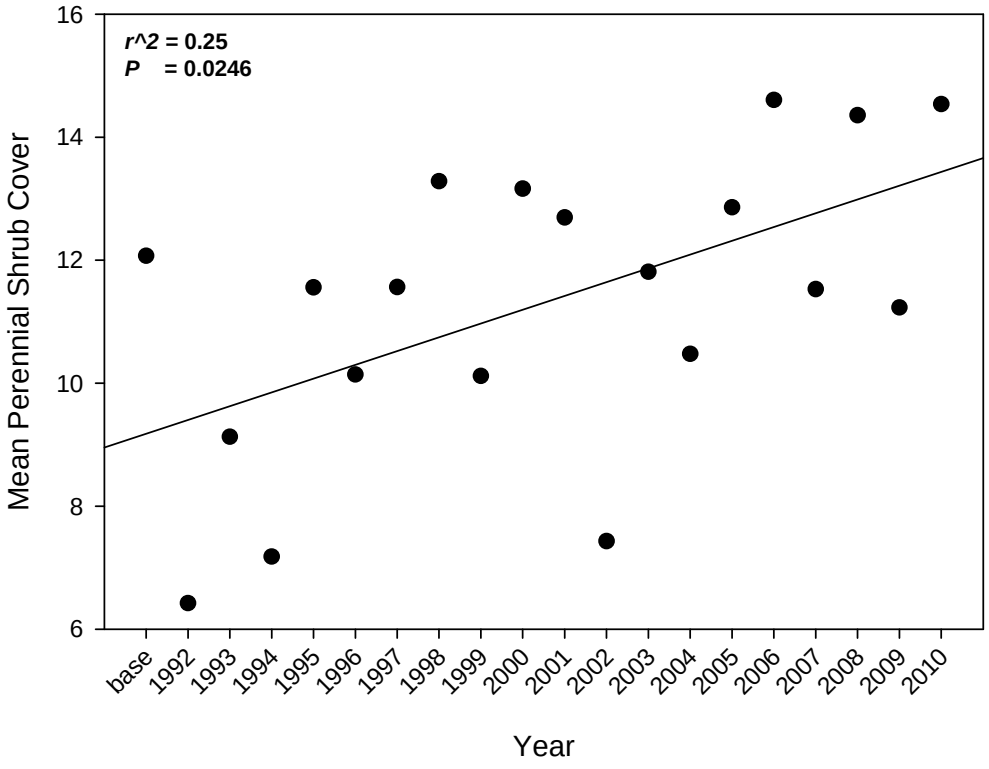


Figure 4. Perennial shrub cover increase over time in wellfield parcels sampled each year between 1992 and 2010 (n = 24, r^2 = 0.25, P = 0.0246).

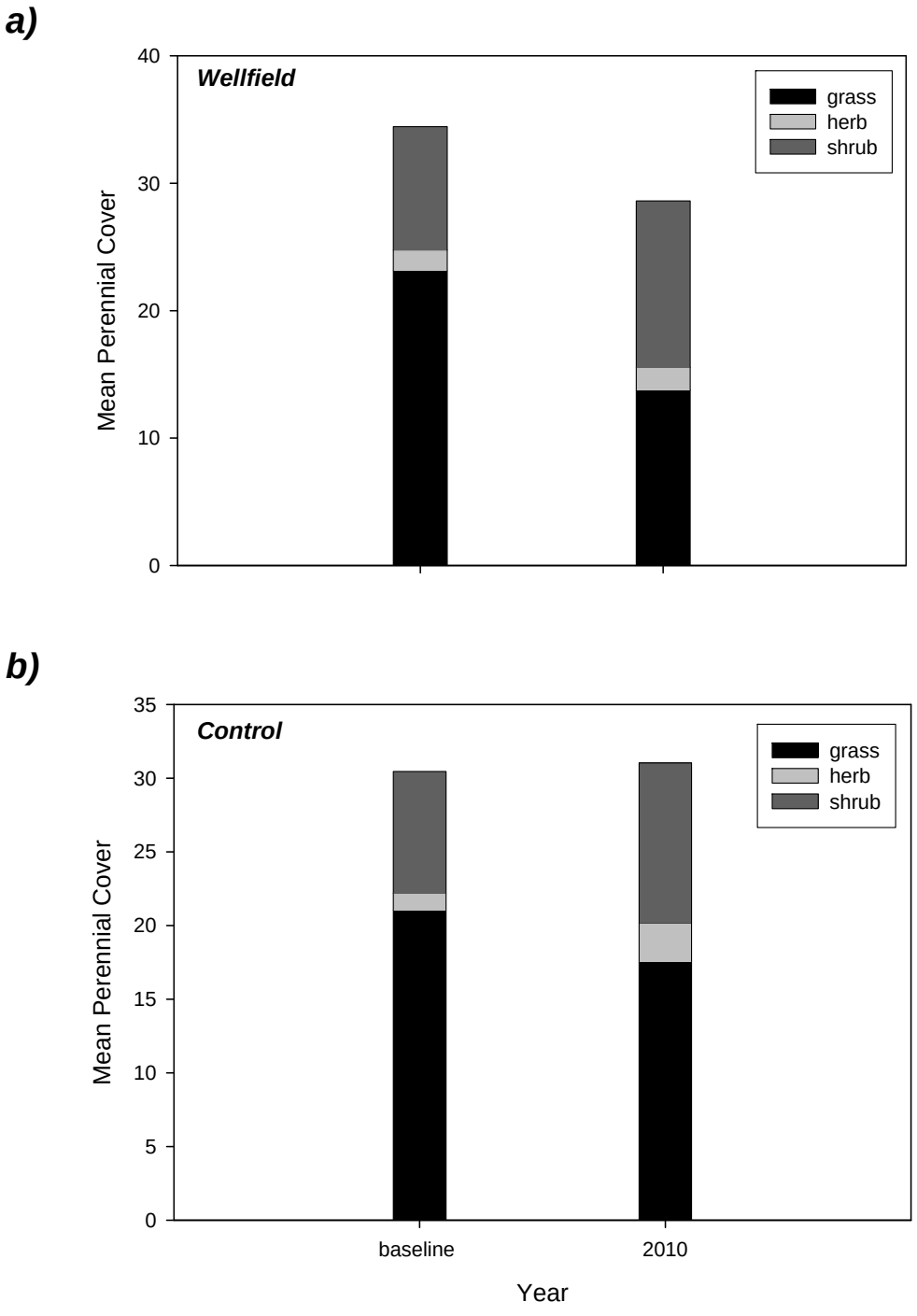


Figure 5. For all parcels sampled in 2010 that have baseline transect data, in *a)* wellfield parcel cover was significantly lower than baseline while in *b)* control cover was not (P = 0.008 and P = 0.79 respectively). In addition, a significant decrease in grass cover was found in wellfield parcels (*a)*, while no change occurred in control parcels (*b*) (P = 0.0001, and P = 0.14 respectively).

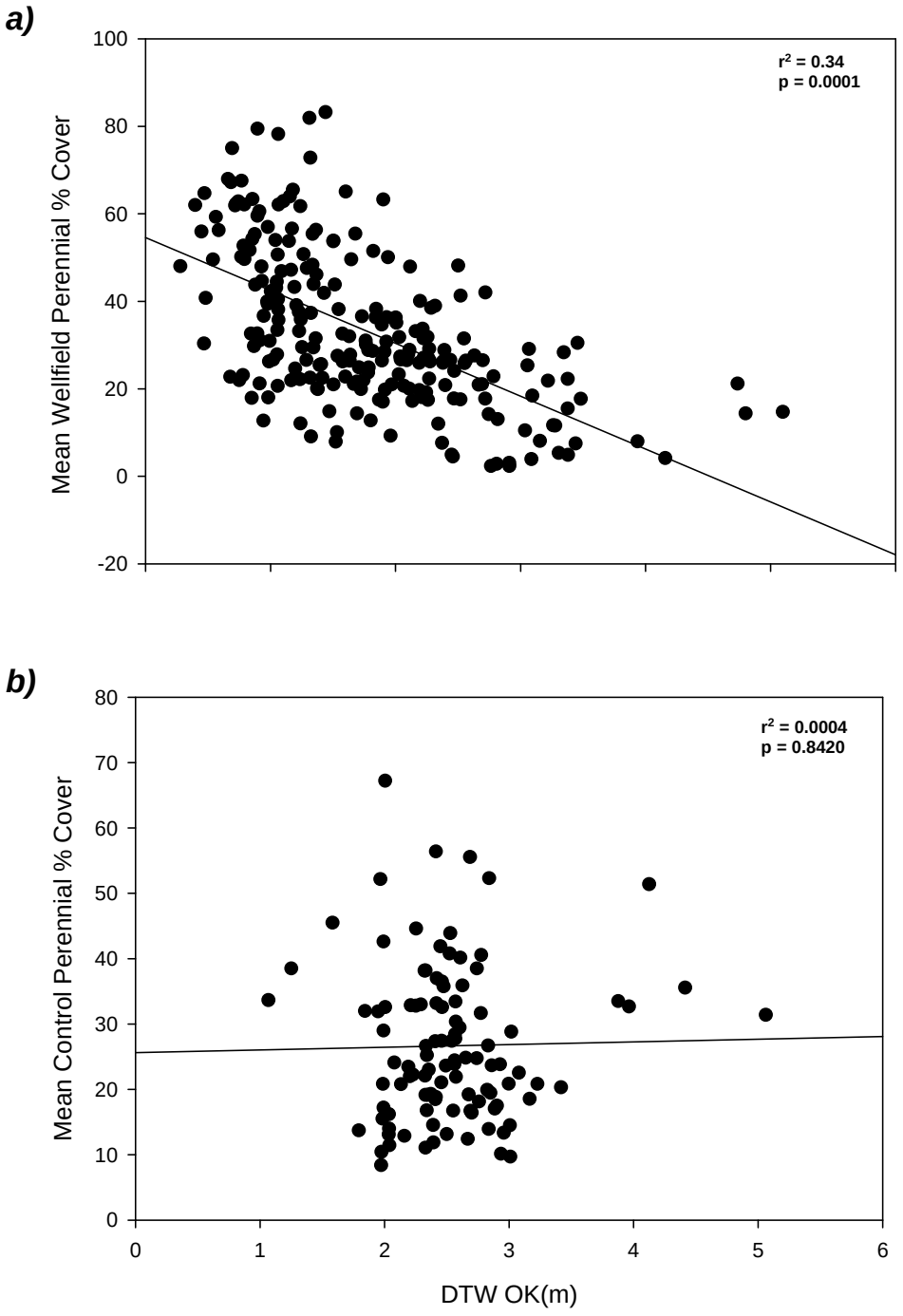


Figure 6. Regressions of wellfield alkali meadow cover against depth to groundwater for *a)* wellfield and *b)* control parcels. Changes in DTW correlate with changes in perennial cover in wellfield parcels while no correlation is found in control parcels ($r^2 = 0.34$, $P = 0.0001$, and $r^2 = 0.0004$, $P = 0.84$; for wellfield and control parcels respectively).

Discussion

Cover Changes—

When conditions are assessed over the period from 1992-2010, parcels subject to groundwater pumping were on average below their baseline measurements while control parcels were above or consistent with baseline (Figure 1). For the year 2010 alone, perennial cover in the rarefied set (n = 45) of wellfield parcels was not below baseline measurements (Figure 2), however, when the 2010 parcel set (n = 94) was considered, perennial cover in wellfield parcels was significantly below baseline (Figure 5). When control parcels are considered in 2010, both the rarefied dataset and the 2010 set indicate perennial cover is slightly above baseline, but this finding is not significant.

In 2010, many vegetation parcels were in poor condition, particularly in the Laws wellfield. Eleven of 17 (or 65%) of parcels reinventoried in this wellfield are in poor condition with perennial cover apparently decreasing with increasing DTW (Appendix 1). Six of these have sufficient monitoring record to determine that perennial cover responds predictably to changes in DTW (Table 2). Other parcels in poor condition occur throughout the valley. In Big Pine cover decreases are correlated with deepening of the water table in BGP047 (Table 2). In the Taboose-Aberdeen wellfield, decreased perennial cover is correlated with a lowered groundwater table in BLK009. Three parcels in the Thibaut-Sawmill (TS) wellfield show decreased cover, but it is unclear whether these changes are due to fluctuations in groundwater, BLK075, BLK077 and IND026. However, in BLK094, decreased cover is correlated with lowering of the water table. In the Independence-Oak wellfield, decreased perennial cover in IND119 is correlated to changes in groundwater depth. In the Symmes-Shepard, Bairs-Georges and Lone Pine wellfields, it is unclear whether decreased cover in six parcels (IND139, MAN007, MAN014, MAN037, LNP045, and LNP050) is related to changes in groundwater depth. Changes in these parcels could be due to a combination of fluctuations in water availability due to precipitation in addition to variability in the water table.

Composition Changes—

In both the rarefied set of parcels, and the 2010 parcel set, perennial grass cover was below baseline in 2010 (Figures 3 and 5), while grass cover in control parcels was not different than baseline. Concurrently, shrub cover has increased over the entire 18-year time period in wellfield parcels (Figure 4, n = 24), but not in control parcels. Lack of change in grass cover in wellfield parcels during this entire period may be due to grass recovery starting in 1997 and continuing during 1998, 1999, and 2000 (Figure 3), a period when water tables were generally high due to increased runoff and low pumping for the previous four years; from 1995 to 1998. Although Figure 1 shows recovery of perennial cover in wellfields in recent years, two results suggest a community-level change may be occurring. In wellfield parcels, shrub cover is increasing (Figure 4) and grass cover has concurrently declined (Figure 3 and 5). Alkali meadow cover has also declined in response to changes in groundwater availability (Figure 6). With no parallel change occurring in control parcels, this change in cover and community type is likely due to the effects of groundwater pumping (Figures 3, 5 and 6).

Driving Factors—

For alkali meadow parcels affected by groundwater pumping (wellfield parcels) perennial cover decreased as depth to groundwater increased (Figure 6). This pattern was not found in control parcels. In contrast, no correlation was found between precipitation and wellfield alkali meadow cover, but there was a slight positive correlation between alkali meadow control cover and precipitation. This indicates that shallow groundwater is important to maintain alkali meadow cover. Because alkali meadows are rare in California, comprising only 0.1% of the vegetation community types in the state, and most (80%) of this community type is found in the Owens Valley (Davis et al., 1998), proper management is essential for its preservation.

Many studies have documented changes in North American grassland communities favoring native shrub species. Often referred to as shrub encroachment, studies have documented composition changes in grasslands over the last century due to disturbance such as large-scale cattle introductions and fire suppression, with climate change cited as a potentially contributing background factor (Brown and Archer, 1999; Van Auken, 2000; Berlow et al. 2002). Encroachment of shrubs coincides with a reduction of grass cover and this can lead to changes in the availability of resources both spatially and temporally causing a positive feedback loop allowing the process of shrub invasion to continue. In the Owens Valley, groundwater pumping and resultant lowering of the water table is an additional factor favoring deeply rooted shrubs over shallower rooted grasses.

Conclusions –

Four main patterns are apparent following the 2010-monitoring season. First, during the time period (1992-2010) wellfield parcels were on average below baseline measurements while controls were above or the same. The relative difference between control and wellfield average cover has also lessened during this period. Second, in 2010 no change was detected in overall wellfield perennial cover according to the rarefied dataset (n = 45), but a larger dataset of all parcels sampled in 2010 (n = 94) indicates perennial cover has decreased in wellfield parcels while it has increased in controls. Third, shrubs have been increasing concurrent with an overall decline in grass cover moderated by a four-year recovery period. Finally, alkali meadow cover has declined corresponding with increasing depth to groundwater (Figure 6).

Water management practices should provide for periods of water table recovery to maintain rare alkali meadows because a shallow groundwater table is necessary to maintain healthy groundwater dependent communities such as those found on the floor of the Owens Valley. It has been documented that perennial phreatophytic plants can extend their root systems to accommodate a deepening aquifer (Sorensen et al., 1991), however the maximum depth these roots can extend is unknown, and a growth limit can be exceeded should groundwater pumping drawdown the water table too rapidly. Perennial grasses are declining likely in favor of deeper-rooted shrubs, because shallow groundwater may not be available on a consistent basis particularly to vegetation parcels near pumping wells. Land and water management practices, including reduced pumping in impacted areas, in combination with water spreading, prescribed burning and re-

vegetation where appropriate would allow recovery in impacted sites to prevent further loss and facilitate recovery of ground-water dependent vegetation.

Literature Cited

Danskin, W.R. 1998. Evaluation of the hydrolic system and selected water-management alternatives in the Owens Valley, California. Water-supply Paper 2370-H. US Geological Survey, Washington, DC.

Davis, F. W., D. M. Stoms, A. D. Hollander, K. A. Thomas, P. A. Stine, D. Odion, M. I. Borchert, J. H. Thorne, M. V. Gray, R. E. Walker, K. Warner, and J. Graae. 1998. *The California Gap Analysis Project--Final Report*. University of California, Santa Barbara, CA. [http://www.biogeog.ucsb.edu/projects/gap/gap_rep.html]

Elmore, A. J., J. F. Mustard, S. J. Manning, and D. B. Lobell. 2001. Quantifying vegetation change in semiarid environments: precision and accuracy of Spectral Mixture Analysis and the Normalized Difference Vegetation Index. *Remote Sensing of the Environment* 73:87-102.

ArcView 3.3. 1992-2002. Environmental Systems Research Institute, Inc., USA.

Harrington, R. and C. Howard. 2000. Depth to groundwater beneath vegetation reinventory parcels. Inyo County Water Department, Technical Report.

Harrington, R. F. 2003. Estimated depth to water beneath vegetation reinventory parcels, 1985-1993. Inyo County Water Department, Technical Report.

Holland, R. F. 1986. Preliminary descriptions of the terrestrial natural communities if California. Unpublished Report. California Department of Fish and Game, Sacramento, CA.

Jabis, M. 2010. Owens Valley Vegetation Conditions 2009. Inyo County Water Department, Technical Report.

JMP. 1989-2007. Version 8. SAS Institute Inc., Cary, NC.

LTWA: Agreement Between the County of Inyo and the City of Los Angeles and its Department if waster and Power on a Long-Term Groundwater Management Plan for Owens Valley and Inyo County. Superior Court of California; Case No.12908, Stipulation and Order for Judgment. See map appendices.

Manning, S. February 1992. Measuring vegetation change: Preliminary report. Inyo

County Water Department, Technical Report.

Manning 1994. Results of 1992 line point transects. Inyo County Water Department, Technical Report.

R Development Core Team. 2011 (continuously updated). R: A Language and Environment for Statistical Computing. Vienna, Austria. ISBN 3-90051-07-0. website: http/www.R-project.org

Sorensen, S. K., P. D. Dileanis, and F. A. Branson. 1991. Soil water and vegetation responses to precipitation and changes in depth to water in Owens Valley, California. Water-Supply Paper 2370-G. US Geological Survey, Washington D.C.

Steinwand, A.L., R.F. Harrington, and D. Or. 2006. Water balance for Great Basin phreatophytes derived from eddy covariance, soil water, and water table measurements. J. Hydrology 329:595-605.

Systat Software. 2004. Sigmaplot for Windows Version 9.01

Zar, H. J. 1999. Biostatistical Analysis, Fourth Edition. Prentice Hall, Upper Saddle River, New Jersey, USA.

Appendix 1 –

Figures 1-168 depict mean vegetation cover response over time for the 168 vegetation parcels ever sampled since 1991 using the Green Book Line Point monitoring program, updated SMA average cover data, and kriged (OK) depth to water (DTW) estimates. The reliability of kriged DTW estimates were determination by Harrington (2003), and were classified as "Reliable", "Relative Recovery Reliable", "Current DTW Not Reliable", "Baseline not Reliable", "Not Reliable", and "No Data". Please see Harrington (2003) for detailed descriptions of each of these categories. Hydrographs are only displayed for vegetation parcels with 'Reliable' or 'Relative Recovery Reliable' estimates. Hydrographs that indicate 'Relative Recovery Reliable' may not reflect actual DTW measurements, but instead show the relative change in DTW relative to baseline measurements (i.e. generally increasing or generally decreasing).

Appendix 2 –

Maps depicting 2010 vegetation conditions relative to baseline according to 2010 statistical results, using a weighted ANOVA followed by the Dunnett's comparison to a control group method. Parcel polygons highlighted in red indicate conditions were significantly below baseline in 2010, while parcels highlighted in tan indicate no difference from baseline and those colored in green were significantly above baseline in 2010.

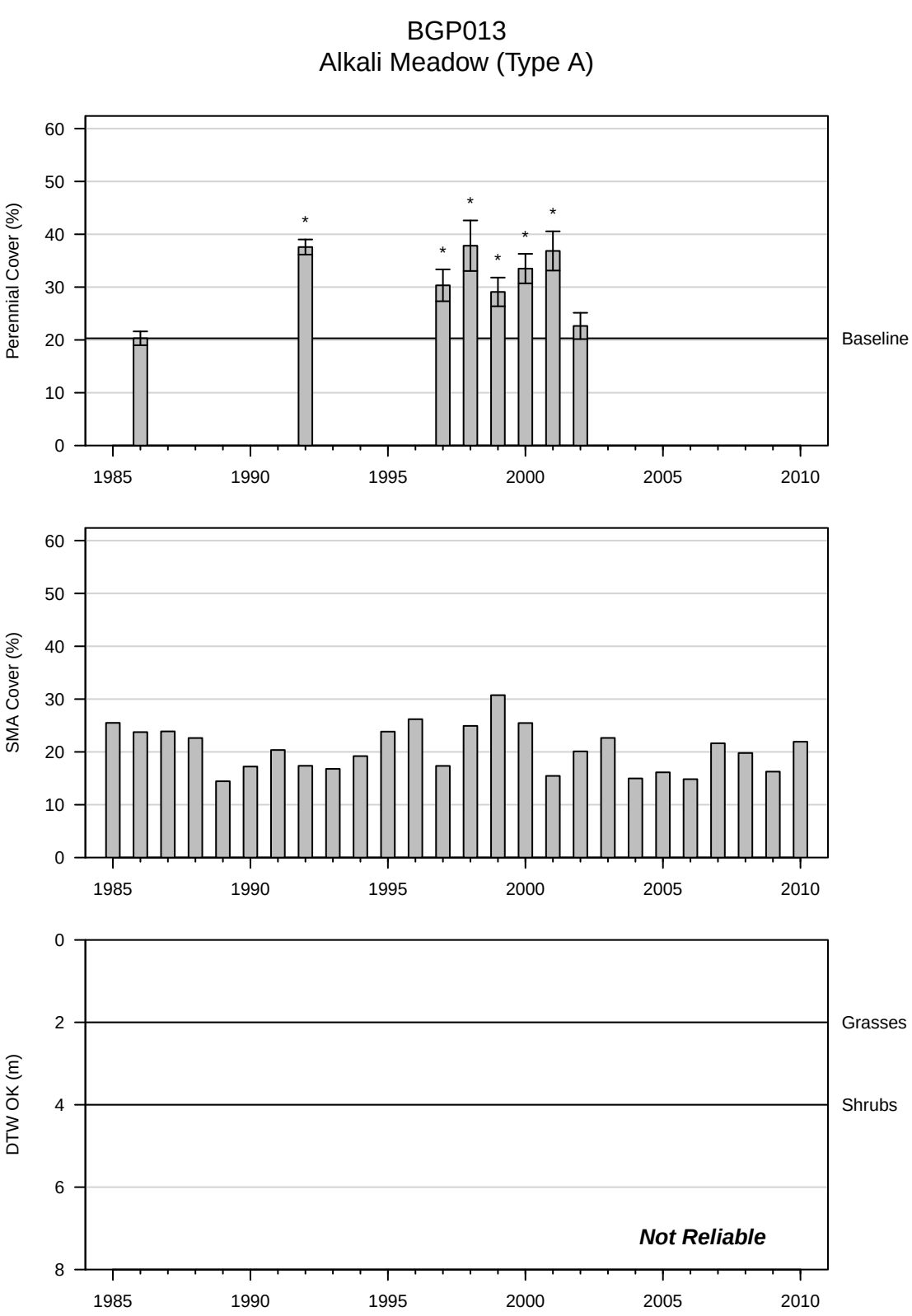


Figure 1: 2002 Control

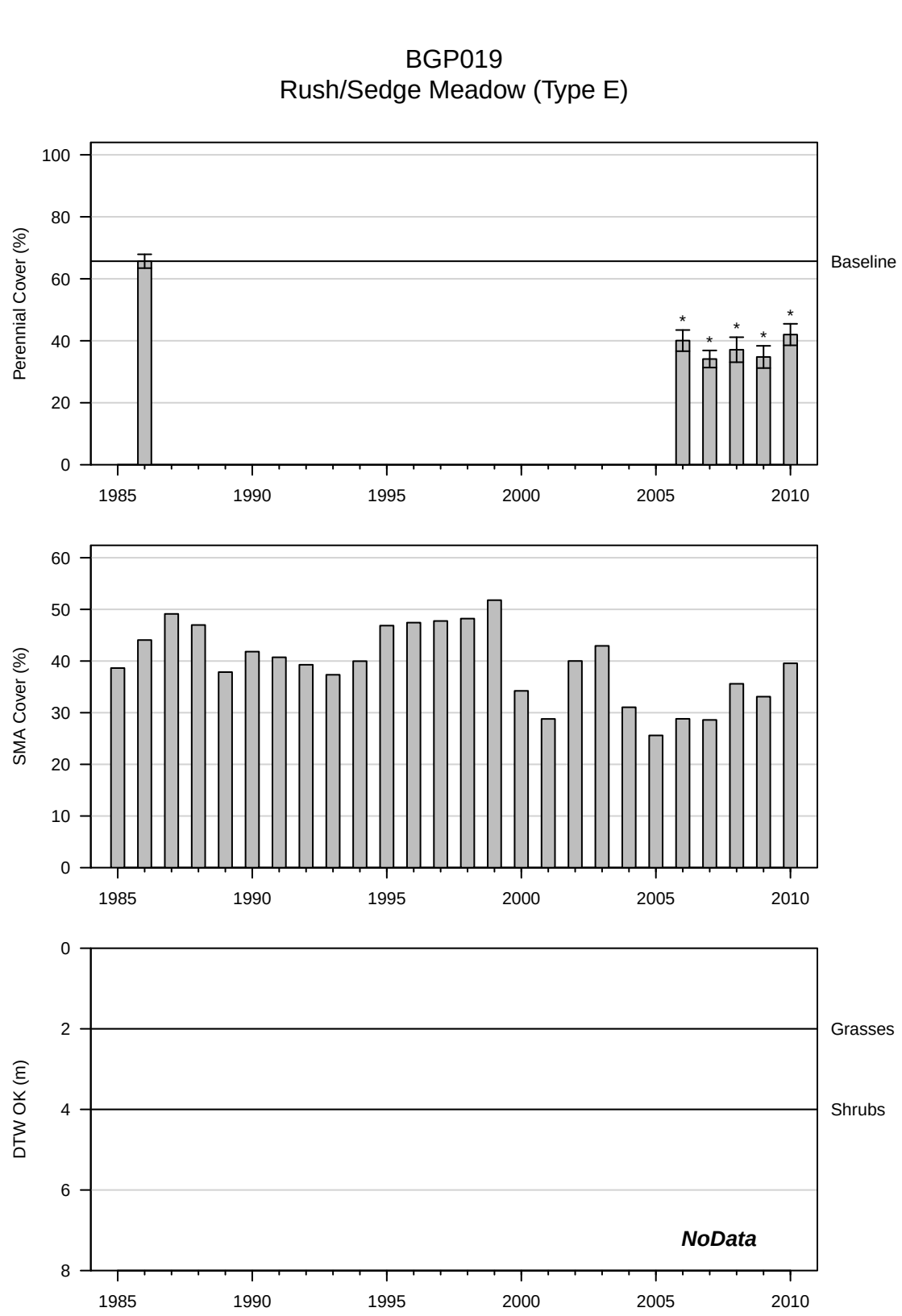


Figure 2: 2010 Control

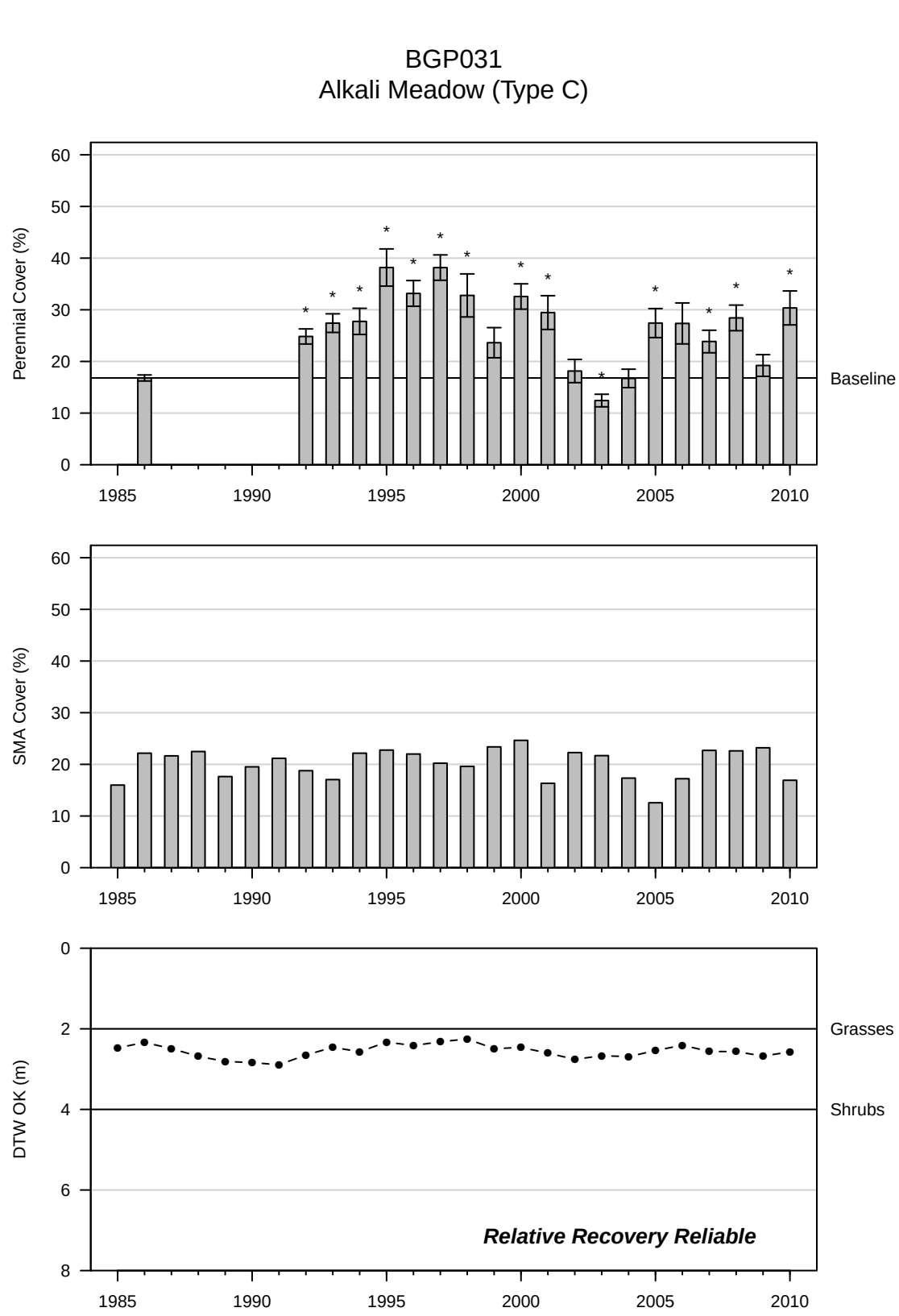


Figure 3: 2010 Control

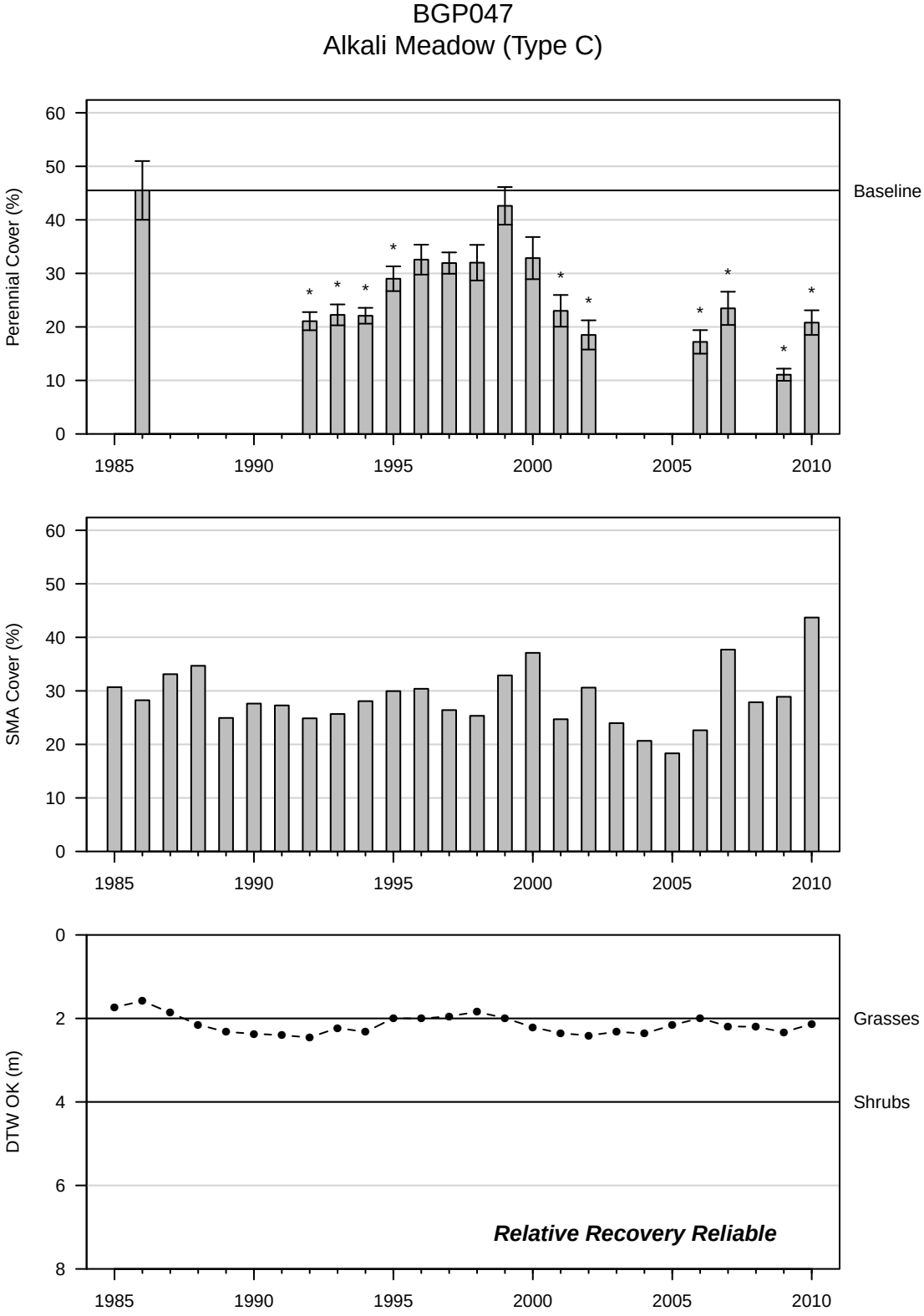


Figure 4: 2010 Control

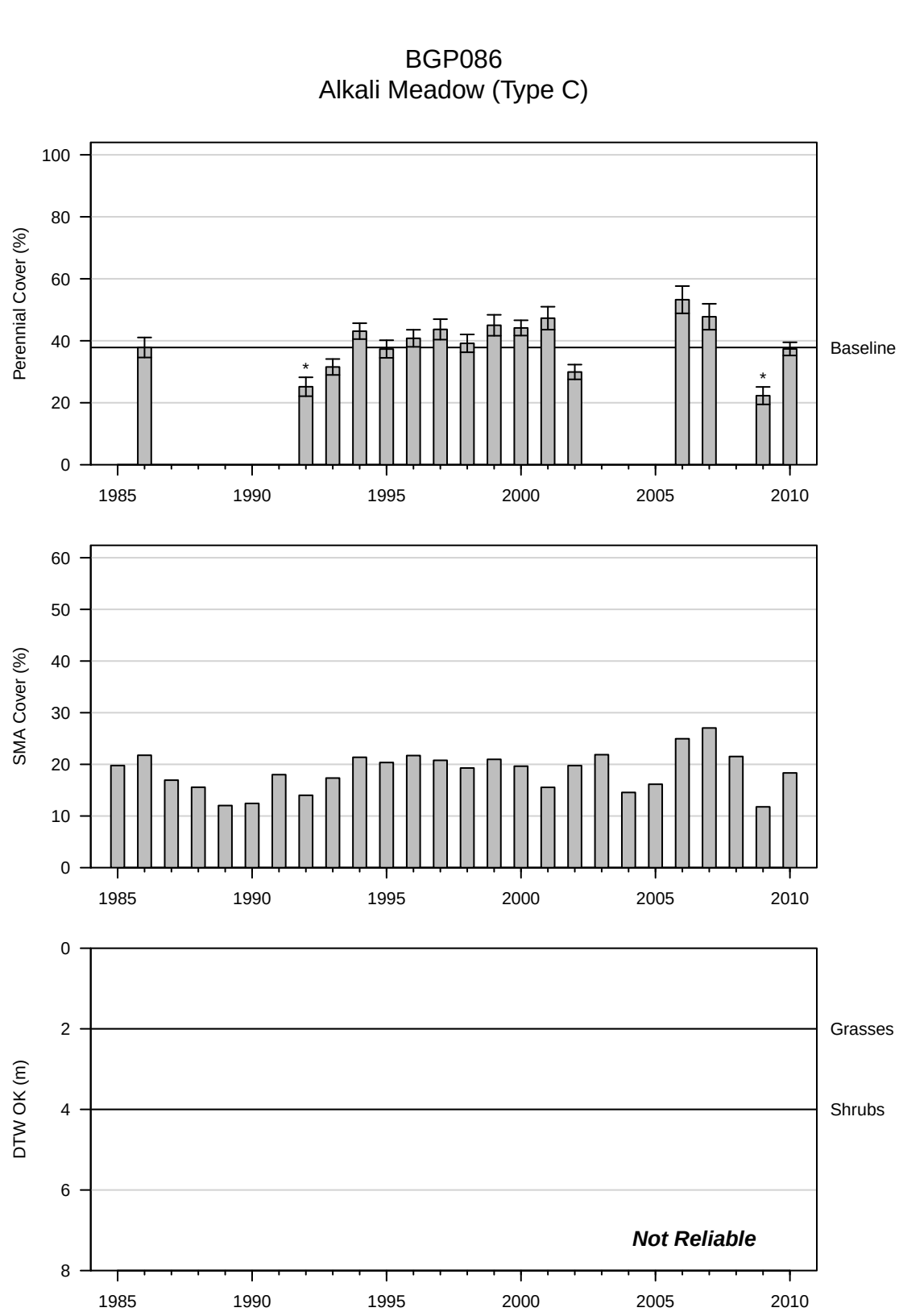


Figure 5: 2010 Wellfield

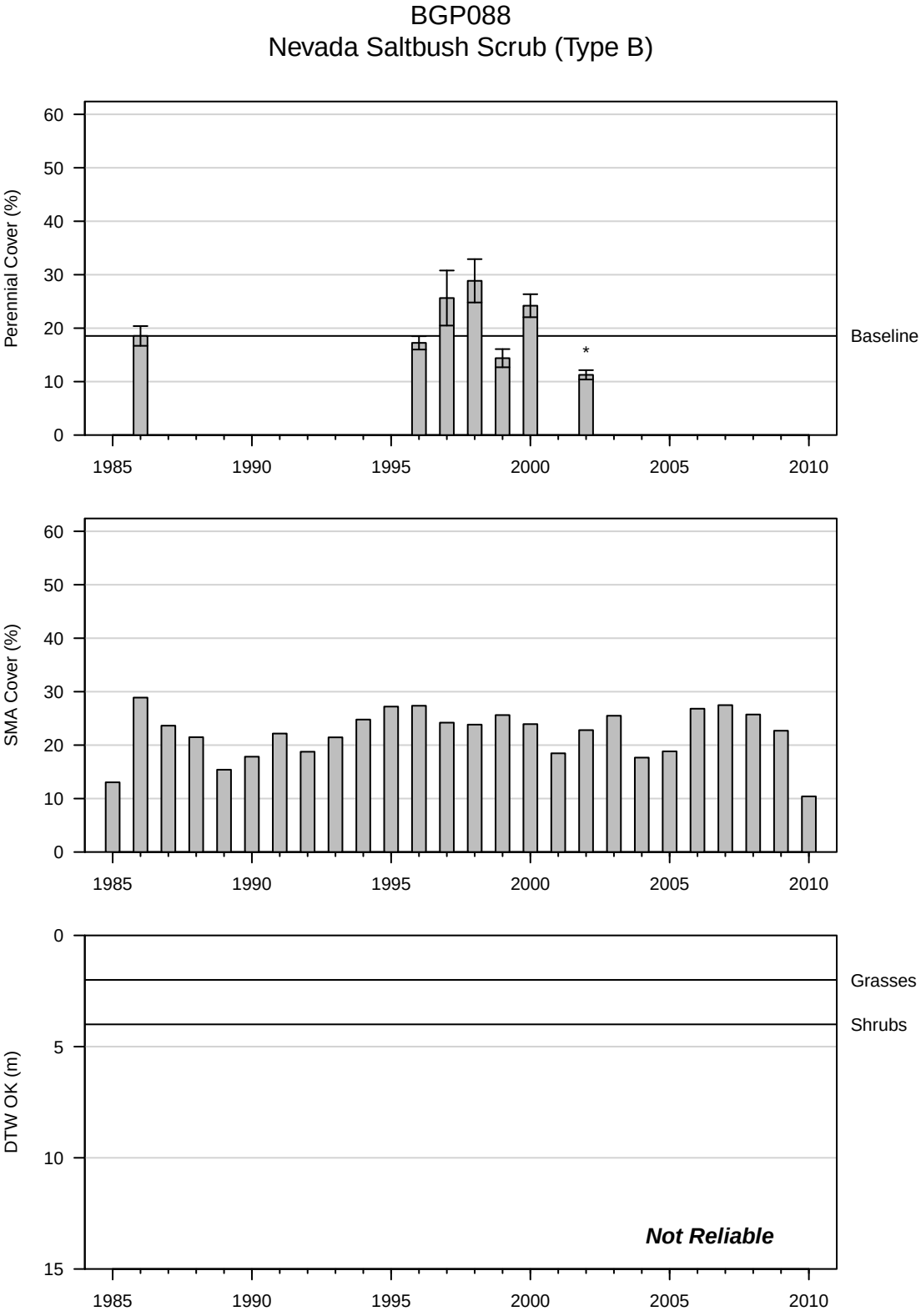


Figure 6: 2002 Wellfield

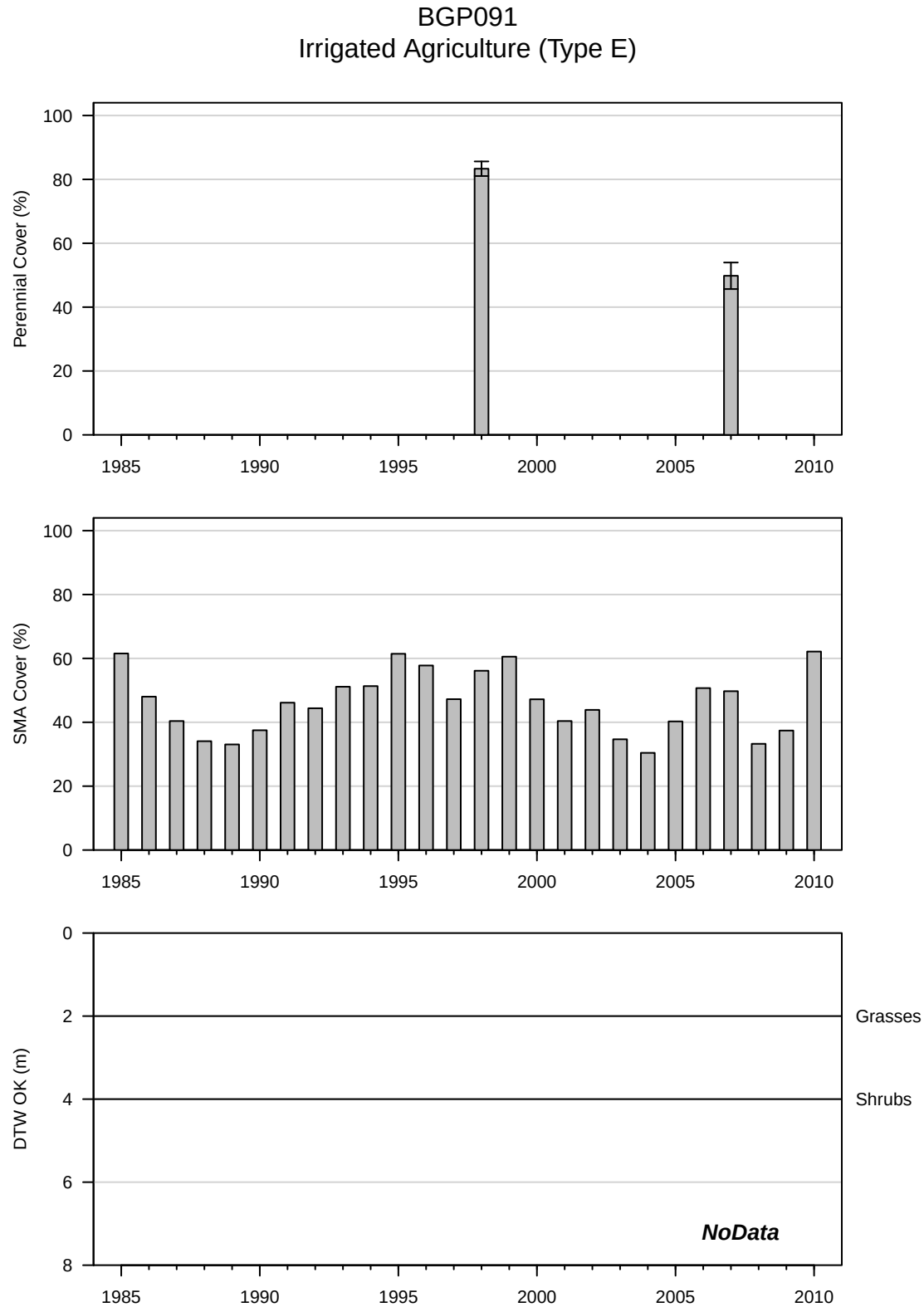


Figure 7: 2007 Wellfield

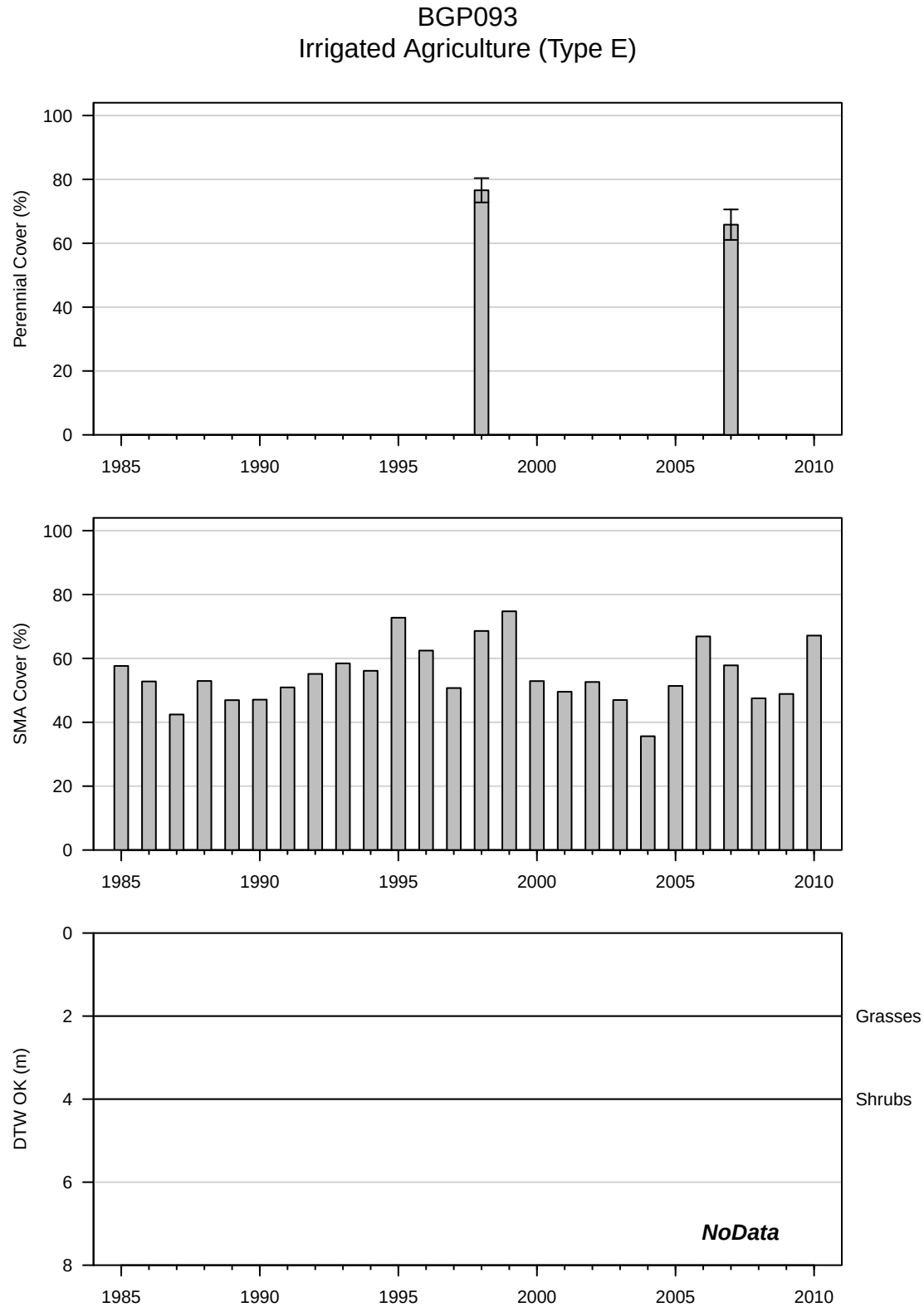


Figure 8: 2007 Wellfield

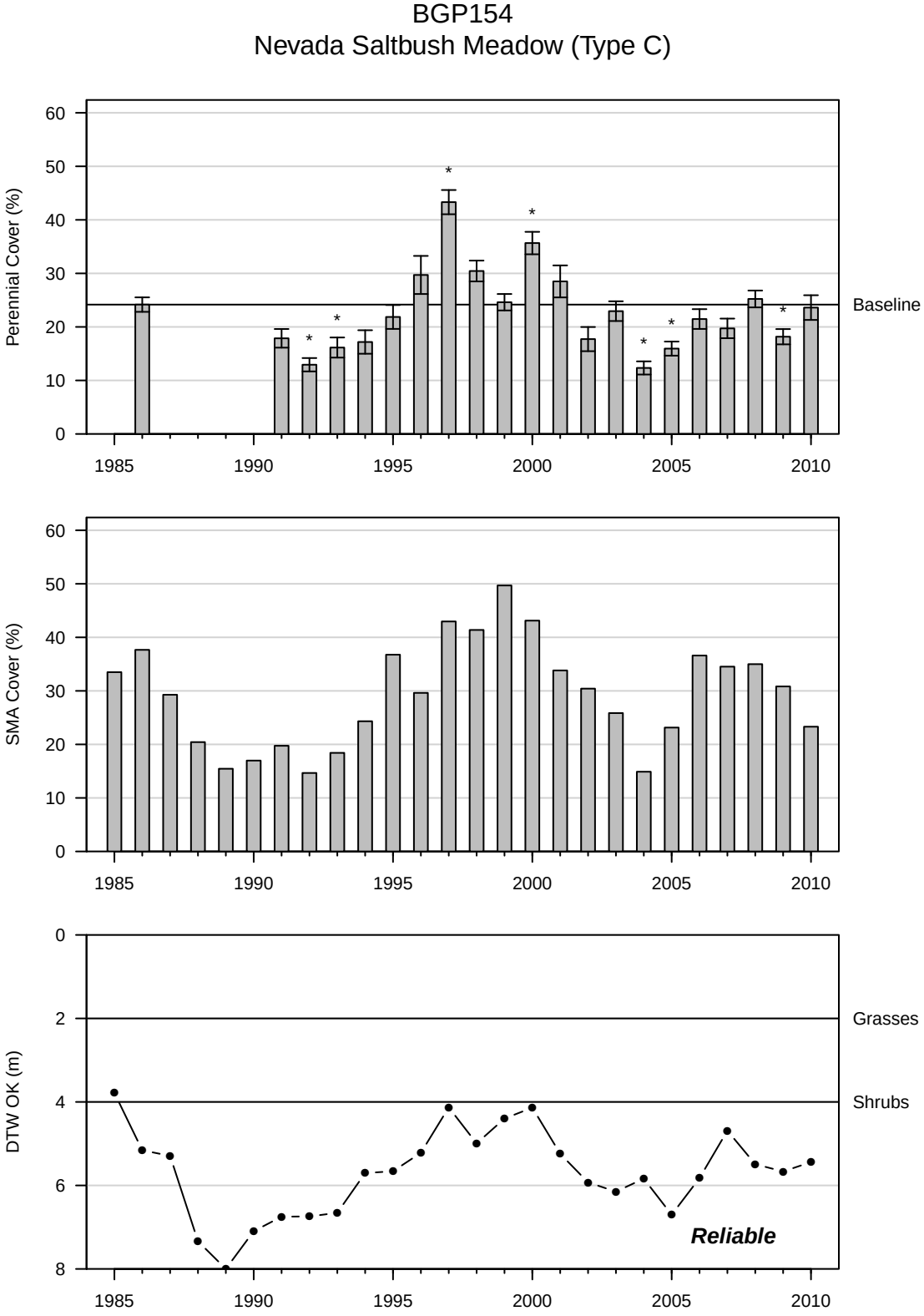


Figure 9: 2010 Wellfield

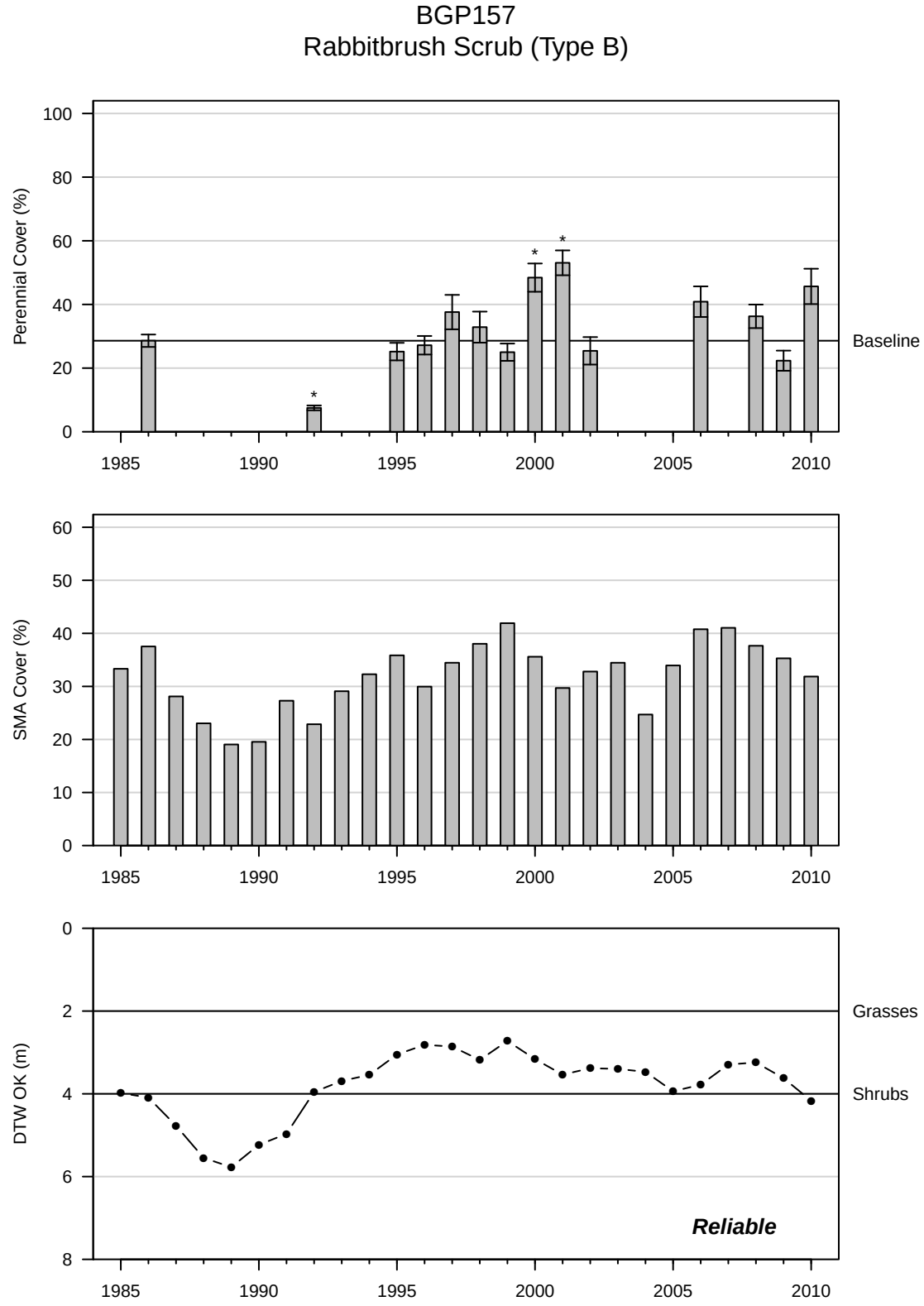


Figure 10: 2010 Wellfield

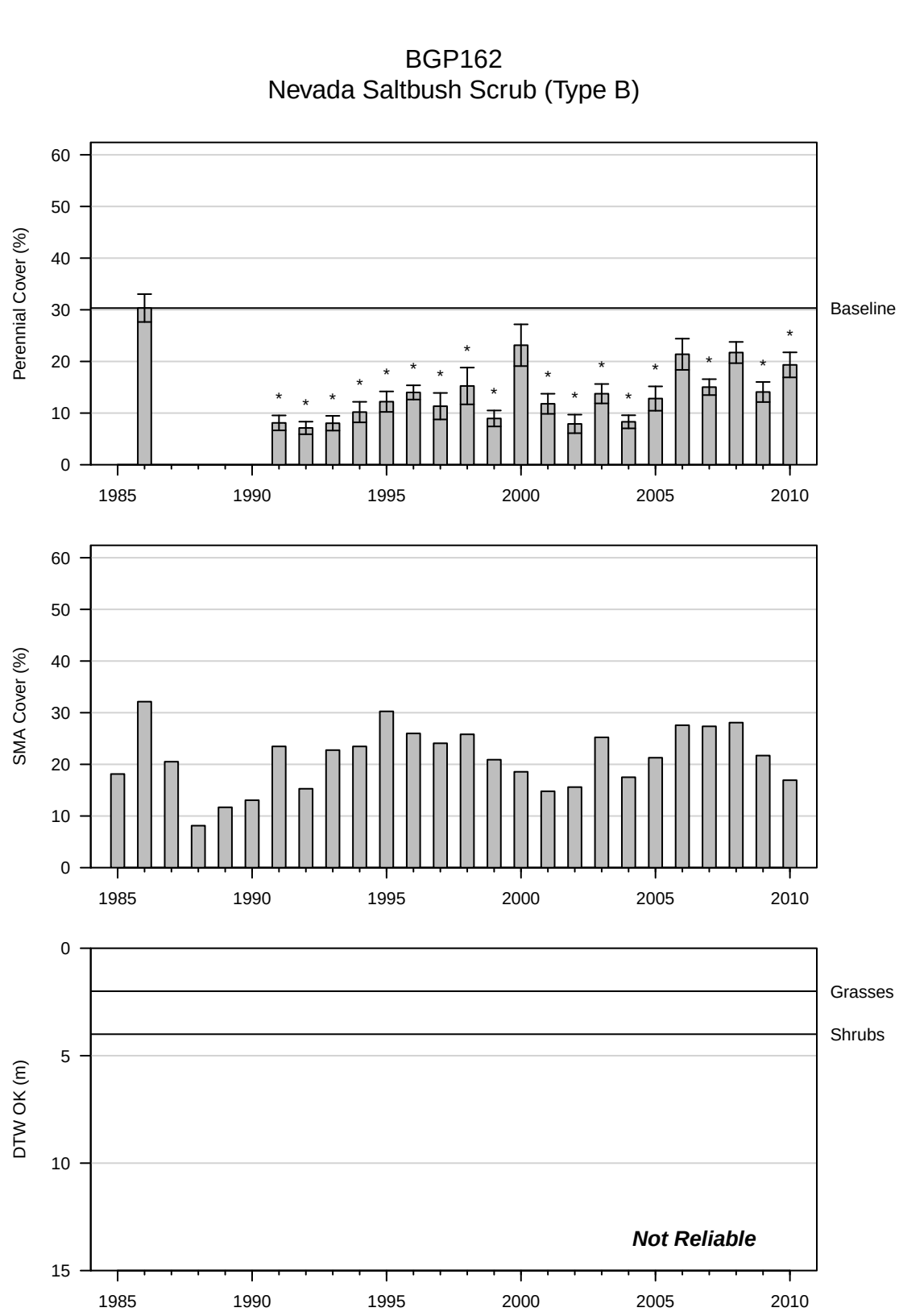


Figure 11: 2010 Wellfield

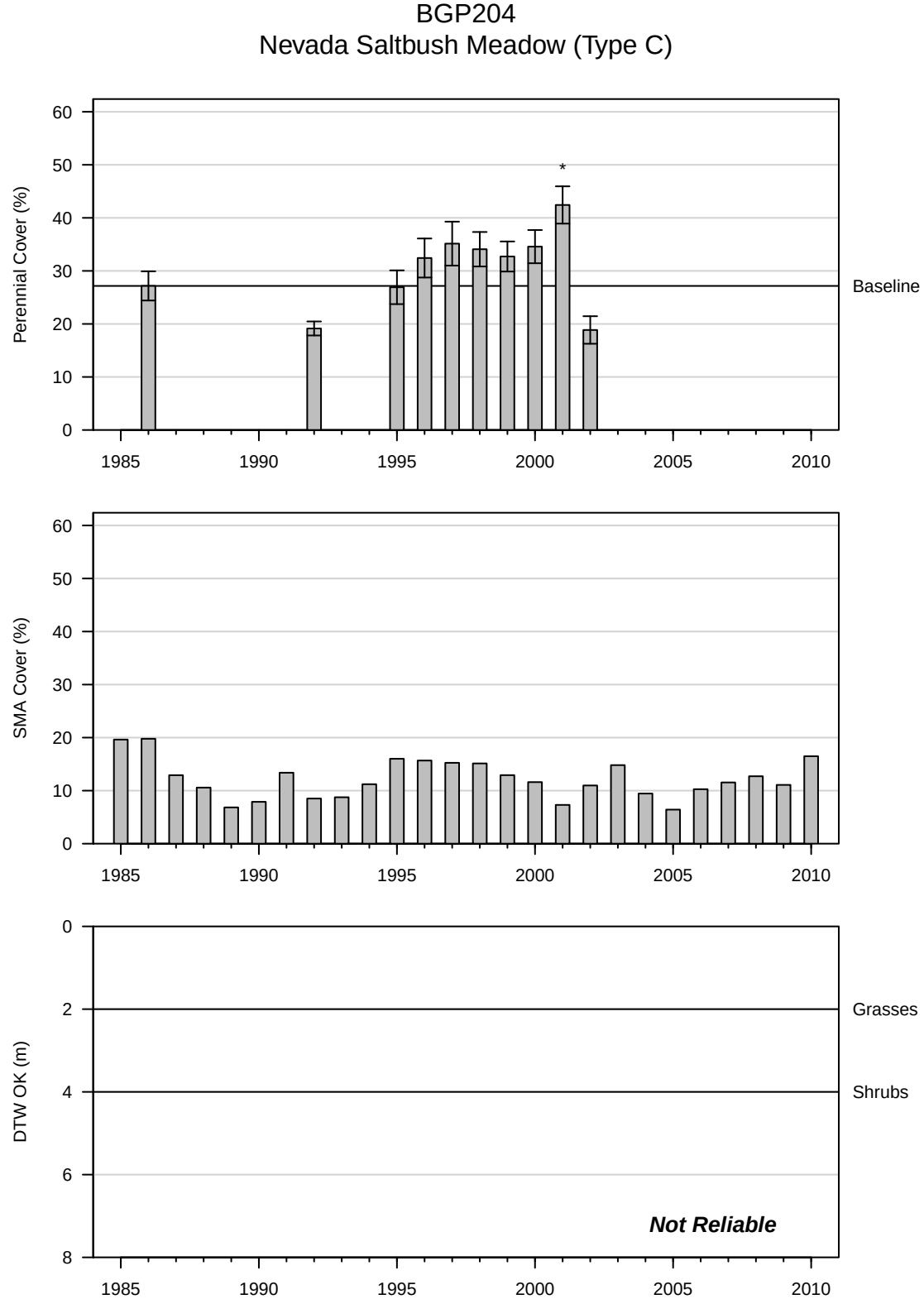


Figure 12: 2002 Control

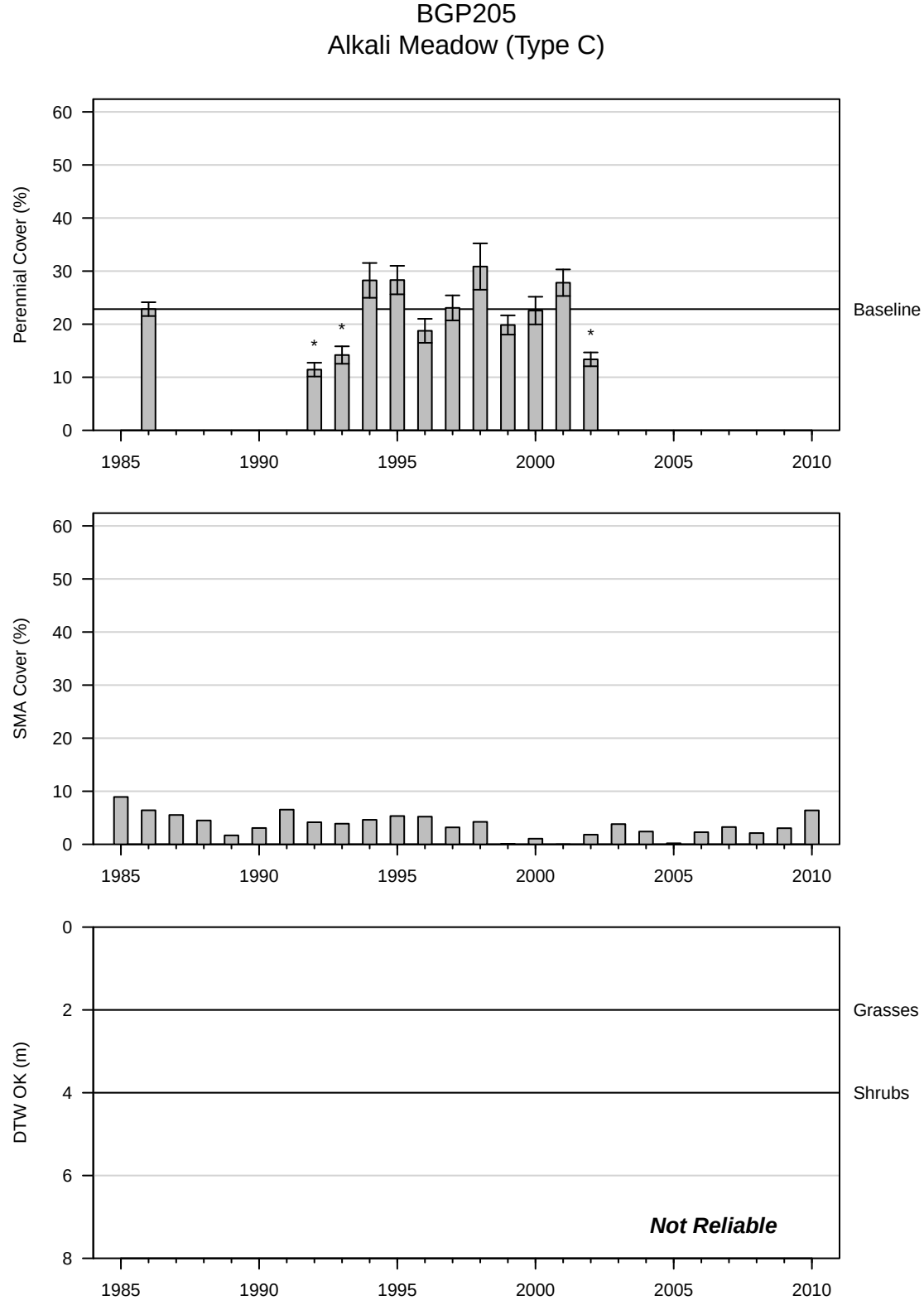


Figure 13: 2002 Control

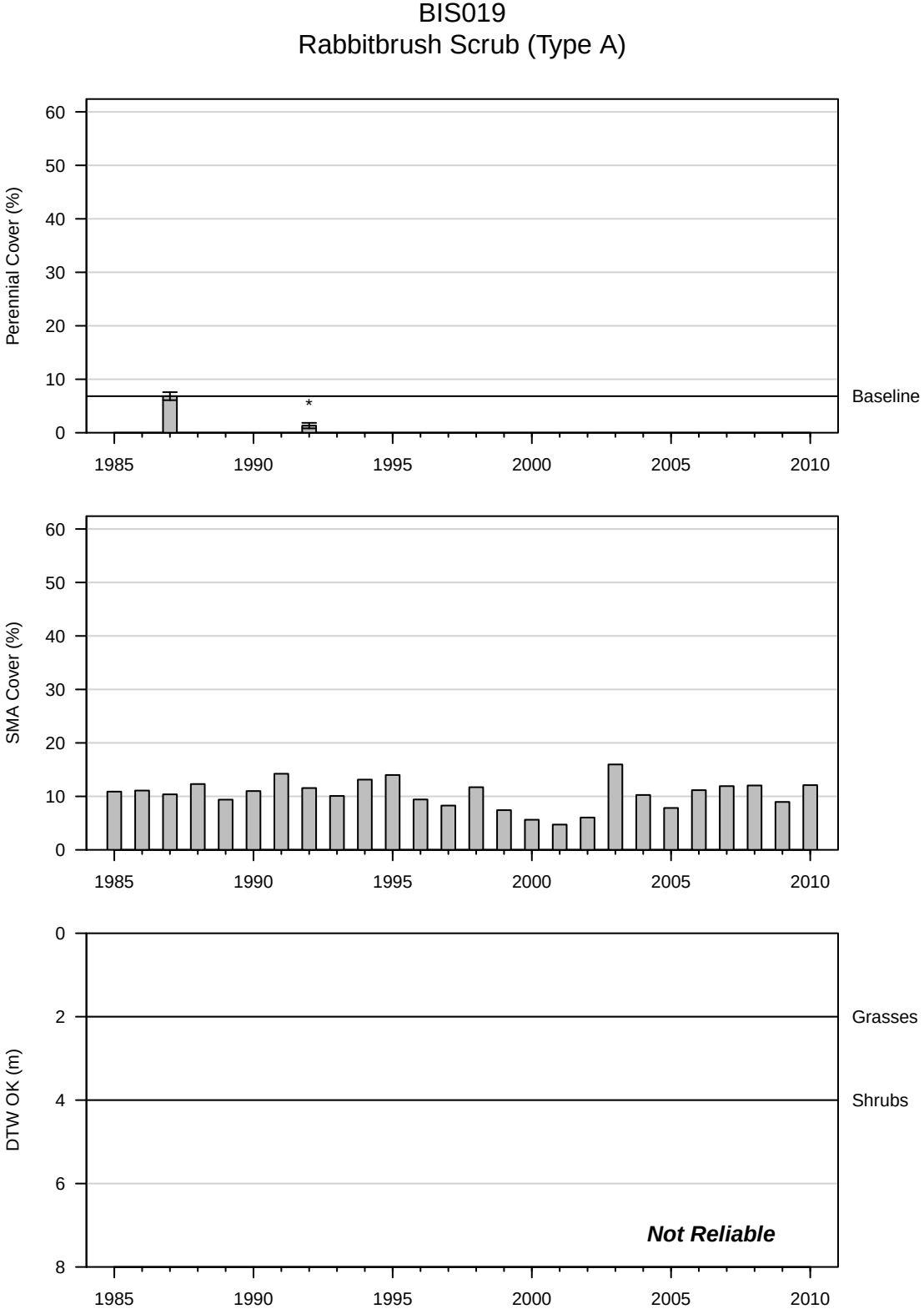


Figure 14: 1992 Control

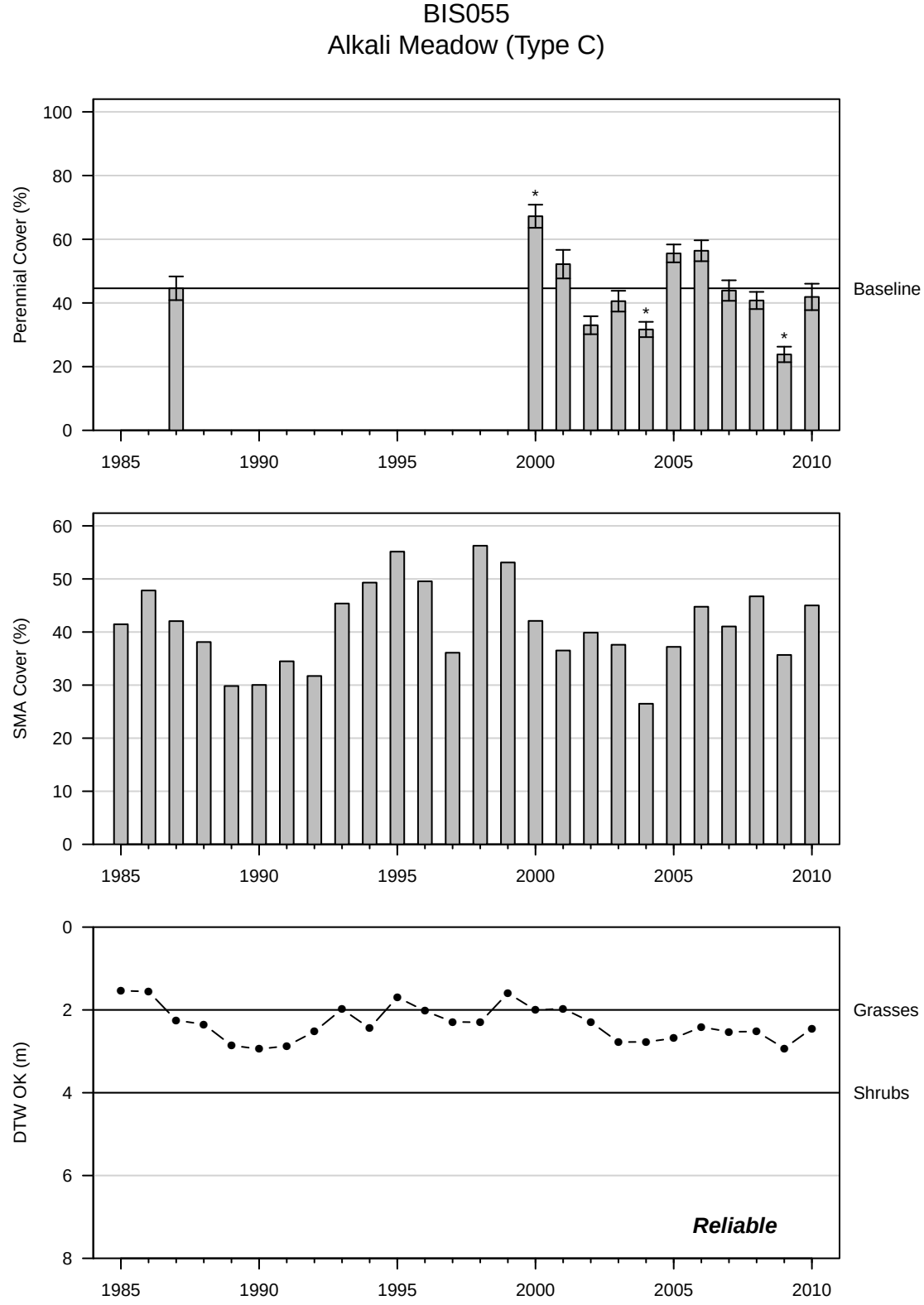


Figure 15: 2010 Control

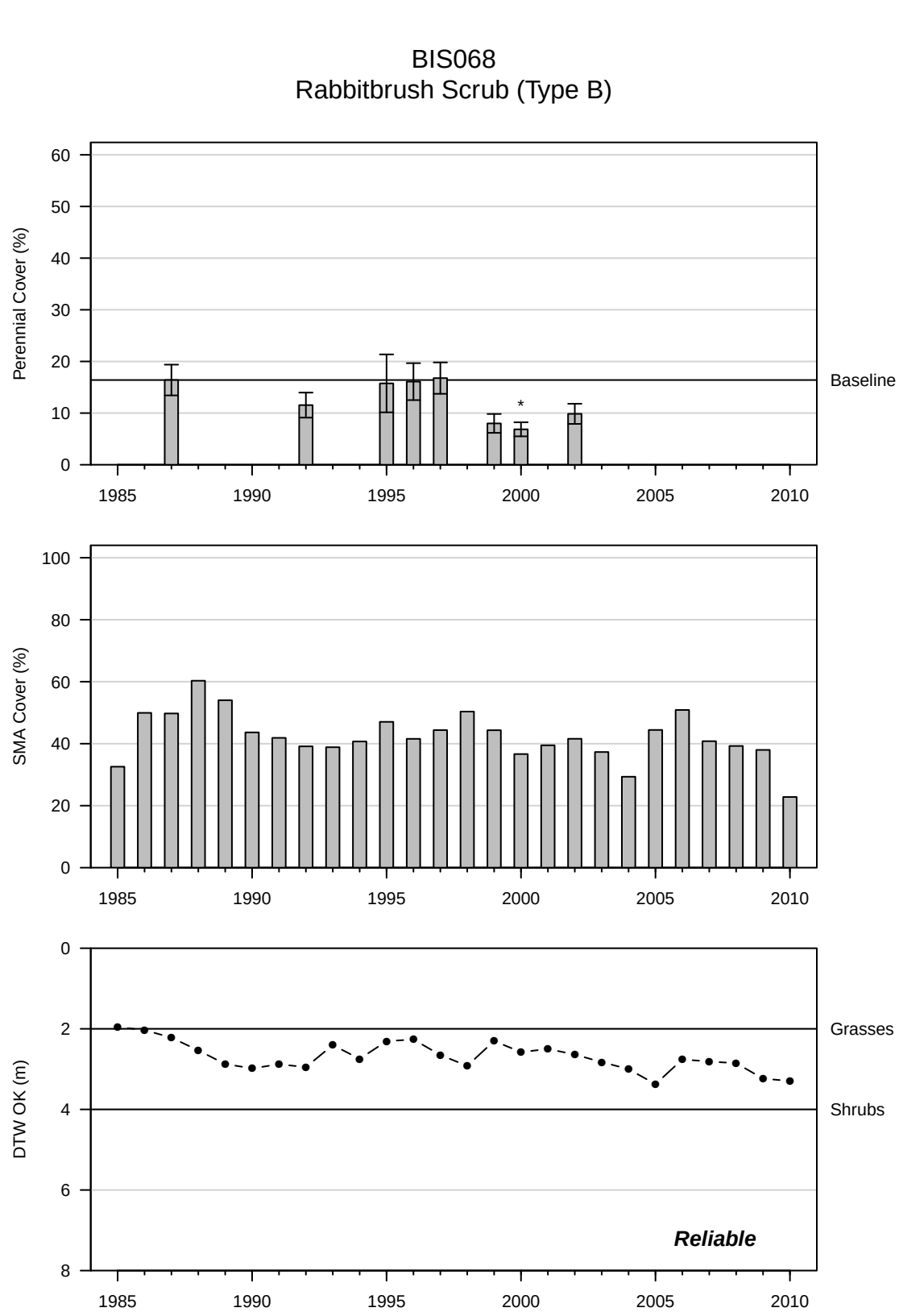


Figure 16: 2002 Control

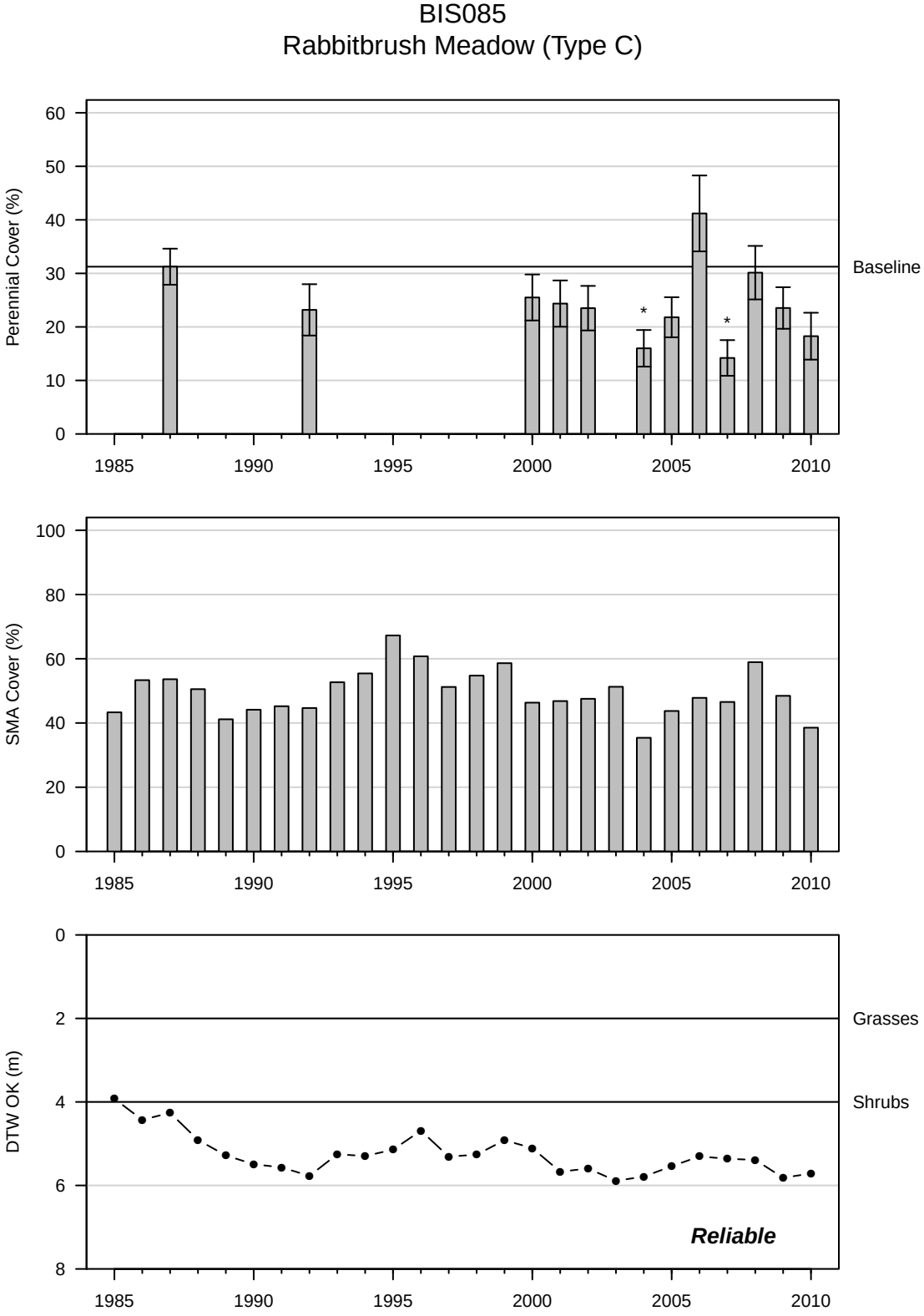
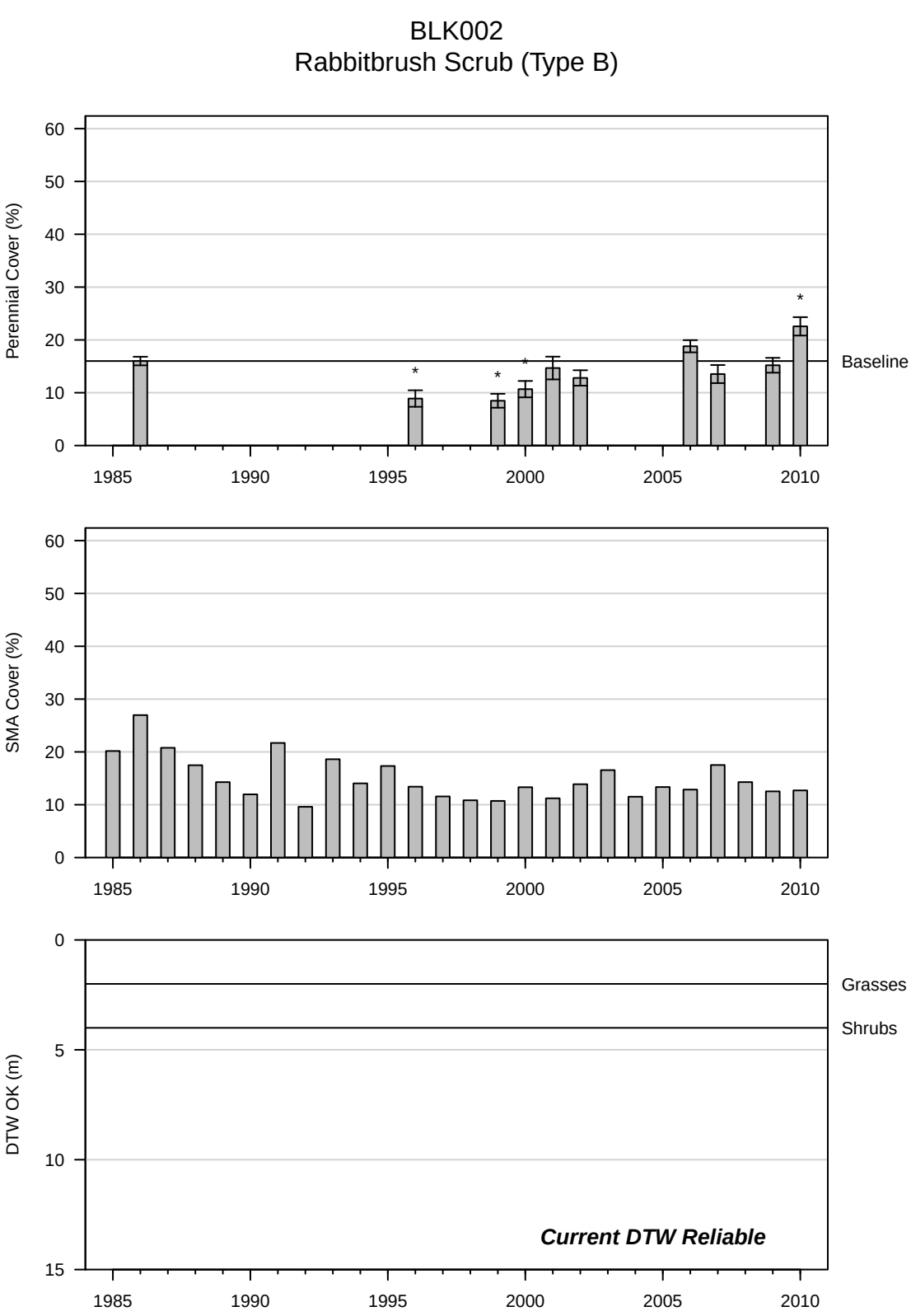


Figure 17: 2010 Wellfield



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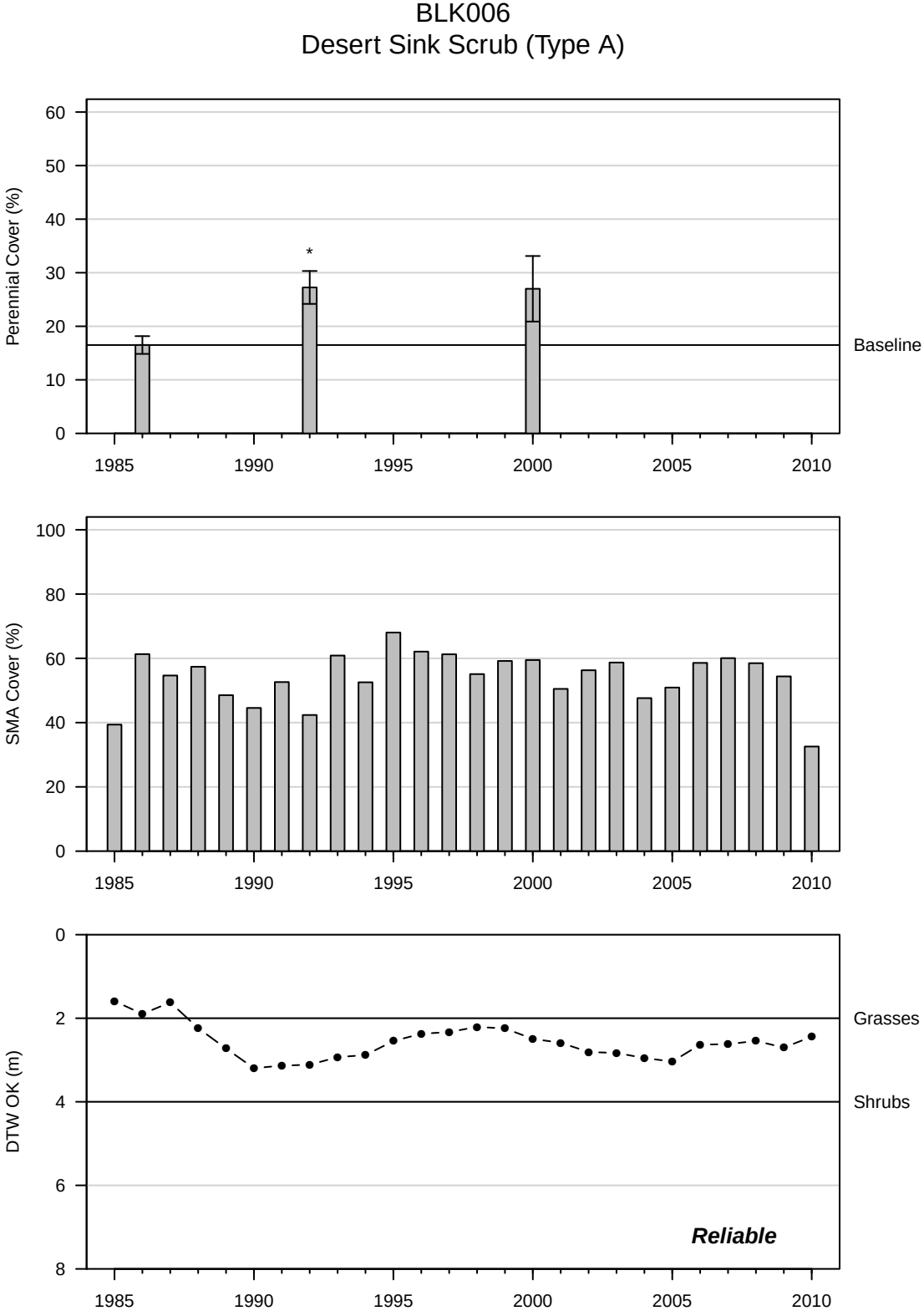


Figure 19: 2000 Wellfield

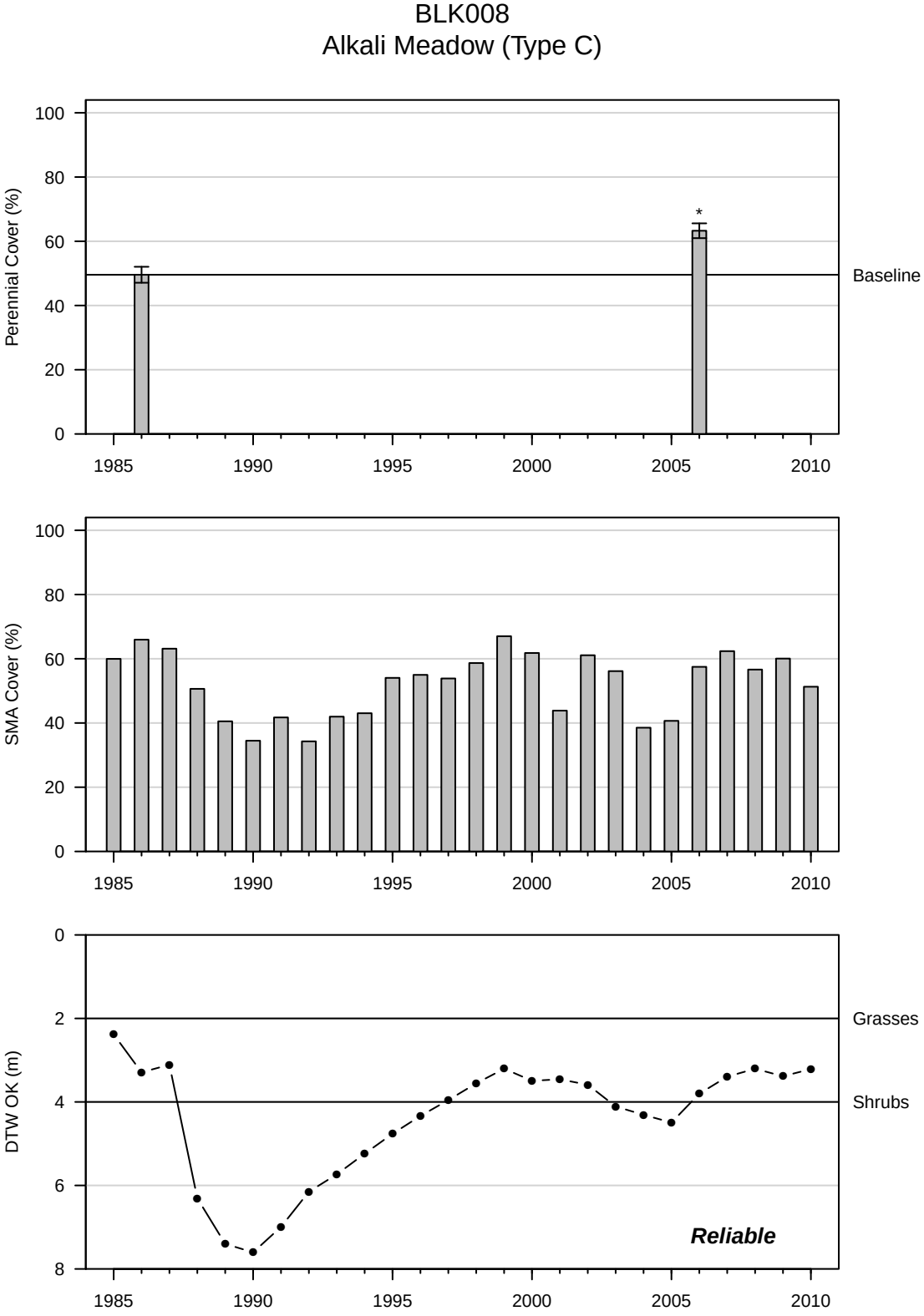


Figure 20: 2006 Wellfield

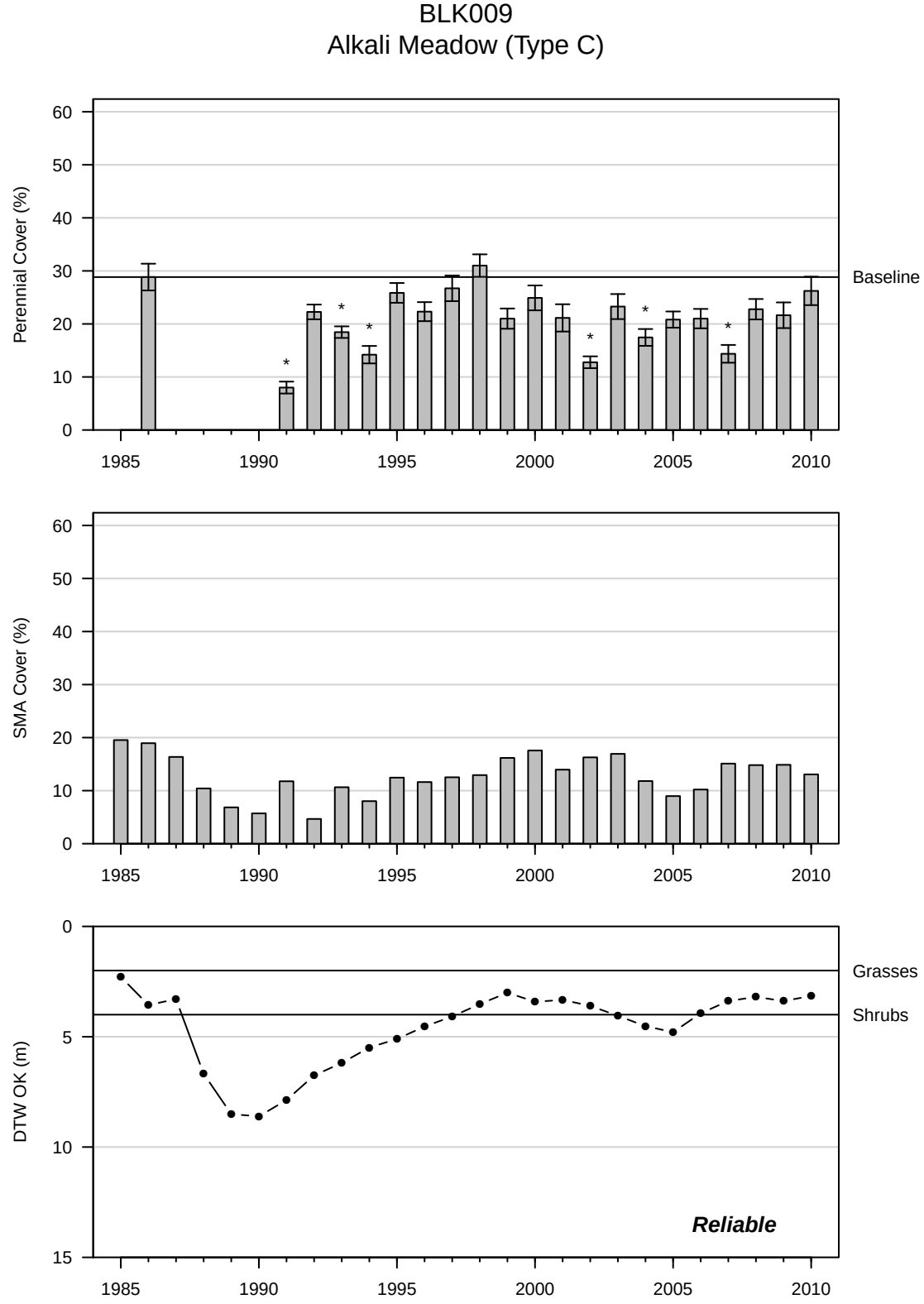


Figure 21: 2010 Wellfield

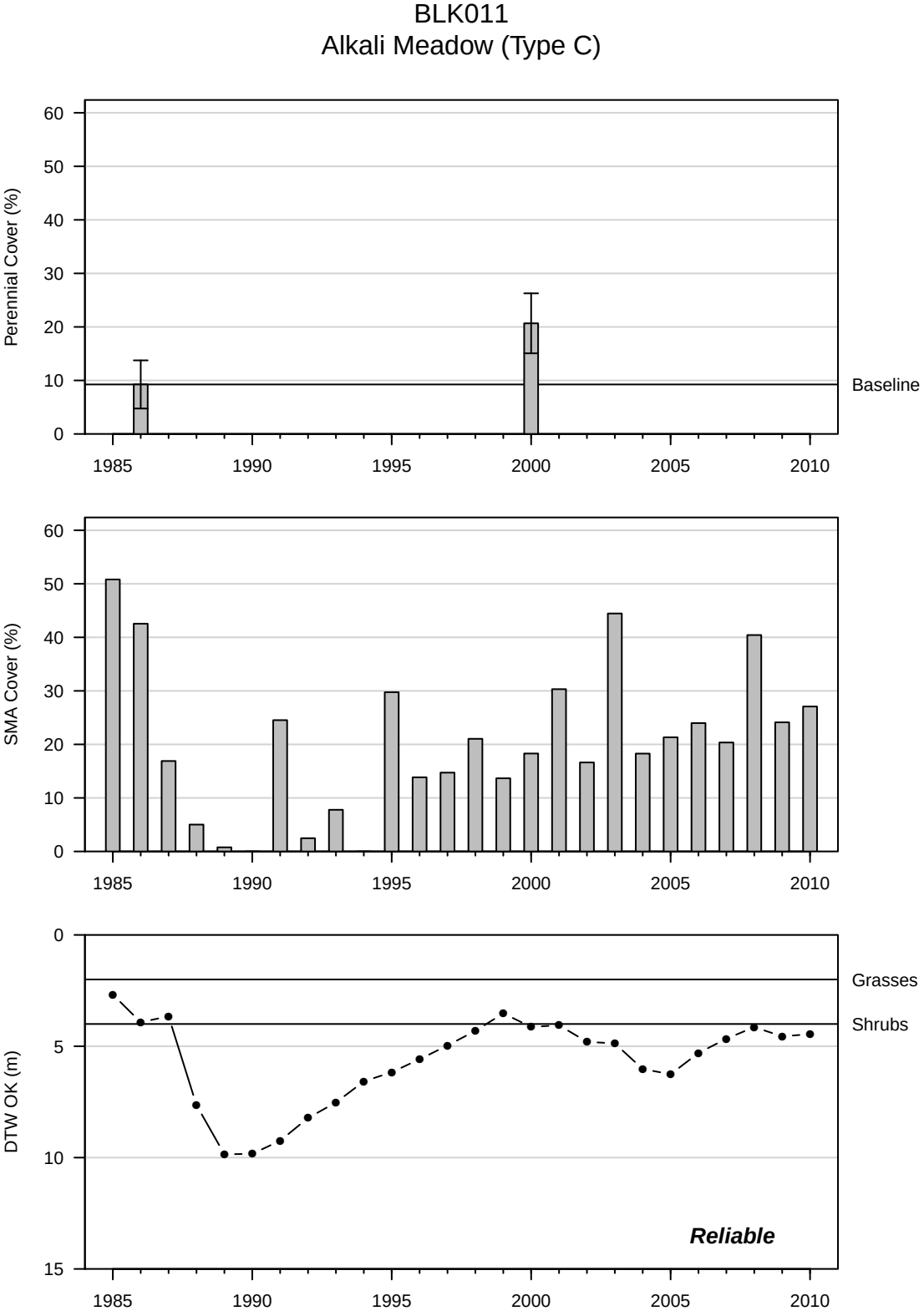


Figure 22: 2000 Wellfield

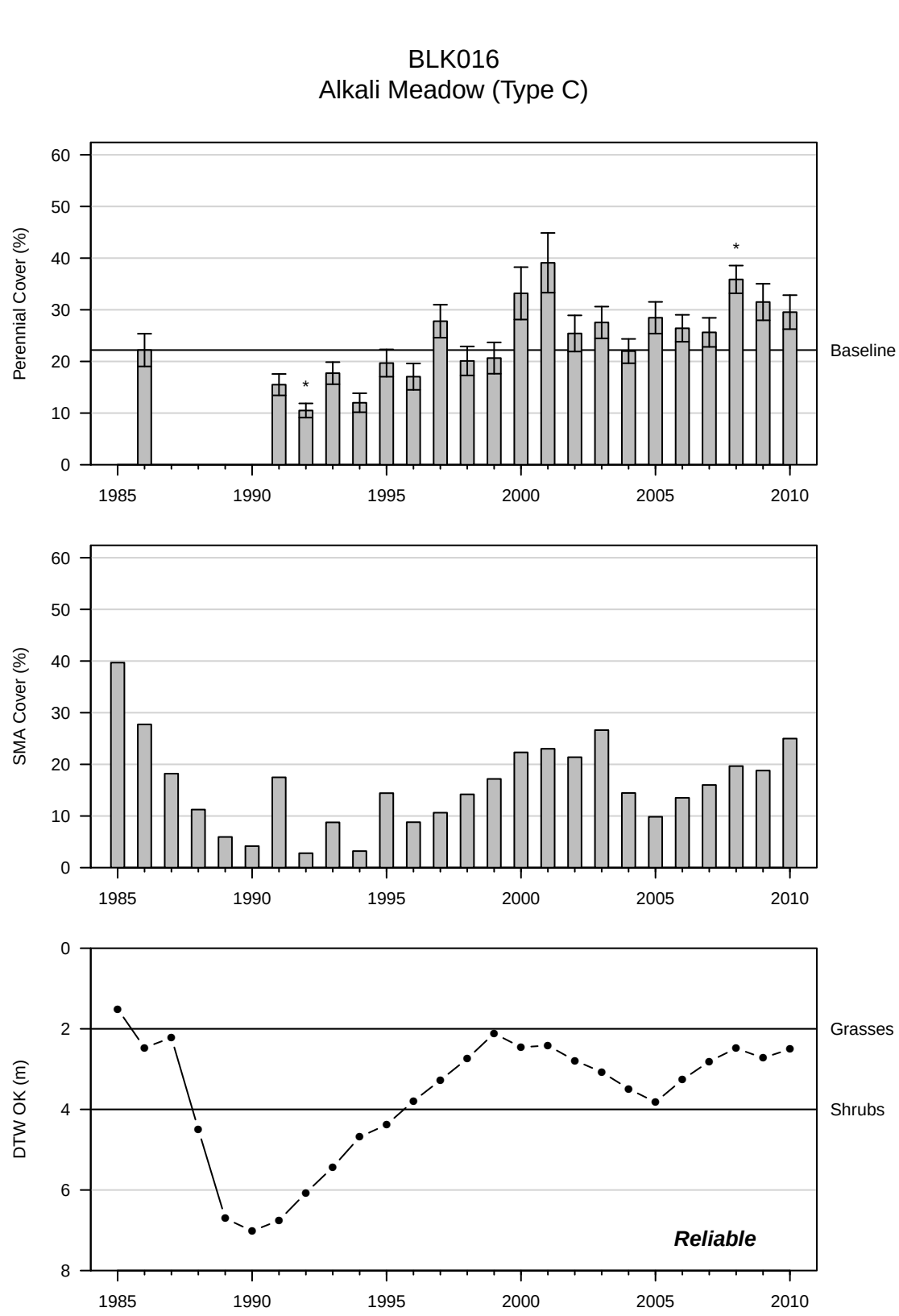


Figure 23: 2010 Wellfield

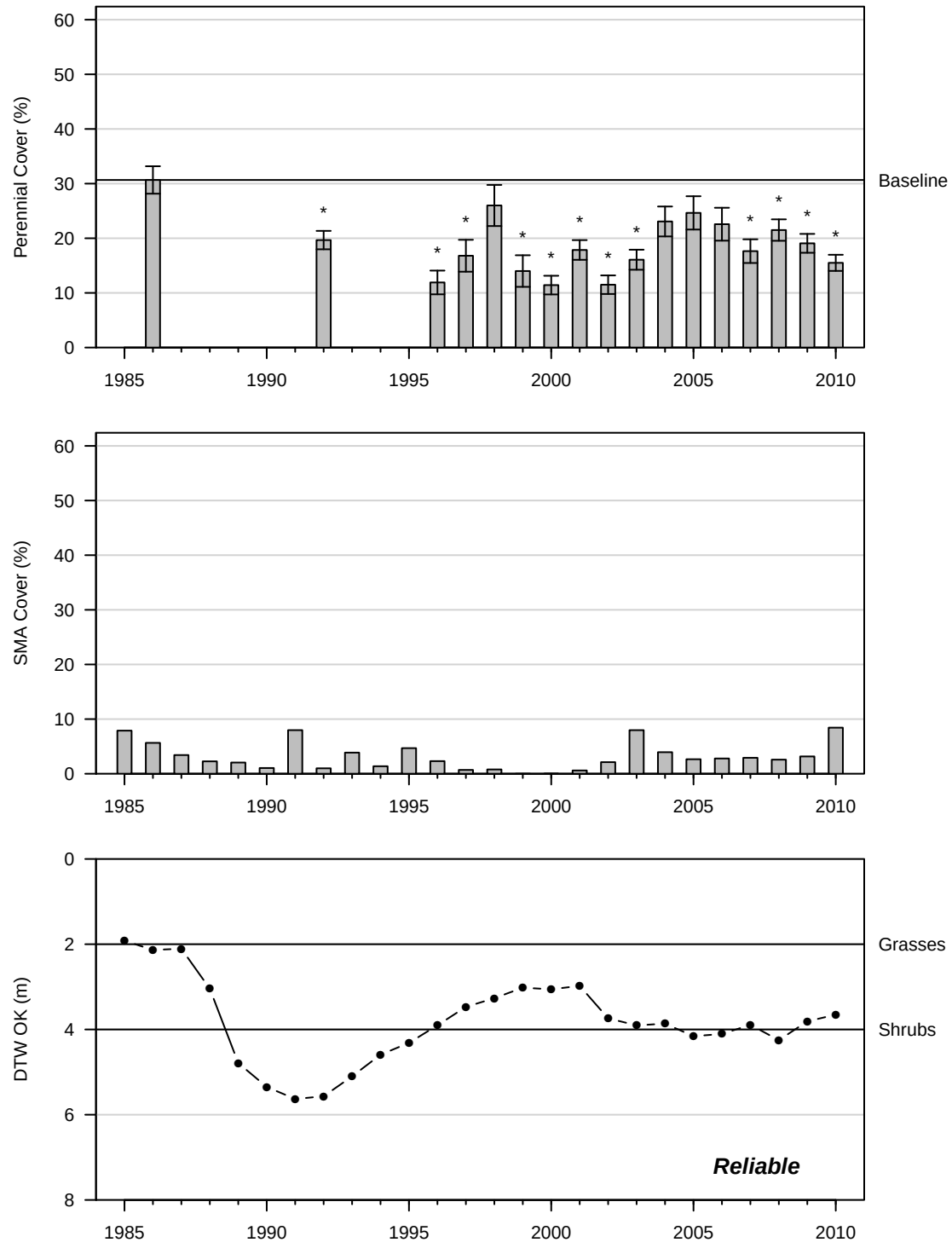


Figure 24: 2010 Wellfield

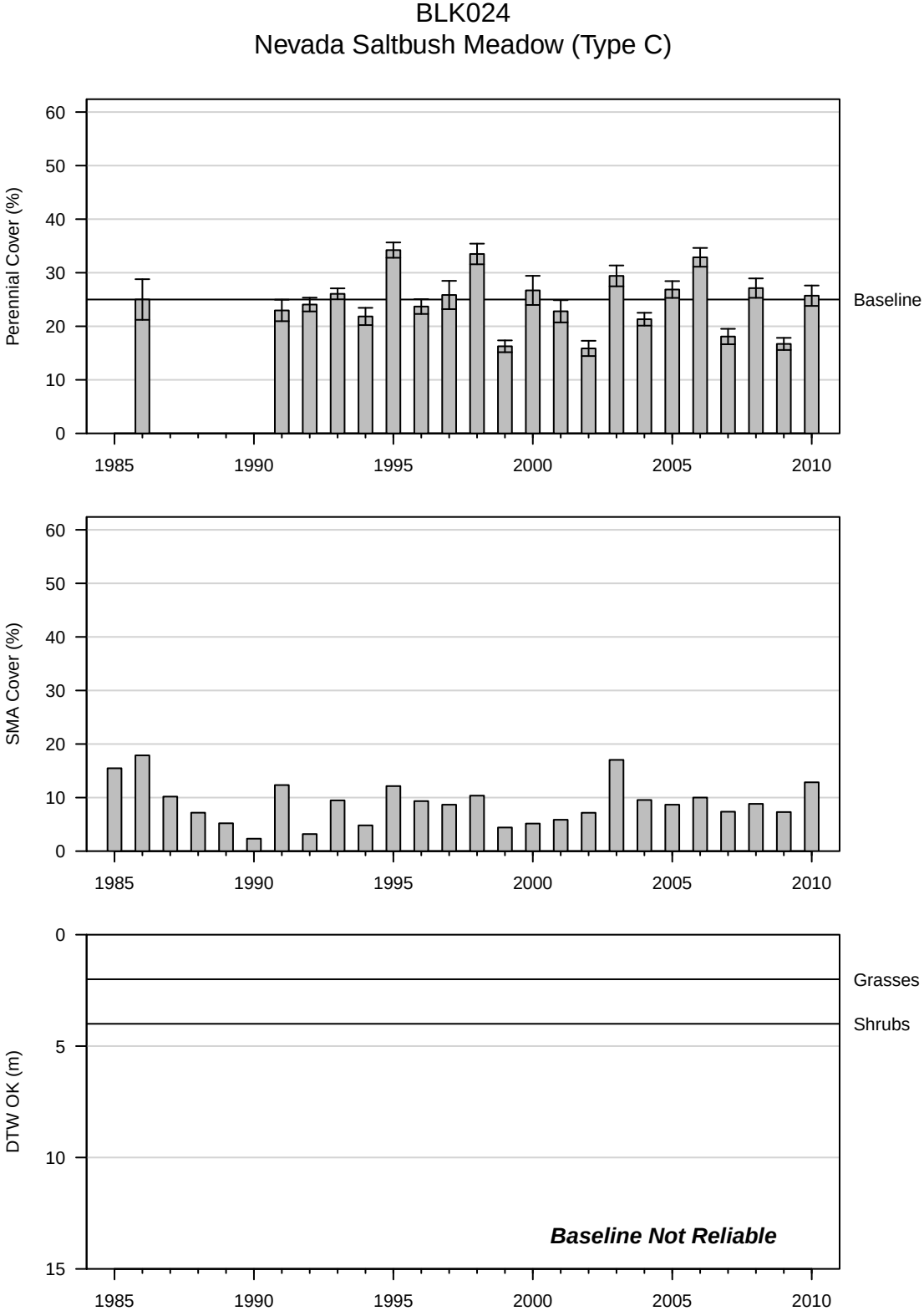


Figure 25: 2010 Wellfield

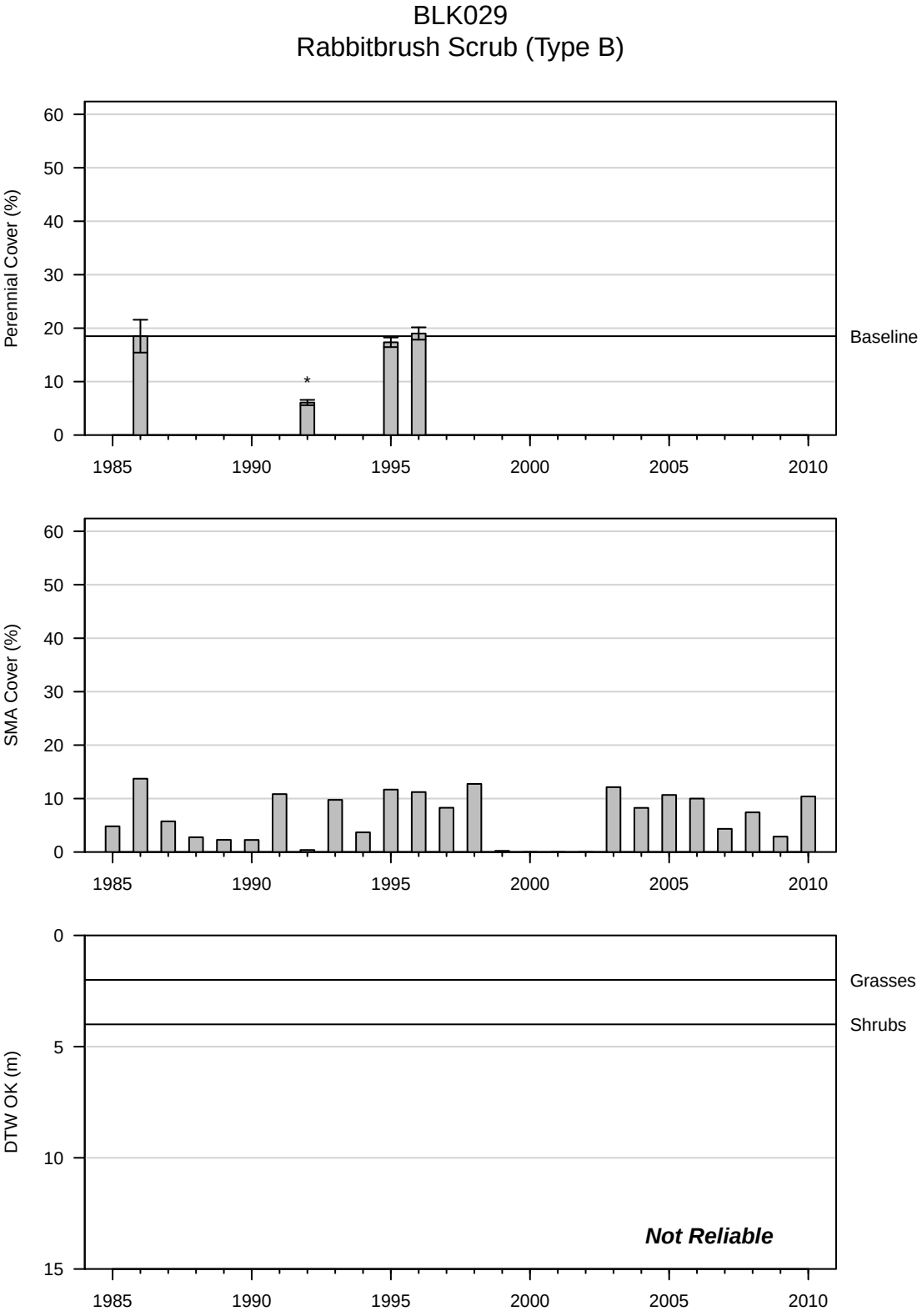


Figure 26: 1996 Wellfield

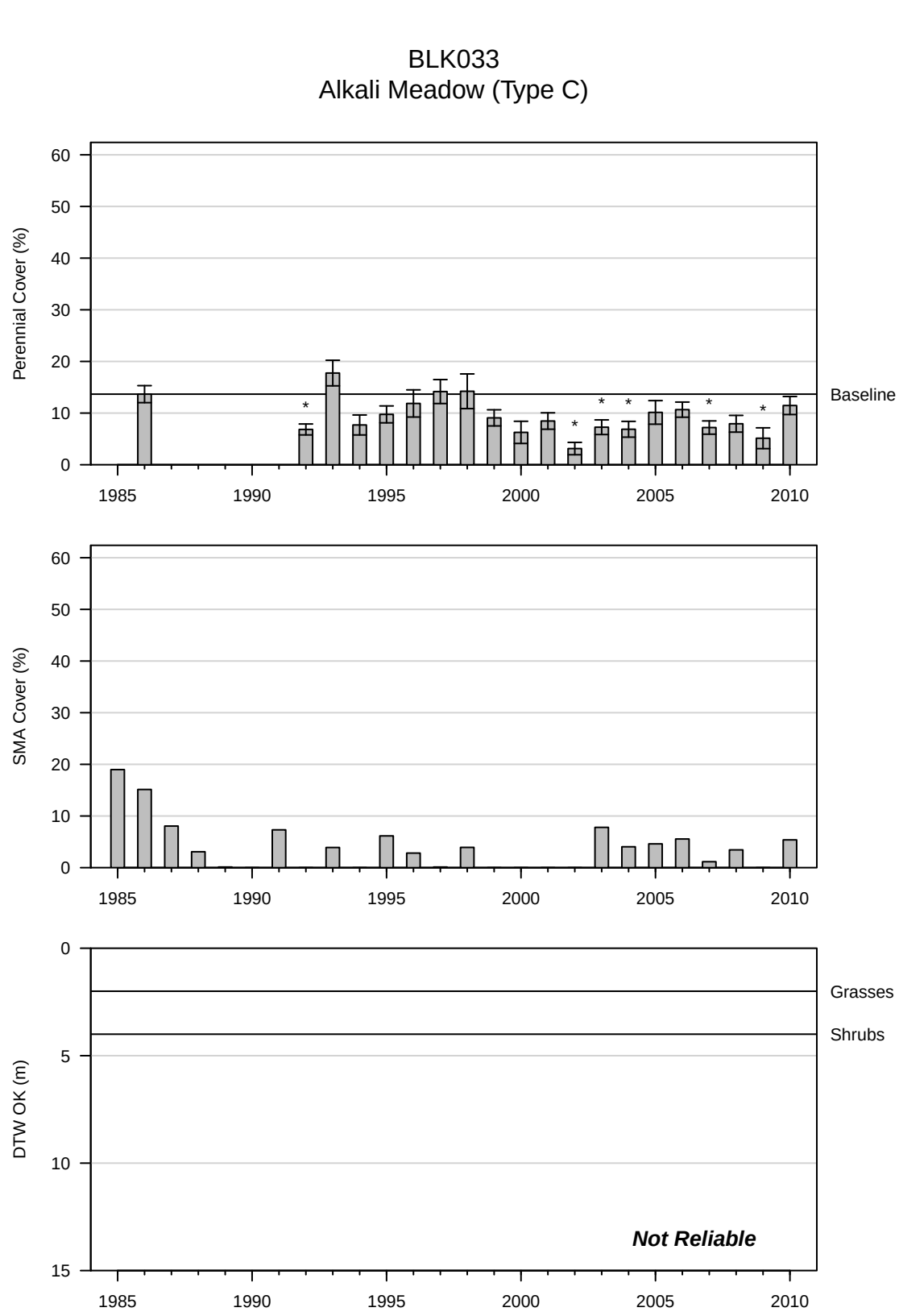


Figure 27: 2010 Wellfield

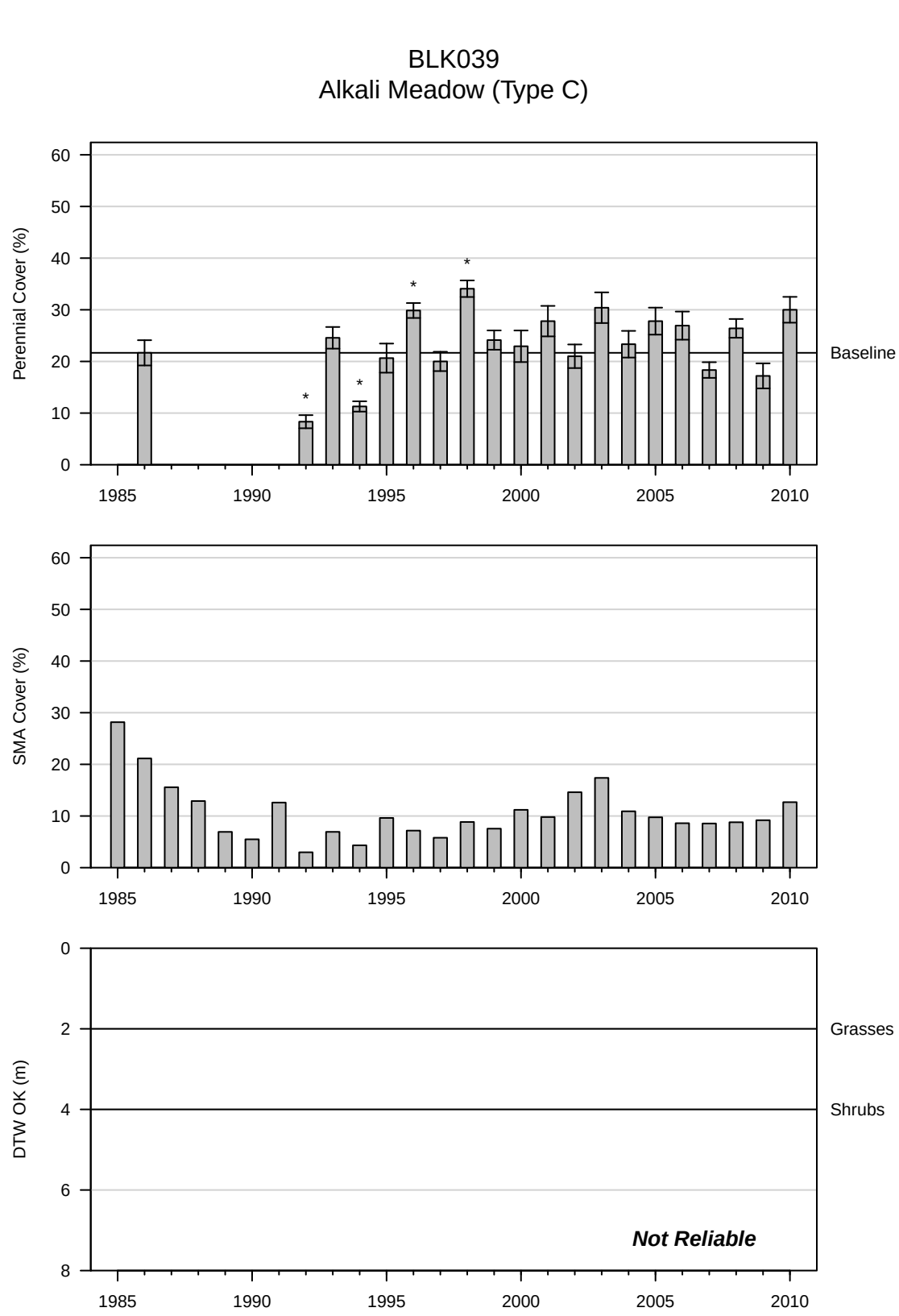


Figure 28: 2010 Wellfield

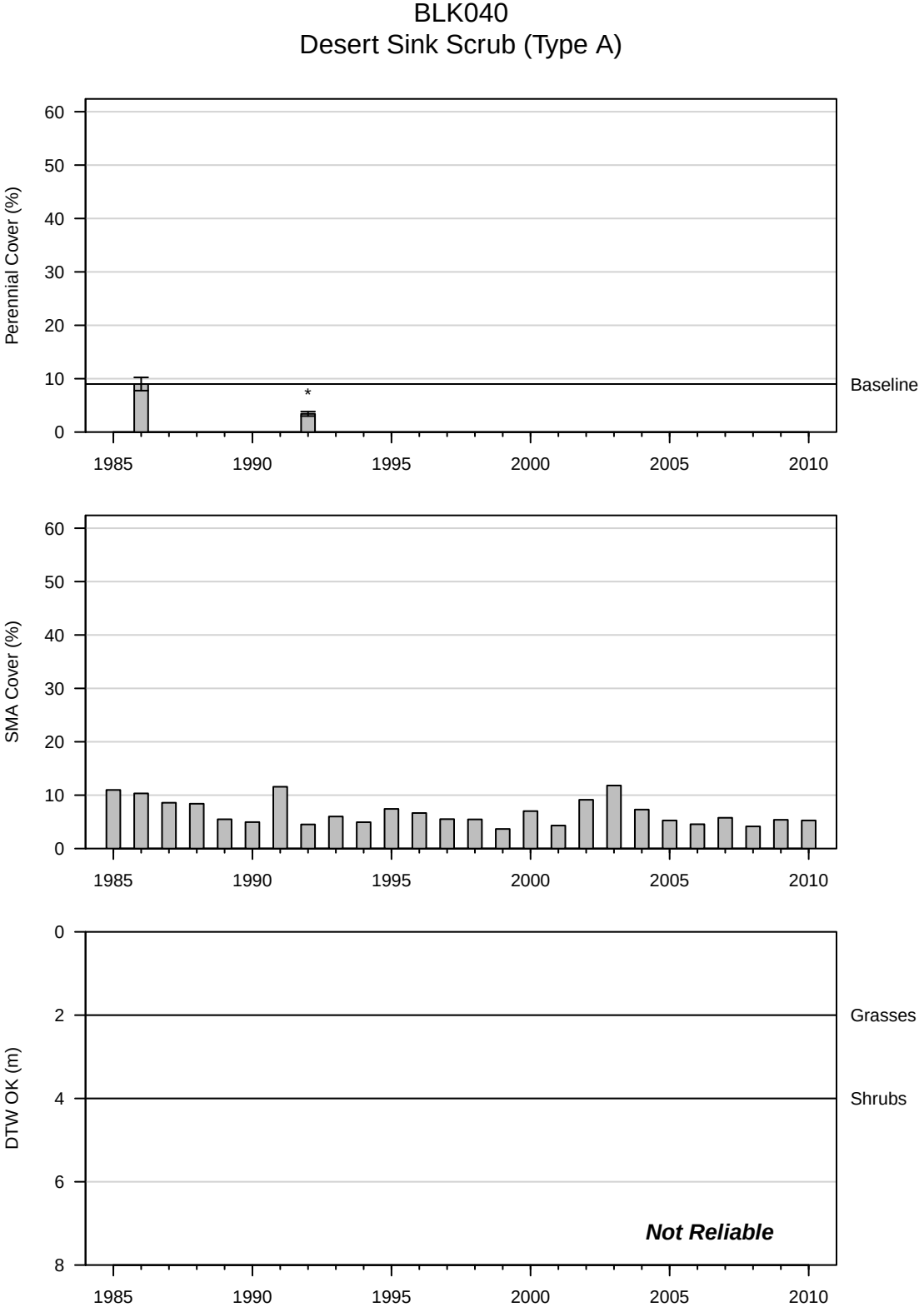


Figure 29: 1992 Wellfield

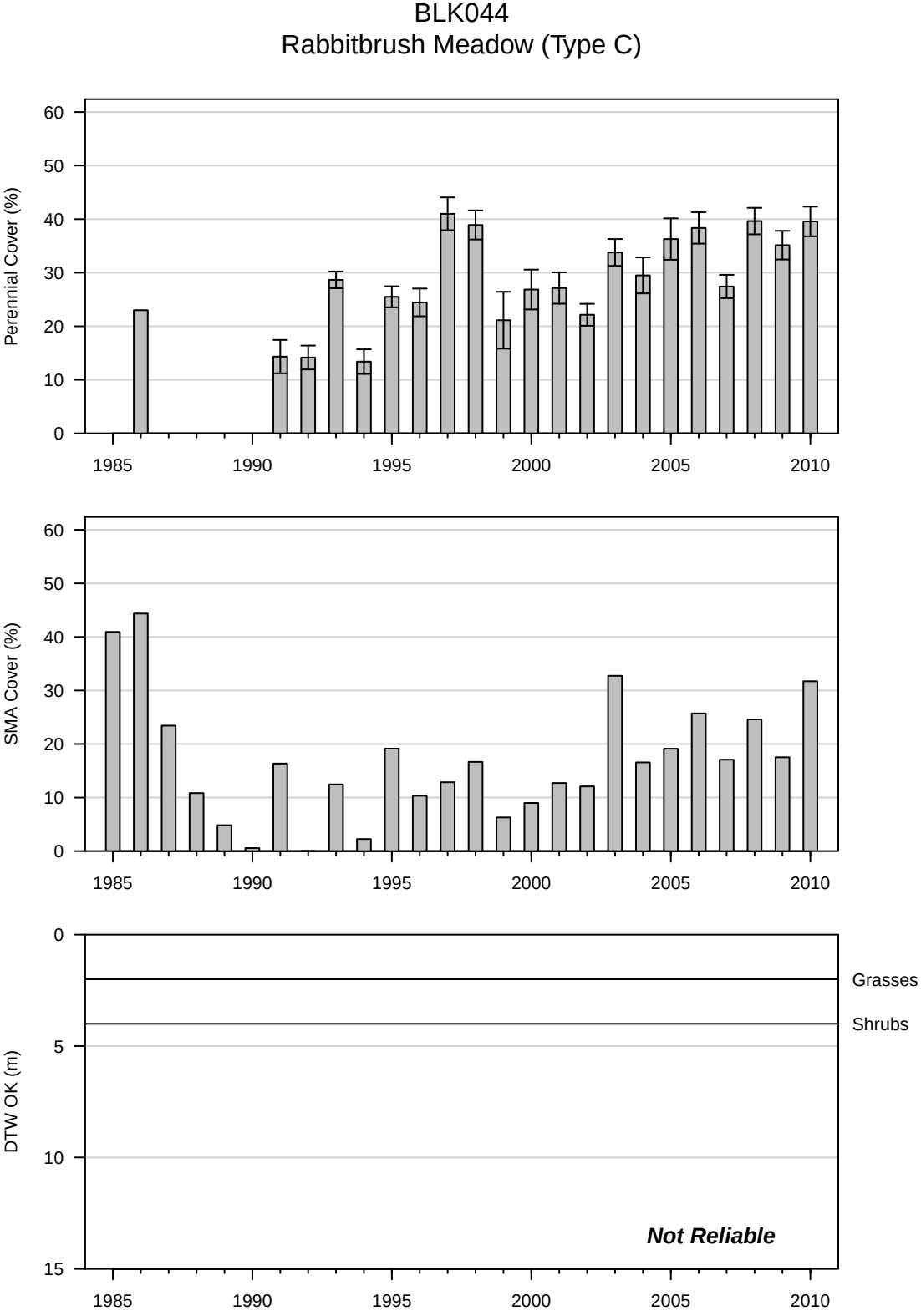


Figure 30: 2010 Wellfield

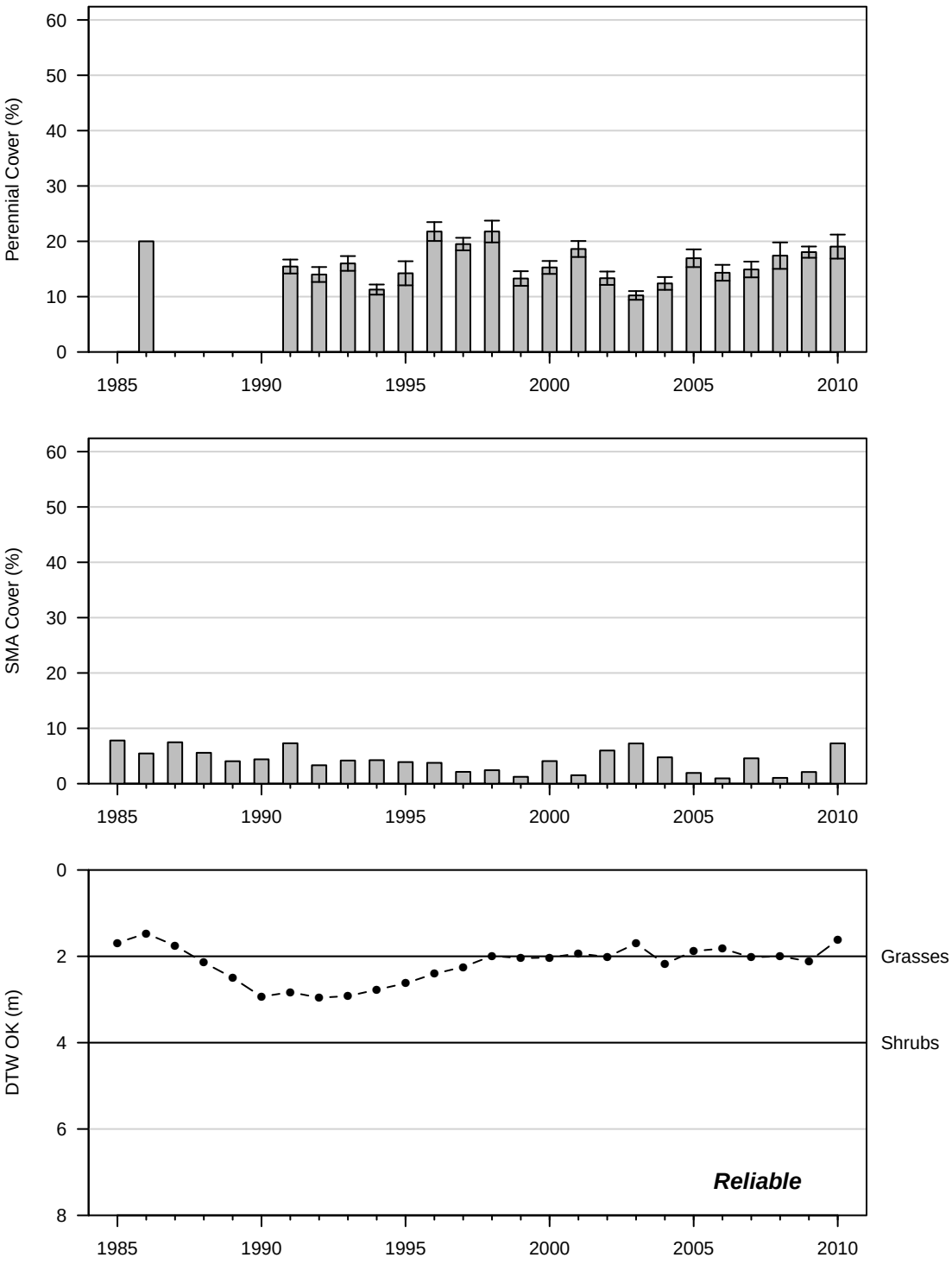


Figure 31: 2010 Wellfield

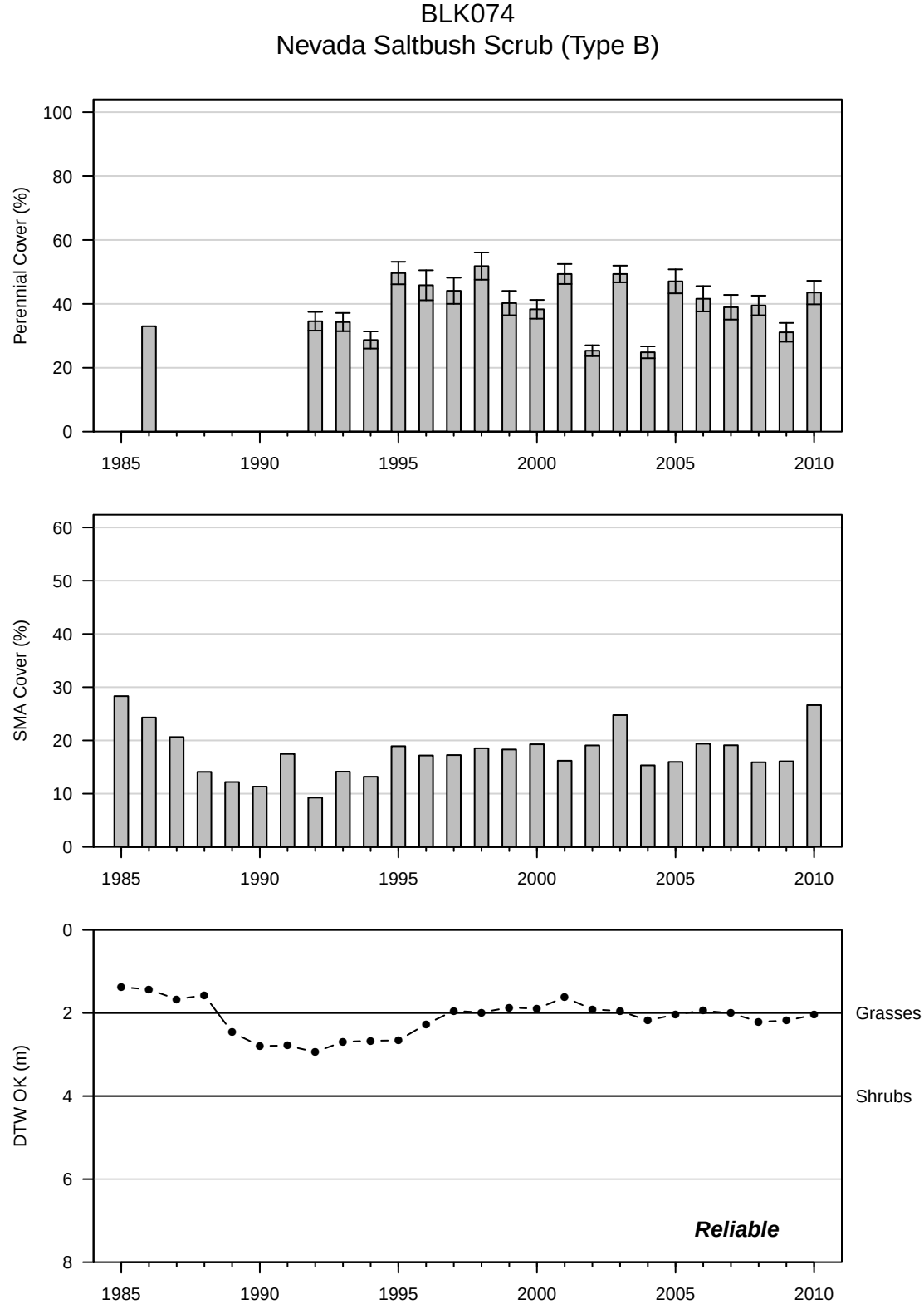


Figure 32: 2010 Wellfield

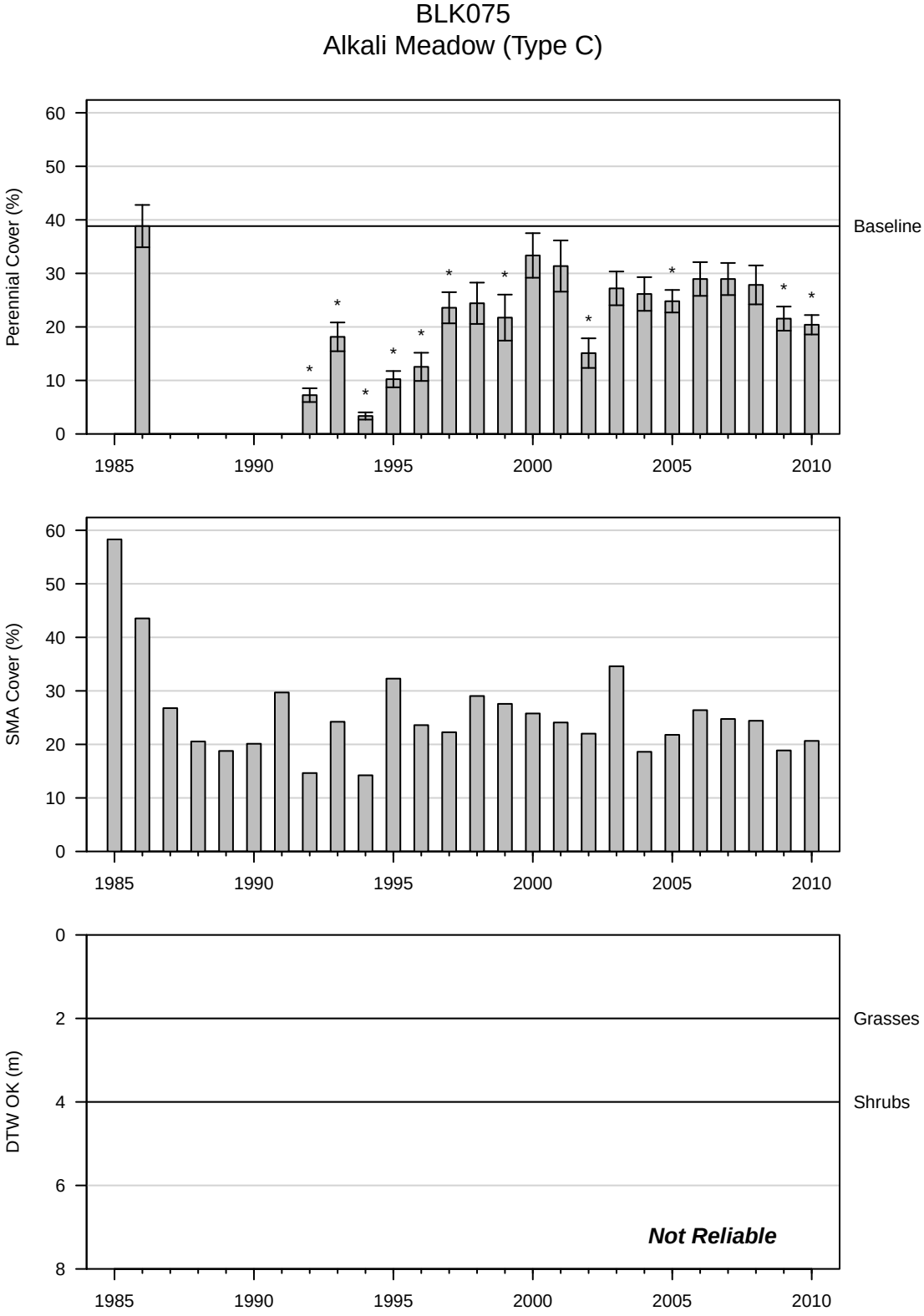


Figure 33: 2010 Wellfield

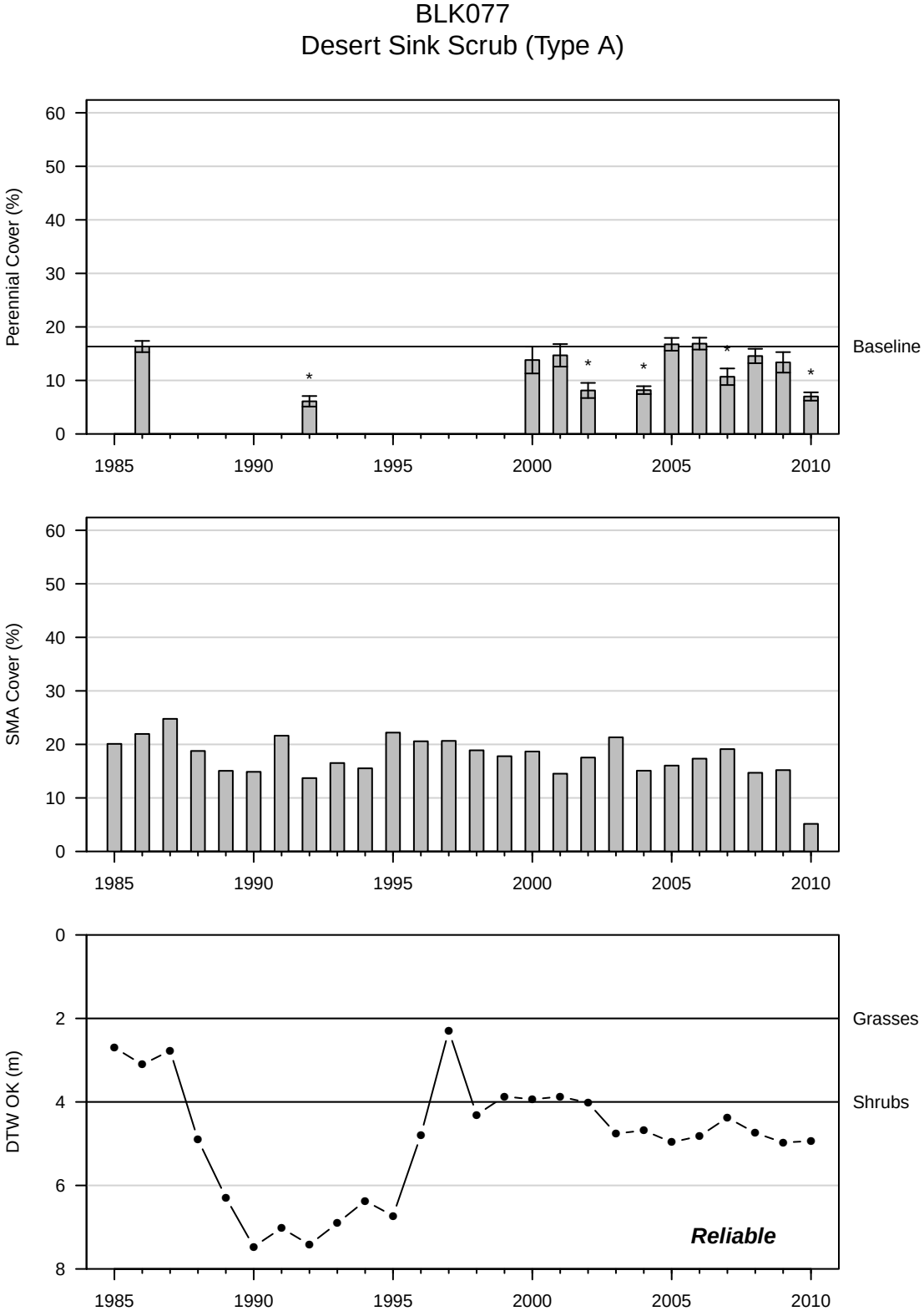


Figure 34: 2010 Wellfield

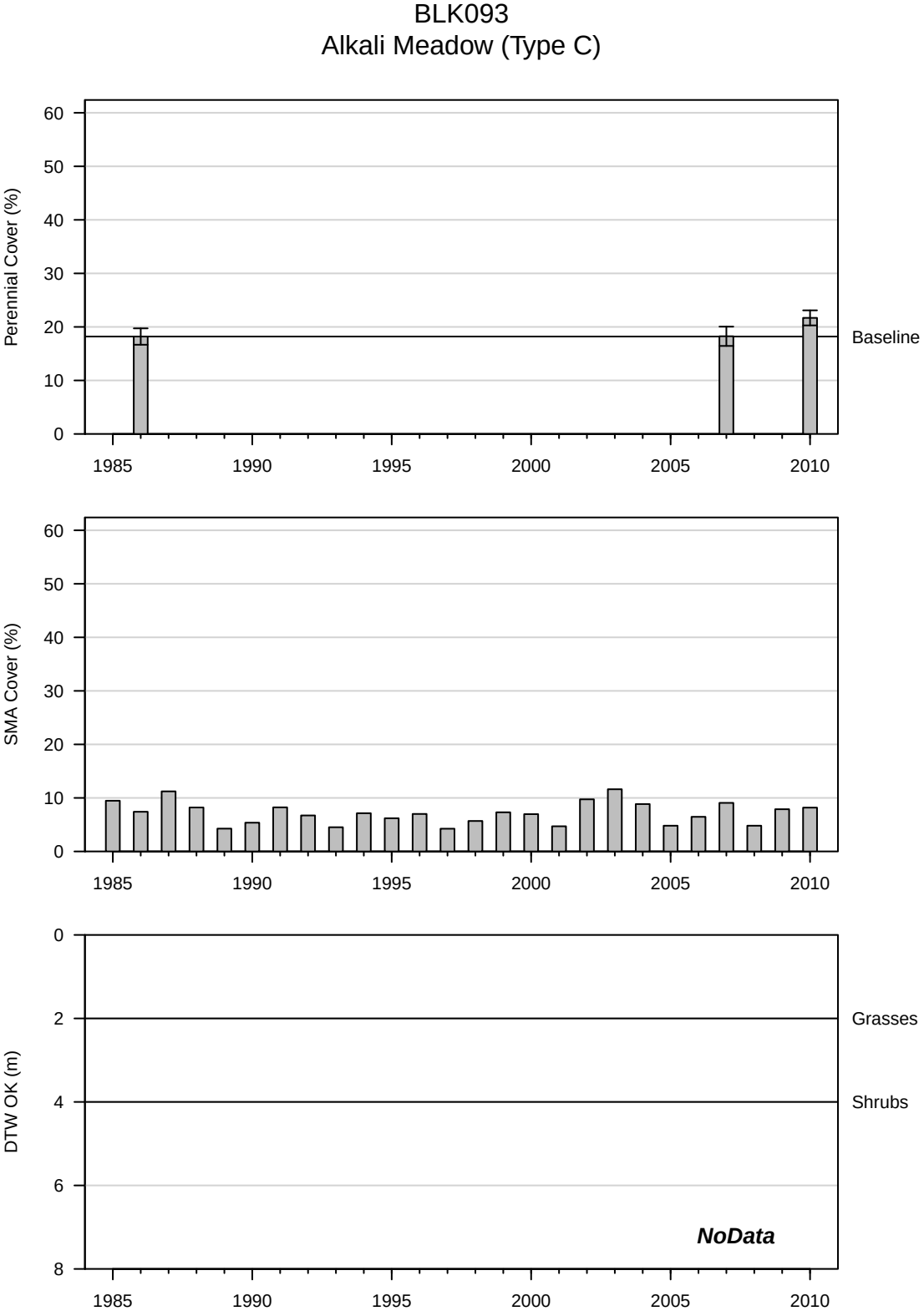


Figure 35: 2010 Wellfield

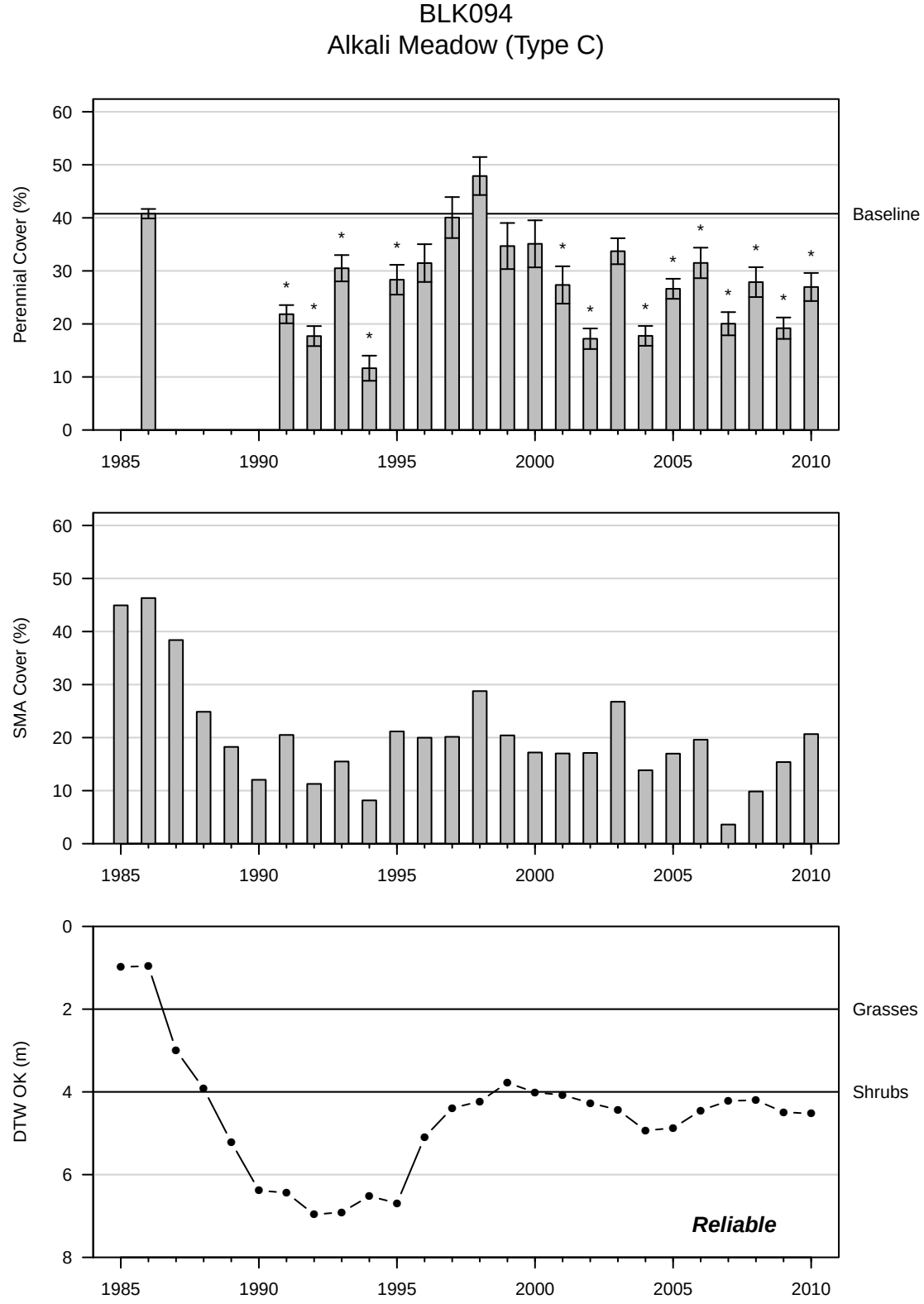


Figure 36: 2010 Wellfield

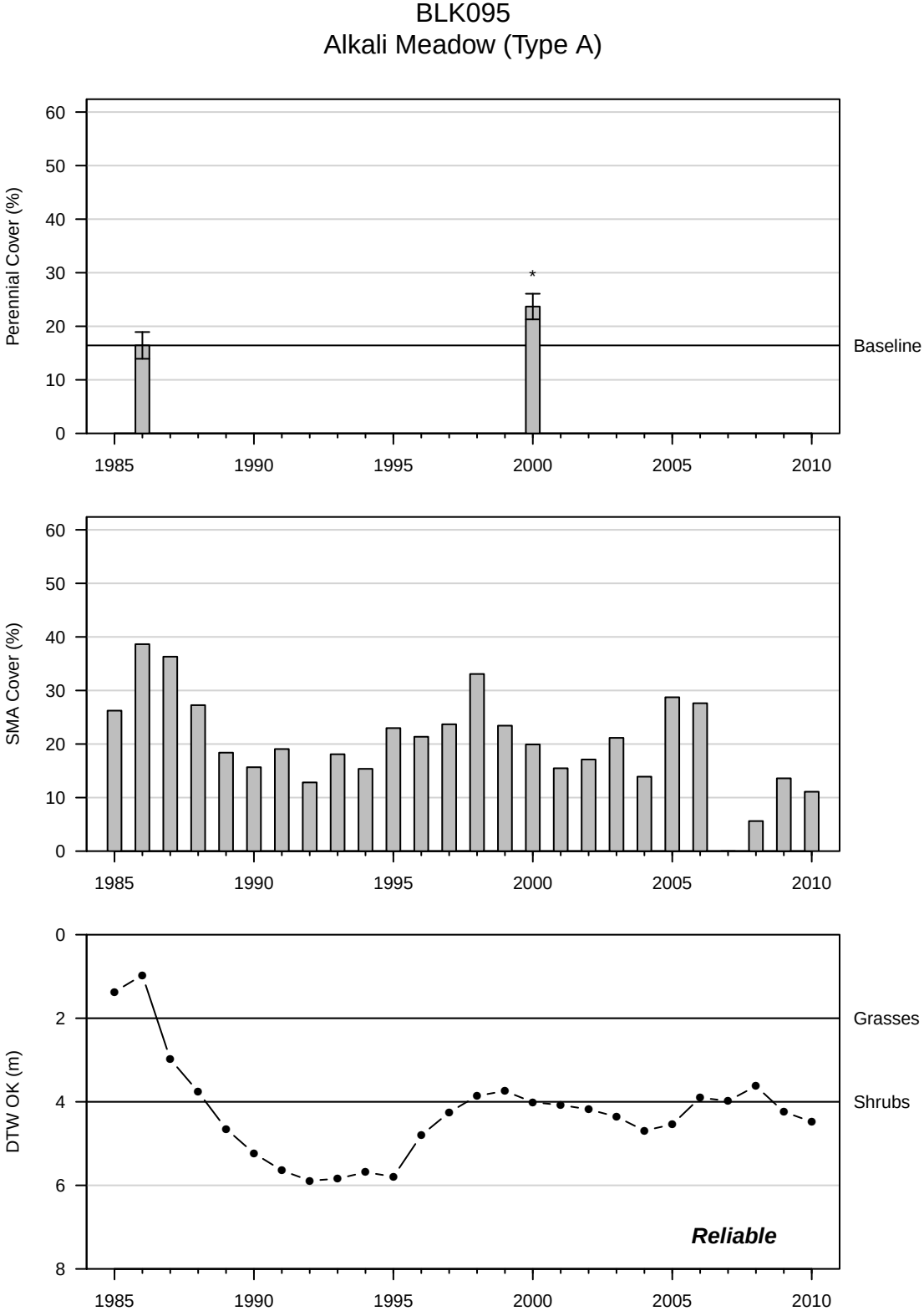


Figure 37: 2000 Wellfield

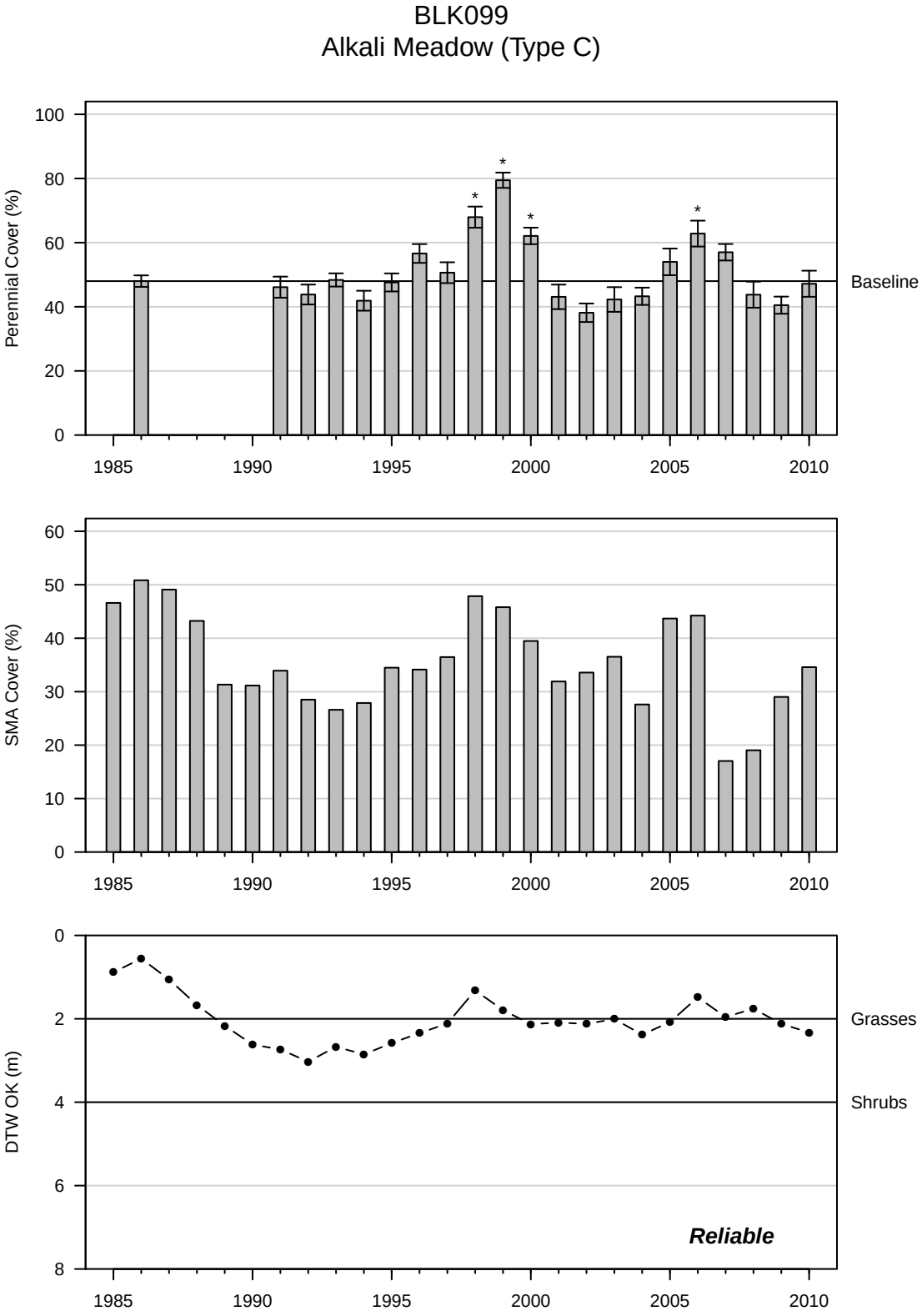


Figure 38: 2010 Wellfield

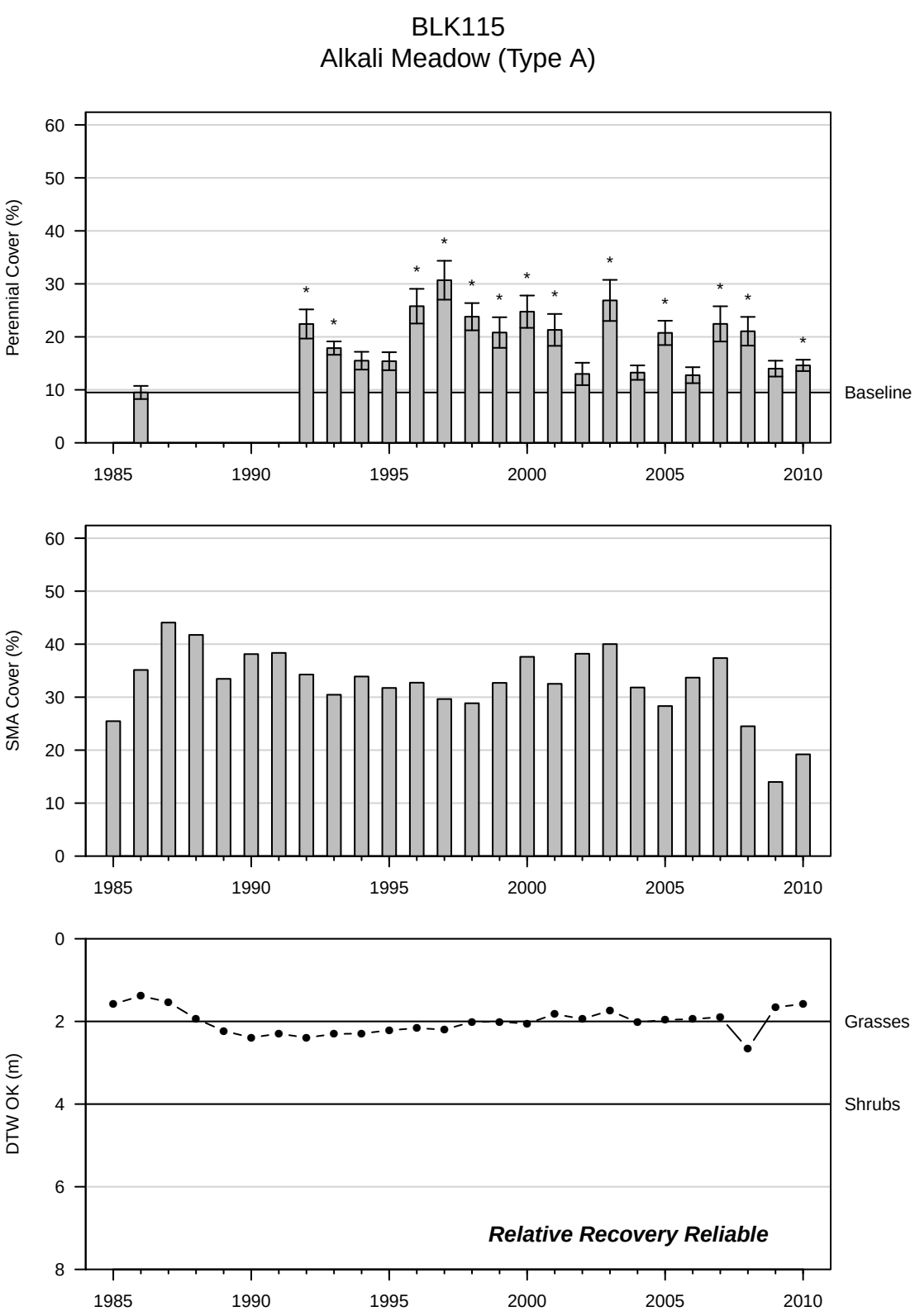


Figure 39: 2010 Control

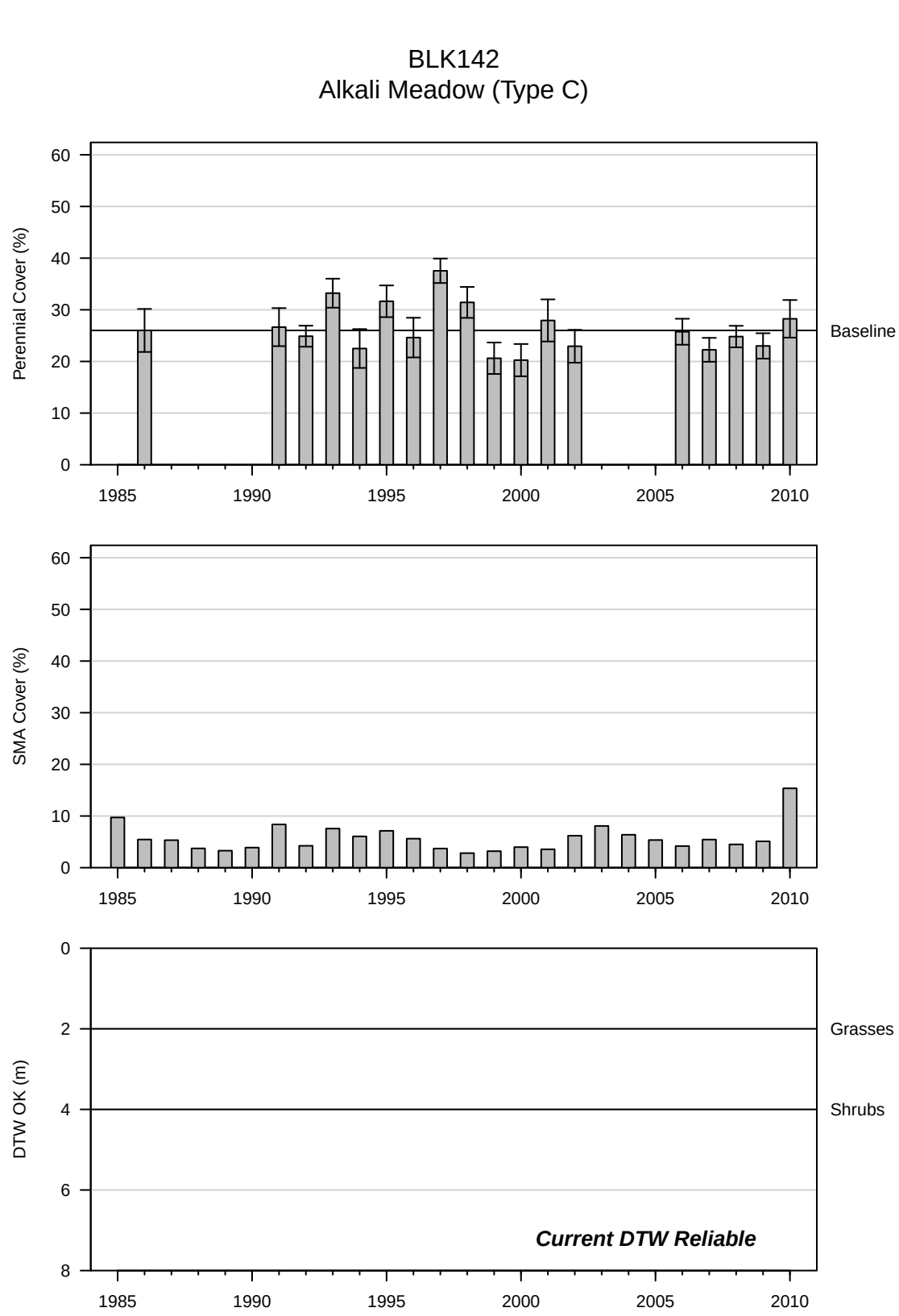


Figure 40: 2010 Wellfield

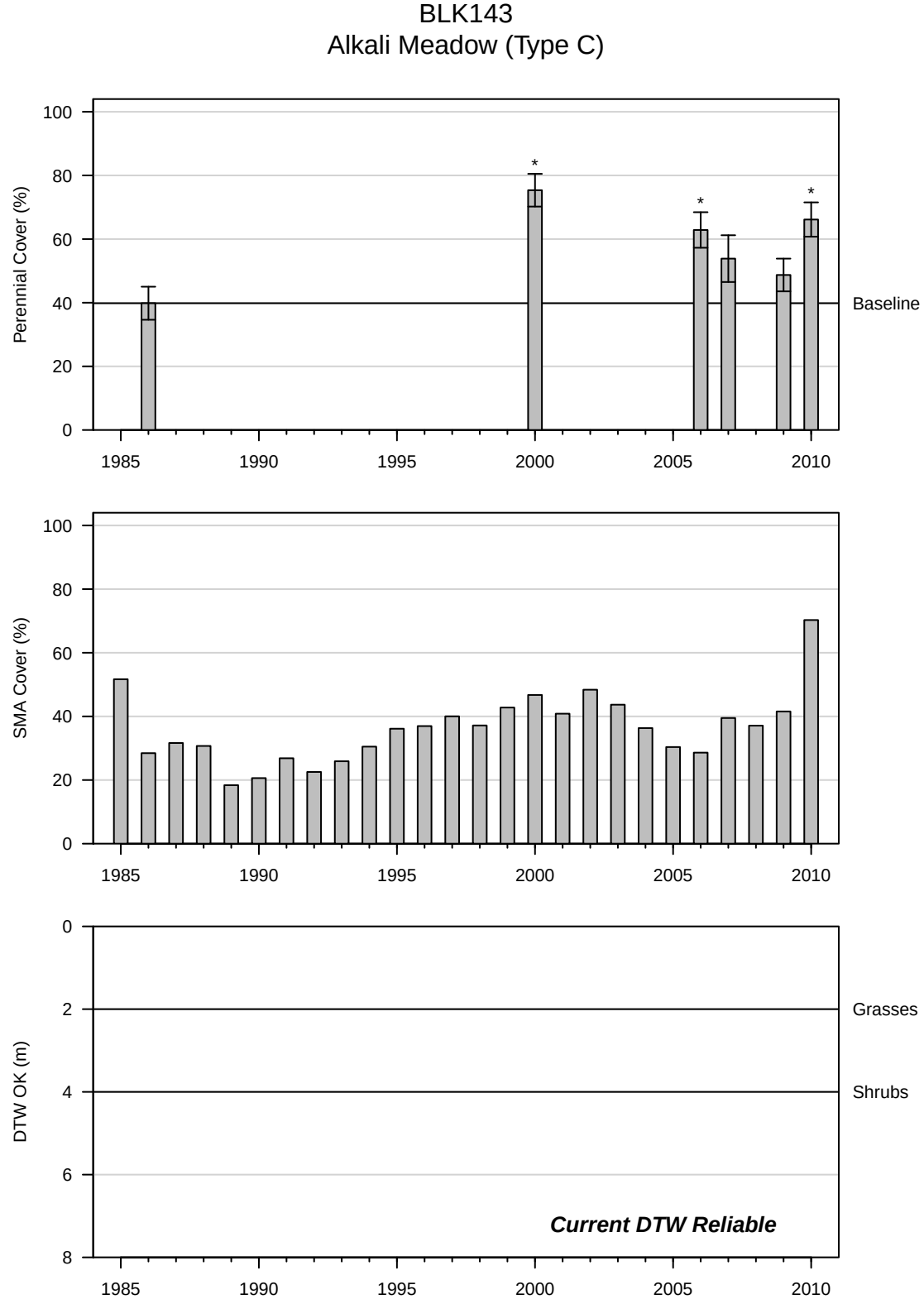


Figure 41: 2010 Wellfield

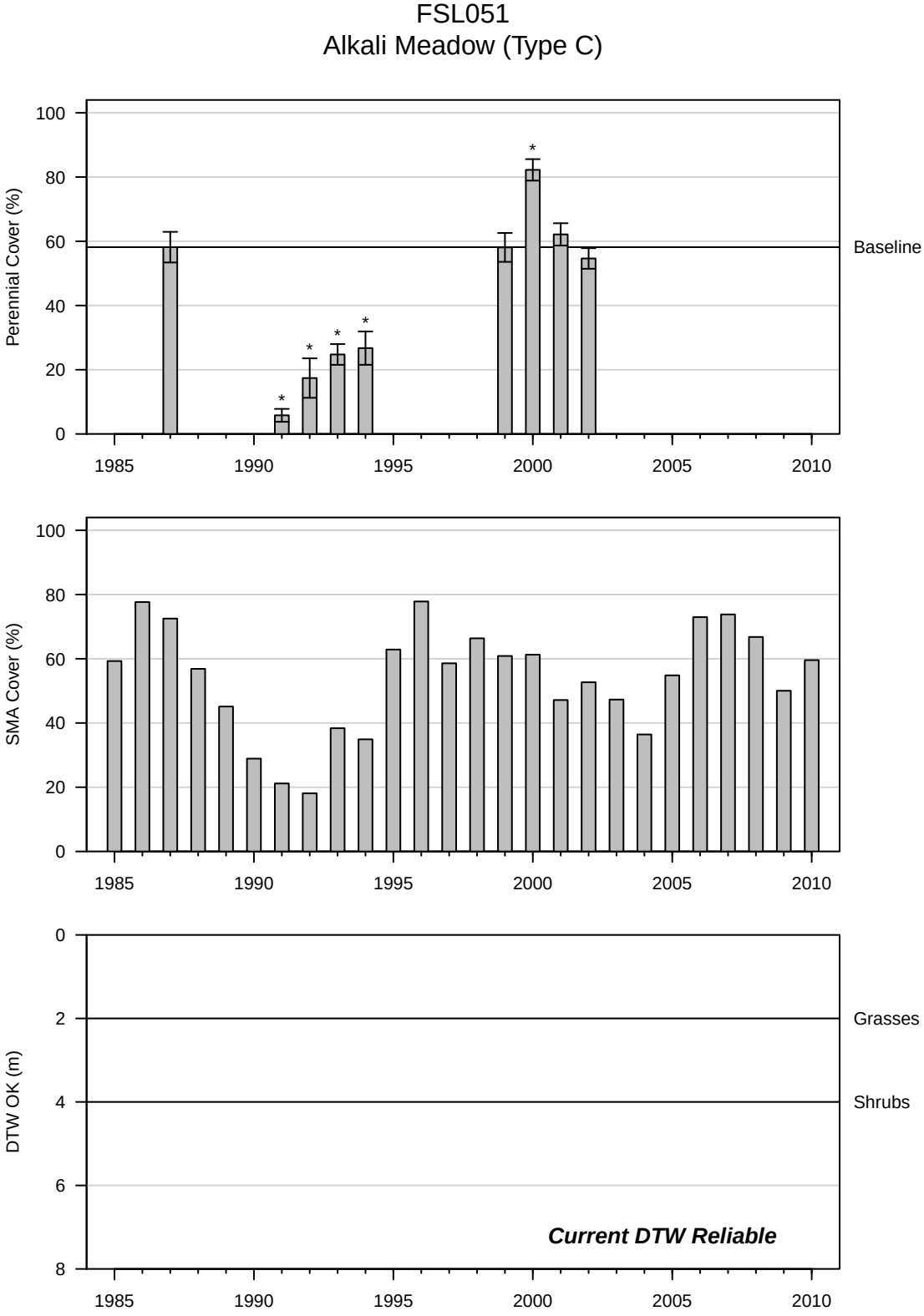
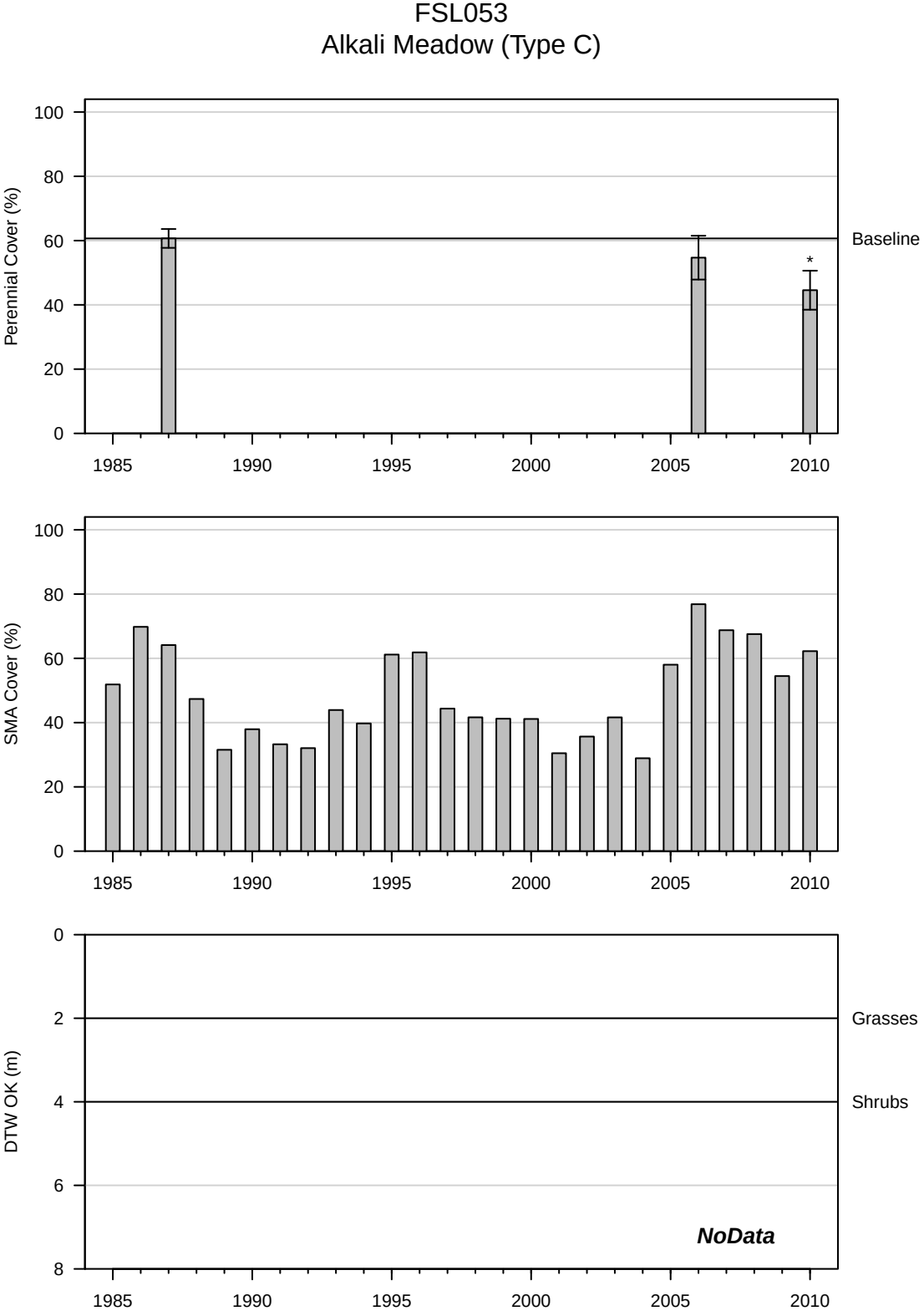


Figure 42: 2002 Wellfield



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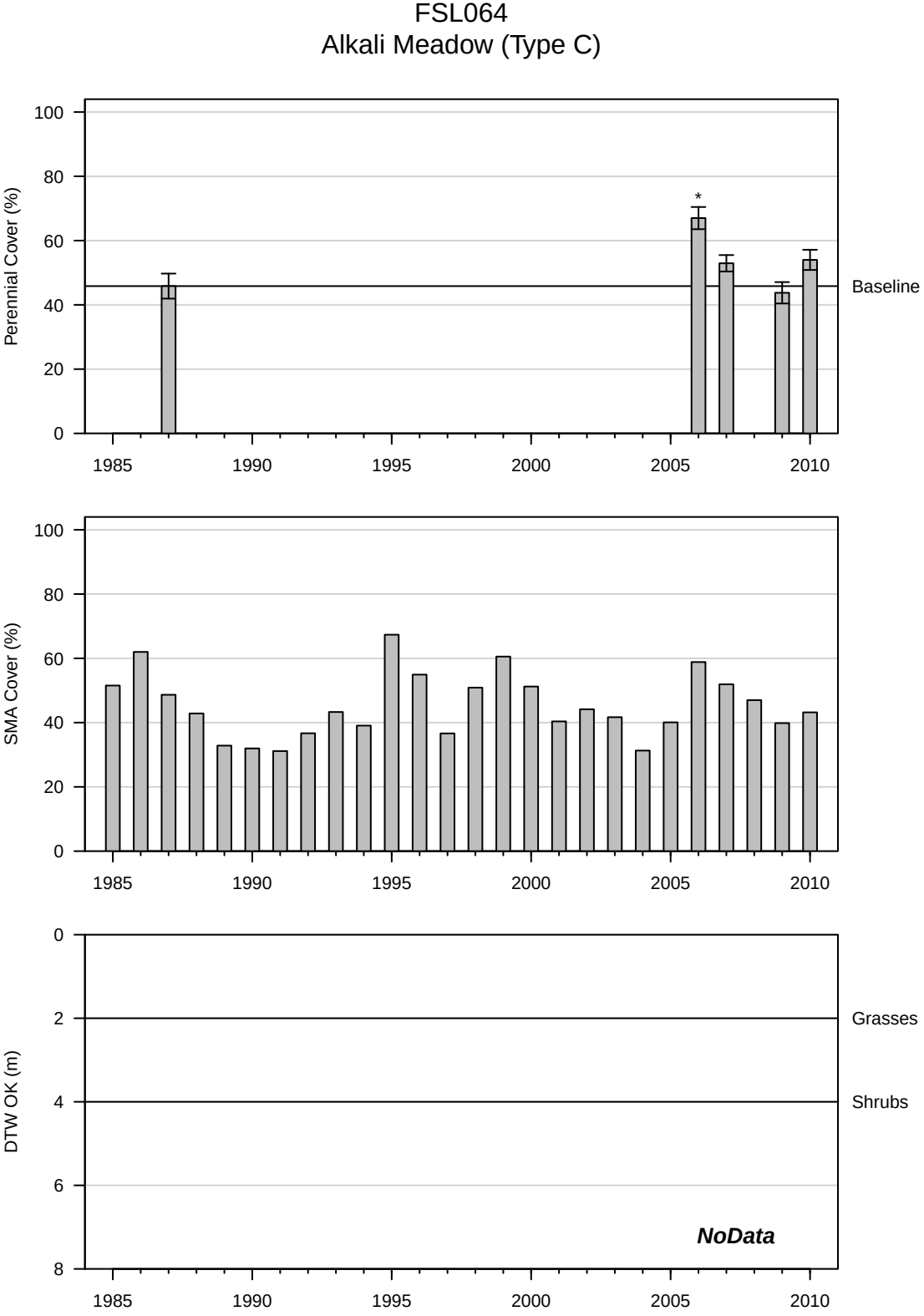

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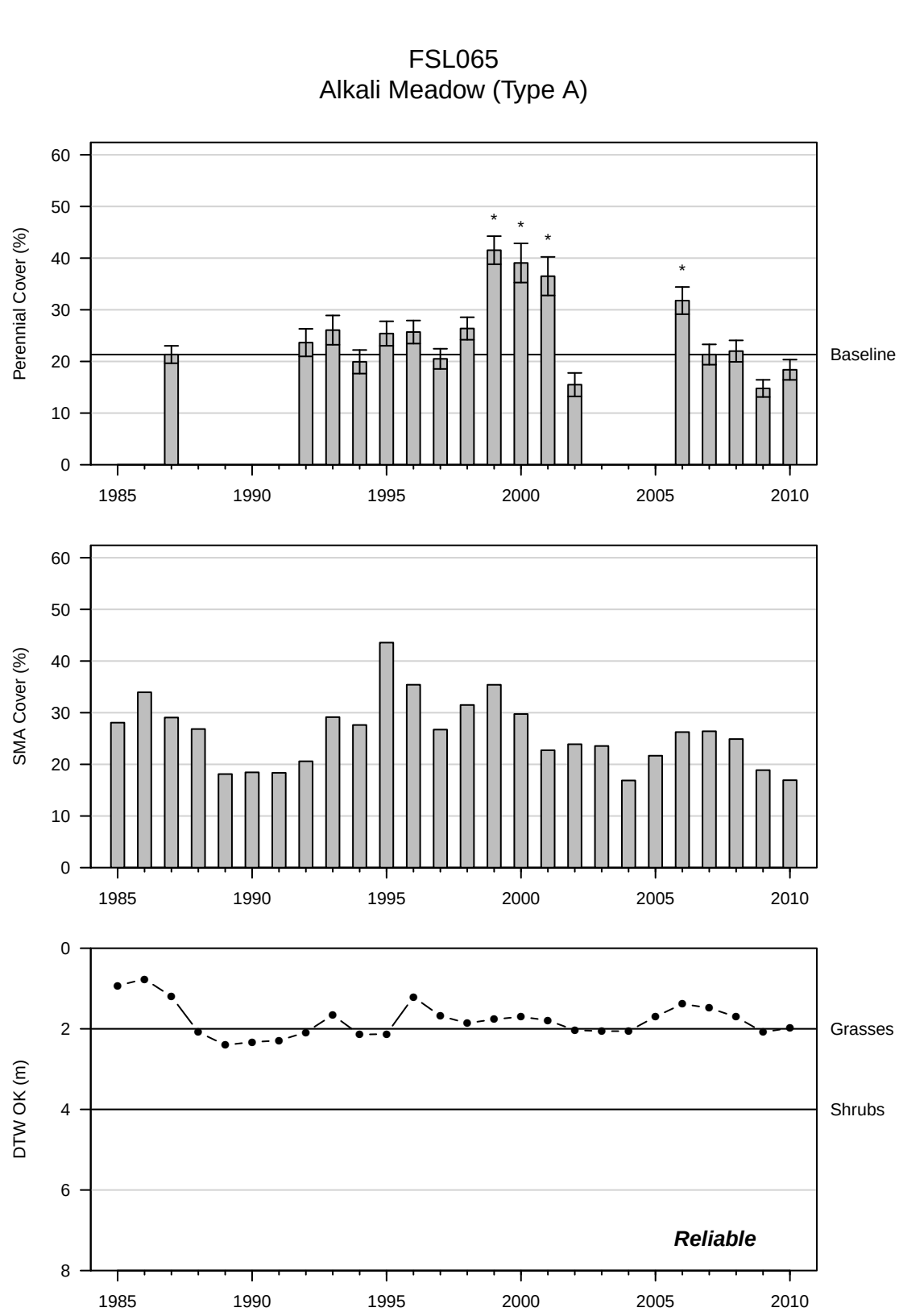

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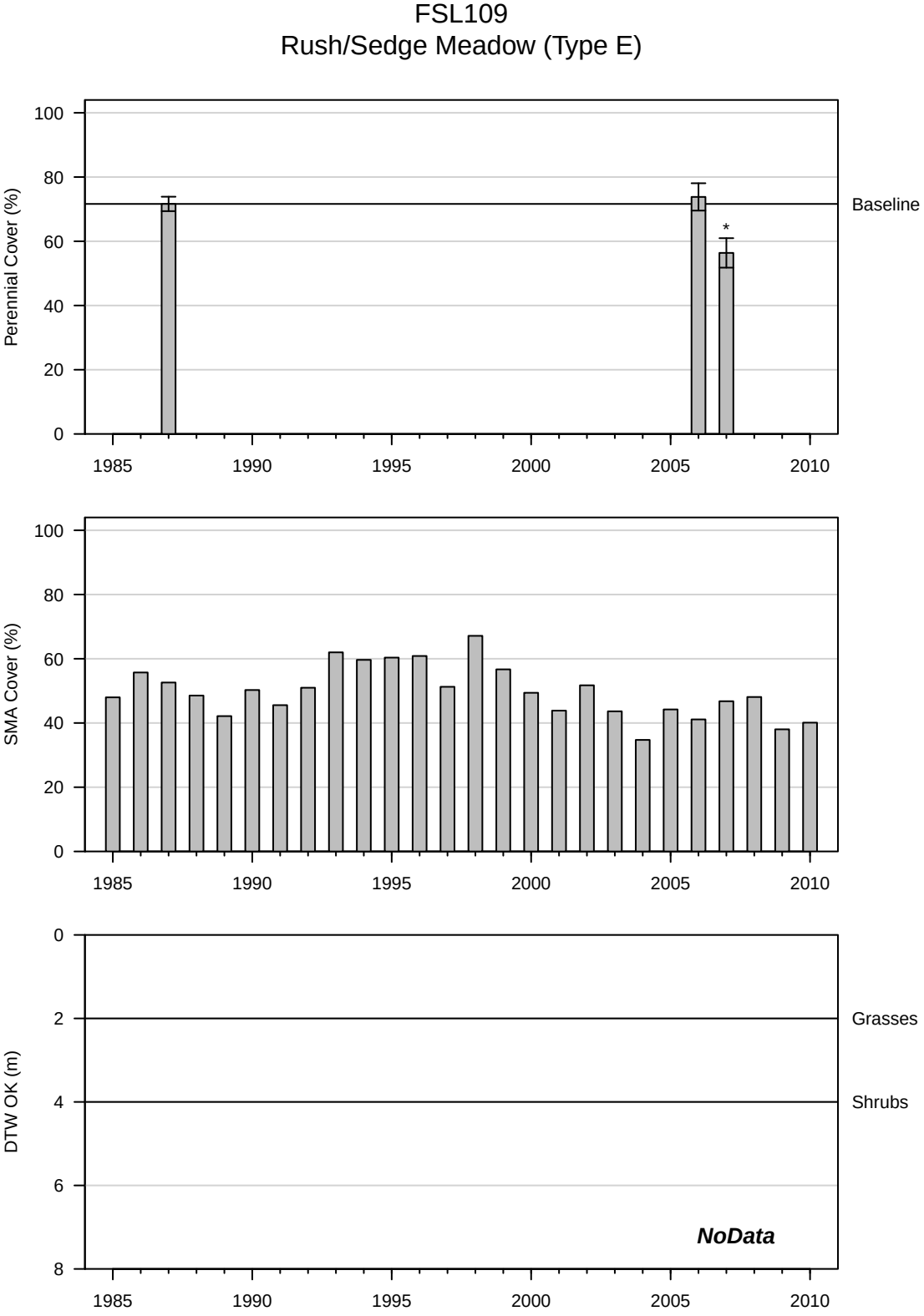


Figure 46: 2007 Control

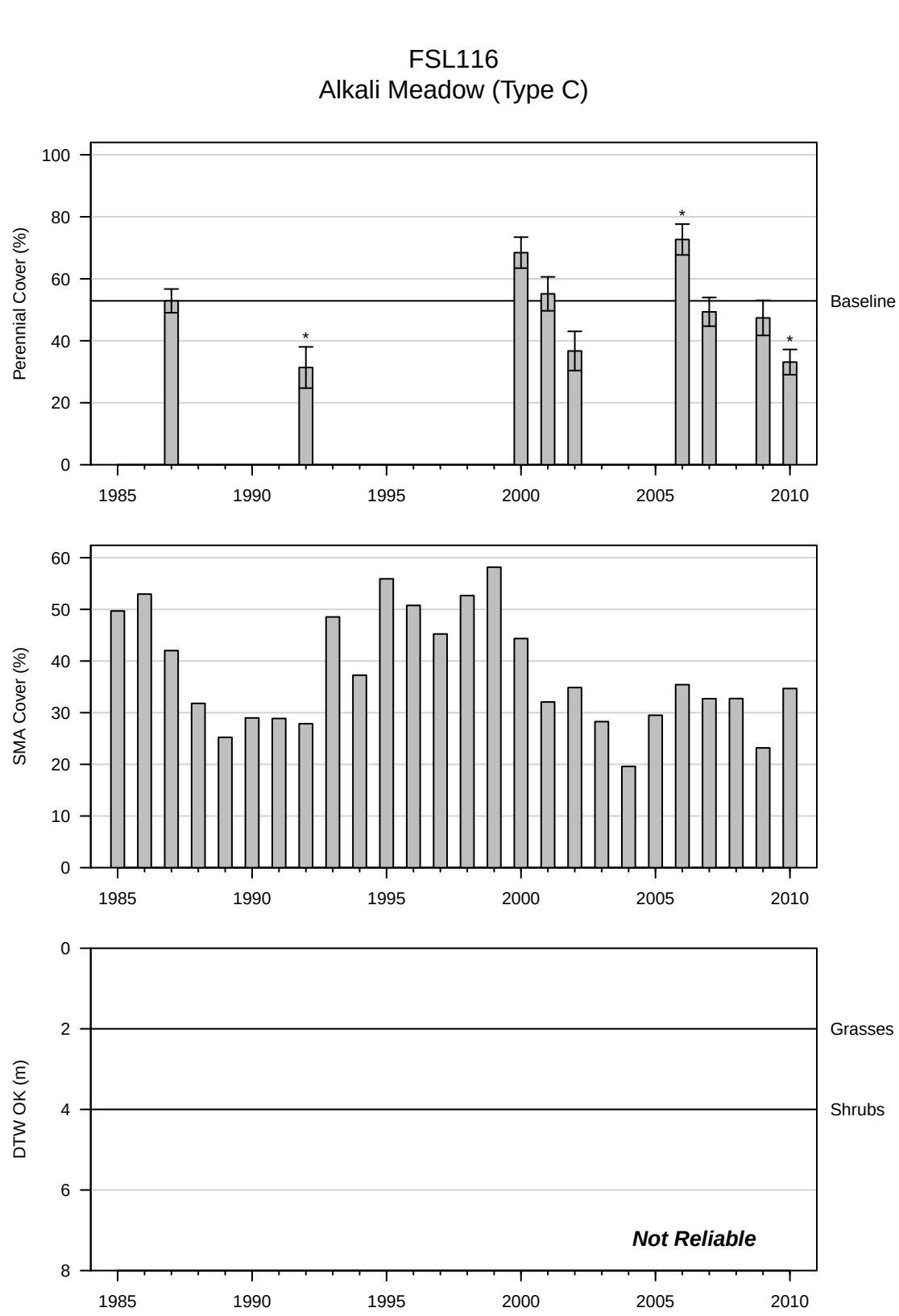


Figure 47: 2010 Wellfield

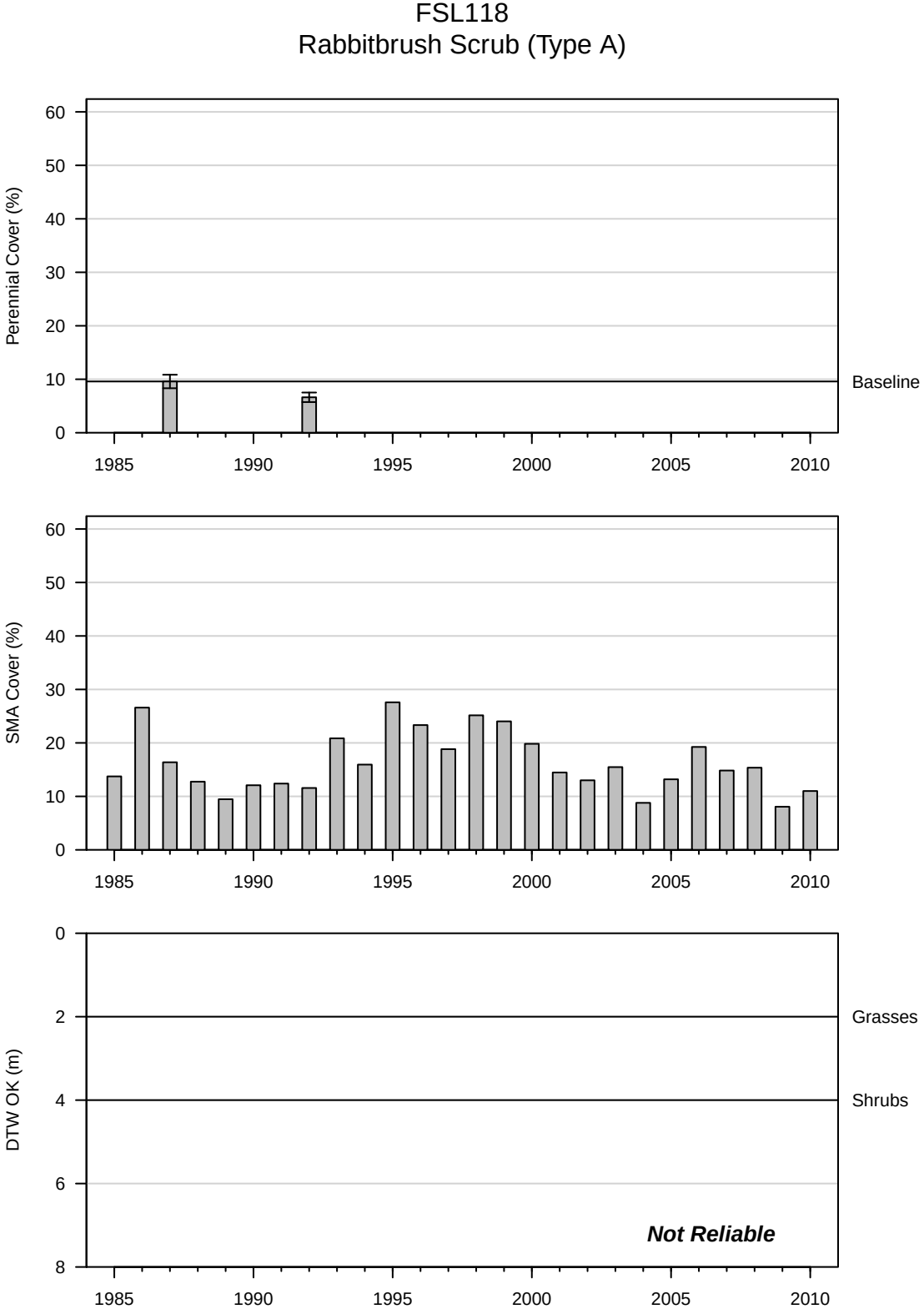


Figure 48: 1992 Wellfield

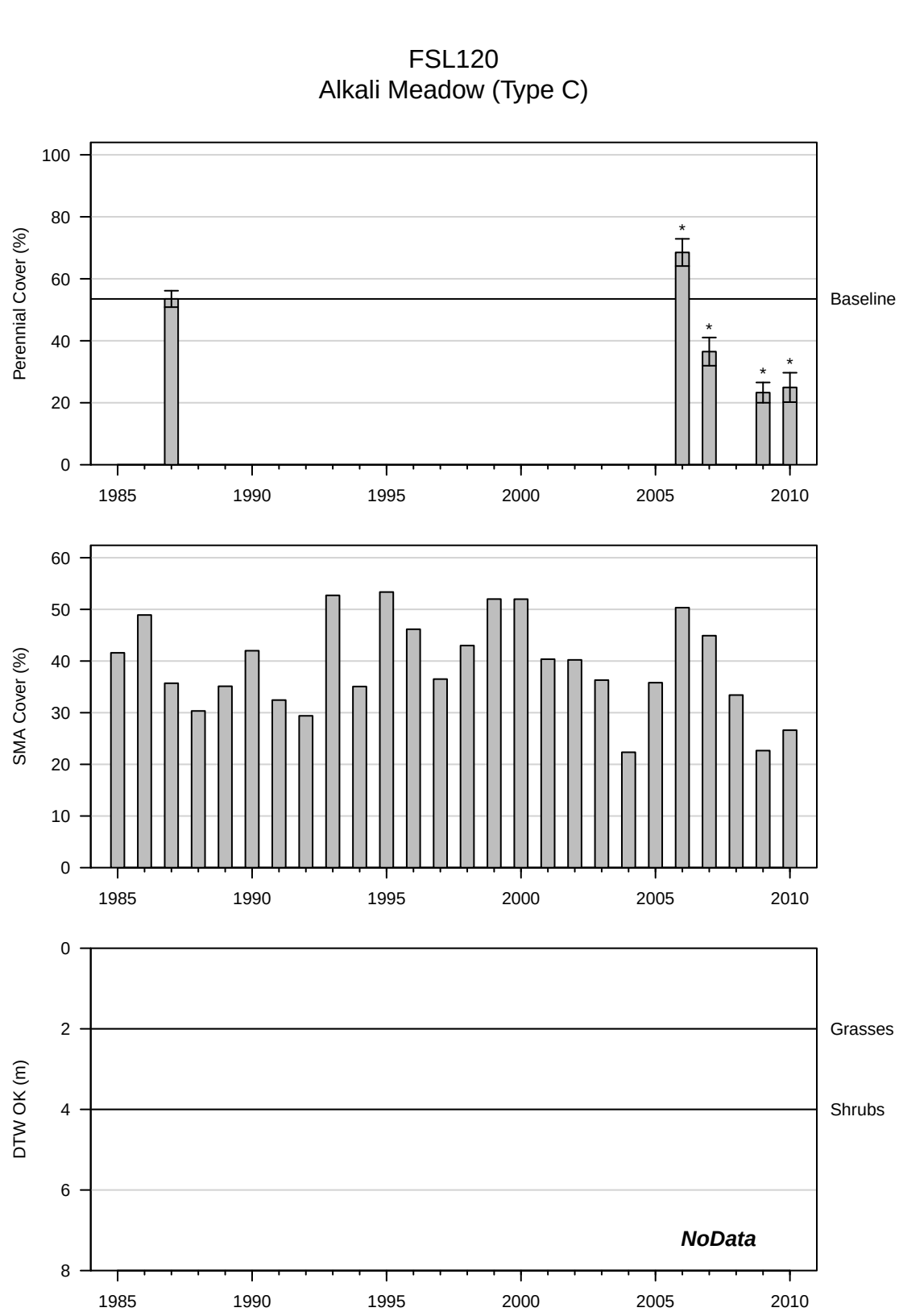


Figure 49: 2010 Wellfield

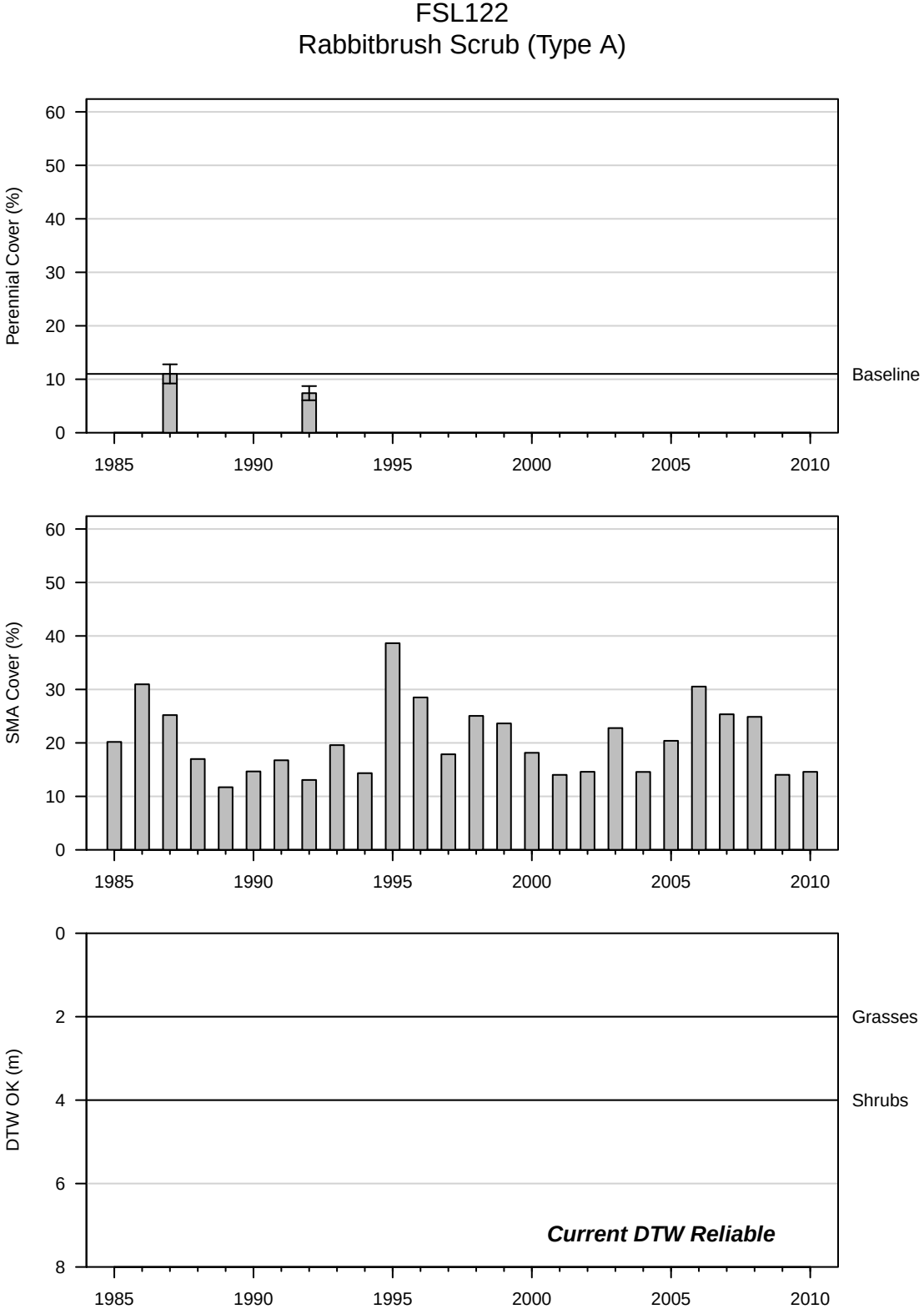


Figure 50: 1992 Wellfield

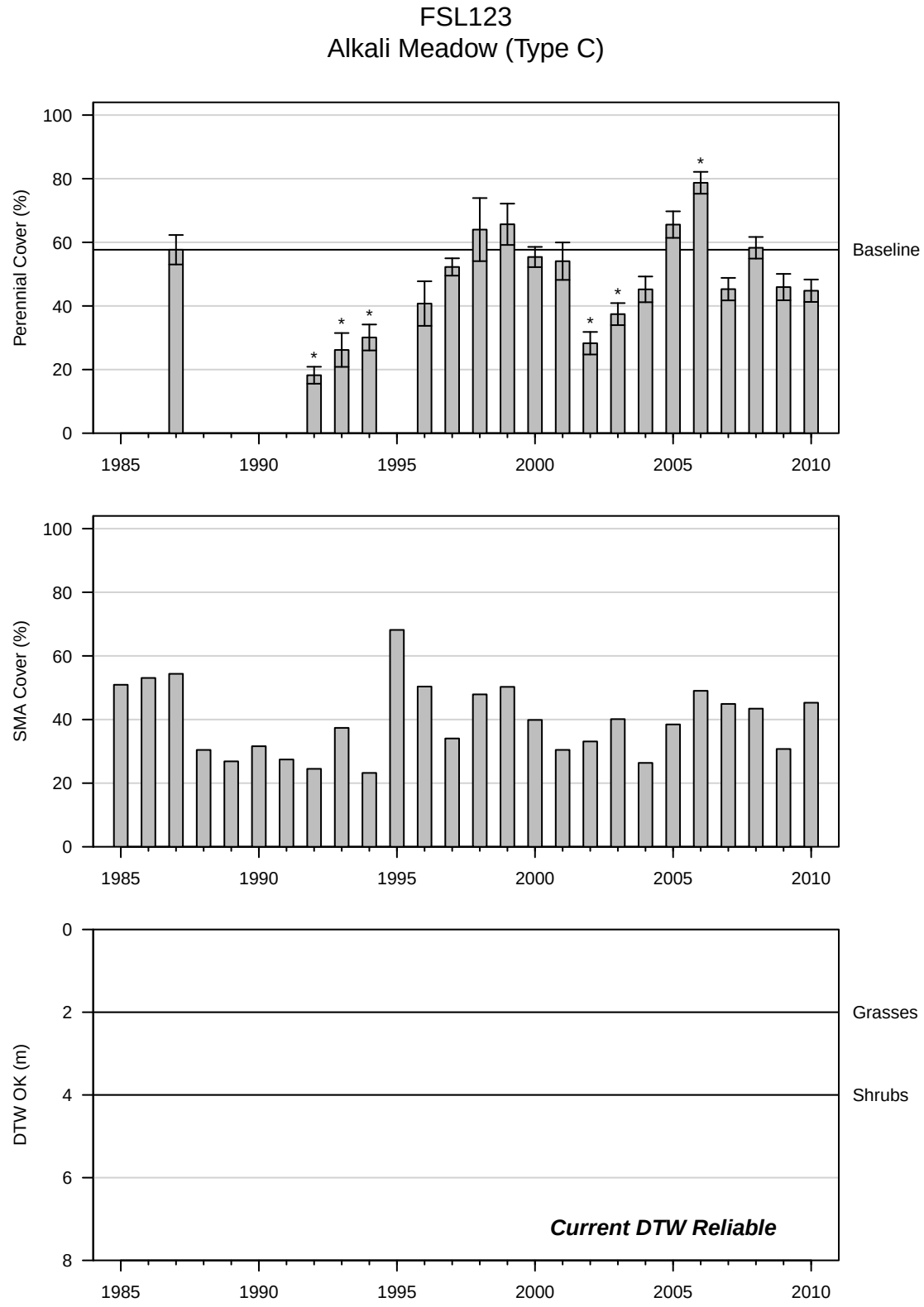


Figure 51: 2010 Wellfield

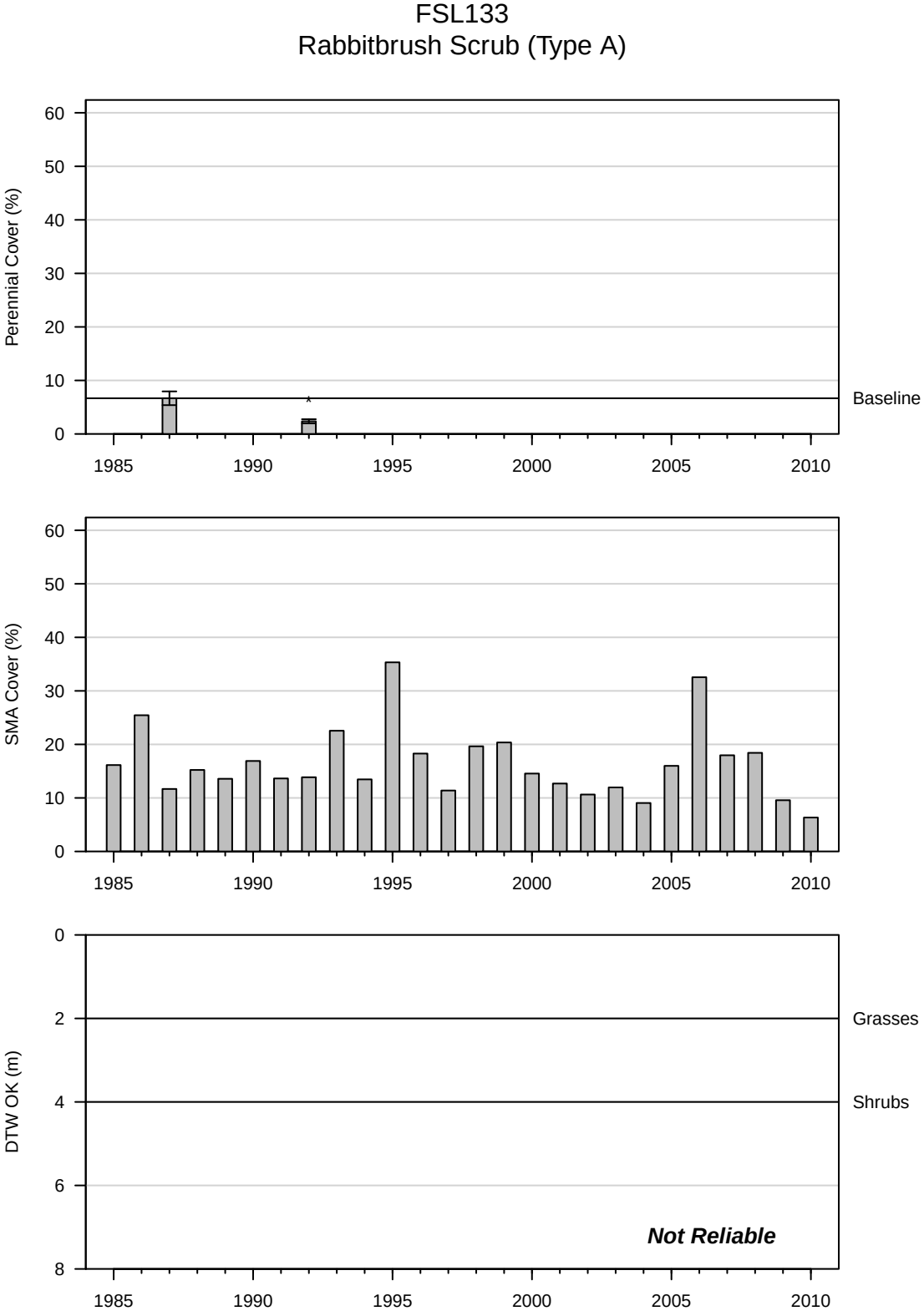


Figure 52: 1992 Wellfield

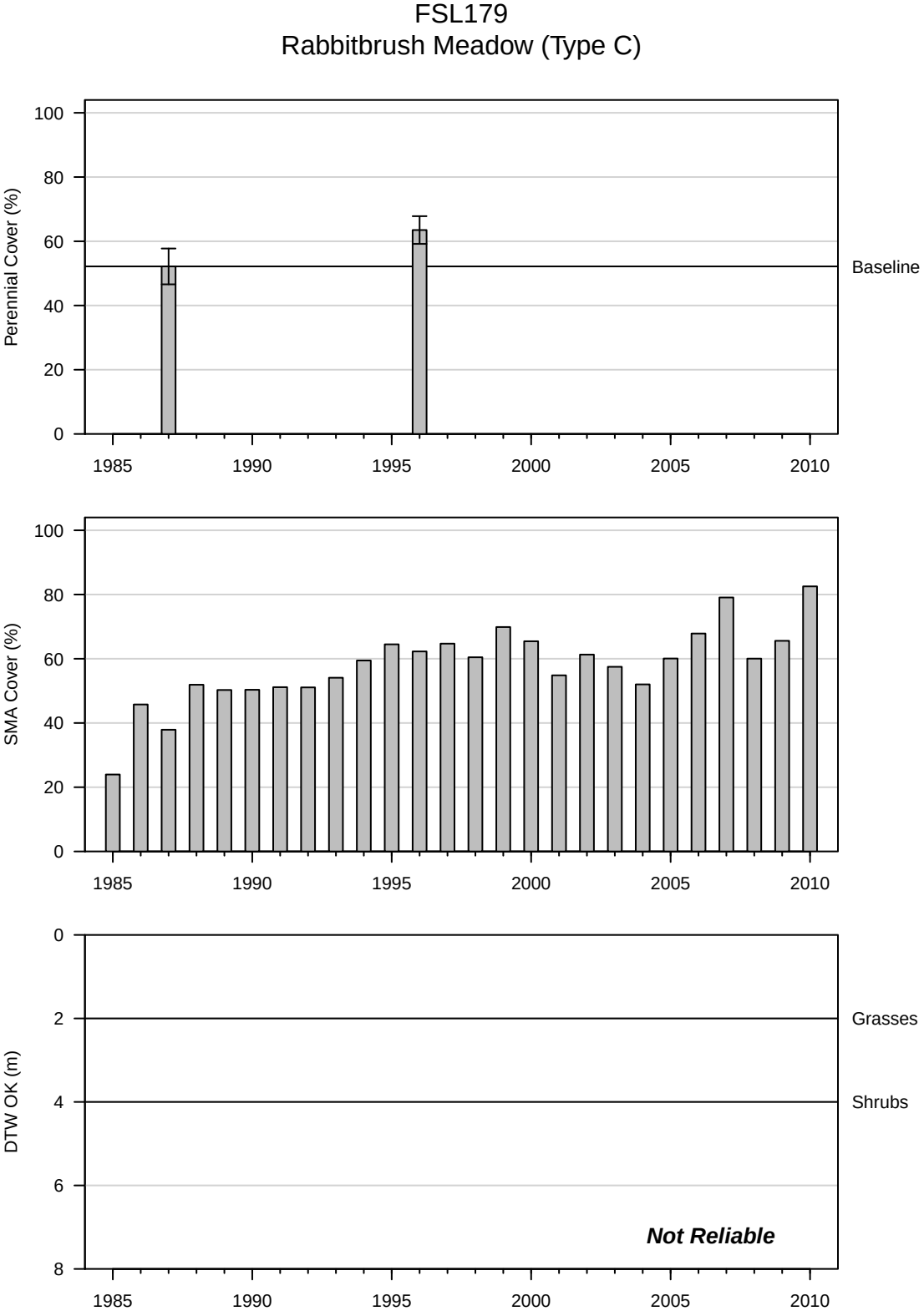


Figure 53: 1996 Control

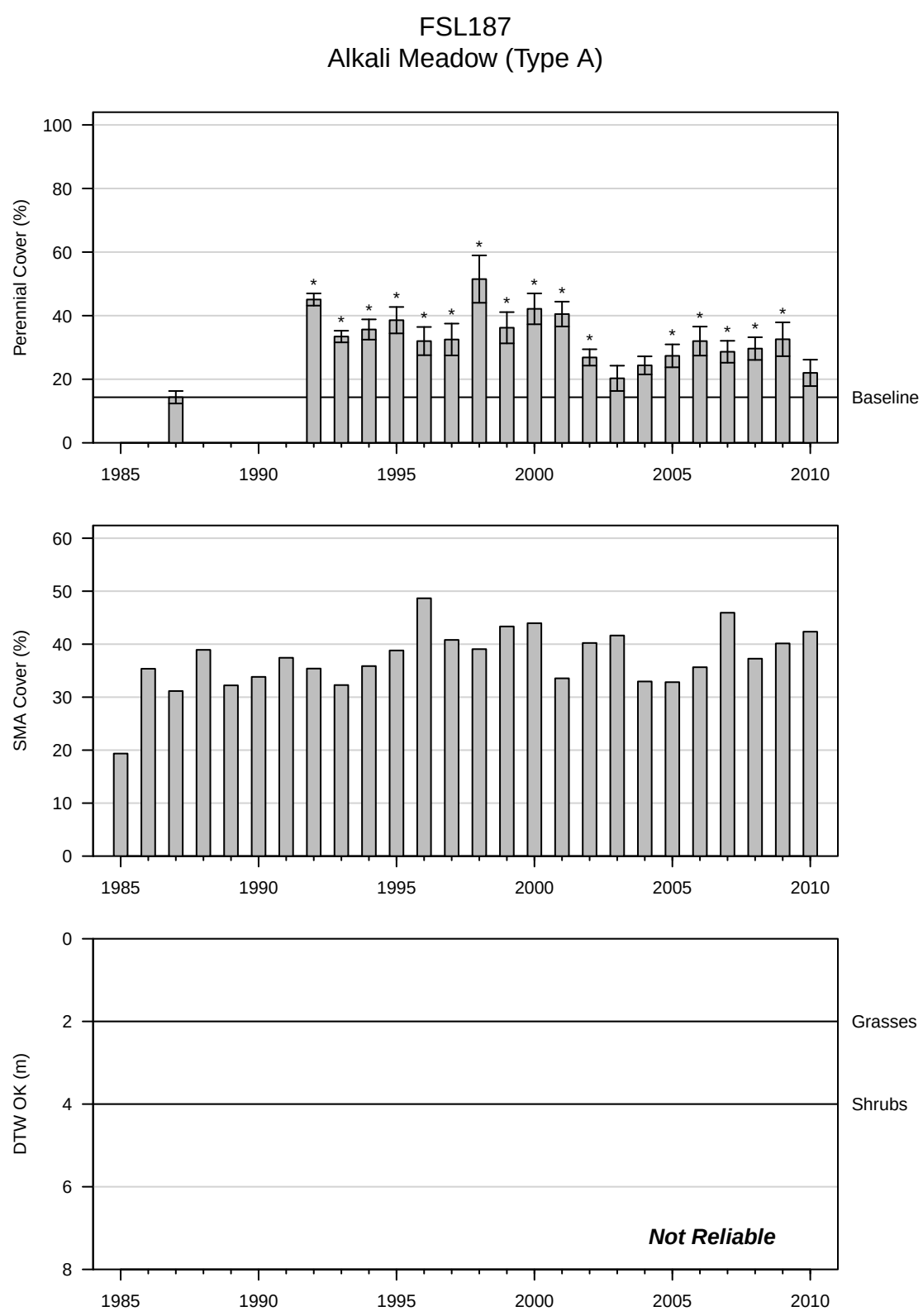
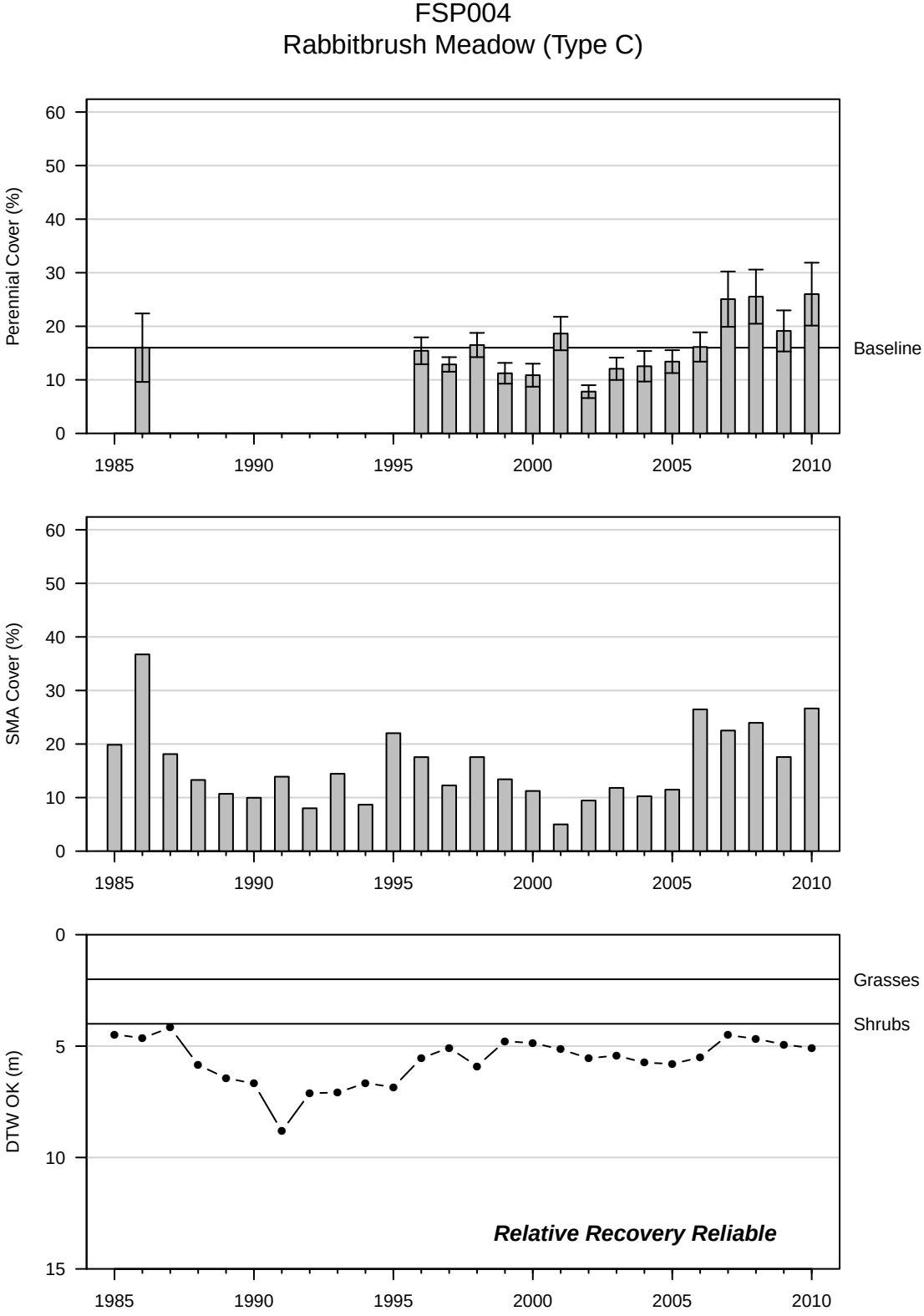


Figure 54: 2010 Control



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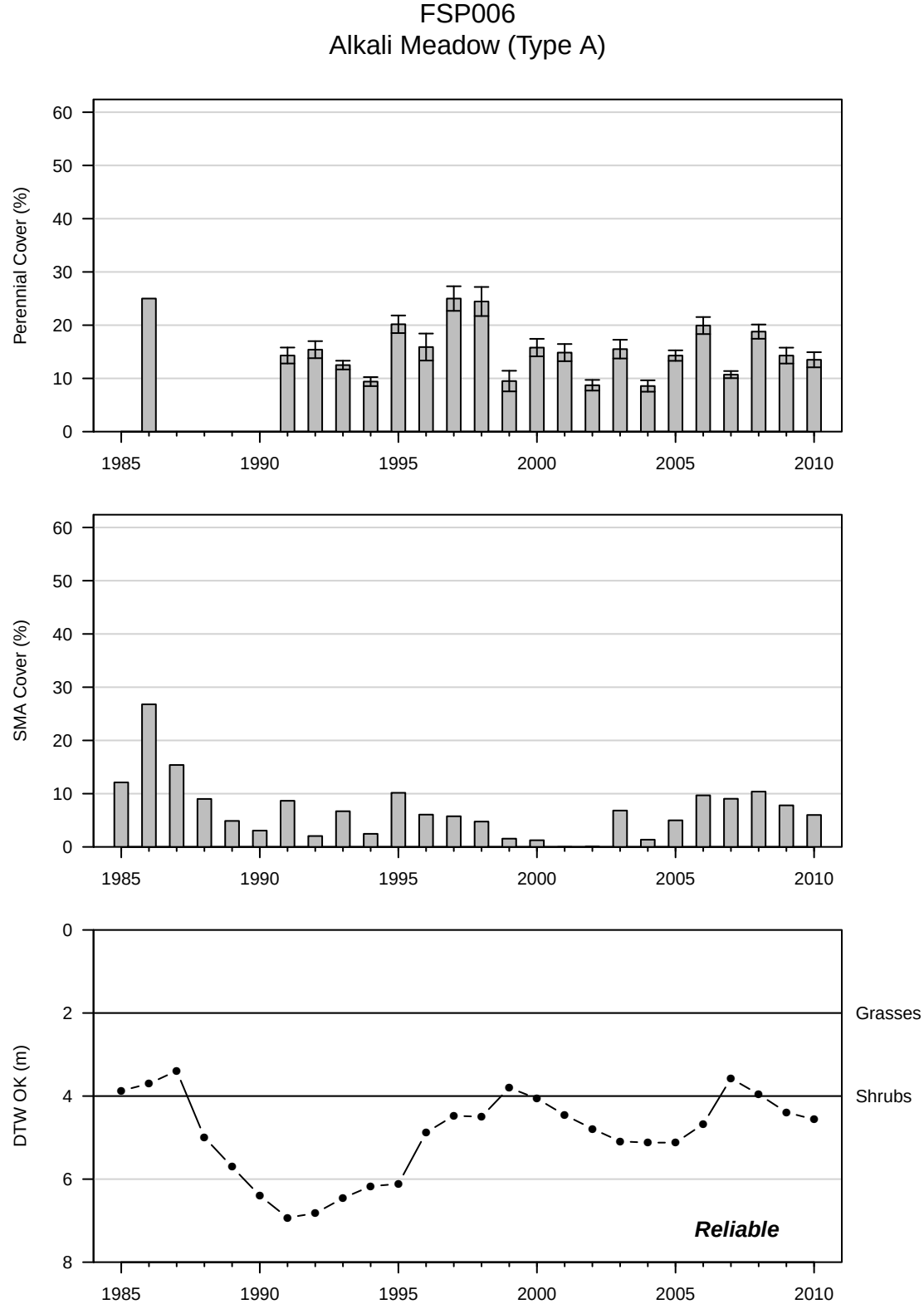


Figure 56: 2010 Wellfield

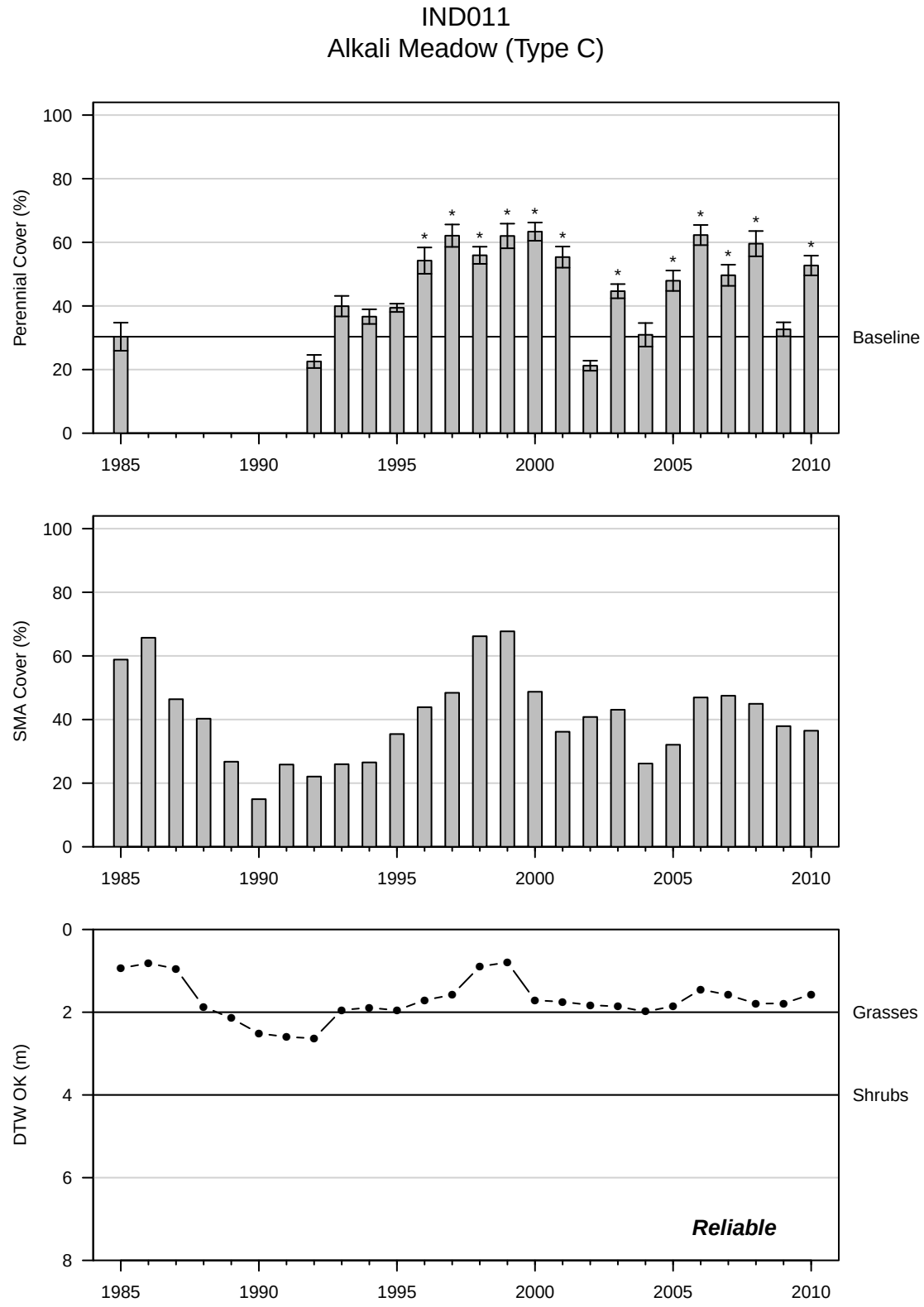
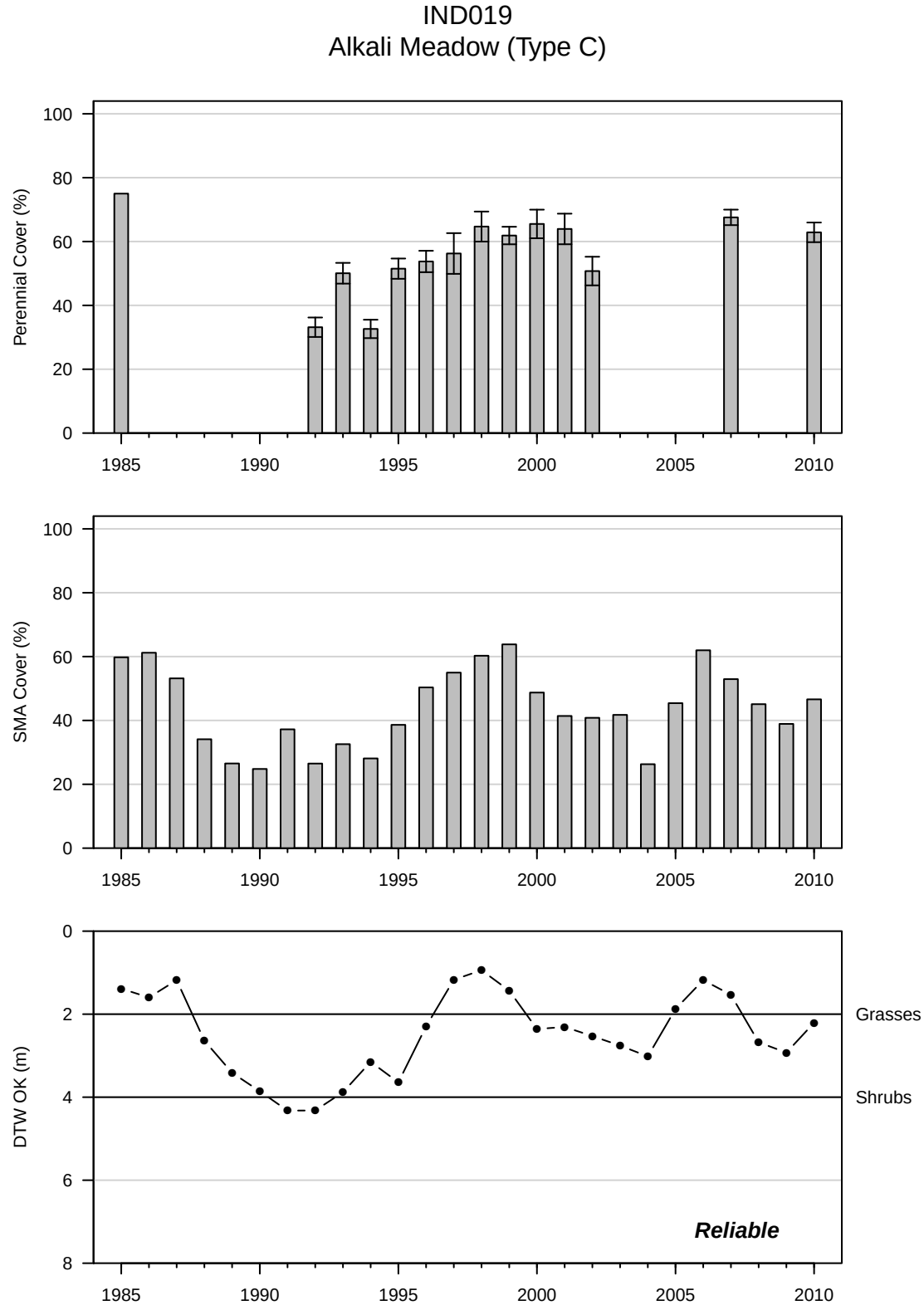


Figure 57: 2010 Wellfield



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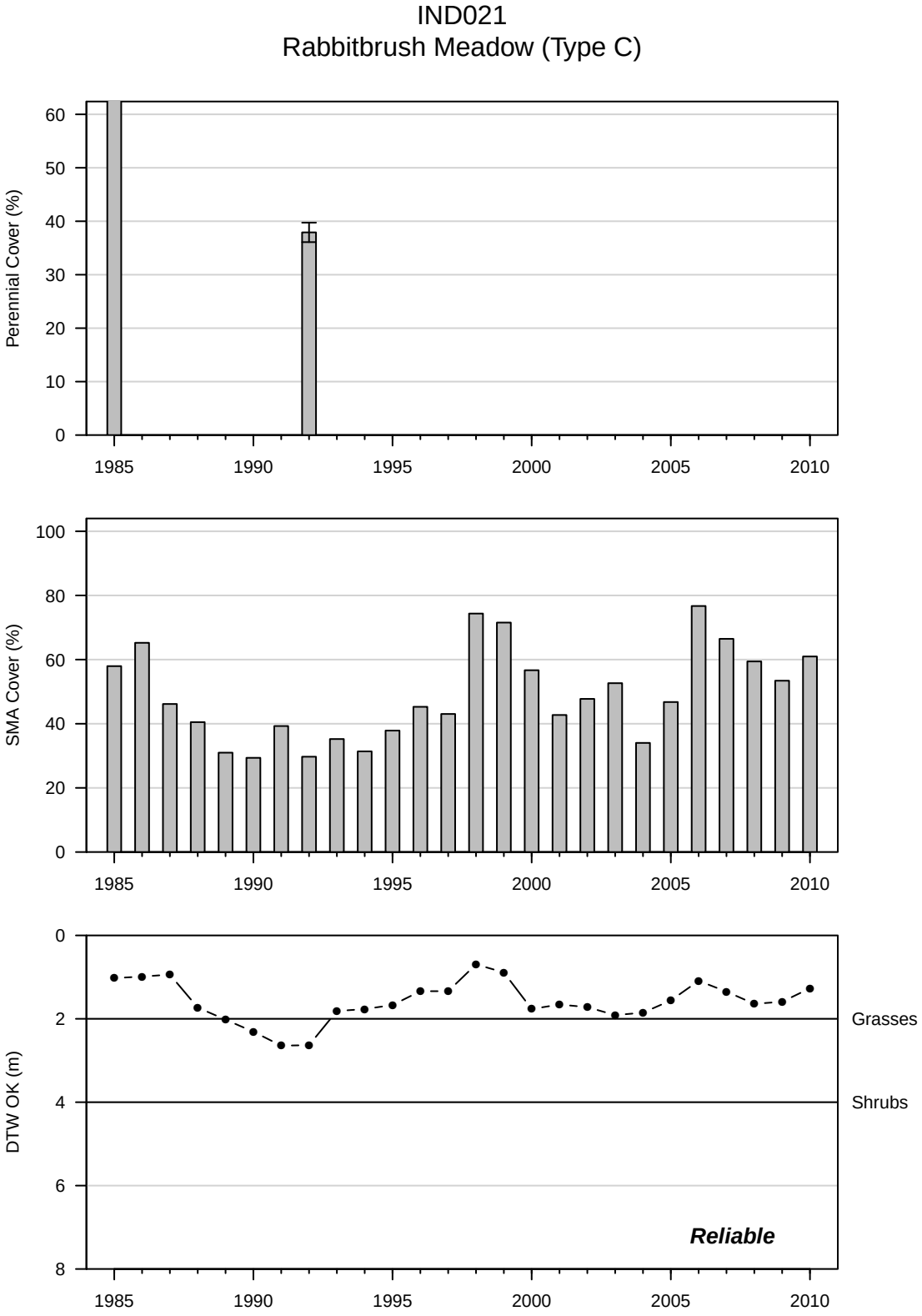
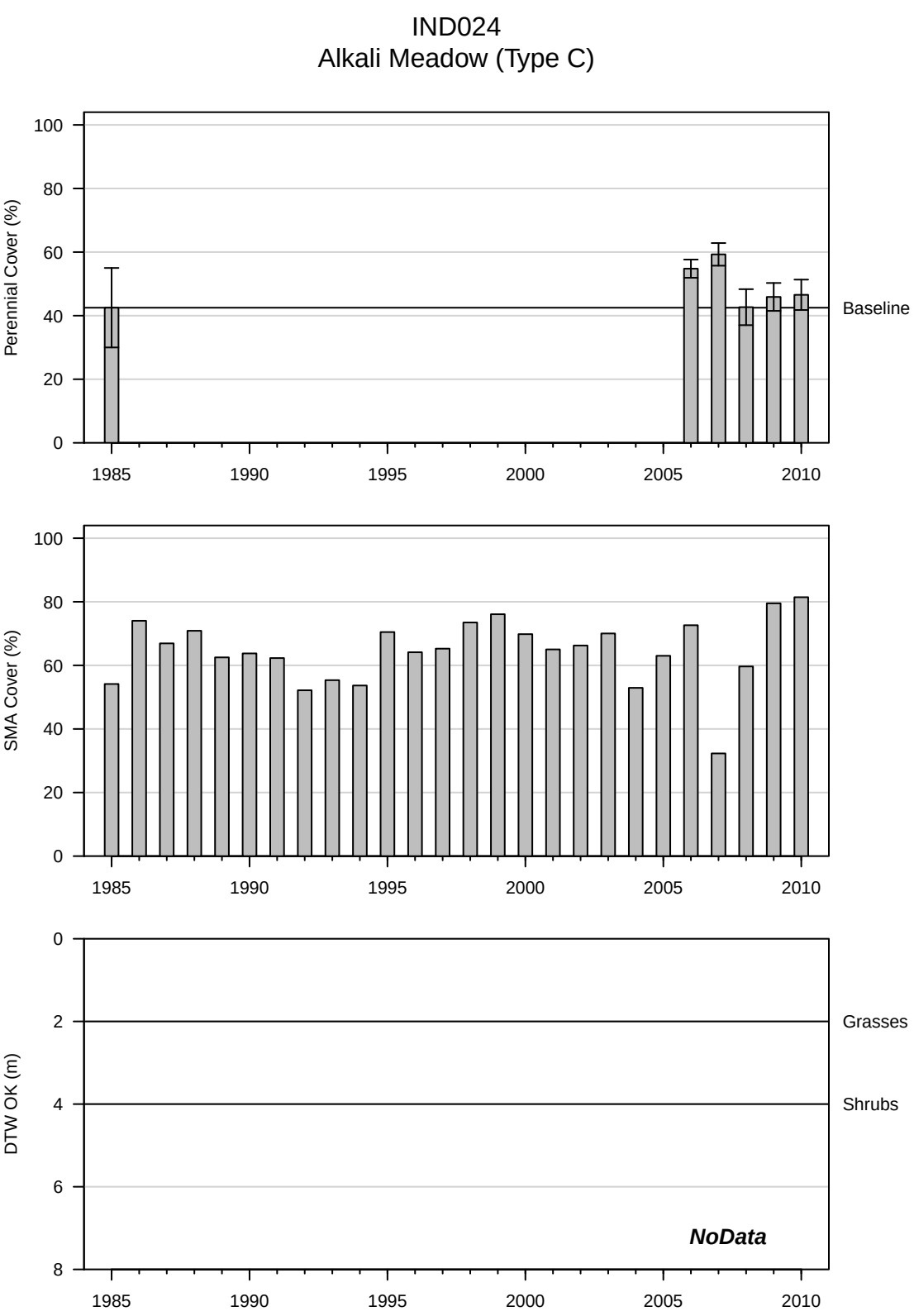


Figure 59: 1992 Wellfield



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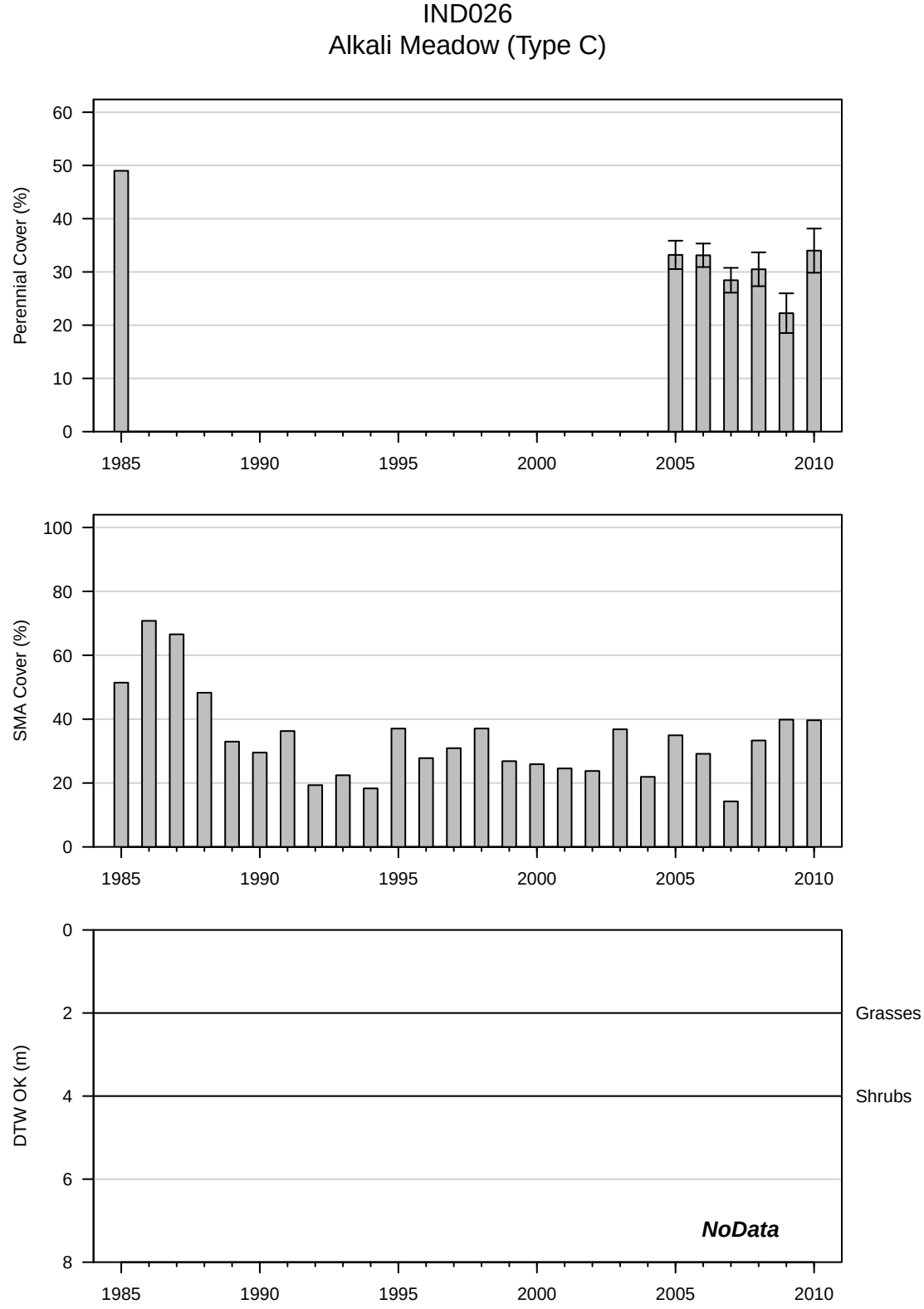


Figure 61: 2010 Wellfield

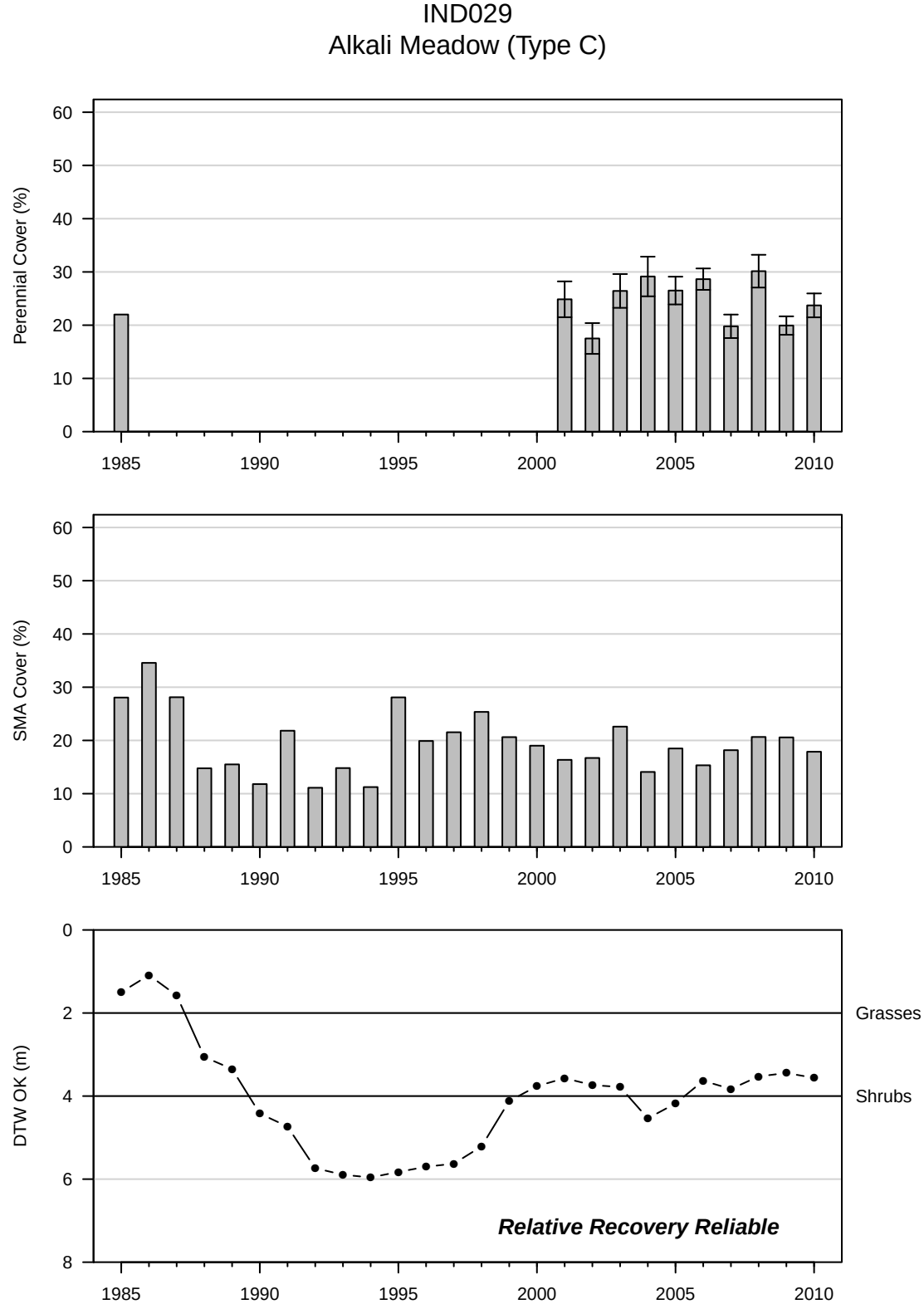


Figure 62: 2010 Wellfield

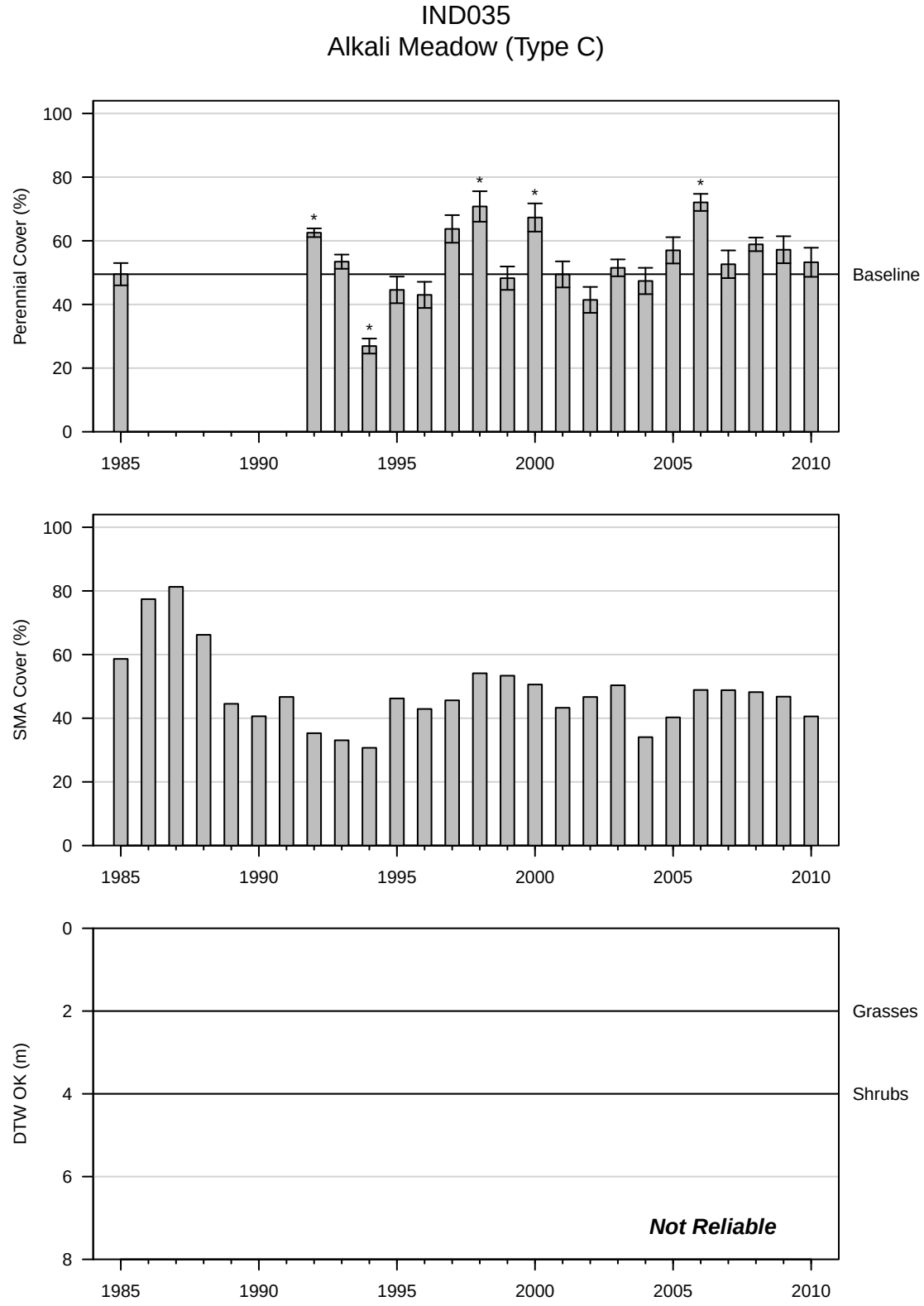


Figure 63: 2010 Wellfield

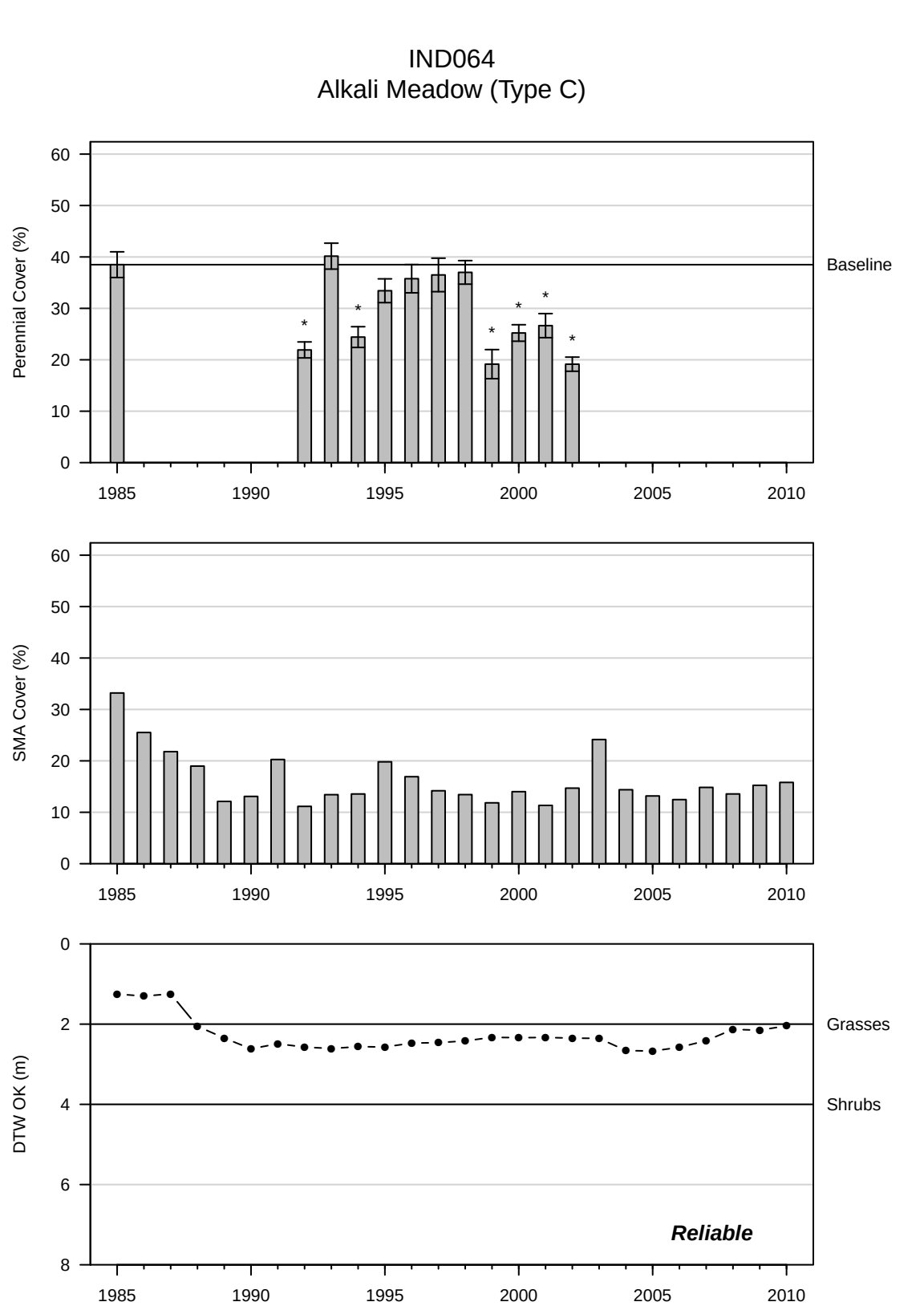


Figure 64: 2002 Control

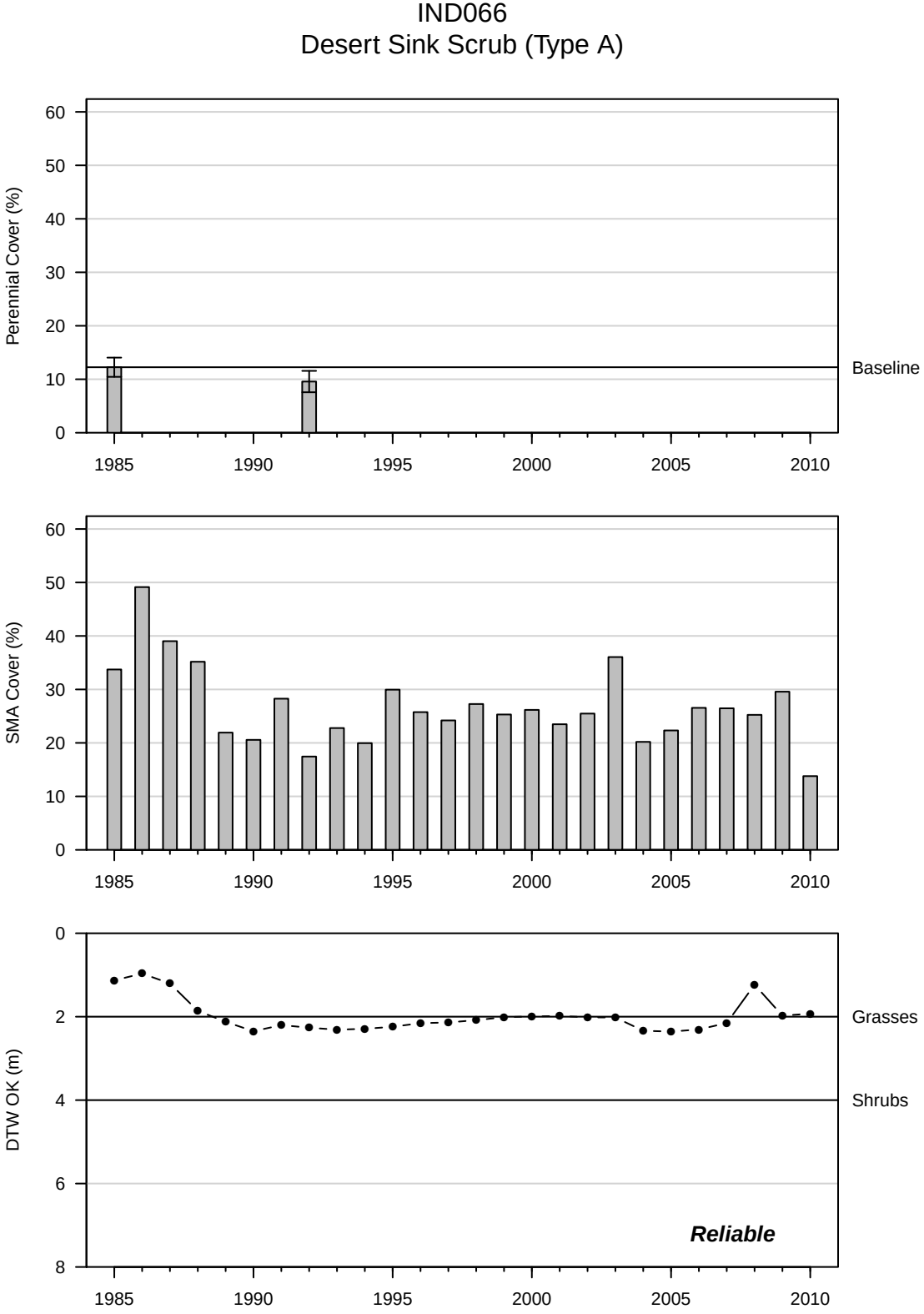


Figure 65: 1992 Control

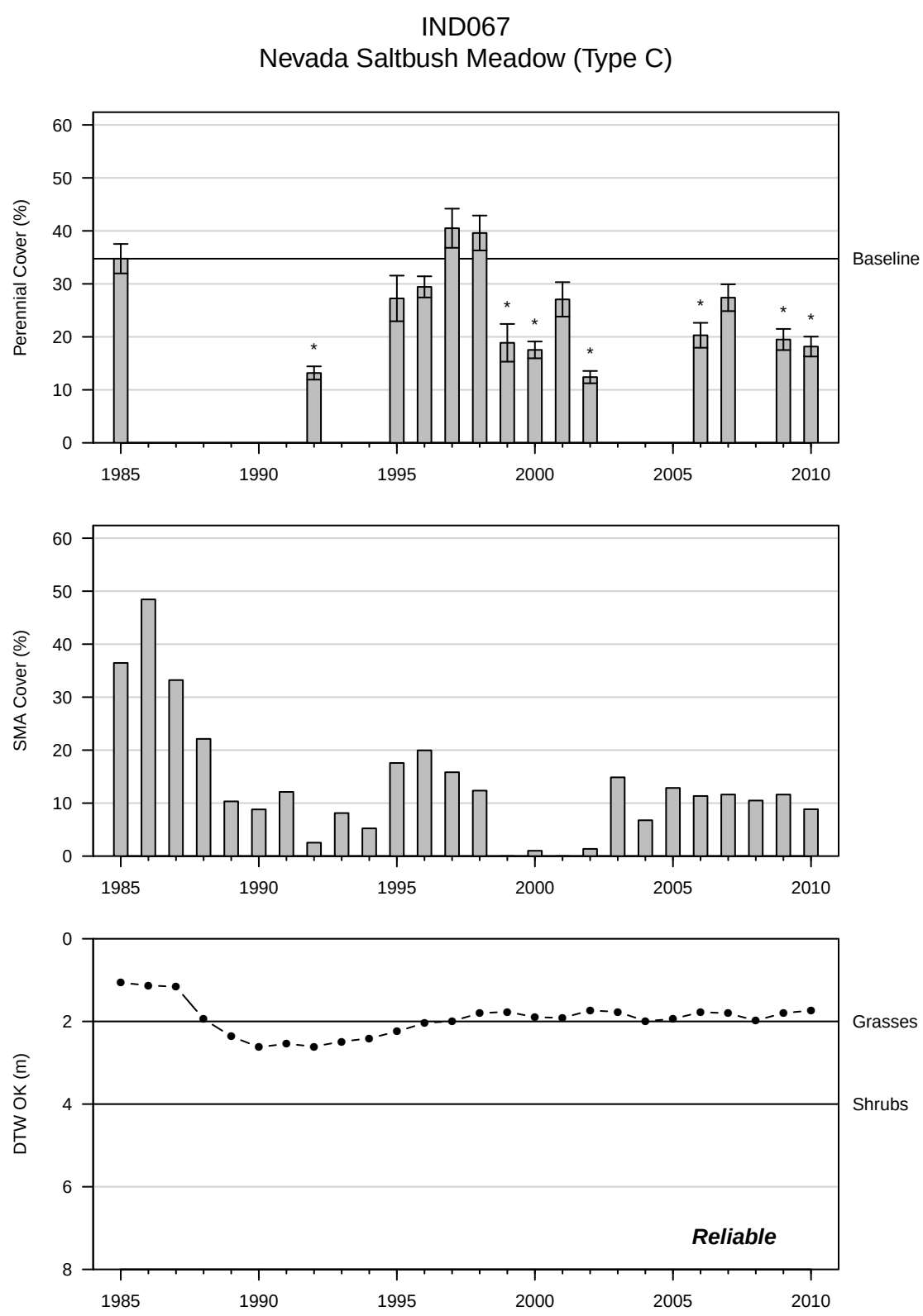


Figure 66: 2010 Control

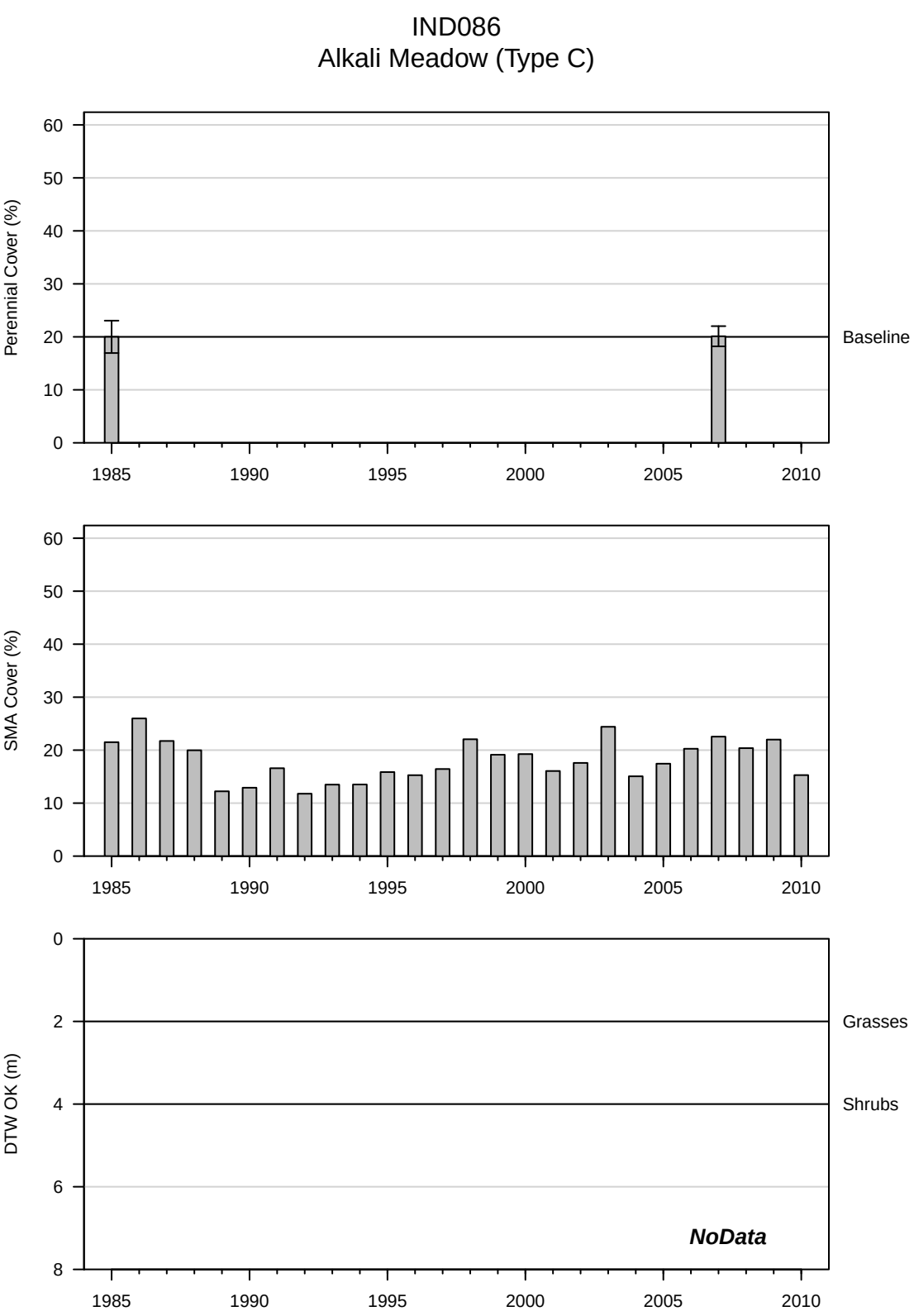


Figure 67: 2007 Control

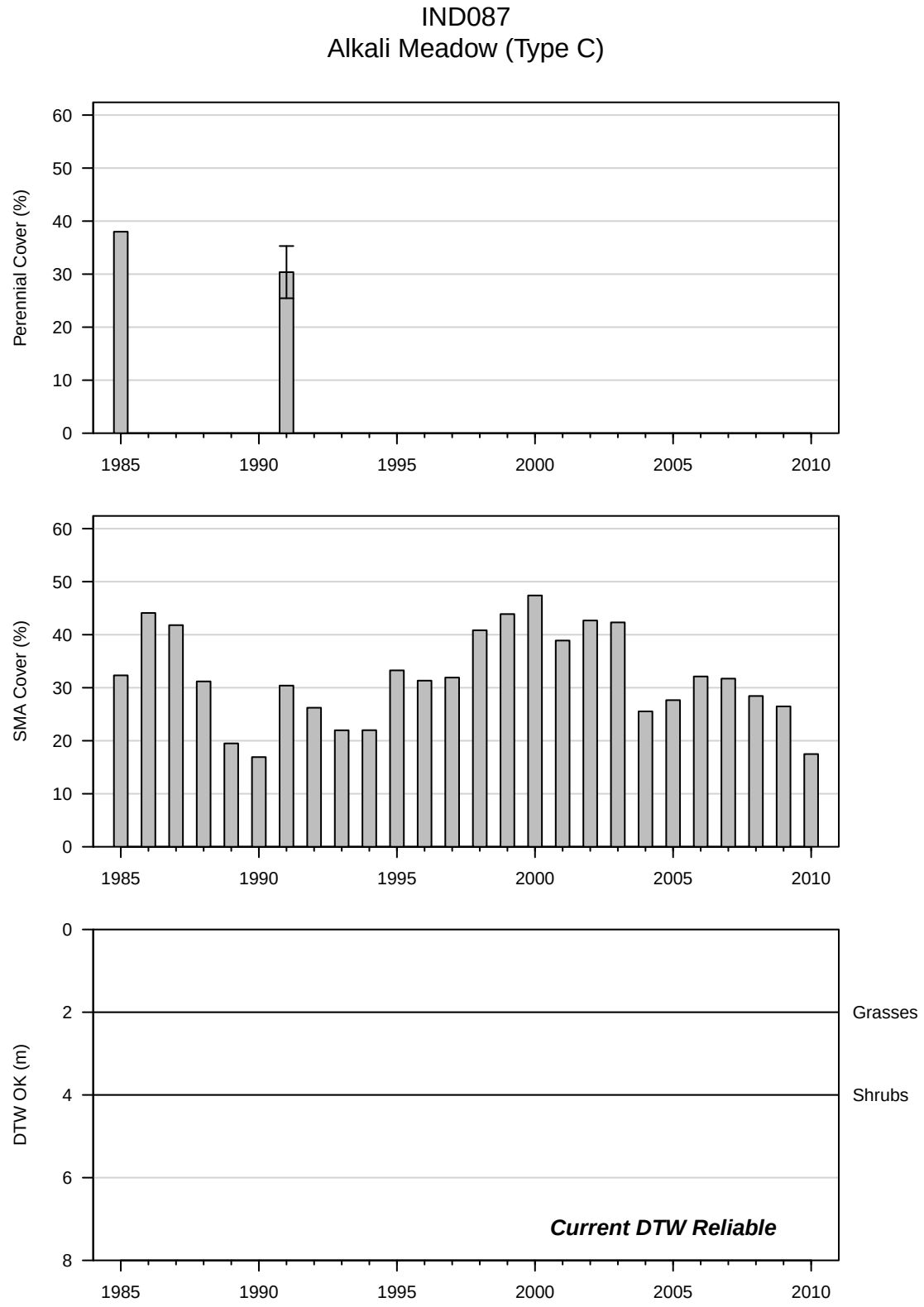


Figure 68: 1991 Control

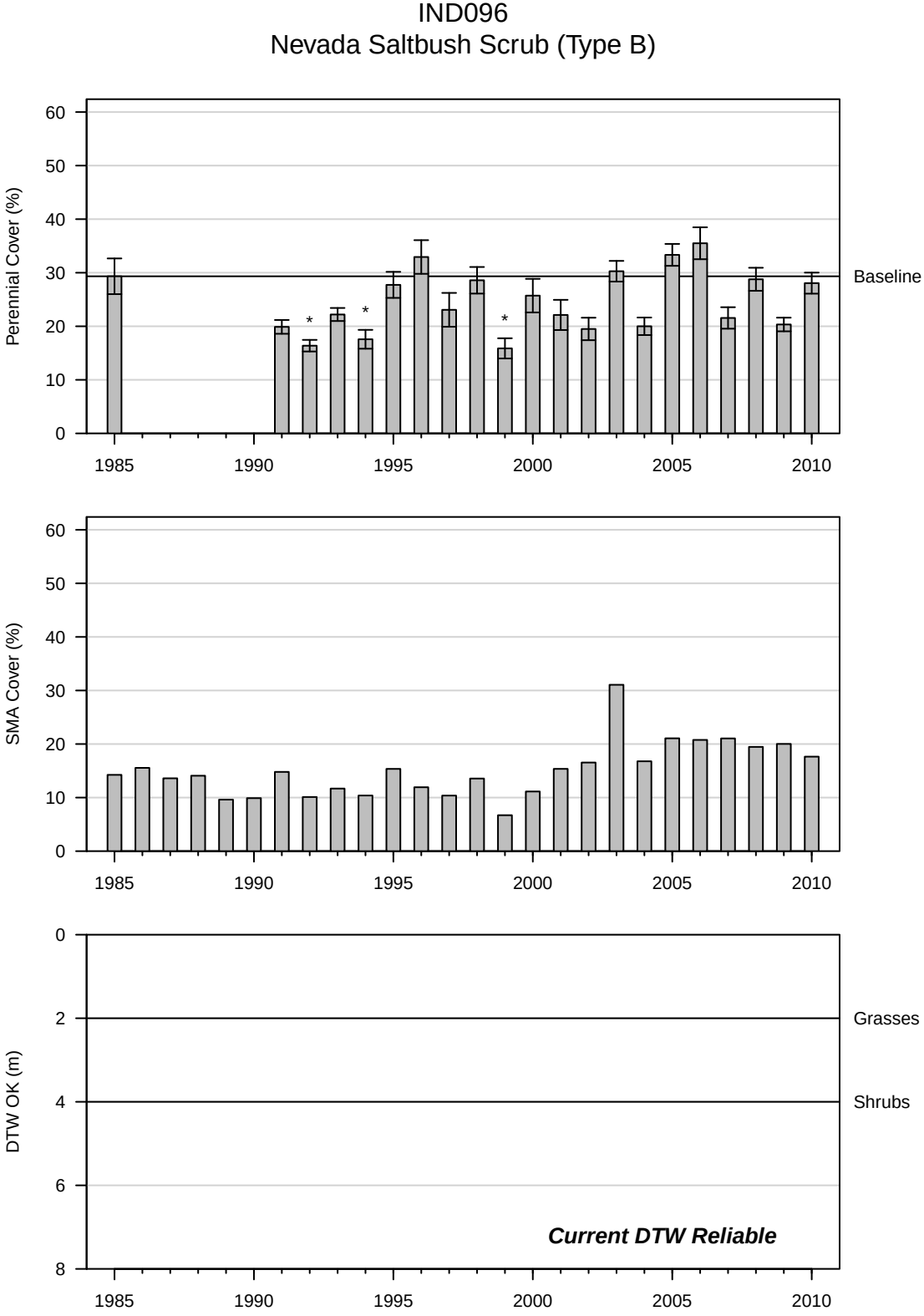


Figure 69: 2010 Control

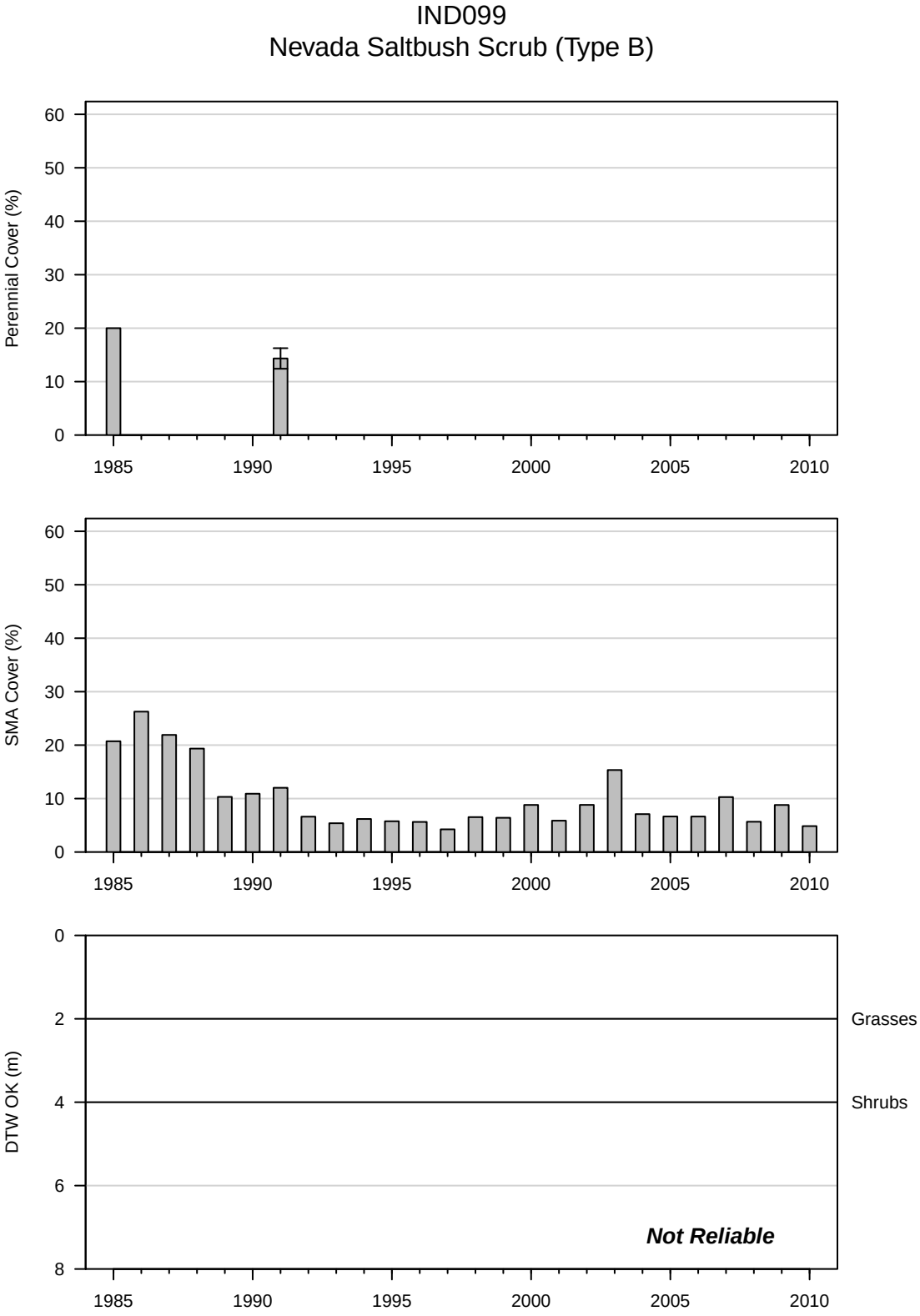


Figure 70: 1991 Control

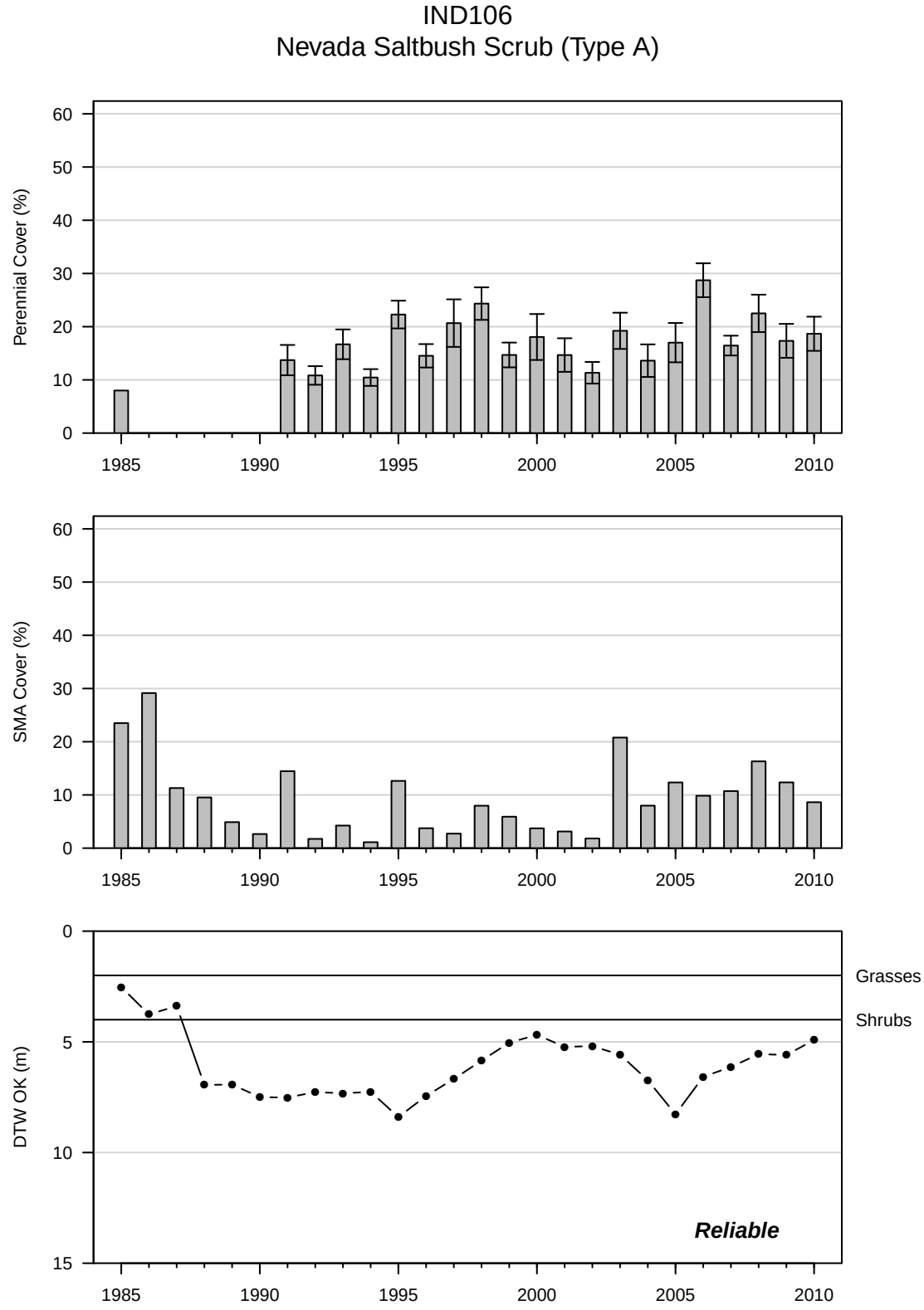


Figure 71: 2010 Wellfield

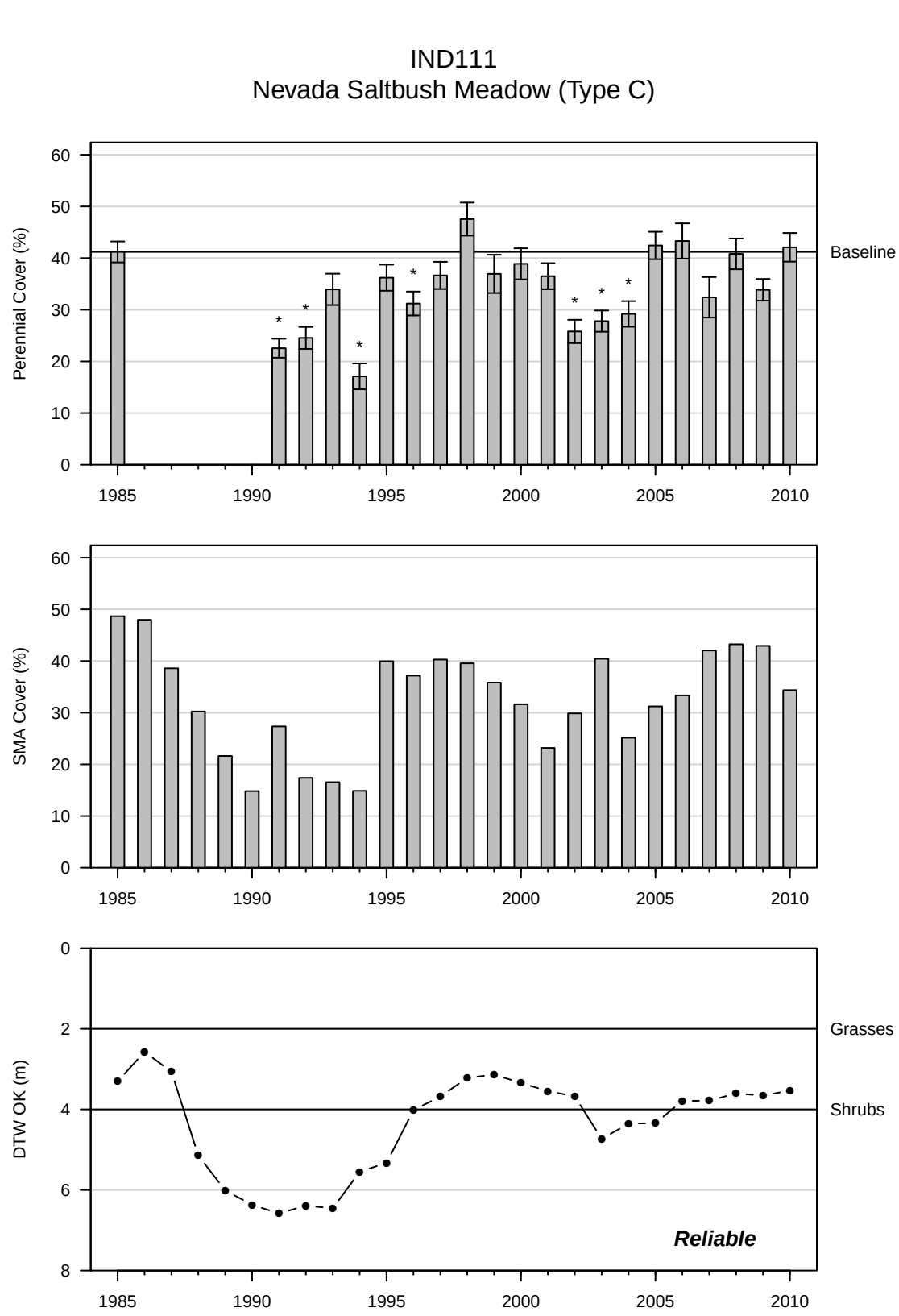


Figure 72: 2010 Wellfield

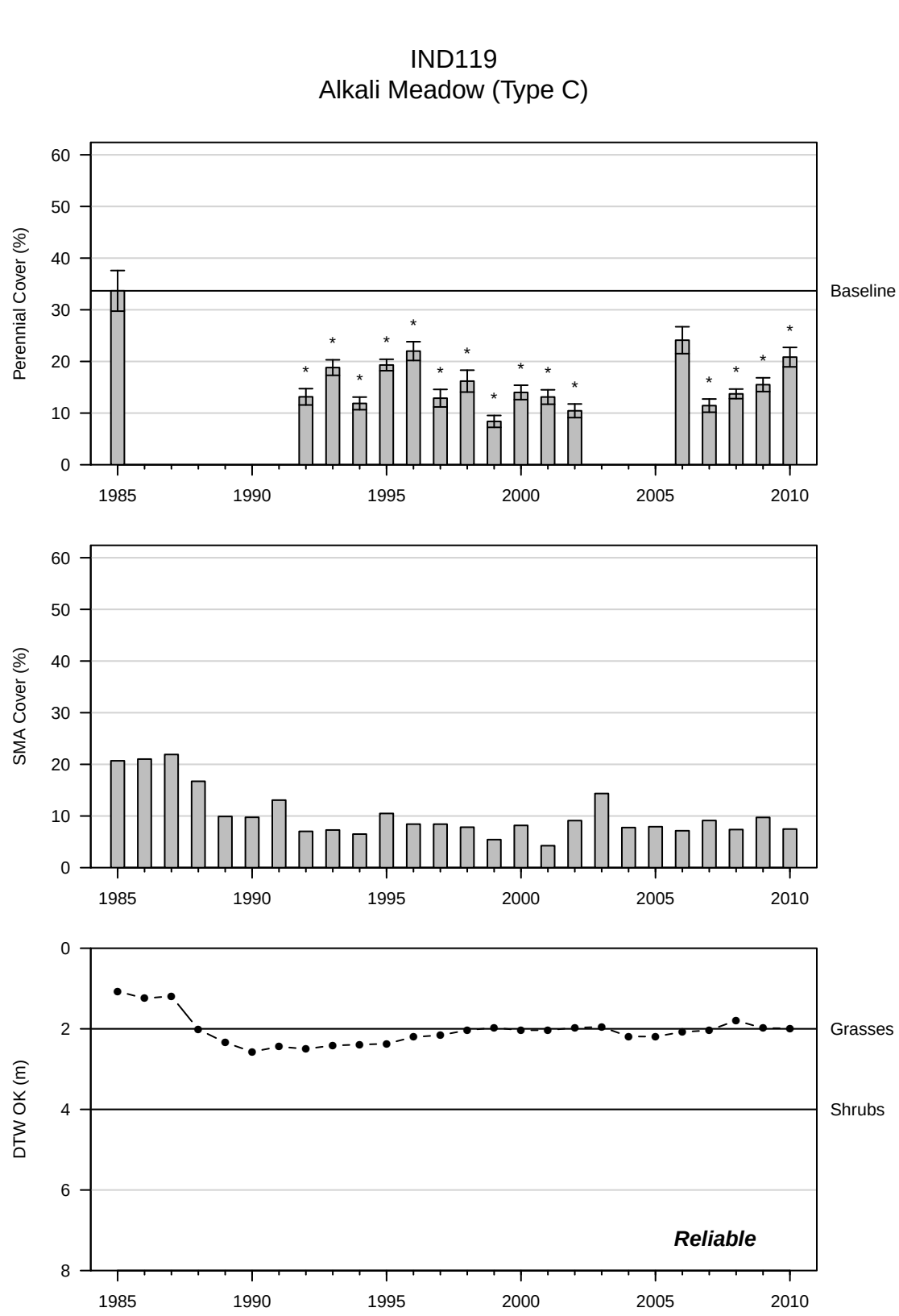


Figure 73: 2010 Control

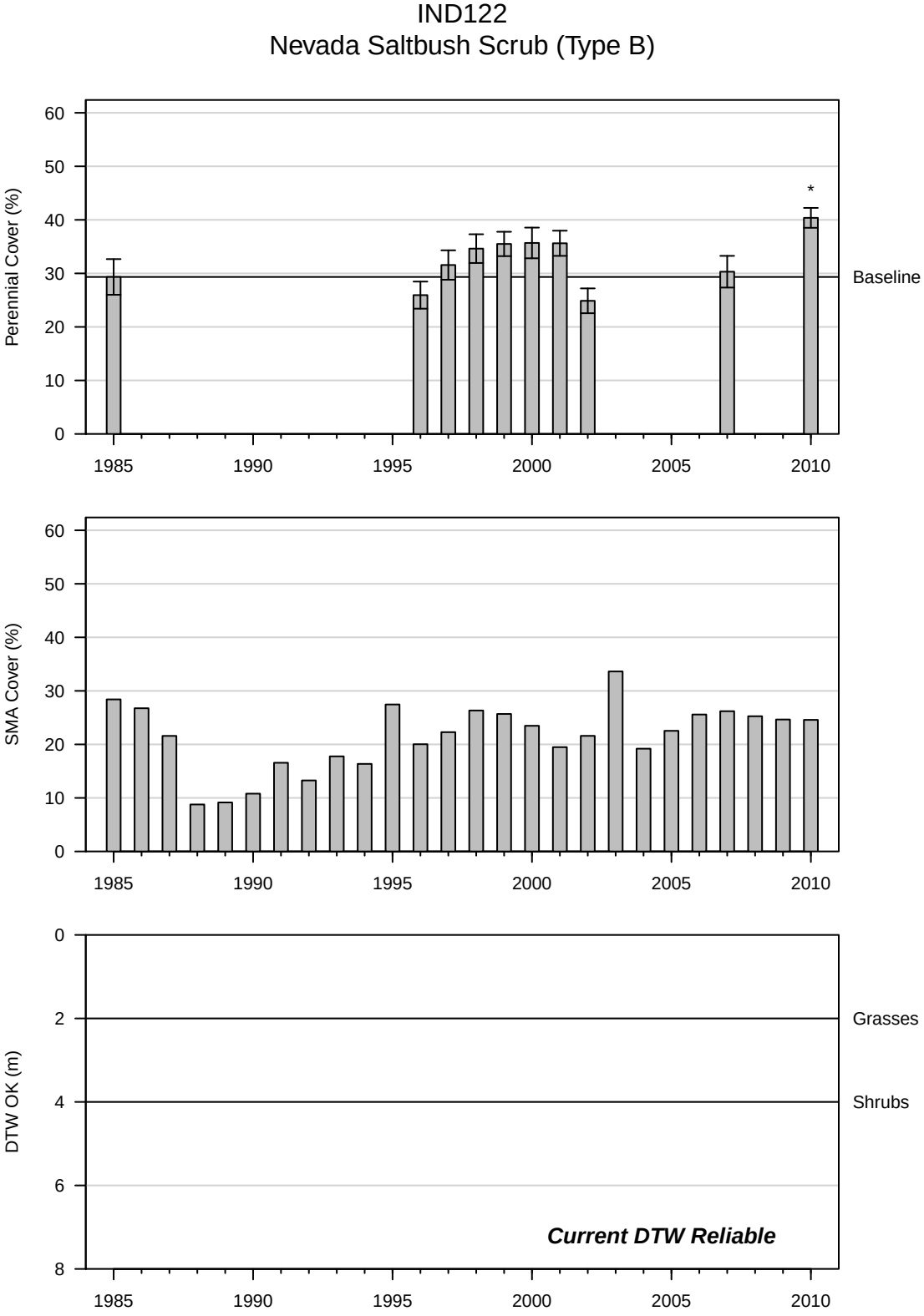


Figure 74: 2010 Control

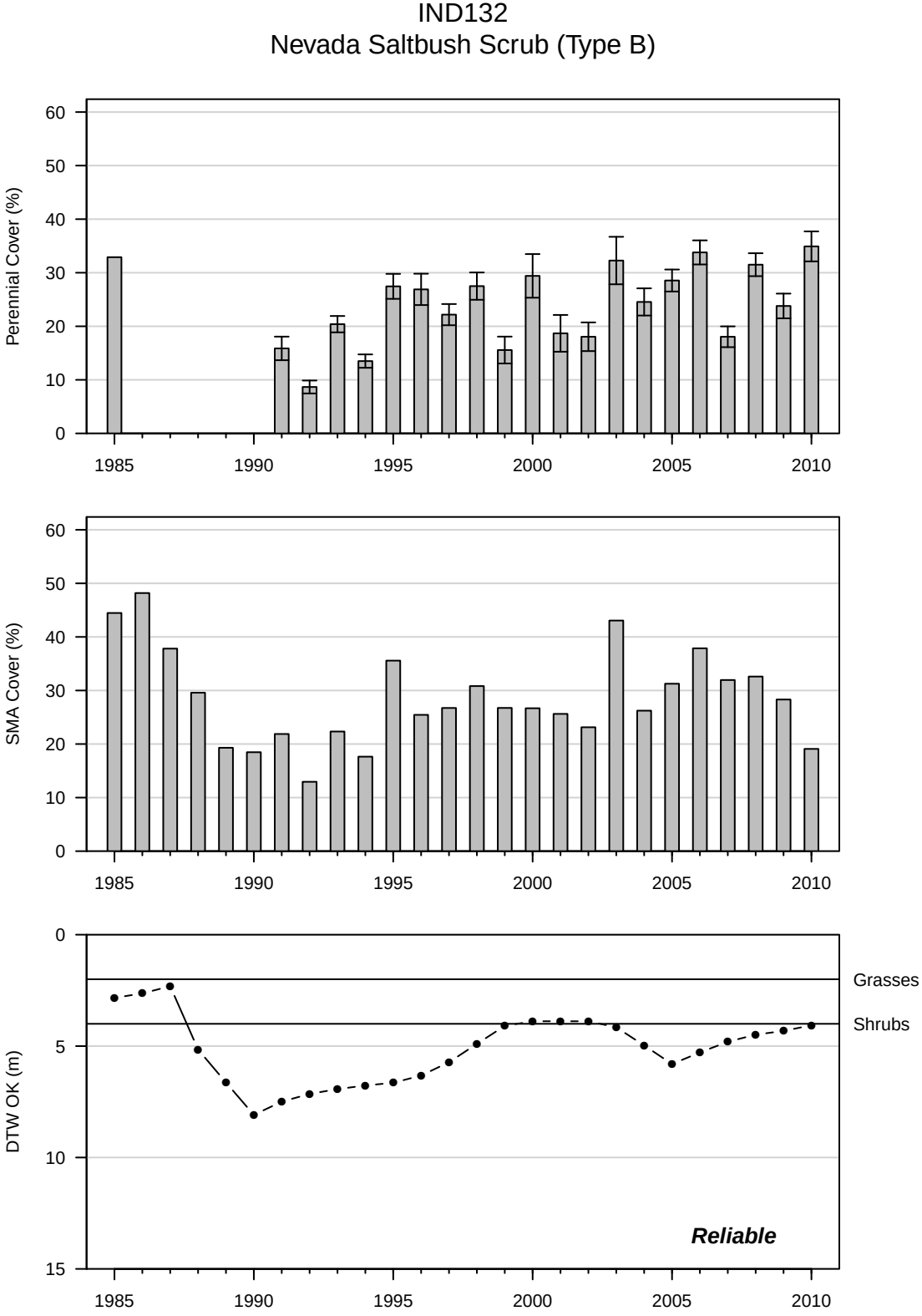


Figure 75: 2010 Wellfield

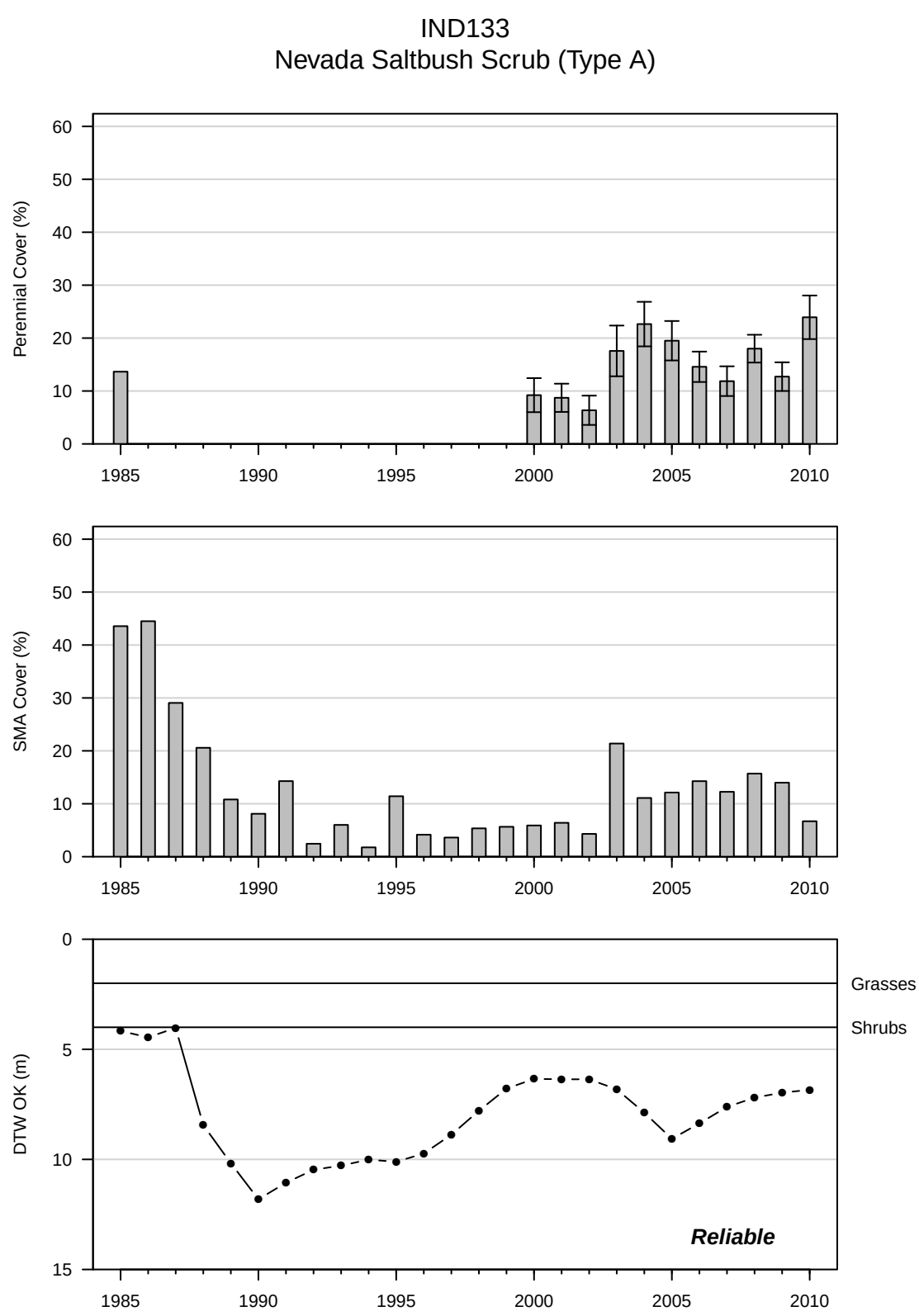


Figure 76: 2010 Wellfield

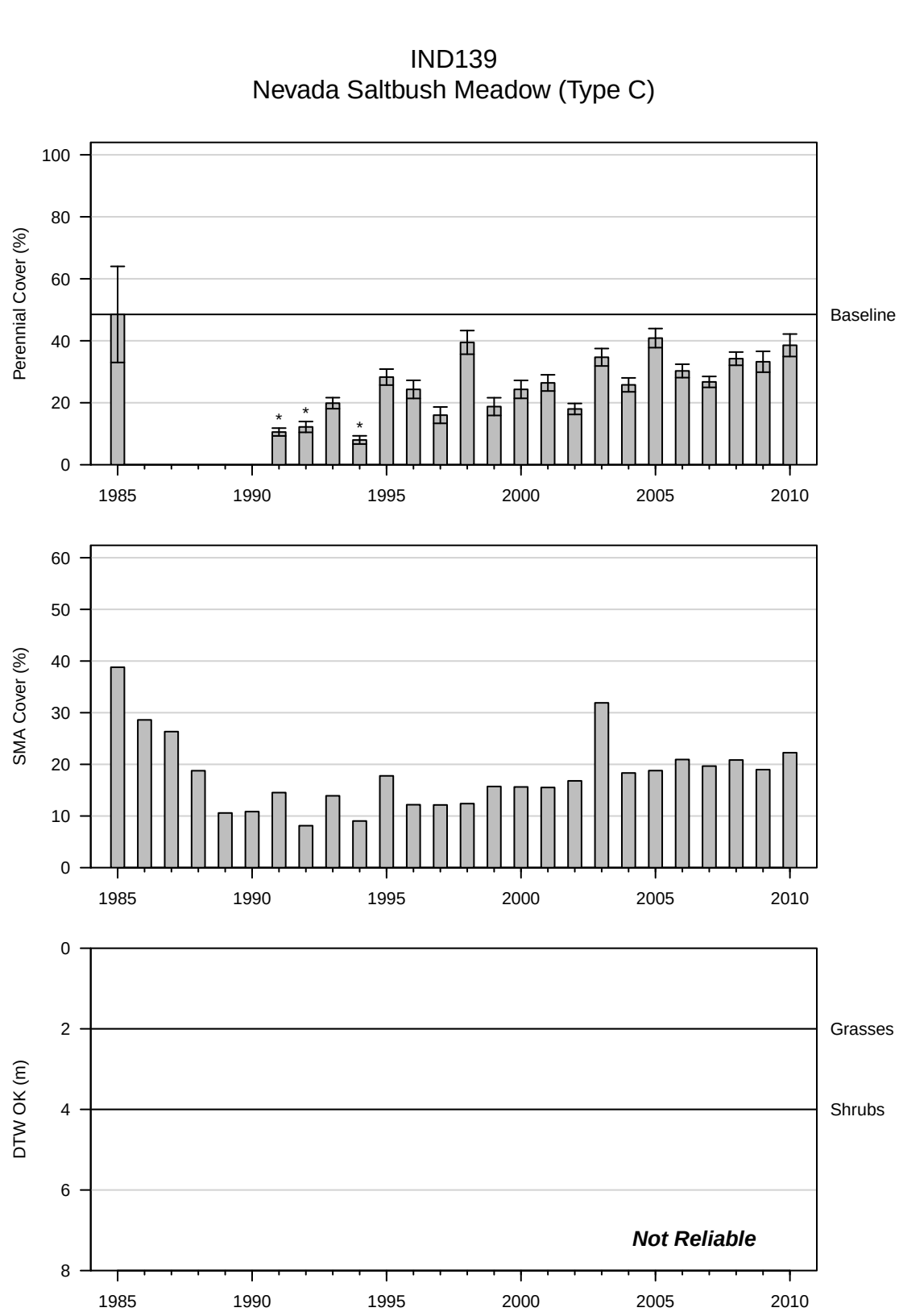


Figure 77: 2010 Wellfield

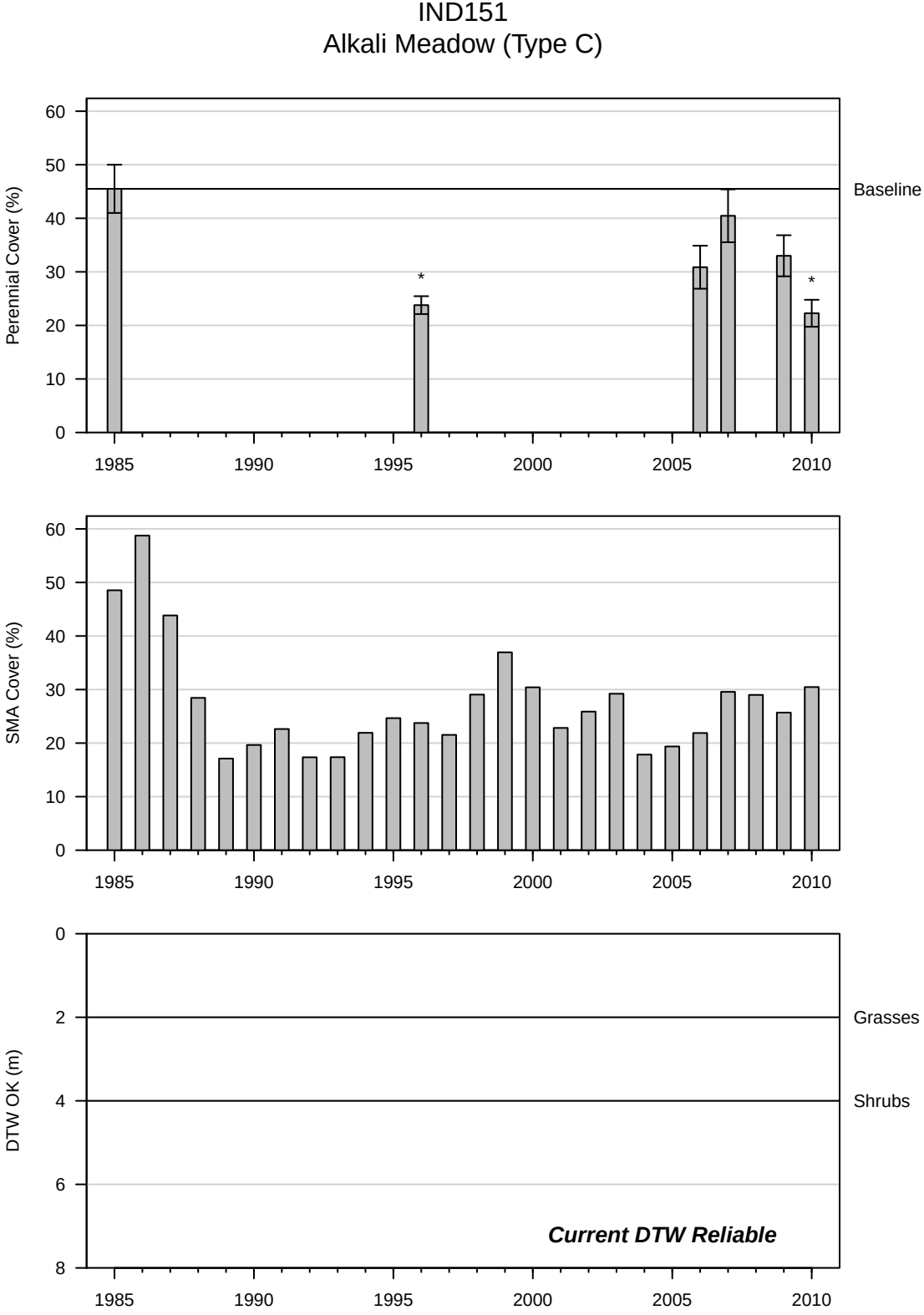


Figure 78: 2010 Control

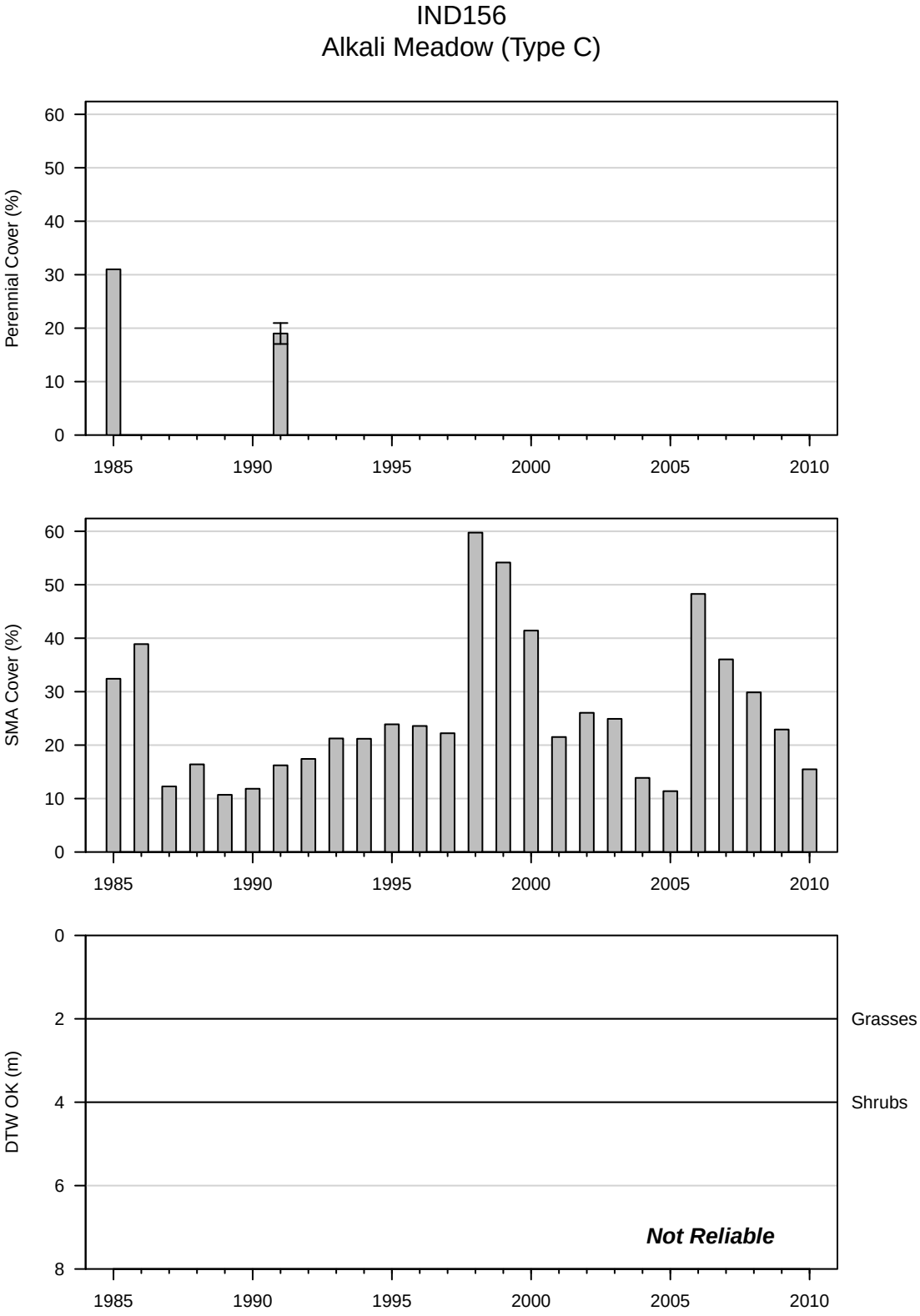


Figure 79: 1991 Control

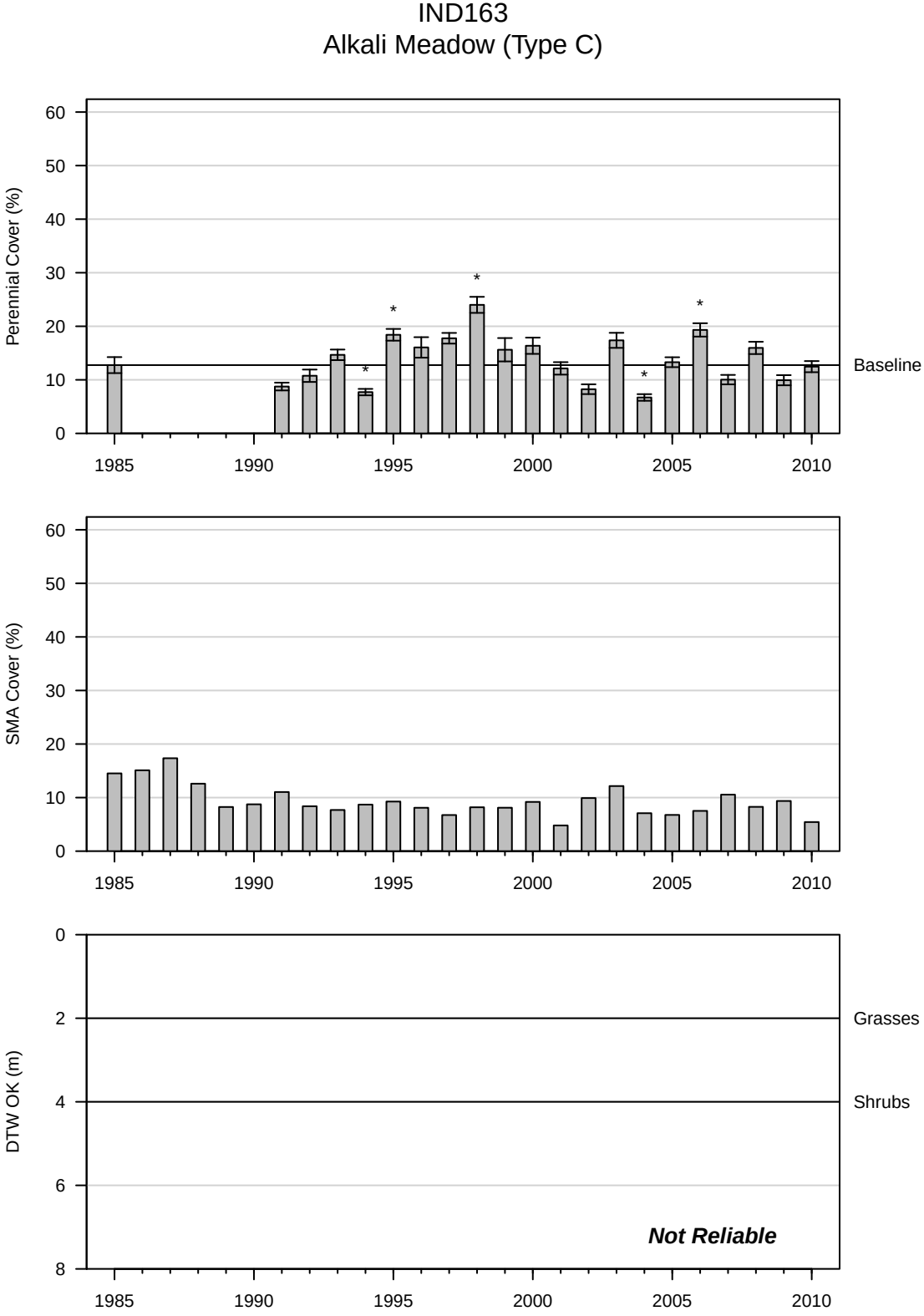


Figure 80: 2010 Control

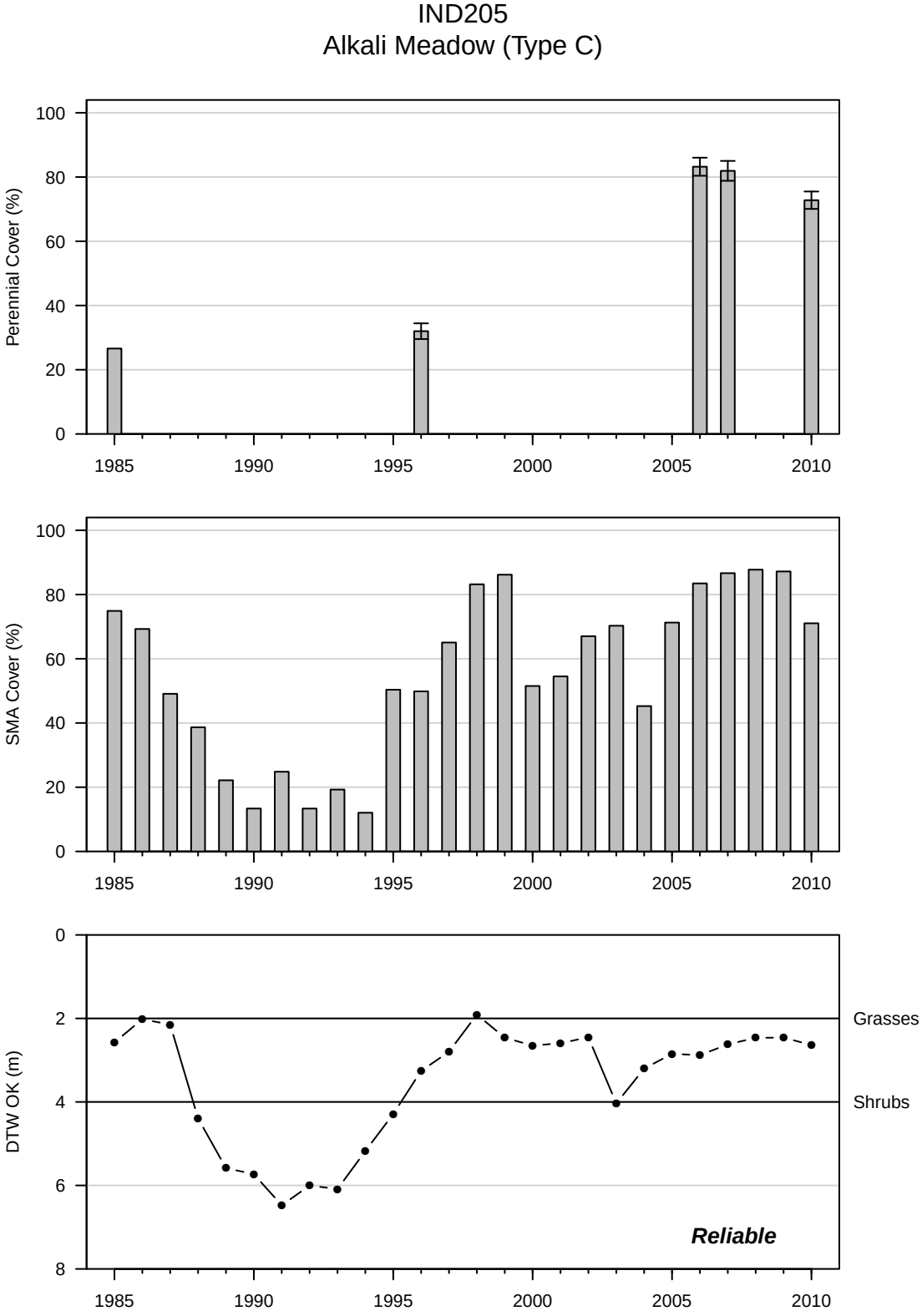


Figure 81: 2010 Wellfield

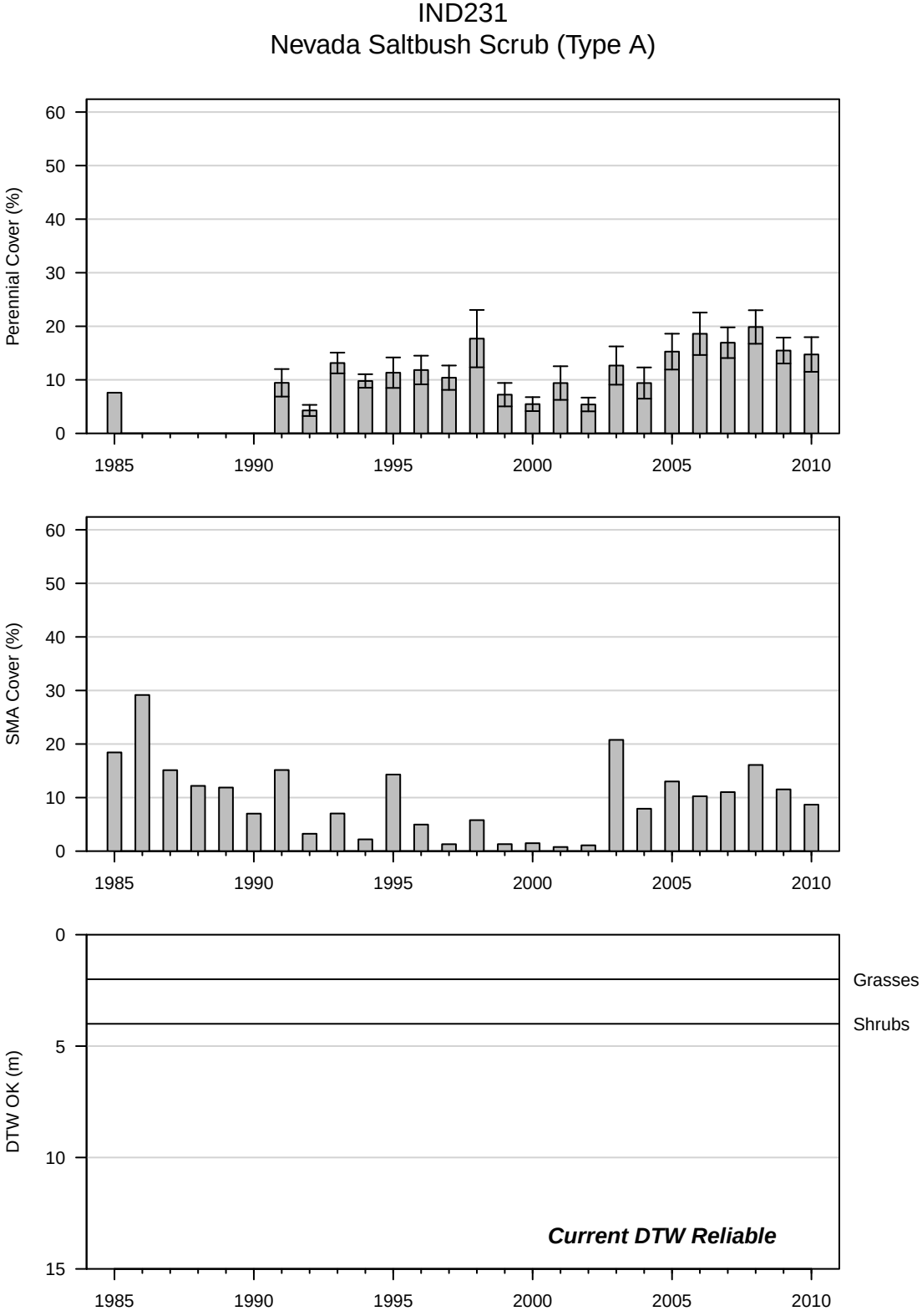


Figure 82: 2010 Wellfield

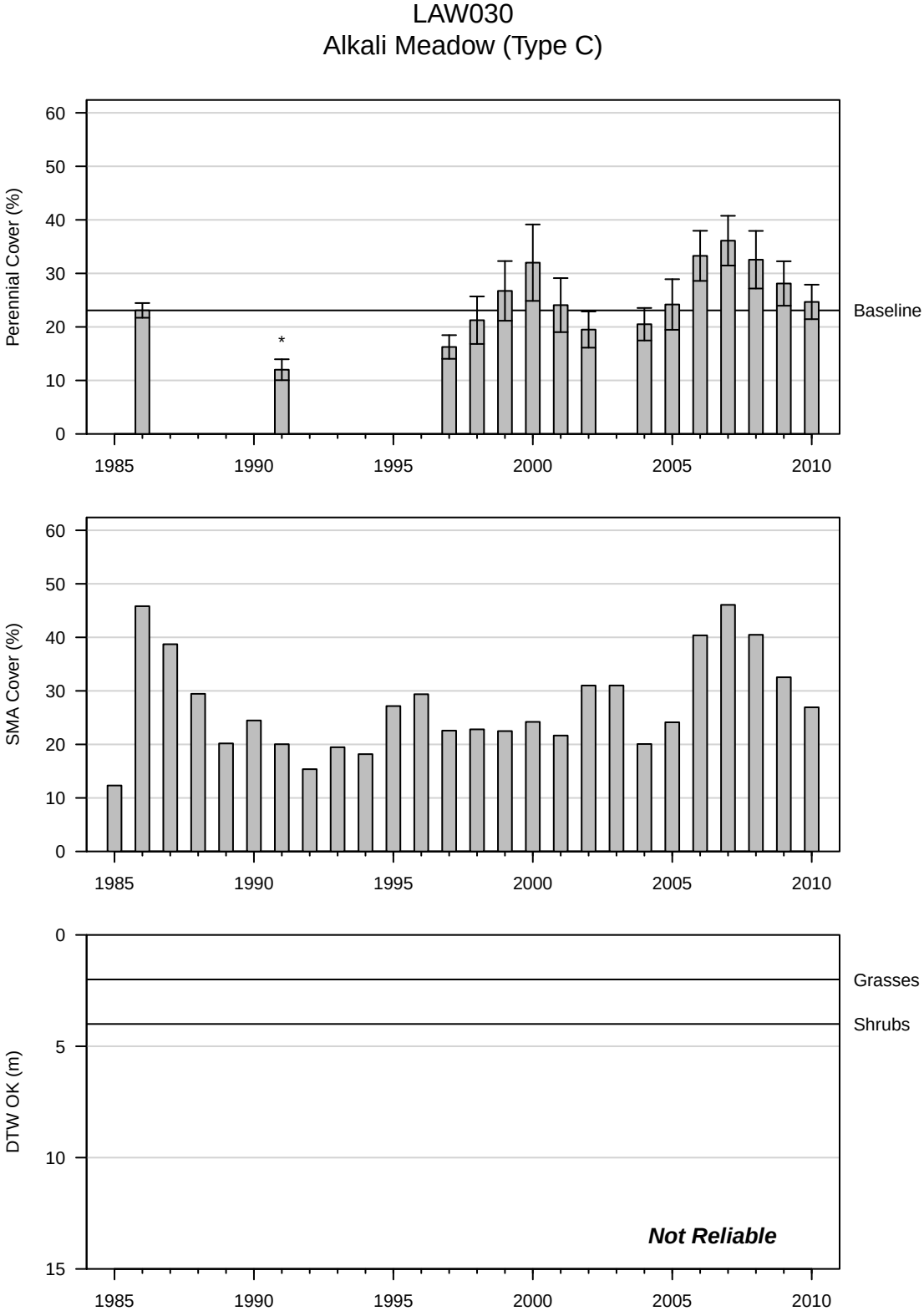


Figure 83: 2010 Wellfield

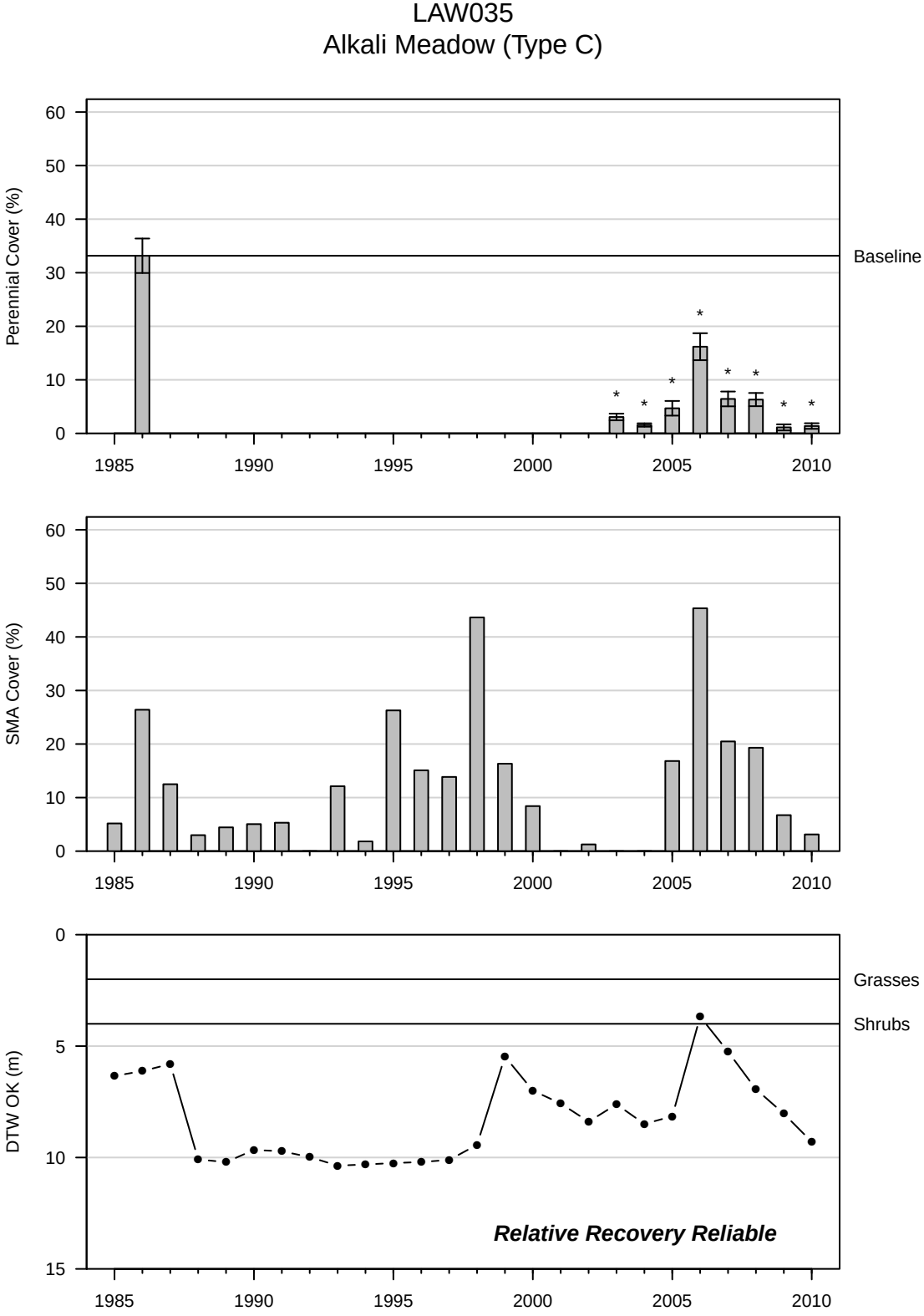


Figure 84: 2010 Wellfield

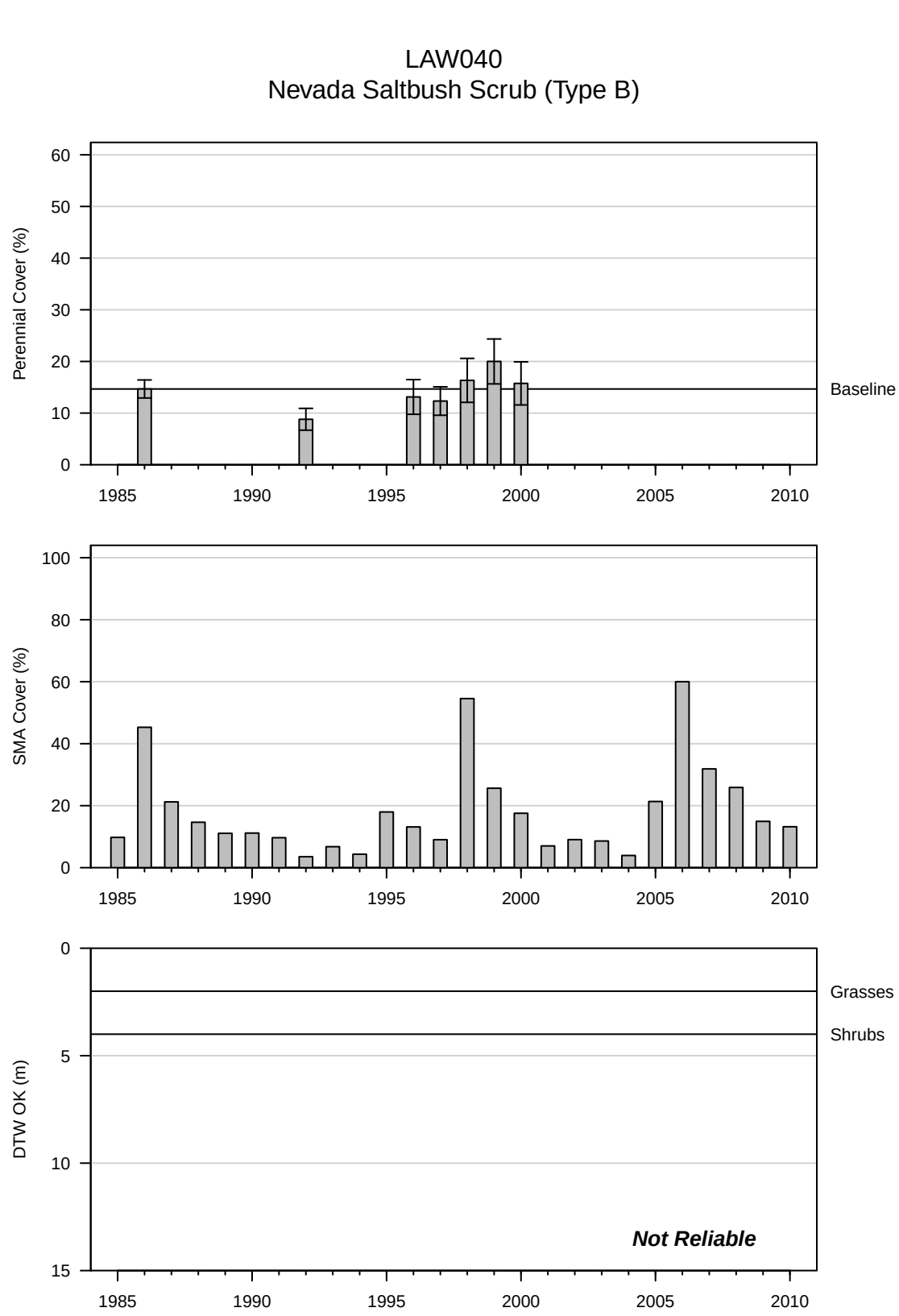


Figure 85: 2000 Wellfield

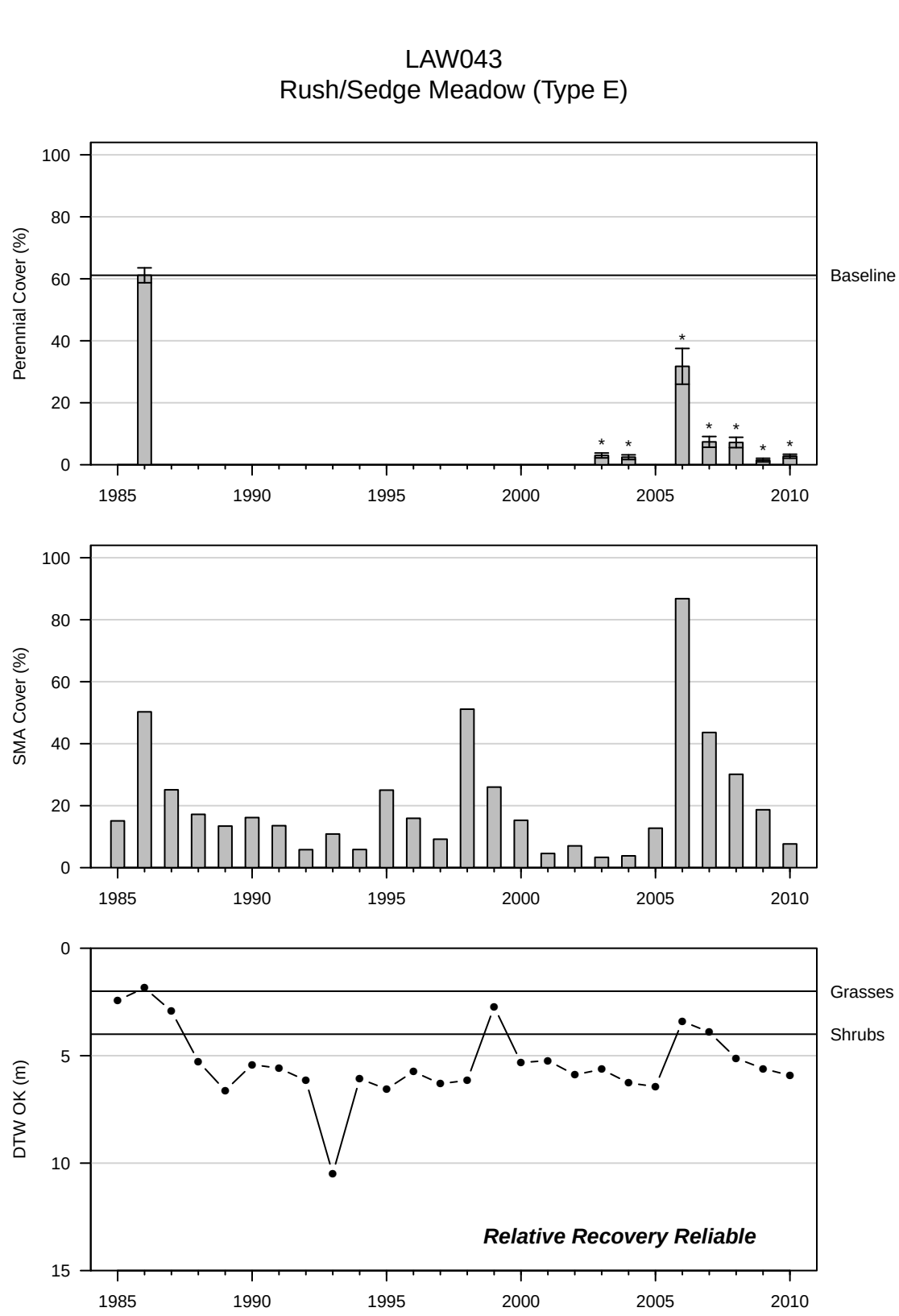


Figure 86: 2010 Wellfield

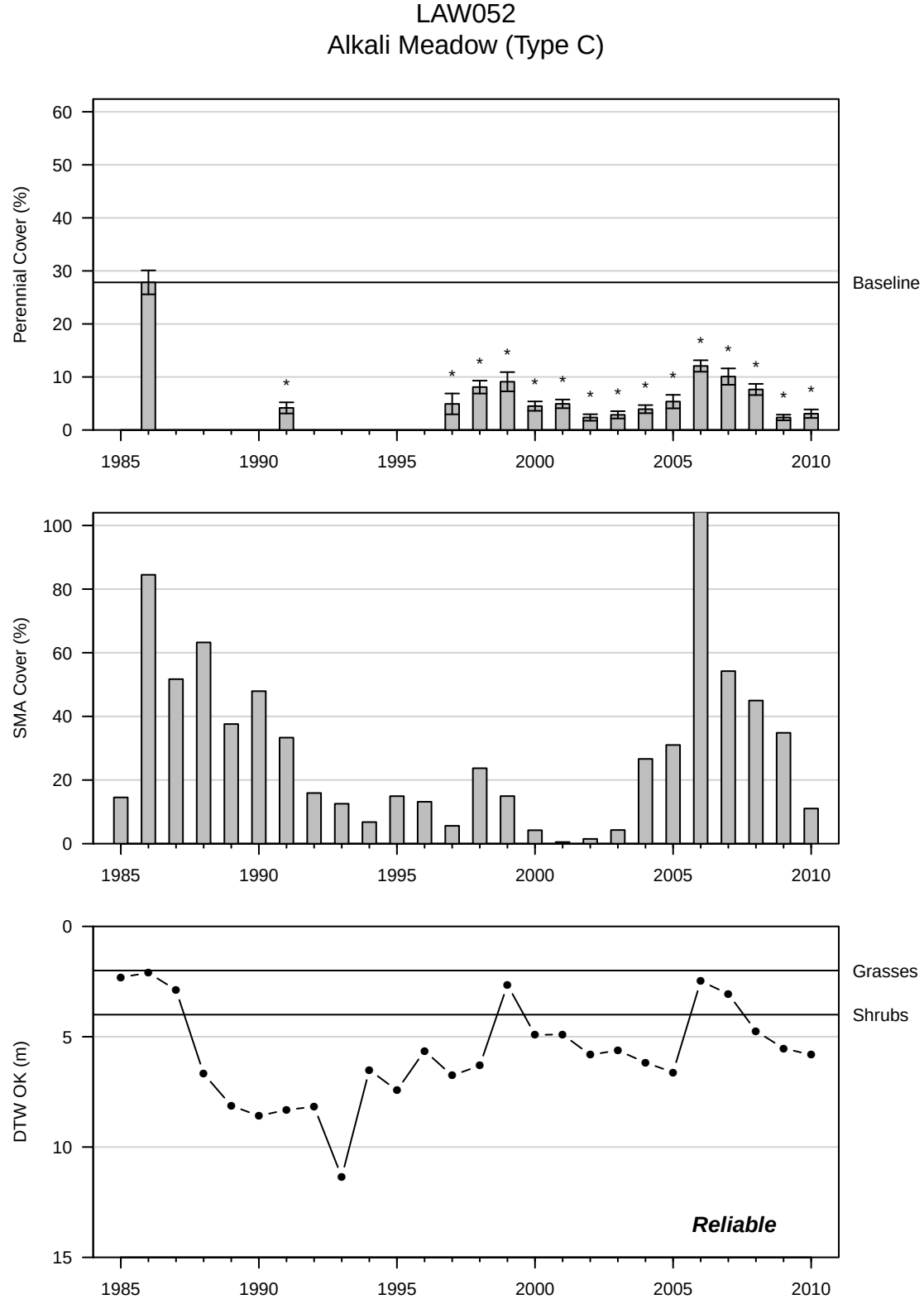
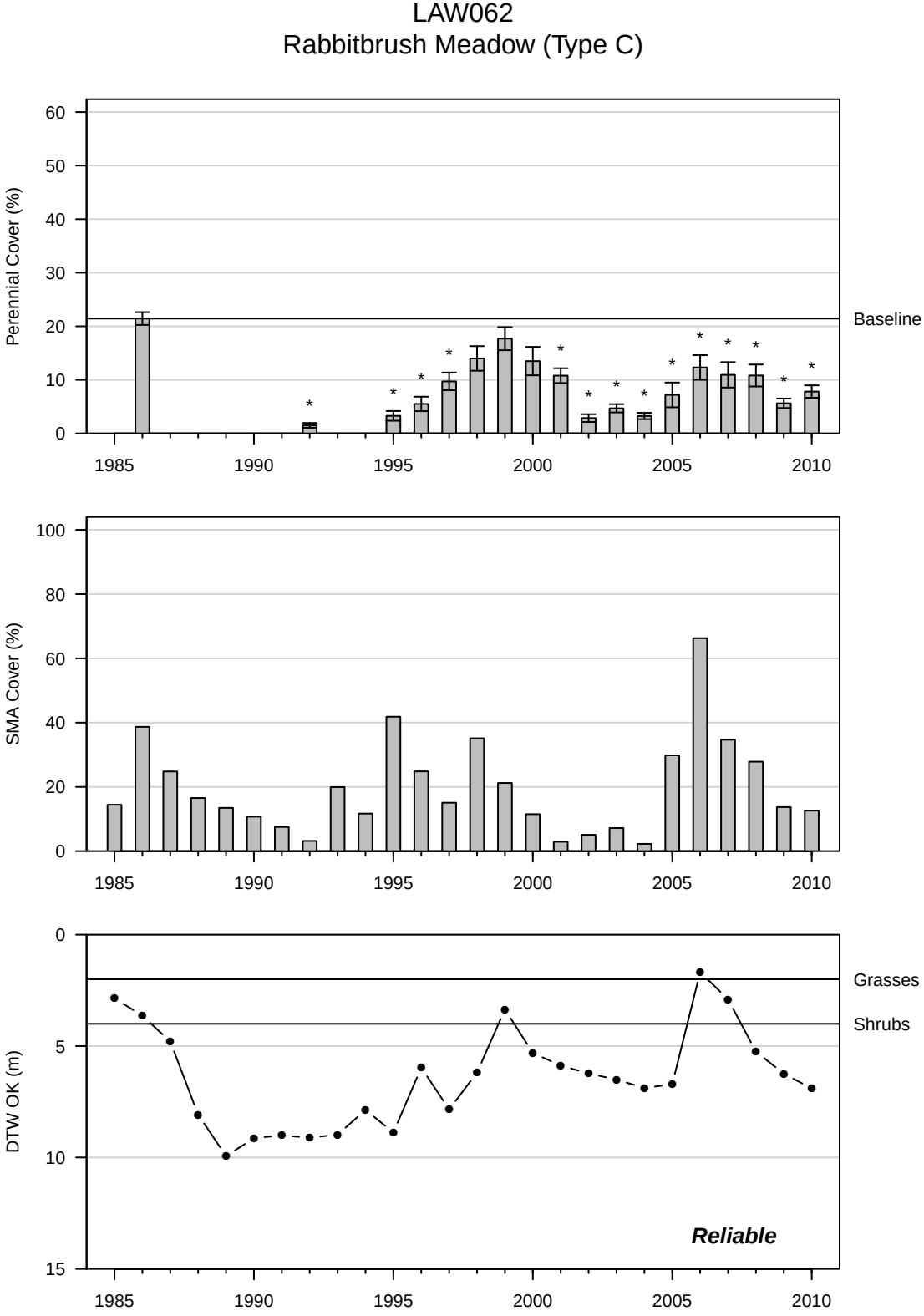


Figure 87: 2010 Wellfield



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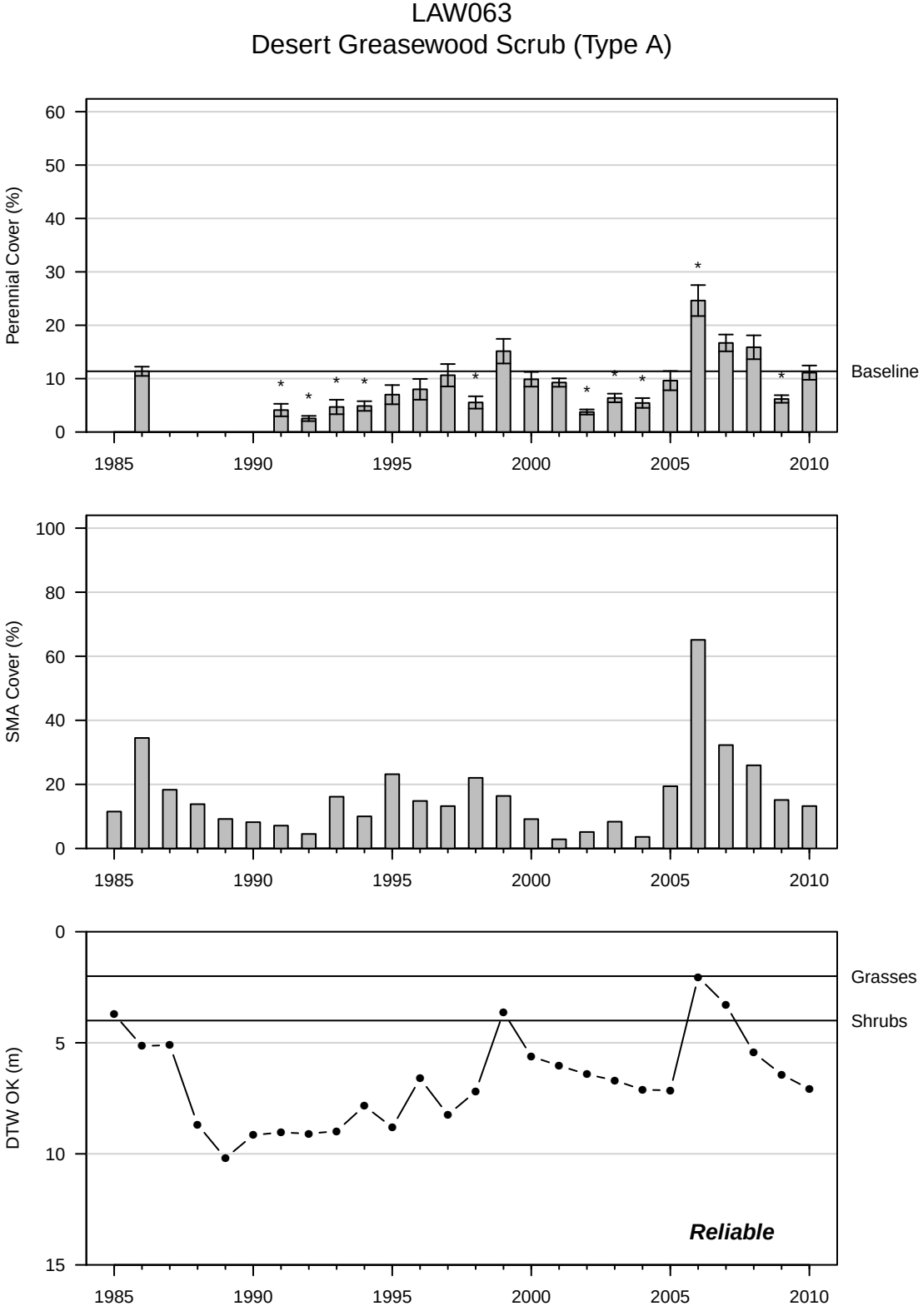

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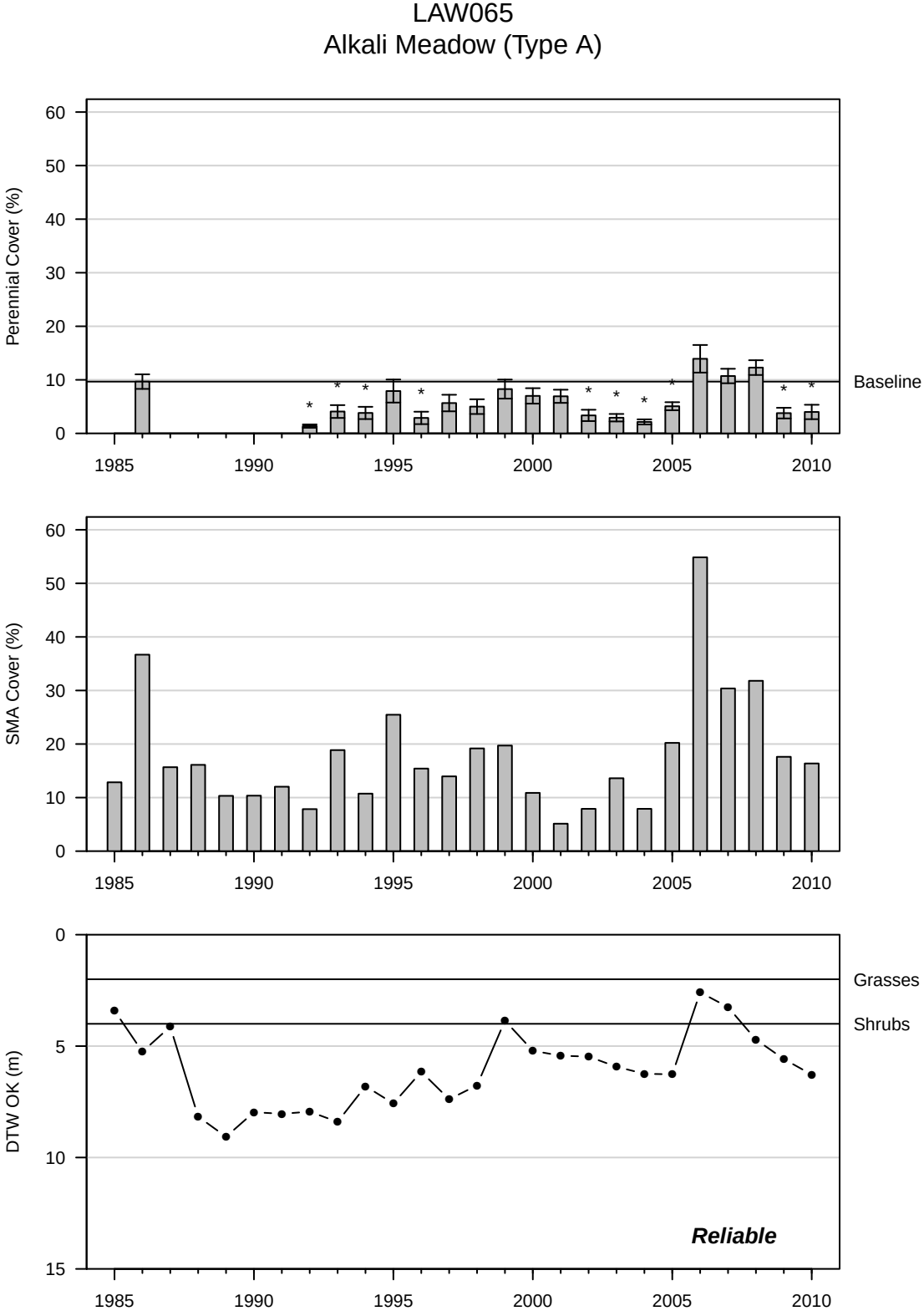

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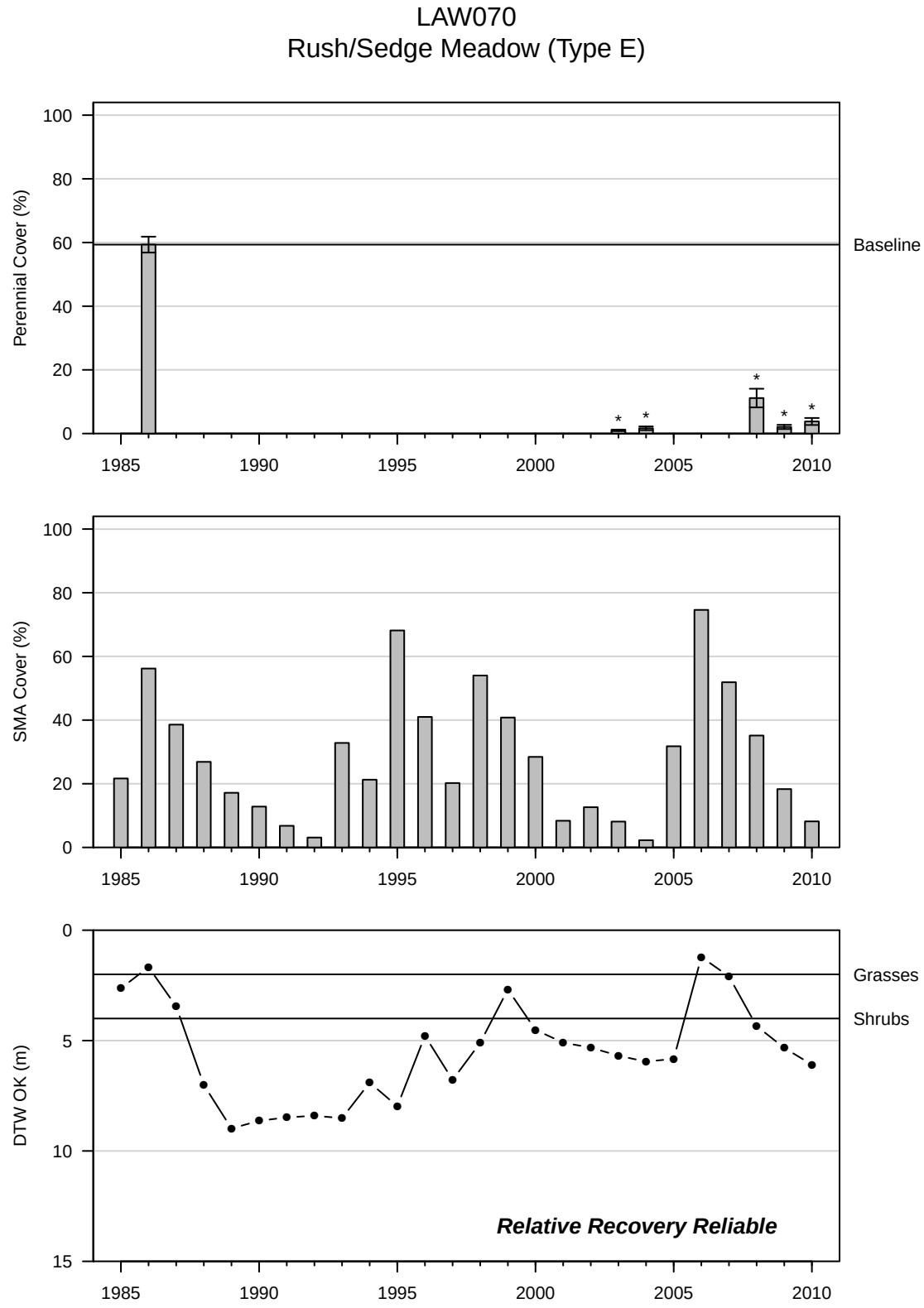
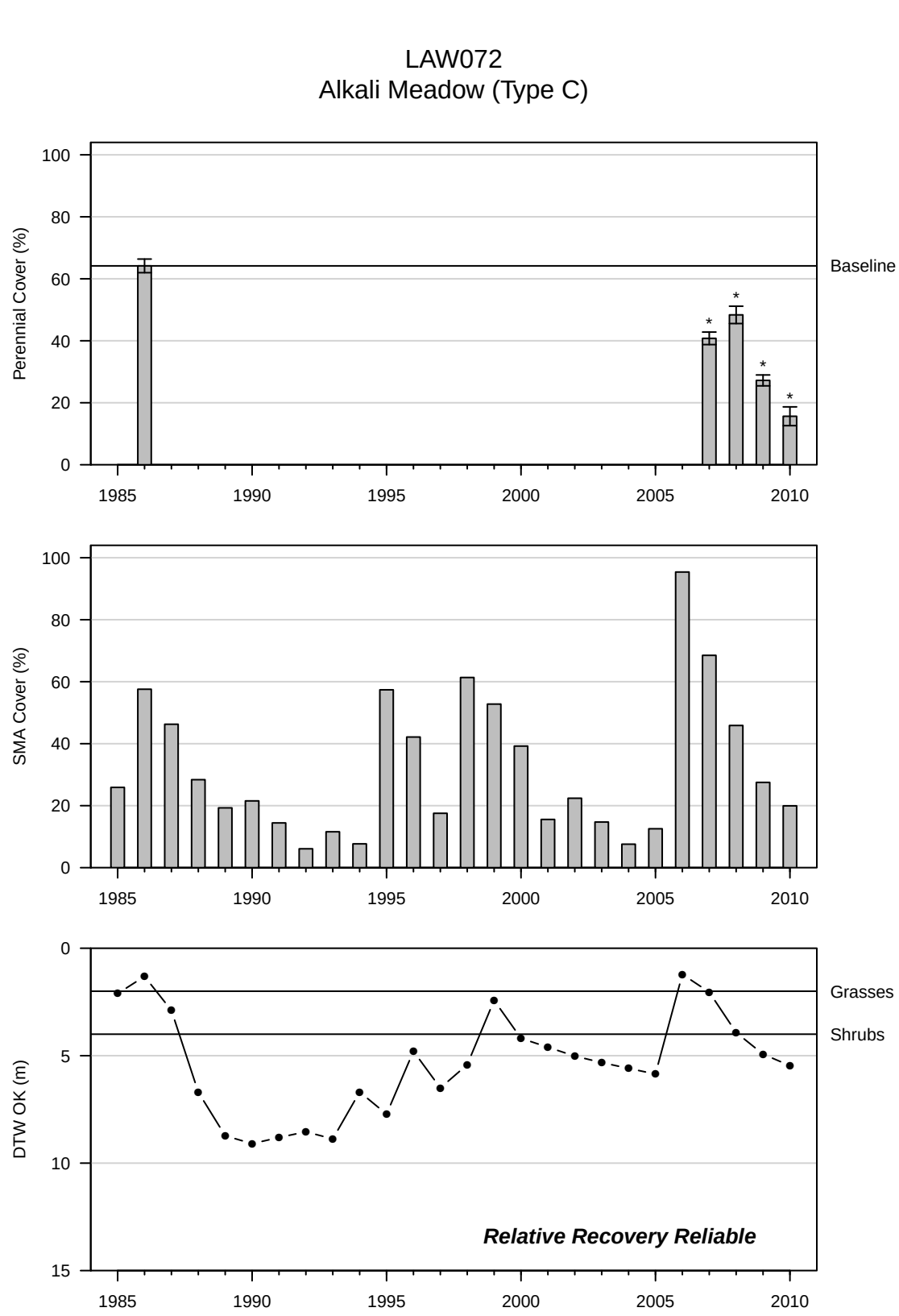


Figure 91: 2010 Wellfield



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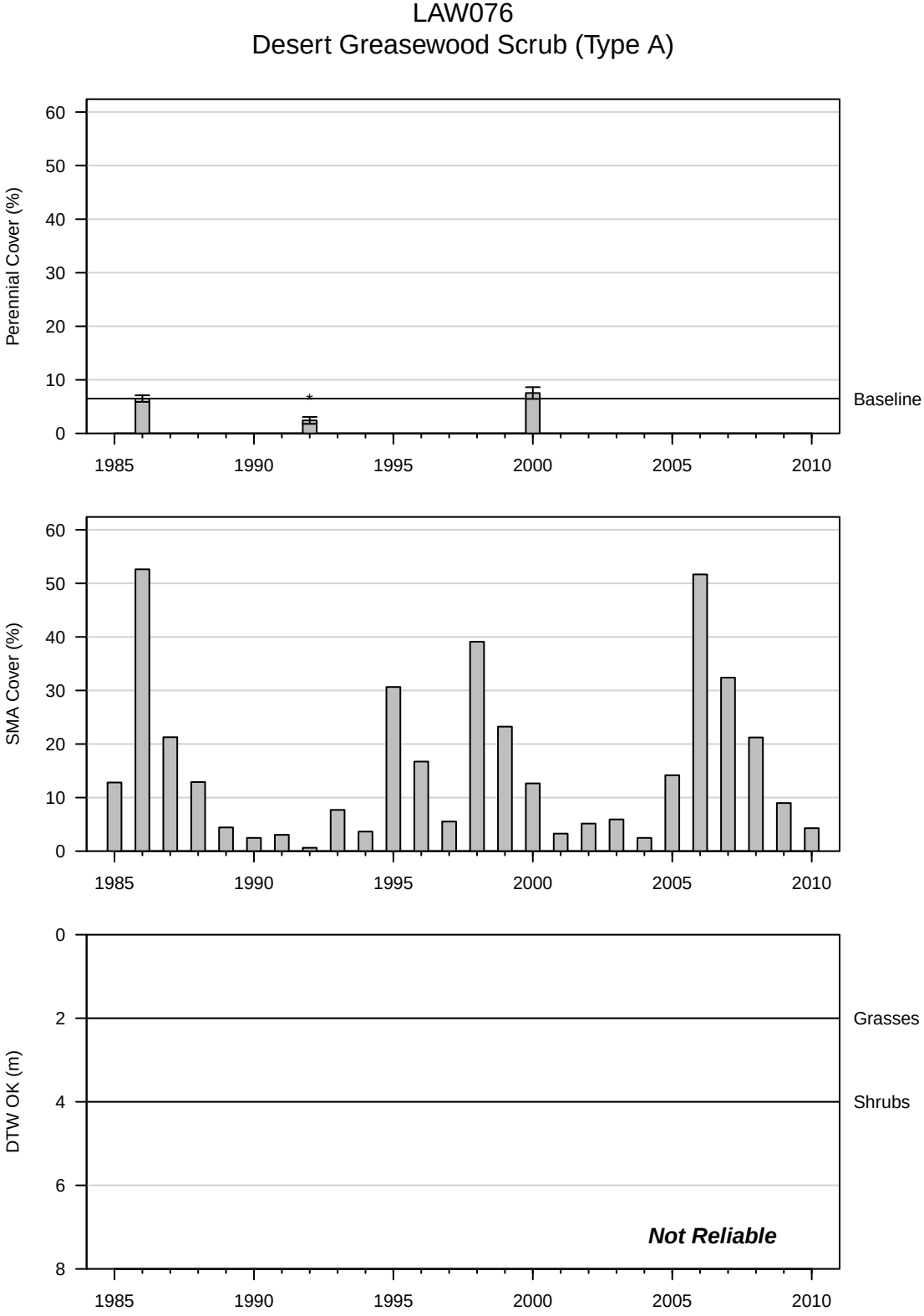


Figure 93: 2000 Wellfield

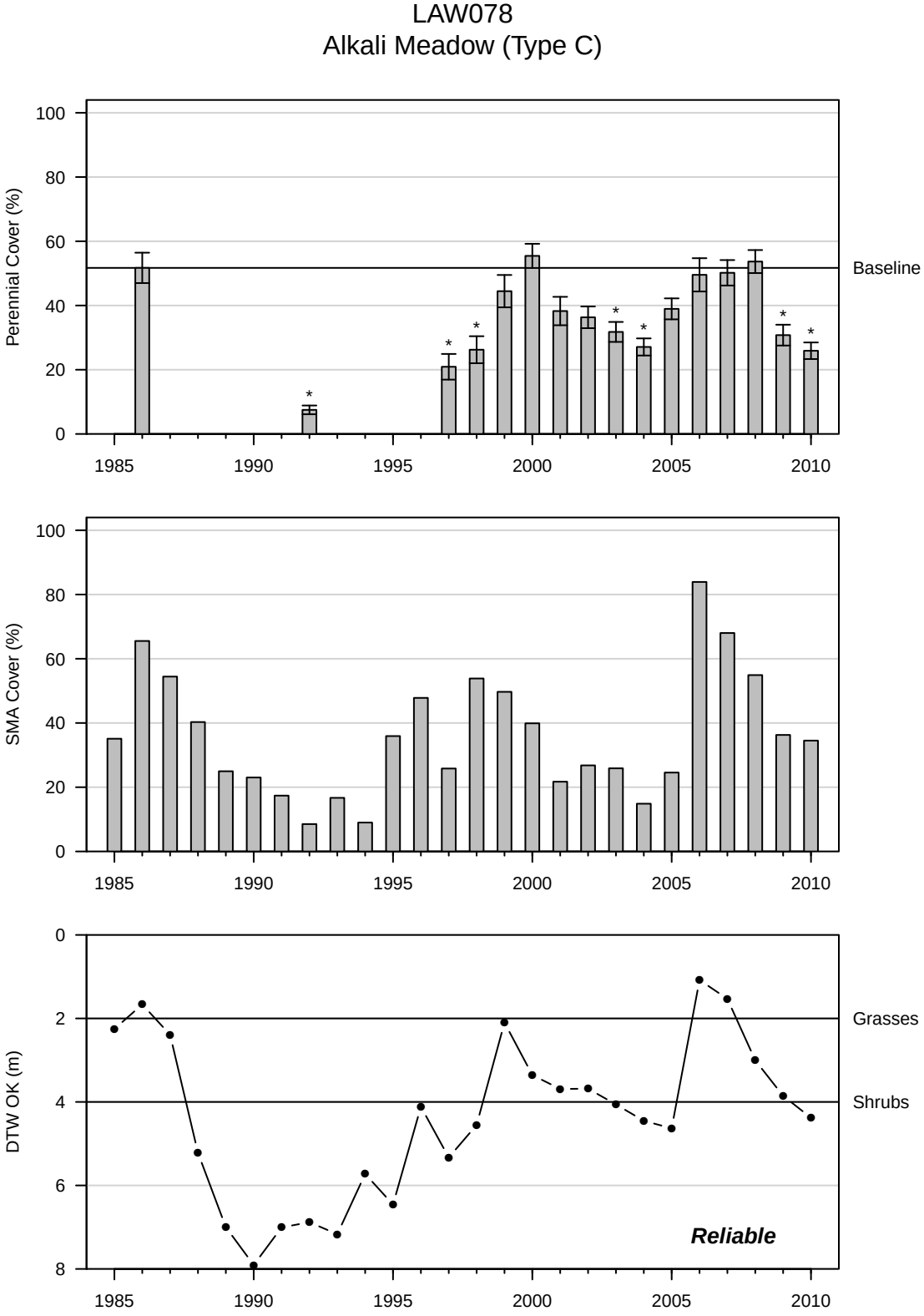


Figure 94: 2010 Wellfield

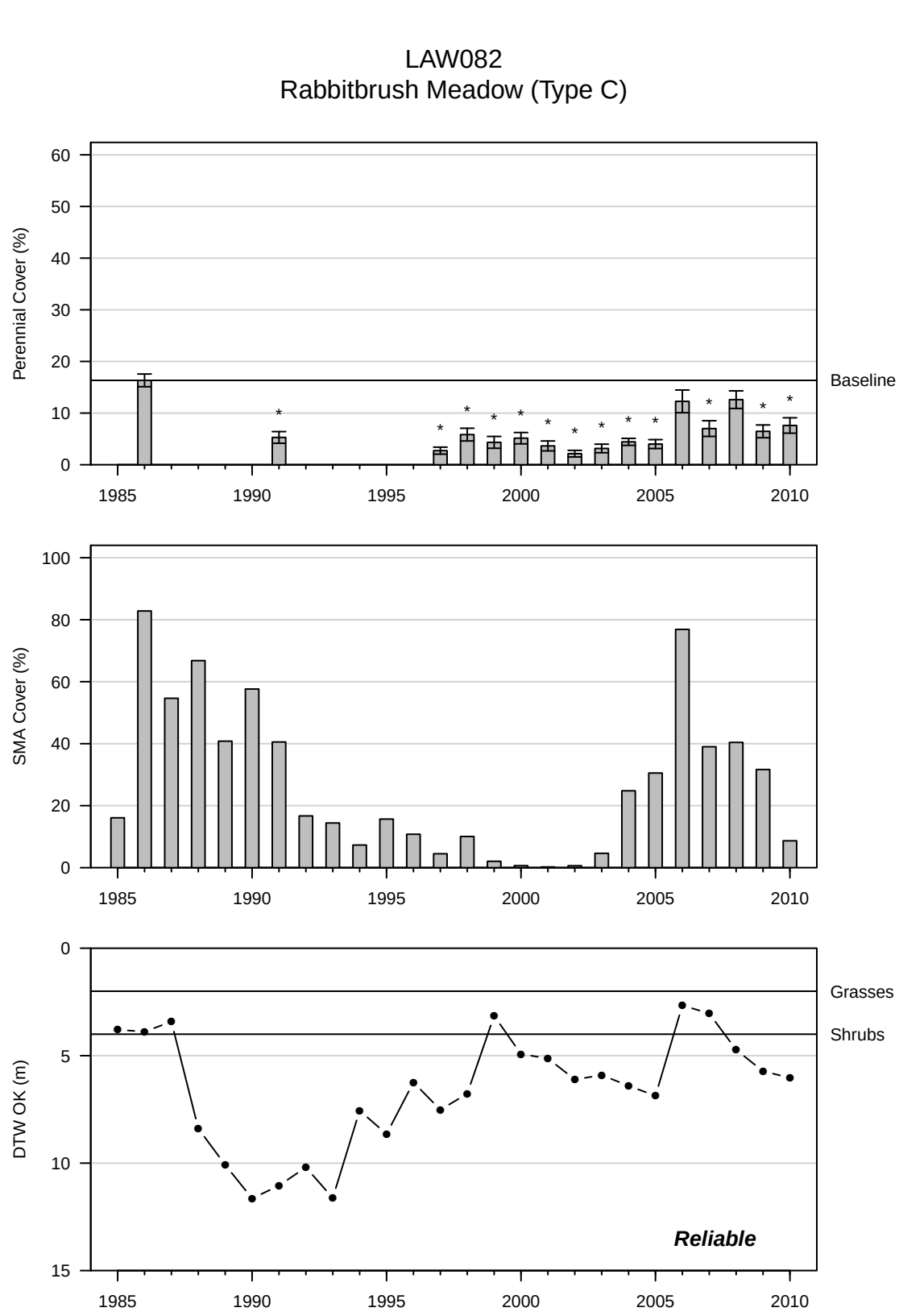


Figure 95: 2010 Wellfield

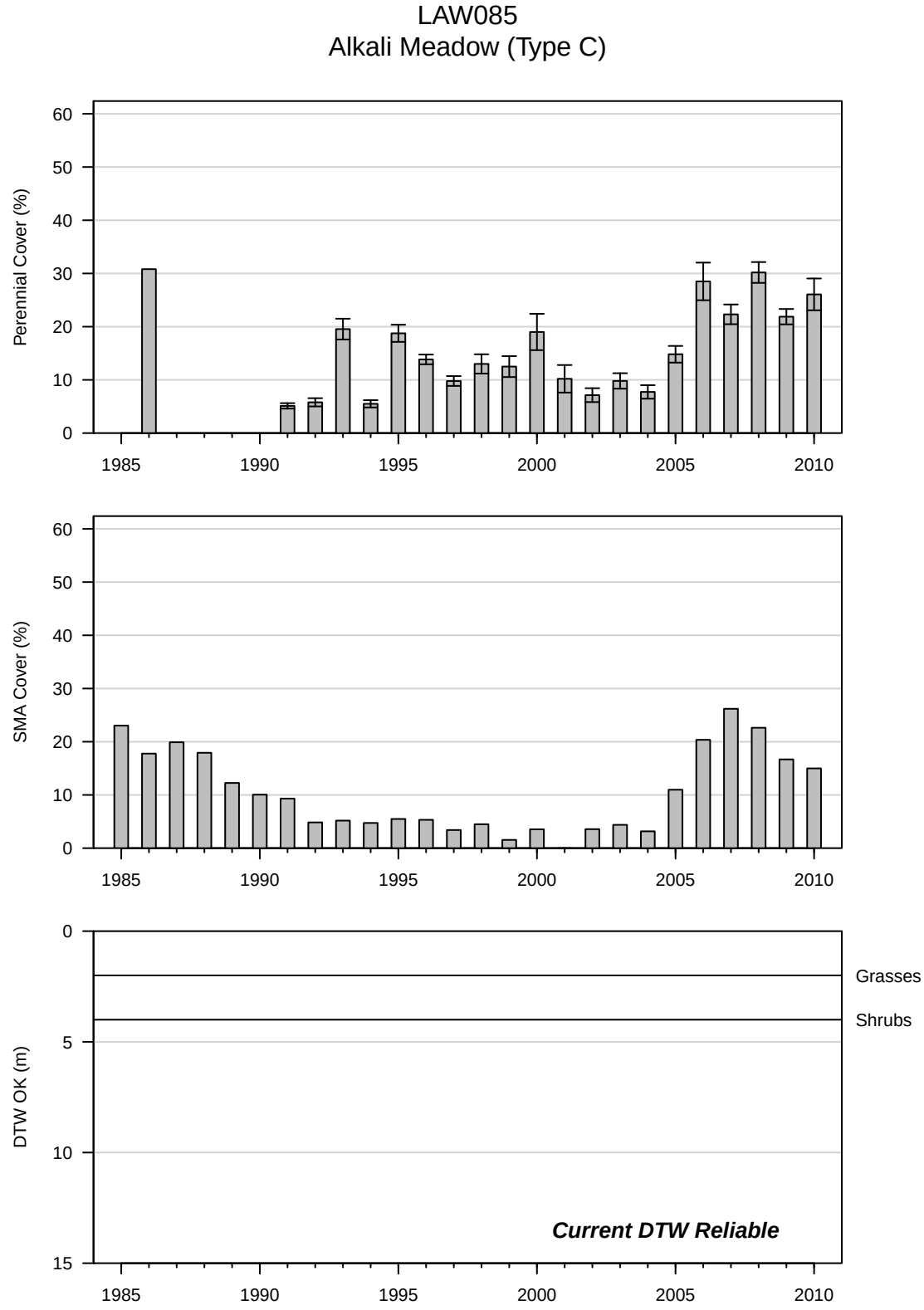


Figure 96: 2010 Wellfield

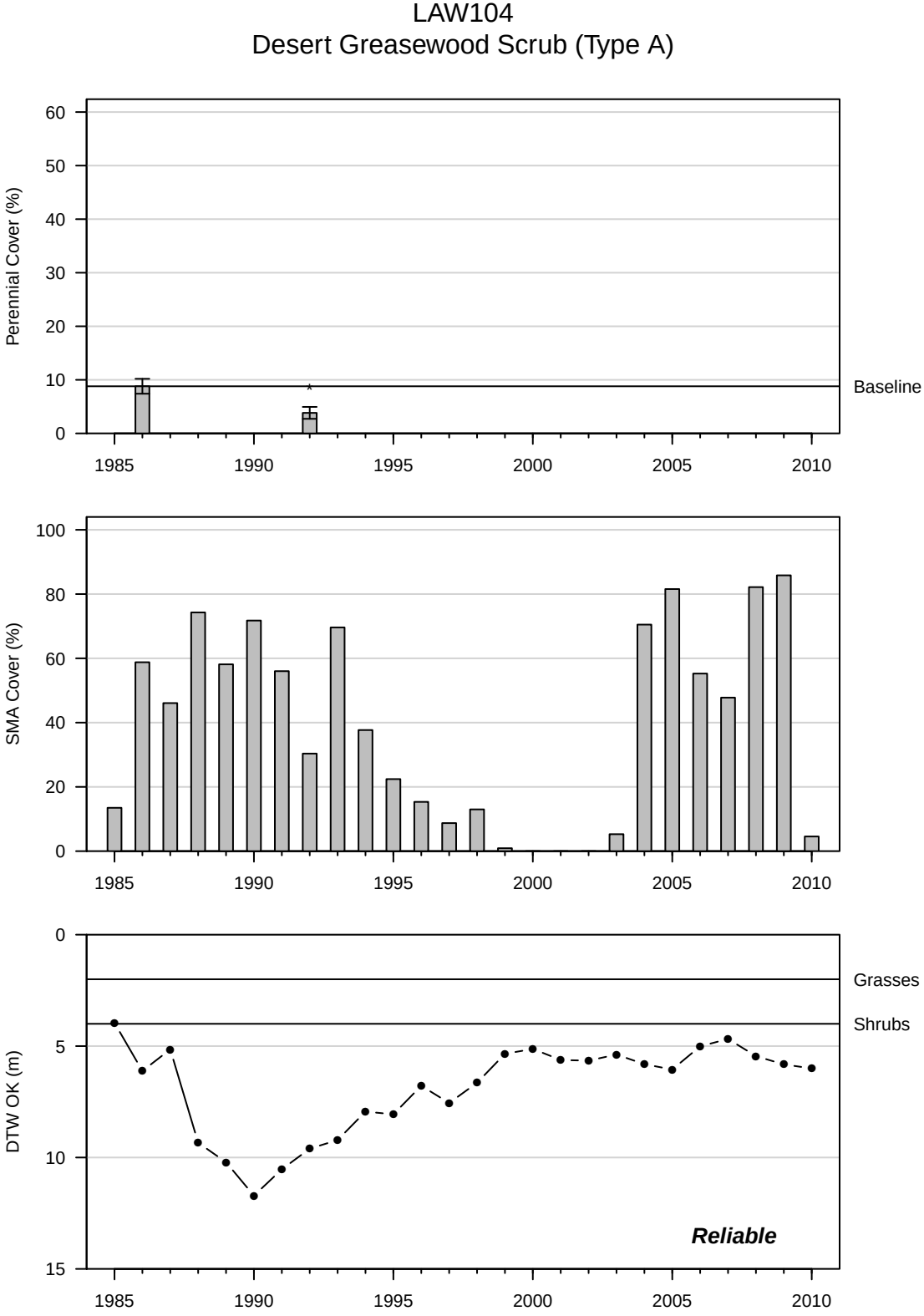


Figure 97: 1992 Wellfield

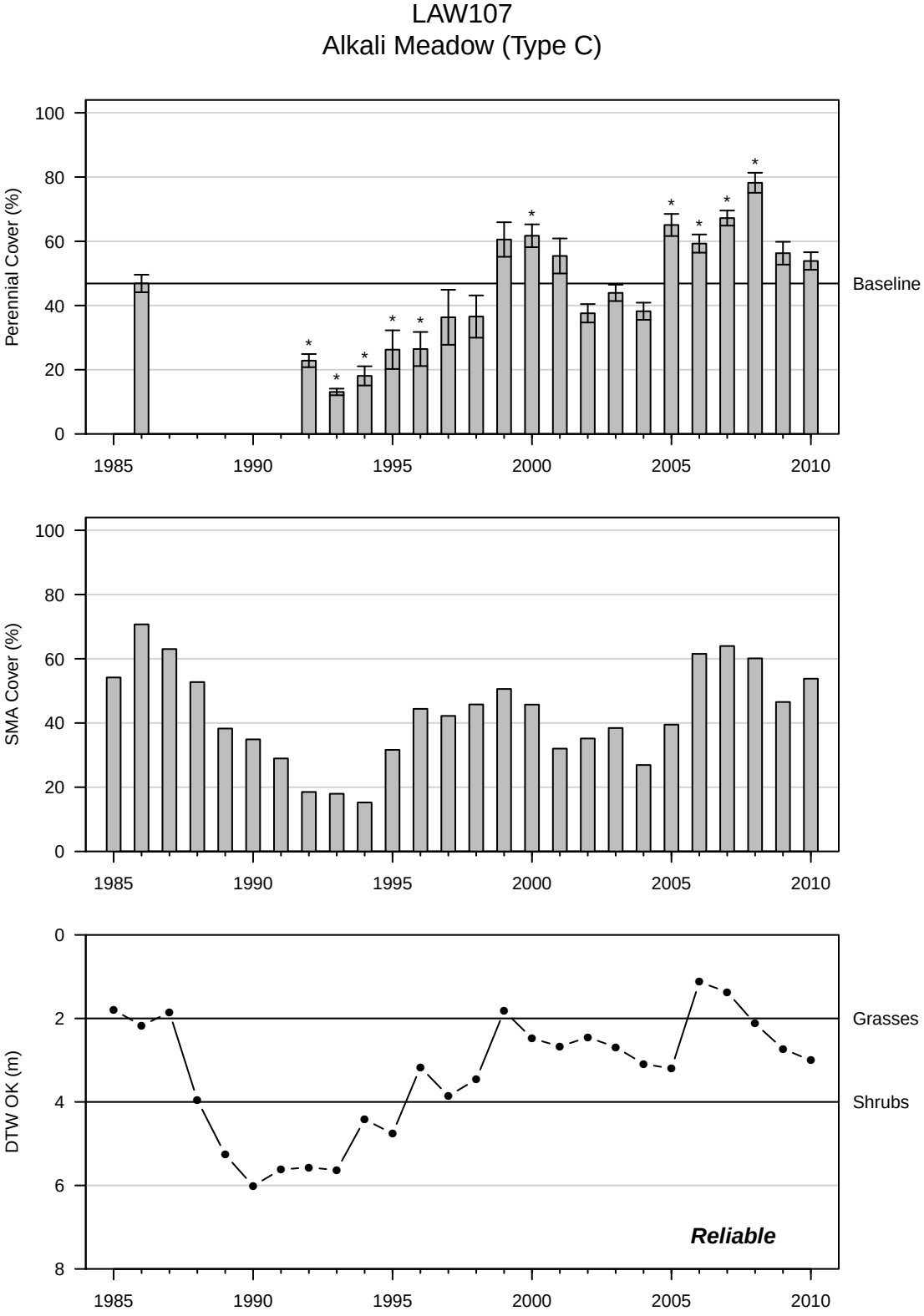


Figure 98: 2010 Wellfield

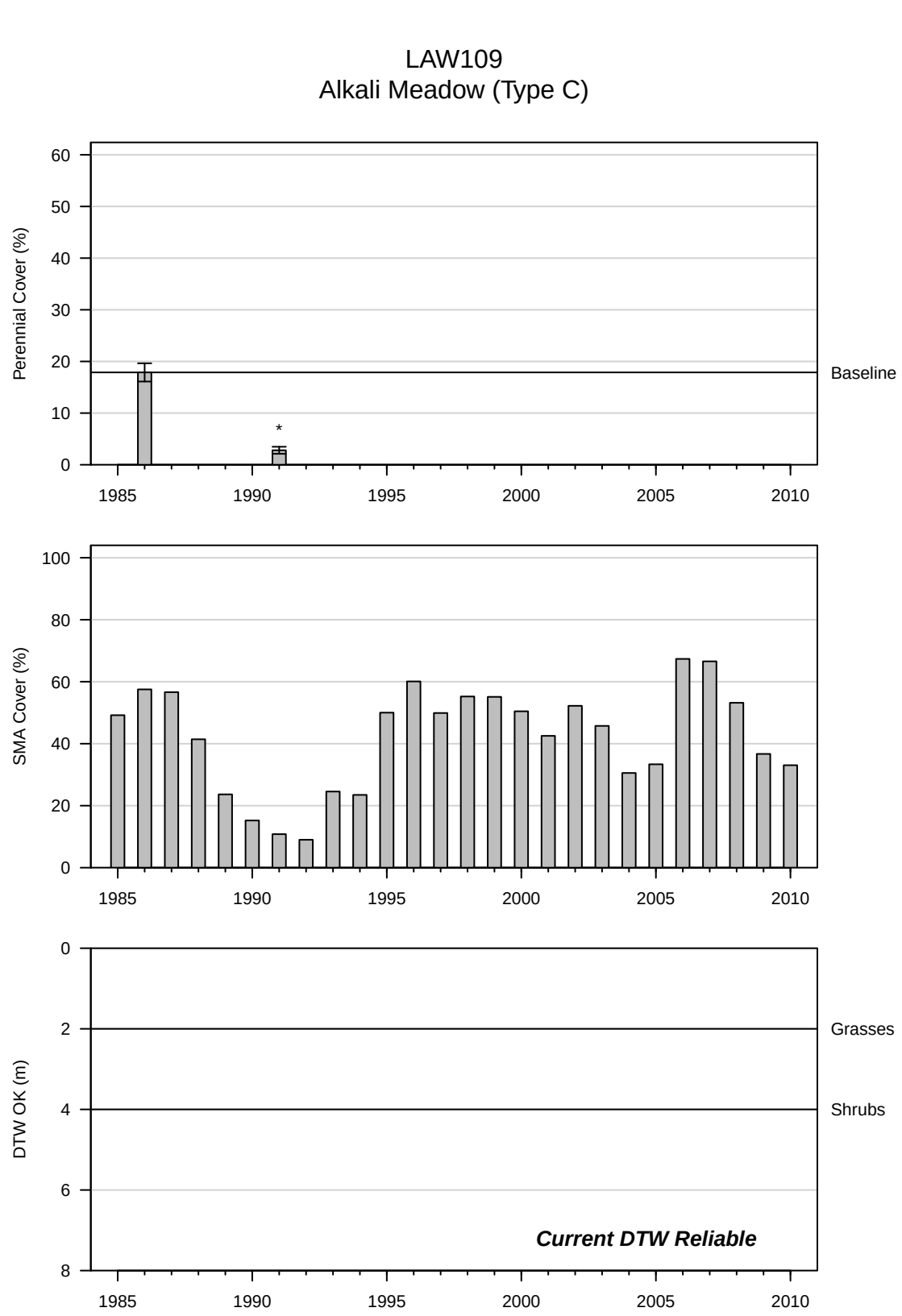


Figure 99: 1991 Wellfield

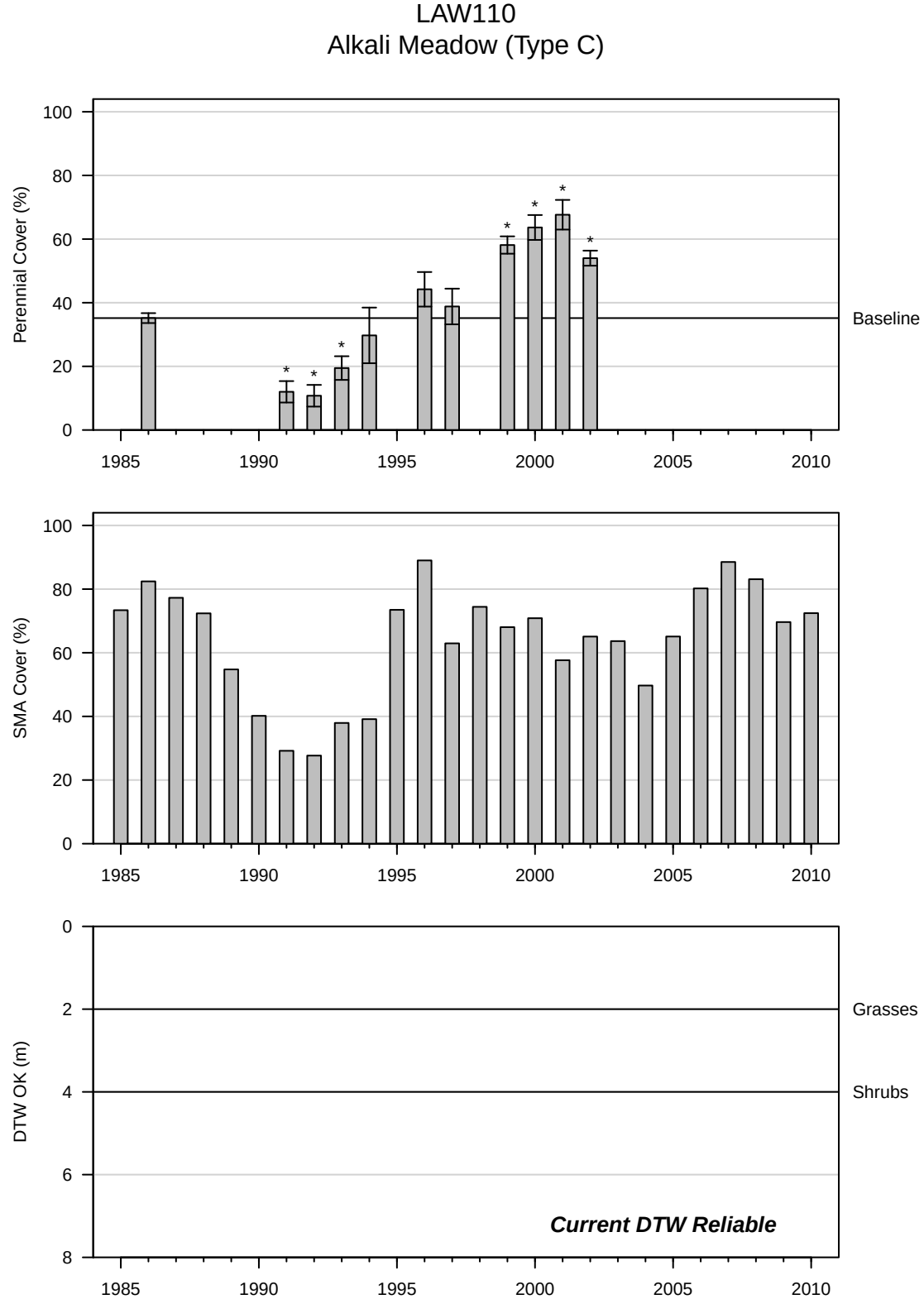


Figure 100: 2002 Wellfield

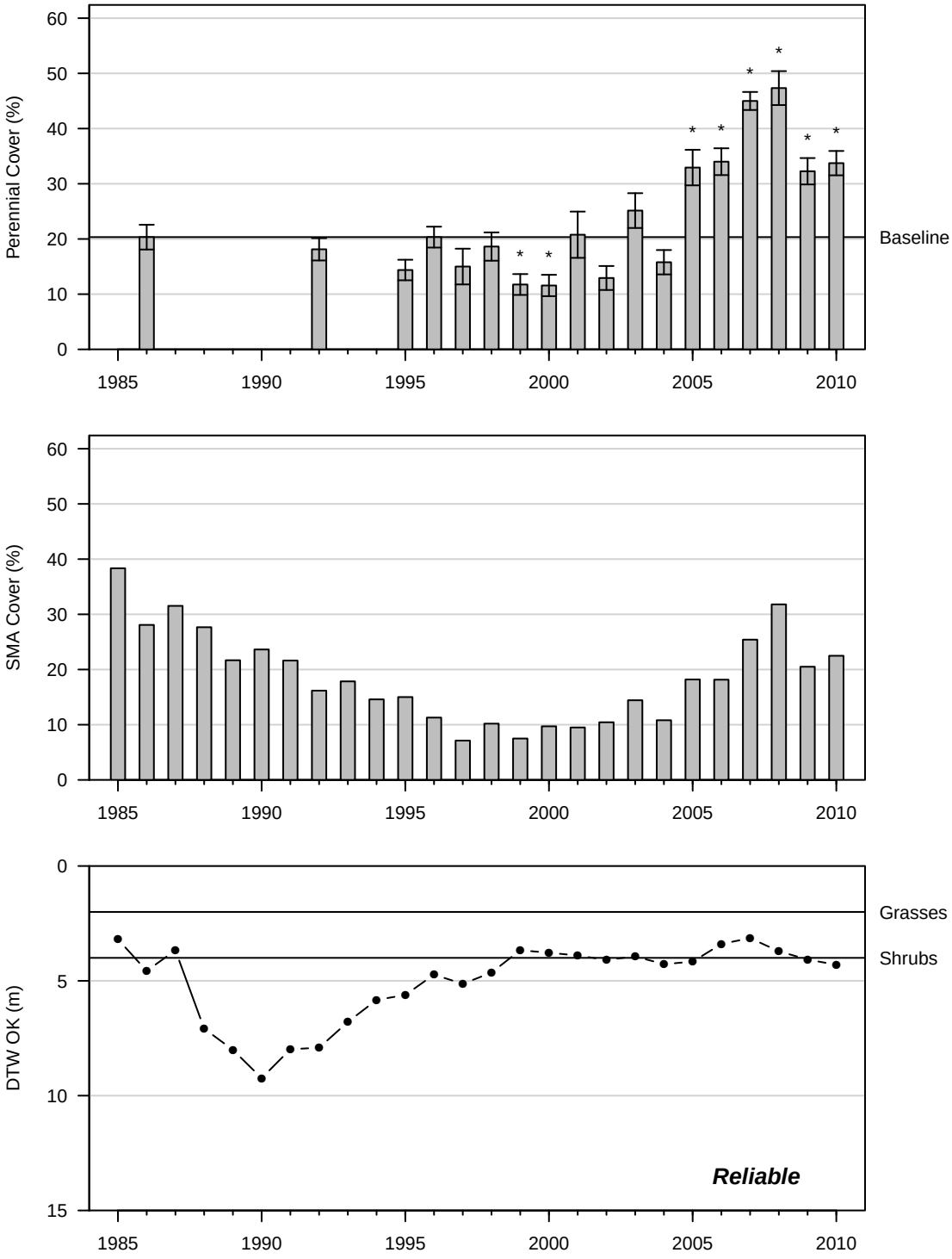
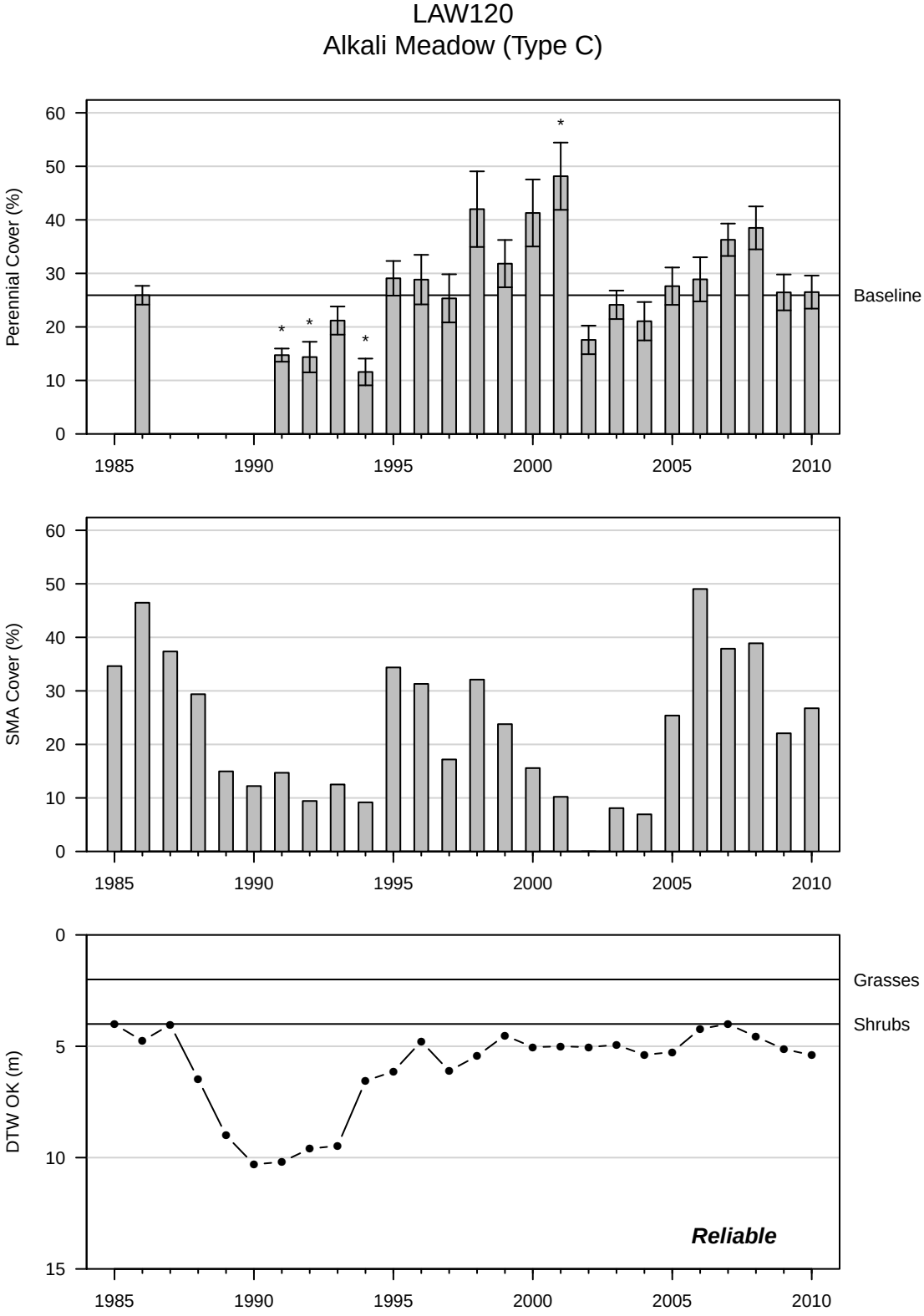


Figure 101: 2010 Wellfield



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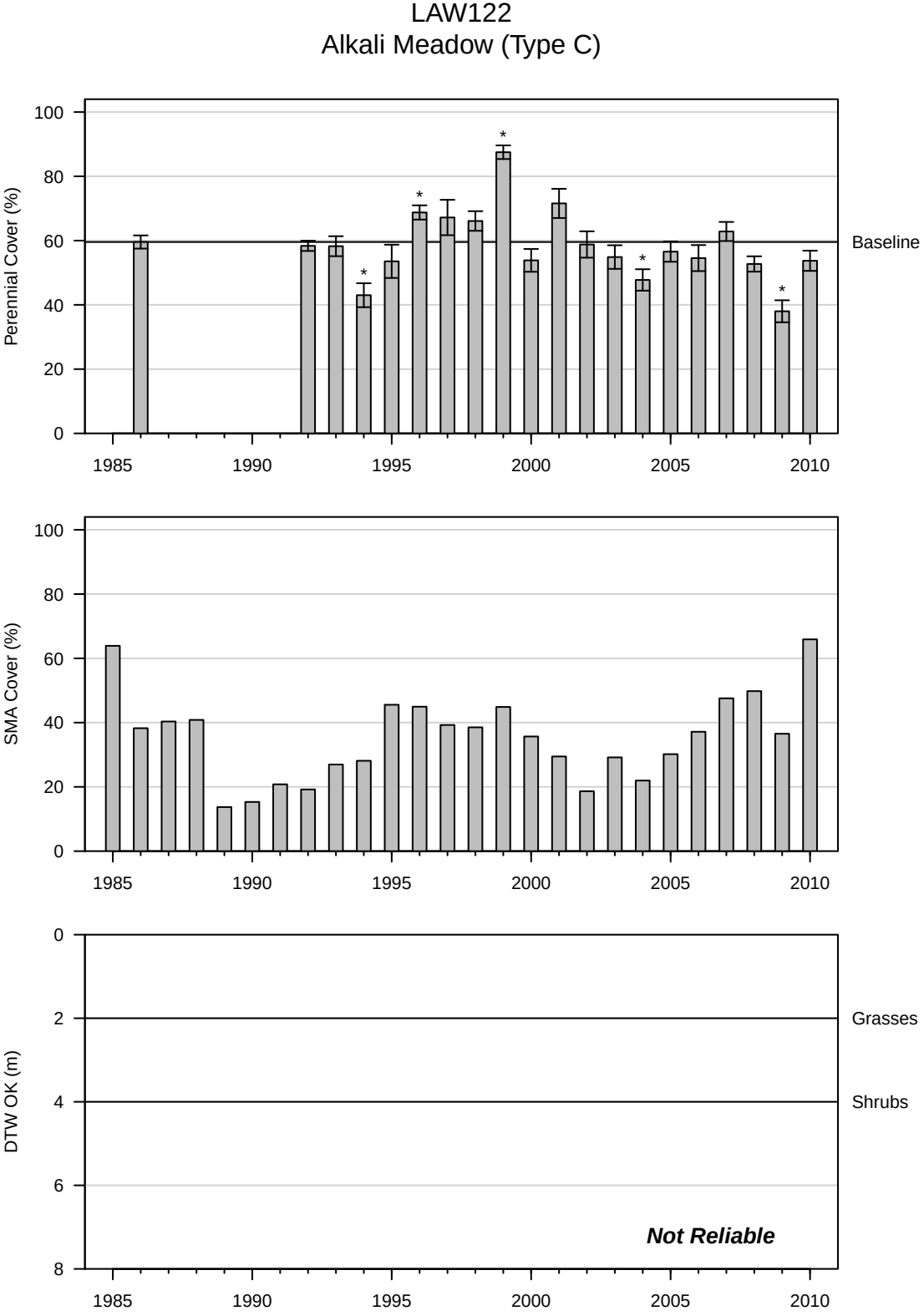


Figure 103: 2010 Wellfield

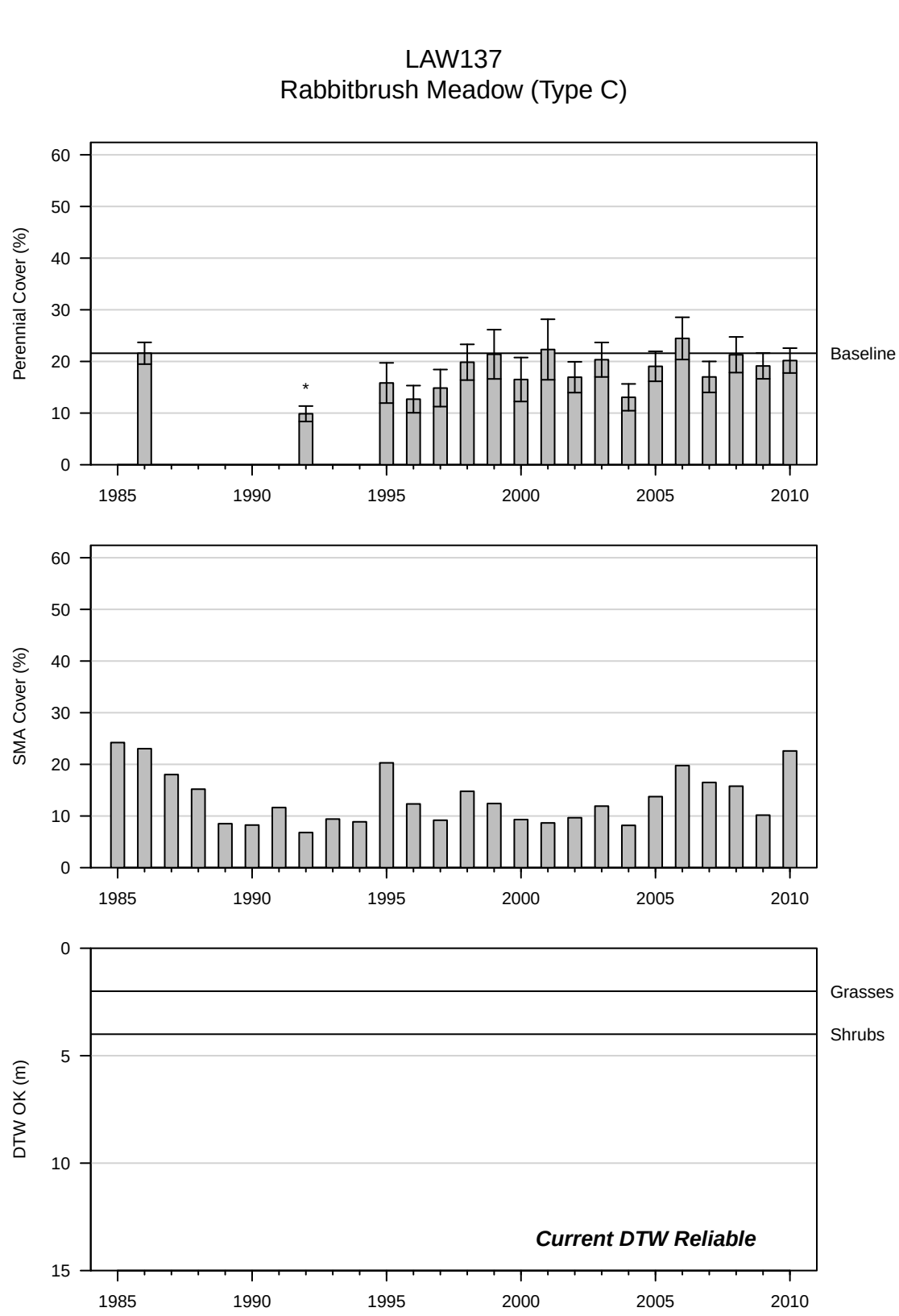


Figure 104: 2010 Wellfield

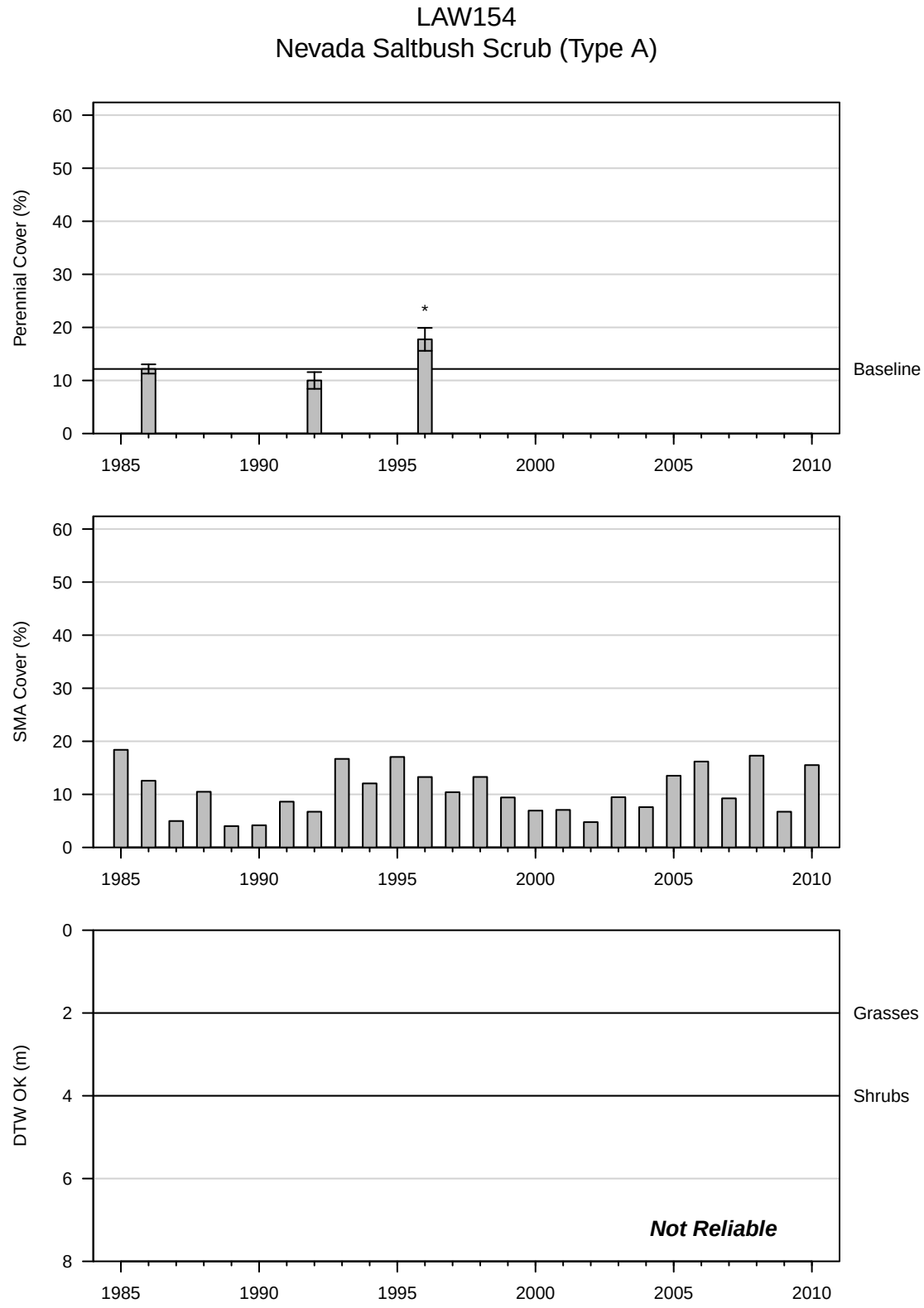


Figure 105: 1996 Control

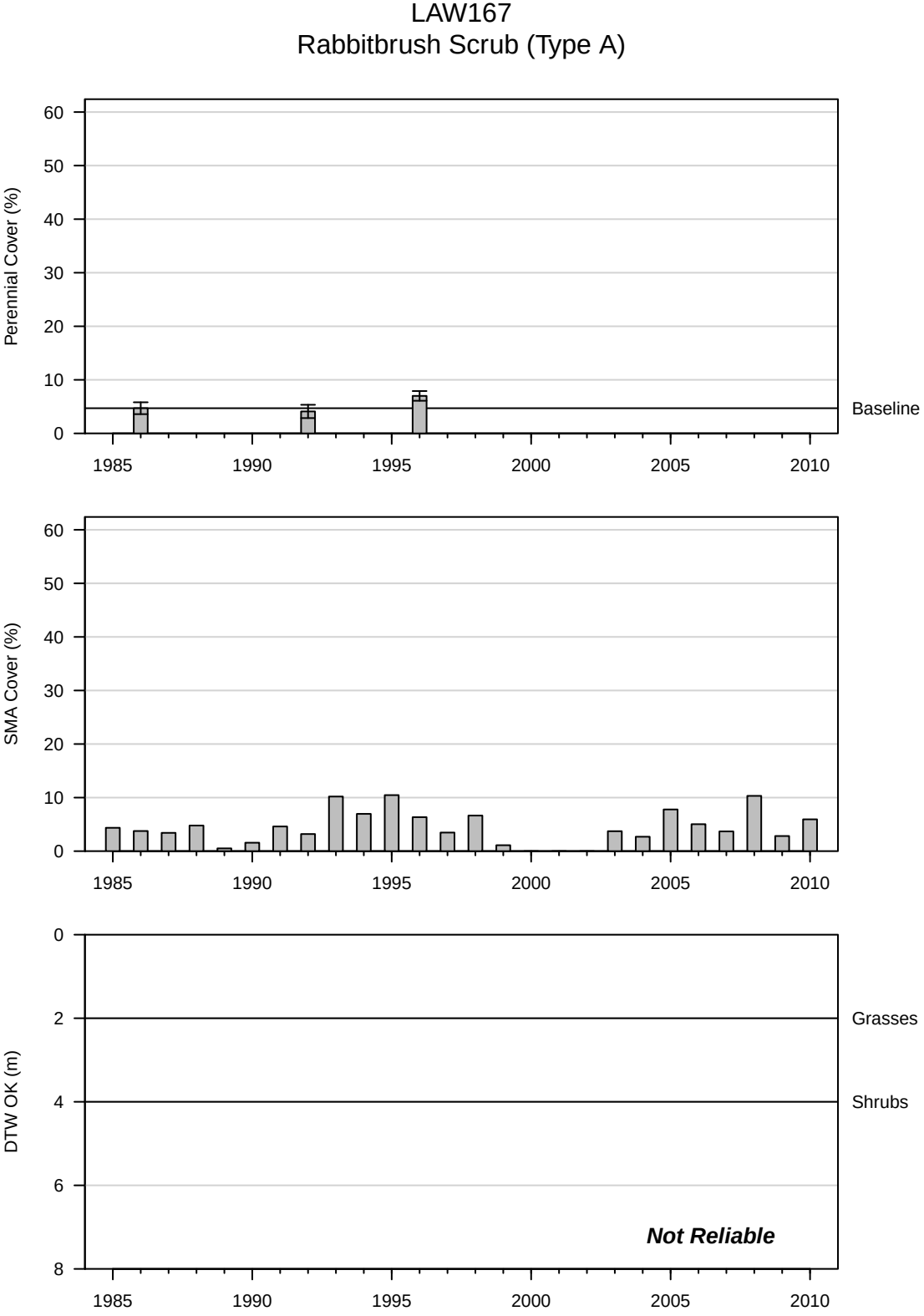


Figure 106: 1996 Control

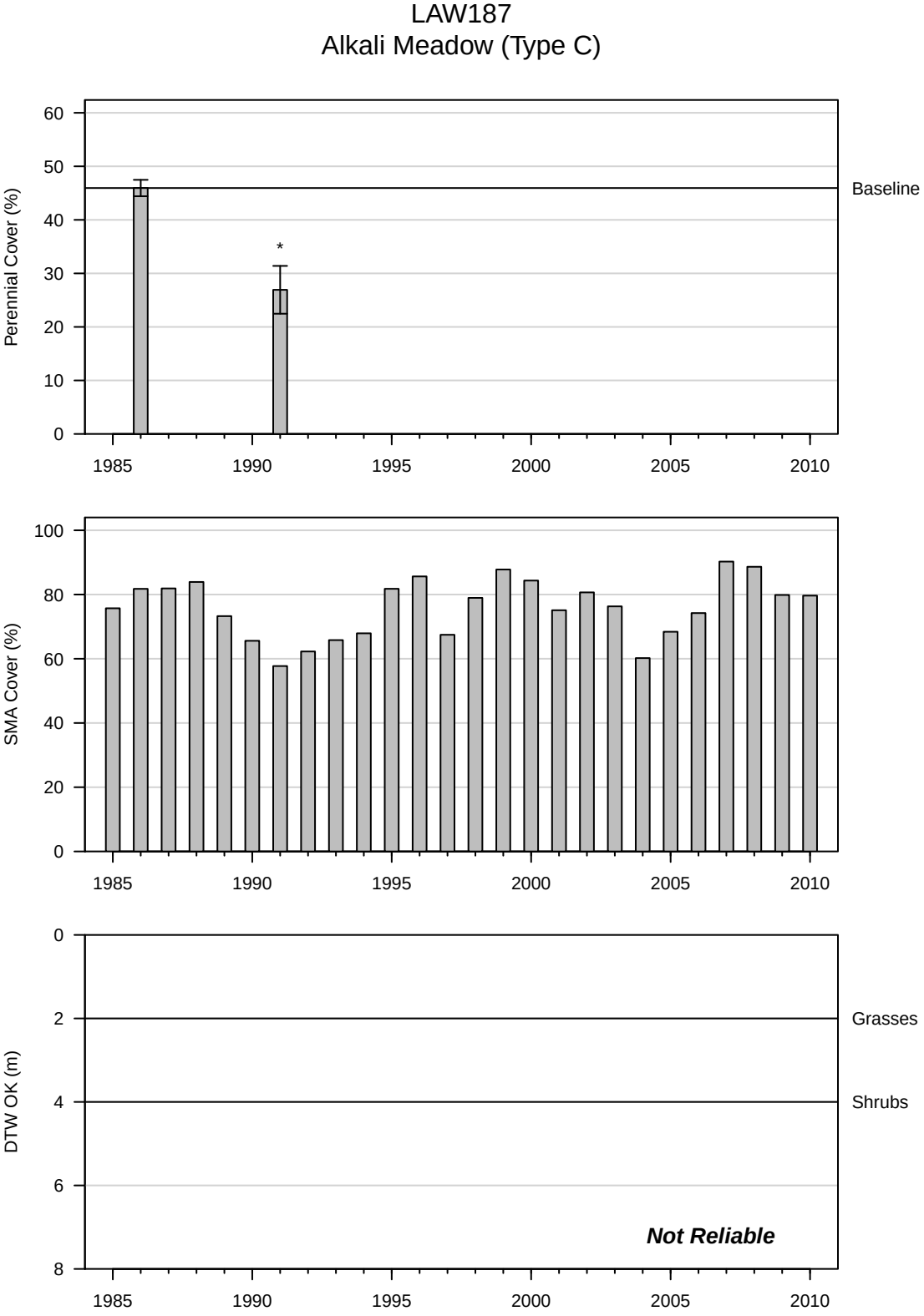


Figure 107: 1991 Control

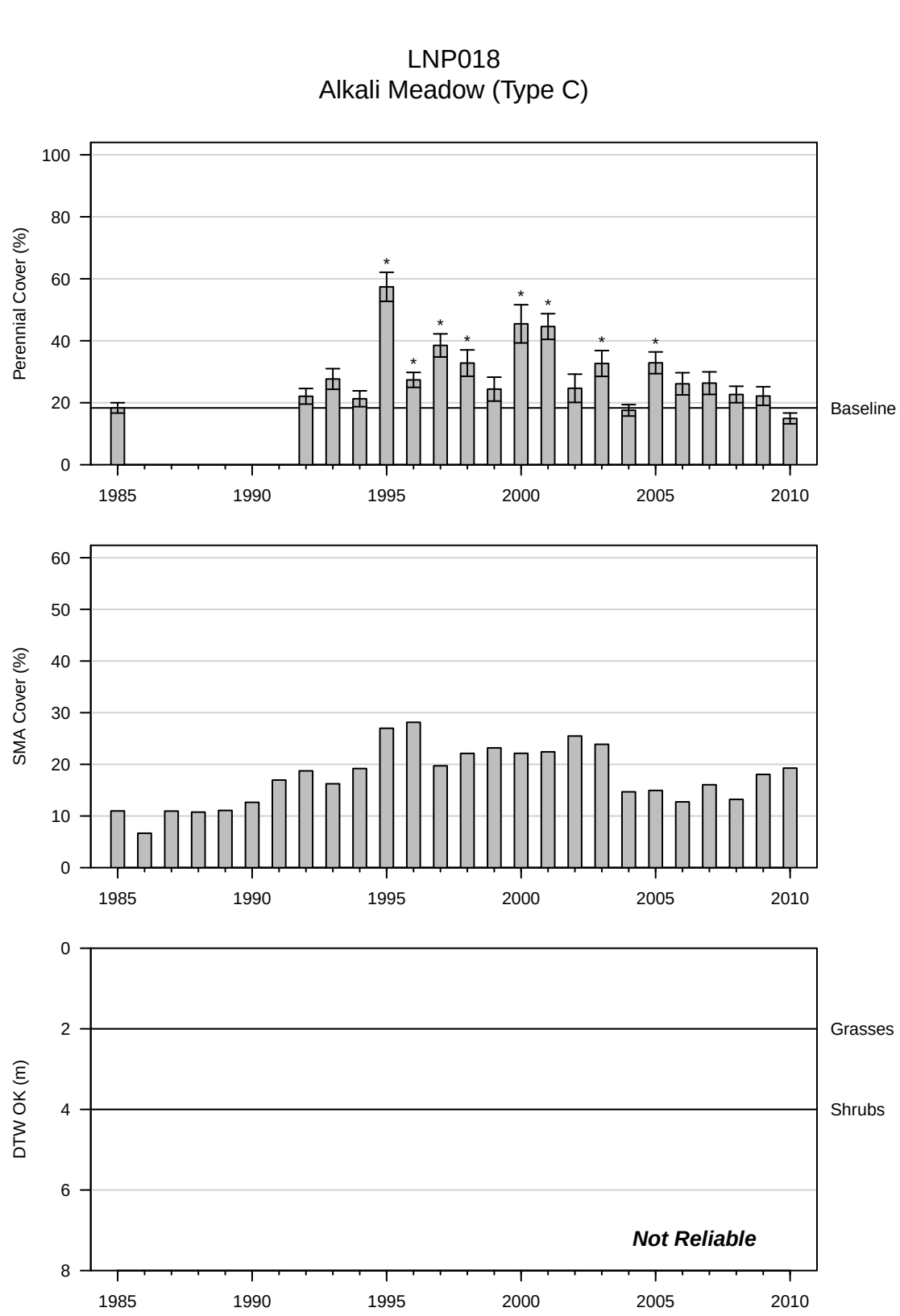


Figure 108: 2010 Control

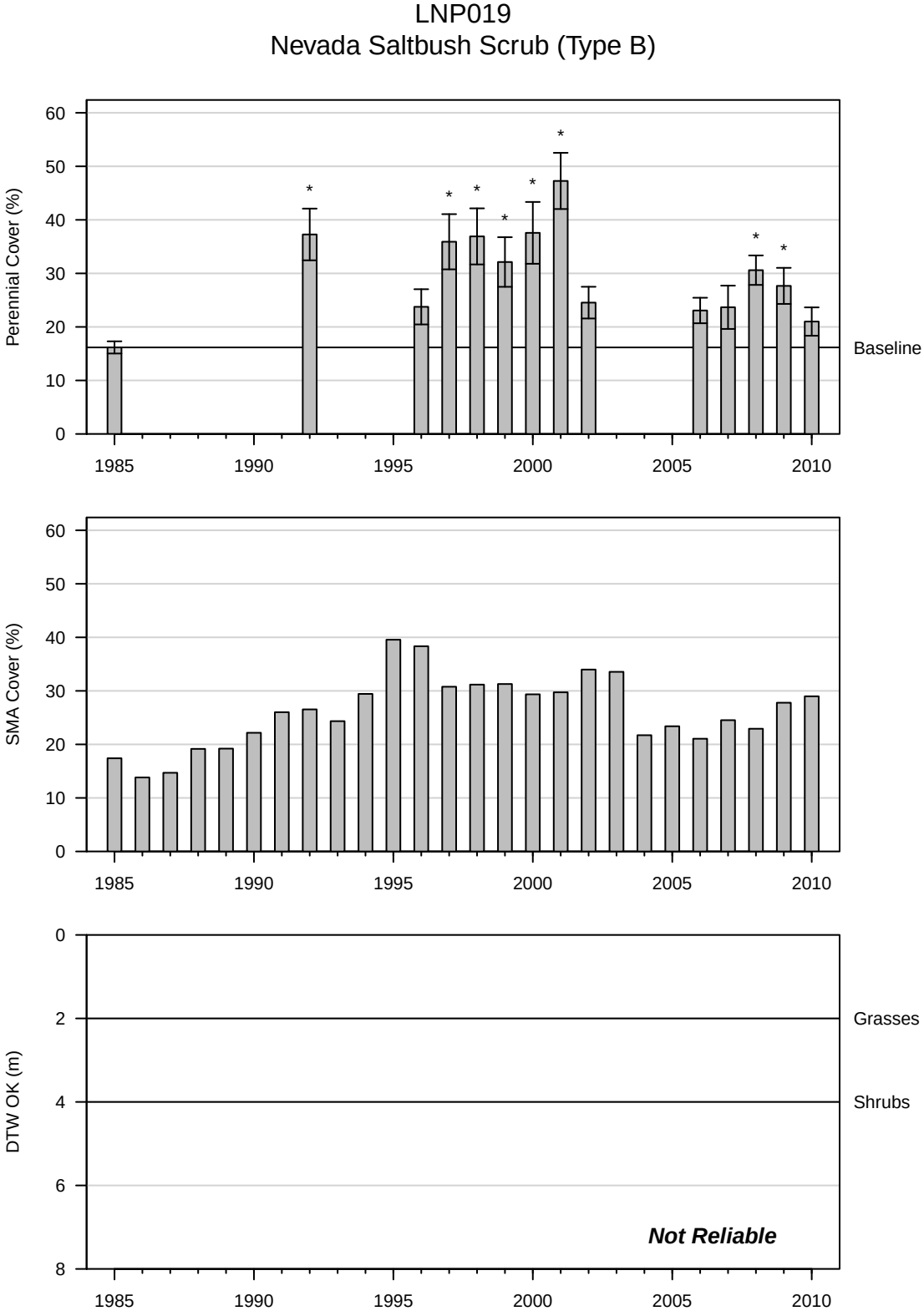


Figure 109: 2010 Control

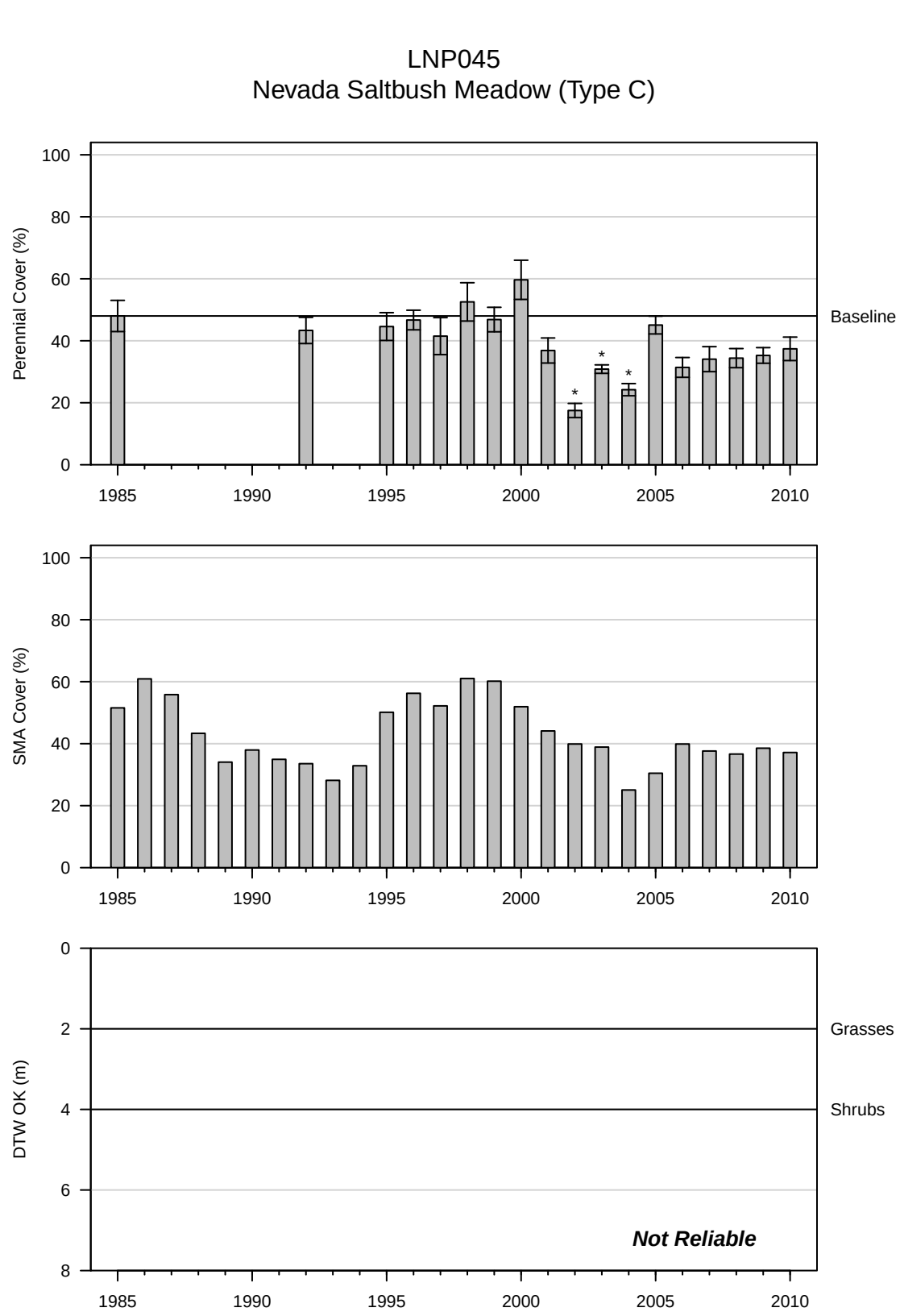


Figure 110: 2010 Wellfield

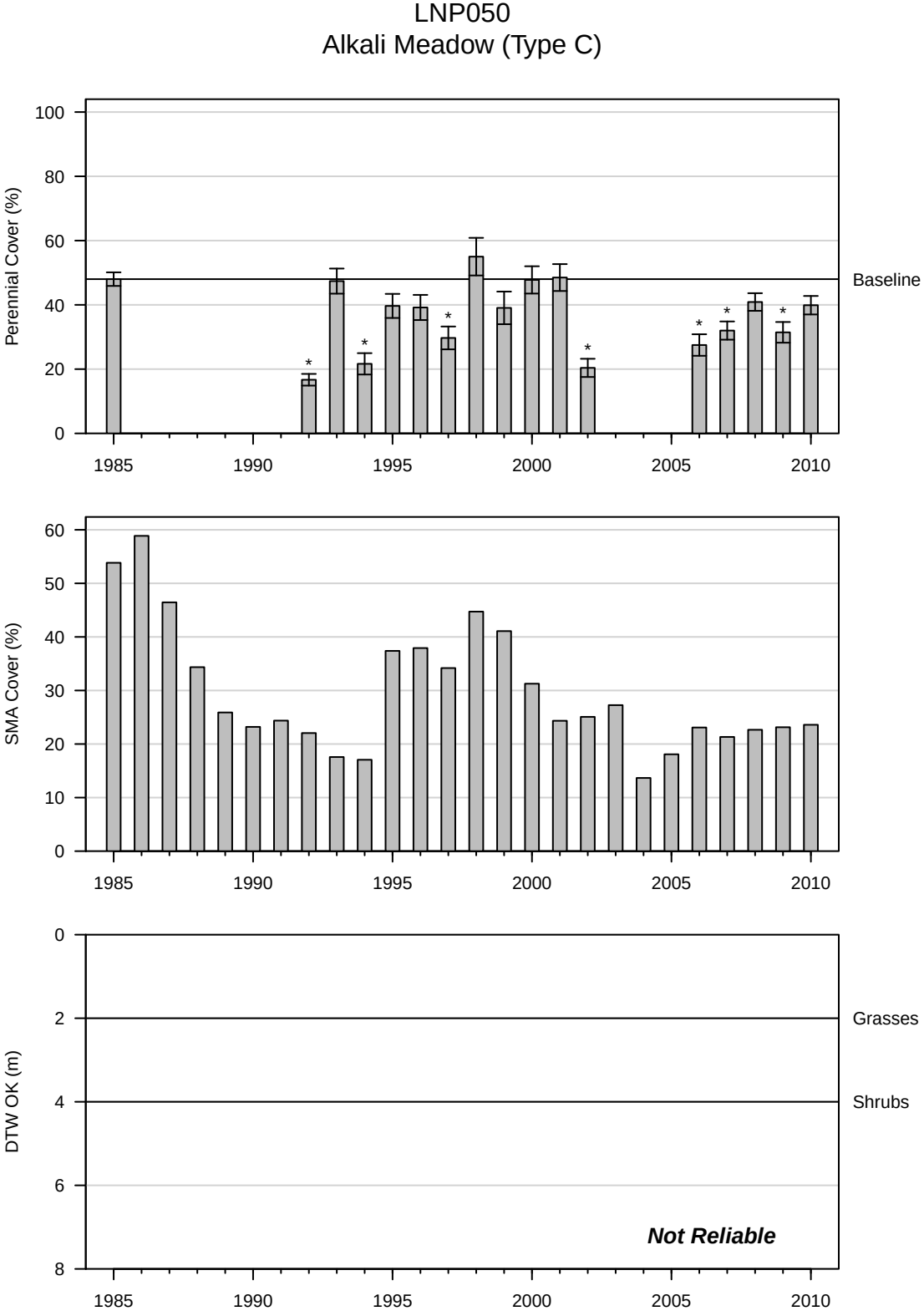


Figure 111: 2010 Control

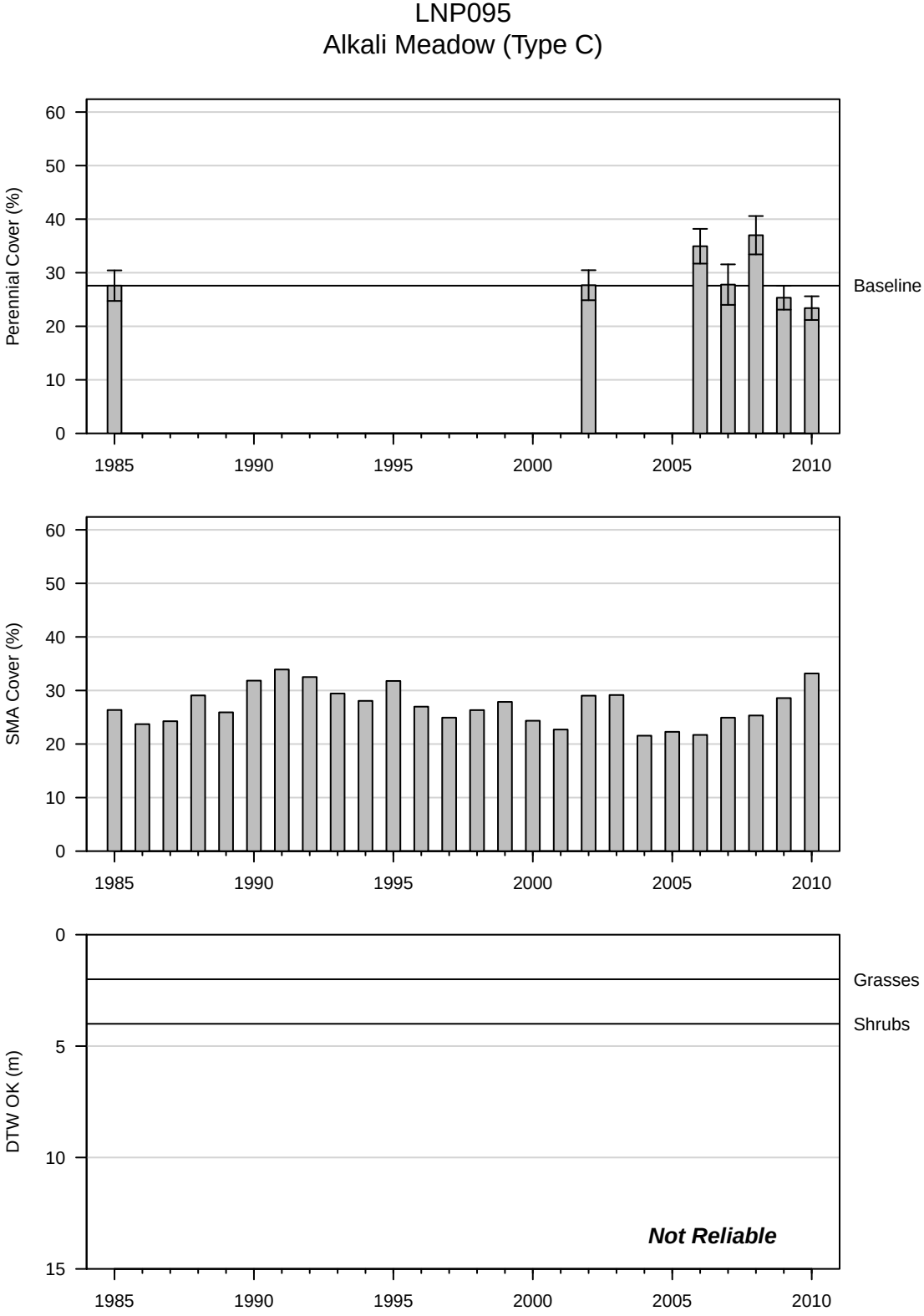


Figure 112: 2010 Control

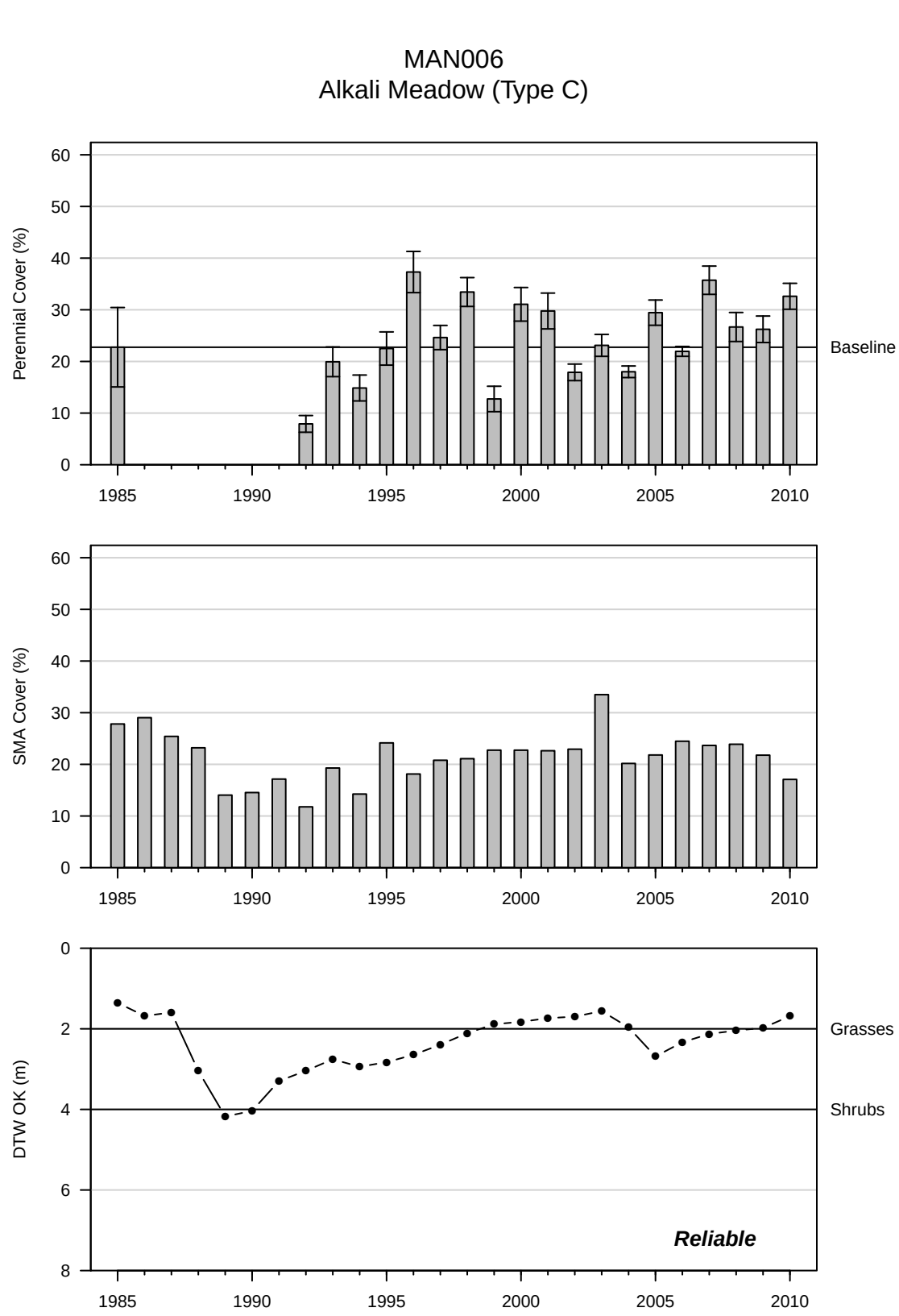


Figure 113: 2010 Wellfield

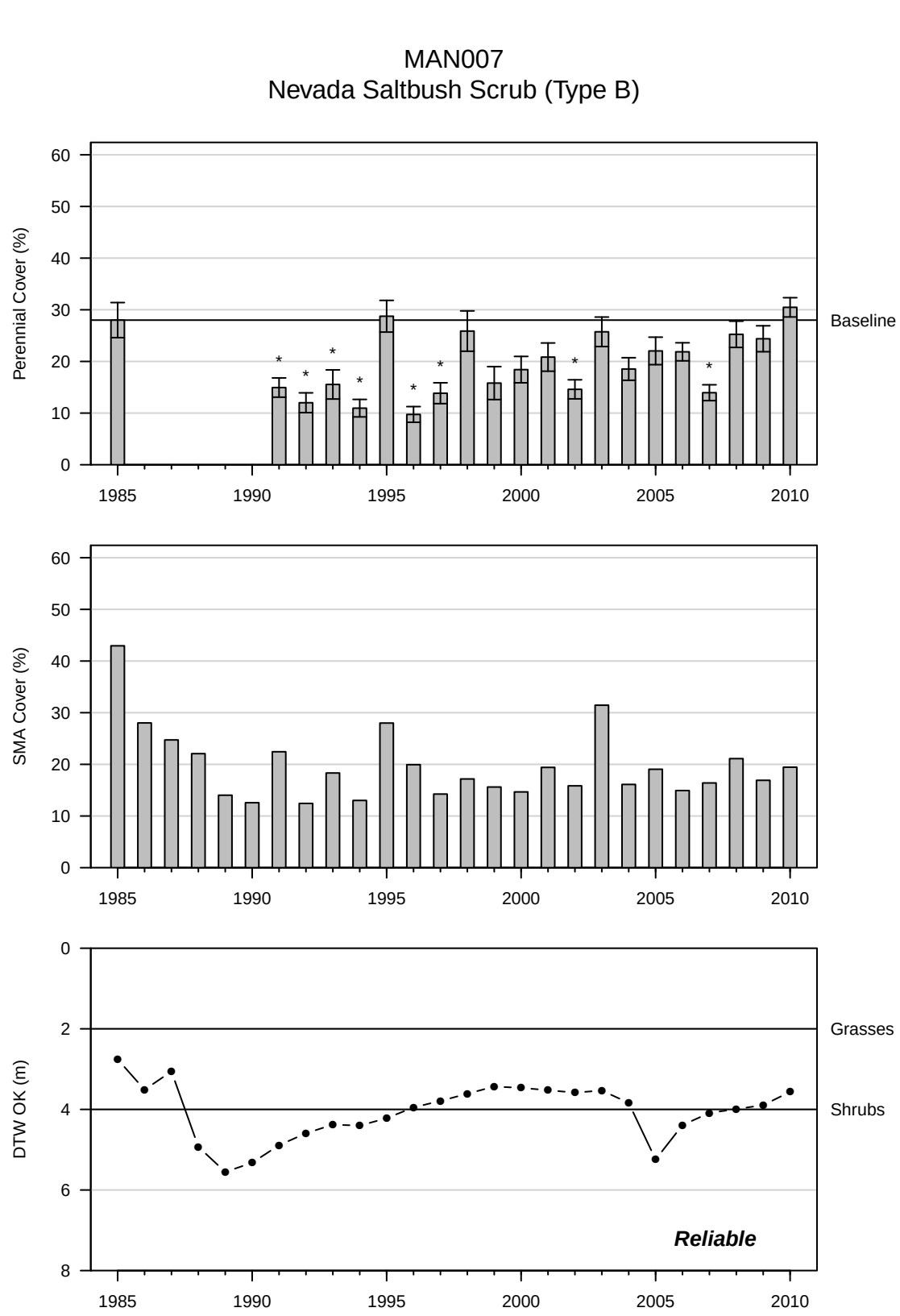


Figure 114: 2010 Wellfield

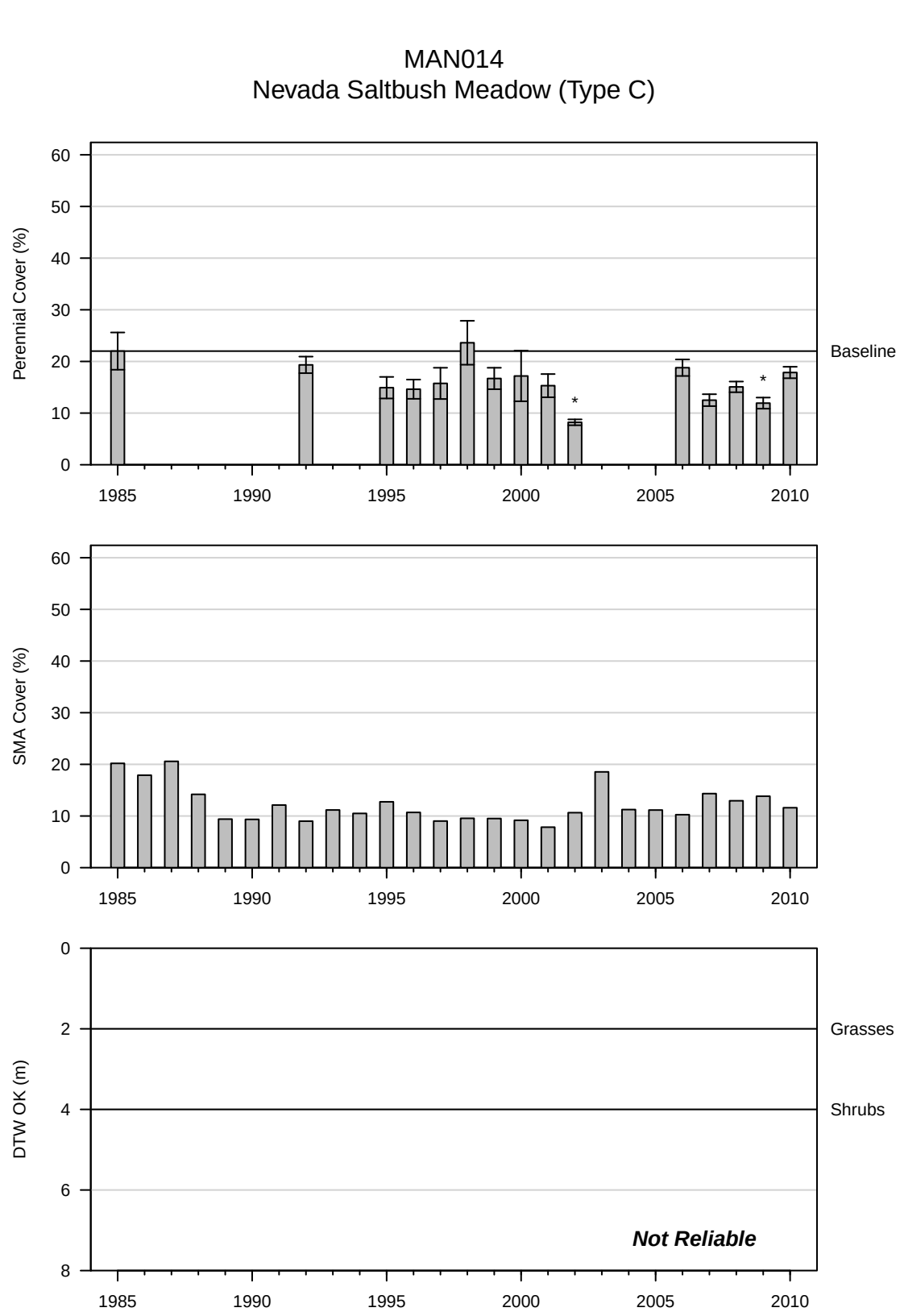


Figure 115: 2010 Control

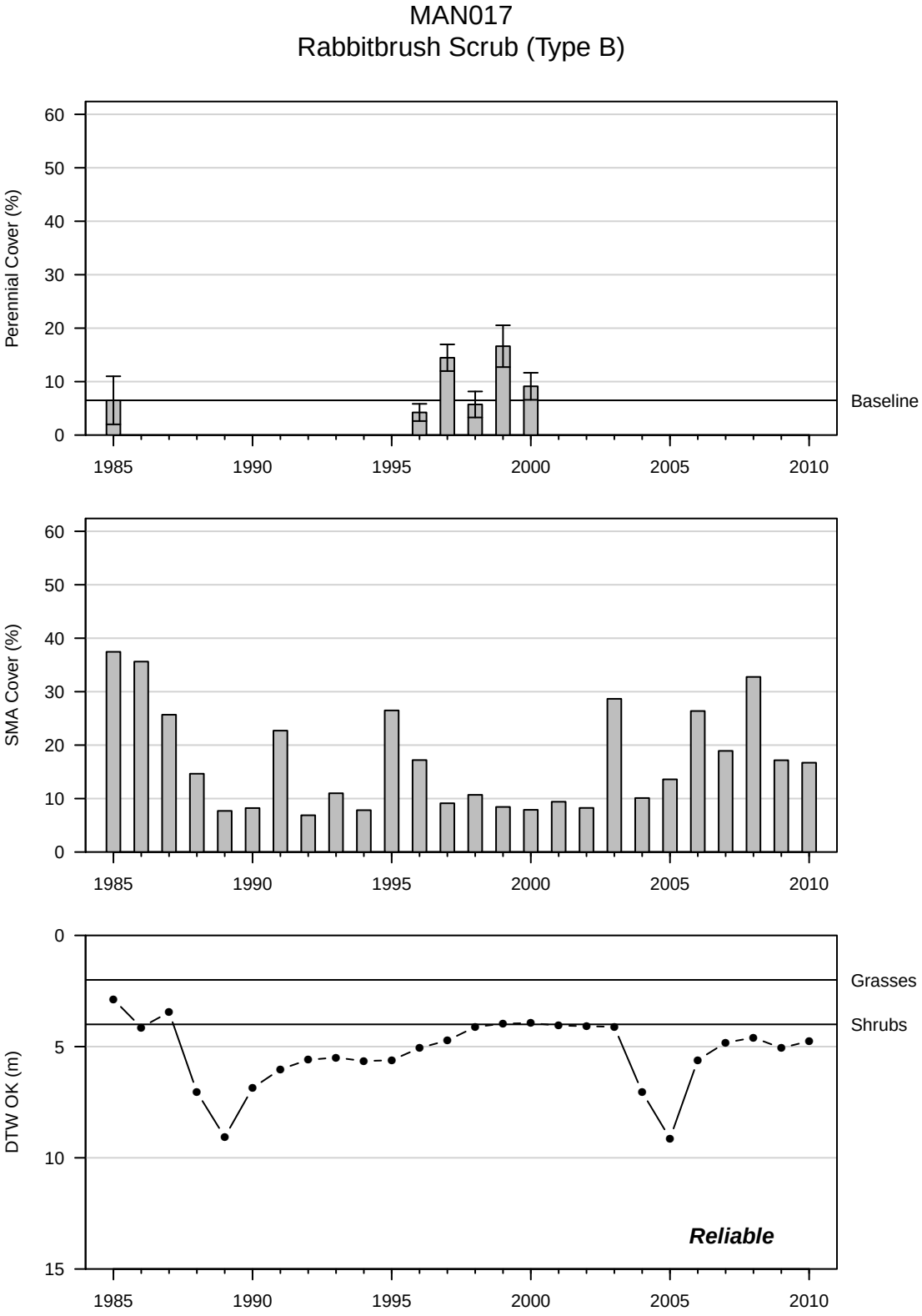


Figure 116: 2000 Wellfield

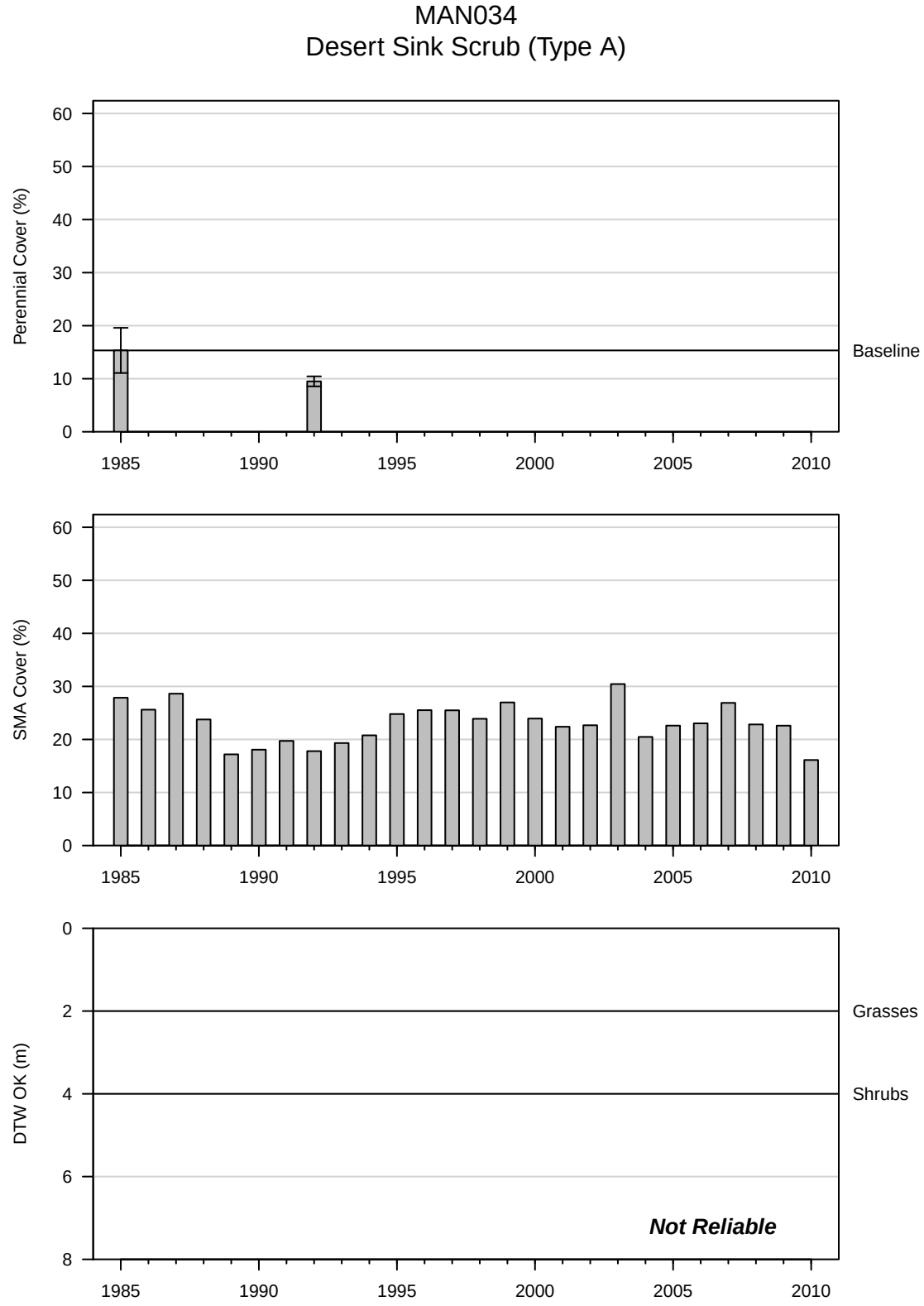


Figure 117: 1992 Wellfield

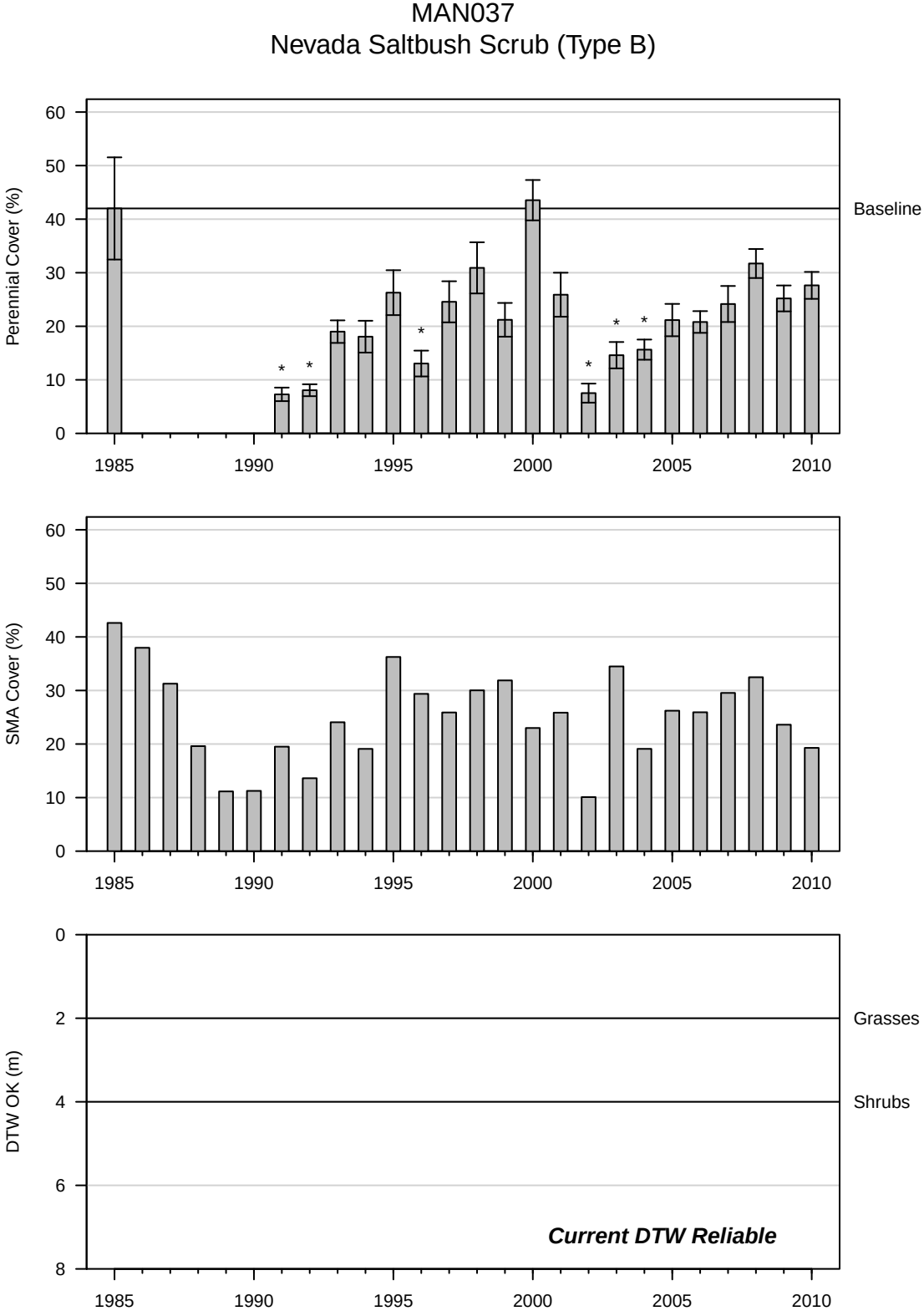


Figure 118: 2010 Wellfield

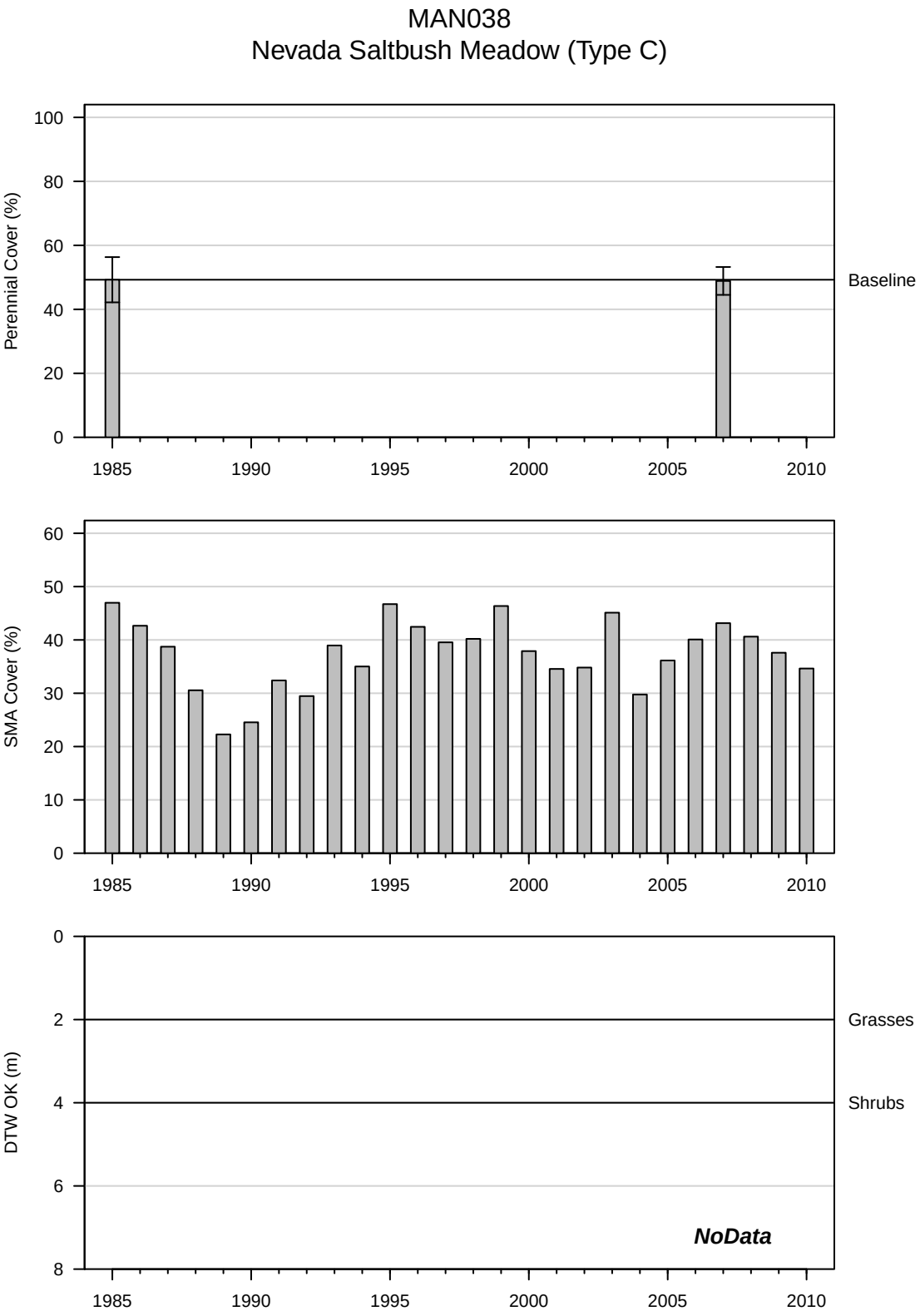


Figure 119: 2007 Wellfield

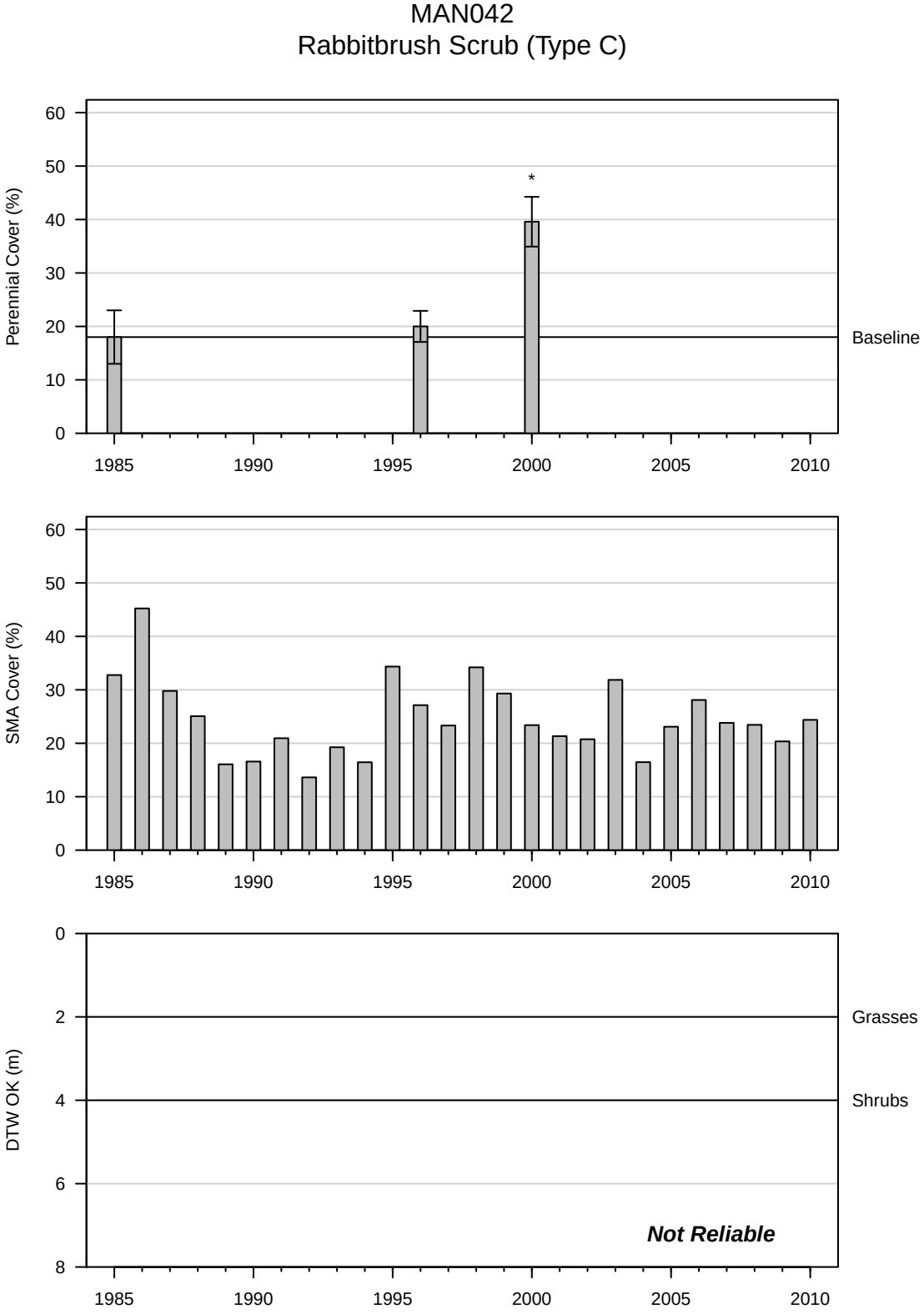


Figure 120: 2000 Wellfield

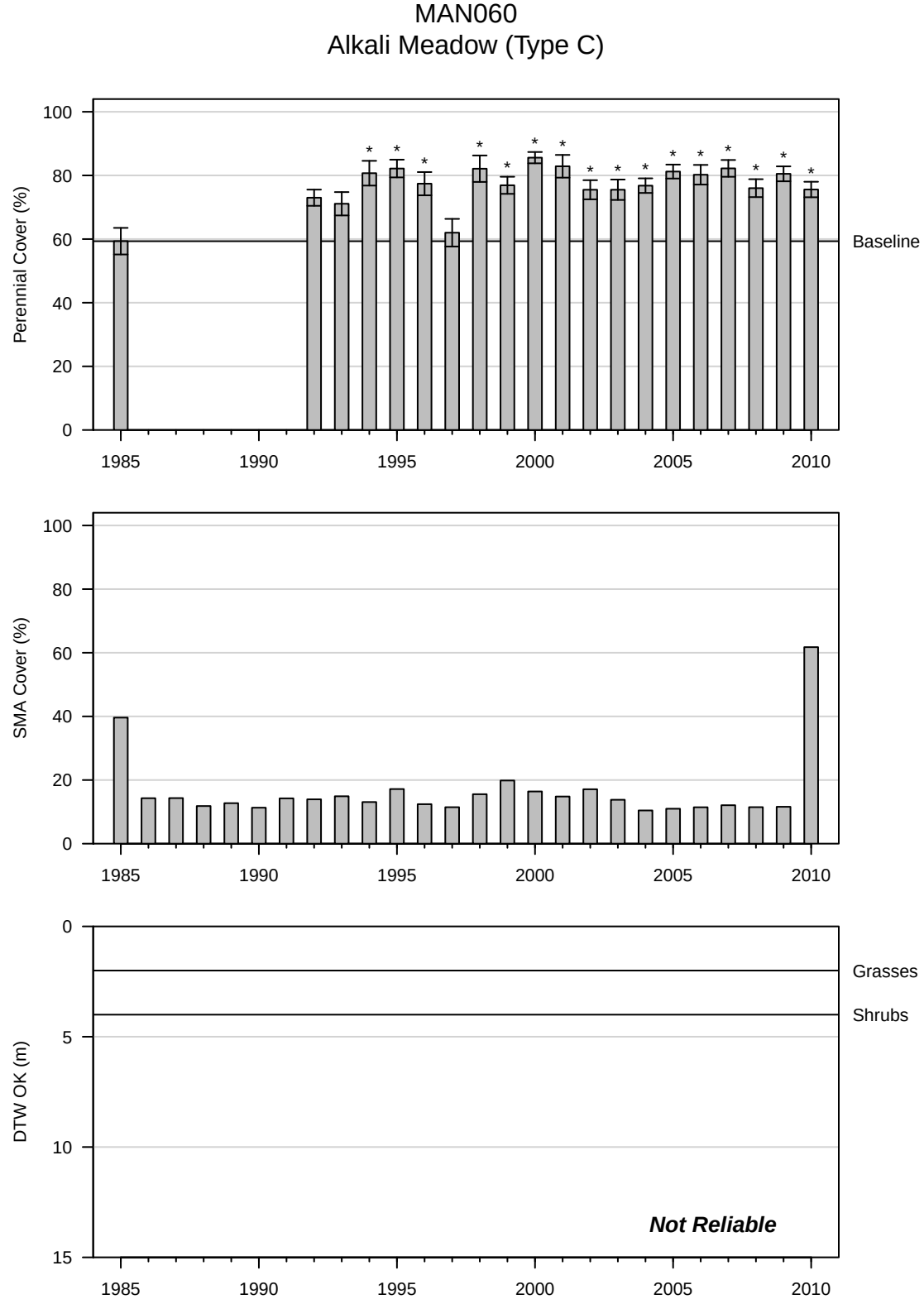


Figure 121: 2010 Control

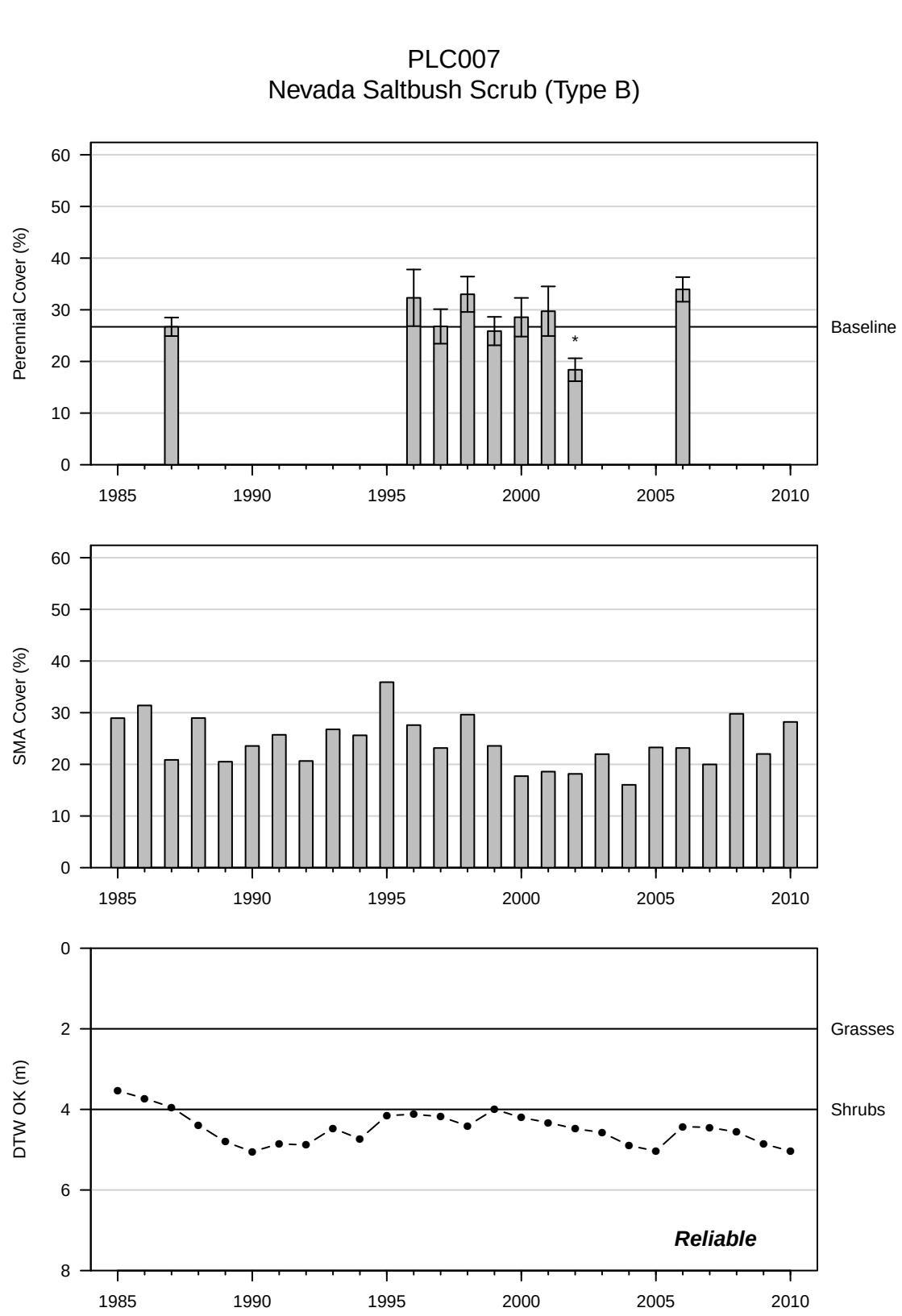


Figure 122: 2006 Wellfield

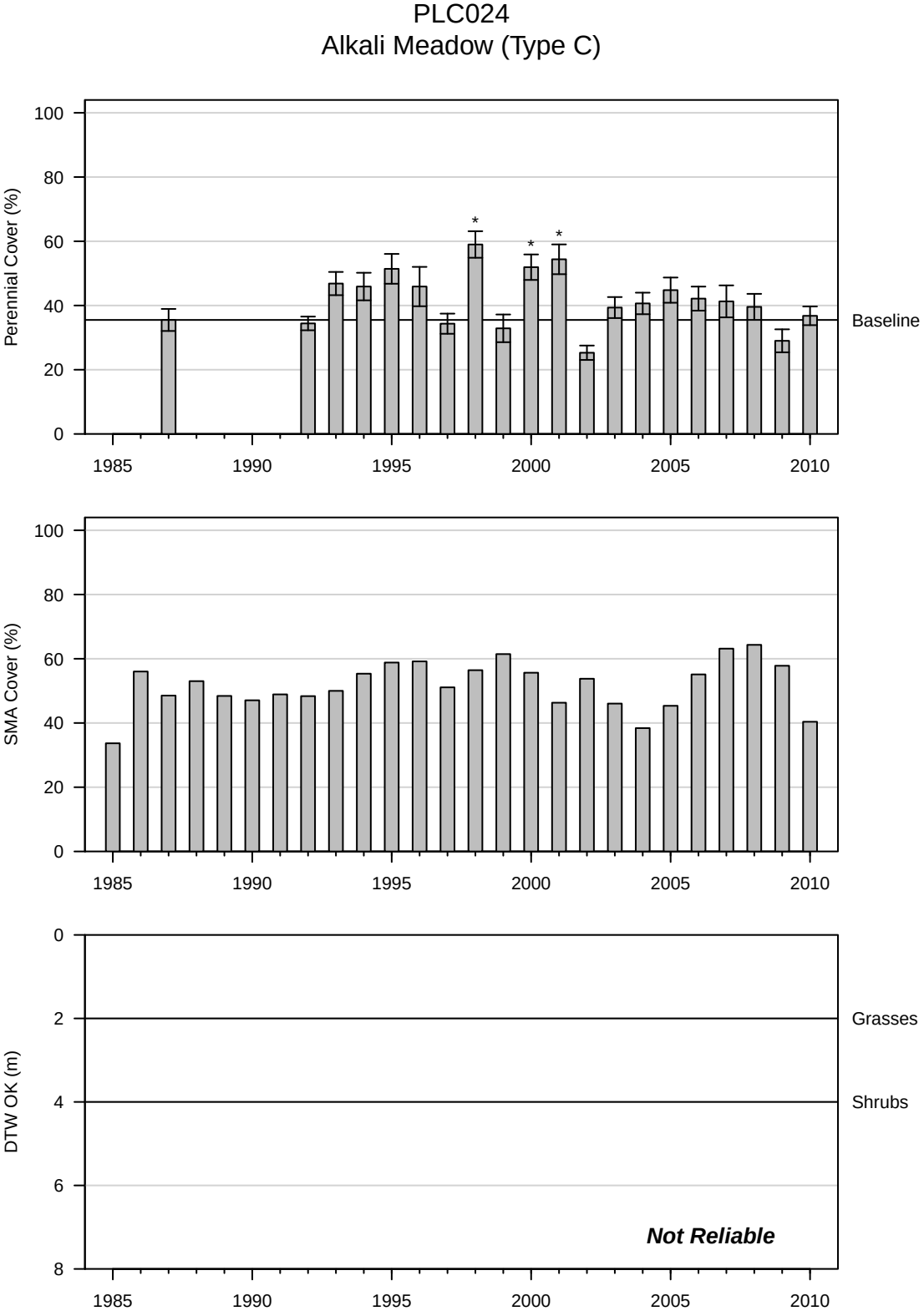


Figure 123: 2010 Control

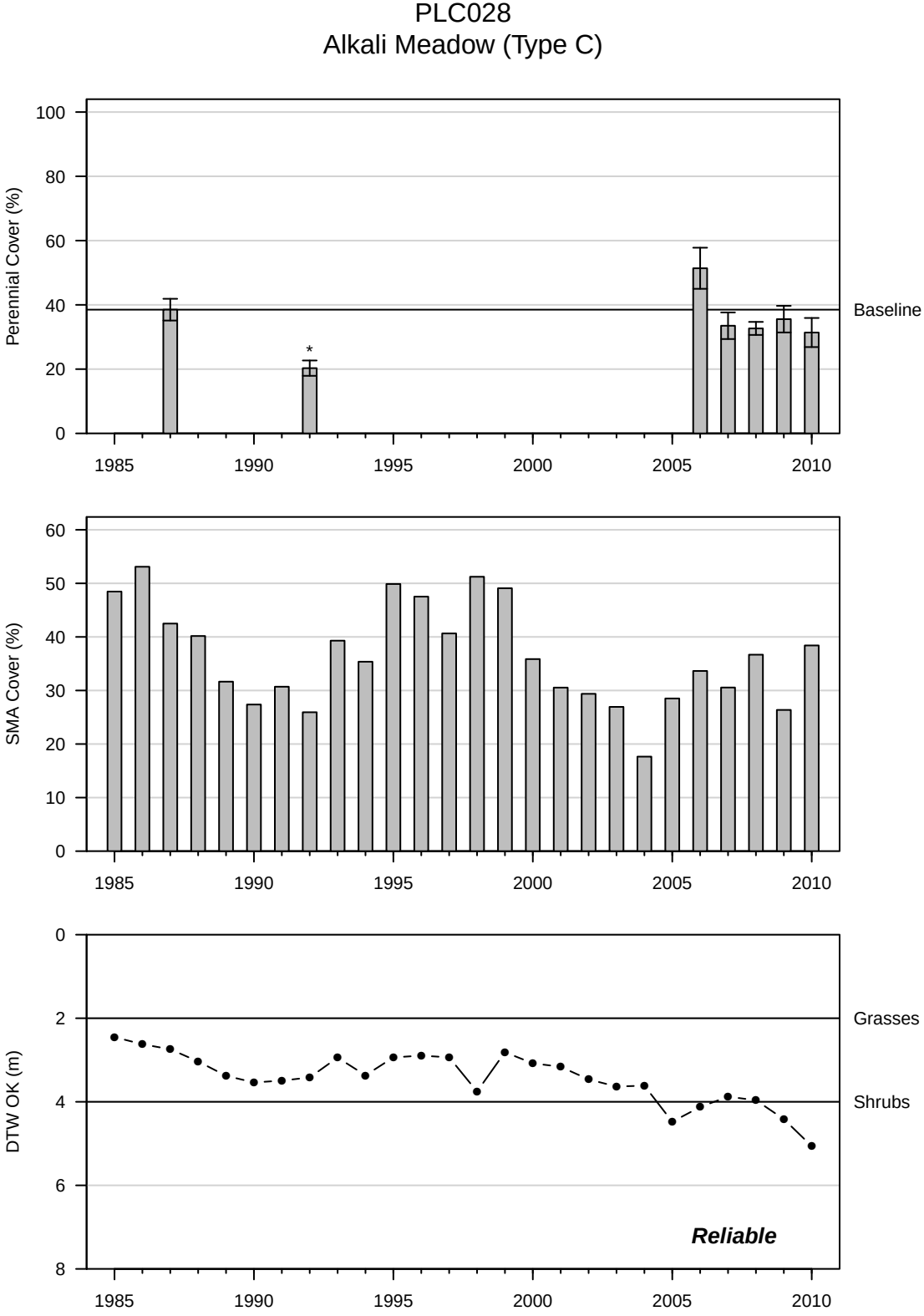


Figure 124: 2010 Control

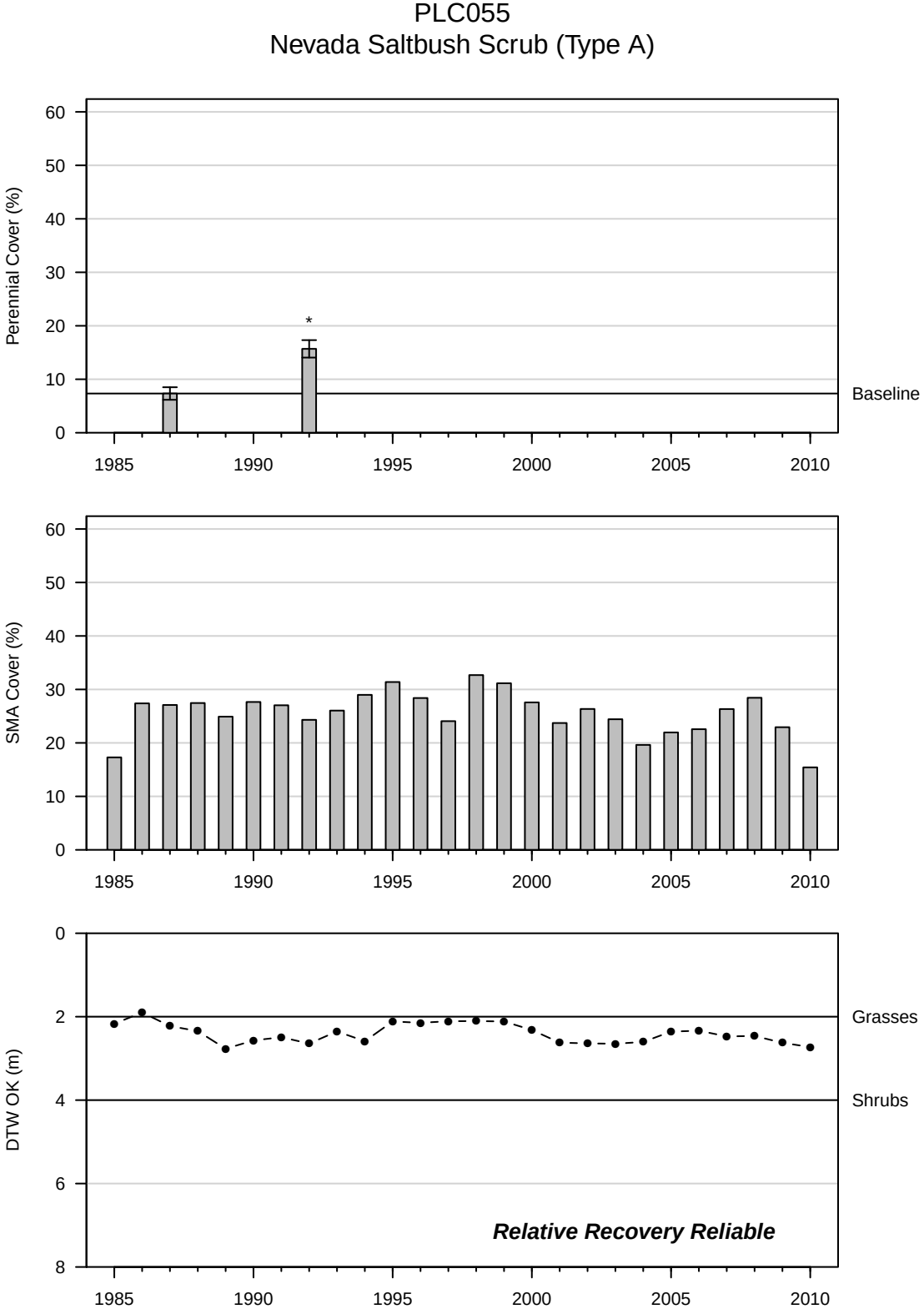


Figure 125: 1992 Control

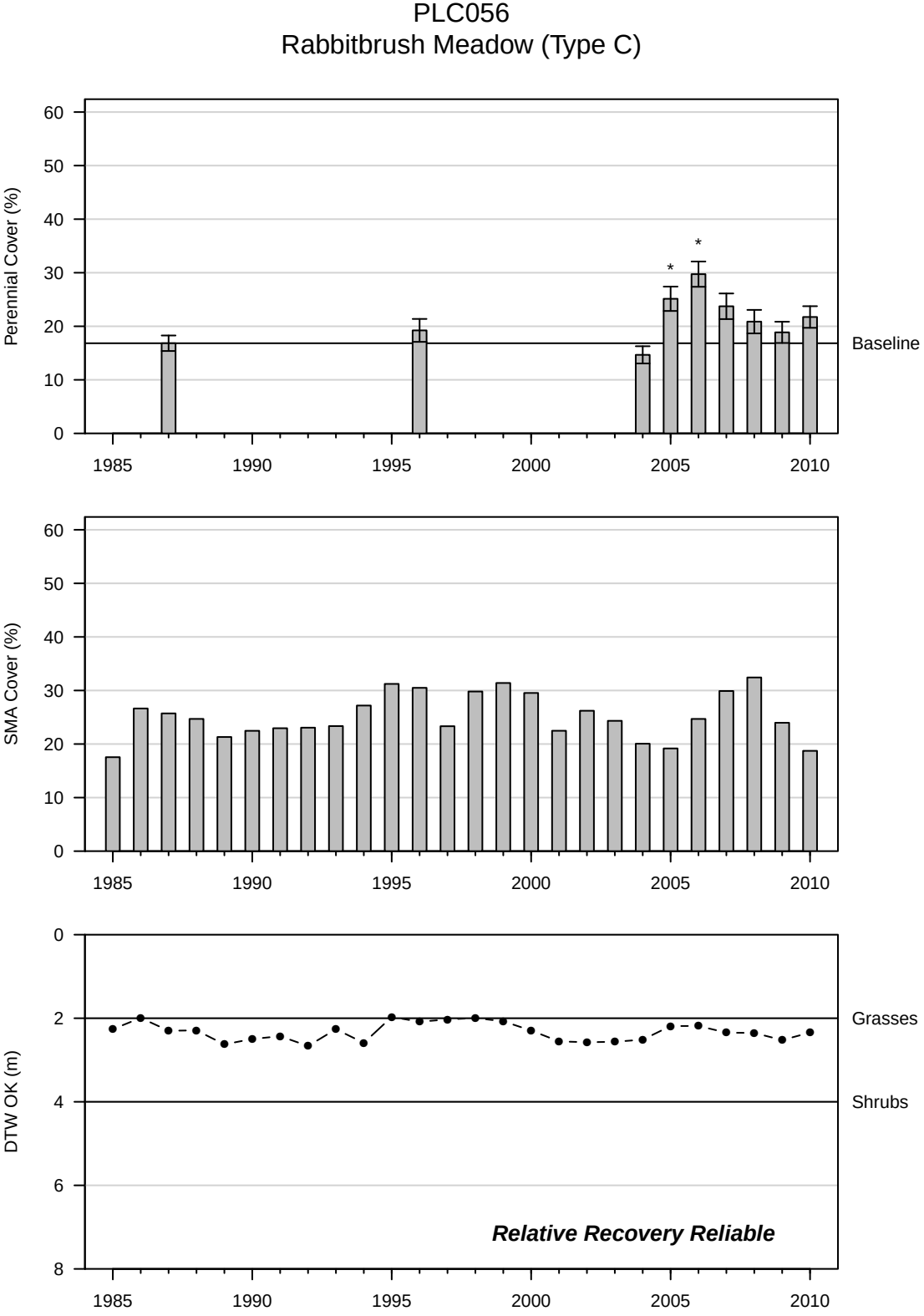


Figure 126: 2010 Control

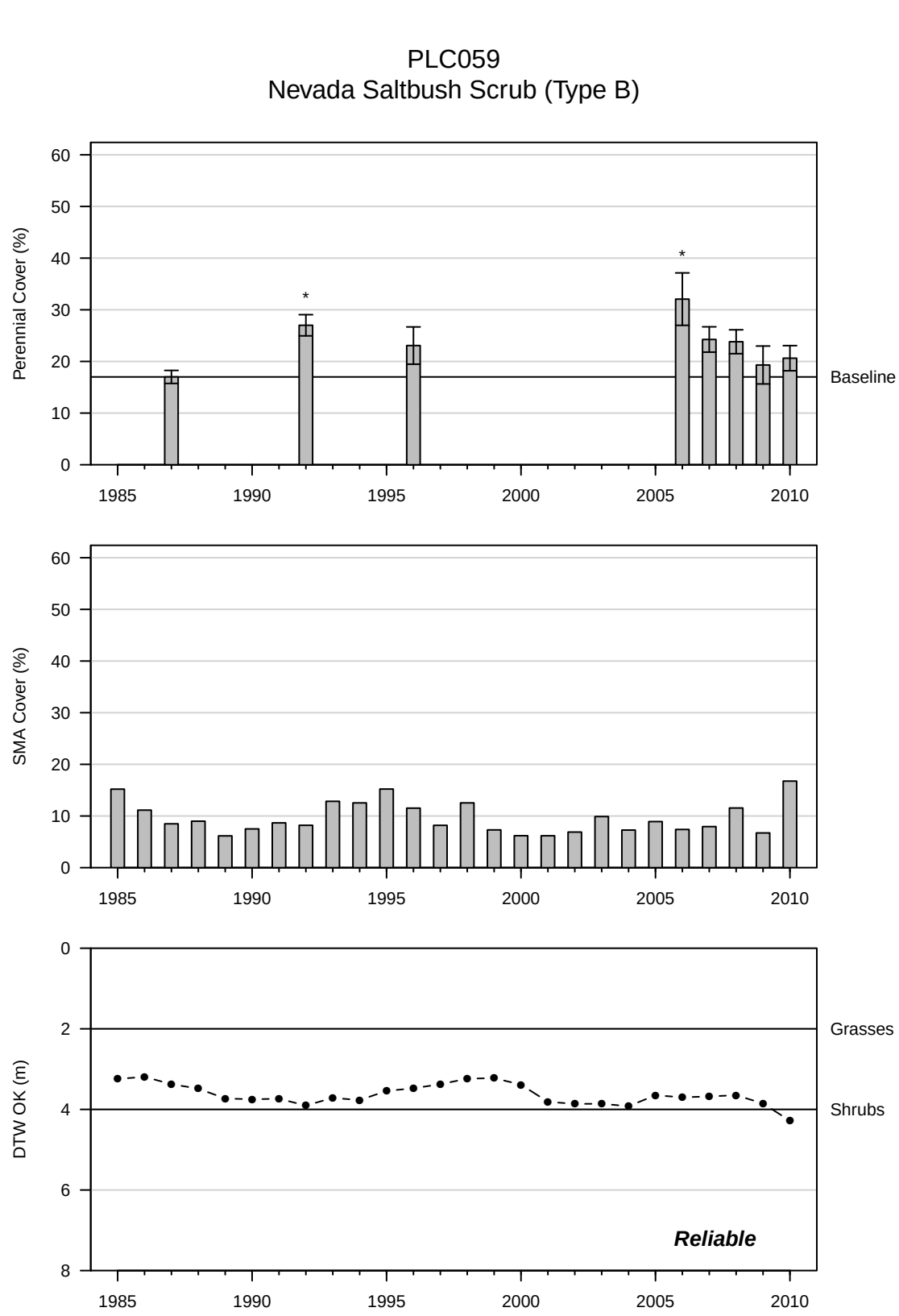


Figure 127: 2010 Control

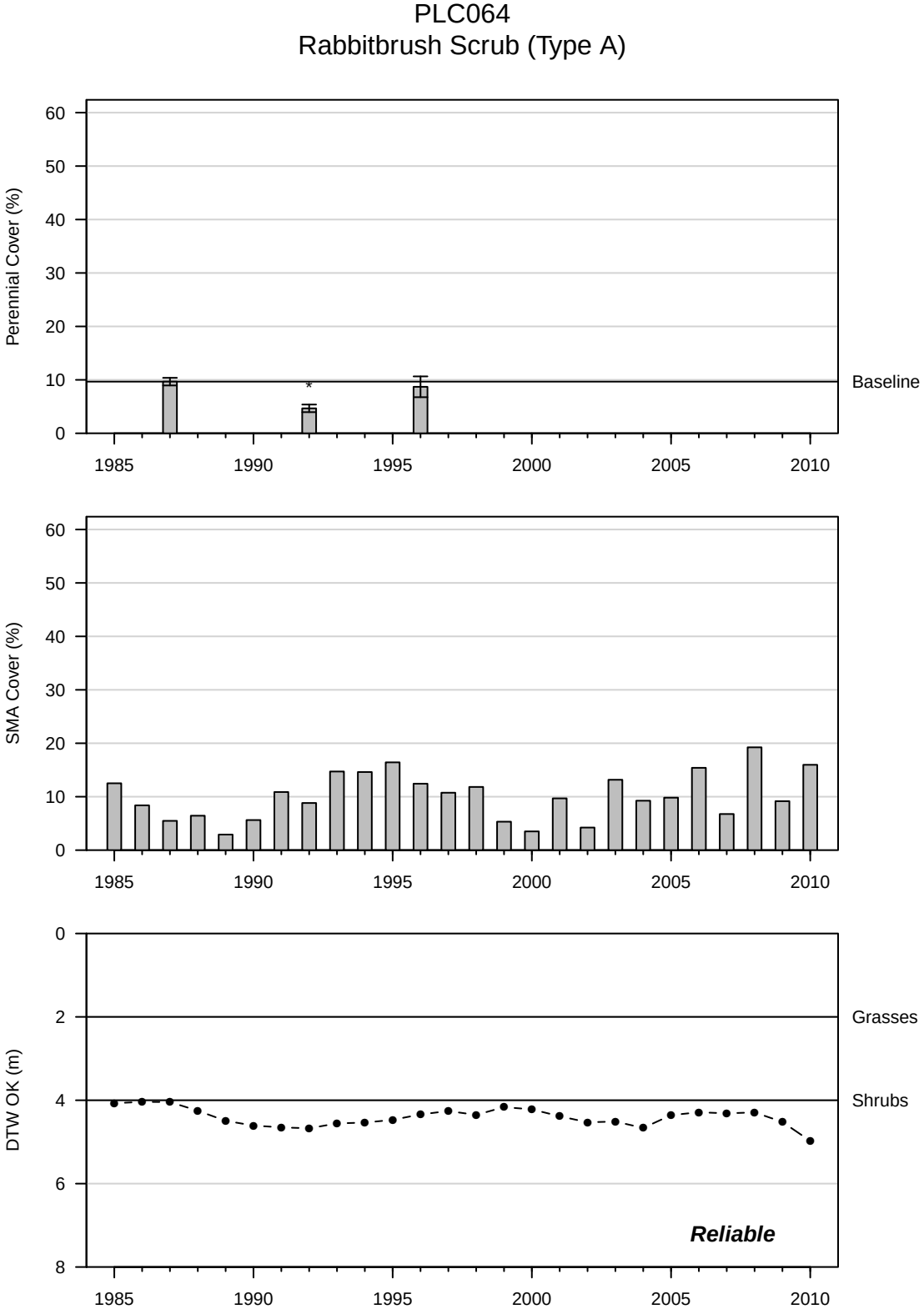


Figure 128: 1996 Control

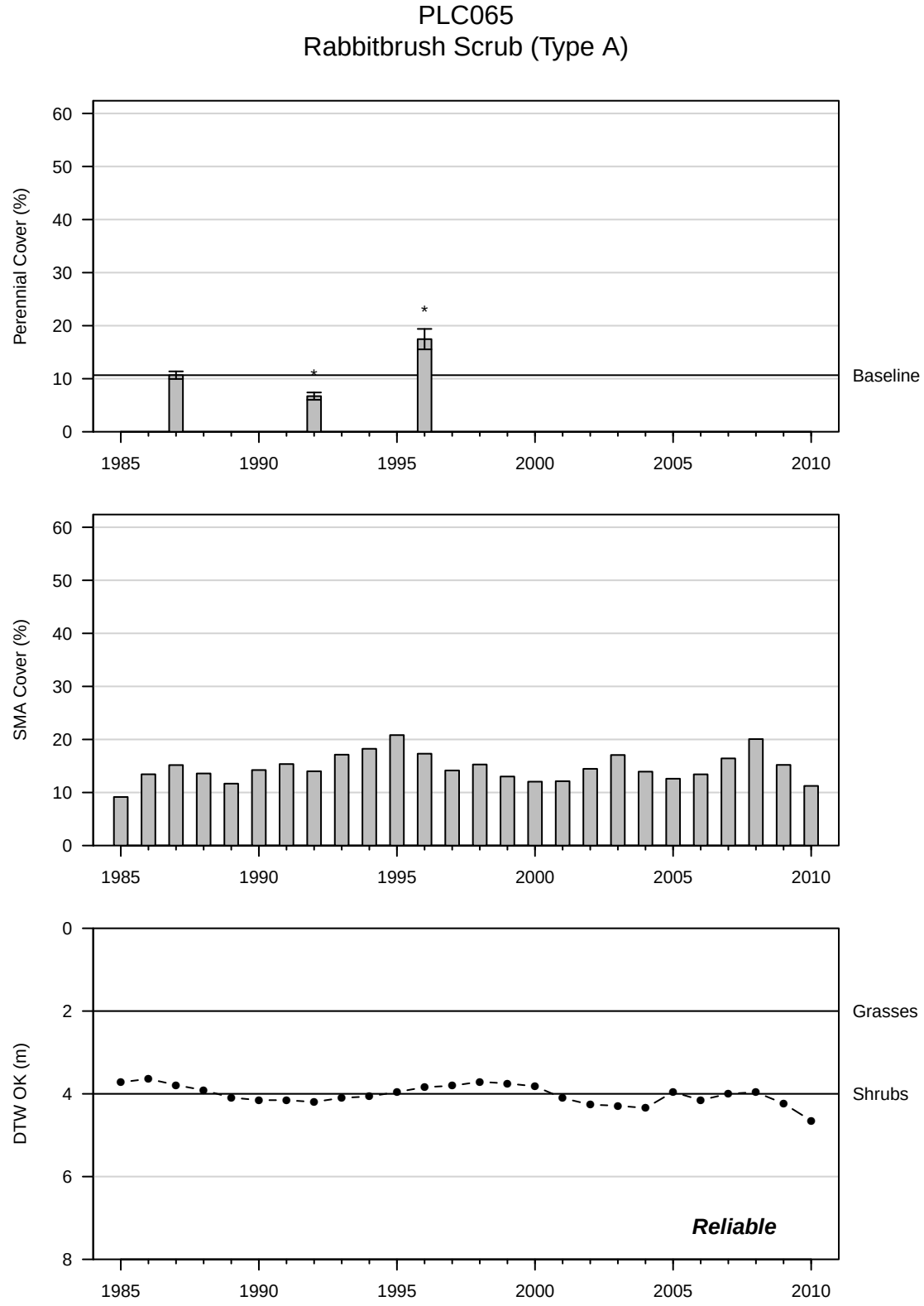


Figure 129: 1996 Control

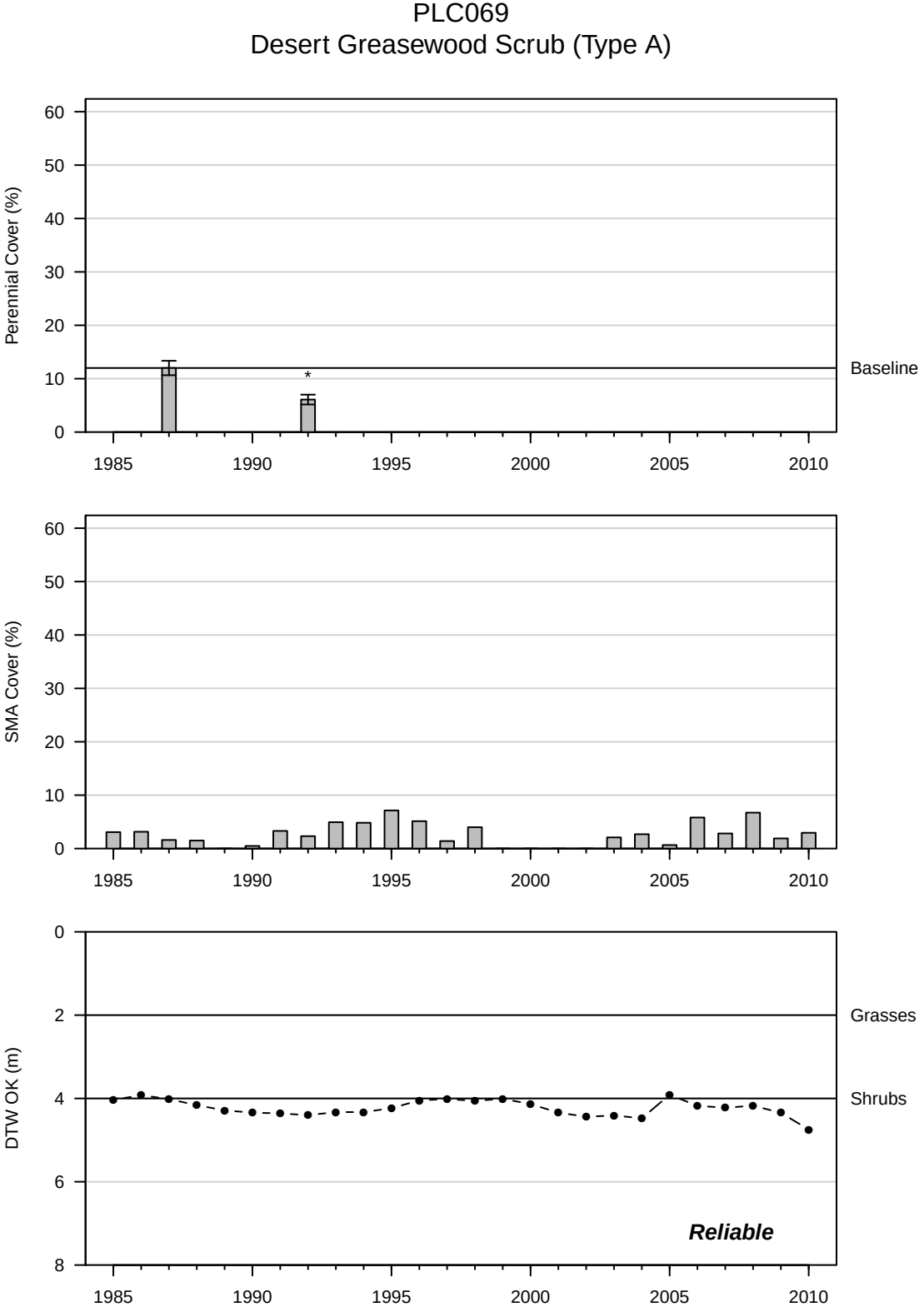


Figure 130: 1992 Control

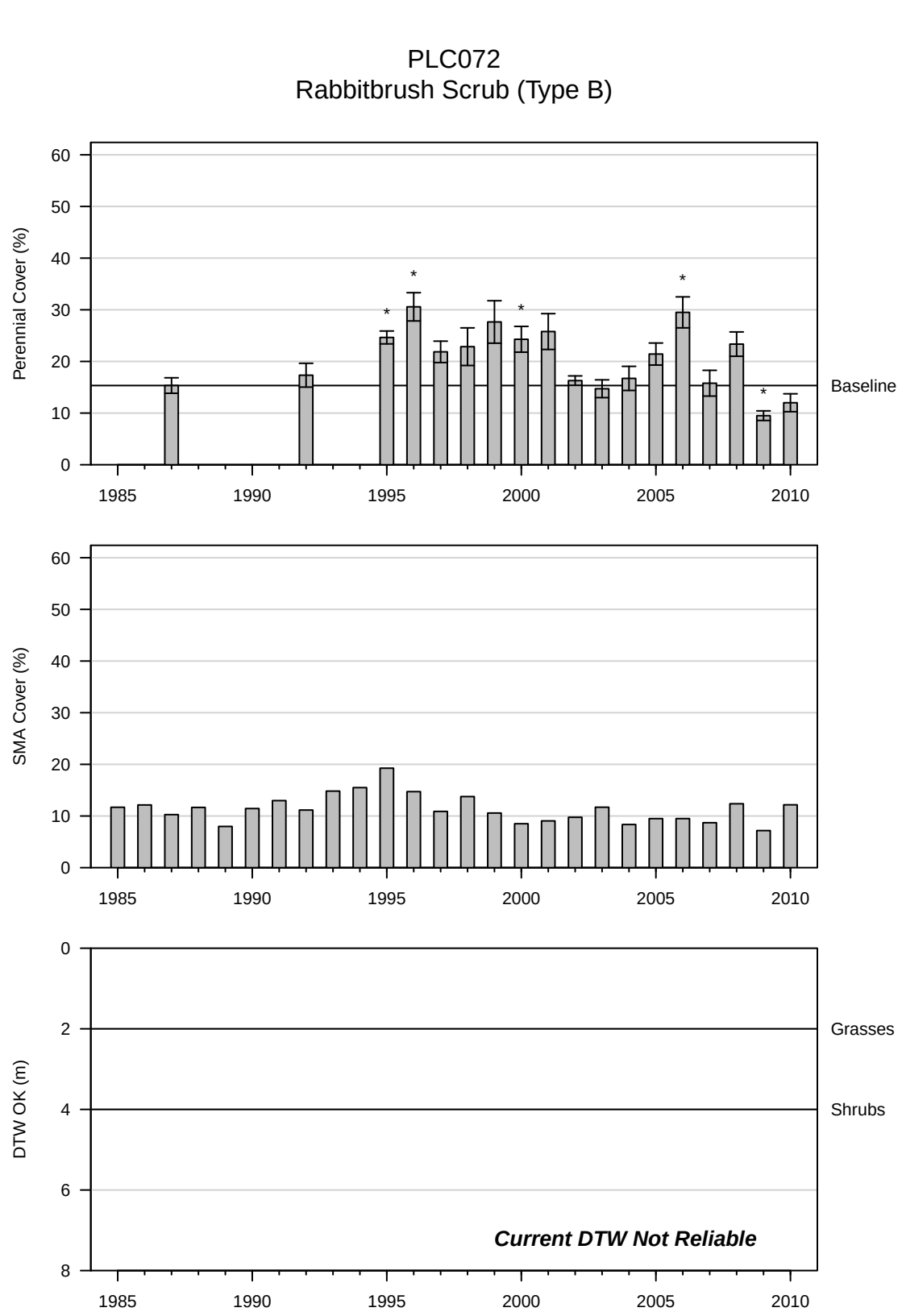


Figure 131: 2010 Control

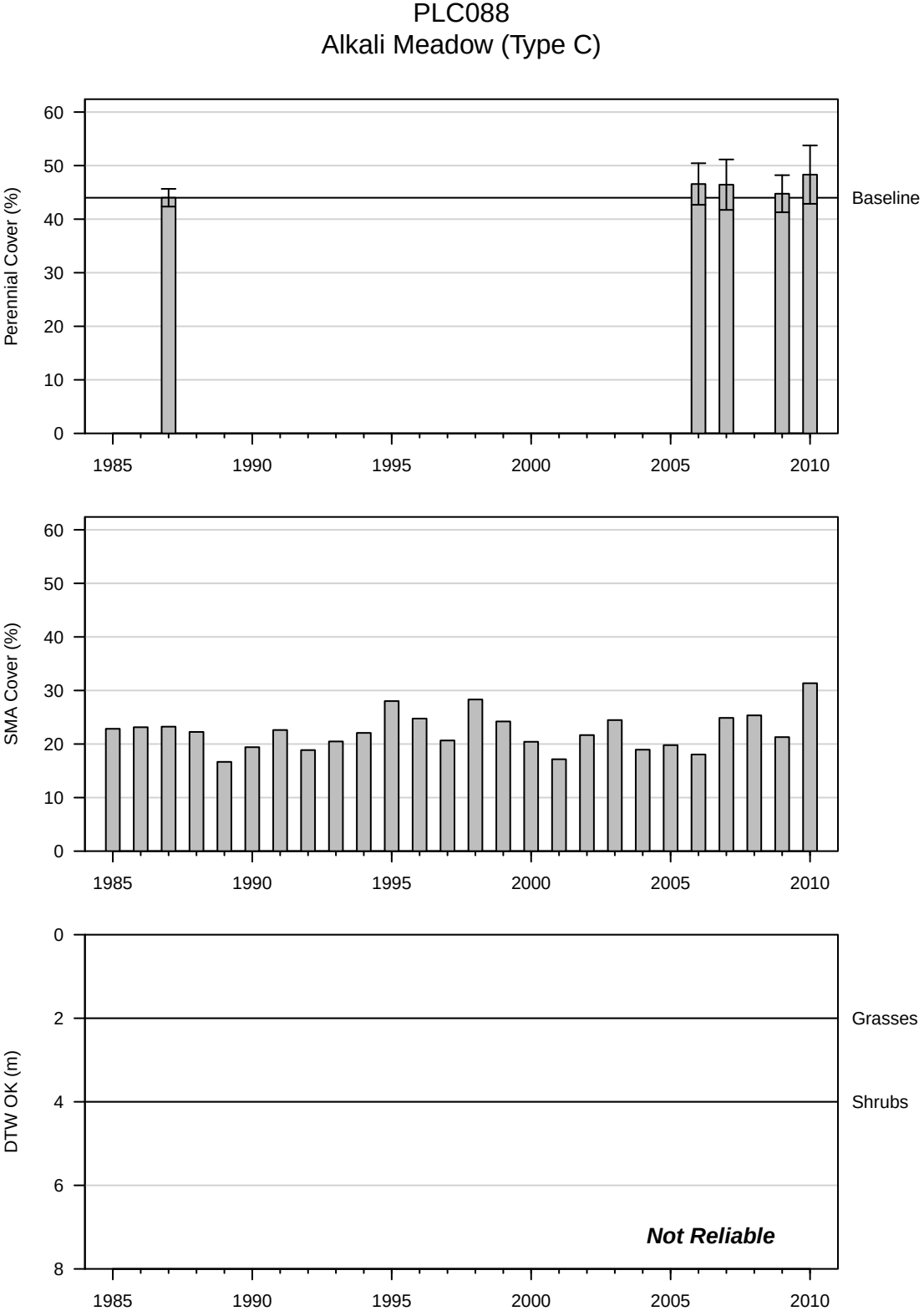


Figure 132: 2010 Control

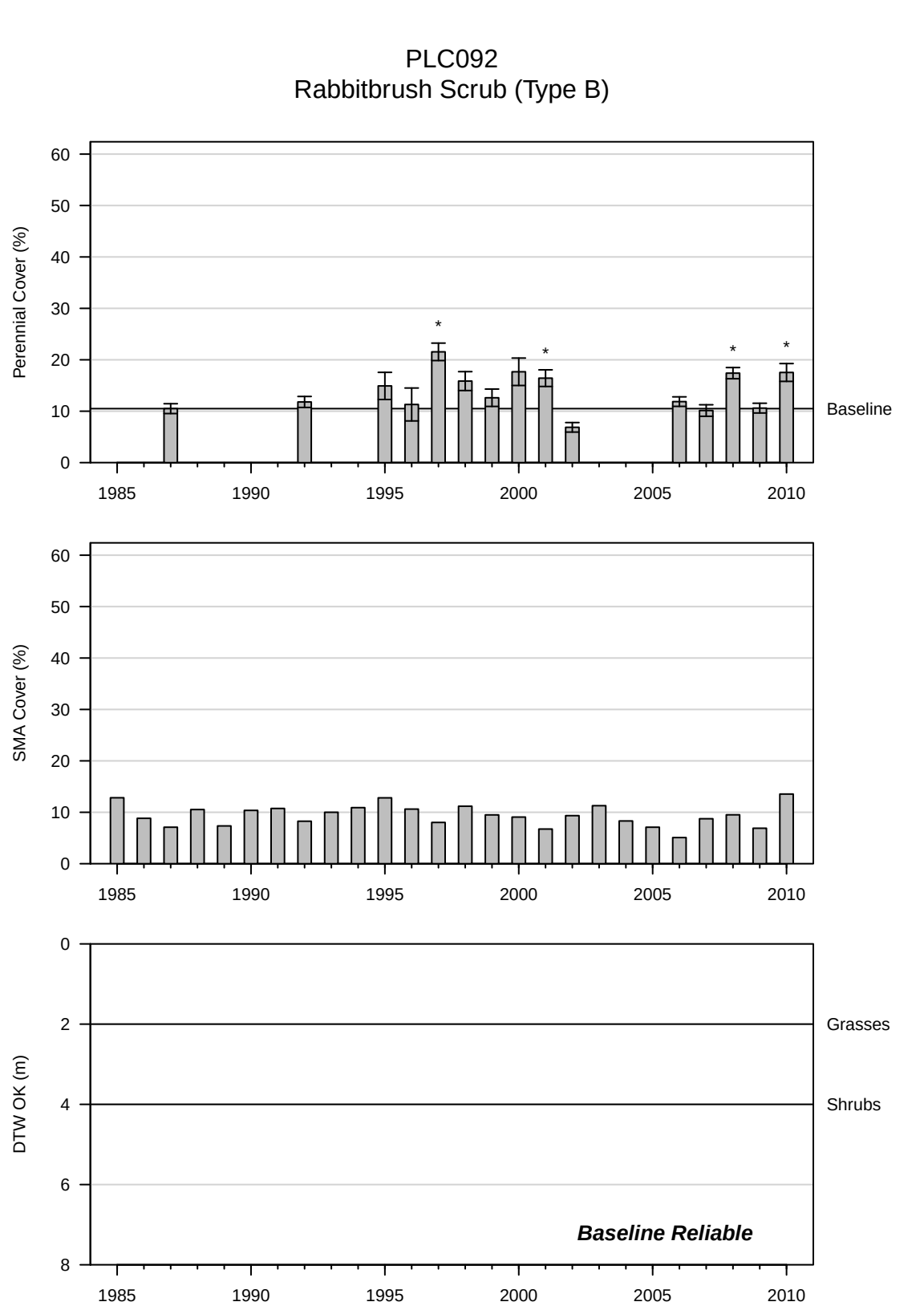


Figure 133: 2010 Control

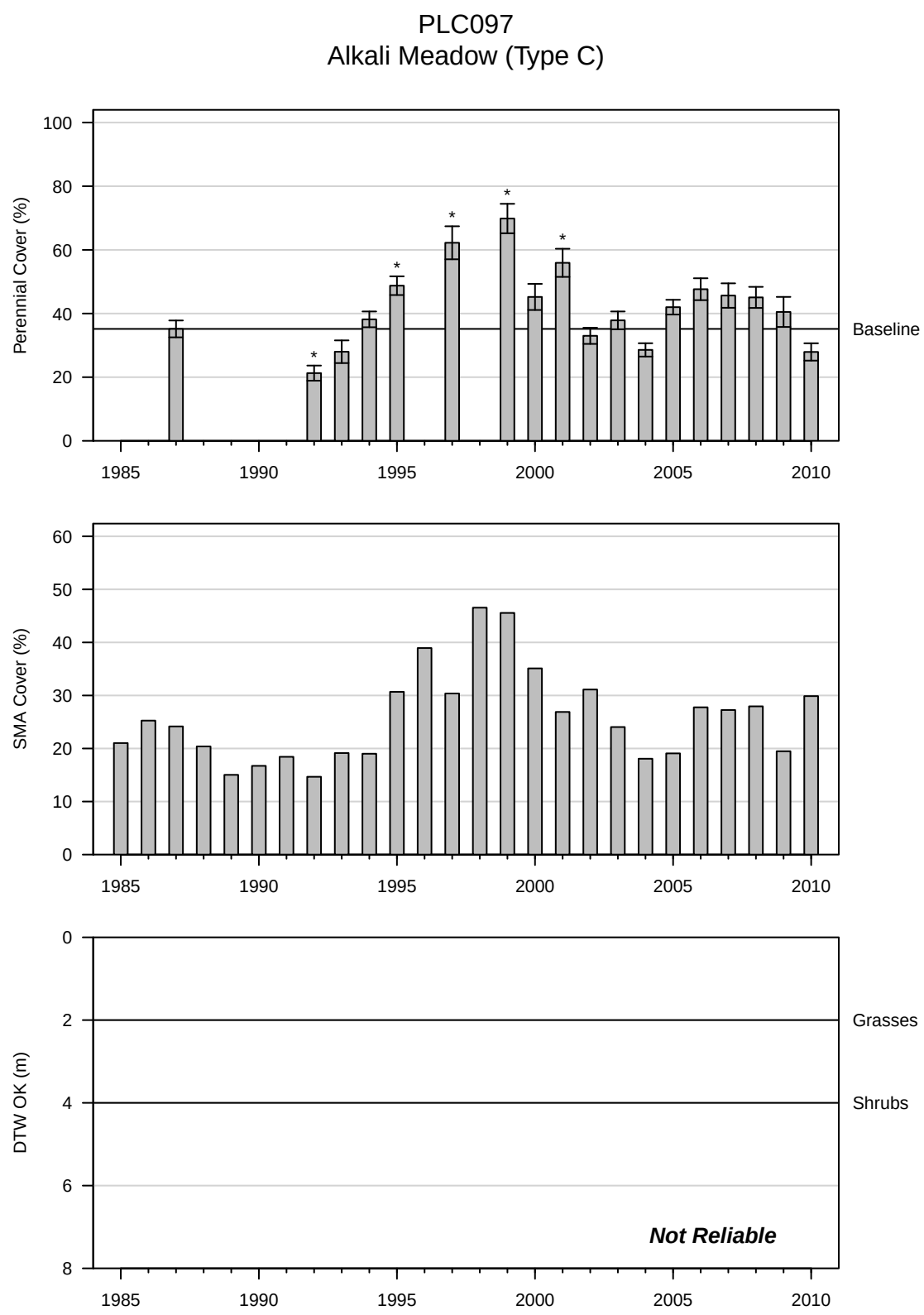


Figure 134: 2010 Control

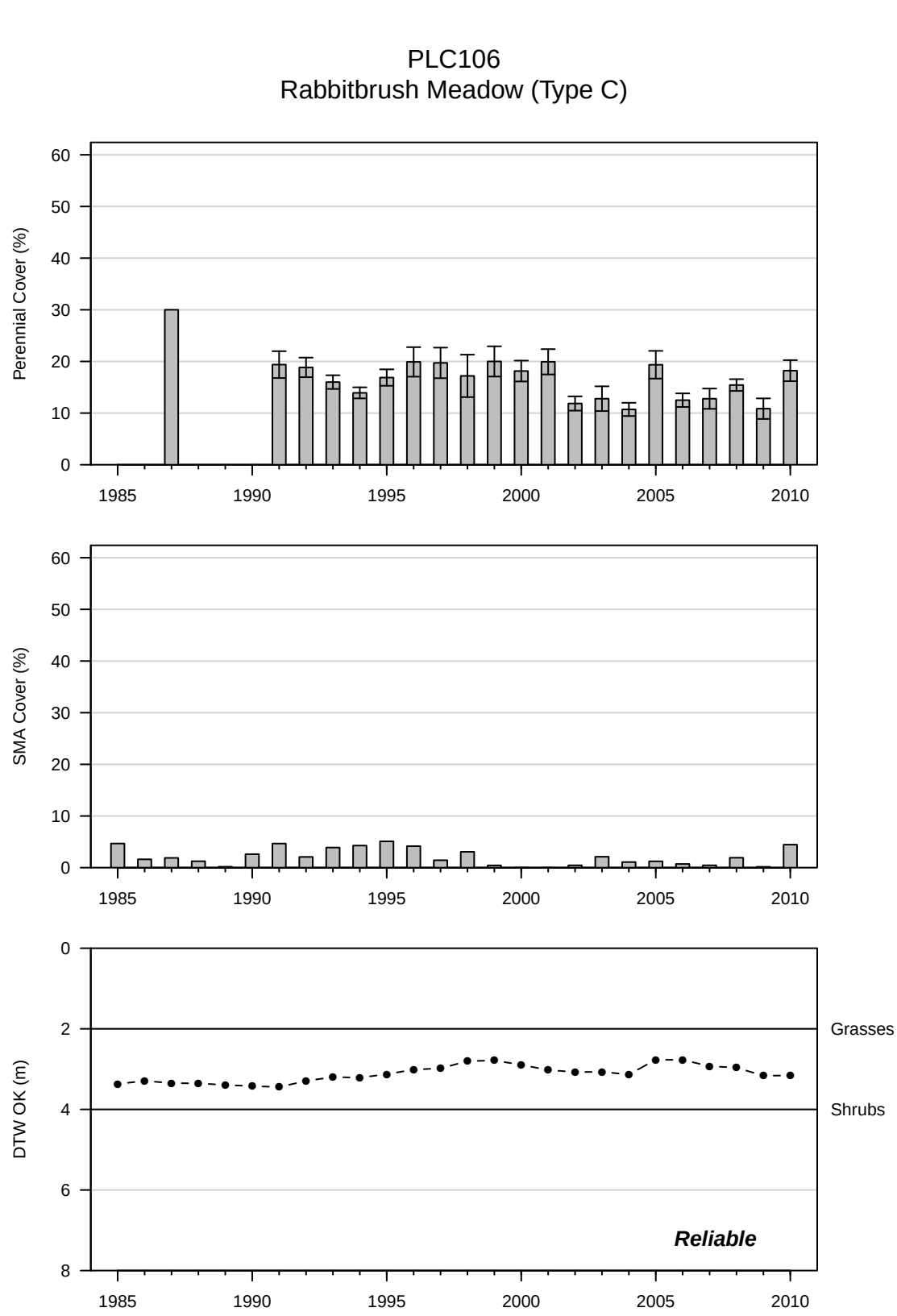


Figure 135: 2010 Control

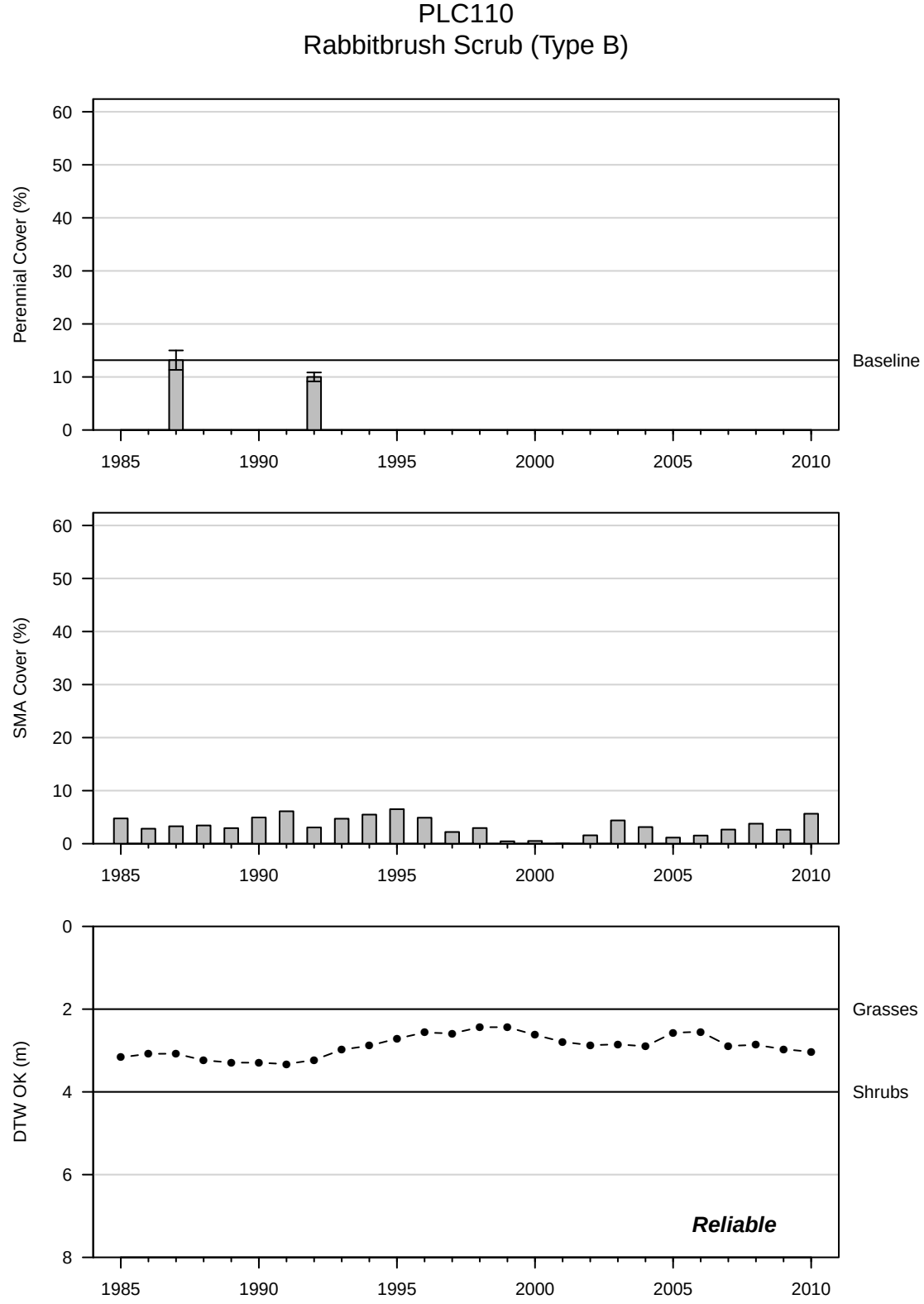


Figure 136: 1992 Control

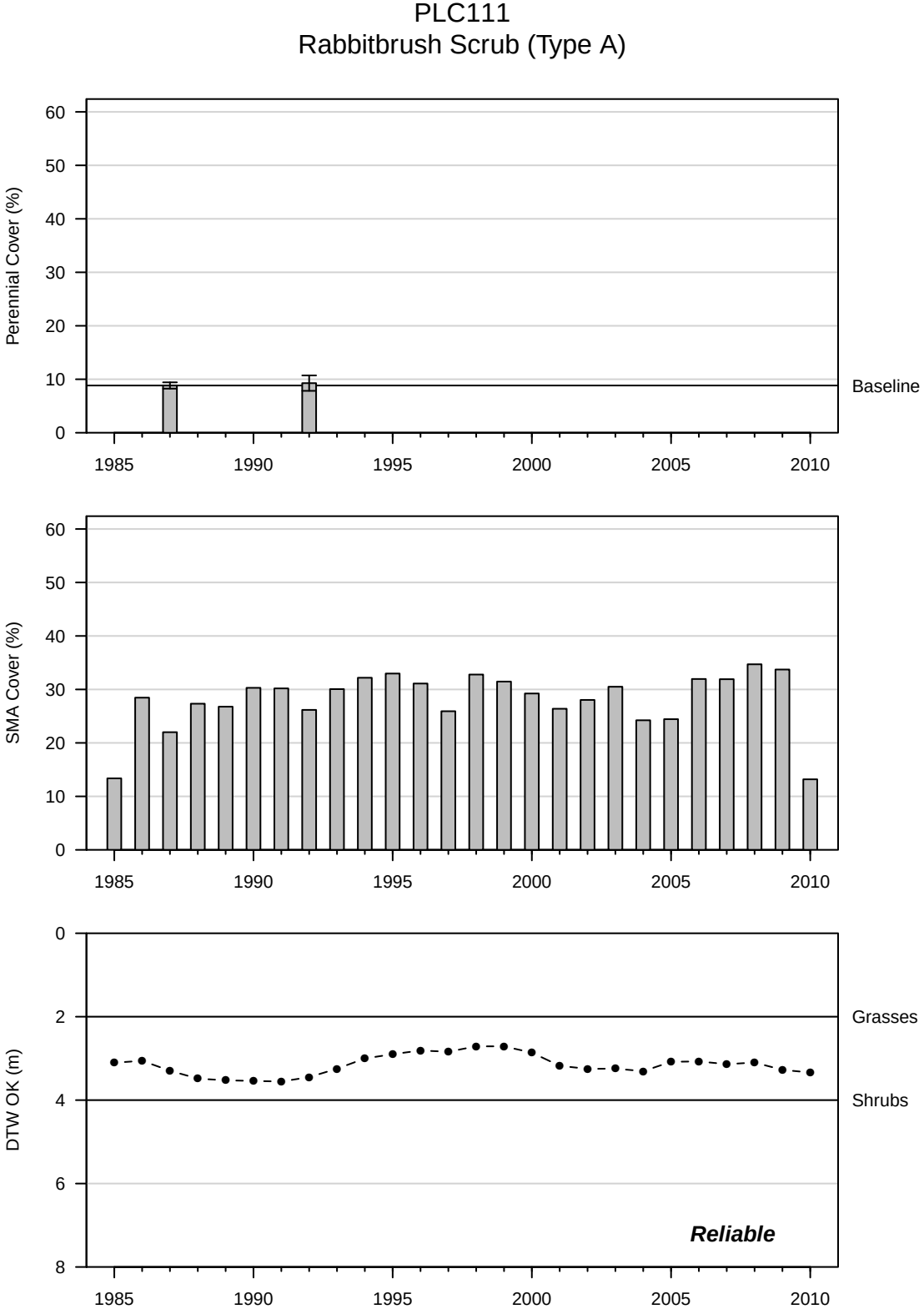


Figure 137: 1992 Control

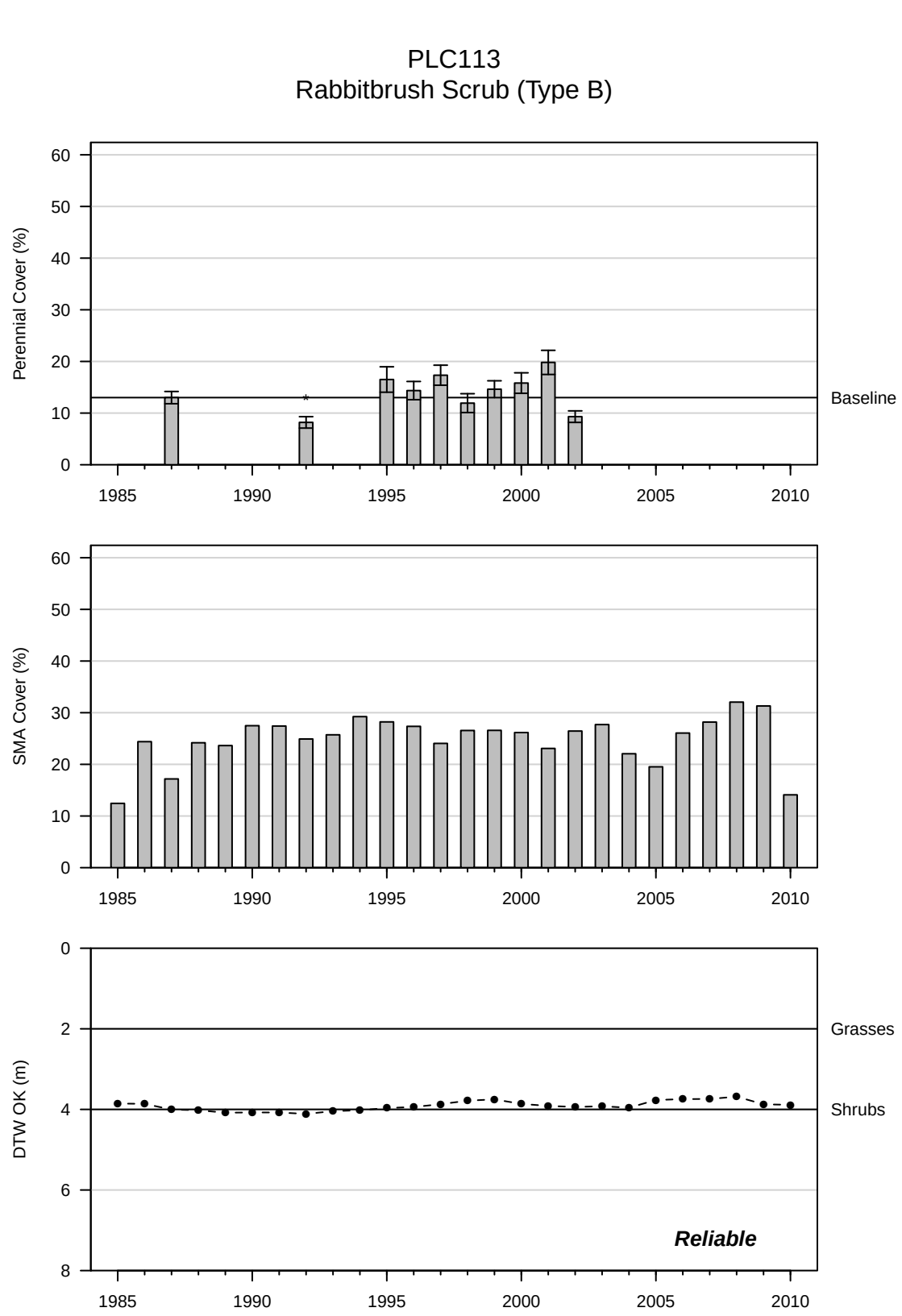


Figure 138: 2002 Control

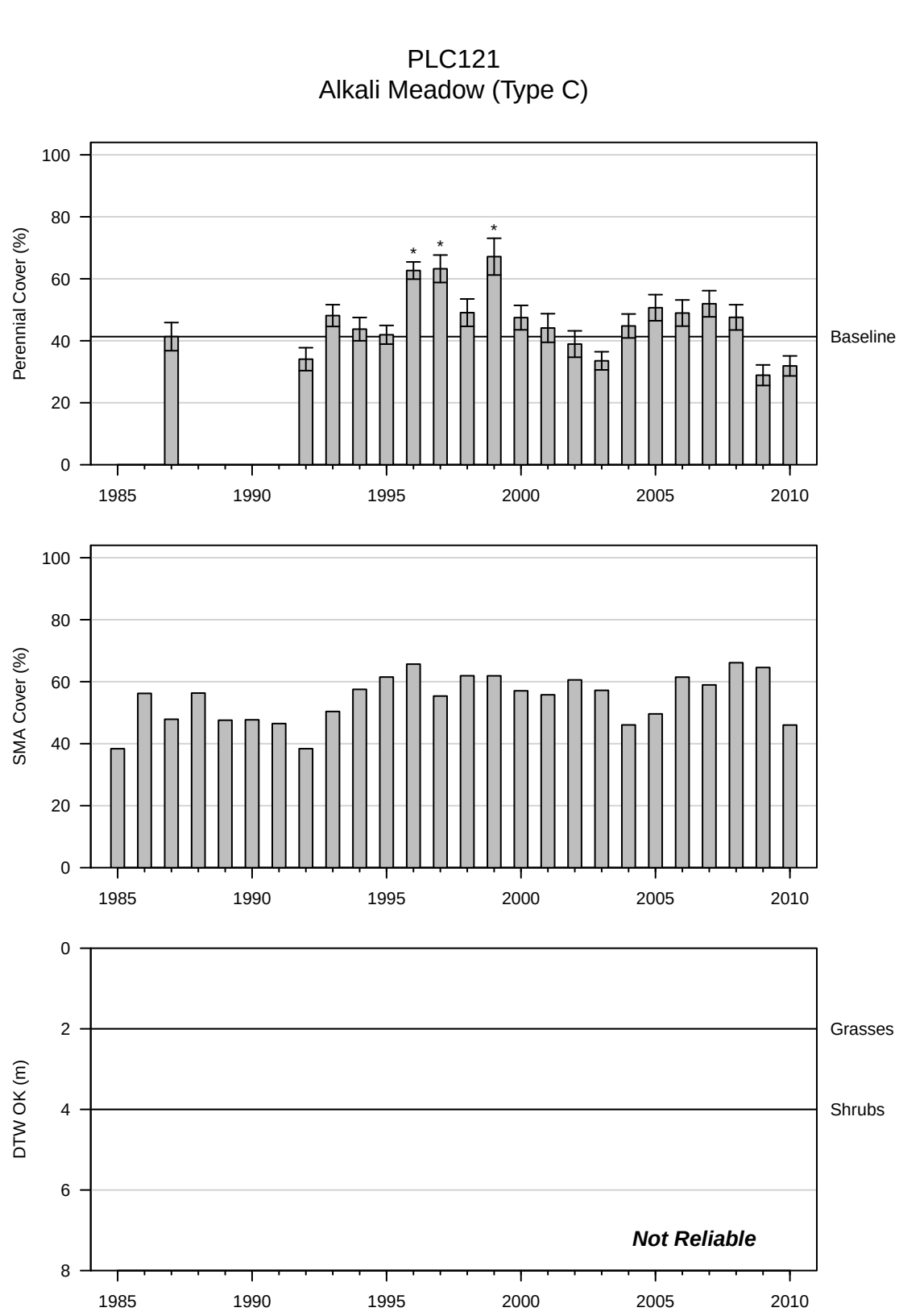


Figure 139: 2010 Control

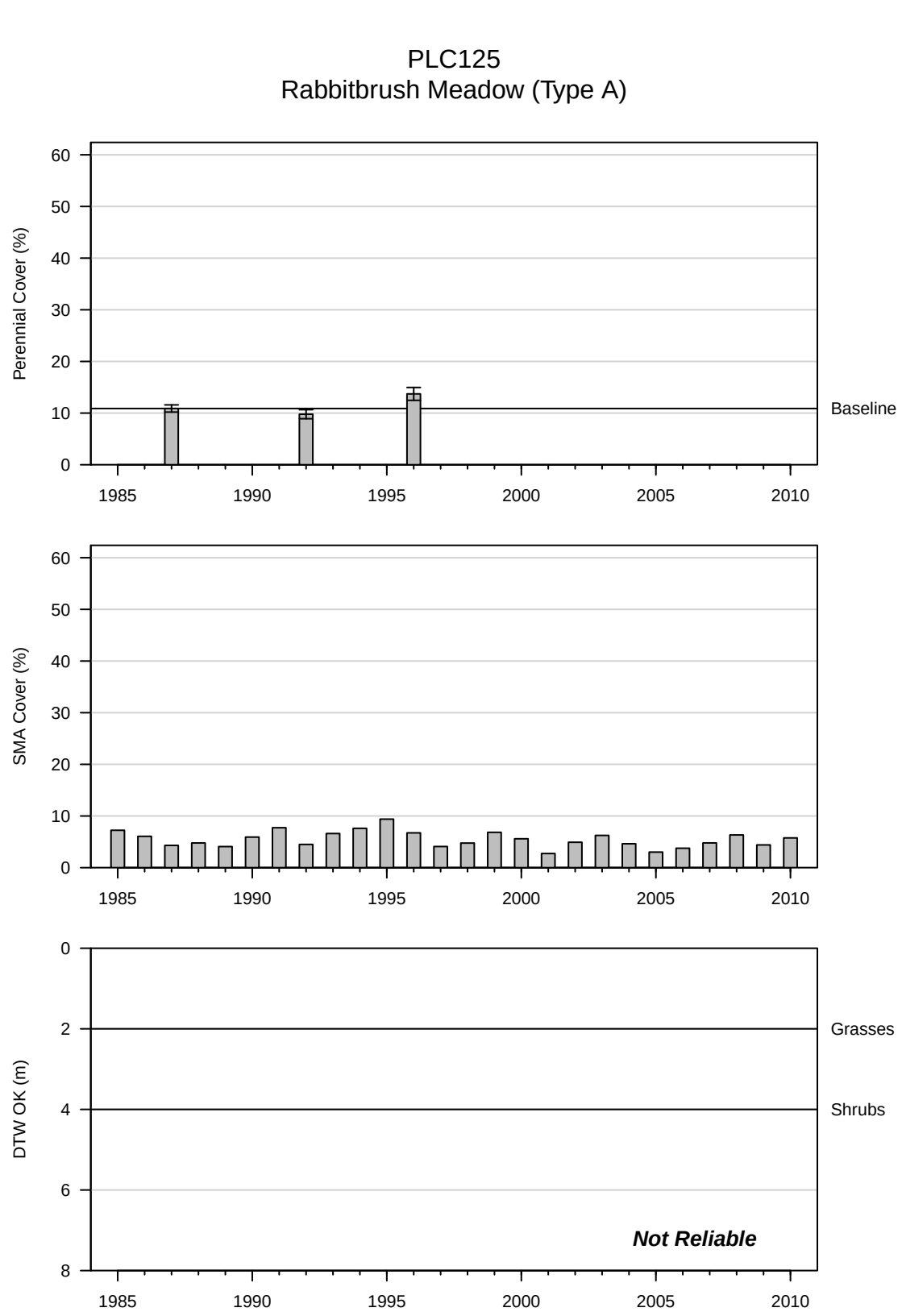


Figure 140: 1996 Control

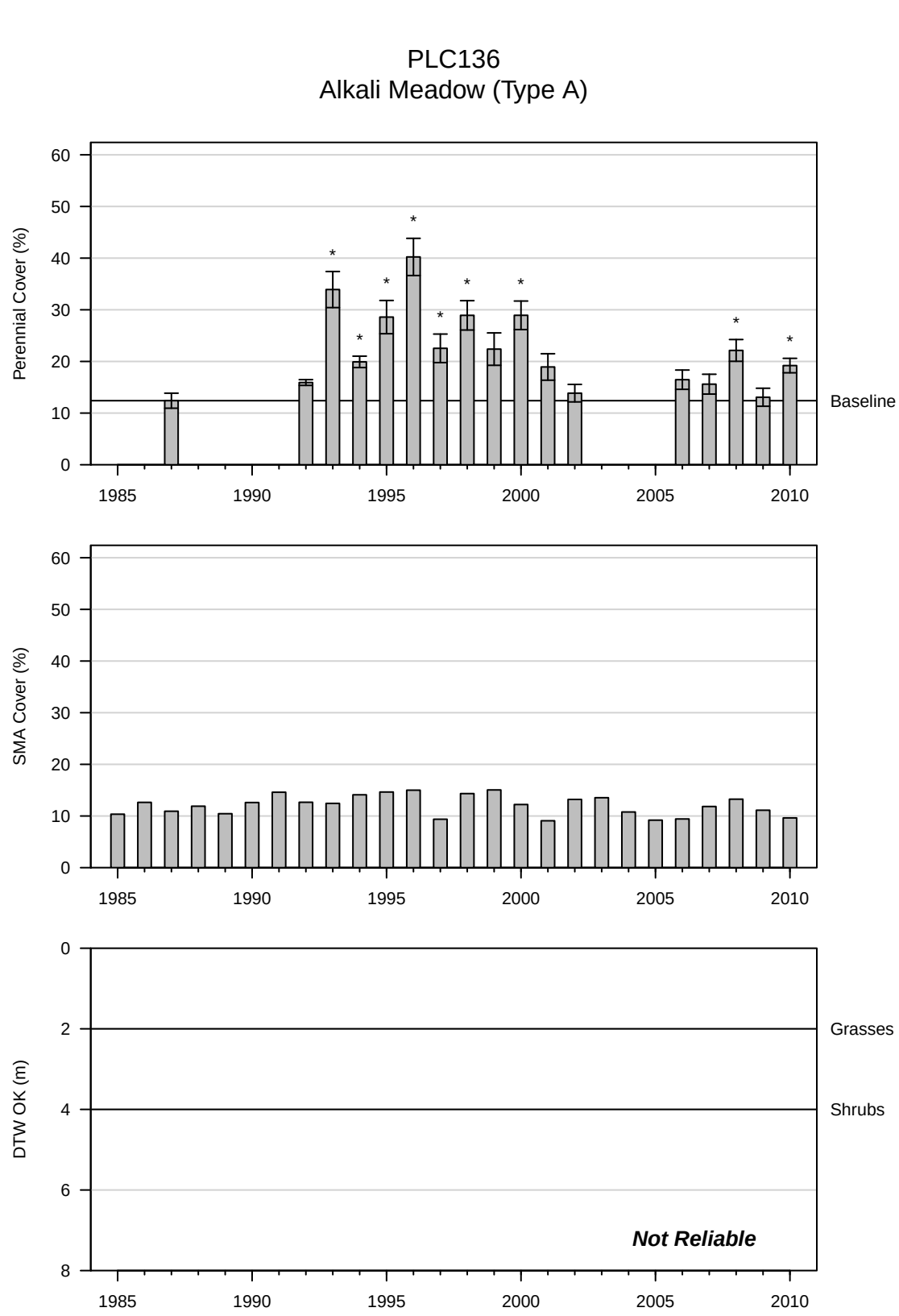


Figure 141: 2010 Control

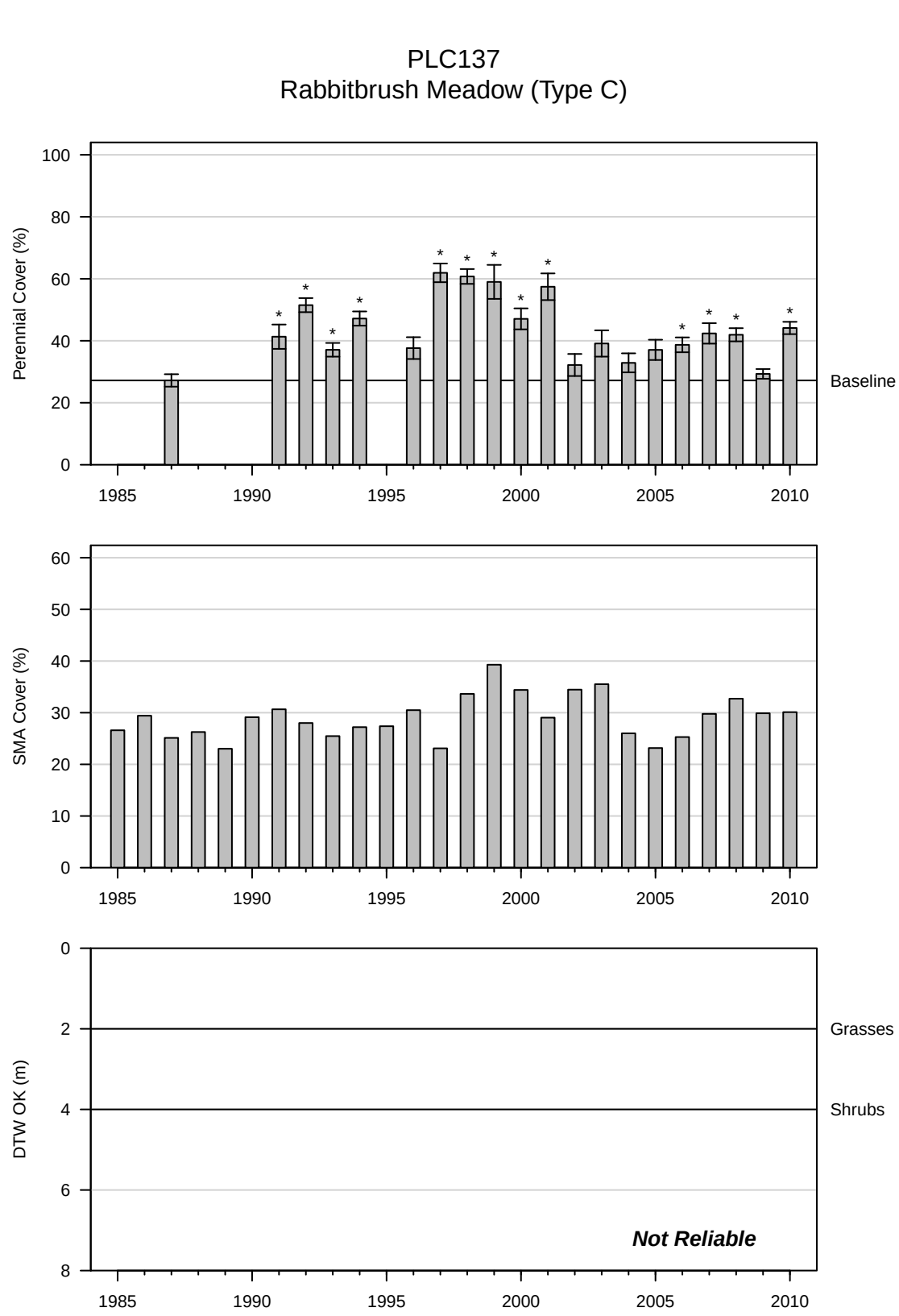


Figure 142: 2010 Control

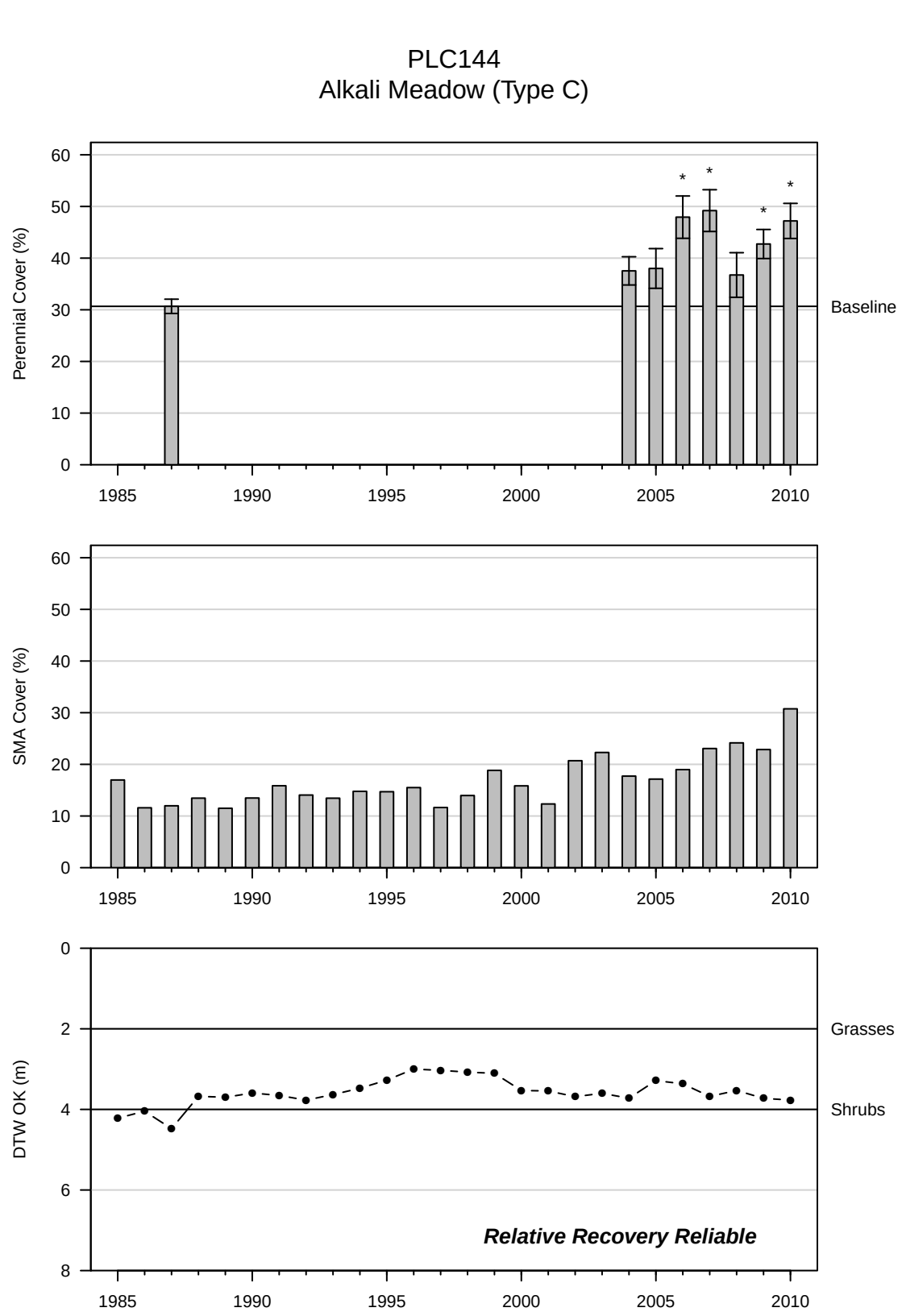


Figure 143: 2010 Control

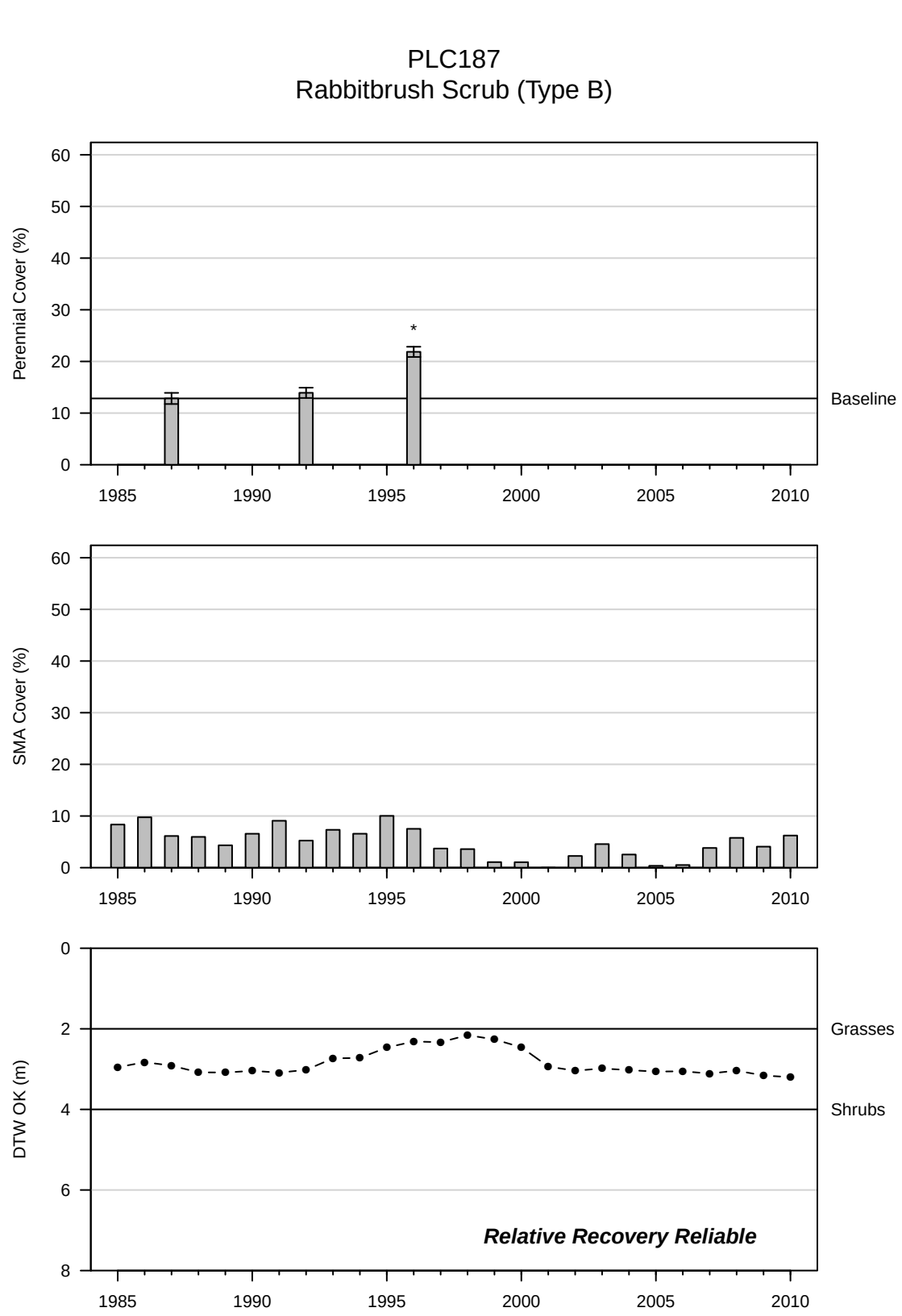


Figure 144: 1996 Control

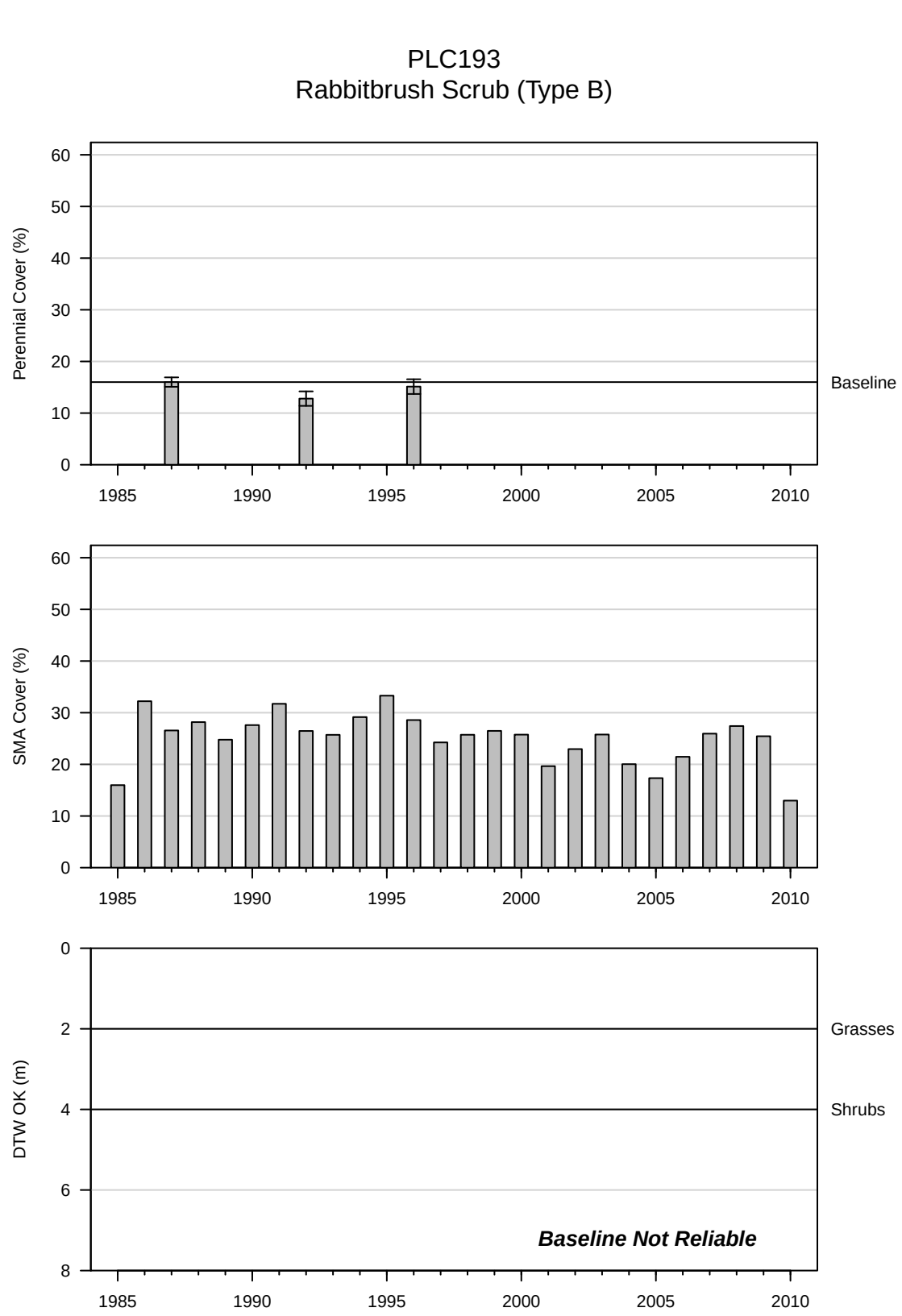


Figure 145: 1996 Control

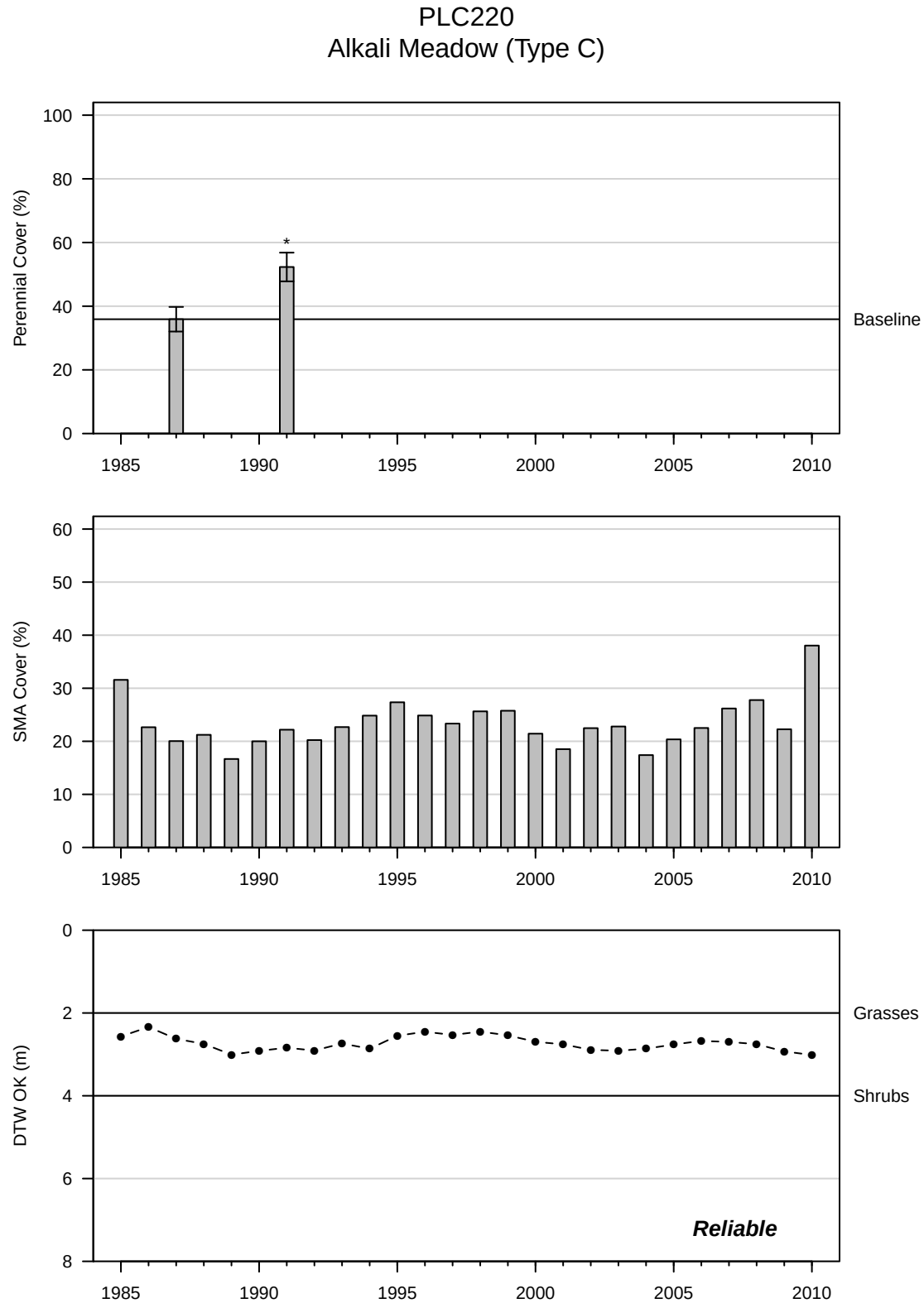


Figure 146: 1991 Control

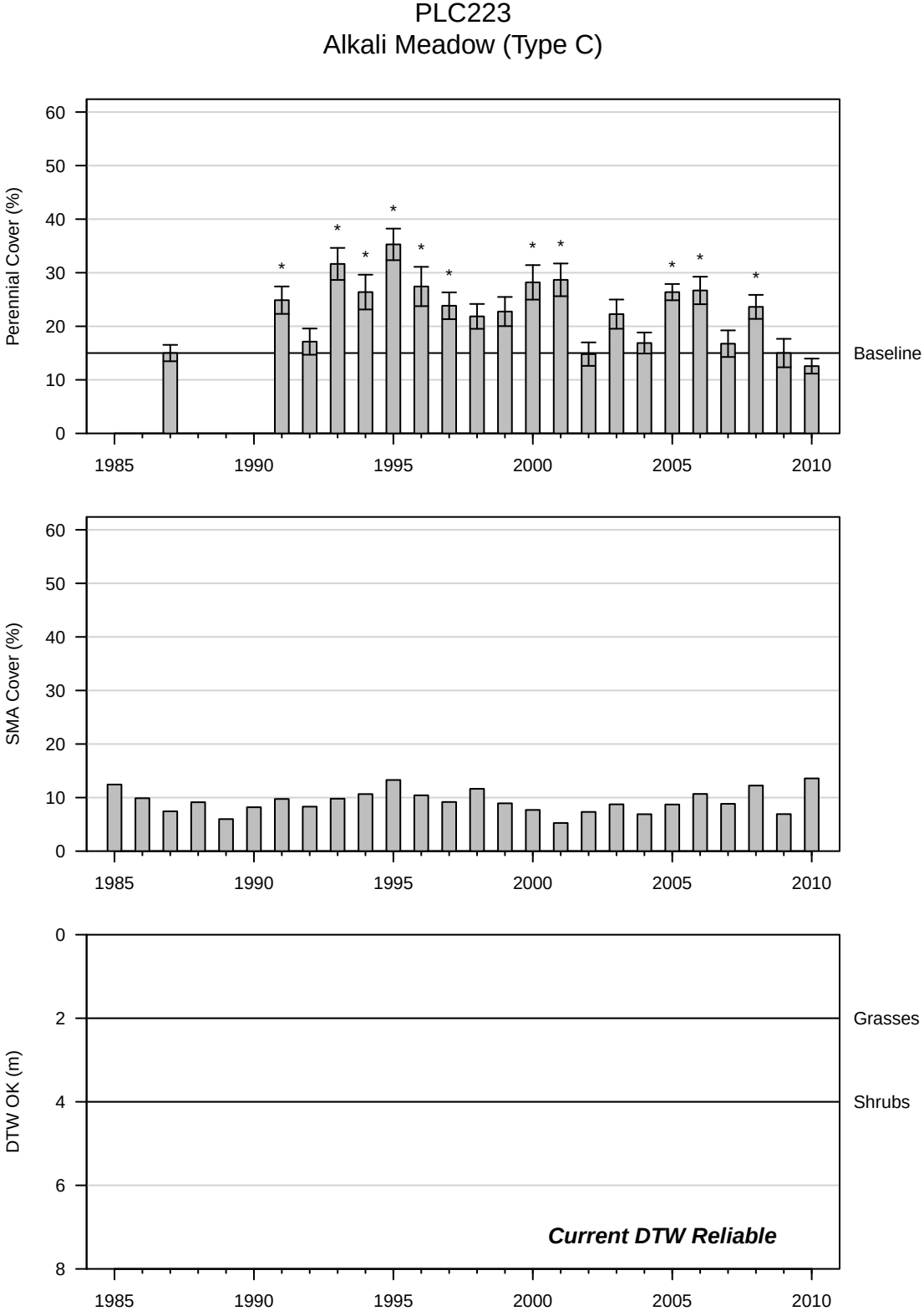


Figure 147: 2010 Control

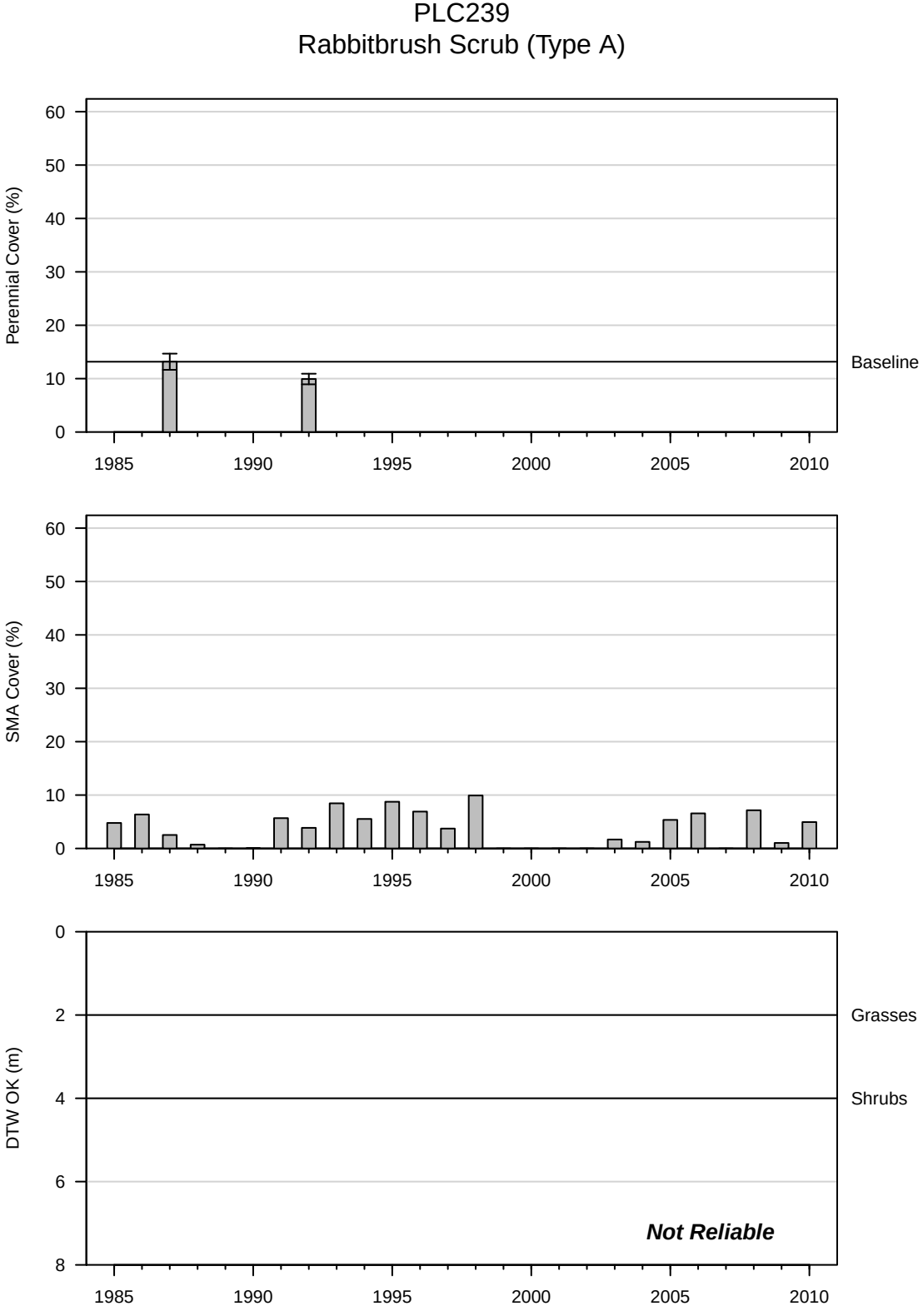


Figure 148: 1992 Control

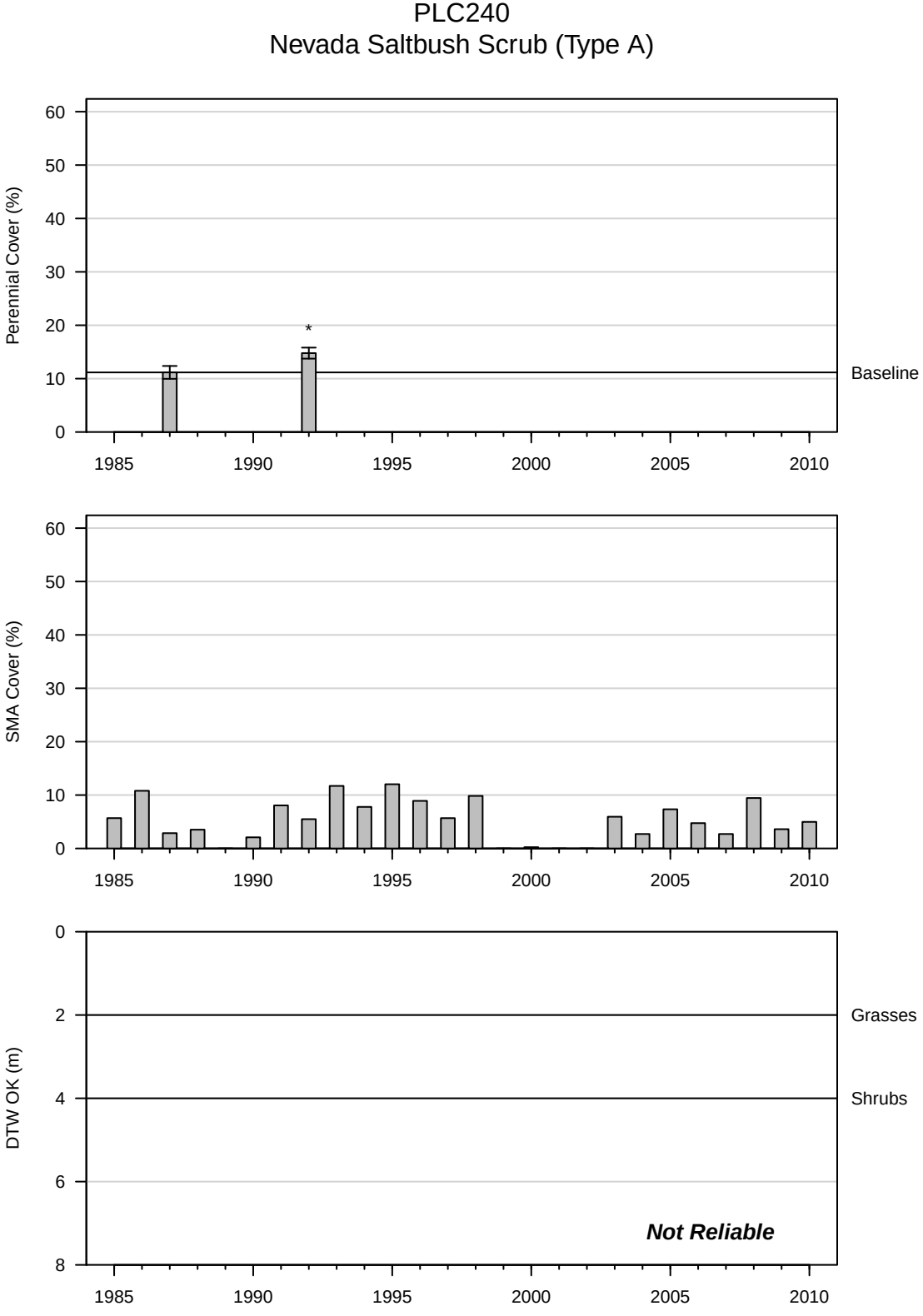


Figure 149: 1992 Control

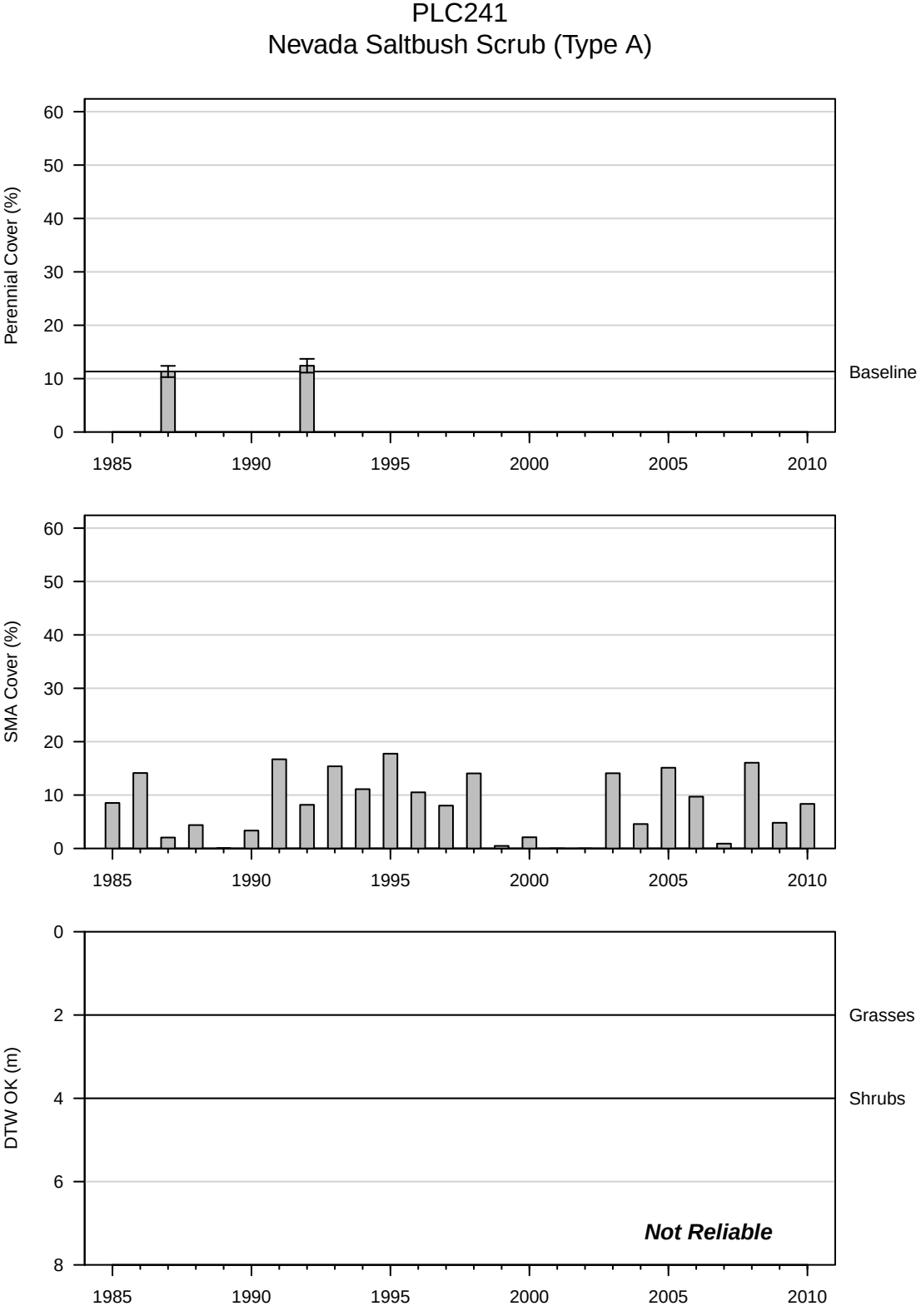


Figure 150: 1992 Control

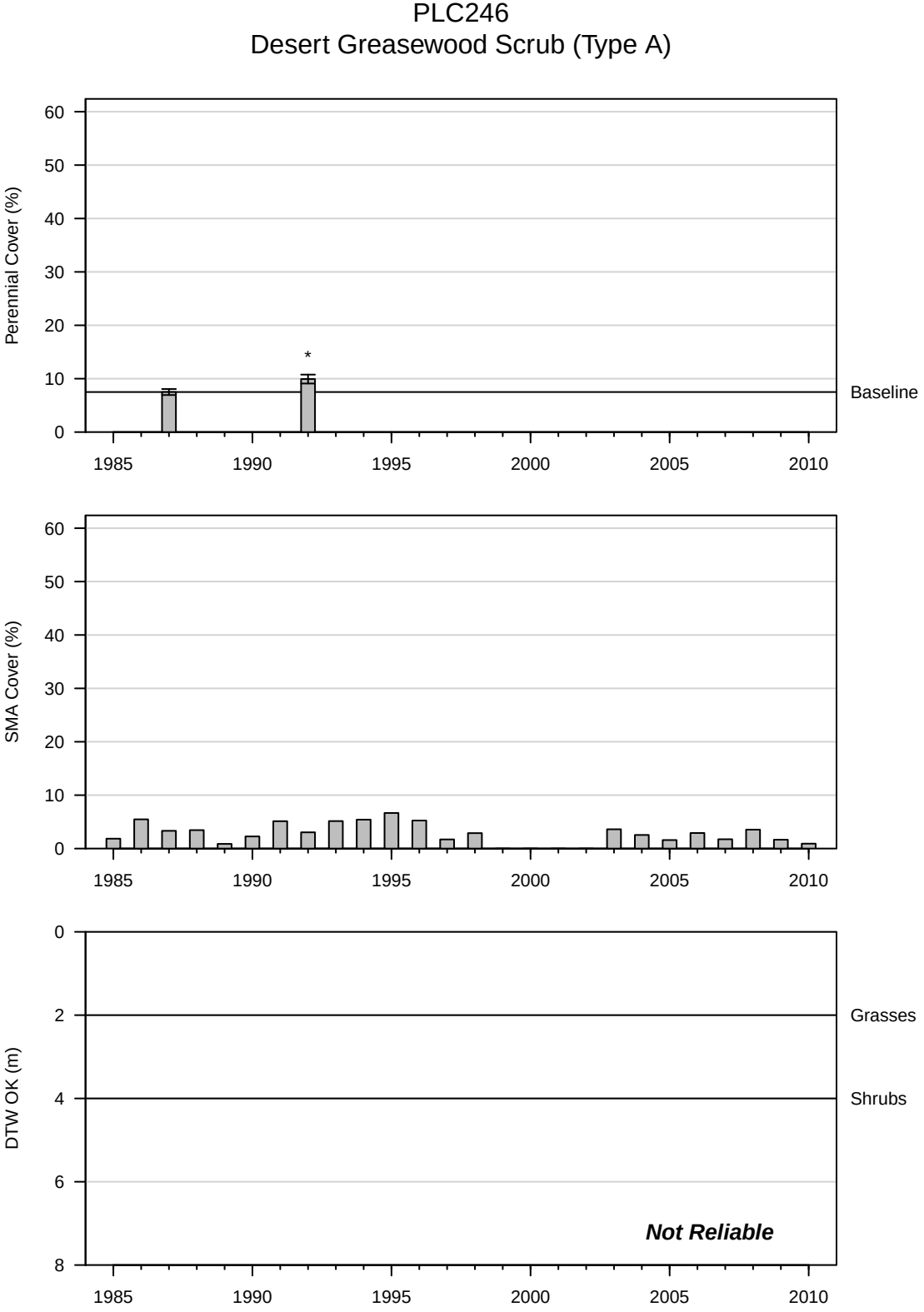


Figure 151: 1992 Control

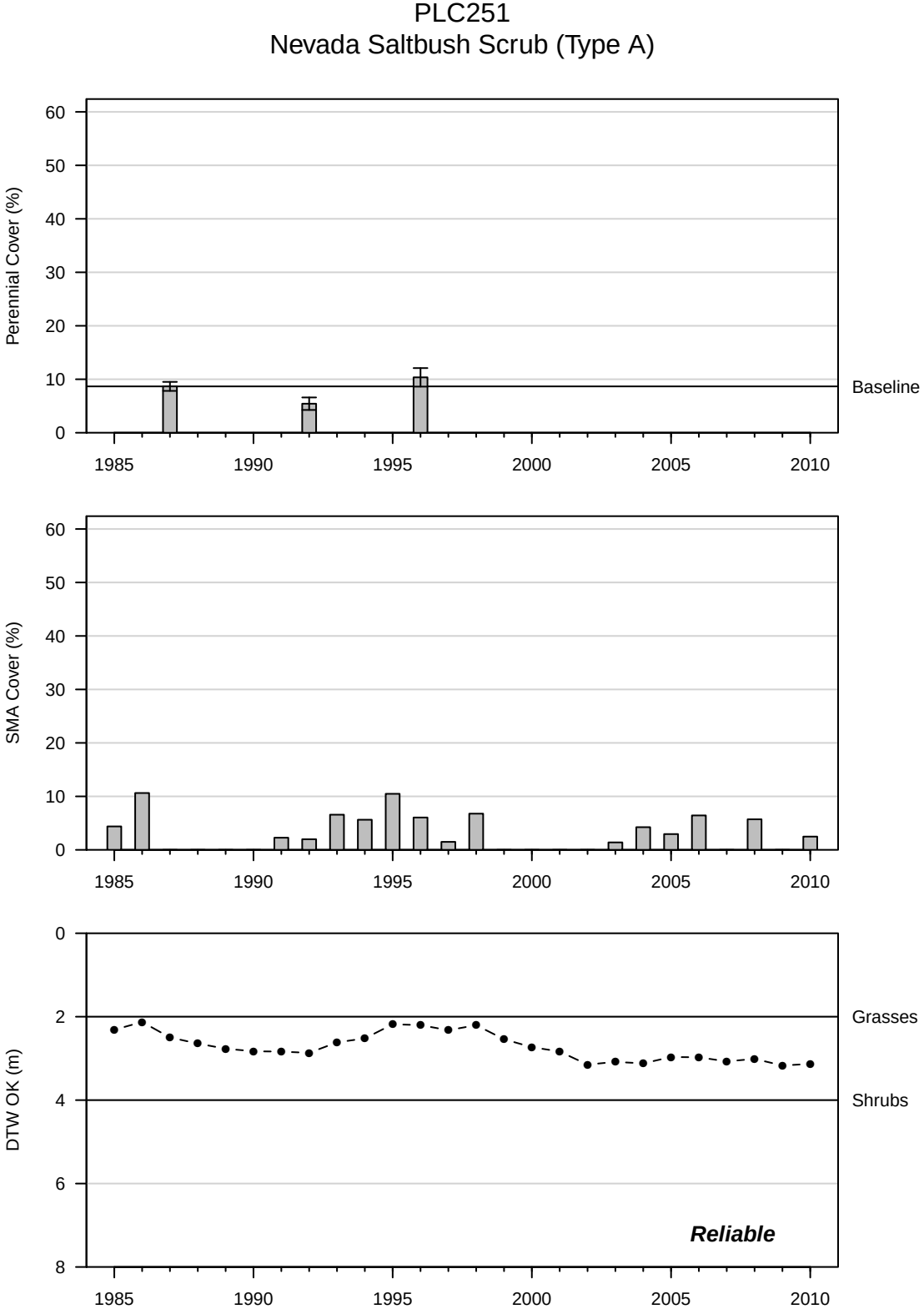


Figure 152: 1996 Control

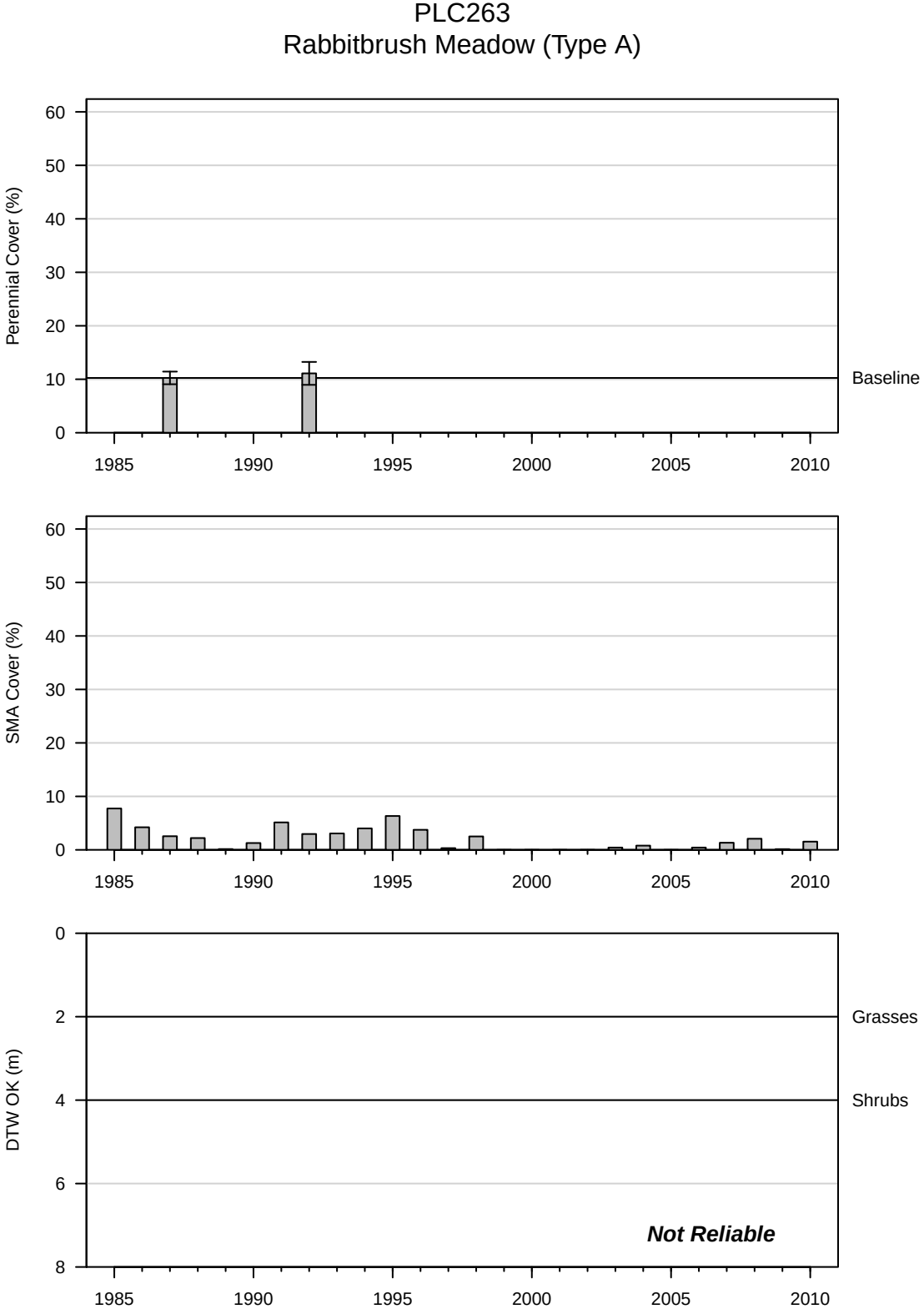


Figure 153: 1992 Control

TIN006
Desert Sink Scrub (Type A)

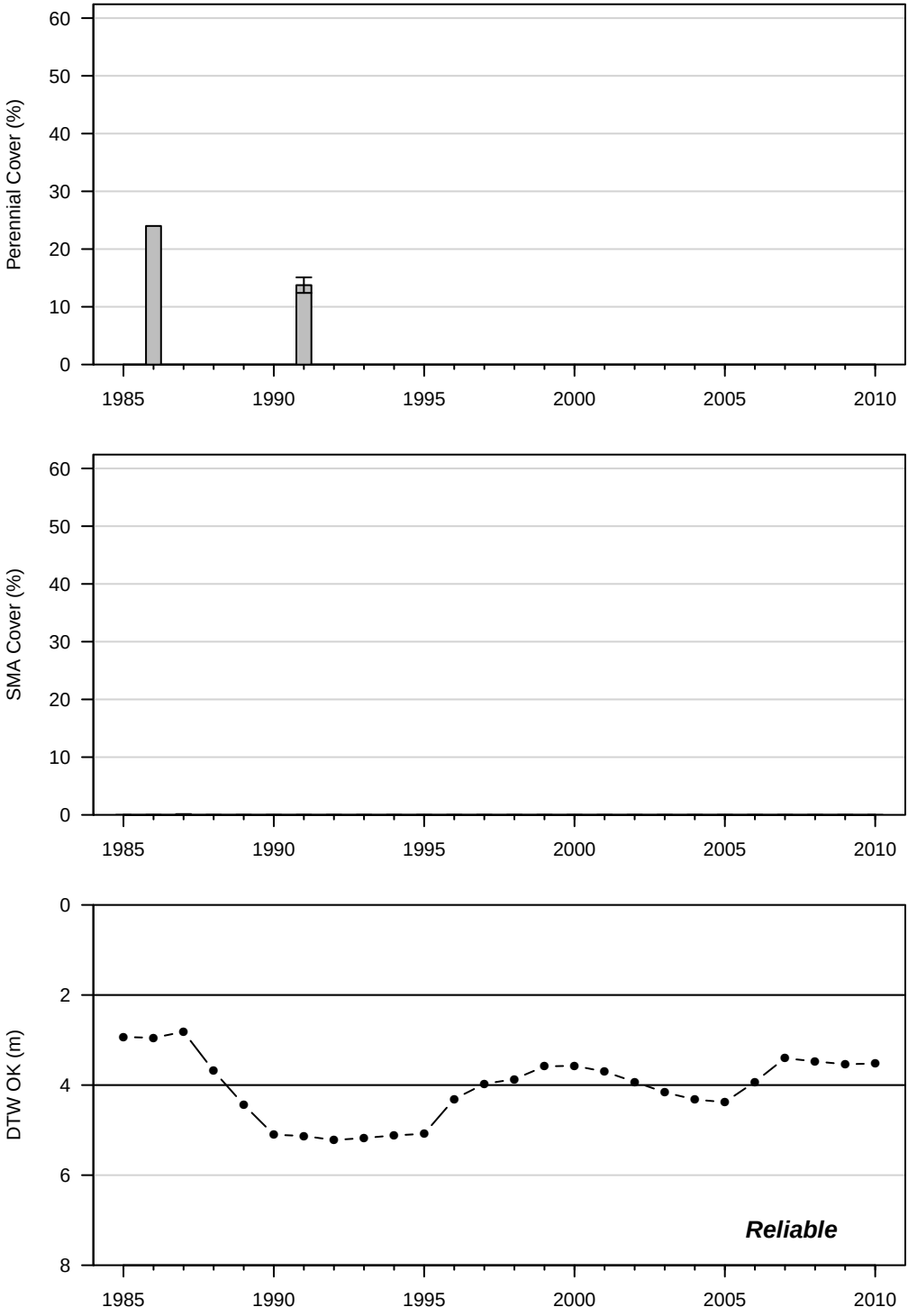


Figure 154: 1991 Wellfield

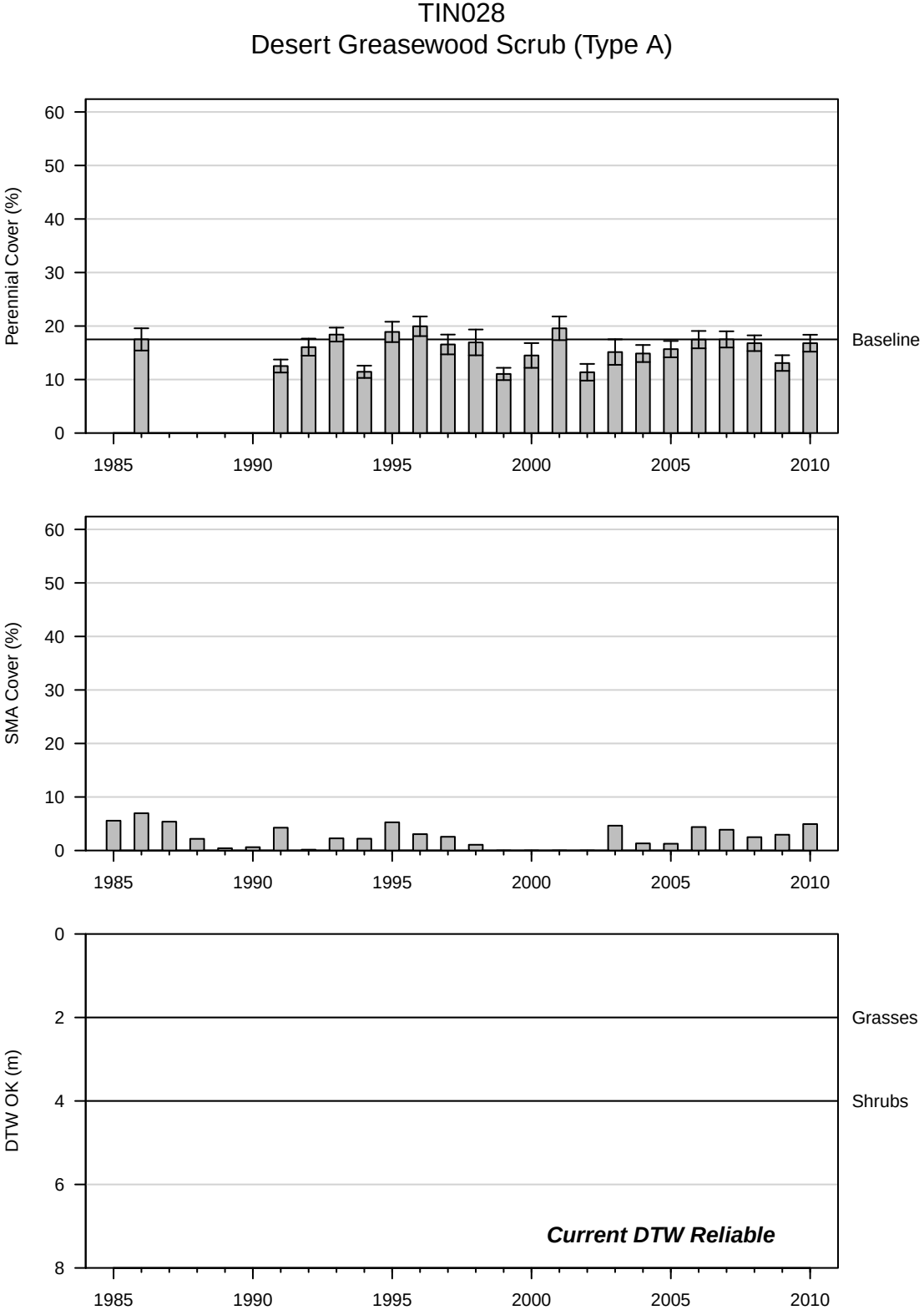


Figure 155: 2010 Wellfield

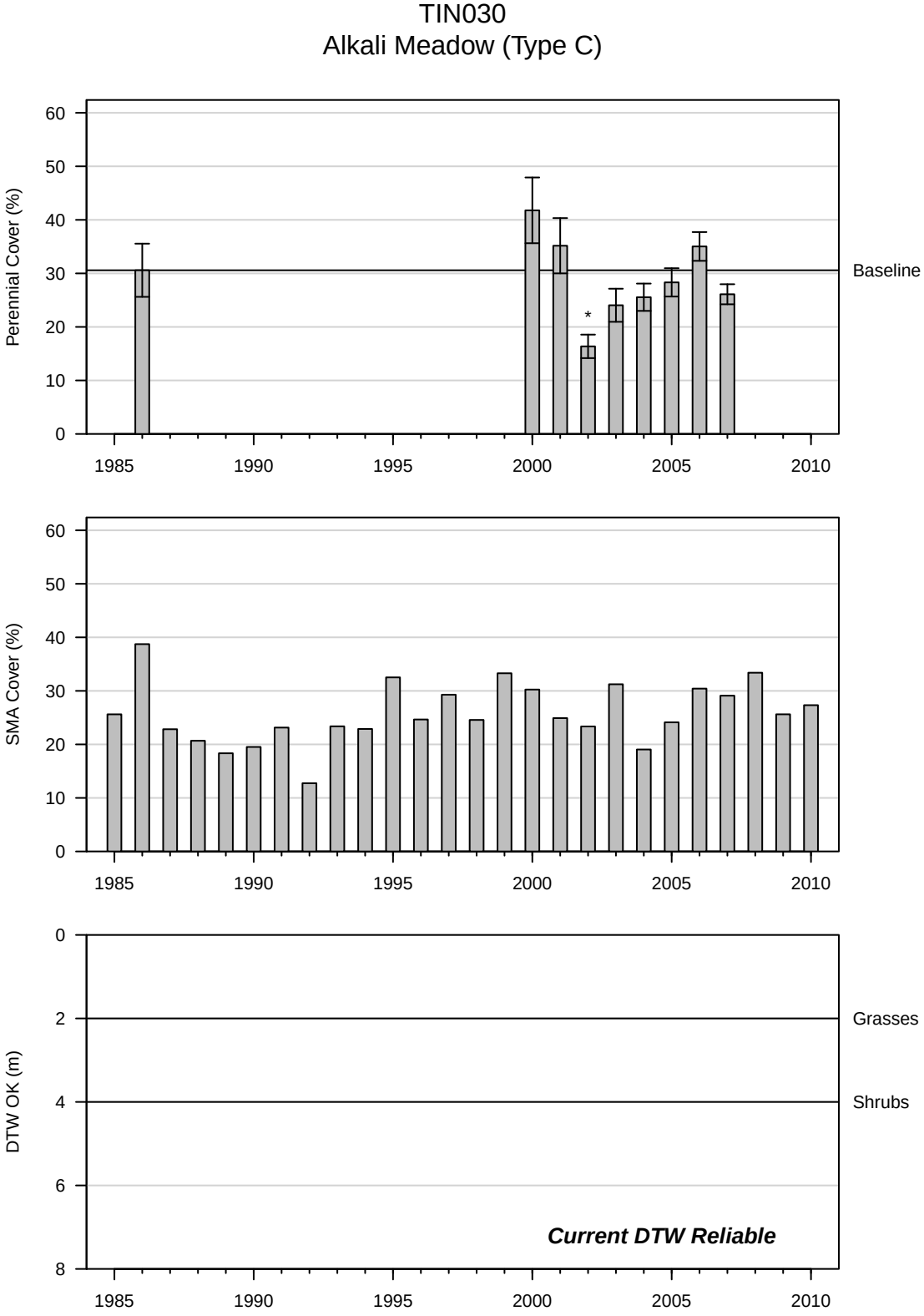


Figure 156: 2007 Wellfield

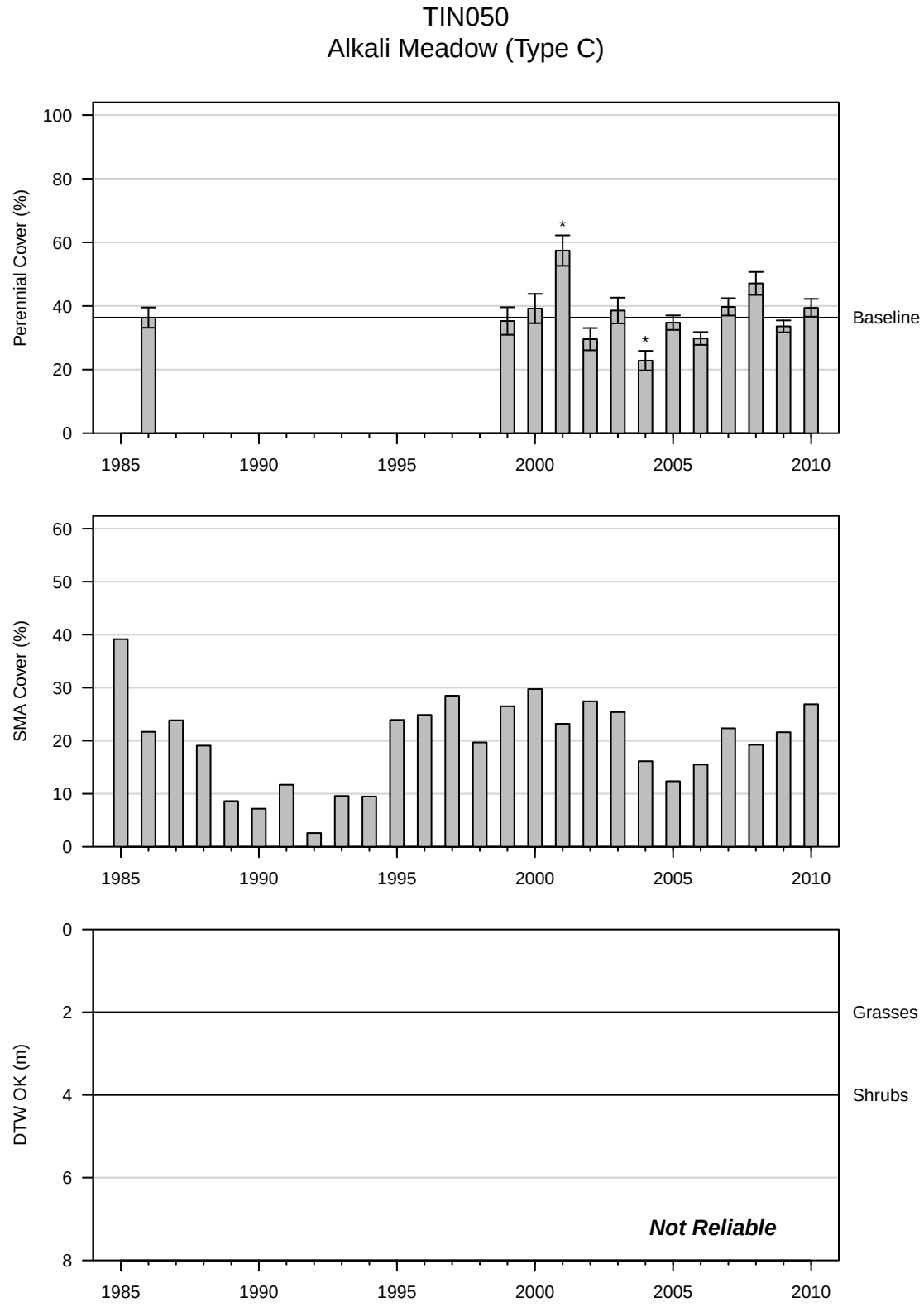


Figure 157: 2010 Wellfield

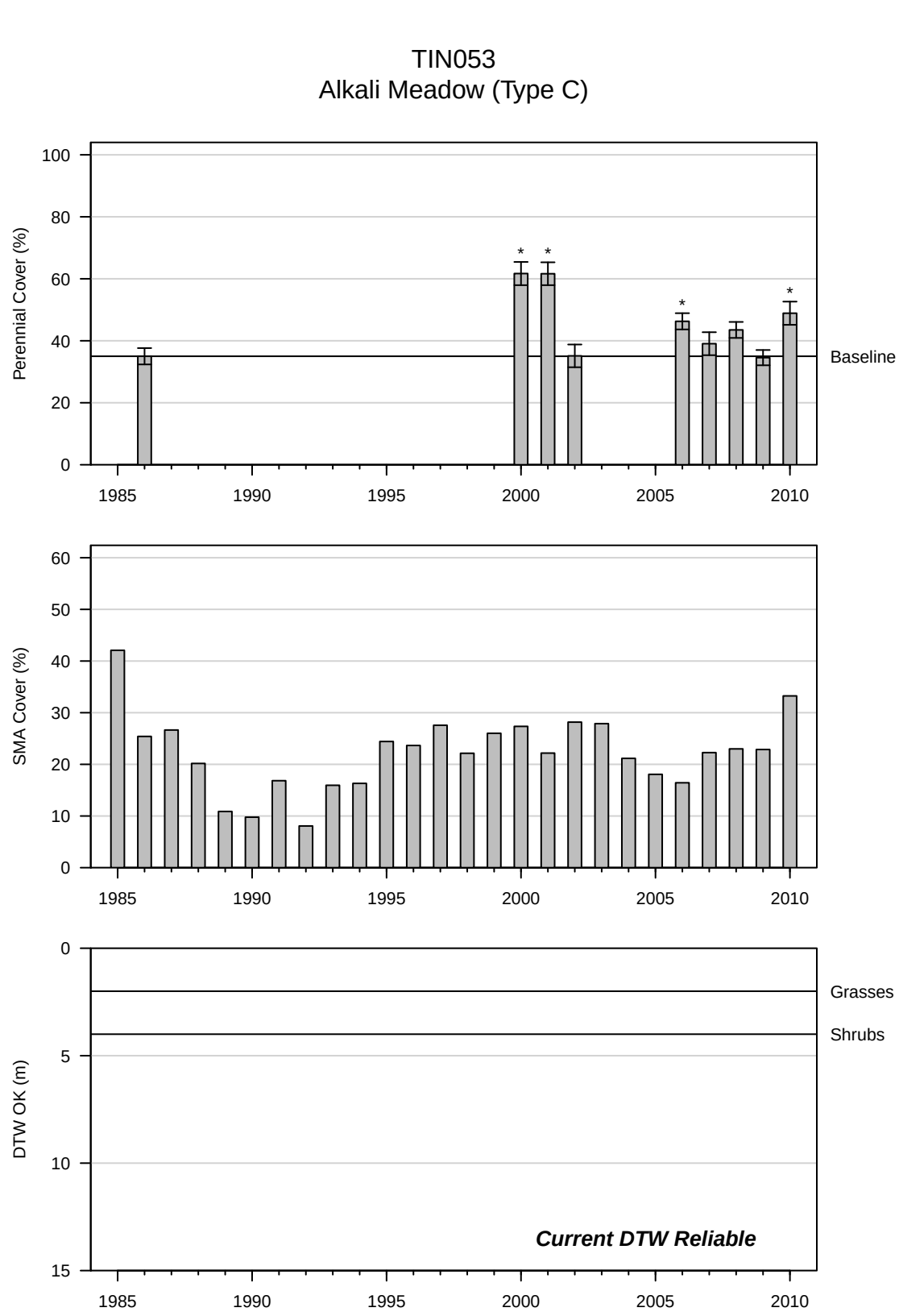


Figure 158: 2010 Wellfield

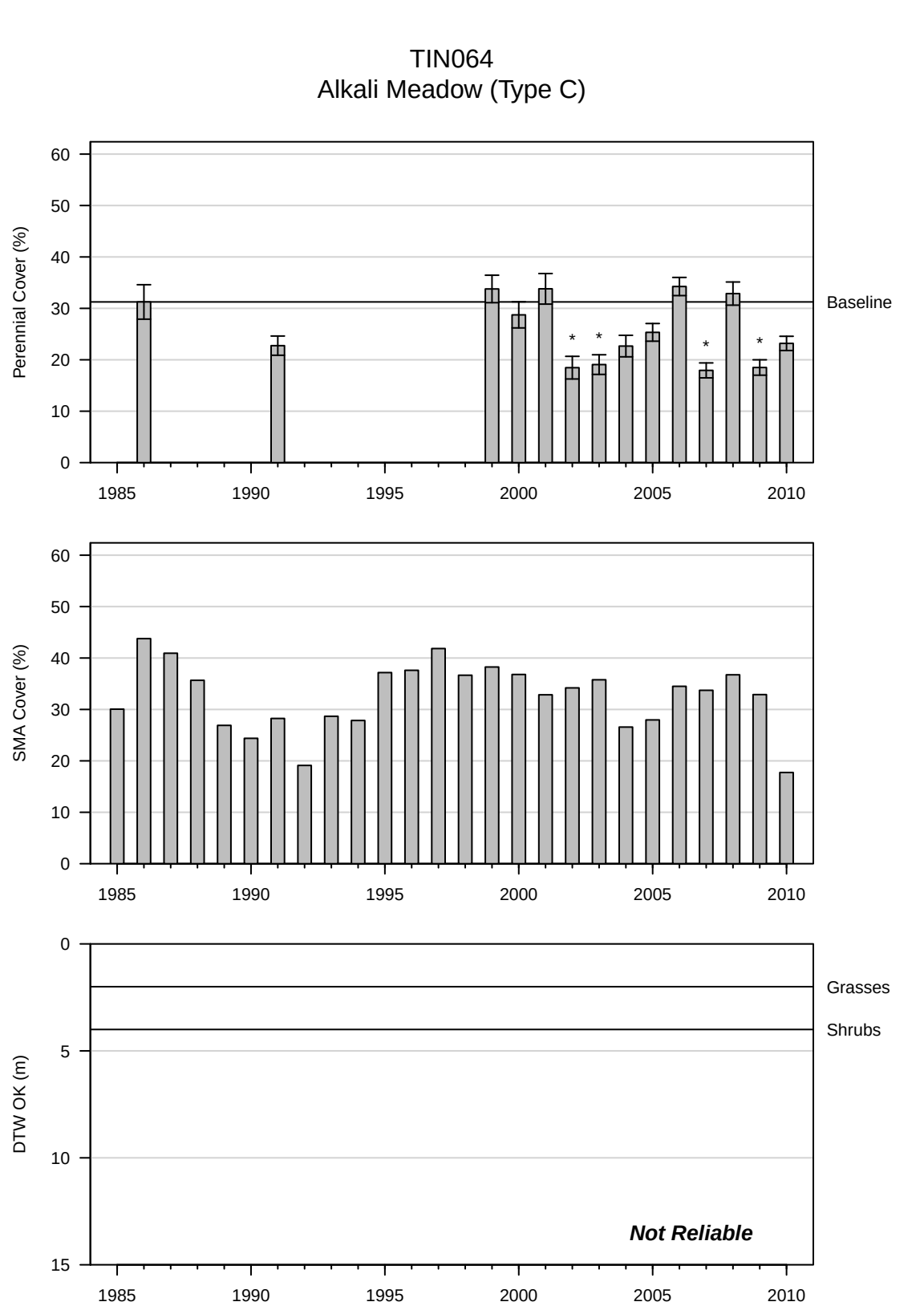


Figure 159: 2010 Wellfield

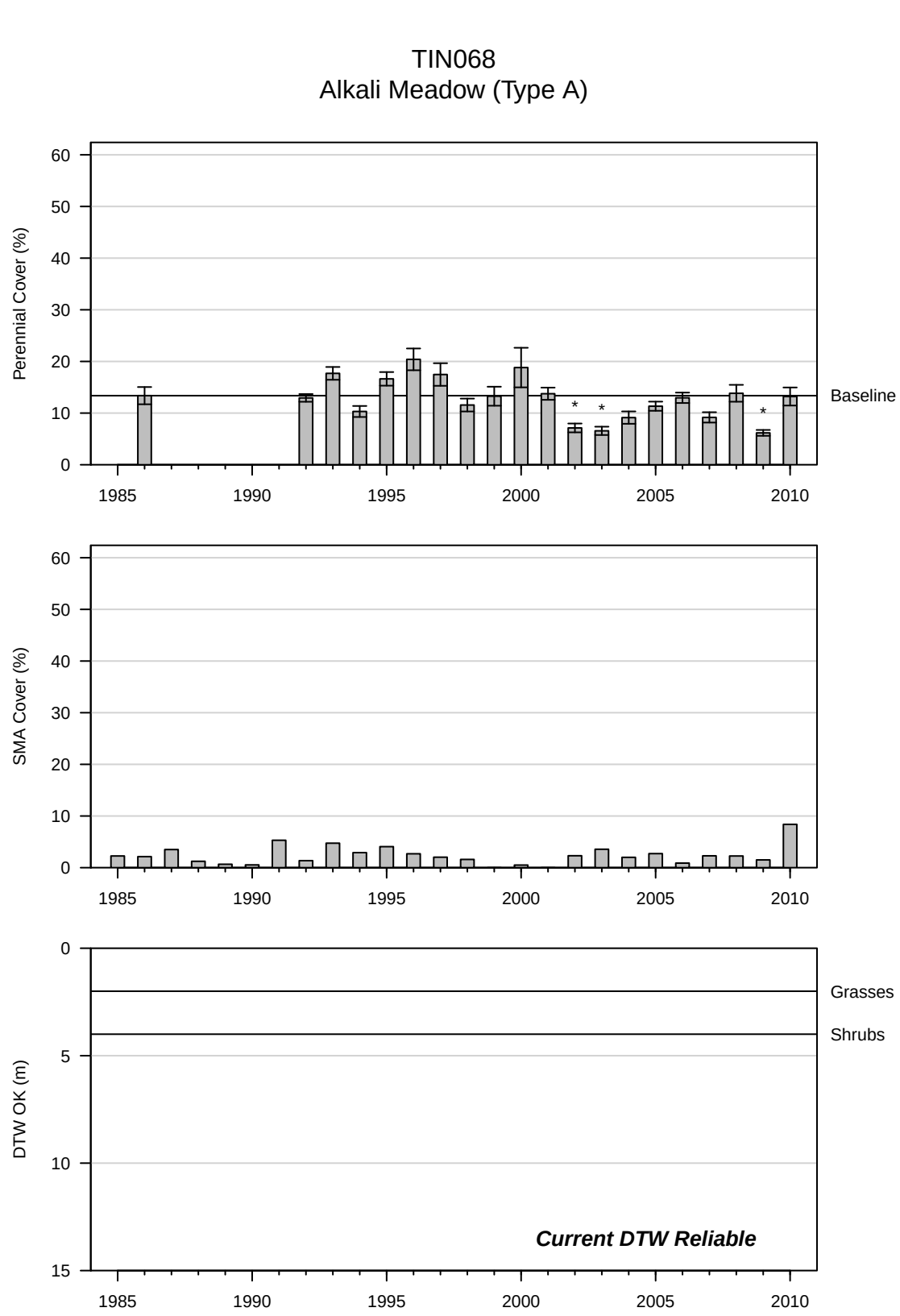


Figure 160: 2010 Wellfield

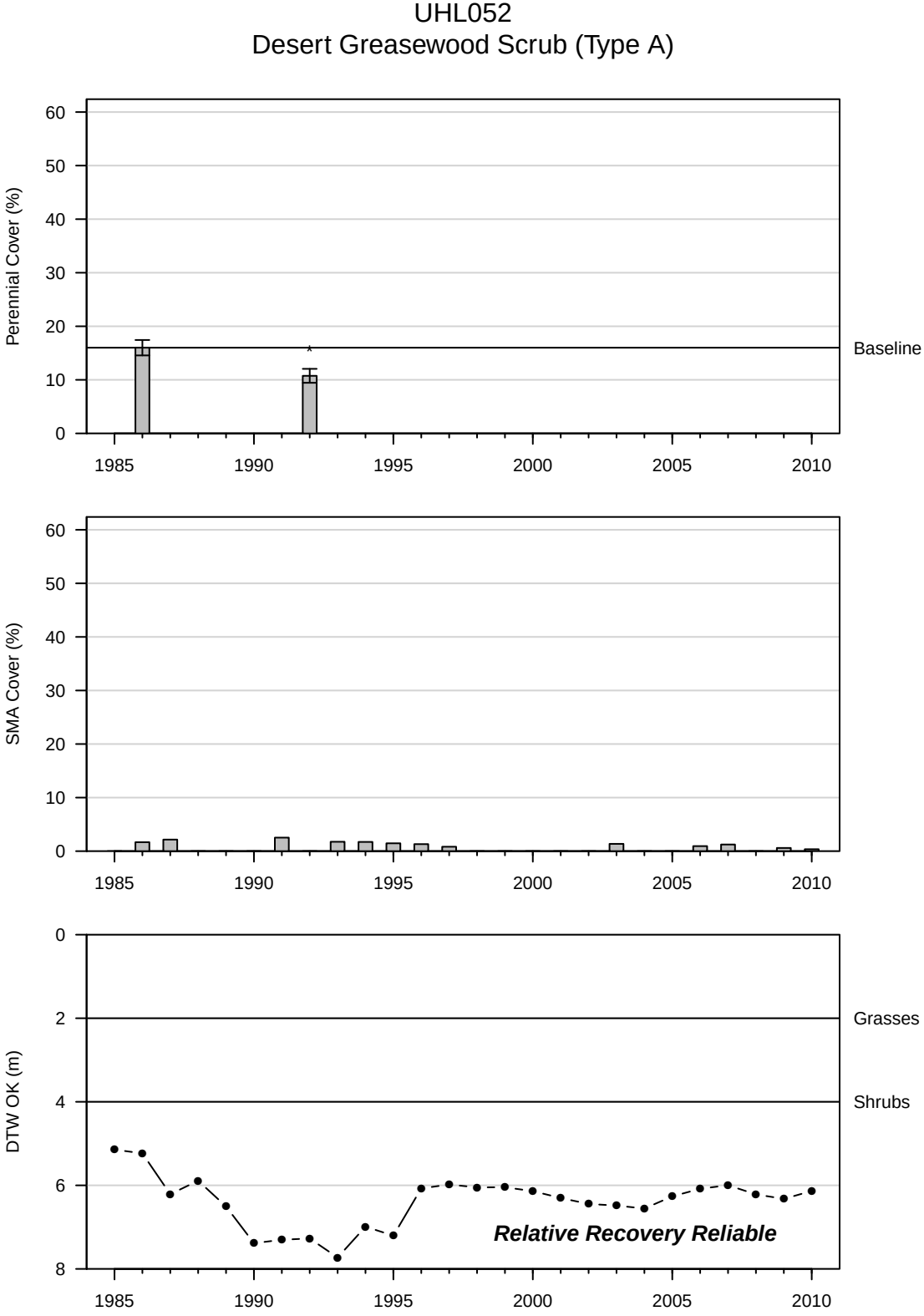


Figure 161: 1992 Wellfield

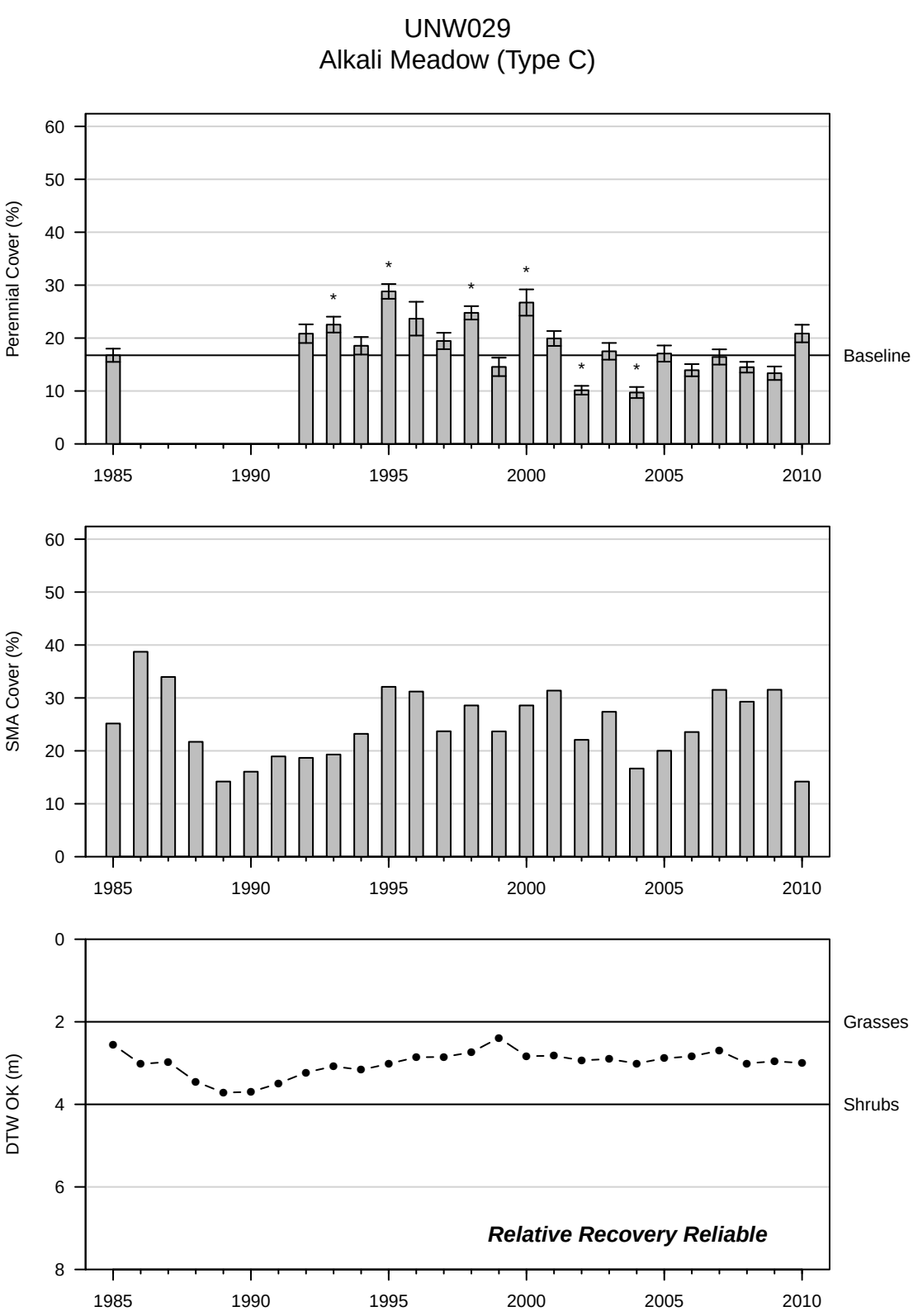


Figure 162: 2010 Control

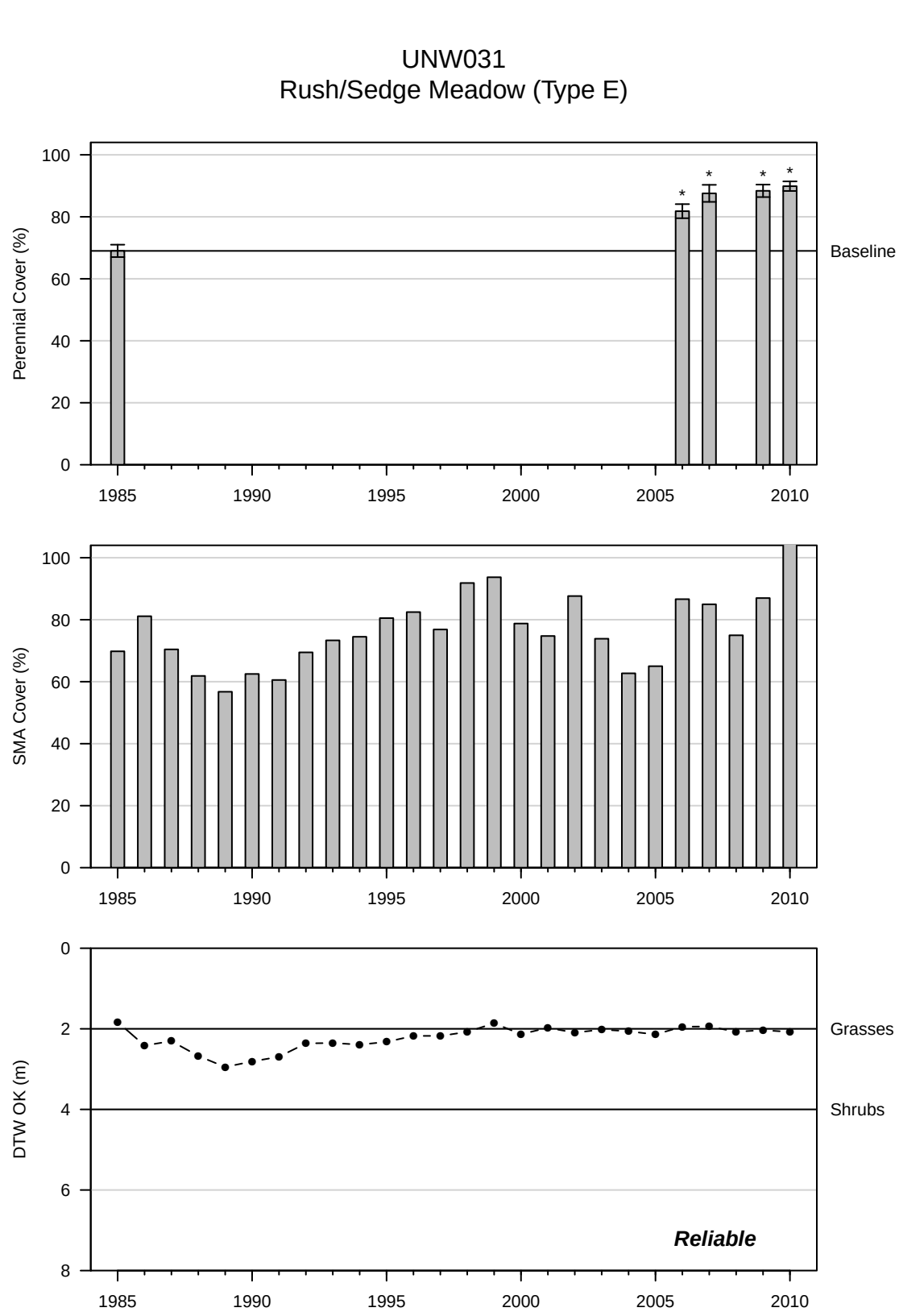


Figure 163: 2010 Control

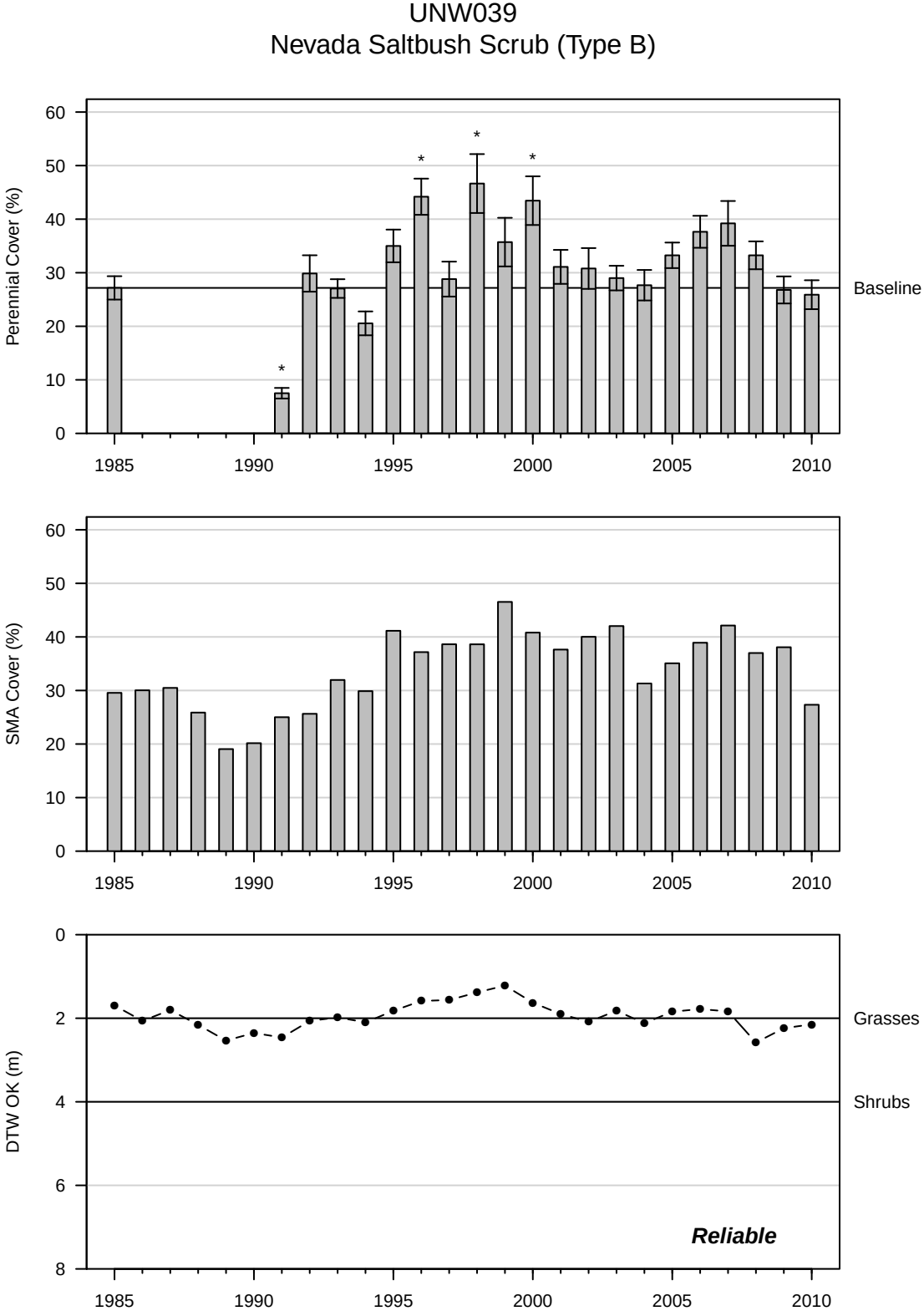


Figure 164: 2010 Control

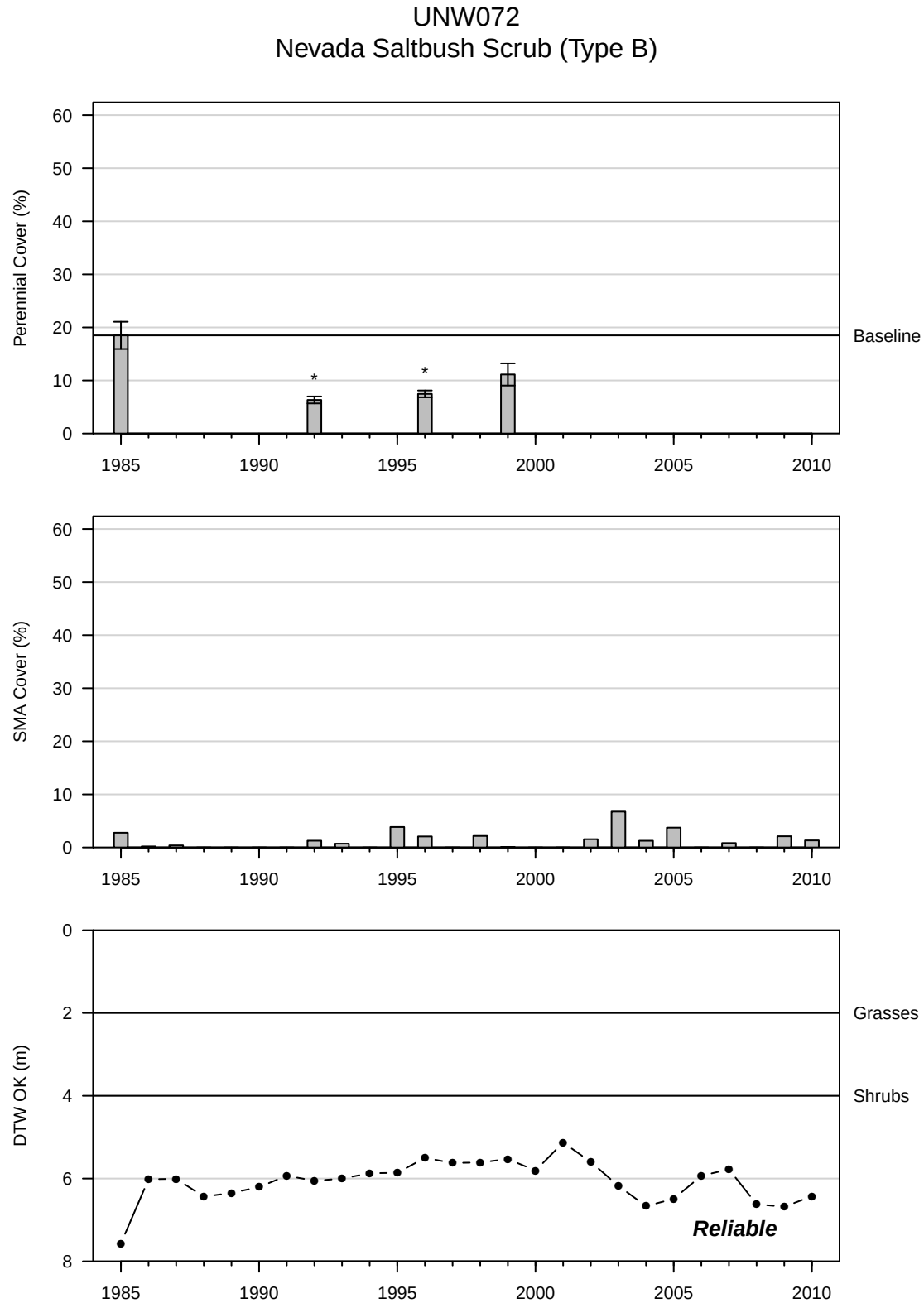


Figure 165: 1999 Control

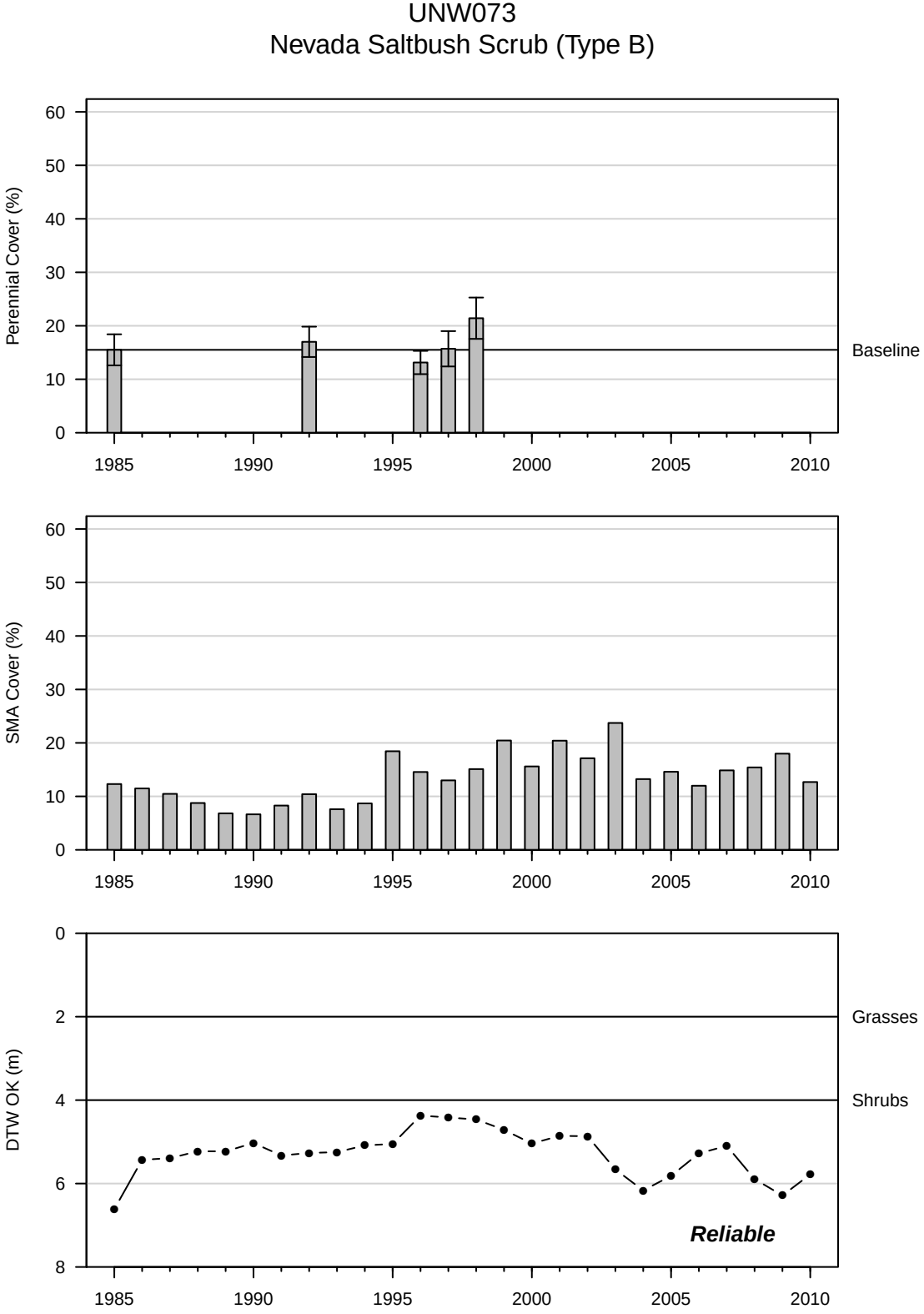


Figure 166: 1998 Control

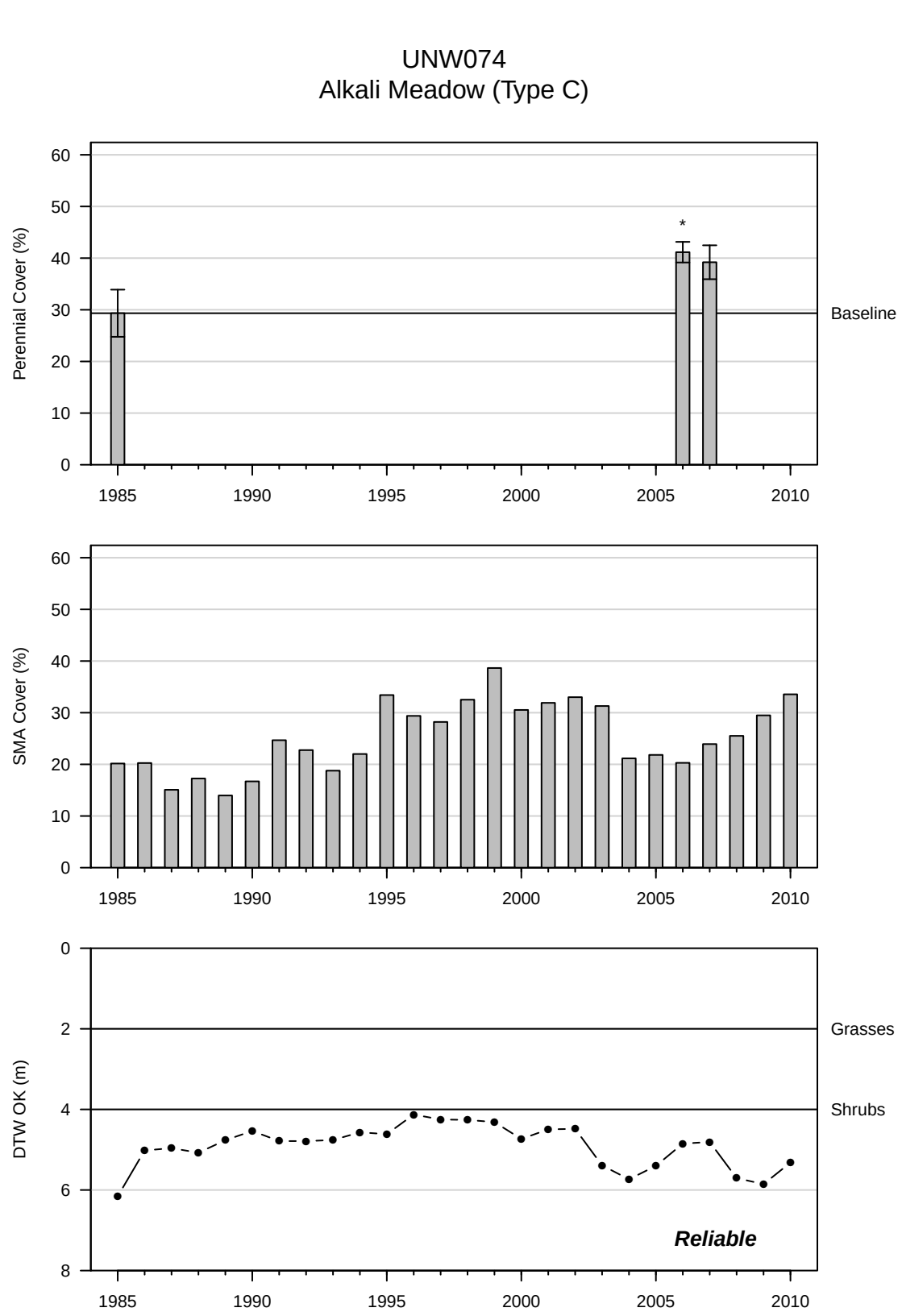


Figure 167: 2007 Control

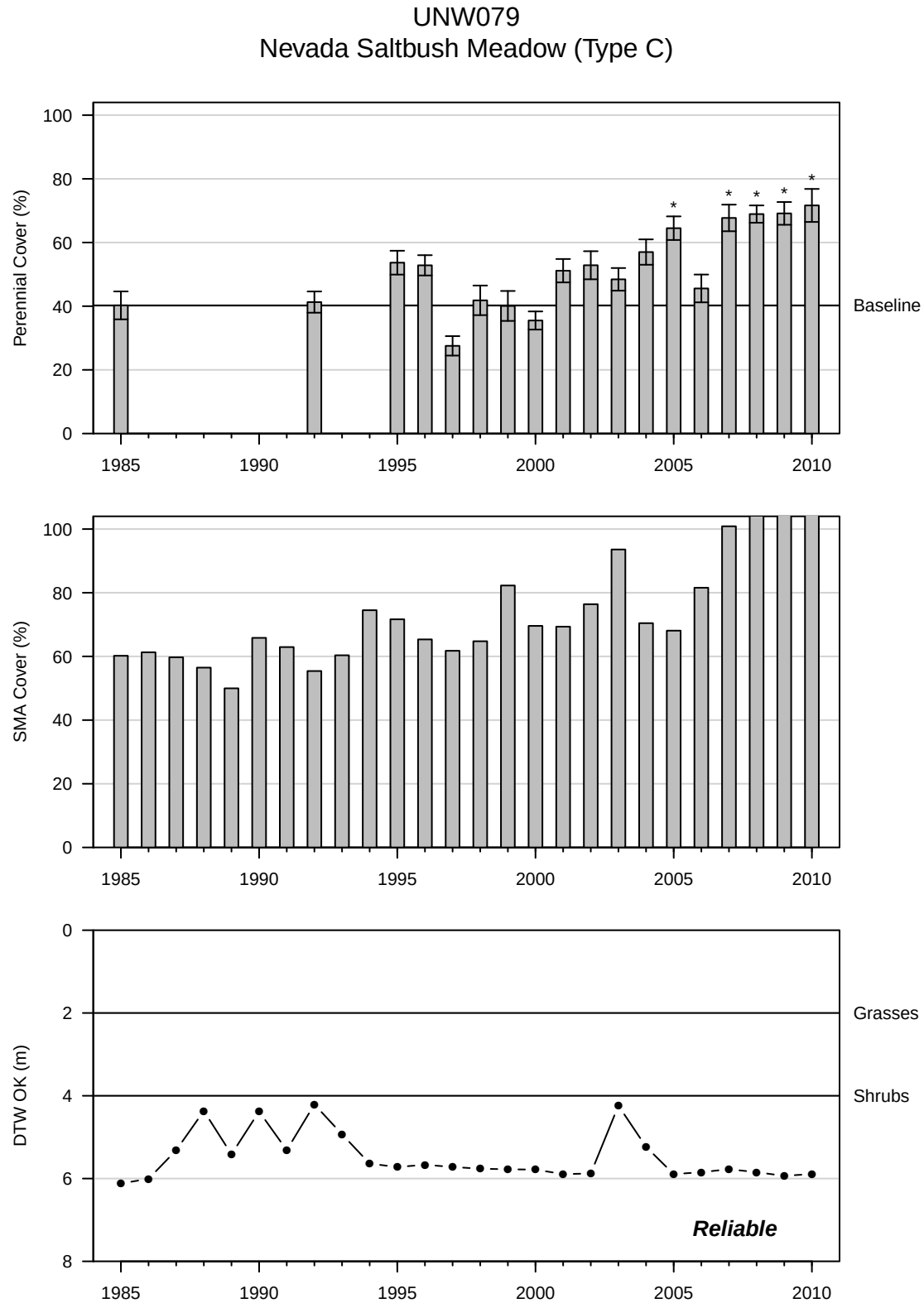
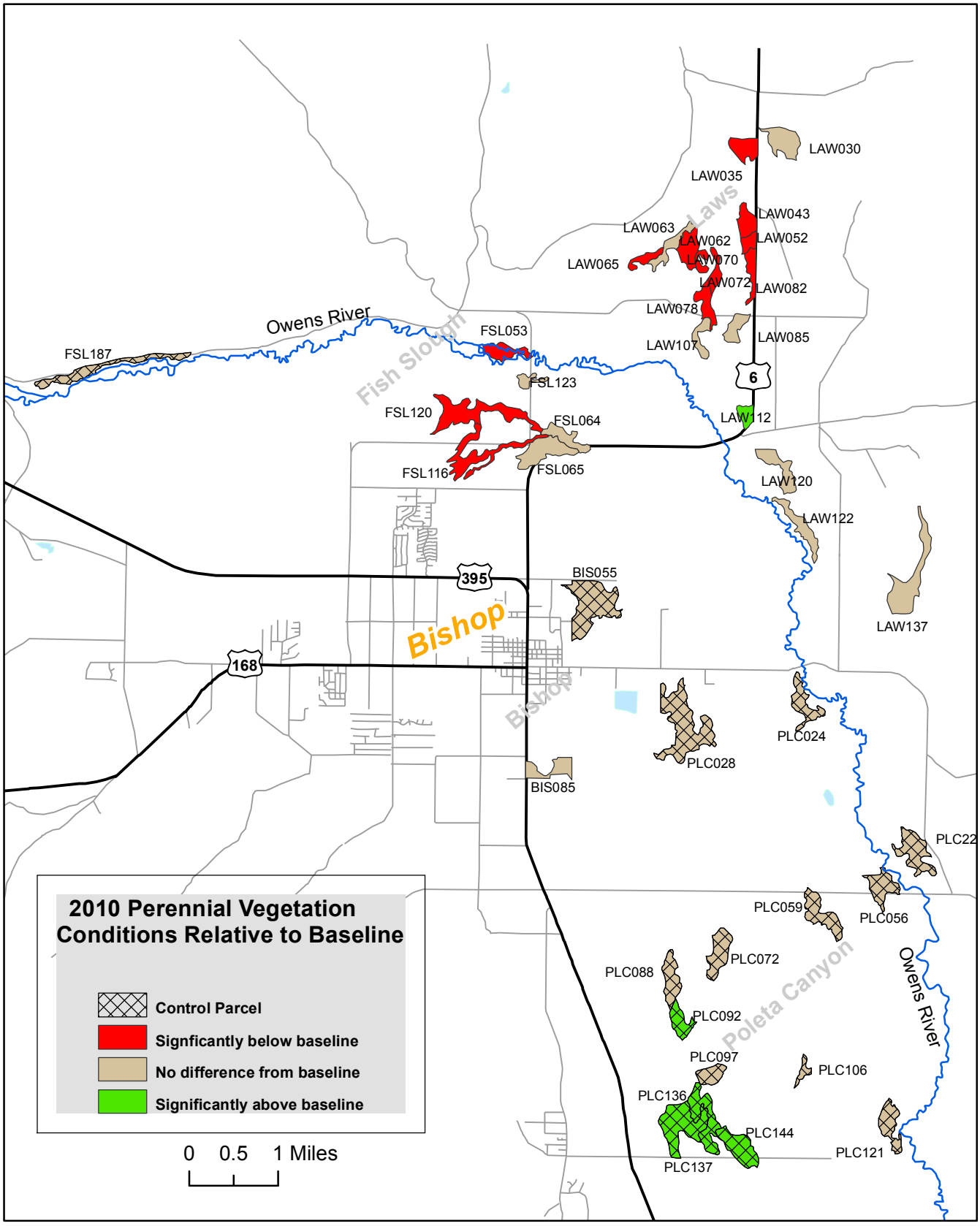
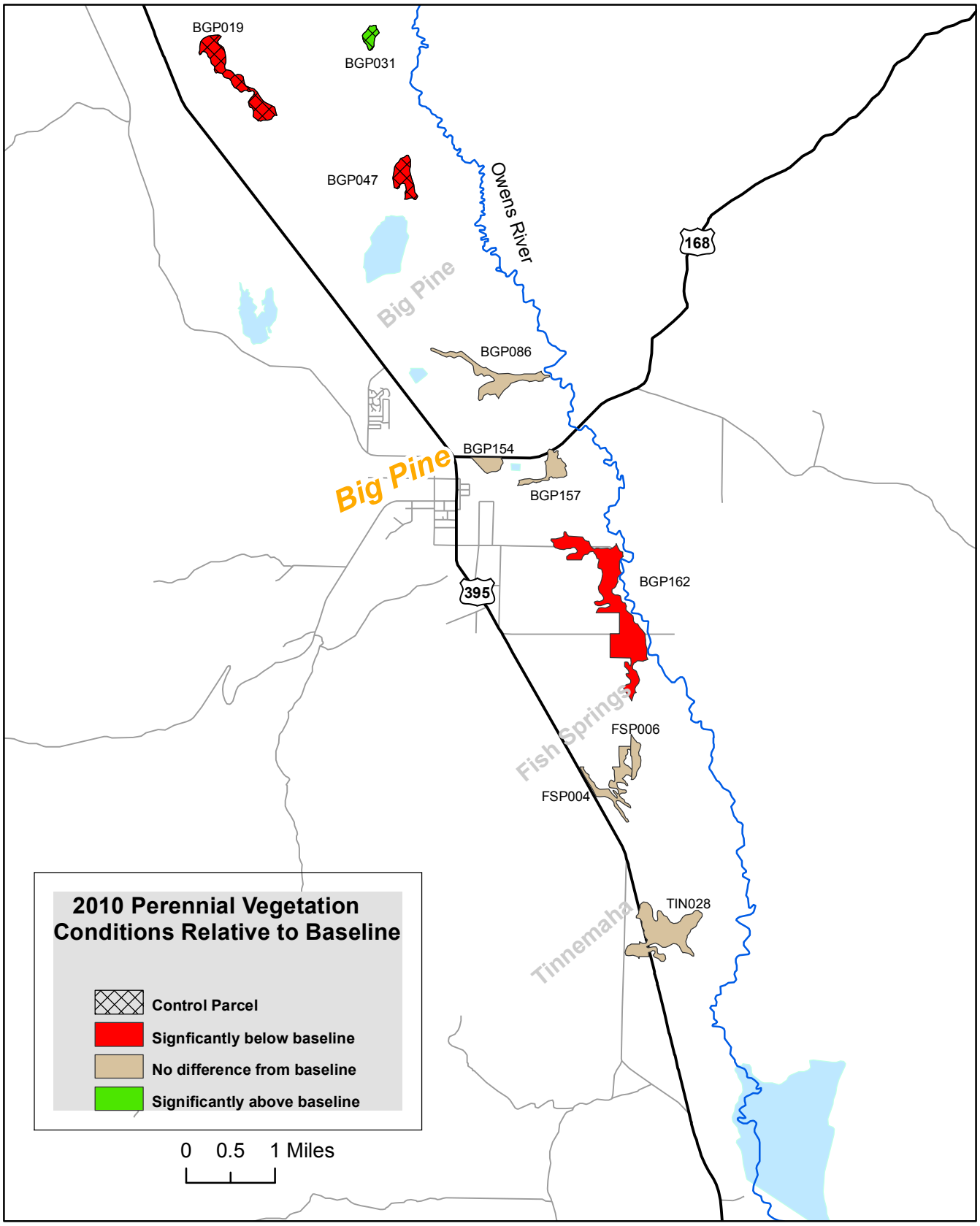
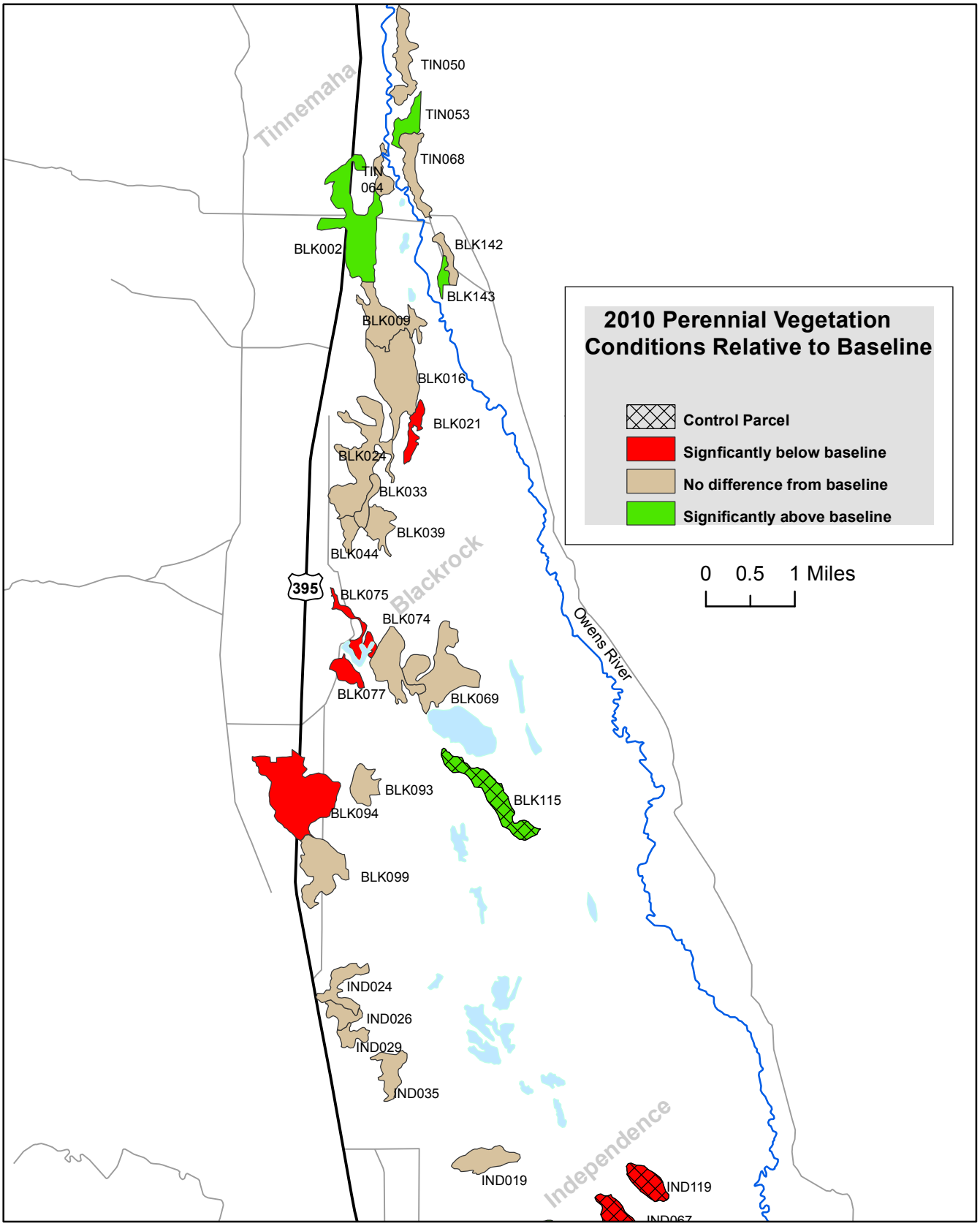
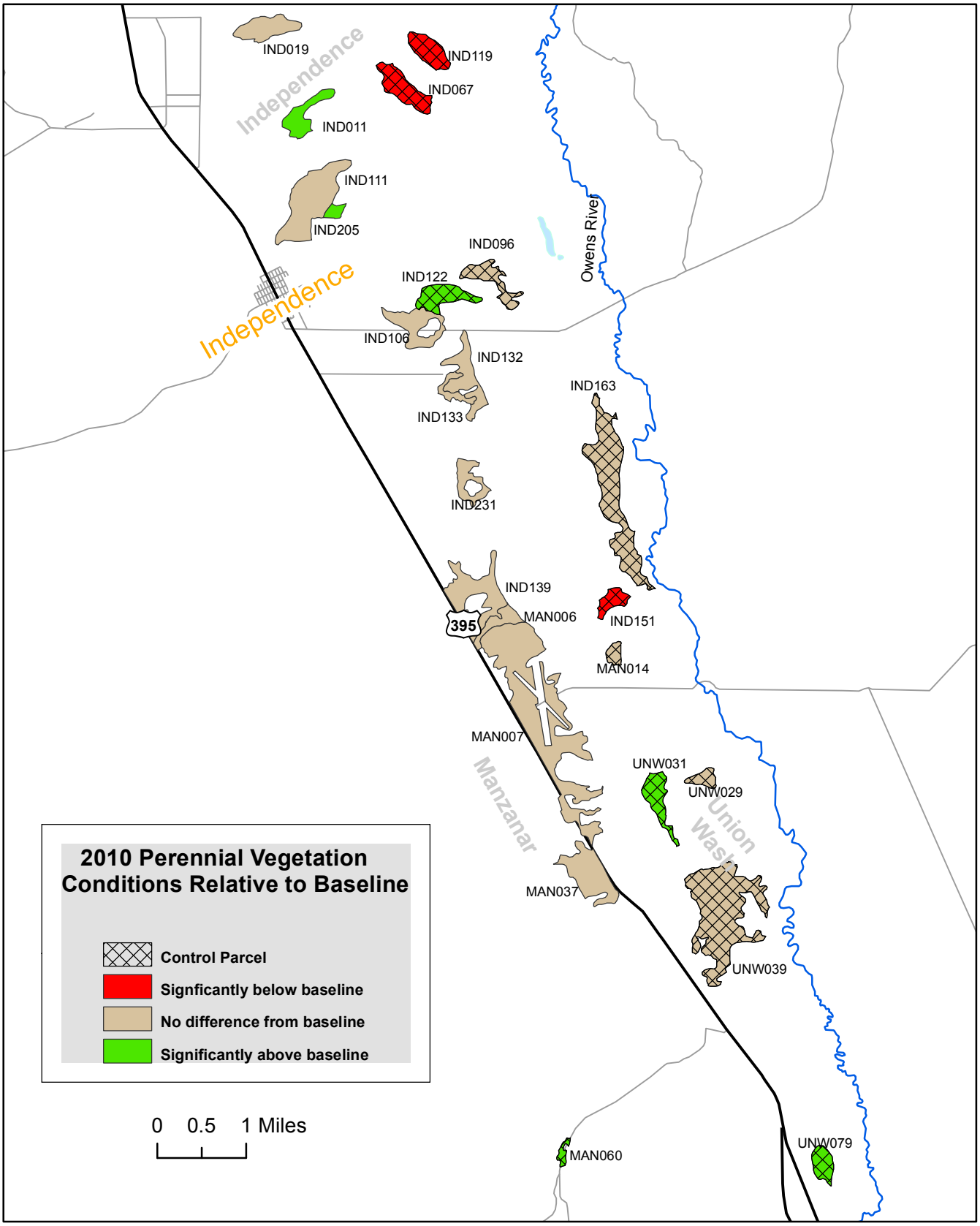


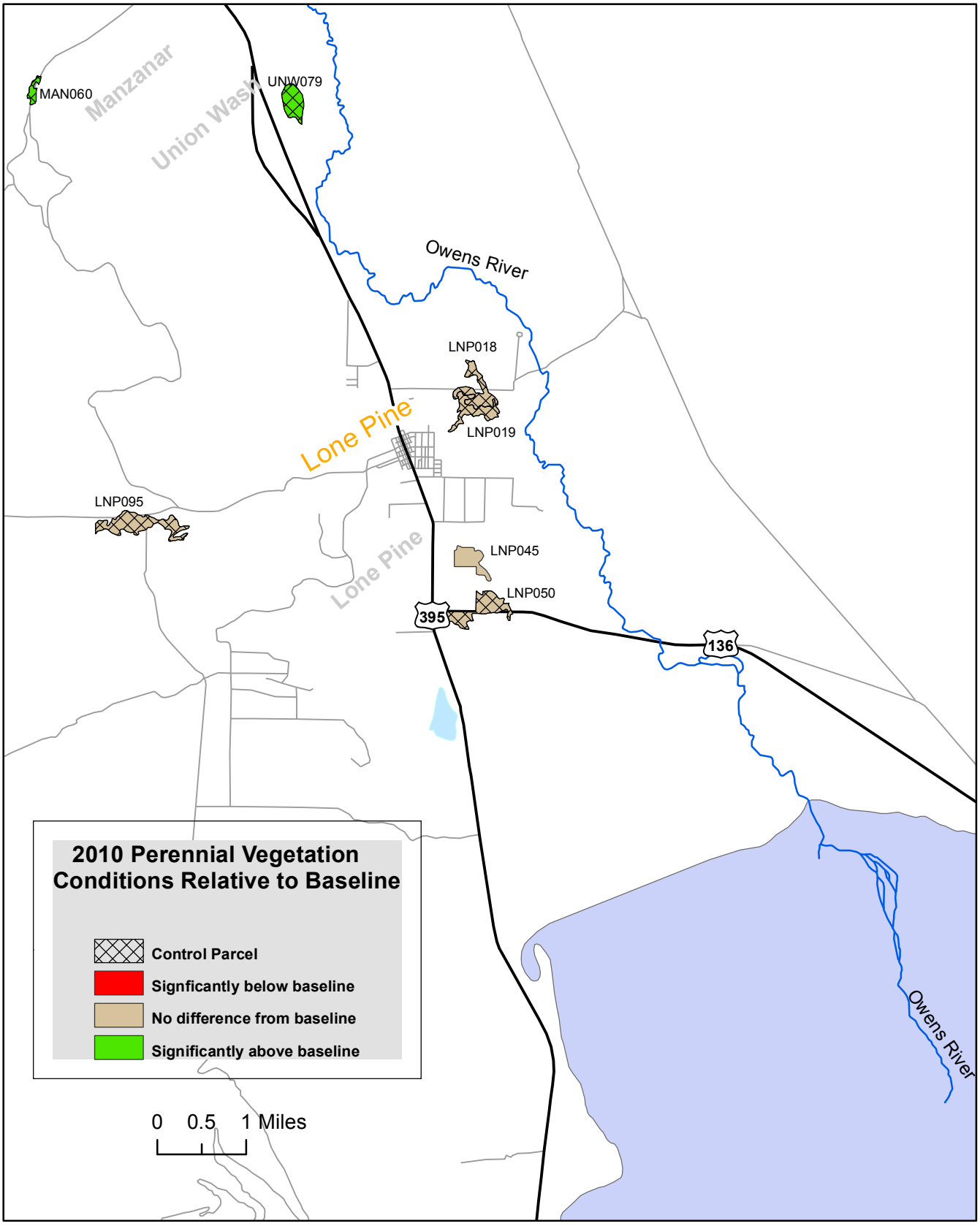
Figure 168: 2010 Control


LAW030
LAW035
LAW043
LAW063
LAW062
LAW052
LAW065
LAW070
LAW072
LAW082
LAW078
LAW085
LAW107
Laws
Owens River
FSL187
FSL053
Fish Slough
FSL123
6
FSL120
FSL064
LAW112
FSL116
FSL065
LAW120
LAW122
LAW137
395
BIS055
Bishop
168
Bishop
PLC024
PLC028
BIS085
PLC22
PLC059
PLC056
PLC072
PLC088
Poleta Canyon
Owens River
PLC092
PLC097
PLC106
PLC136
PLC144
PLC121
PLC137
2010 Perennial Vegetation Conditions Relative to Baseline
Control Parcel
Signficantly below baseline
No difference from baseline
Significantly above baseline
0 0.5 1 Miles


BGP019
BGP031
BGP047
Owens River
168
Big Pine
BGP086
BGP154
Big Pine
BGP157
BGP162
395
Fish Springs
FSP006
FSP004
TIN028
Tinnemaha
2010 Perennial Vegetation Conditions Relative to Baseline
Control Parcel
Signficantly below baseline
No difference from baseline
Significantly above baseline
0 0.5 1 Miles


2010 Perennial Vegetation Conditions Relative to Baseline
Control Parcel
Signficantly below baseline
No difference from baseline
Significantly above baseline
0 0.5 1 Miles
Tinnemaha
Blackrock
Owens River
Independence
395
TIN050
TIN053
TIN068
TIN 064
BLK002
BLK142
BLK143
BLK009
BLK016
BLK021
BLK024
BLK033
BLK039
BLK044
BLK075
BLK074
BLK077
BLK069
BLK093
BLK094
BLK115
BLK099
IND024
IND026
IND029
IND035
IND019
IND119


IND019
IND119
IND067
Independence
IND011
IND111
IND205
IND096
Owens River
IND122
Independence
IND106
IND132
IND133
IND163
IND231
IND139
MAN006
395
IND151
MAN014
MAN007
Manzanar
UNW031
UNW029
Union Wash
MAN037
UNW039
MAN060
UNW079
2010 Perennial Vegetation Conditions Relative to Baseline
Control Parcel
Signficantly below baseline
No difference from baseline
Significantly above baseline
0 0.5 1 Miles


MAN060
Manzanar
Union Wash
UNW079
Owens River
LNP018
LNP019
Lone Pine
LNP095
Lone Pine
LNP045
LNP050
395
136
Owens River
2010 Perennial Vegetation Conditions Relative to Baseline
Control Parcel
Signficantly below baseline
No difference from baseline
Significantly above baseline
0 0.5 1 Miles