UNIVERSITY OF FLORIDA

Assessment of Depressional Wetland Characteristics Influencing On-site and LiDAR Delineation Methods

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Introduction

Wetland protection started within the United States following the Clean Water Act of 1972. Wetlands can be defined as areas that under normal circumstances are saturated or inundated by groundwater or surface water for periods long enough to support vegetation which is adapted to live in saturated soil conditions (Cowardin *et al.*, 1979). These areas serve many functions such as improving water quality through plant uptake of nutrients, providing groundwater recharge, supporting diverse ecosystems, and providing stormwater retention and treatment. To protect these areas, they must first be identified and delineated

Delineation methods require the identification of hydrologic indicators, vegetation, and soils that under normal conditions are dependent on saturated conditions to exist (Environmental Laboratory, 1987). Wetlands in the state of Florida are generally delineated using the procedures that are outlined in Chapter 62-340, Florida Administrative Code. The exceptions are wetlands that fall under federal jurisdiction that are connected to navigable waters and are delineated using the rules established by the United States Army Corps of Engineers (Environmental Laboratory, 1987).

State Level Delineation in Florida

Most delineation of wetlands in Florida is carried out jointly through the Environmental Resource Permit (ERP) program of the Florida Department of Environmental Protection (FDEP) and the five state water management districts (Florida Department of Environmental Protection Staff, 2011). Other local governmental authorities may be delegated authority for wetland delineation, but Broward County is the only one to date. The ERP program exists so that wetlands and waterways will not be harmed due to new construction. An ERP is issued either by the water management district or FDEP for a specific purpose and looks to assure that the applicant will not cause adverse impacts on water resources. In some cases mitigation may be required; for example, if a wetland were filled on a construction site, one could be created elsewhere to offset the effects. The ERP program aims to minimize the loss of wetland functions while recognizing private property rights, growth, and economic pressures (St. Johns River Water Management District Staff).

State methods of wetland delineation differ from the 1987 methodology adopted by the United States Army Corps of Engineers. In most cases the two methodologies produce similar delineated wetland boundaries, but in some areas significant differences do exist. As part of a permit application review or upon request, DEP or one of the water management districts performs wetland delineations on a property. There are three types of delineation requests which include formal delineations, delineations through a permit application, and informal determinations (Florida Department of Environmental Protection Staff, 2011).

Delineation of wetlands requires onsite identification of the wetland boundary. Observations that must be made onsite include vegetative community breaks, hydric soils, and hydrologic indicators. Using the state methodology as outlined in Chapter 62-340, F.A.C. a wetland can be delineated by definition or by using one of five field tests. Using the definition of a wetland requires that there be a clear vegetative community break and an abrupt boundary that separates the upland from the wetland. Field tests (Table 1), named A, B, C, D, and Altered Sites respectively, may be used and are also defined in the Florida Administrative Code (Gilbert *et al.*, 1995).

Vegetation is a key aspect of delineating wetlands. In fact, specific types of wetlands are often named after vegetative communities because these communities are often the most obvious aspect of the wetland (Tobe *et al.*, 1998). The A and B tests require specific vegetation be present in conjunction with hydrologic indicators or hydric soils. The tests require that vegetation be inventoried at three strata, starting with the canopy, which includes all woody plants and palms with a diameter at breast height (DBH) of four inches or more. The subcanopy is the next stratum observed and includes plants with trunks / stems with a DBH of one to four inches. The final and lowest vegetative stratum observed is ground cover. This stratum includes all other vegetation not included in the canopy or subcanopy. Ground cover does not include aquatic plants (free floating or underwater plants) or vines. Individual vegetation species can be categorized into four groups for inventorying wetlands and to determine if test requirements are met. These groups are upland (UPL), facultative (FAC), facultative wet (FACW), and obligate (OBL) (Gilbert *et al.*, 1995).

Soils are also important in delineating wetland boundaries. The C and D tests require observations be made of types of soil present or hydric soil indicators, which may need to be in conjunction with hydrologic indicators depending on which test is being used. The altered sites field test is used at sites where landscape and/or hydrology have been changed. For all wetland delineation activities, reasonable scientific judgment should be used to take into account all pertinent factors of the hydrology in the area (Gilbert *et al.*, 1995).

Need for Off-Site Wetland Quantification

Given the resource-intensive nature of the wetland delineation process, there is great need for off-site tools that aid in quantifying wetlands remotely. Air photos are useful and becoming increasingly more available at high enough resolution (e.g. sub meter pixels) to allow for precise, remote delineation of wetlands. Often, then wetland boundary is not well expressed in the canopy vegetation. In these situations, air photos may not allow for the user to accurately identify the wetland boundary off-site. Spatial data layers such as the National Wetlands Inventory (NWI) provide pre-delineated wetland boundaries. These layers are useful as off-site screening tools, but they don't provide the same precision as on-site delineation. Light Detection and Ranging (LiDAR) has recently been used to remotely visualize the land surface for the purposes of wetland delineation.

Pilot Work Using LiDAR to Quantify Depressional Wetlands

LiDAR is conducted by flying aircraft over an area of interest and capturing laser return signals from the earth's surface. The laser returns are recorded as part of the dataset and can be interpreted as elevations given as XYZ coordinates. The raw data from the LiDAR dataset can be converted to bare-earth data by removing points that were returned due to vegetation or other obstructions that did not allow the point to penetrate to the ground. These bare-earth data can be modeled to create a digital elevation model (DEM) (Mahler 2012).

Ellis *et al.* (2012) demonstrated that these models could be used to approximate the wetland boundary to within 3 m using traditional triangular irregular network (TIN) modeling. Landscape visualization was improved using polynomial trend surface models. These findings provided the evidence that LiDAR could provide off-site wetland delineations that approached the accuracy of on-site delineations.

Further investigations by Mahler (2012) have shown that polynomial models more accurately reflect wetland boundaries than TIN or ordinary kriging (OK). The LP70 model was shown in the study to have the straightest path with the lowest average error of 0.296 m out of the four models used. The study also showed that of all four models at all four wetlands tended to overestimate to some degree the extent of the wetland, with the exception of the LP70 model for Wetland 1. Mahler (2012) continues by comparing LiDAR point density to error, which showed that a lower LiDAR bare earth point density correlates to a higher error in boundary lines. The LP70 model was not as influenced by neighboring points, thus allowing the model to smooth out the land surface. Also mentioned is the fact that the LP70 and OK models had much lower maximum slope breaks at 6% and 7% than the TIN and LP100 models with 19% and 14% respectively. This is due to the erratic nature of the TIN and LP100 models in being influenced much more heavily by nearby LiDAR return points.

Further investigation is needed to determine possible causes of error in delineating depressional wetlands using LiDAR data with local polynomial processing models. If errors can be identified with on-site or LiDAR delineation methods it may someday be possible to achieve sub-meter accuracy, which is set as a goal in delineating wetland boundaries (Gilbert *et al.*, 1995).

Objectives

The goal of this study is to explore characteristics of a depressional wetland that are used in the delineation process to understand how these characteristics correlate with LiDAR-based delineation methods. The following objectives will be used to accomplish this goal: 1)

Document the detailed land and vegetative conditions at each delineated location of the wetland edge. 2) Determine whether land or vegetation affect on-site wetland delineation.

Methods

Site Description

The wetland studied is located within Austin Cary Memorial Forest (ACMF), which is owned by the University of Florida, School of Forest Resources and Conservation. The forest is roughly 2075 acres (840 ha) in size and located approximately 9.3 miles (15 km) Northeast of Gainesville, FL. The area is managed with prescribed burns as well as silviculture, which allows for well-defined vegetation community breaks between uplands and wetlands. This management also allows for the flatwoods' composition to be primarily of a canopy of slash pine (*Pinus elliottii*) with an understory cover of saw palmetto (*Serenoa repens*). The soils in this area are predominantly mapped as Pomona sand and Pomona sand depressional, which is suiting for a landscape that can be described as a flat sand hill with areas of depressional wetlands (Soil Survey Staff). The depressional wetlands in the area generally fit the description of cypress domes.

The specific wetland for this study (Wetland 1) was chosen because it has previously been delineated, surveyed, and has existing LiDAR-based digital elevation models from the study done by Mahler in 2012 (Figure 1). Furthermore, this wetland was chosen due to its characteristics as a cypress dome with well-defined vegetative community breaks.

Transects

At each previously delineated location, 10 m transects were established perpendicular to the wetland boundary, which was effectively perpendicular to the slope of the land. Each transect was centered about the wetland delineation point (transect station 5 m). The transects extended five meters upslope and five meters downslope. Each transect was 10 m in length with station 0 m in the upland, station 5 m at the delineated wetland boundary, and station 10 m in the wetland. The beginning, ending, and wetland delineation points were also marked with PVC pipe. At every 0.5 m station along each transect, ground elevation was determined using a survey level.

Vegetation was inventoried by percent cover along each transect at 1 m intervals with a belt width of 2 m. Percent cover was recorded using the guidelines set forth in the Florida Wetlands Delineation Manual where vegetation is grouped into three distinct strata. These strata are canopy, sub canopy, and ground cover. Each individual vegetation species observed was recorded along with the percent cover, unless percent cover was negligible (< 1%). Vines are not included in delineating wetlands and were therefore excluded from the data set (Gilbert *et al.*, 1995). Identification of vegetation was done with some assistance of St. Johns River Water Management District staff.

Lichen line elevations in Wetland 1 were captured on 30 different trees within the interior of the wetland. These lichen lines serve as the main hydrologic indicator for this study. Nails were driven into the trees at the point of the lichen line determination, which was made with the assistance of St. Johns River Water Management staff. Each tree used for lichen line determinations was marked and labeled. All lichen line elevations were recorded using surveying equipment and referenced back to surveyed elevations.

Results and Discussion

Elevation

Table 2 displays the data of all elevations along the transects of each wetland delineated point. The average wetland elevation based on the 12 wetland delineated points was 48.28 m. Elevation maximum along all transects was 48.97 m (+0.69 m) and minimum was 47.82 m (-0.46 m). Both were derived from transect 69 (Figure 3), which is the most erratic of all the transects (Figure 15). Maximum and minimum elevations of all transects excluding transect 69 were 48.60 m (+0.32 m) and 48.05 m (-0.23 m). This suggests that the elevation change along transect 69 is not consistent with that of the other 11 transects (Figures 4-14), which show smoother patterns of elevation change that reflect the wetland as a whole (Figure 16). The elevation pattern of the wetland has an implication on the vegetative community breaks; therefore, having an impact on wetland delineation methods. Transects like transect 69 could be roots for error in wetland delineation due to their erratic behavior in elevation.

In more than half of the transects elevation was affected by vehicle tracks / ruts that were observed on-site, which can also be seen graphically in Figures 3-14. The change in elevation related to tire ruts does not affect the delineation methods of the wetland but slope around the tire ruts tend to be steeper, causing a more drastic elevation break between the wetland and upland boundary (Figures 7-9). This artificial slope break may have implications on the vegetative community breaks at these transects and be a cause of error in delineation methods.

Absolute value of slope for all transects suggests that the point of maximum slope (10.50%) for all transects occurs at the wetland delineation points at 5 m (Figure 17). Maximum slope for a single transect occurred at 5.5 m with a value 23.16%, which reinforces the findings that maximum slope for a depressional wetland occurs at or near the wetland / upland boundary where delineation points were established.

Vegetation

In general, the use of the A and B wetland delineation tests tended to expand the delineation outward, suggesting either that these tests tend to overestimate the wetland extent or delineation points were established inward of where the actual delineation points should have been. Ground cover species were more numerous and abundant by percent cover when compared to the canopy and subcanopy strata. Canopy and subcanopy data show that no vegetation was present for these strata at several transects, thus indicating that plants meeting the required DBH were not present at these levels and that a thick canopy does not exist around Wetland 1. The B test overall tended to be met more and bring the wetland boundary closer to the upland than the A test when ground cover was included in the wetland determination. This suggests that the B test tends to push the wetland boundary outward more so than the A test. However, there were three transects where the A test was met further upland than the B test using ground cover. Several of the transects (69, 71, 72, 75, 76) show that delineating with the A or B tests using ground cover vegetation will put the wetland boundary at or very close to the actual delineated points, suggesting this type of delineation method to be accurate for determining wetland boundaries. It is possible that these delineated points were, in fact, delineated using the A or B tests. Delineation of wetlands through vegetative quantification alone as indicated by the A and B tests suggests that the wetland boundary will be delineated correctly or slightly overestimated.

Lichen Lines

Lichen lines were used as the hydrologic indicator for this study and were found to have a strong correlation with the wetland delineated boundary. The average of all 30 lichen line elevations was 48.31 m, which was calculated to be only 2.84 cm above the average wetland elevation (Figure 19). The minimum elevation of the lichen lines surveyed was 14.34 cm below the average lichen line elevation and was considered to be an outlier of the dataset. The maximum elevation of lichen line above the average was 5.78 cm. One standard deviation of the lichen line dataset is equivalent to 3.50 cm. The majority of elevations are clustered near the average lichen line elevation. Lichen line elevation tended to be slightly higher than that of the average wetland delineated elevation, but overall the data suggests that lichen line elevations are strong indicators of wetland delineation boundaries with little variability amongst elevation.

Conclusions

The extent of depressional wetlands is controlled by elevation and topography. The slope of the land from upland to wetland has been shown to be near the maximum where the wetland delineated boundary exists. Delineating wetlands using vegetation through the FDEP A and B test methodology has not produced conclusive evidence that vegetation is a strong indicator alone of wetland boundaries. Vegetation at ground cover in this study did produce some indication that using A and B tests would move the wetland boundary uphill, but this was not the case at all transects. On the contrary, this could indicate that the methods used to delineate the established points set the wetland boundary too far inward of where it actually exists. Lichen line elevation proved to be the most consistent indicator of wetland delineation with little variability amongst elevations; overestimating the average delineated wetland boundary by only 2.84 cm vertically. Lichen line elevation is in agreement with vegetation in that both indicators either overestimate the wetland boundary or that the established delineated points were set inward of where the actual wetland boundary exists.

Additional research is needed at other wetland sites to supplement findings of this study. More characteristics of wetlands should also be included in this data to analyze errors associated with delineation methods in contrast to LiDAR-based models. Some of these characteristics include hydric soils and horizontal error of delineated points to average elevation. Slope should also be further explored at additional sites to see if maximum slope correlates to vegetative community breaks and ultimately wetland delineated boundaries. Other hydrologic indicators should be studied to see how they compare with lichen lines in predicting wetland boundaries.

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Figures

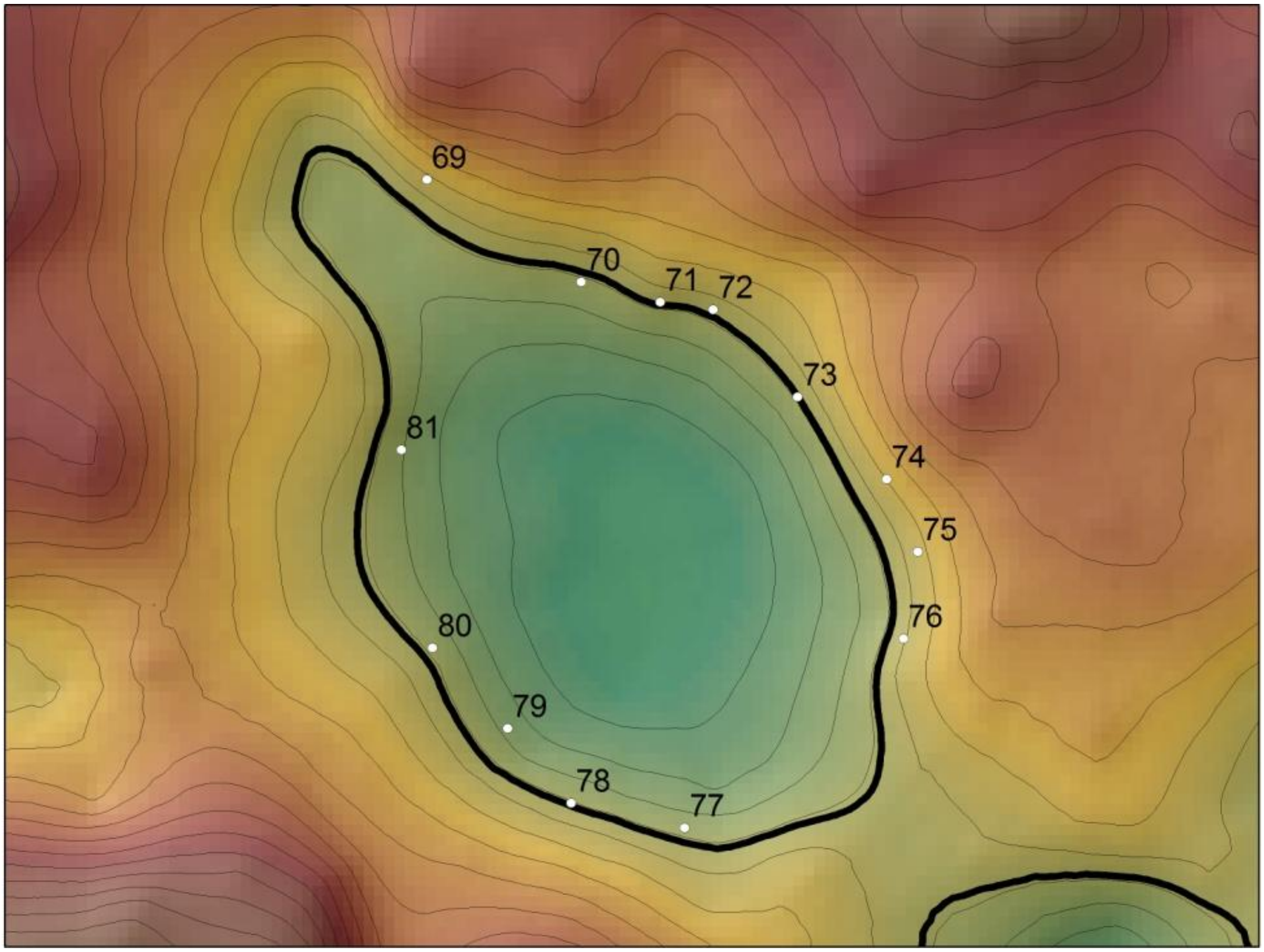

Figure 1: Digital Elevation Model showing Wetland 1 boundary and delineated points

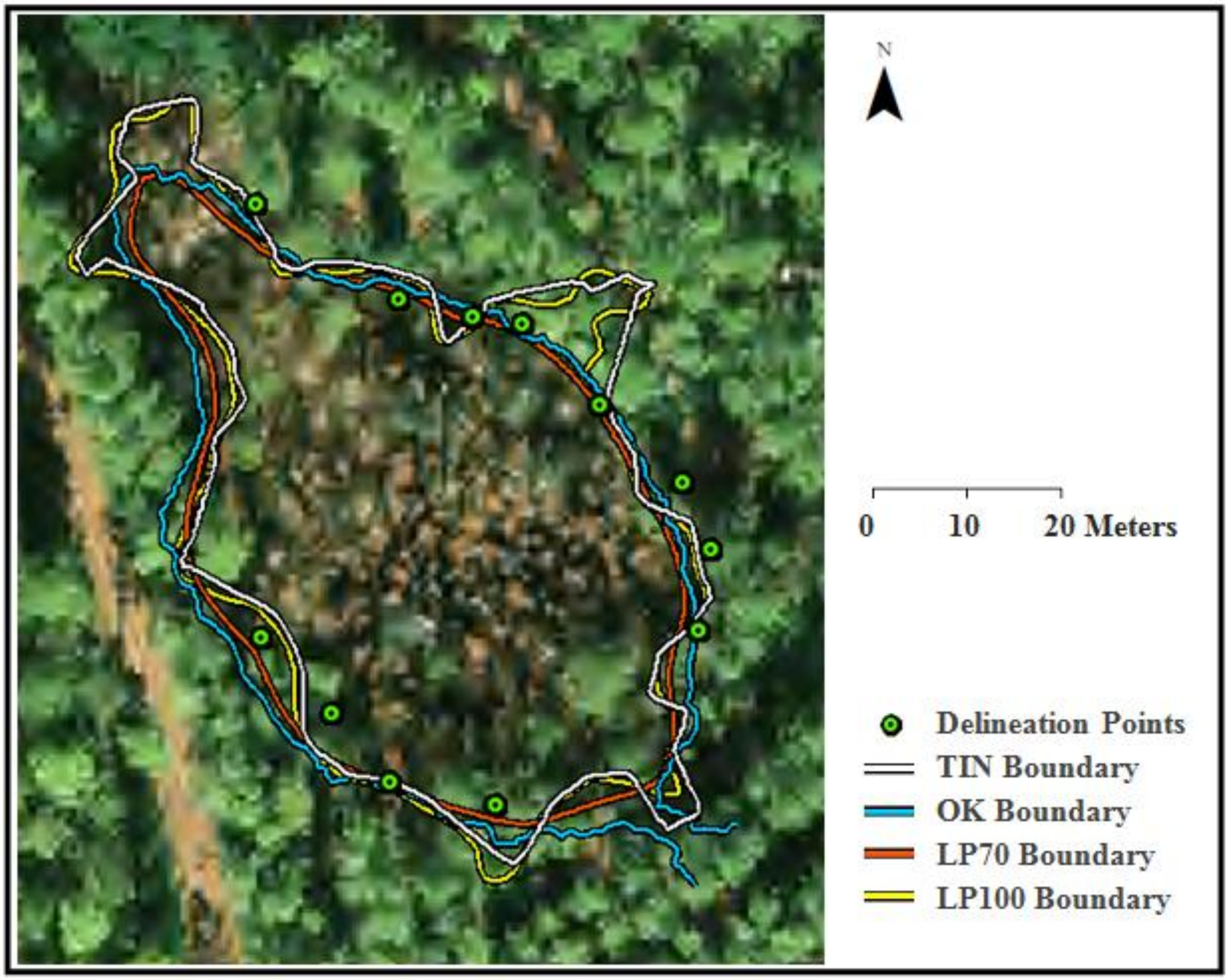

Figure 2: Modeled Boundaries of Wetland 1. Taken from Mahler 2012.

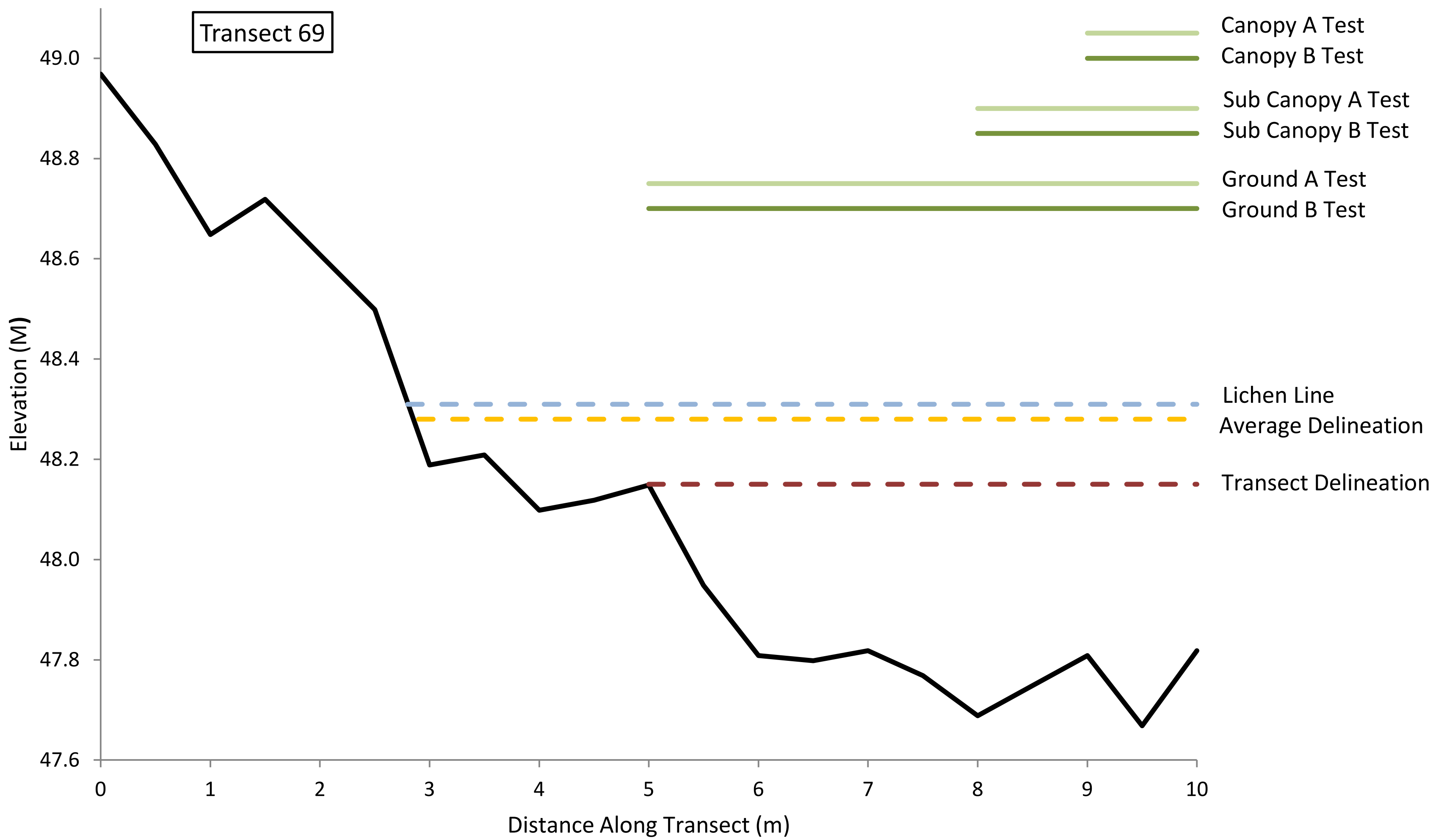

Figure 3: Elevation of transect 69 showing where wetland delineation A and B tests are met with average lichen line elevation and average wetland delineated elevation

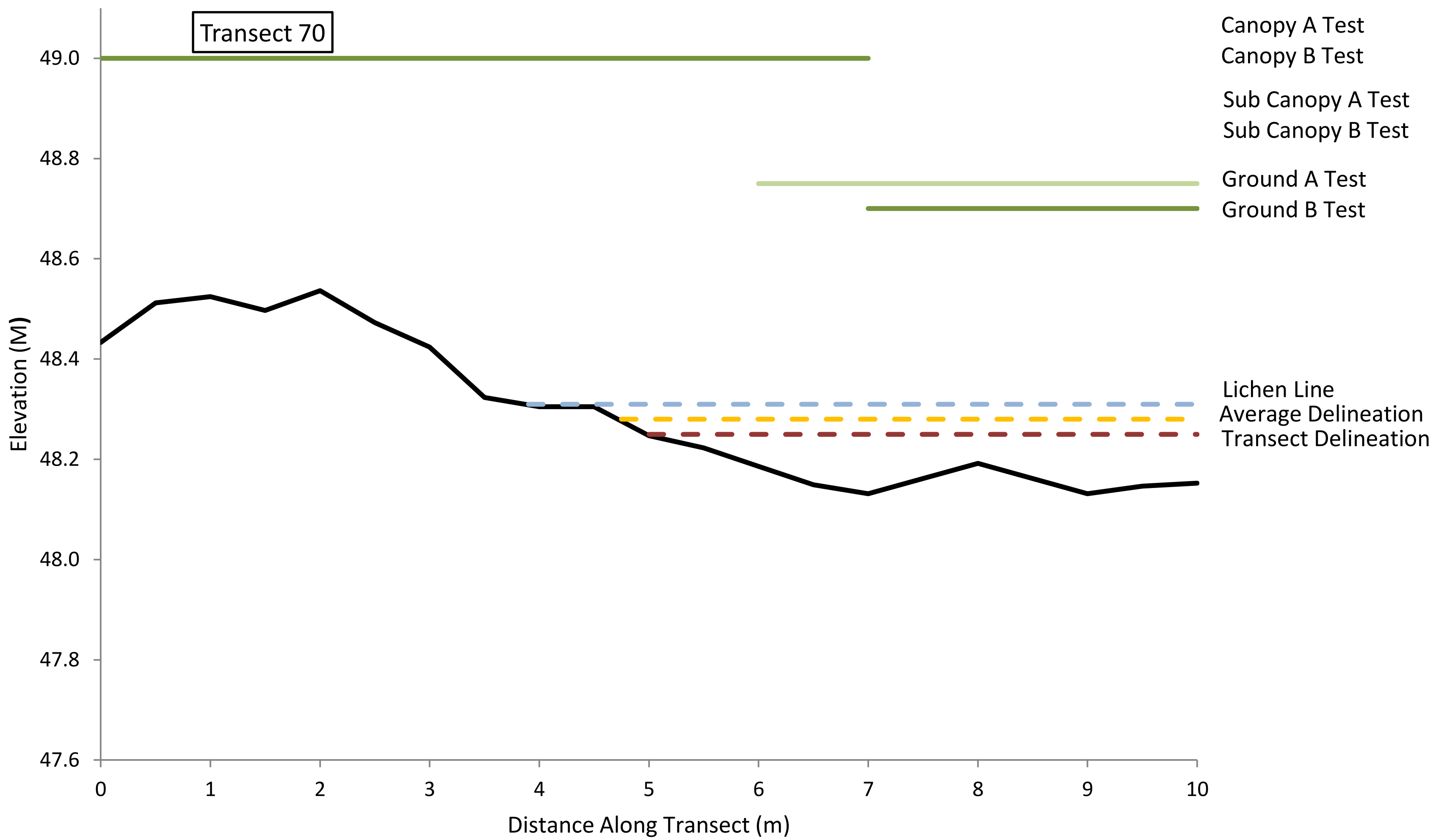

Figure 4: Elevation of transect 70 showing where wetland delineation A and B tests are met with average lichen line elevation and average wetland delineated elevation

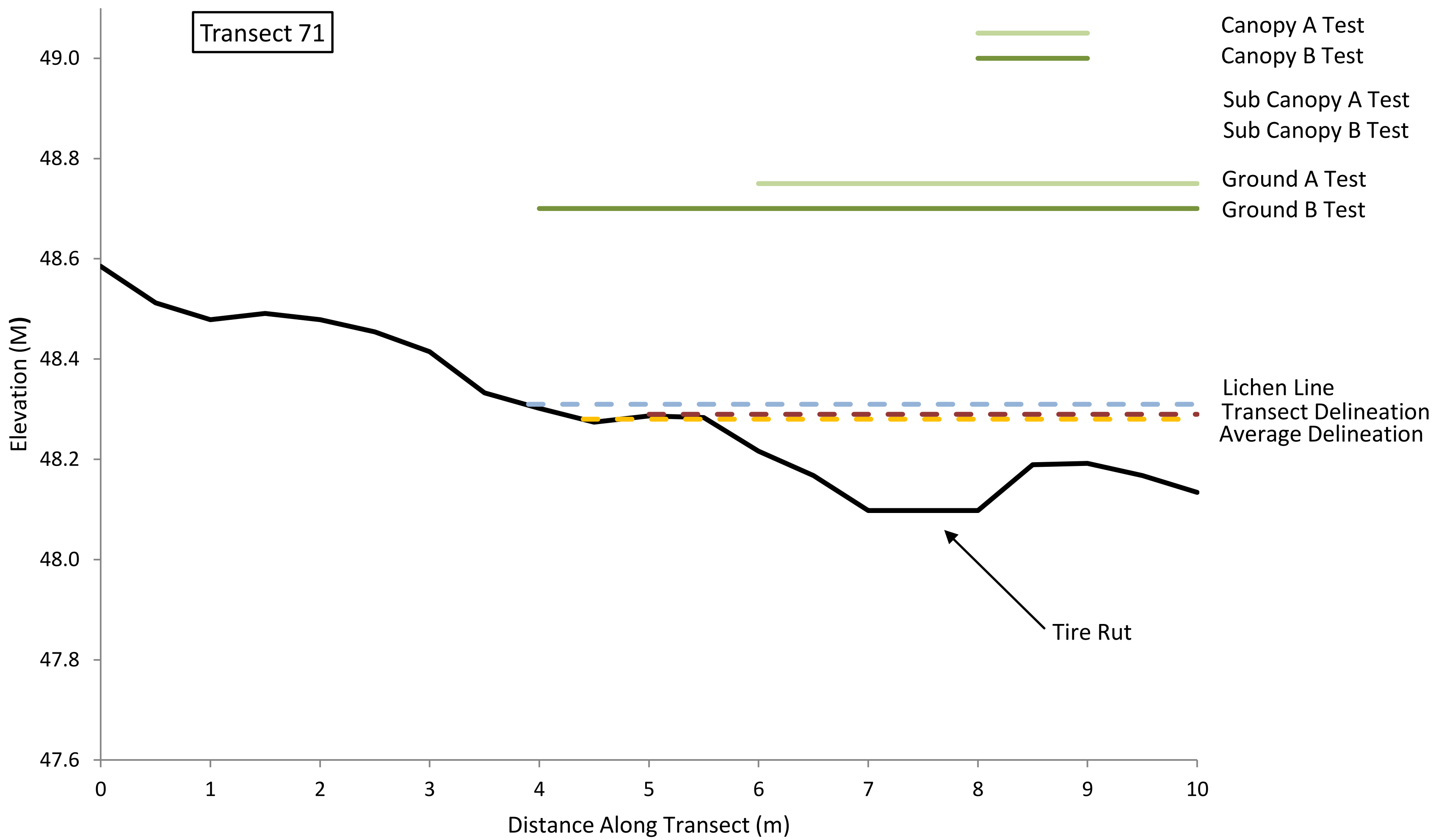

Figure 5: Elevation of transect 71 showing where wetland delineation A and B tests are met with average lichen line elevation and average wetland delineated elevation

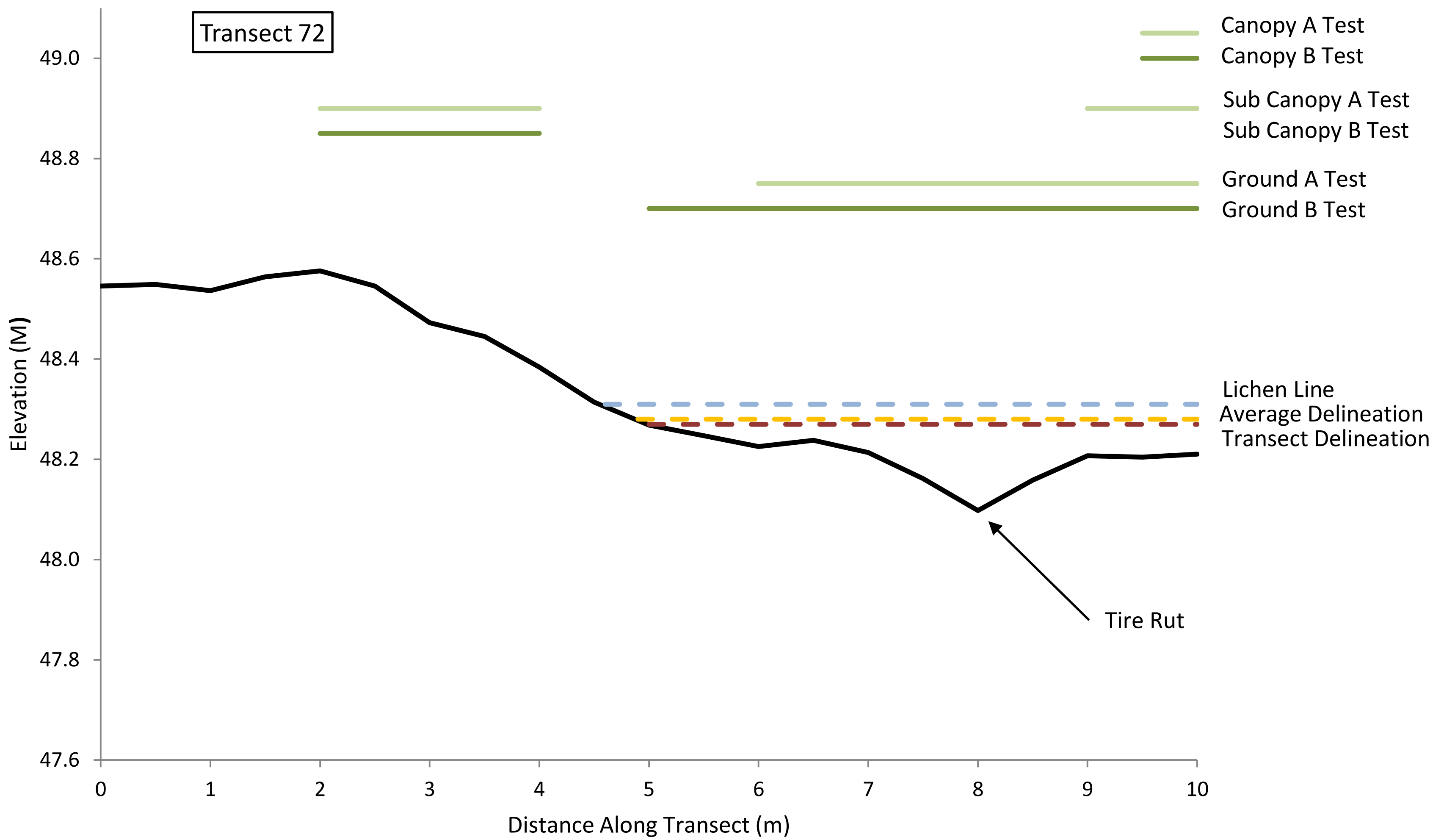

Figure 6: Elevation of transect 72 showing where wetland delineation A and B tests are met with average lichen line elevation and average wetland delineated elevation

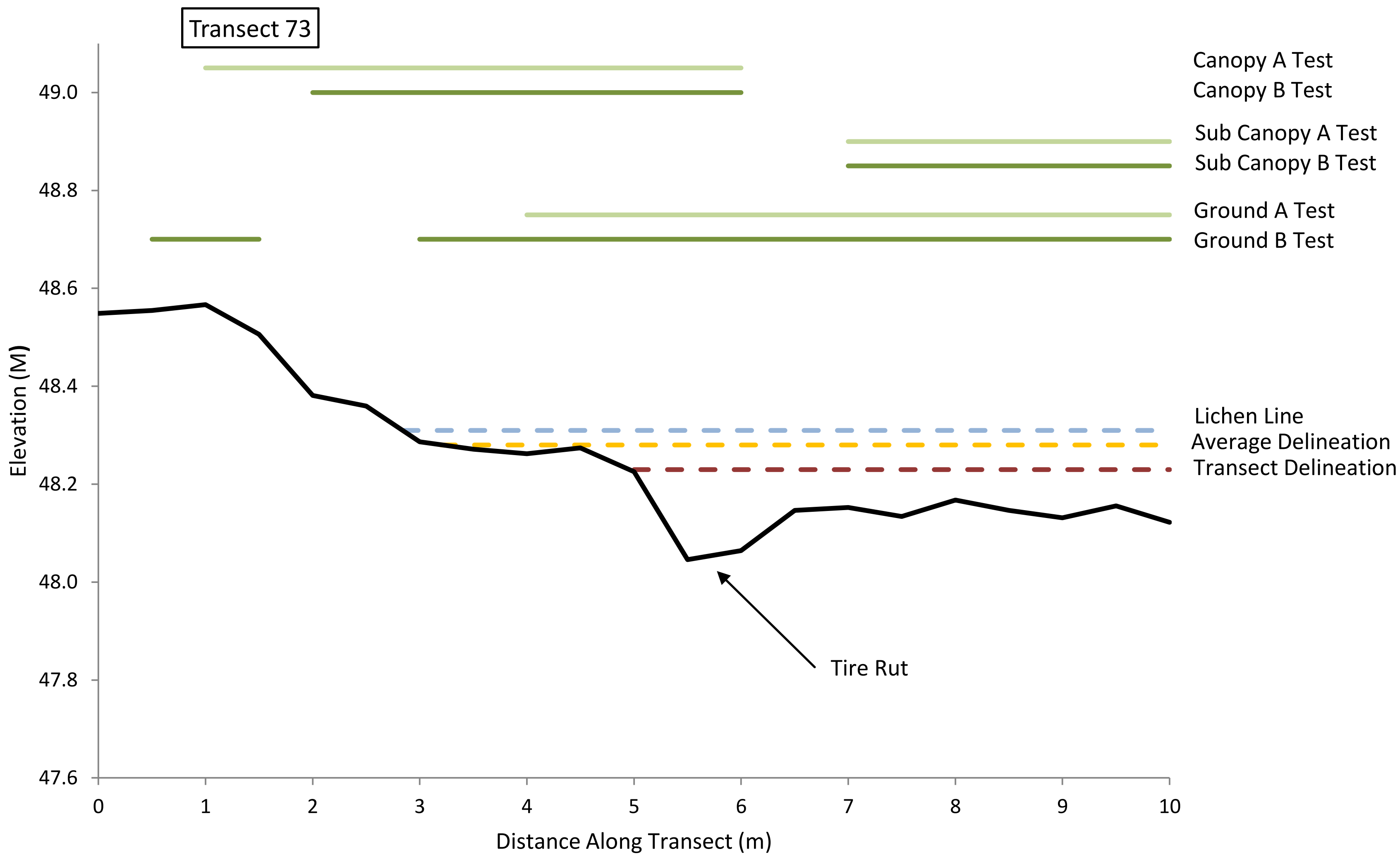

Figure 7: Elevation of transect 73 showing where wetland delineation A and B tests are met with average lichen line elevation and average wetland delineated elevation

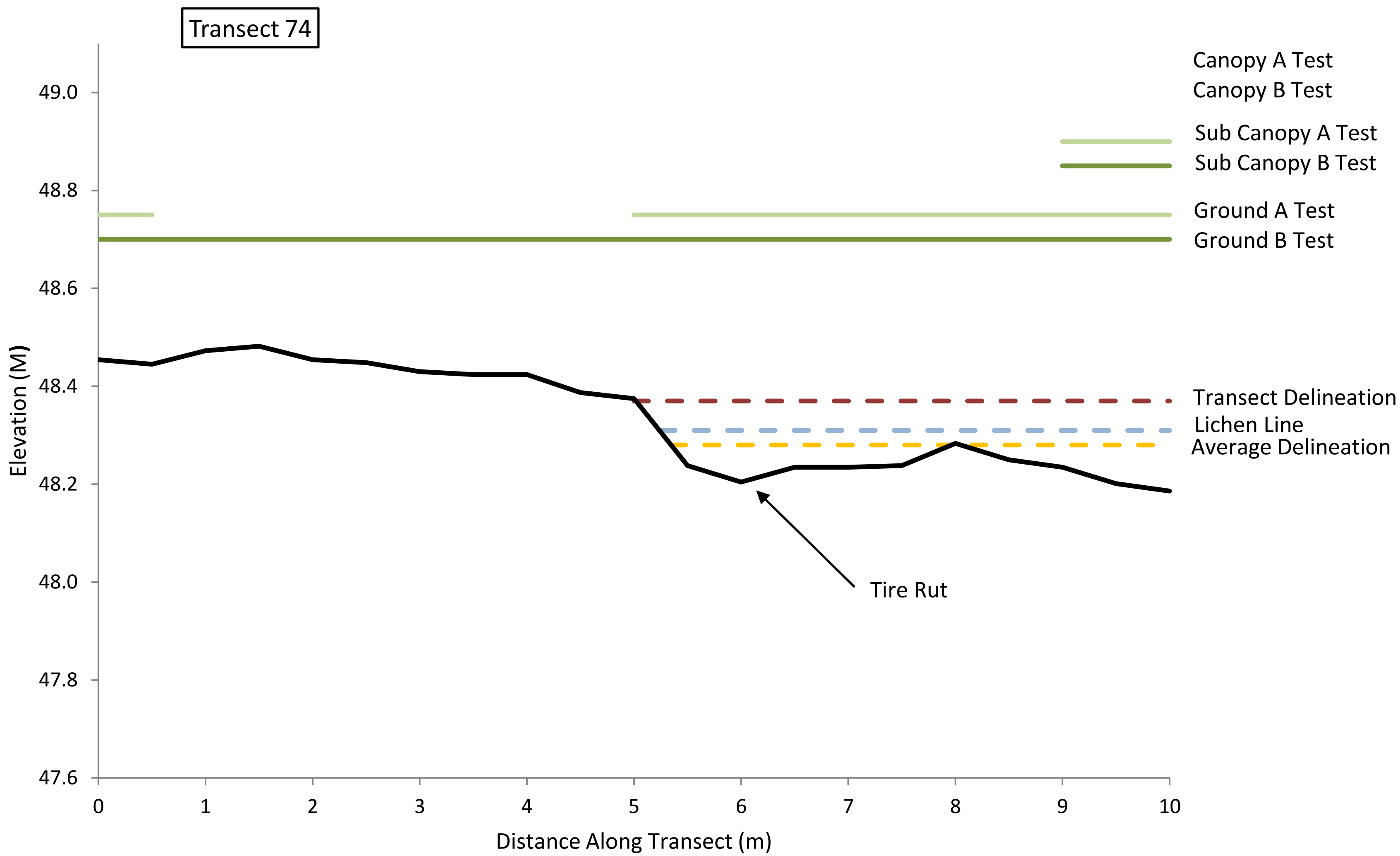

Figure 8: Elevation of transect 74 showing where wetland delineation A and B tests are met with average lichen line elevation and average wetland delineated elevation

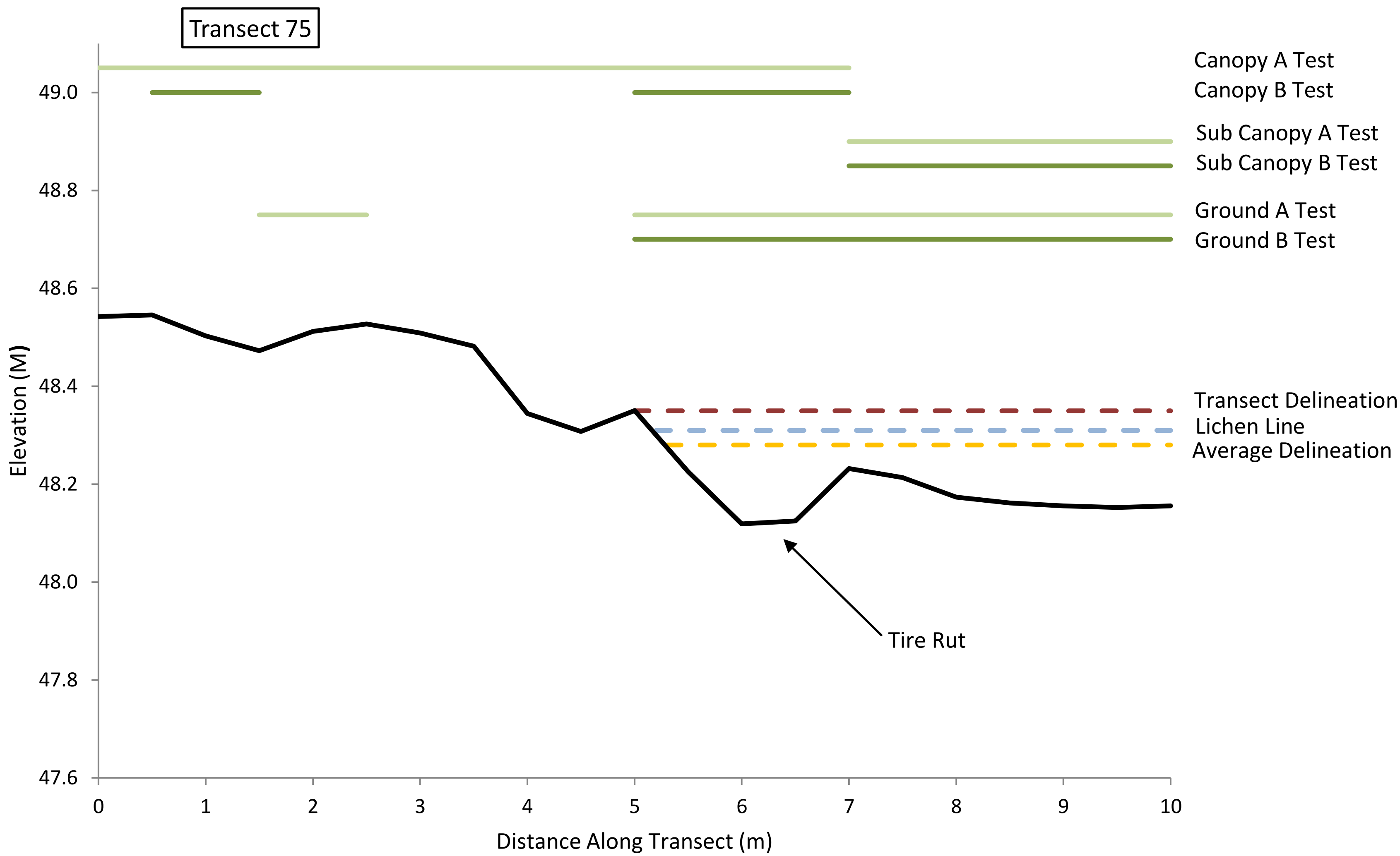

Figure 9: Elevation of transect 75 showing where wetland delineation A and B tests are met with average lichen line elevation and average wetland delineated elevation

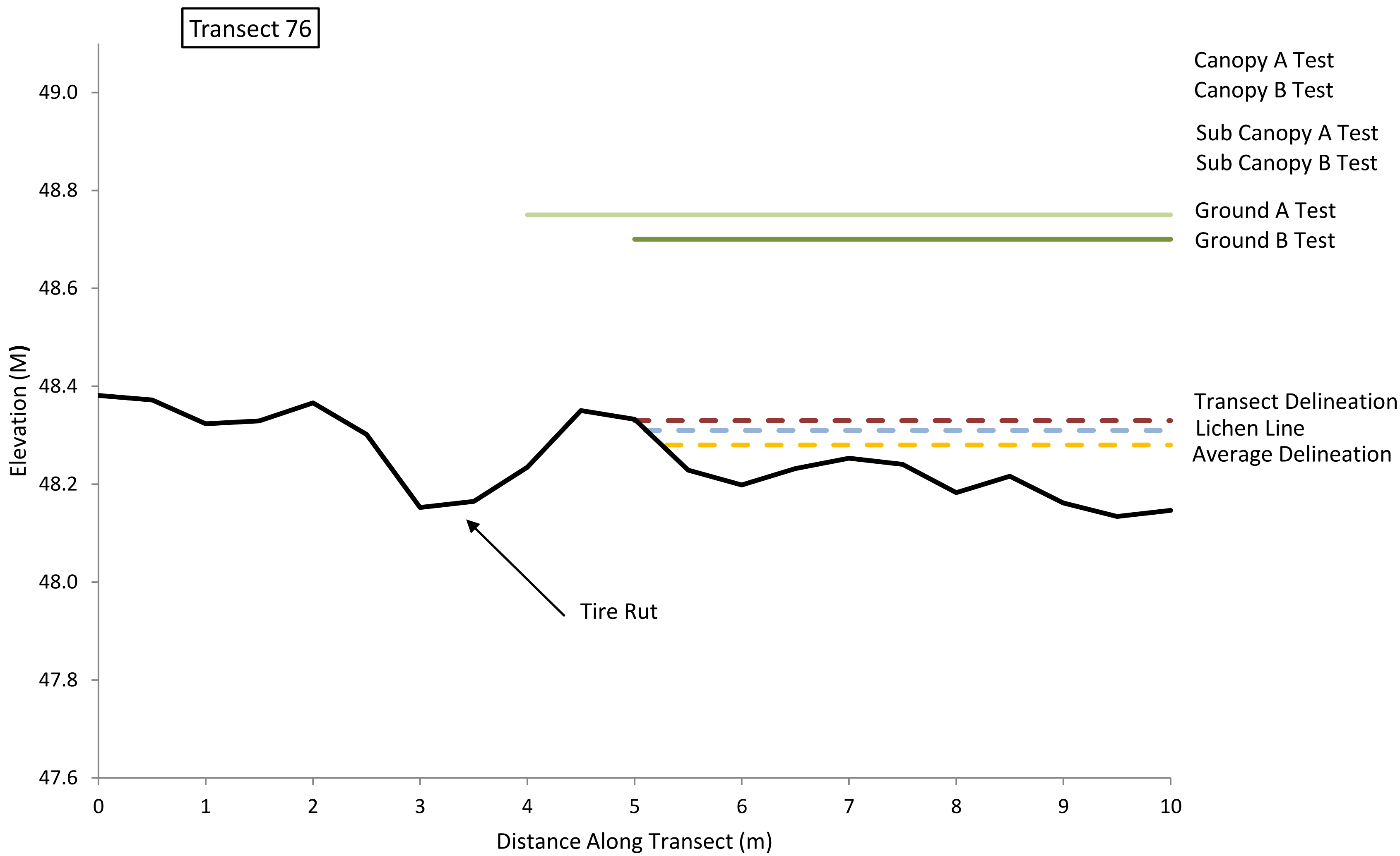

Figure 10: Elevation of transect 76 showing where wetland delineation A and B tests are met with average lichen line elevation and average wetland delineated elevation

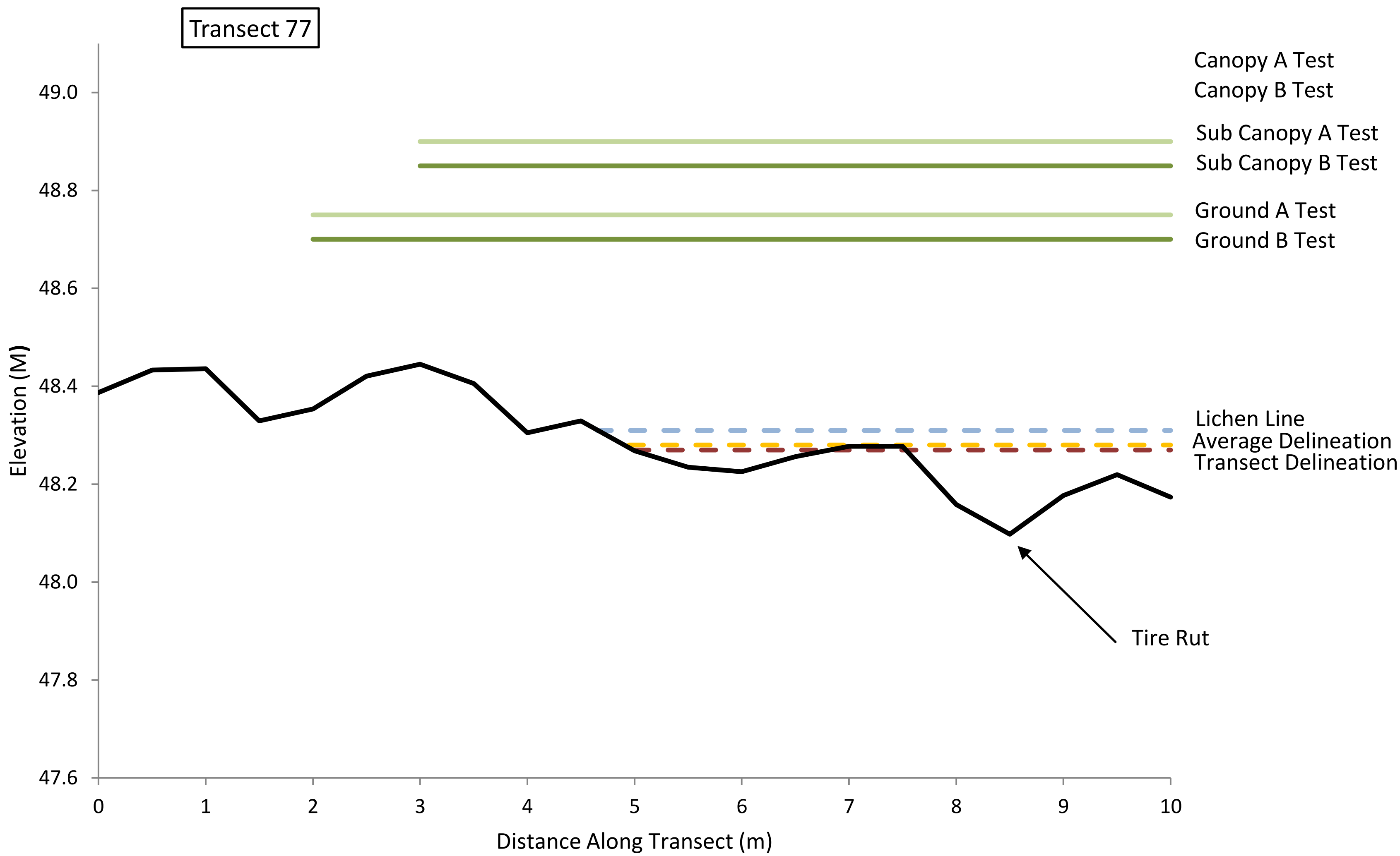

Figure 11: Elevation of transect 77 showing where wetland delineation A and B tests are met with average lichen line elevation and average wetland delineated elevation

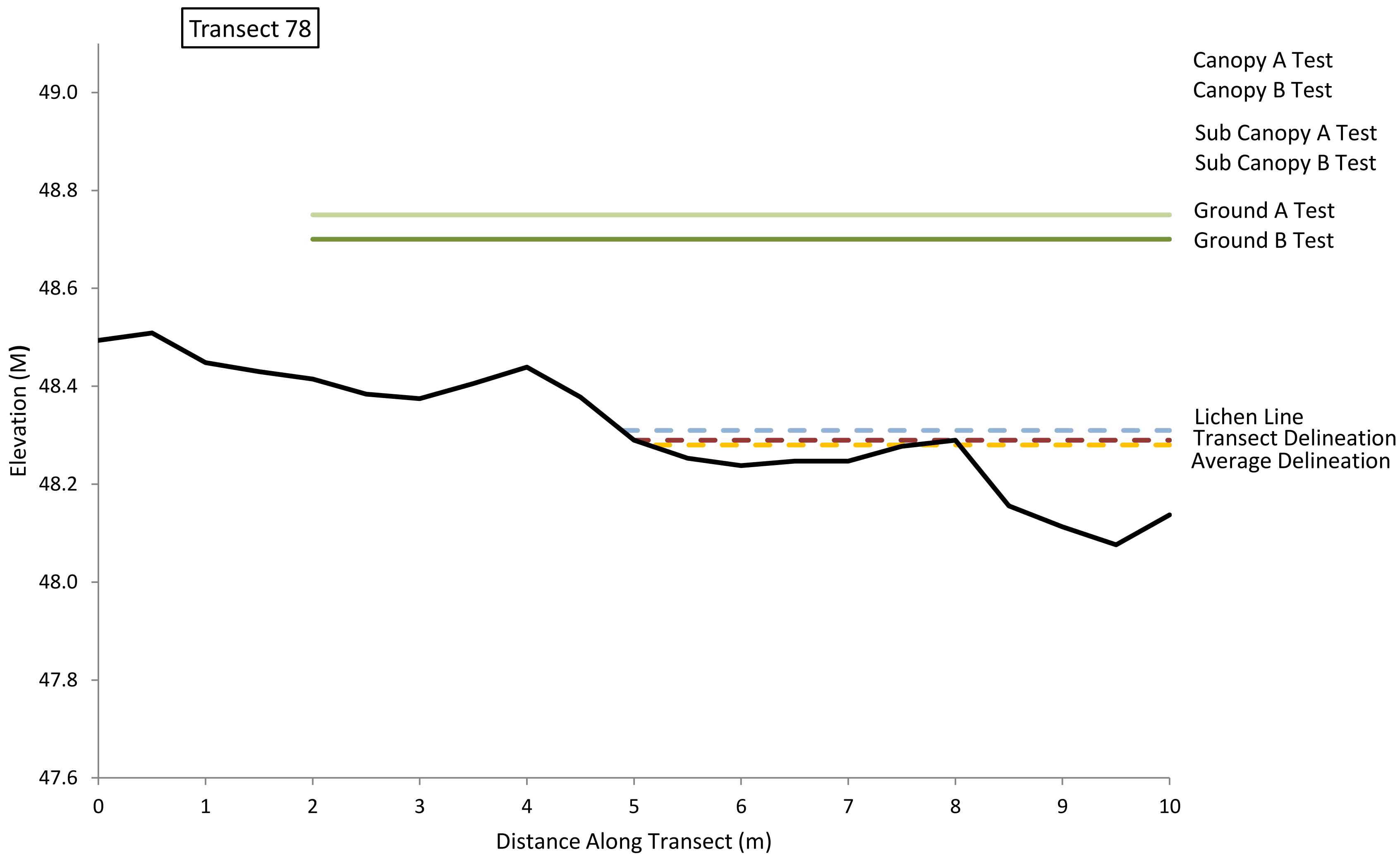

Figure 12: Elevation of transect 78 showing where wetland delineation A and B tests are met with average lichen line elevation and average wetland delineated elevation

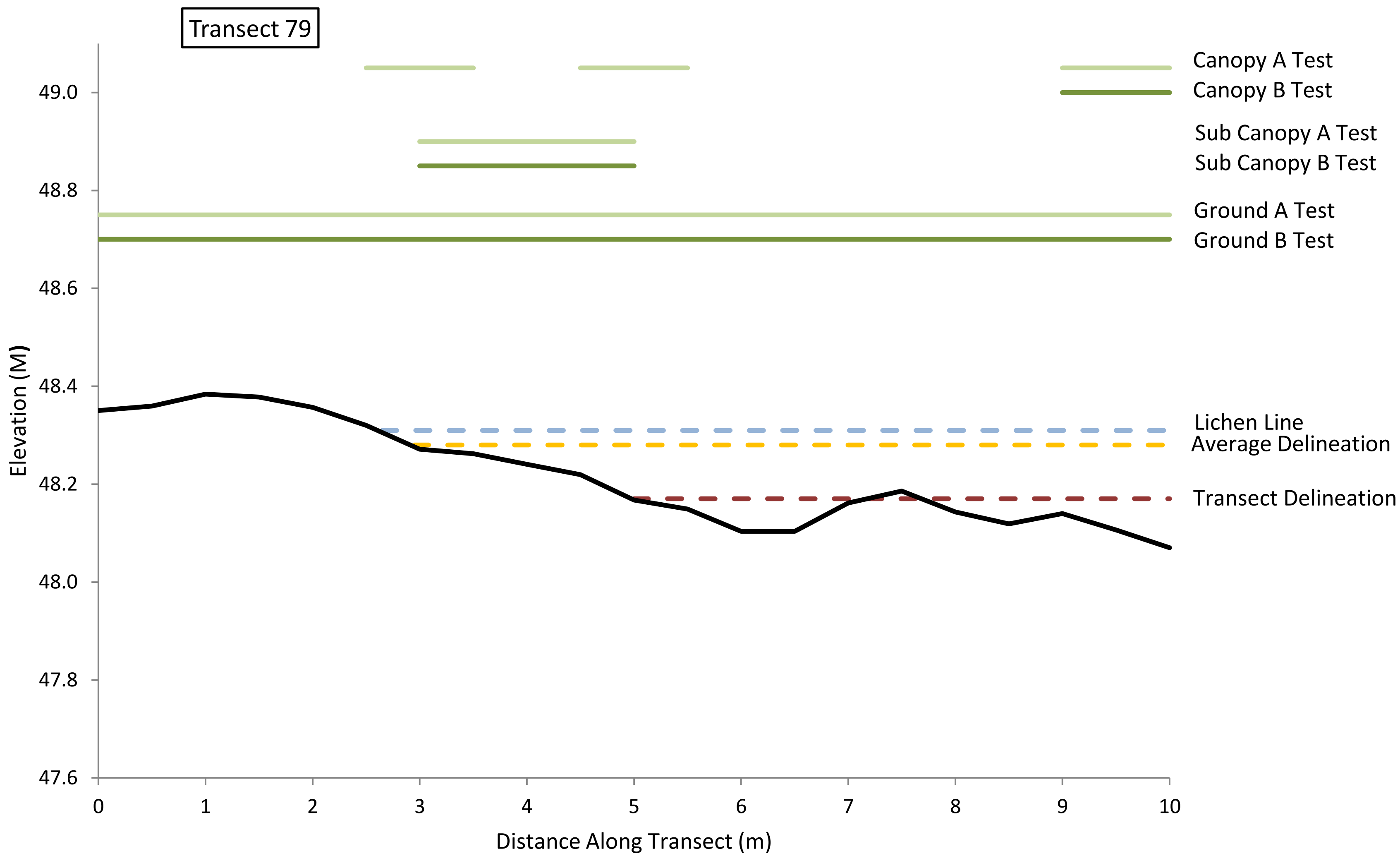

Figure 13: Elevation of transect 79 showing where wetland delineation A and B tests are met with average lichen line elevation and average wetland delineated elevation

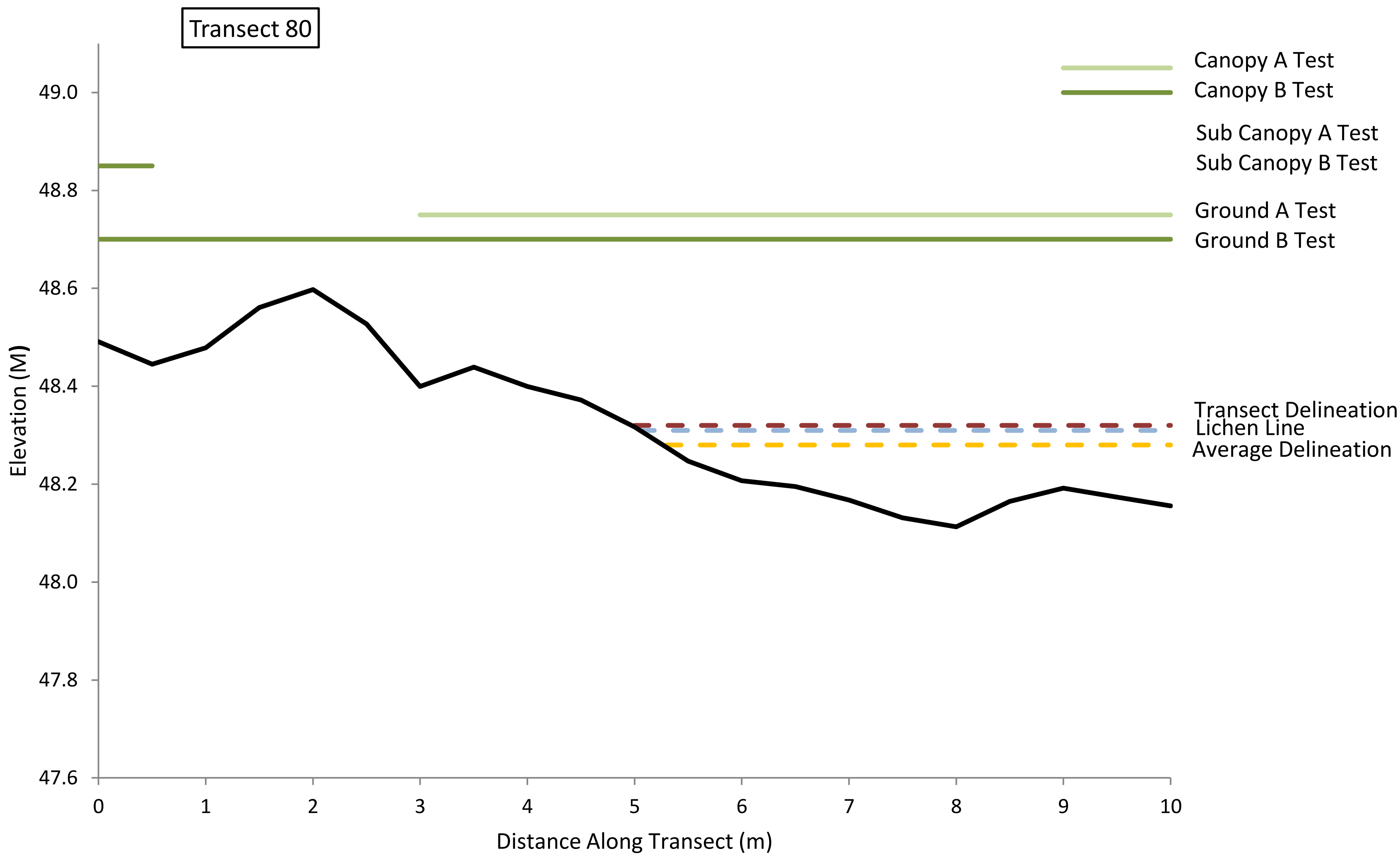

Figure 14: Elevation of transect 80 showing where wetland delineation A and B tests are met with average lichen line elevation and average wetland delineated elevation

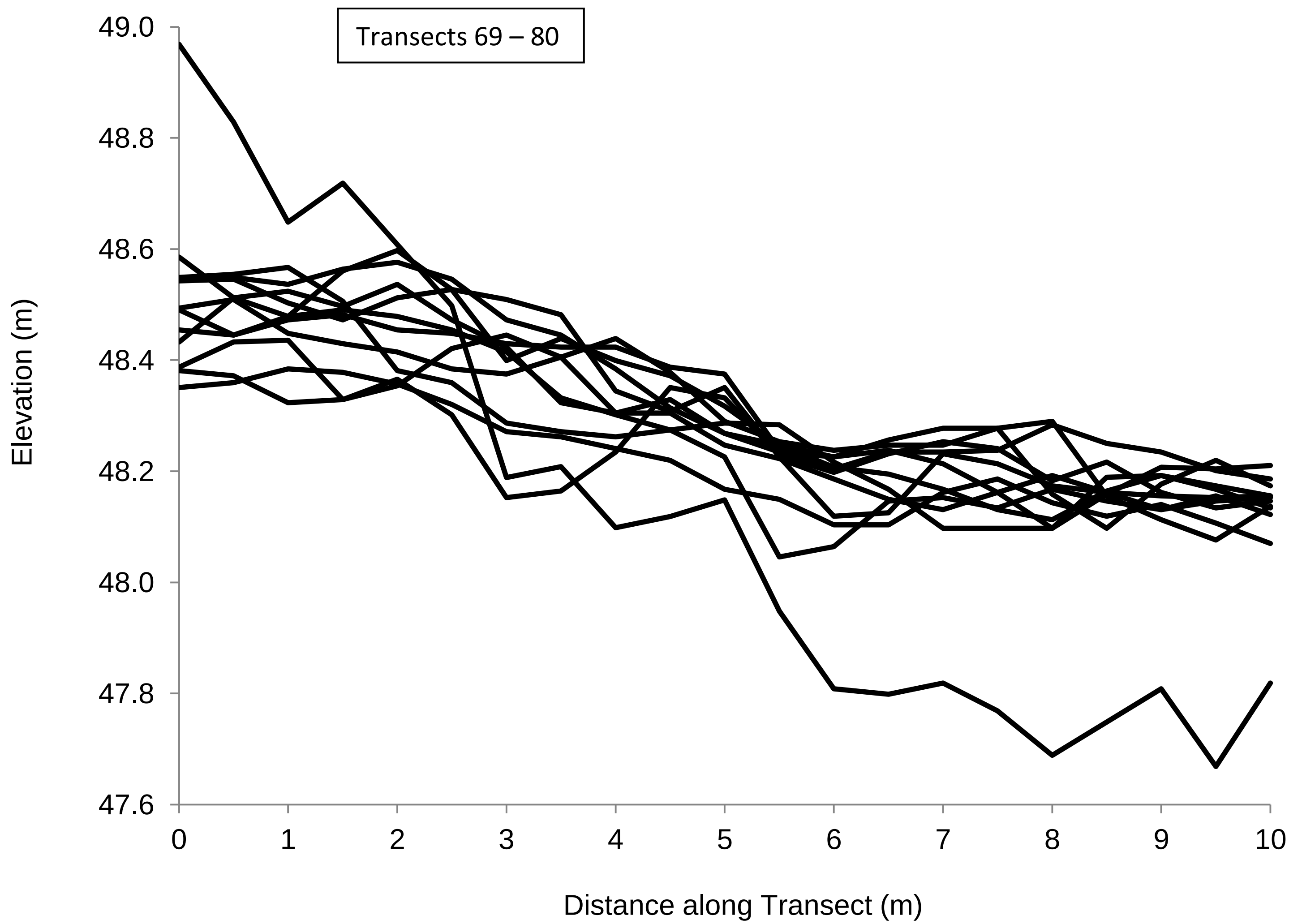

Figure 15: Elevation along all transects of Wetland 1

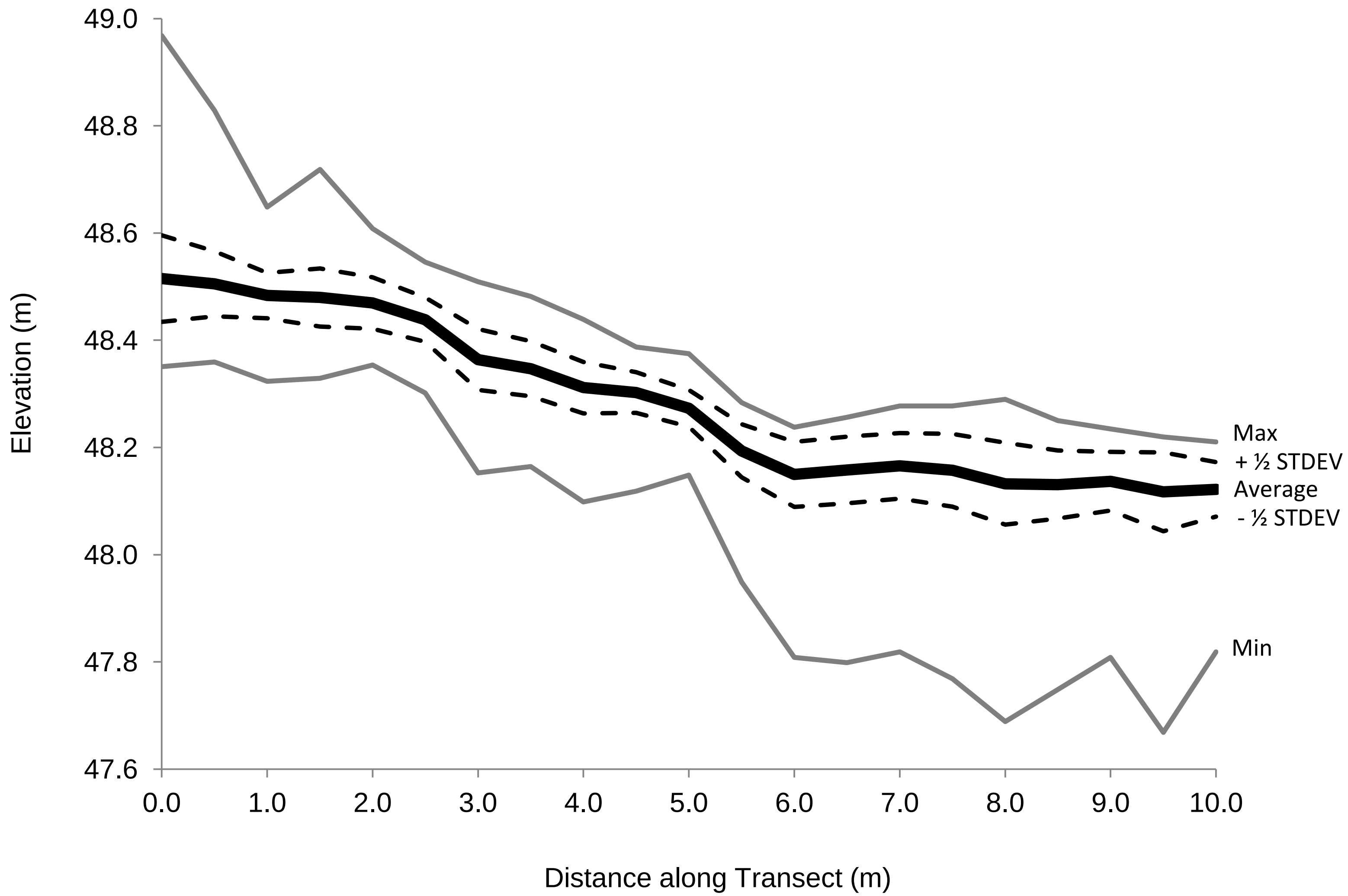

Figure 16: Elevations shown for average, maximum, minimum, and +/- ½ standard deviation for all transects combined

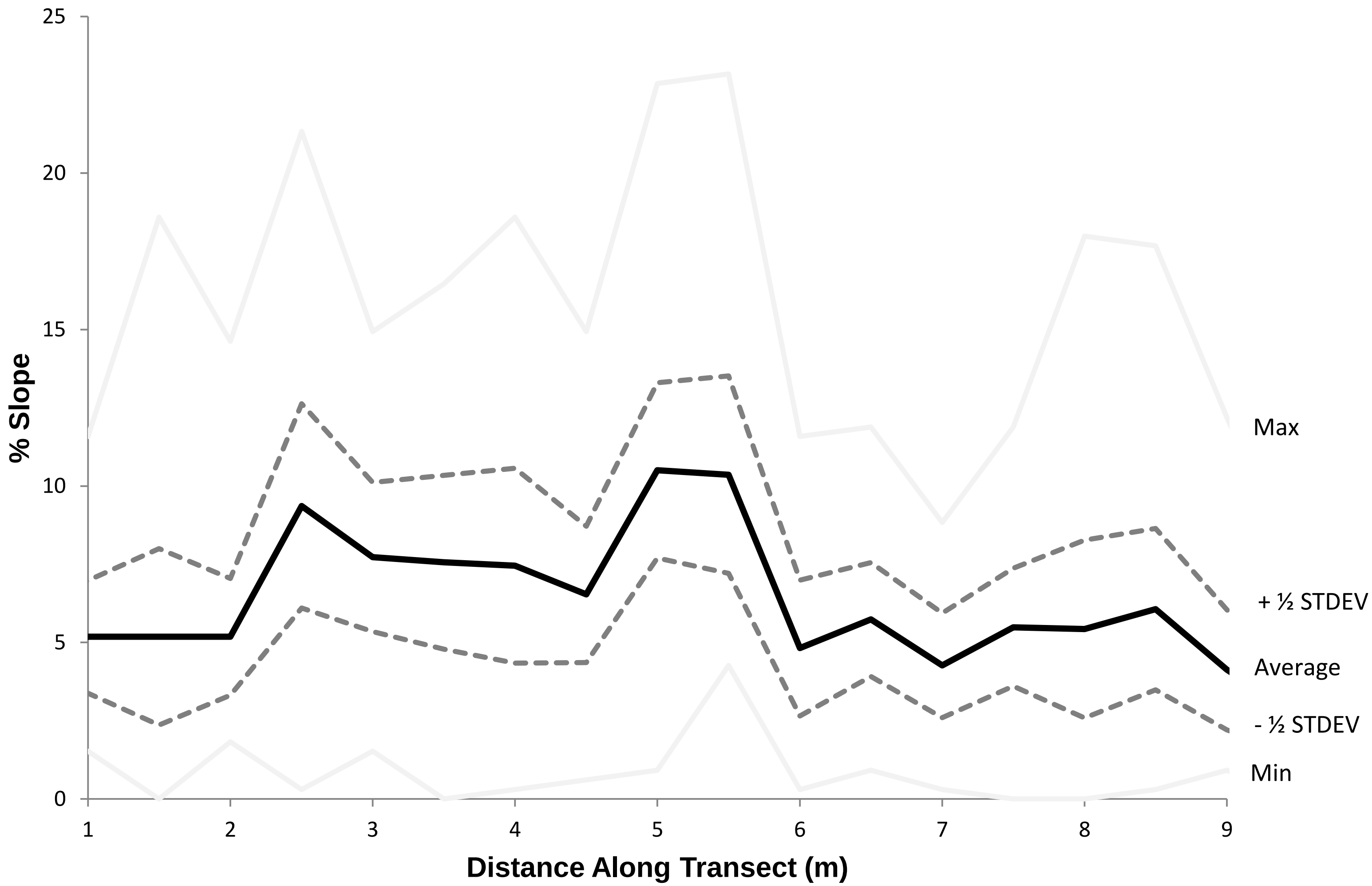

Figure 17: Average slope (absolute) of along all transects combined

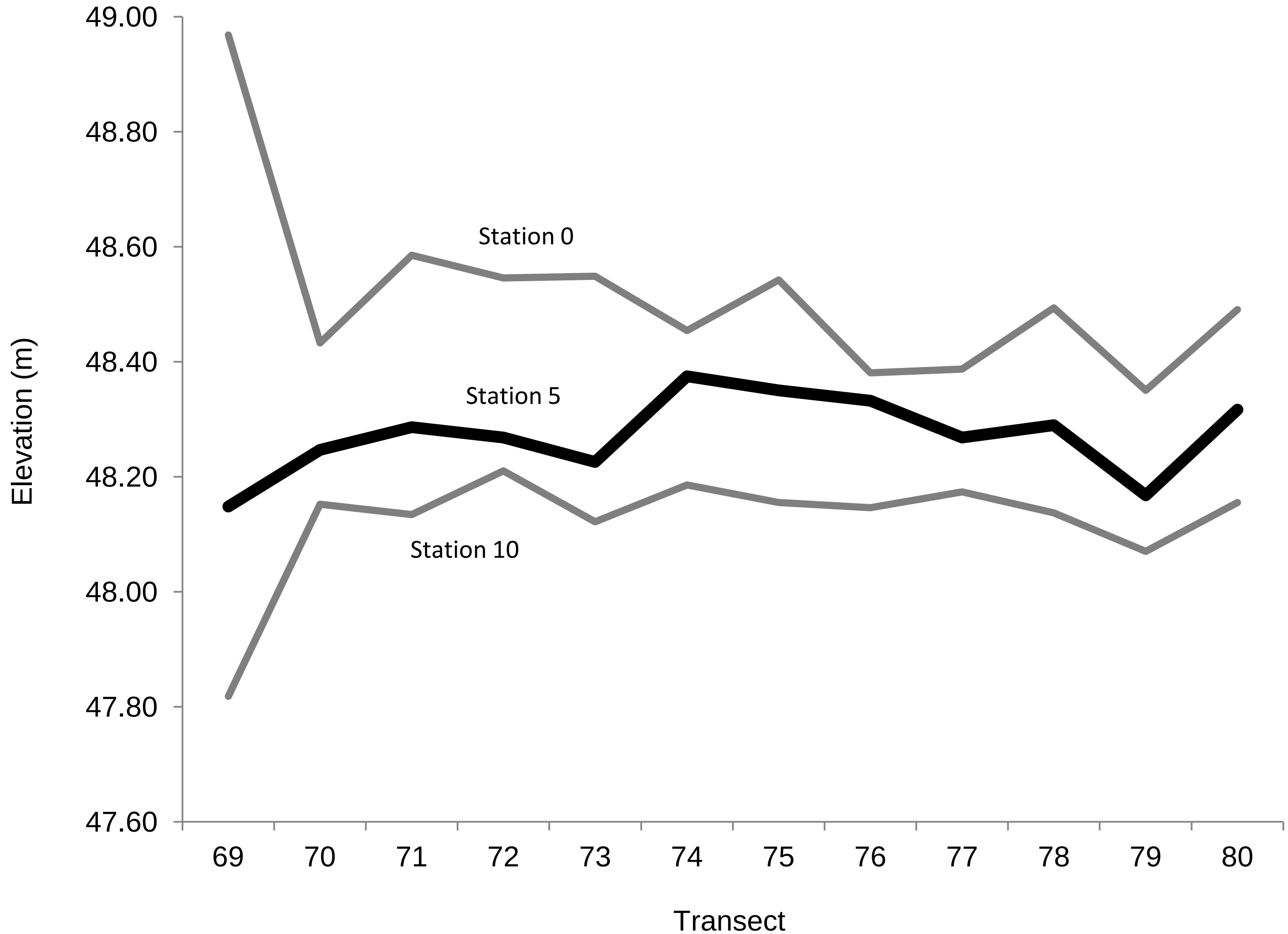

Figure 18: Elevations across all transects at the upland (station 0), center (station 5), and wetland (station 10) extents

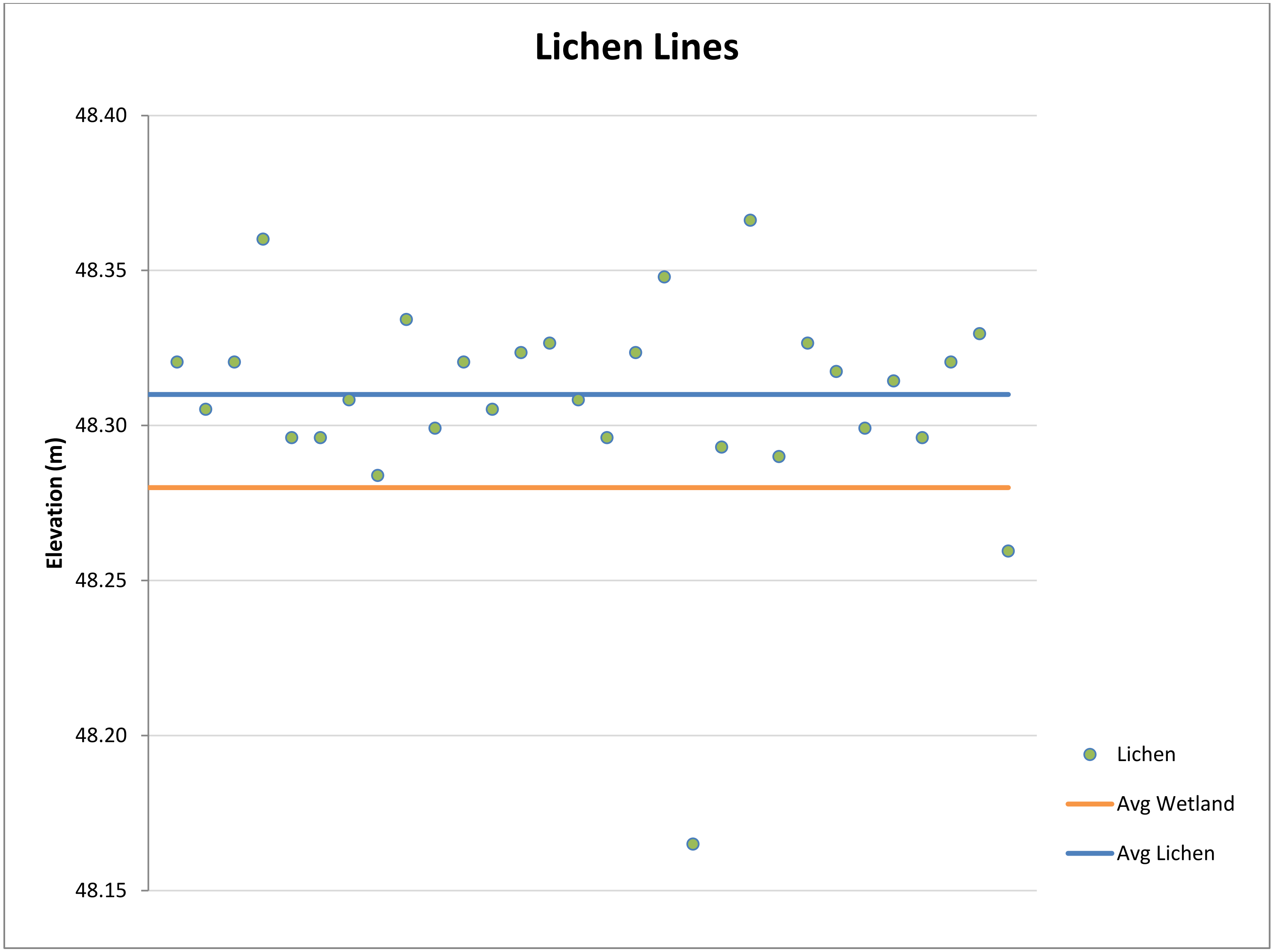

Figure 19: Lichen line elevations with average and wetland elevation average

Tables

Table 1: Field tests used for wetland delineation in accordance with Chapter 62-340.300 F.A.C. Taken from Mahler 2012.

Test Type	Definition of Test
"A" Test	Obligate Vegetation > Upland Vegetation AND Hydric Soils or Riverwash OR Hydrologic Indicators
"B" Test	Obligate + Facultative Wet Vegetation ≥ 80% AND Hydric Soils or Riverwash OR Hydrologic Indicators
"C" Test	An undrained hydric soil that meets at least one of the following criteria: 1. Soils classified as Umbraqualfs, Sulfaqualfs, Hydraquents, Humaquepts, Histosols (except Folists), Argiaquaolls, or Umbraquults 2. Saline Sands 3. Frequently Flooded or Depressional map units as designated by the USDA.
"D" Test	Hydric Soil + Hydrologic Indicator OR One of the following hydric soil indicators: A4, A7, A8, A9, F2, S4, A5 OR Any NRCS hydric soil indicator in which all the requirements are met starting at the soil surface.

Table 2: Elevations along all transects at delineation points

Station	69	70	71	72	73	74	75	76	77	78	79	80
0	48.97	48.43	48.59	48.55	48.55	48.45	48.54	48.38	48.39	48.49	48.35	48.49
0.5	48.83	48.51	48.51	48.55	48.55	48.45	48.55	48.37	48.43	48.51	48.36	48.45
1	48.65	48.52	48.48	48.54	48.57	48.47	48.50	48.32	48.44	48.45	48.38	48.48
1.5	48.72	48.50	48.49	48.56	48.51	48.48	48.47	48.33	48.33	48.43	48.38	48.56
2	48.61	48.54	48.48	48.58	48.38	48.45	48.51	48.37	48.35	48.41	48.36	48.60
2.5	48.50	48.47	48.45	48.55	48.36	48.45	48.53	48.30	48.42	48.38	48.32	48.53
3	48.19	48.42	48.41	48.47	48.29	48.43	48.51	48.15	48.45	48.37	48.27	48.40
3.5	48.21	48.32	48.33	48.45	48.27	48.42	48.48	48.16	48.41	48.41	48.26	48.44
4	48.10	48.30	48.30	48.38	48.26	48.42	48.34	48.23	48.30	48.44	48.24	48.40
4.5	48.12	48.30	48.27	48.31	48.27	48.39	48.31	48.35	48.33	48.38	48.22	48.37
5	48.15	48.25	48.29	48.27	48.23	48.37	48.35	48.33	48.27	48.29	48.17	48.32
5.5	47.95	48.22	48.28	48.25	48.05	48.24	48.23	48.23	48.23	48.25	48.15	48.25
6	47.81	48.19	48.22	48.23	48.06	48.20	48.12	48.20	48.23	48.24	48.10	48.21
6.5	47.80	48.15	48.17	48.24	48.15	48.23	48.12	48.23	48.26	48.25	48.10	48.20
7	47.82	48.13	48.10	48.21	48.15	48.23	48.23	48.25	48.28	48.25	48.16	48.17
7.5	47.77	48.16	48.10	48.16	48.13	48.24	48.21	48.24	48.28	48.28	48.19	48.13
8	47.69	48.19	48.10	48.10	48.17	48.28	48.17	48.18	48.16	48.29	48.14	48.11
8.5	47.75	48.16	48.19	48.16	48.15	48.25	48.16	48.22	48.10	48.16	48.12	48.16
9	47.81	48.13	48.19	48.21	48.13	48.23	48.16	48.16	48.18	48.11	48.14	48.19
9.5	47.67	48.15	48.17	48.20	48.16	48.20	48.15	48.13	48.22	48.08	48.11	48.17
10	47.82	48.15	48.13	48.21	48.12	48.19	48.16	48.15	48.17	48.14	48.07	48.16
Average	48.14	48.30	48.30	48.34	48.26	48.34	48.32	48.25	48.30	48.31	48.22	48.32