Appendix 1. Photographs

Photo 1. Driftwood at Lonesome Beach

Photo 2. Lonesome Beach pebble distribution

Photo 3. Sand flats created by deposition from the Sucker River

Photo 4. Superior Beach – dense cobbles at shore and development in beach-grass zone

Photo 5. Sparsely vegetated sand flats and shallow bars in the Sucker River provide suitable feeding habitat at Lonesome Beach

Photo 6. Carpenter Creek sand flats - 2006

Photo 7. Carpenter Creek sand flats – 2009. Abandonment of the channel is causing increased vegetation.

Photo 7. Beach-grass advancing close to the shoreline at Town Beach. West Bay is visible beyond the Carpenter Creek mouth

Photo 8. Scattered small areas of medium to large pebbles at 25-40% cover close to the beach-grass high dune at South Beach – Carpenter Creek

Photo 9. South-beach Sucker River mouth Sucker River feeding area.

Appendix 2. Grand Marais Harbor Figures

Figure 1. Preliminary plan view of Preferred Alternative breakwater alignment

Appendix 3. Critical Habitat Figures

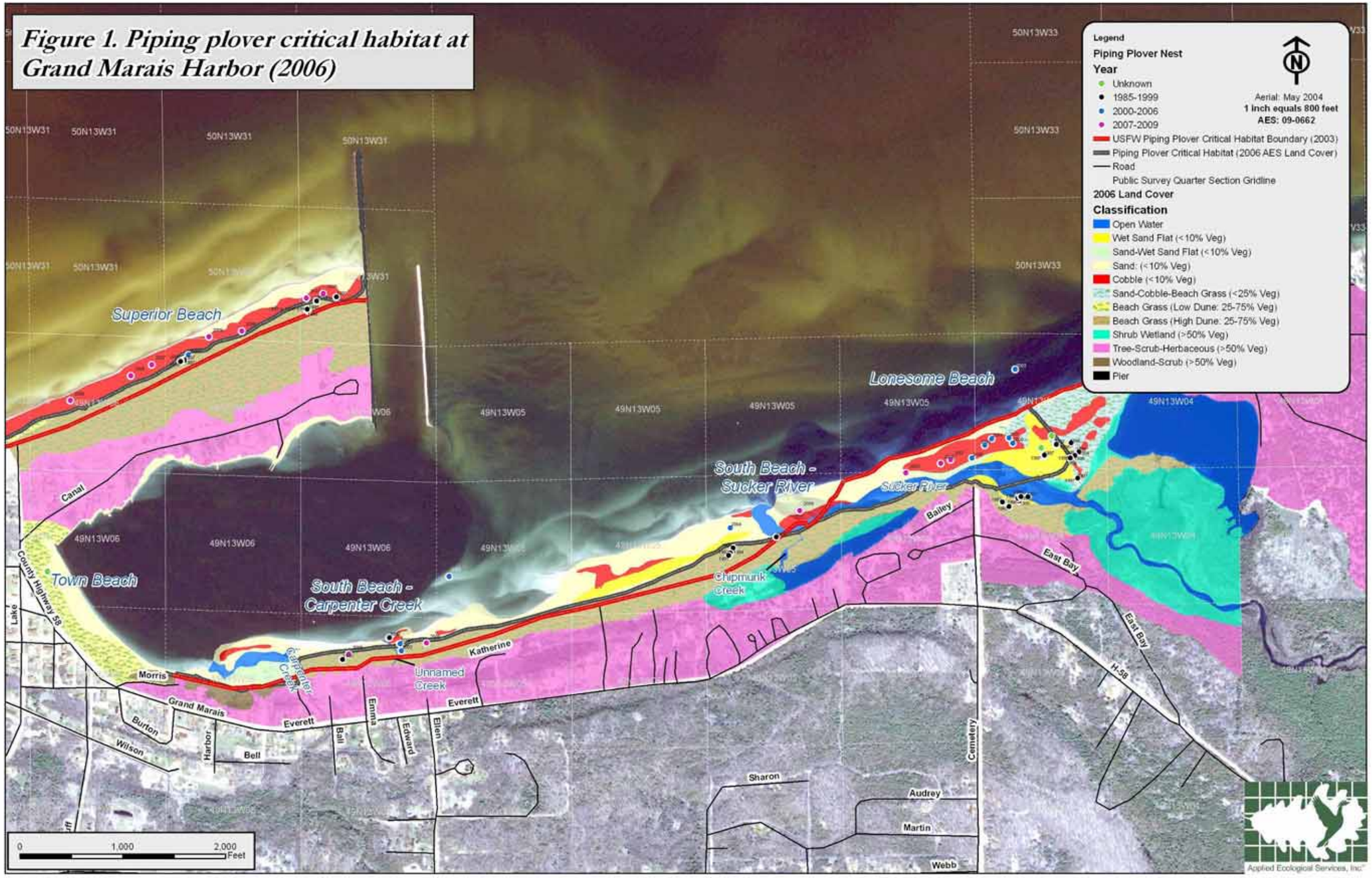

Figure 1. Piping plover critical habitat at Grand Marais Harbor (2006)

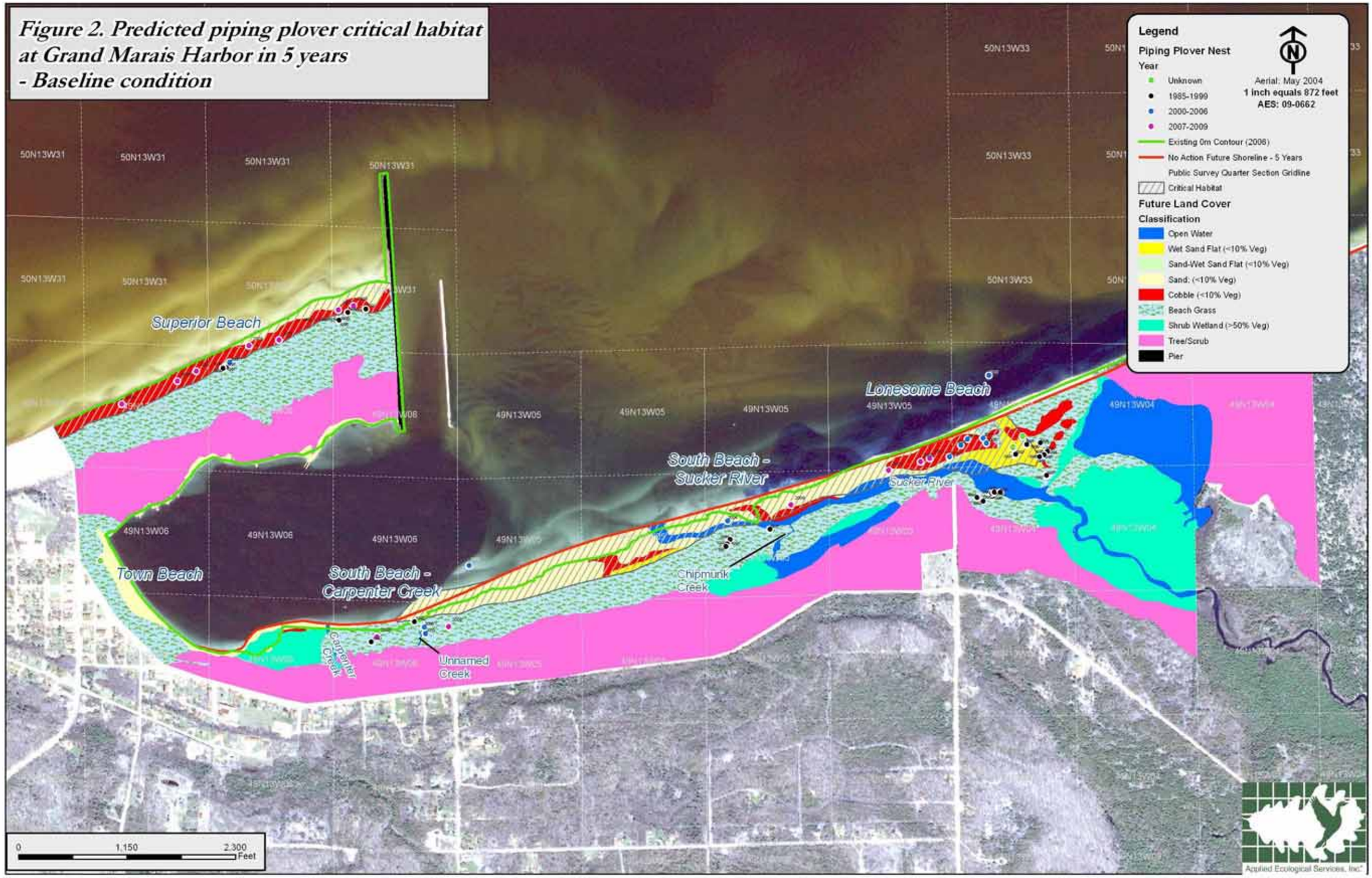

Figure 2. Predicted piping plover critical habitat at Grand Marais Harbor in 5 years - Baseline condition

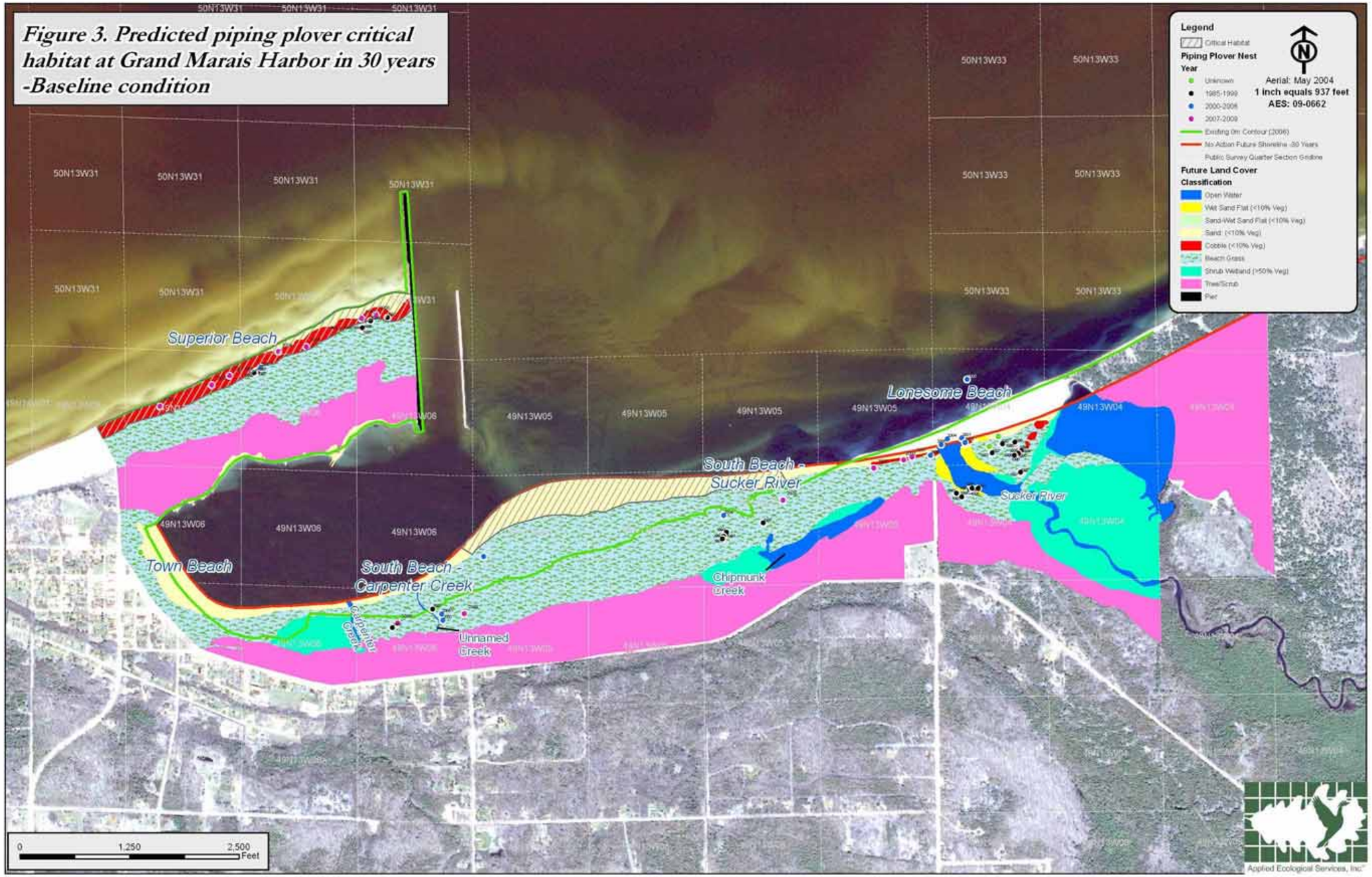

Figure 3. Predicted piping plover critical habitat at Grand Marais Harbor in 30 years -Baseline condition

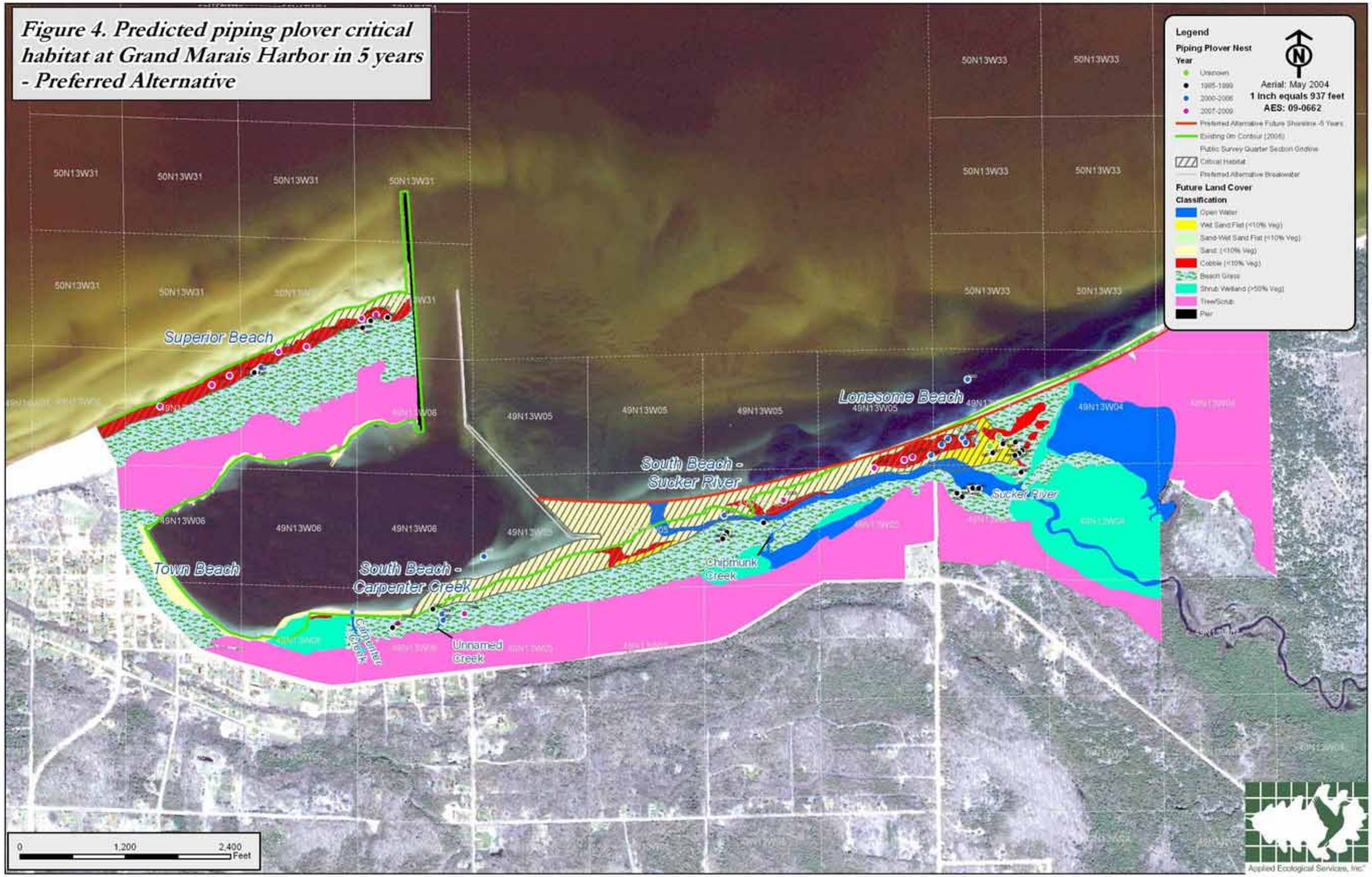

Figure 4. Predicted piping plover critical habitat at Grand Marais Harbor in 5 years - Preferred Alternative

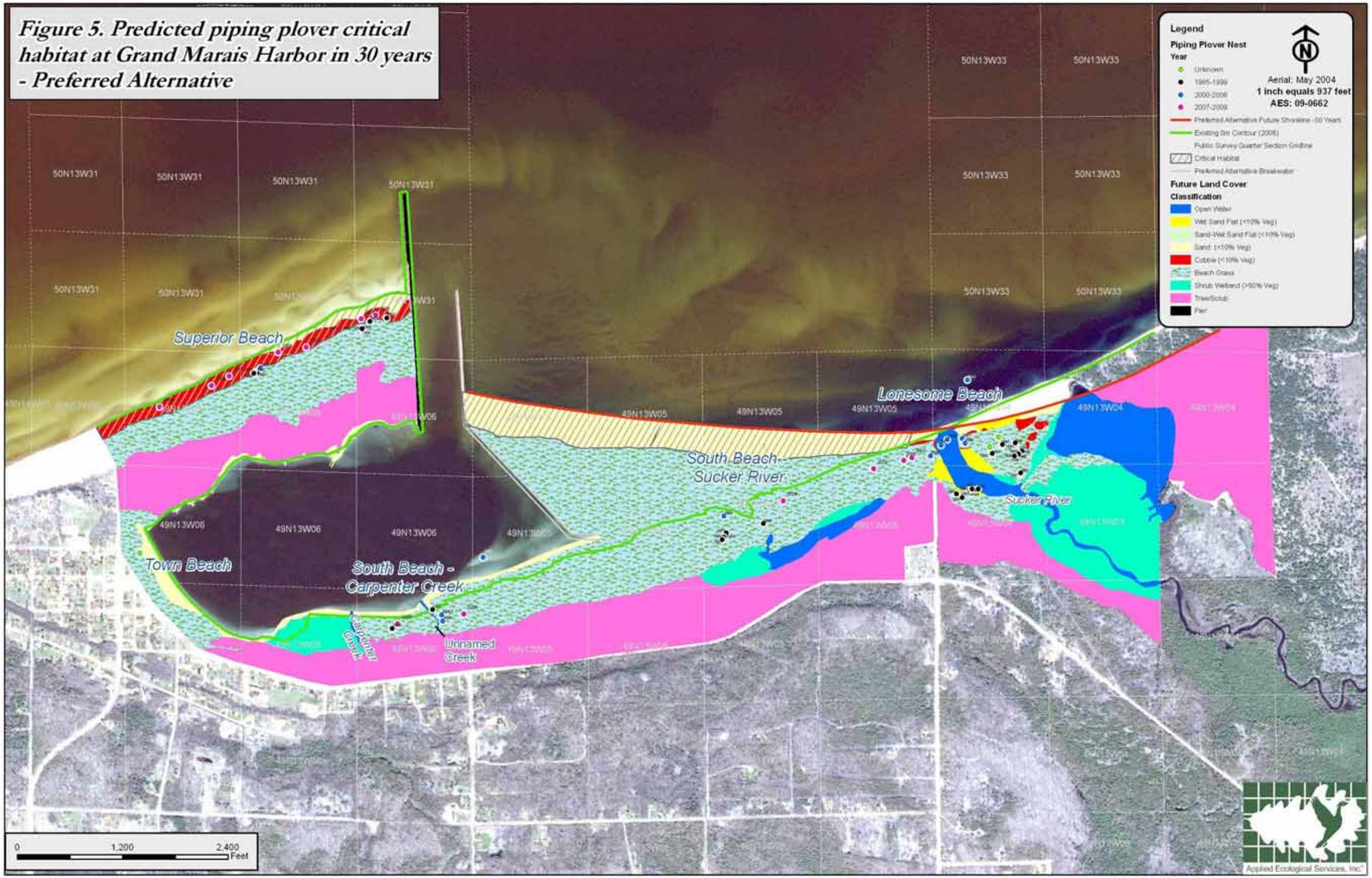

Figure 5. Predicted piping plover critical habitat at Grand Marais Harbor in 30 years - Preferred Alternative

Appendix 4. Estimated Rates of Lakeward Advance by Beach-grass and Woody Plants, Grand Marais, Michigan.

The shoreline environment is dynamic, and areas of dune, open beach and even treeline change continuously in response to changing topography and lake levels. As sand accretes on new beaches it can be expected that beach-grass (*Ammophila breviligulata*) will quickly colonize new areas that are removed from the physical constraints of pounding waves and scouring ice and wind. Since piping plovers typically avoid areas that have more than 10% vegetative cover (Wemmer 2000), it is important to determine the potential rate of beach-grass expansion in order to understand the availability of areas for nesting/feeding. Behind the beach-grass trees and shrubs form a treeline, which piping plovers prefer to avoid when nesting and feeding. Individual birds can become habituated to treelines and nest closer to them than is typical for the species. The rate of treeline advance could also impact available habitat for nesting/feeding.

Beach-grass is a rhizomatous species that tolerates burial from blowing sand. Buried runners extend rapidly to bring the growing tips of the apical meristem close to the new sand surface. During high water years sand is blown from bare sand beaches into beach-grass zones. The beach-grass slows the air's movement near the soil surface, causing deposition and further burial of the beach-grass. Rhizome extension occurs, and the height of the dune increases, but the dune does not advance, or advances only slowly, towards the shoreline.

When water levels fall, sand from the bare sand beaches must travel farther to reach the high beach-grass dune. It either drops out of the air current as a low foredune, or travels to the base of the high dune where it accumulates and reduces the steepness of the high dune facing the lake. By means of seeds, broken-off roots, and extending rhizomes, beach-grass colonizes and eventually dominates the foredune or new sand on the lakeside of the high dune. This expands the beach-grass area.

While beach-grass rhizomes are documented to grow at a rate of up to 2.5m per year (Voss 1972) the movement at the more dynamic beaches of Grand Marais is more complicated. "Occupation" is a more accurate term to describe how beach-grass claims bare sand. In addition to tillering outward, propagules take hold wherever a rhizome or seed becomes established. The microsite conditions necessary for this are not known, but observations of the beaches at Grand Marais demonstrate that propagules are common everywhere except at the steep, continuously wave-swept shoreline. Consequently, a reduction in the disturbance intensity on a beach can favor the expansion of the propagules. A contagion-like pattern of expansion likely results, with tufts of beach-grass spreading outward in all directions and eventually coalescing to form continuous beach-grass cover. In addition, once beach-grass is established, it captures sand and begins to build a dune. This sheltering could also facilitate infilling by seed between the growing dunes.

In order to quantify historical beach-grass and woody plant expansion at Grand Marais, two areas, Superior Beach and West Bay, were chosen as representative areas. These areas were chosen because the vegetation change here was not complex and represents two different probable future conditions at Grand Marais. Superior Beach is an exposed beach that will not be affected by the breakwater. West Bay is a sheltered beach that will be enclosed by the breakwater.

Since there were no empirical studies available which documented how the width of beach-grass dune areas changes, the estimate of the edge of the beach-grass zone was completed using photo interpretation. The shorelines, beach-grass zone, and treelines for the historical photos were mapped (Figures 1 & 2). The change in shoreline, beach-grass zone, and treelines were estimated at several points within the Superior Beach and West Bay historical nesting territories. The boundary of the historical beach-grass zone was interpreted based on the appearance of known beach-grass zones on recent aerial photographs. The beach-grass migration/movement for the Grand Marais piping plover study has an associated error rate due to the quality of the historical aerial photographs and interpretation of historical land covers from the photos.

The Superior beach dune complex appeared to have experienced a rapid change in beach-grass occupancy from 1998-2004 in the high dune area, possibly expanding 54 meters lakeward in 6 years. The visual estimate of the distance between the beach-grass zones over this time period could be in error by 50% given the condition of the aerial photographs over that time period. Therefore the expansion could range from 1.5 to 13.5 m/year.

The West Bay dune complex has a more complex pattern of beach-grass movement, and measured expansion is likely to be less predictive and less accurate. The shoreline in this area has been dramatically modified by the Lake Superior hydraulics. It was assumed for analysis purposes that beach-grass movement was lakeward each year, but there were undoubtedly ebbs and flows in the beach-grass zone. Rates probably varied depending on the position of the beach-grass zone. The advance was probably fastest when crossing high dune areas, and slower as the beach-grass approached the lake. The beach-grass movement in this area was estimated at 1.7 to 7.1 m/year. Again the visual estimate could be in error by as much as 50% given the condition of the aerial photographs.

Patterns of change in the shoreline, beach-grass zone, and treeline suggest that the beach-grass can expand at least 3m per year in periods of lower than average lake levels, and may be capable of advancing 9m per year in some cases (Table 1). It is likely that the beach-grass occupancy of bare sand will be slowed or reversed during periods of high levels. In actuality, beach-grass is expected to advance until equilibrium is reached

with lake levels, exposure to waves, and shoreline erosion and deposition rates. By comparison, the treeline was relatively stable during periods of low lake water levels when increases would be expected. Colonization of the beach-grass zone by shrubs and tree seedlings is difficult because of competition with beach-grass roots for water, high surface soil temperatures, and desiccating wind. Significant treeline advance only occurs over long time periods. The historical 1939 aerial photo with a functional breakwater shows that the treeline was near the water's edge inside the harbor. It is reasonable to assume the treeline will advance if the shoreline is sheltered from the lake, but it may require decades to reach the shoreline.

Table 1. Shoreline, beach-grass front, and treeline expansion in sheltered and exposed beaches

	Sheltered Beach (West Bay)						**Exposed Beach (Superior Beach)**					
	Shoreline (m)		**Beach-grass Zone (m)**		**Treeline (m)**		**Shoreline (m)**		**Beach-grass Zone (m)**		**Treeline (m)**	
	Total	*Annual*	*Total*	*Annual*	*Total*	*Annual*	*Total*	*Annual*	*Total*	*Annual*	*Total*	*Annual*
1974-1983 (9 growing seasons)	38	4.2	30	3.3	13	1.4	10	1.1	27	3	0	0
1998-2004 (6 growing seasons)	-9	-1.5	28	4.7	0	0	14	2.3	54	9	0	0

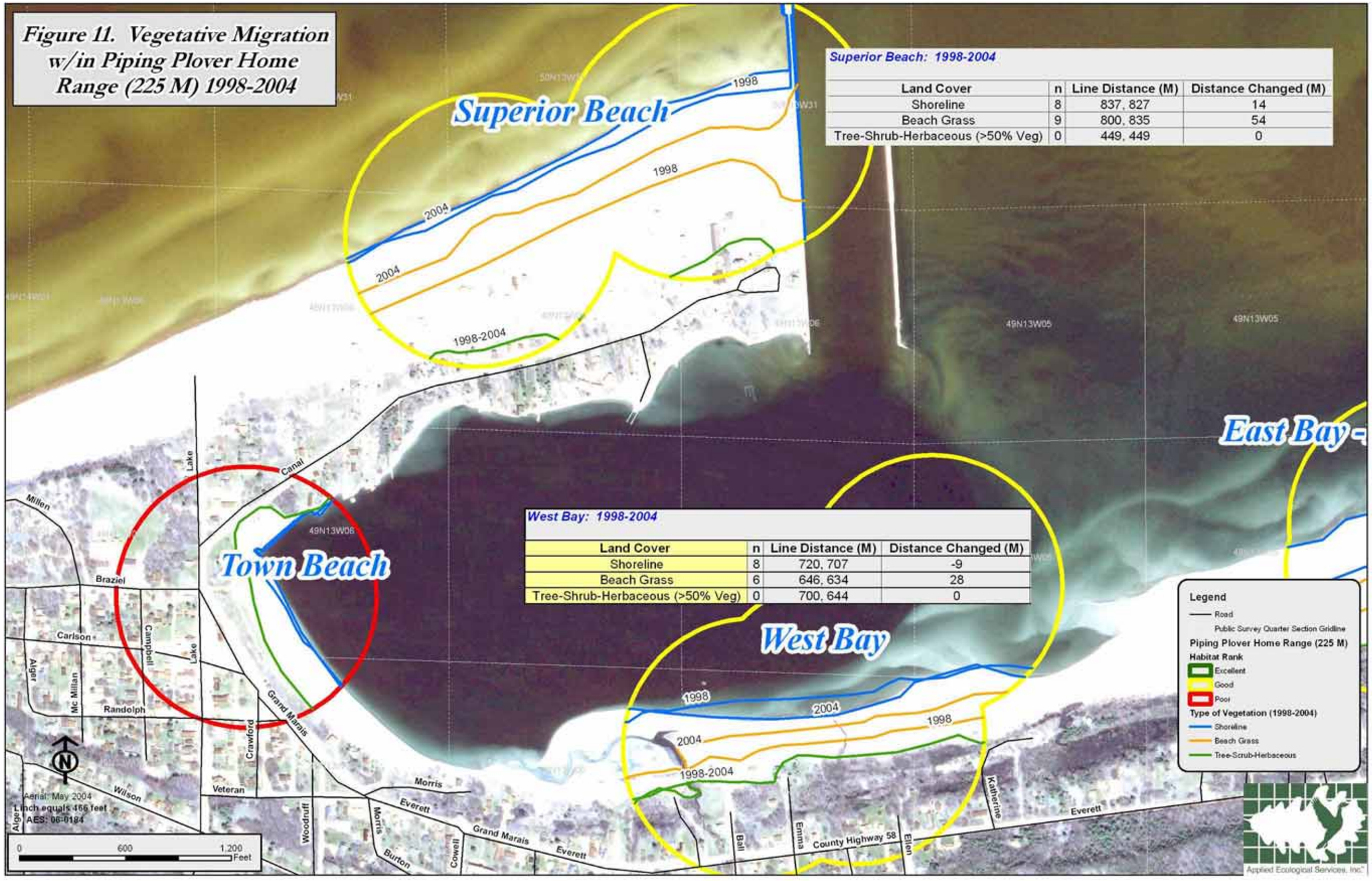

Figure 11. Vegetative Migration w/in Piping Plover Home Range (225 M) 1998-2004

Superior Beach: 1998-2004

Land Cover	n	Line Distance (M)	Distance Changed (M)
Shoreline	8	837, 827	14
Beach Grass	9	800, 835	54
Tree-Shrub-Herbaceous (>50% Veg)	0	449, 449	0

West Bay: 1998-2004

Land Cover	n	Line Distance (M)	Distance Changed (M)
Shoreline	8	720, 707	-9
Beach Grass	6	646, 634	28
Tree-Shrub-Herbaceous (>50% Veg)	0	700, 644	0

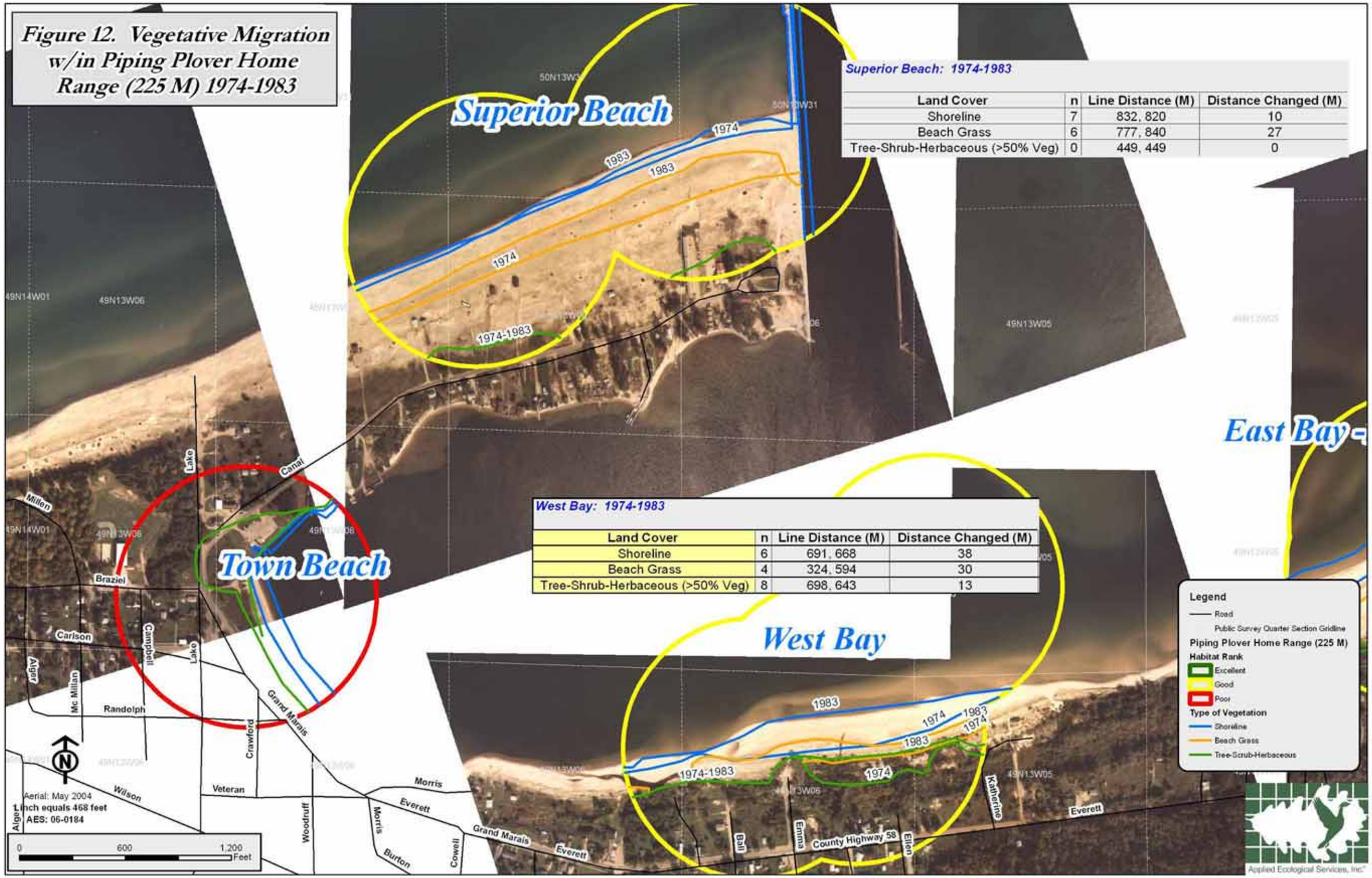

Figure 12. Vegetative Migration w/in Piping Plover Home Range (225 M) 1974-1983

Superior Beach: 1974-1983

Land Cover	n	Line Distance (M)	Distance Changed (M)
Shoreline	7	832, 820	10
Beach Grass	6	777, 840	27
Tree-Shrub-Herbaceous (>50% Veg)	0	449, 449	0

West Bay: 1974-1983

Land Cover	n	Line Distance (M)	Distance Changed (M)
Shoreline	6	691, 668	38
Beach Grass	4	324, 594	30
Tree-Shrub-Herbaceous (>50% Veg)	8	698, 643	13

Appendix 5. Piping Plover Habitat Suitability Assessment at Grand Marais Harbor, Michigan.

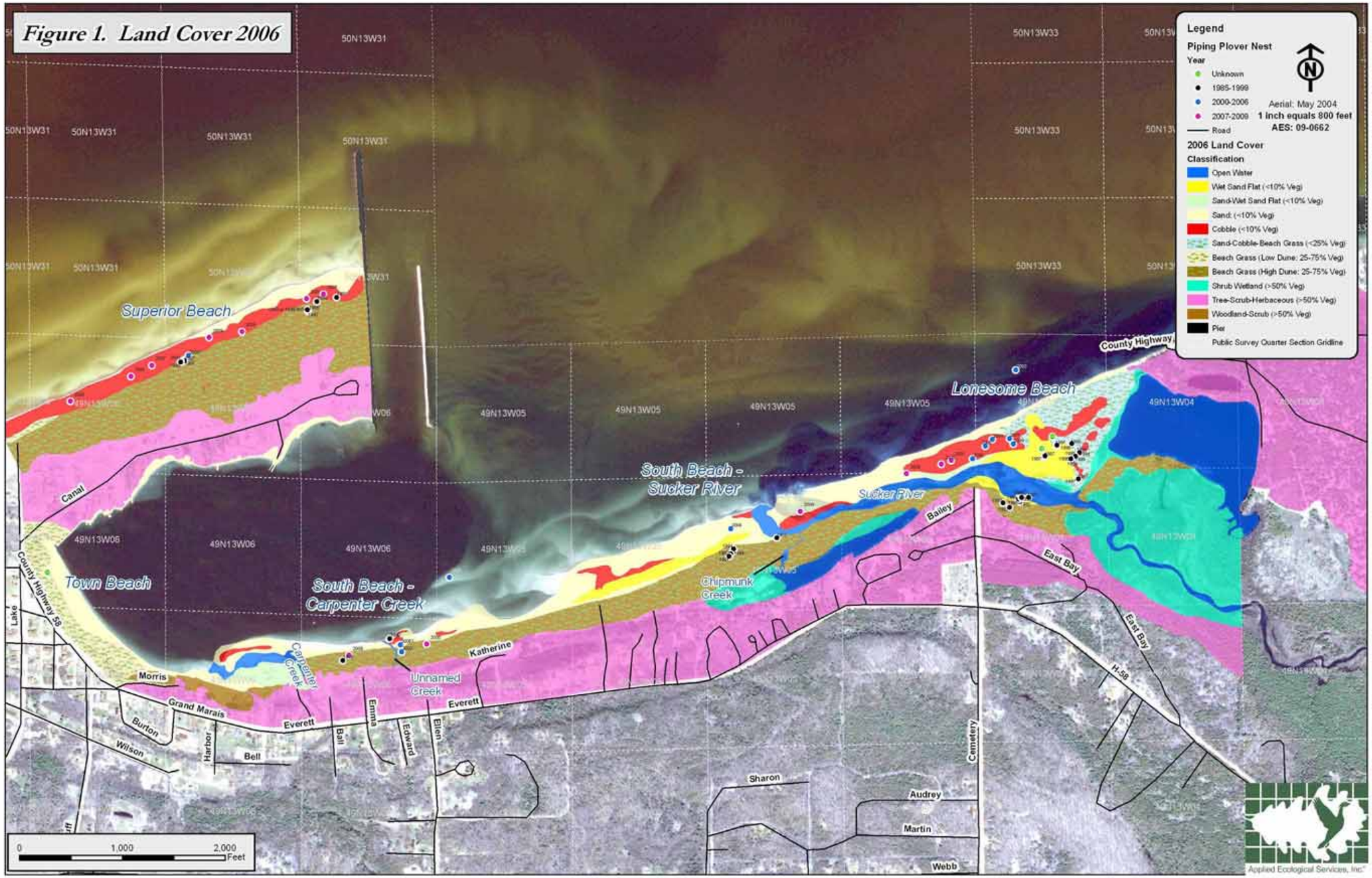
Figure 1. Land Cover 2006
Legend
Piping Plover Nest
Year
Unknown
1985-1999
2000-2006
2007-2009
Road
Aerial: May 2004
1 inch equals 800 feet
AES: 09-0662
2006 Land Cover
Classification
Open Water
Wet Sand Flat (<10% Veg)
Sand-Wet Sand Flat (<10% Veg)
Sand (<10% Veg)
Cobble (<10% Veg)
Sand-Cobble-Beach Grass (<25% Veg)
Beach Grass (Low Dune: 25-75% Veg)
Beach Grass (High Dune: 25-75% Veg)
Shrub Wetland (>50% Veg)
Tree-Scrub-Herbaceous (>50% Veg)
Woodland-Scrub (>50% Veg)
Pier
Public Survey Quarter Section Gridline
Superior Beach
Town Beach
South Beach - Carpenter Creek
South Beach - Sucker River
Lonesome Beach
Sucker River
Chipmunk Creek
Unnamed Creek
Carpenter Creek
County Highway 58
County Highway
Canal
Lake
Morris
Grand Marais
Everett
Burton
Wilson
Harbor
Bell
Ball
Emma
Edward
Ellen
Katherine
Bailey
East Bay
H-58
Cemetery
Sharon
Audrey
Martin
Webb
50N13W31
50N13W33
49N13W05
49N13W06
49N13W04
0
1,000
2,000
Feet
Applied Ecological Services, Inc.

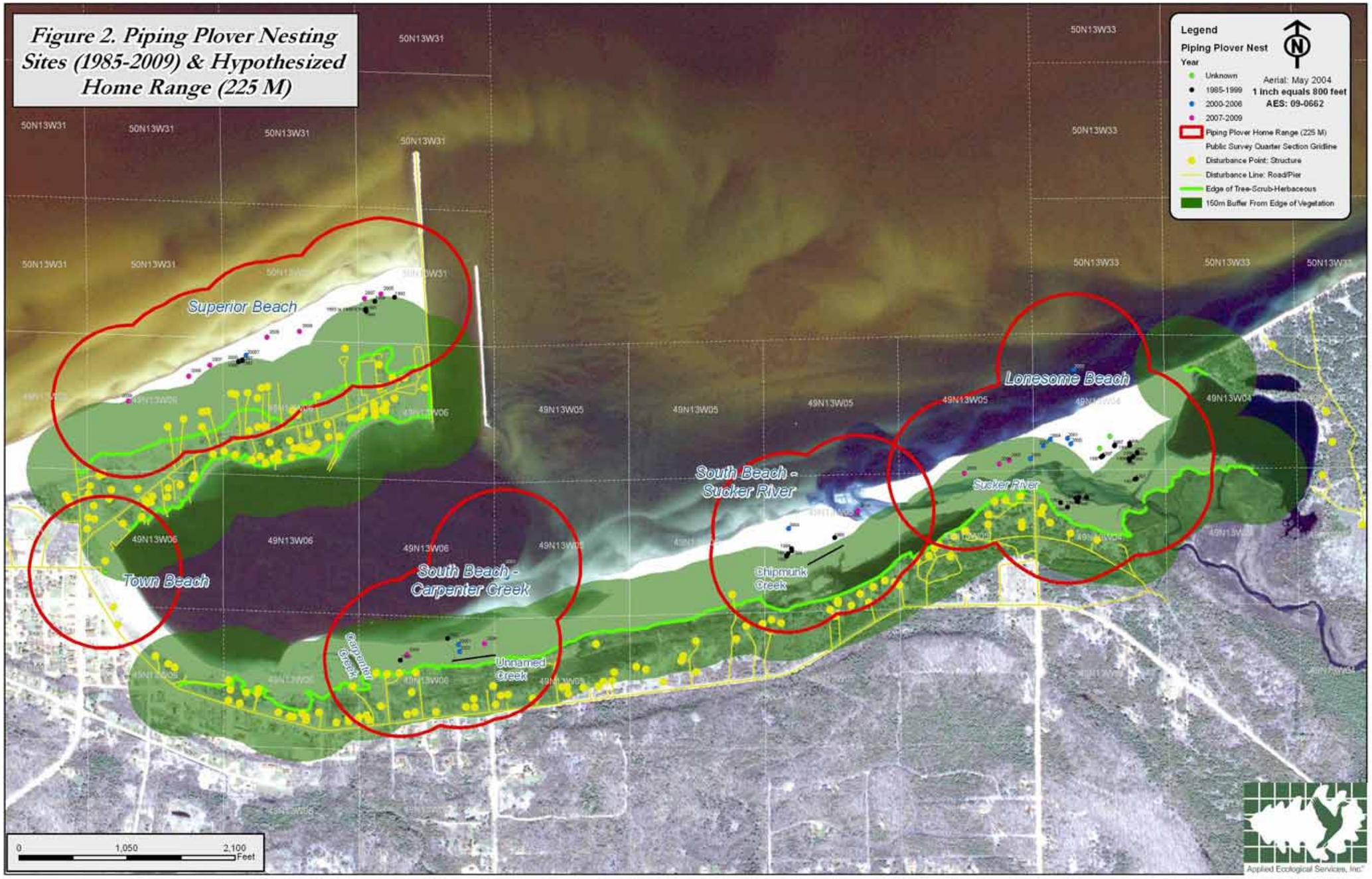
Figure 2. Piping Plover Nesting Sites (1985-2009) & Hypothesized Home Range (225 M)
Legend
Piping Plover Nest
Year
Unknown
1985-1999
2000-2006
2007-2009
Aerial: May 2004
1 inch equals 800 feet
AES: 09-0662
Piping Plover Home Range (225 M)
Public Survey Quarter Section Gridline
Disturbance Point: Structure
Disturbance Line: Road/Pier
Edge of Tree-Scrub-Herbaceous
150m Buffer From Edge of Vegetation
Superior Beach
Town Beach
South Beach - Carpenter Creek
South Beach - Sucker River
Lonesome Beach
Sucker River
Chipmunk Creek
Carpenter Creek
Unnamed Creek
50N13W31
50N13W33
49N13W05
49N13W06
49N13W04
0
1,050
2,100
Feet
Applied Ecological Services, Inc.

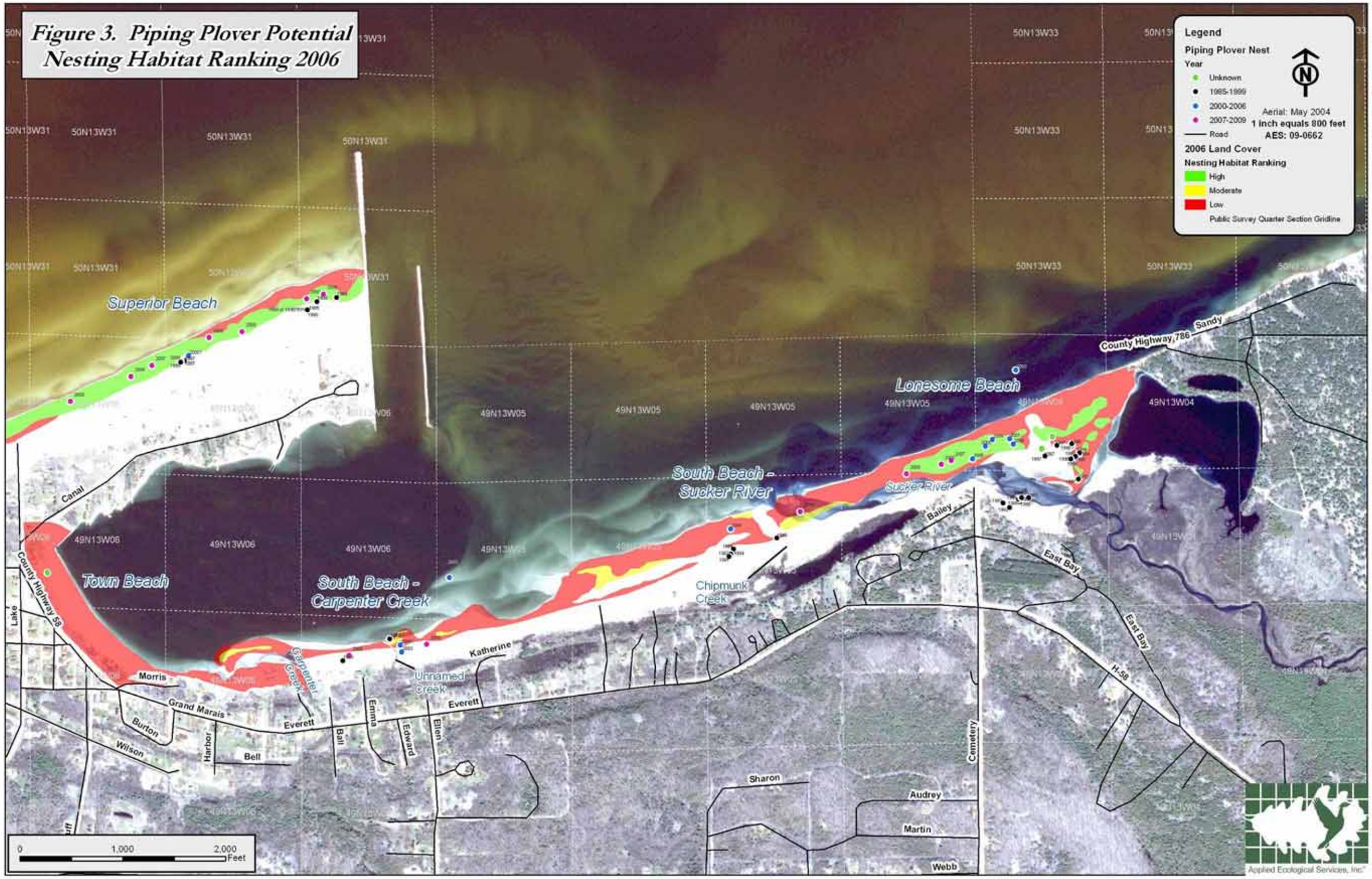
Figure 3. Piping Plover Potential Nesting Habitat Ranking 2006
Legend
Piping Plover Nest
Year
Unknown
1985-1999
2000-2006
2007-2009
Road
Aerial: May 2004
1 inch equals 800 feet
AES: 09-0662
2006 Land Cover
Nesting Habitat Ranking
High
Moderate
Low
Public Survey Quarter Section Gridline
Superior Beach
Town Beach
South Beach - Carpenter Creek
South Beach - Sucker River
Lonesome Beach
Sucker River
Chipmunk Creek
Unnamed Creek
Carpenter Creek
County Highway 786
Sandy
Bailey
East Bay
H-38
Canal
County Highway 58
Lake
Morris
Grand Marais
Everett
Katherine
Burton
Wilson
Harbor
Bell
Ball
Emma
Edward
Ellen
Cemetery
Sharon
Audrey
Martin
Webb
49N13W06
49N13W05
49N13W04
50N13W31
50N13W33
0
1,000
2,000
Feet
Applied Ecological Services, Inc.

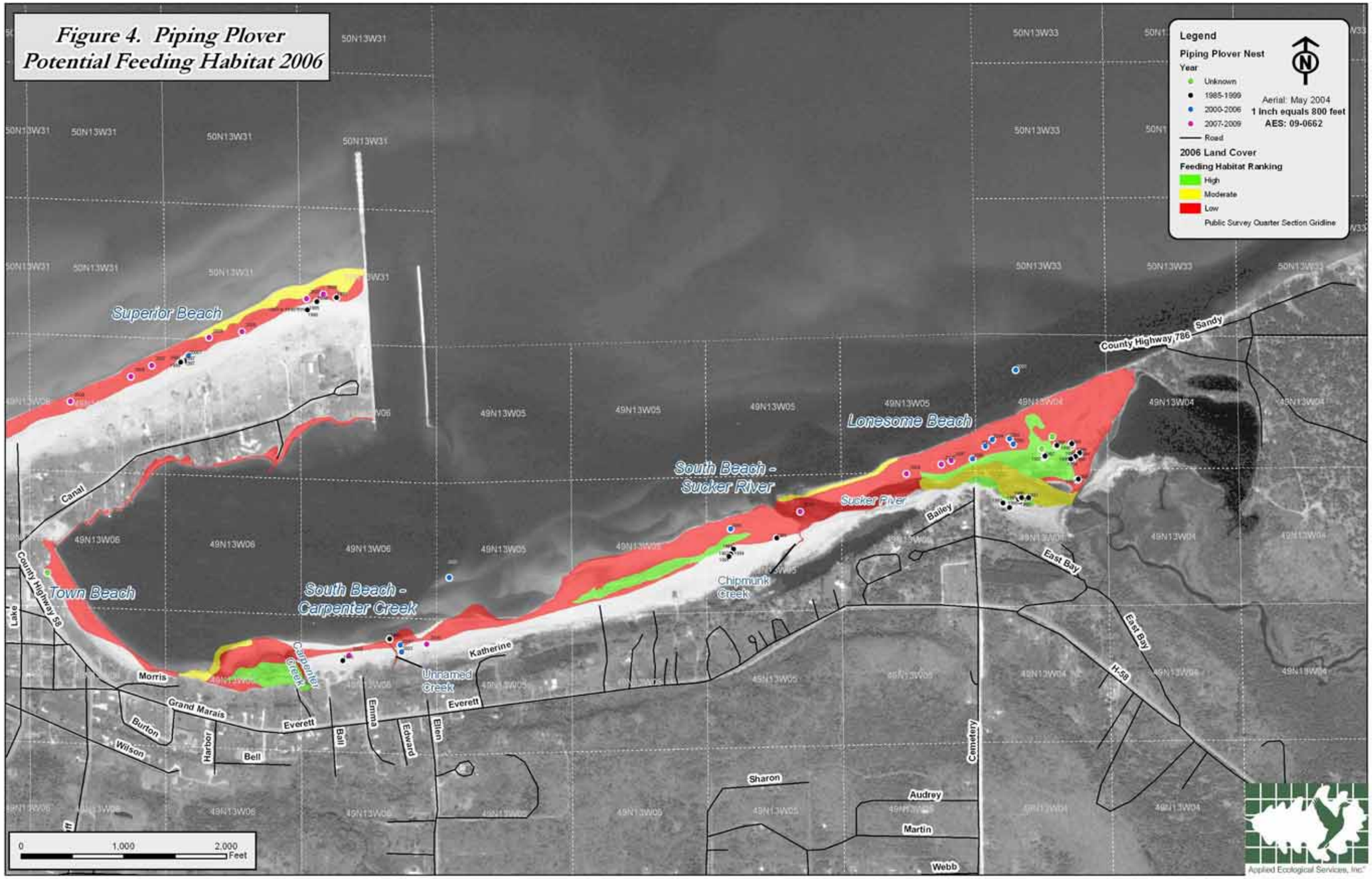
Figure 4. Piping Plover Potential Feeding Habitat 2006
Legend
Piping Plover Nest
Year
Unknown
1985-1999
2000-2006
2007-2009
Road
2006 Land Cover
Feeding Habitat Ranking
High
Moderate
Low
Public Survey Quarter Section Gridline
Aerial: May 2004
1 inch equals 800 feet
AES: 09-0662
Superior Beach
Town Beach
South Beach - Carpenter Creek
South Beach - Sucker River
Lonesome Beach
Sucker River
Chipmunk Creek
Unnamed Creek
Carpenter Creek
County Highway 786
Sandy
Canal
County Highway 58
Lake
Morris
Grand Marais
Everett
Burton
Wilson
Harbor
Bell
Emma
Edward
Ellen
Katherine
Bailey
East Bay
H-58
Cemetery
Sharon
Audrey
Martin
Webb
0
1,000
2,000
Feet
Applied Ecological Services, Inc.

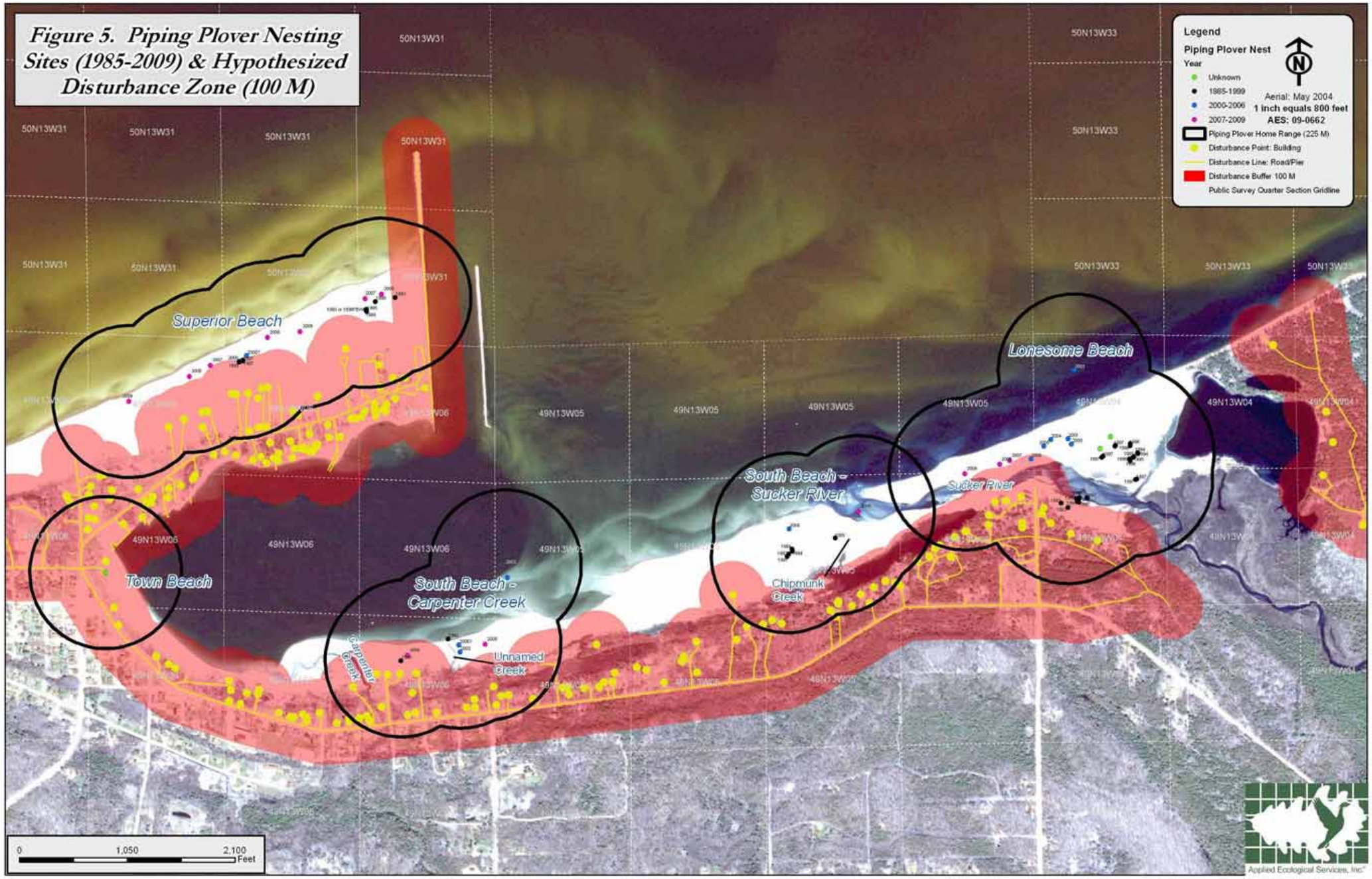

Figure 5. Piping Plover Nesting Sites (1985-2009) & Hypothesized Disturbance Zone (100 M)

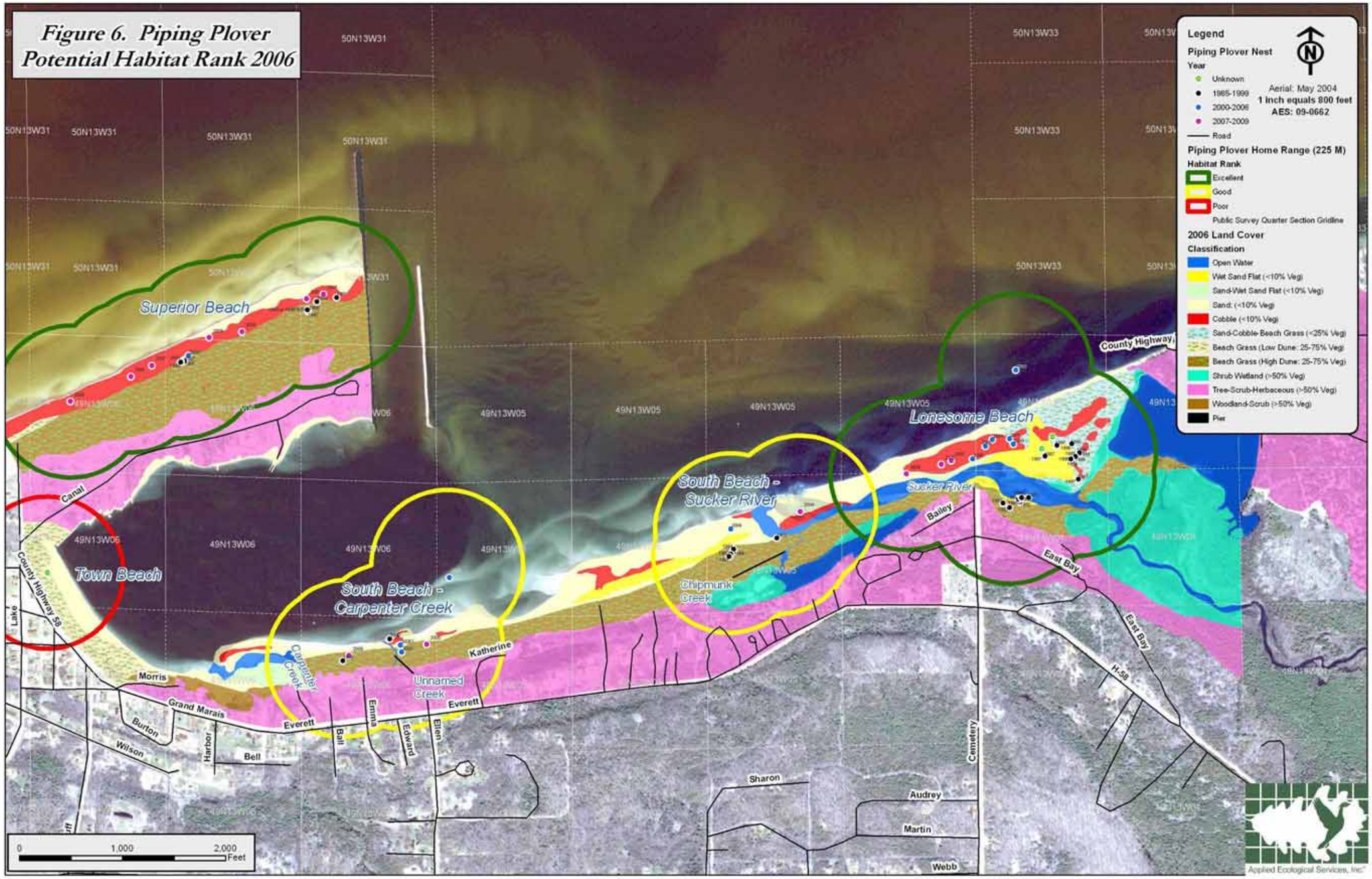

Figure 6. Piping Plover Potential Habitat Rank 2006

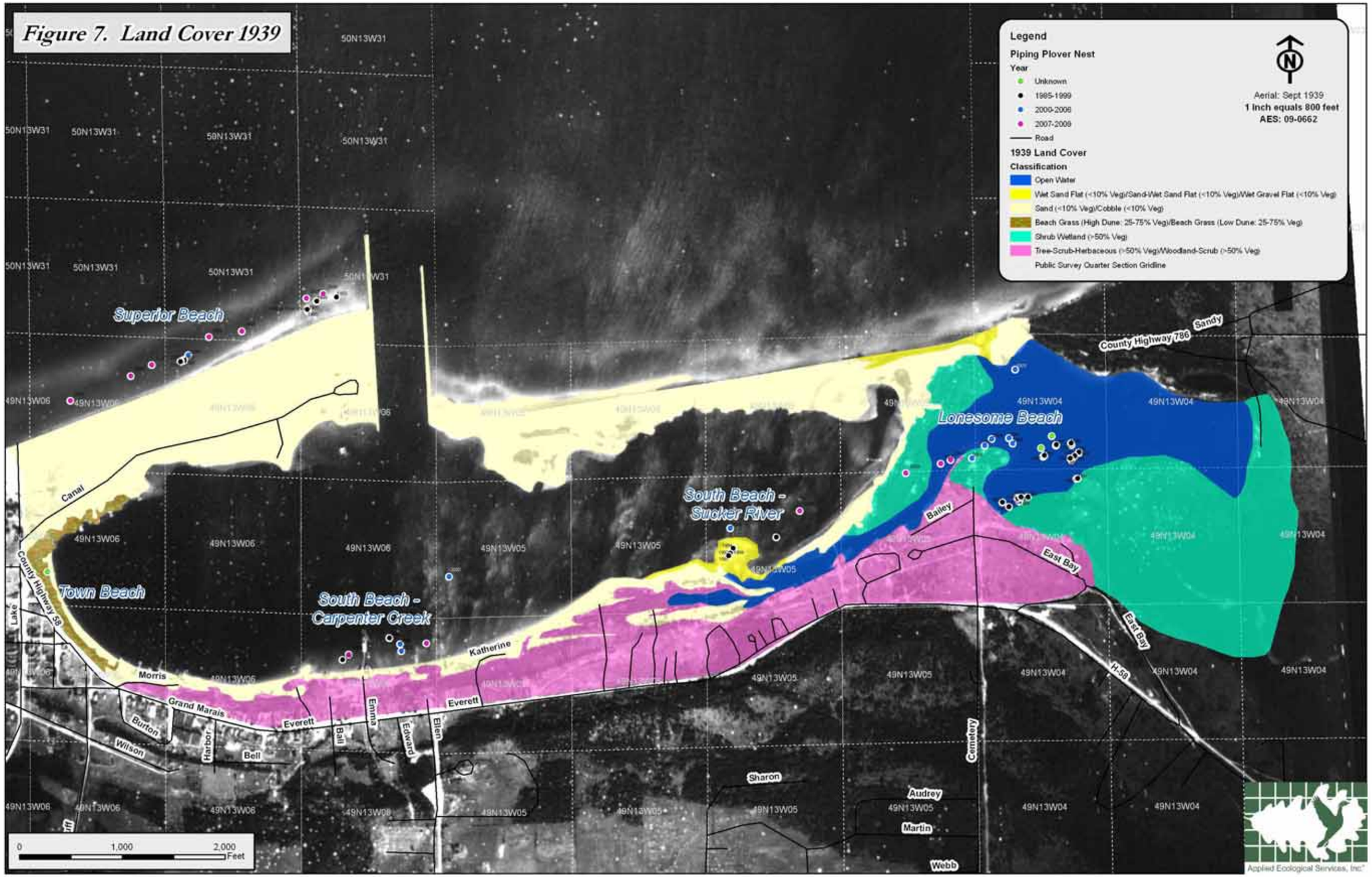
Figure 7. Land Cover 1939
Legend
Piping Plover Nest
Year
Unknown
1985-1999
2000-2006
2007-2009
Road
1939 Land Cover
Classification
Open Water
Wet Sand Flat (<10% Veg)/Sand-Wet Sand Flat (<10% Veg)/Wet Gravel Flat (<10% Veg)
Sand (<10% Veg)/Cobble (<10% Veg)
Beach Grass (High Dune: 25-75% Veg)/Beach Grass (Low Dune: 25-75% Veg)
Shrub Wetland (>50% Veg)
Tree-Scrub-Herbaceous (>50% Veg)/Woodland-Scrub (>50% Veg)
Public Survey Quarter Section Gridline
Aerial: Sept 1939
1 Inch equals 800 feet
AES: 09-0662
Superior Beach
Town Beach
South Beach - Carpenter Creek
South Beach - Sucker River
Lonesome Beach
County Highway 786
Sandy
Canal
County Highway 58
Lake
Morris
Grand Marais
Burton
Wilson
Harbor
Bell
Everett
Ball
Emma
Edward
Ellen
Katherine
Bailey
East Bay
H-58
Cemetery
Sharon
Audrey
Martin
Webb
50N13W31
49N13W06
49N13W05
49N13W04
0
1,000
2,000
Feet
Applied Ecological Services, Inc.

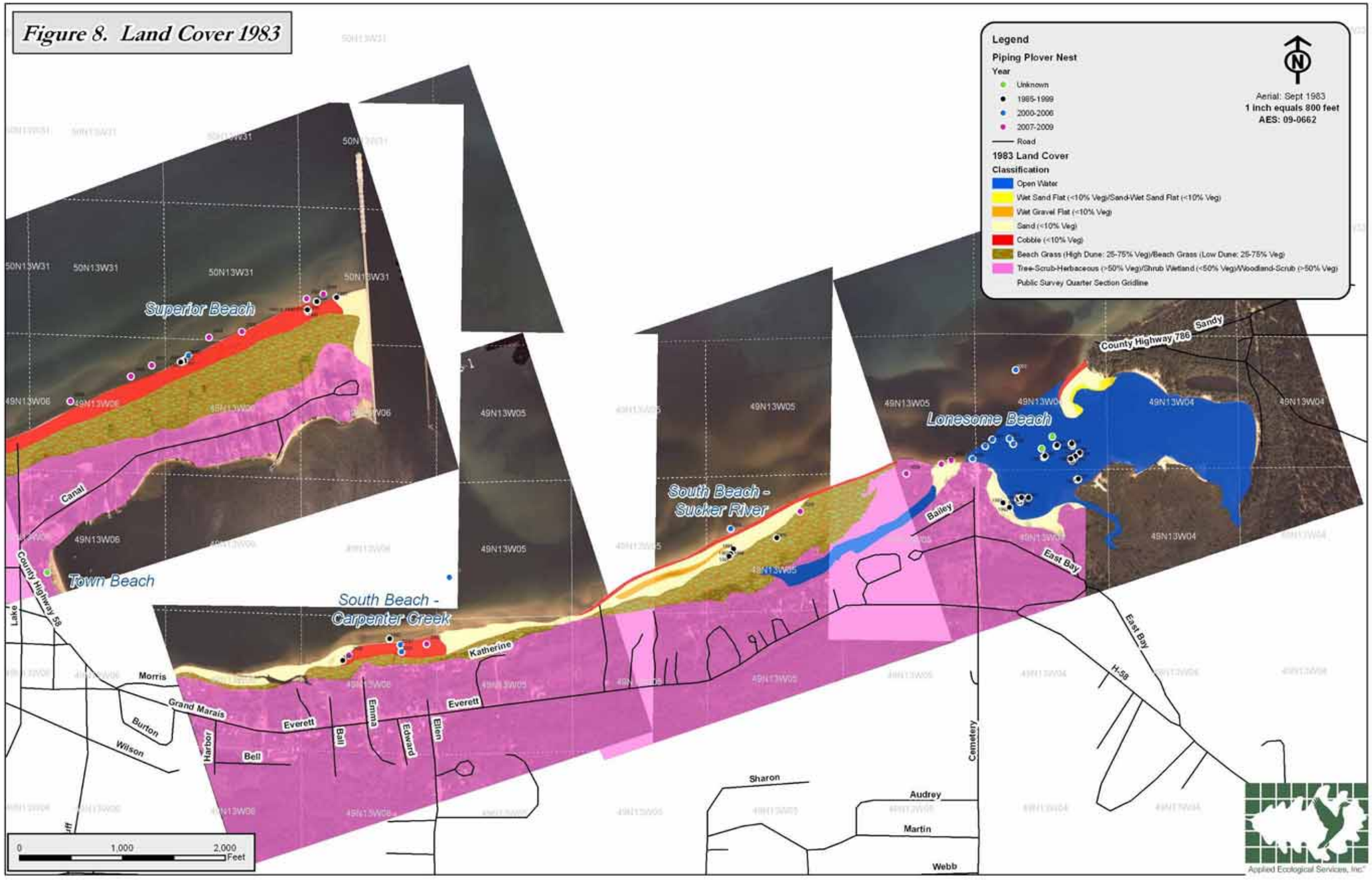
Figure 8. Land Cover 1983
Legend
Piping Plover Nest
Year
Unknown
1985-1999
2000-2006
2007-2009
Road
1983 Land Cover
Classification
Open Water
Wet Sand Flat (<10% Veg)/Sand-Wet Sand Flat (<10% Veg)
Wet Gravel Flat (<10% Veg)
Sand (<10% Veg)
Cobble (<10% Veg)
Beach Grass (High Dune: 25-75% Veg)/Beach Grass (Low Dune: 25-75% Veg)
Tree-Scrub-Herbaceous (>50% Veg)/Shrub Wetland (<50% Veg)/Woodland-Scrub (>50% Veg)
Public Survey Quarter Section Gridline
N
Aerial: Sept 1983
1 inch equals 800 feet
AES: 09-0662
Superior Beach
Town Beach
South Beach - Carpenter Creek
South Beach - Sucker River
Lonesome Beach
County Highway 786
Sandy
Canal
County Highway 58
Lake
Morris
Grand Marais
Burton
Wilson
Harbor
Bell
Everett
Ball
Emma
Edward
Ellen
Katherine
Bailey
East Bay
H-58
Cemetery
Sharon
Audrey
Martin
Webb
49N13W06
49N13W05
49N13W04
50N13W31
0
1,000
2,000
Feet
Applied Ecological Services, Inc.

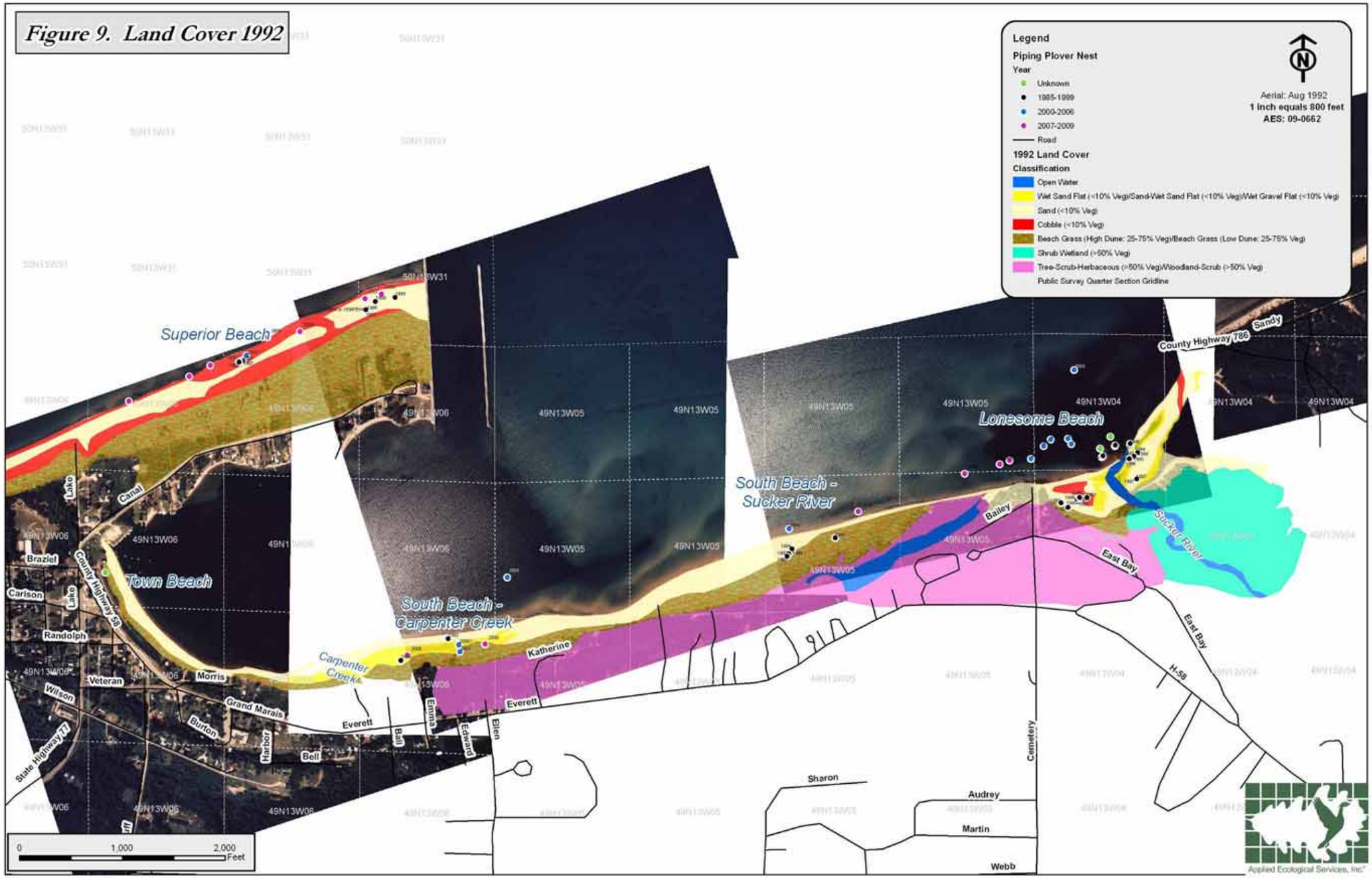
Figure 9. Land Cover 1992
Legend
Piping Plover Nest
Year
Unknown
1985-1999
2000-2006
2007-2009
Road
1992 Land Cover
Classification
Open Water
Wet Sand Flat (<10% Veg)/Sand-Wet Sand Flat (<10% Veg)/Wet Gravel Flat (<10% Veg)
Sand (<10% Veg)
Cobble (<10% Veg)
Beach Grass (High Dune: 25-75% Veg)/Beach Grass (Low Dune: 25-75% Veg)
Shrub Wetland (>50% Veg)
Tree-Scrub-Herbaceous (>50% Veg)/Woodland-Scrub (>50% Veg)
Public Survey Quarter Section Gridline
Aerial: Aug 1992
1 inch equals 800 feet
AES: 09-0662
Superior Beach
Town Beach
South Beach - Carpenter Creek
South Beach - Sucker River
Lonesome Beach
Carpenter Creek
Sucker River
County Highway 786
Sandy
Bailey
East Bay
Katherine
Everett
Emma
Edward
Ellen
Ball
Bell
Harbor
Burton
Grand Marais
Morris
Veteran
Wilson
Randolph
Carlson
Braziel
Lake
Canal
County Highway 58
State Highway 77
H-58
Cemetery
Sharon
Audrey
Martin
Webb
49N13W04
49N13W05
49N13W06
0
1,000
2,000
Feet
Applied Ecological Services, Inc.

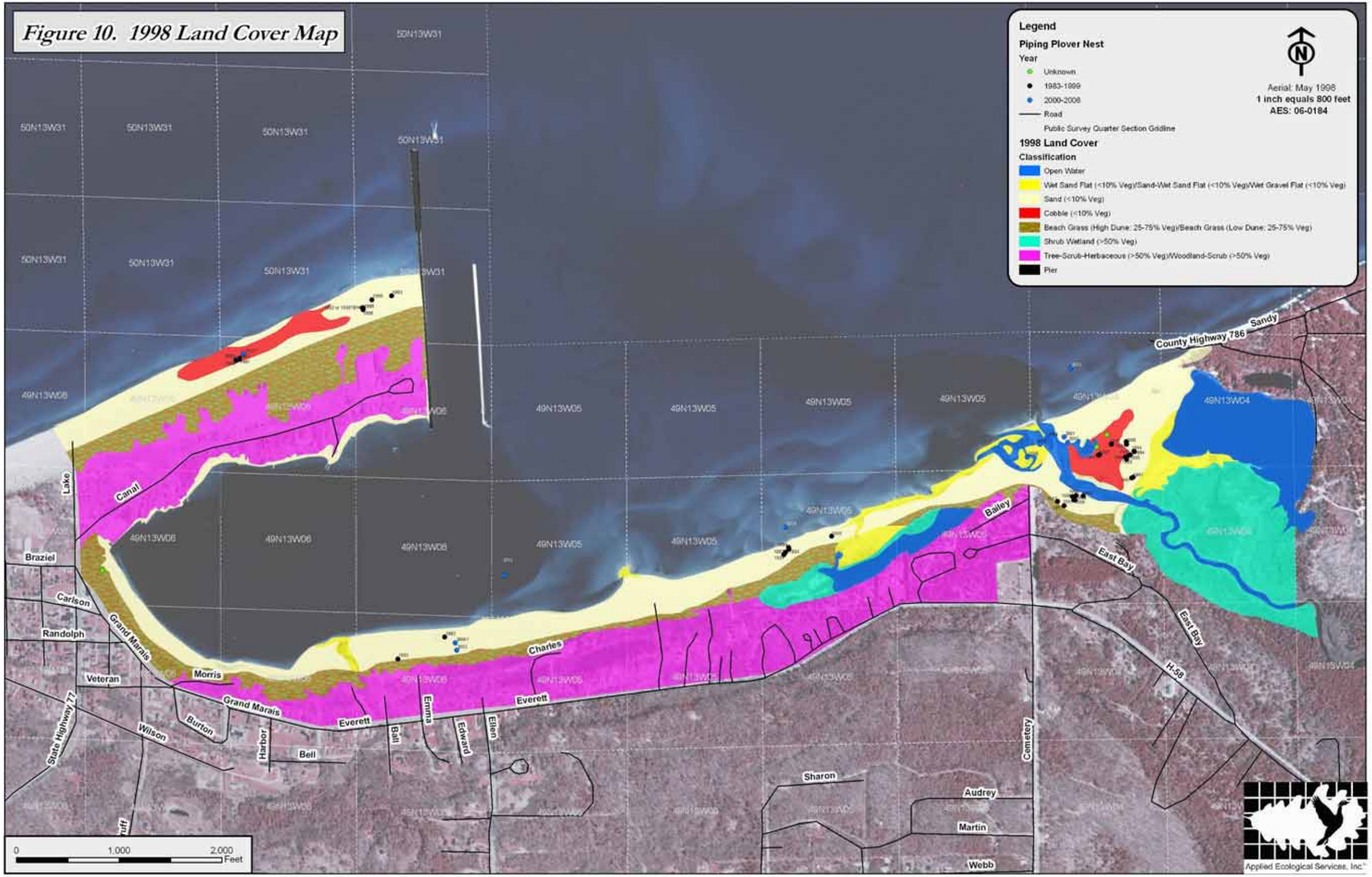
Figure 10. 1998 Land Cover Map
Legend
Piping Plover Nest
Year
Unknown
1983-1999
2000-2008
Road
Public Survey Quarter Section Gridline
1998 Land Cover
Classification
Open Water
Wet Sand Flat (<10% Veg)/Sand-Wet Sand Flat (<10% Veg)/Wet Gravel Flat (<10% Veg)
Sand (<10% Veg)
Cobble (<10% Veg)
Beach Grass (High Dune: 25-75% Veg)/Beach Grass (Low Dune: 25-75% Veg)
Shrub Wetland (>50% Veg)
Tree-Scrub-Herbaceous (>50% Veg)/Woodland-Scrub (>50% Veg)
Pier
Aerial: May 1998
1 inch equals 800 feet
AES: 06-0184
County Highway 786
Sandy
Canal
Lake
Braziel
Carlson
Randolph
Grand Marais
Morris
Veteran
State Highway 77
Wilson
Burton
Harbor
Bell
Ball
Emma
Edward
Ellen
Everett
Charles
Bailey
East Bay
H-58
Cemetery
Sharon
Audrey
Martin
Webb
0
1,000
2,000
Feet
Applied Ecological Services, Inc.

Appendix 6.

Table 1. Factors affecting nesting site selection and reproductive success in Great Lakes Piping Plover Populations

	USFWS 2003	Price 2002	Wemmer 2000	Powell & Cuthbert 1992	Haffner 2005	Haig 1992	Thomas *et al.* 2003	Burg 1994
Near Nest								
Vegetation Cover (%)	<50	<50 [1]	5.3(5.5) [2]					
Escape Cover (cobble, plant tufts, driftwood) (%)	0 - 97	0 - 61	22(33) [1]					
Beach Width (m)	7 - 89	>26.3 [1]	37(62) [1]	>30				
On Beach								
Distance to Trees (m)	>35	>50 [3]	231 (150)[4]	>400				
Shoreline Length (m)		>800						
Linear Travel Distance (95% of time) (m)			200[5]		480			
Home Range[2] (m on side / km[2])					590 / 0.35			
Home Range while incubating / fledging (m on side / km[2])				<200	173 / 0.03			
In Response to Other Plovers, People, Dogs, Buildings								
Nest Separation (m)						100		
Distance to People / Dogs causing behavior change (m)							30	100
Distance to Building (m)				>100				

[1] Significant in statistical test of model
[2] (for successful nests)
[3] From high water mark
[4] From nest
[5] Wemmer, 2001

0 375 750 1,125 m
0 1,100 2,200 3,300 ft
Scale 1:20,630

Figure 7 - Summary of Piping Plover Habitat Impacts
No Project versus Breakwater Alternatives

Spatial Reference: NAD_1983_UTM_Zone_16N

Baird

Shoreline accretion under the Baseline condition and under the Preferred Alternative was quantified along six transects drawn roughly perpendicular to the shoreline (see map above). The distance from the existing shoreline to the predicted shoreline was measured (Table 1).

Table 1. Shoreline Accretion under Baseline condition and Preferred Alternative

	Shoreline Accretion in Feet					
Transect Number	**1**	**2**	**3**	**4**	**5**	**6**
Baseline – 5 Years	380	120	20	10	-60	-80
Preferred Alternative – 5 Years	0	340	90	30	-100	-130
Baseline – 30 Years	1080	650	240	10	-260	-340
Preferred Alternative – 30 Years	0 at coast 690 at breakwater	1420	820	330	-140	-300