Mapping of Depositional and Non-Depositional Areas in an Agricultural and Residential California Stream in 2010: Implications for Pyrethroid Toxicity

Final Report

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Good laboratory practice requirements of 40 CFR Part 160 do not apply to the study described in this document.

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GENERAL INFORMATION

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1.0 EXECUTIVE SUMMARY

This 2010 study used sediment mapping to determine the spatial extent of depositional and non-depositional areas in the wetted stream bed of an agricultural stream (Del Puerto Creek) and residential stream (Pleasant Grove Creek) located in California's Central Valley. After the stream mapping was completed, eight pyrethroids were analytically measured from randomly selected sites in depositional and non-depositional areas in the lower, middle and upper sections of Del Puerto Creek.

Based on a random sampling design, only 4% of the 99 sediment sampling sites in Del Puerto Creek were classified as depositional areas. When evaluating the entire wetted stream bed area, 12.2% of the 14 km of Del Puerto Creek was classified as depositional area. A comparison of depositional areas for the lower, middle and upper creek sections also demonstrated that depositional areas were more dominant in the lower section of Del Puerto Creek. For all three stream sections, % TOC was more dominant in depositional areas vs. non-depositional areas. Total pyrethroids in Del Puerto Creek were much higher in depositional areas vs. non-depositional areas and much lower upstream. Pyrethroid concentrations reported in depositional areas in Del Puerto Creek in this 2010 study were much lower (e.g., 37x lower for bifenthrin) than concentrations reported in this same creek by other investigators from 2005 to 2008.

Twelve percent of the 99 sediment sampling sites in Pleasant Grove Creek were classified as depositional areas. Based on the entire wetted stream bed area, 16.1% of the 41 km of Pleasant Grove Creek was classified as depositional area. Depositional areas were more dominant in the lower section of Pleasant Grove Creek when compared to the middle and upper section. All 33 transects sampled in the middle section of Pleasant Grove Creek were non-depositional areas.

The importance of appropriate sediment collection methods is highlighted based on our mapping results of depositional and non-depositional areas in an agricultural and residential stream in California. The protocol currently used by the State of California for sediment sampling methods for collecting sediment for both chemistry and sediment toxicity testing in wadeable streams generally targets depositional areas without considering the spatial context (representativeness) of these areas relative to the entire wetted stream bed of the water body and resulting range of habitats. Failure to present such a rationale is in direct conflict with California's Surface Water Ambient Monitoring Program (SWAMP) protocols. SWAMP protocols clearly state that the collection of sediment is purposefully biased towards collection of fine materials. This aspect must therefore be discussed thoroughly in any subsequent interpretative reporting of the data, with regards to potential "representativeness" of the collected sample to the environment from which it was collected. Our sediment mapping results from a representative agricultural and residential stream in California's Central Valley clearly demonstrate the importance of this "representativeness issue" since non-depositional areas were much more abundant than depositional areas.

The general focus of sediment sampling methodologies, that target fine grain material from depositional areas, is to provide sediment for chemical measurements and toxicity testing.

However, an equally important consideration is to collect sediment in wetted stream areas that will allow an accurate assessment of the status of resident benthic communities that live in these lotic environments. For Del Puerto Creek, Pleasant Grove Creek and many other urban and agricultural creeks in California, the beneficial use that must be protected is warm freshwater habitat (i.e., benthic communities) so it is logical that preferred habitat for benthic communities should also be considered when selecting sediment collection sites. Targeting only depositional areas for sediment collections and concurrent benthic collections will likely add systematic errors from a biological perspective because many sensitive benthic taxa prefer to reside in non-depositional areas.

2.0 INTRODUCTION

In agricultural areas of California’s Central Valley pyrethroid insecticides are used to control pests on a number of different crops. In urban and residential areas, pyrethroid insecticides have largely replaced organophosphate pesticides in recent years for structural pest control, landscape maintenance and residential home and garden use. Pyrethroids have been identified in both an agricultural (Del Puerto Creek) and residential (Pleasant Grove Creek) stream in California (Weston et al. 2008; Weston et al. 2005a) at water column concentrations that may occasionally exceed the standard laboratory (clean water) measured LC50 for the amphipod *Hyalella azteca*. *Hyalella* is known to be one of the most sensitive aquatic species to pyrethroids (Giddings et al. 2006). Both Del Puerto Creek and Pleasant Grove Creek have been listed as impaired water bodies (303 d listings) based on the presence of pyrethroids (http://www.waterboards.ca.gov/water_issues/programs/tmdl/integrated2010.shtml).

The targeted sampling method used to obtain sediment for both pyrethroid analysis and toxicity tests for the studies described above involved sampling the top 2 to 3 cm of sediment from depositional areas (areas high in % silt/clay and low in % sand) from the streams. In previous California studies, sediment samples from both Kirker Creek (mean value of 46 % sand based on 14 sites) and Pleasant Grove Creek (mean value of 60 % sand based on 21 sites) exhibited moderate to high percentages of sand even when depositional areas were targeted for sampling in a 2006 study (Hall et al. 2008a). This raises the critical question of the “representativeness” of the sediment sampling techniques used by various investigators (e.g.,Weston et al. 2005a; Weston et al. 2005b; Amweg et al. 2006) for reporting pyrethroid toxicity in Central Valley streams. If only a small percentage of a wetted stream bed sampling reach is actually depositional then reporting residues of hydrophobic pesticides, such as pyrethroids in sediment samples, that represent only a small area of the reach would not reflect the residues experienced by most benthic taxa present in the majority of the transect and would be likely to overstate the potential overall ecological exposure and risk. This issue was partially addressed in a preliminary pilot study during the fall of 2007 with detailed mapping of depositional and non-depositional areas on a limited spatial scale (two sites) in Pleasant Grove Creek (Hall et al. 2008b) coupled with concurrent pyrethroid residue measurements. Results from the 2007 study exhibited high variability among replicates for pyrethroid concentrations at both targeted (selective for areas with fine grain material) and random sites. Concentrations of various pyrethroids were higher in targeted sampling from depositional areas at the sites.

Additional sediment sampling methods research (Hall et al. 2009a) was continued in Pleasant Grove Creek in 2008 at nine sites with the following objectives: **(1)** determine the % of the sample site (~ 75 m of stream segment) that is depositional (i.e., fine grain sediment such as silt and clay) and non-depositional (i.e, larger grain sediment such as sand and gravel) area based on stream mapping of all sites; **(2)** determine variability of pyrethroid concentrations from targeted sampling of three depositional areas and three "best available habitat" areas for benthic macroinvertebrates (biological areas) at all sites; and **(3)** compare pyrethroid concentrations from the two targeted sampling approaches in depositional and biological areas for all sites.

Based on sampling of nine sites in Pleasant Grove Creek, non-depositional areas were dominant. These non-depositional areas, where sediment bearing residues of hydrophobic chemicals such as pyrethroids are not expected to accumulate, generally are the preferred habitat for most taxa of benthic macroinvertebrates. The % sand was reported to be more variable from depositional areas when compared to "best available habitat" areas from the various study sites. In general, variability of total pyrethroids residues between replicates was higher in depositional areas when compared with "best available habitat" areas. This result is logical because high variability for pyrethroids would be expected in depositional areas where these insecticides are more likely to be found due to heterogeneous deposition of sediments. Additionally, comparison of total pyrethroids (mean values) from depositional samples with "best available habitat" area samples for all nine sites demonstrated that total pyrethroid concentrations were consistently higher in depositional samples at each site.

In 2009 sediment sampling methods research was expanded to an urban stream (Arcade Creek) in California's Central Valley (Hall et al., 2009b). The general goal of the 2009 Arcade Creek study was to expand the previously limited spatial scale sediment sampling methods research conducted in Pleasant Grove Creek in 2007 and 2008 to a larger scale (entire stream) in an urban California stream (Arcade Creek) located in Sacramento. The specific objective was to conduct wetted stream-bed mapping at randomly selected sites to determine the spatial extent of depositional and non-depositional areas for the entire length of Arcade Creek. Pyrethroid residue sampling and analysis was not conducted concurrently with the mapping work during the 2009 study. Arcade Creek was selected for the 2009 study because the Central Valley Regional Water Quality Control Board will list this creek as an impaired water body due to pyrethroids in the next round of 303 (d) listings based on results from sediment toxicity tests with *Hyalella* in concert with sediment measurements of pyrethroids (http://www.waterboards.ca.gov/water_issues/programs/tmdl/integrated2010.shtml). Based on a random sampling design, only 15% of the 99 sediment sampling sites (transects) in Arcade Creek were classified as depositional areas (Hall et al. 2009b). A comparison of depositional areas for the lower, middle and upper creek segments (~ 8 km each) also demonstrated that depositional areas were much more dominant in the lower segment of Arcade Creek. By contrast, depositional areas in the middle and upper segments of Arcade Creek were rare.

In 2010 our sediment sampling methods research program was expanded to use sediment mapping to determine the spatial extent of depositional and non-depositional areas in the entire wetted stream bed of an agricultural stream (Del Puerto Creek) and residential stream (Pleasant Grove Creek) located in California's Central Valley. After the stream mapping described above was completed, eight pyrethroids were also analytically measured from randomly selected sites in depositional and non-depositional areas in the lower, middle and upper sections of Del Puerto Creek.

3.0 MATERIALS AND METHODS

3.1 Stream Description

Del Puerto Creek is an agricultural stream in the San Joaquin River watershed that originates in the hills east of San Jose, California with minimal development in the upper watershed (Figure 1 and 2). This stream flows northeastward through agricultural lands near Patterson and then flows for approximately 14 km across the valley floor before its confluence with the San Joaquin River. A wide variety of crops including almonds, walnuts, apricots, tomatoes, and beans are grown in the lower part of this watershed. Del Puerto Creek is currently listed as an impaired water body based on the presence of chlorpyrifos, diazinon and pyrethroids under 303 (d) of the Clean Water Act (http://www.waterboards.ca.gov/water_issues/programs/tmdl/integrated2010.shtml). The listing identifies bifenthrin, lambda-cyhalothrin, esfenvalerate/fenvalerate, and permethrin as pyrethroids of concern, with their presence attributed to unknown sources.

Pleasant Grove Creek (PGC) and its tributaries (South Branch and Kaseberg Creek) is a residential creek in Roseville, California that is characterized by numerous contiguous subdivisions of single family homes which are less than 10 years old (Figure 1 and 3). There is no industry in the area and only sparse commercial development and agriculture. Pleasant Grove Creek is a slow-moving stream 2 to 4 m in width and 0.5 to 1 m in depth in most reaches when water is present. During the summer, the primary source of water to the system is runoff from residences from over-irrigation of landscapes and lawns. A complete description of this stream is available in Hall et al. 2008a.

3.2 Sediment Mapping Methods

Reconnaissance work was conducted in Del Puerto Creek and Pleasant Grove Creek in January and February of 2010 to select sample sites and obtain permission to access the sites. In March through May of 2010, the stream mapping for both streams was conducted to determine the spatial extent of depositional (fine grain material such as silt and clay) and non-depositional (larger grain material such as sand and gravel) areas in the creeks using a coarse wetted stream bed mapping approach. The wetted stream length of Del Puerto Creek (approximately 14 km in Figure 2) and Pleasant Grove Creek (approximately 41 km in Figure 3) was mapped and a stratified random design was used to select sample sites. Streams were separated into three equal segments – upper, middle and lower stream segments - and 33 samples (transects) were randomly collected from each segment to ensure equal distribution of sample sites. Google Earth Pro (Version 5.0) was used to identify all possible sampling grids considered in the final randomized site selection process. A total of 99 1 x 1 m grids were randomly selected from each stream for sediment characterization. A grid tool (1 x 1 m) described in Hall et al. 2008b was used to visually determine the predominant substrate type (depositional versus non-depositional areas) in the wetted stream bed of the study sites. This 1 x 1 m grid tool was used to determine a 1 m linear transect at each site. For example, if the stream was 1 m in width the grid tool was placed over the wetted stream bed one time for substrate type assessment. If the stream width was 2 m, the grid tool was placed over the wetted stream bed twice for substrate type assessment. A Global Positioning System (GPS) was used to accurately locate the coordinates of each grid that was sampled. Total transect area, depositional area (m^2) and % depositional sediment was determined at each site.

A series of maps was developed showing the location of all 99 sample sites along with the % of depositional area in the wetted stream bed by site. A final calculation was also made to determine the % depositional area of the entire wetted stream bed.

A Kruskal-Wallis One-Way Analysis of Variance on Ranks with a Tukey Test was used to examine the data for any statistical differences among the lower, middle and upper segments for the following measurements: (1) mean transect area; (2) mean depositional area for 1 m width transects across the entire stream; and (3) mean % depositional area.

3.3 Pyrethroid, Total Organic Carbon (TOC) and Grain Size Analysis

After the stream mapping described above for Del Puerto Creek had determined a total of 99 depositional and non-depositional areas (33 in each of the three stream sections) the following pyrethroids were measured in sediment from three randomly selected depositional areas and three non-depositional areas for each of the three stream sections: bifenthrin, cypermethrin, cyfluthrin, deltamethrin, esfenvalerate, fenpropathrin, lambda-cyhalothrin, and permethrin. A stainless steel spoon (similar to a scoop) was used to collect the top 2-3 cm of sediment from either depositional or non-depositional areas. Approximately 500 ml of sediment was collected for pyrethroid analysis (and TOC and grain size as described below). All sampling equipment was cleaned between sites using nitric acid, ethanol, and distilled water. Sampling procedures for sediment sampling are described in detail in Hall et al. 2008a.

Pyrethroid residues were extracted from sediment by shaking with methanol/water mixture and hexane for one hour. The sample was centrifuged and an aliquot of the upper hexane layer evaporated to dryness and re-dissolved in a small volume of hexane. The hexane sample was then subjected to a silica solid phase extraction (SPE) procedure prior to residue determination by gas chromatography with mass selective detection using negative ion chemical ionisation (GC-MS/NICI). The limit of quantitation of the method was 0.11 to 0.35 ng/g dry weight for all pyrethroids except permethrin which was 1.1 to 3.5 ng/g (see Robinson, 2005 for details). Morse Laboratories in Sacramento, California conducted the pyrethroid analysis.

Total Organic Carbon (U. S. EPA, 2004) and grain size (American Society for Testing and Materials, 1998) were measured for each of the 18 sediment samples from depositional and non-depositional areas in the lower, middle and upper sections of Del Puerto Creek as described above for pyrethroids. Sediment samples were stored in a cooler on ice in the field and later transferred to a refrigerator before shipment to Alpha Analytical Laboratory in Mansfield, Massachusetts for TOC and grain size analysis.

3.4 Water Quality Measurements

The following water quality measurements were taken at every 10 sites approximately evenly spaced for both streams: temperature (C), specific conductivity (µS), pH, dissolved oxygen (mg/L), salinity (ppt) and turbidity (NTU).

4.0 RESULTS AND DISCUSSION

4.1 Water Quality Measurements

The only consistent water quality parameter reported in Table 1 for all Del Puerto Creek sites was salinity (0.3 to 0.7 ppt). Parameters such as temperature (13.1 to 20.3 C), specific conductivity (875 to 1,181 µS), pH (8.67 to 9.03), dissolved oxygen (9.54 to 12.41 mg/L) and turbidity (0.65 to 31.8 NTU) were variable across the various sites. Spatial trends indicated lower turbidity at upstream sites.

With the exception of salinity (0 to 0.2 ppt), all water quality parameters in Pleasant Grove Creek sites were spatially variable (Table 1). The following ranges were reported for the 10 sites: temperature (15.9 to 22.9 C); specific conductivity (89 to 480 µS); pH (6.71 to 7.92); dissolved oxygen (2.64 to 12.43 mg/L); and turbidity (2.91 to 15.4 NTU). Turbidity was generally reported to increase at the two downstream sites relative to the upstream sites.

4.2 Stream Mapping of Depositional and Non-depositional Areas

4.2.1 Del Puerto Creek

Four percent of the 99 sediment sampling sites in Del Puerto Creek were classified as depositional areas (Table 2 and Figure 4). From a spatial perspective, depositional areas were more abundant in the lower section of Del Puerto Creek when compared with middle and upper sections (Table 2, Figure 4). For example, three transects in the lower section (Figure 4a) were predominately depositional areas while only one transect in the middle section was dominated by fine grain material (Figure 4b). All 33 transects sampled in the upper section of Del Puerto Creek were non-depositional areas (Figure 4c).

Based on statistical analysis, mean total transect area in Del Puerto Creek decreased from upstream to downstream as presented in Figure 5. These results were considered atypical since the wetted area of a stream is usually greater in downstream areas compared to upstream areas as we have reported from a previous sediment mapping study in Arcade Creek (Hall et al. 2009b). Although the total transect area sampled was greater in the upper section of the creek, compared to the middle and downstream sections, both the mean depositional area per transect (Figure 6) and the mean % depositional by transect (Figure 7) was statistically greater in the lower section of the creek. Based on the entire wetted stream bed area, 12.2% of the 14 km of Del Puerto Creek was classified as depositional area.

4.2.2 Pleasant Grove Creek

Twelve percent of the 99 sediment sampling sites in Pleasant Grove Creek were classified as depositional areas (Table 3 and Figure 8). Depositional areas were more dominant in the lower section of Pleasant Grove Creek (Figure 8a) when compared to the middle section (Figure 8b) and upper section (Figure 8c). All 33 transects sampled in the middle section of Pleasant Grove Creek were non-depositional areas (Figure 8b).

A comparison of the mean total transect area for the lower, middle and upper sections of Pleasant Grove Creek showed that the lower section had significantly more total area than the other two sections (Figure 9). A similar result was reported from our previous sediment mapping study in Arcade Creek (Hall et al. 2009b). Results from statistical analysis comparing the mean depositional area for the lower, middle and upper sections of Pleasant Grove Creek showed that the lower section had significantly more depositional area than the middle area (Figure 10). However, a comparison of the mean % depositional area for the lower, middle and upper sections showed no statistical difference between the three sections (Figure 11). Based on the entire wetted stream bed area, 16.1% of the 41 km of Pleasant Grove Creek was classified as depositional area.

4.3 Total Organic Carbon, Grain Size and Pyrethroids

Total Organic Carbon concentrations ranged from 0.776 to 2.0 % in Del Puerto Creek depositional areas with a mean value of 1.13% for all 9 sites (Table 4). For the non-depositional areas in Del Puerto Creek, % TOC ranged from 0.127 to 0.226 with a mean value of 0.164. As anticipated, TOC concentrations were much higher in depositional areas when compared to non-depositional areas.

The mean % TOC values for depositional areas (3 values per stream section) were 0.86% for the lower section, 1.1% for the middle section and 1.4 % for the upper section (Table 4). These data suggest that TOC concentration increased slightly from downstream to upstream. For non-depositional areas, the mean % TOC for the lower, middle and upper stream sections was similar ranging from 0.15 to 0.18 % TOC.

Percent sand ranged from 6.2 to 25.1% in Del Puerto Creek depositional areas with a mean value of 17.5% for all 9 sites (Table 4). For non-depositional areas in Del Puerto Creek, % sand ranged from 49 to 87.7 % with a mean value of 69.3%. As expected, % sand was much lower in depositional areas compared to non-depositional areas.

From a spatial perspective, mean % sand in depositional areas of the three stream sections (lower, middle and upper) was comparable ranging from 15.2 to 19.7% (Table 4). However, mean % sand for non-depositional areas was lower in the lower stream section (61%) when compared to the middle (75.2%) and upper (72.3%) sections.

Ranges of pyrethroid concentrations (normalized to 1 % TOC) presented in Table 5 from the 9 depositional areas in the upstream, middle and downstream sections of Del Puerto Creek were as follows: bifenthrin (0.029 – 7.3 ng/g); fenpropathrin (0 – 0.008 ng/g); lambda cyhalothrin (0.094 – 10.63 ng/g); permethrin (0 – 0.957 ng/g); cyfluthrin (0 – 0.096 ng/g);

cypermethrin (0.026 – 0.056 ng/g); esfenvalerate (0.101 – 7.09 ng/g); and deltamethrin (0 ng/g).

As expected, the pyrethroid concentrations (normalized to 1% TOC) from the 9 non-depositional areas in the upper, middle and lower sections of Del Puerto Creek were much lower, as reported in Table 5. Ranges of pyrethroid concentrations were as follows: bifenthrin (0 – 0.225 ng/g); fenpropathrin (0 – 0.009 ng/g); lambda cyhalothrin (0.016 – 0.634 ng/g); permethrin (0 – 0.205 ng/g); cyfluthrin (0 ng/g); cypermethrin (0.019 – 0.102 ng/g); esfenvalerate (0.004 – 0.256 ng/g); and deltamethrin (0 ng/g).

A spatial scale analysis of mean total pyrethroid concentrations in Figure 12 illustrates that total pyrethroid concentrations were lower in both depositional and non-deposition areas in the upper section of Del Puerto Creek when compared with the middle or lower section. For all three stream sections, mean total pyrethroid concentrations were much higher in depositional areas compared to non-depositional areas (Figure 12).

Toxic unit (TU) calculations were determined for each pyrethroid by dividing the 1% TOC normalized concentration by the *Hyalella* LC50 concentration (a species highly sensitive to pyrethroids) that was also 1% TOC normalized (Table 6). TU concentrations exceeding 1.0 were considered potentially toxic. The TU approach indicated that bifenthrin and lambda-cyhalothrin were each potentially toxic at one depositional site. The sum of TUs for four depositional sites were also predicted to be toxic due to pyrethroids.

Pyrethroid concentrations from the current study in Del Puerto Creek were compared with similar measurements conducted by Weston et al. 2008 in this agricultural stream (Table 7). Weston et al. (2008) measured pyrethroid concentrations from 25 depositional sites located in both mainstem and irrigation laterals during the late winter and early spring of 2005/2006. In contrast, we measured pyrethroid concentrations from a total of 18 sites (9 depositional areas and 9 non-depositional areas) during March of 2010. Pyrethroid concentrations measured by both groups were similar with the exception of deltamethrin which was not measured by Weston et al. 2008. The maximum concentrations of all pyrethroids measured in depositional areas from the Weston et al. 2008 study were substantially higher than the concentrations from depositional areas reported in our study (Table 7). For example, the following differences (based on maximum concentrations) were reported from the Weston et al. 2008 study: (1) bifenthrin was 37x higher; (2) lambda-cyhalothrin was 8x higher; (3) cyfluthrin was 15x higher; (4) permethrin was 21x higher; and (5) esfenvalerate was 2x higher. Differences in pyrethroid concentrations between the two studies could be caused by differences in the areas actually sampled as Weston et al. 2008 sampled both mainstem sites and irrigation laterals (i.e., thin layer of soft sediment from concrete lined laterals adjacent to farm fields) and we measured only mainstem sites. The time period for sampling could also be a factor in explaining the different concentrations. Our study was conducted in March of 2010 (representing the most current use patterns) while the Weston et al. 2008 study was conducted in late winter and early spring of 2005/2006 which may represent outdated use patterns.

Our measured pyrethroid concentrations from Del Puerto Creek were also compared with measurements from another study conducted in this creek by Ensminger et al. 2009 (Table 8). Ensminger et al. 2009 measured pyrethroids monthly at one site over a 7 month period between December 2007 and June 2008. By contrast, we measured pyrethroid concentrations from a total of 18 sites (9 depositional areas and 9 non-depositional areas) during one sampling event in March of 2010. The same 8 pyrethroids were measured by both groups. Maximum concentrations of cypermethrin, deltamethrin, fenpropathrin, lambda cyhalothrin, and permethrin were similar for both groups (Table 8). The maximum concentrations of bifenthrin and cyfluthrin reported by Ensminger et al., 2009 were 10x and 28x times higher than the maximum values reported in our 2010 study. However, the maximum value of esfenvalerate (10.7 ng/g) reported in our study was much higher than reported by Ensminger et al. 2009. The differences in maximum concentrations for the above three pyrethroids reported by the two groups may be due to different sampling scale designs. For example, different sampling programs could produce different ranges of concentrations due to variability in inputs of pyrethroids to the creek. Ensminger et al. 2009 sampled only one site but the site was sampled monthly for 7 months (expanded temporal scale with limited spatial scale) while we sampled a total of 9 depositional areas and 9 non-depositional areas in the entire stream during one sampling event (expanded spatial scale with limited temporal scale). It is also possible that the time period for sampling could explain differences in maximum pyrethroid concentrations as our study represents the most recent use patterns (March 2010) while the Ensminger et al. 2009 study (December 2007 to June 2008) may not represent current use patterns.

5.0 CONCLUSIONS

The results from sediment sampling in a representative agricultural (Del Puerto Creek) and residential (Pleasant Grove Creek) stream in California's Central Valley clearly demonstrated that non-depositional areas are much more abundant than depositional areas in these streams. These results are not surprising as other investigators have reported that non-depositional stream bed material is much more dominant than depositional stream bed material in Del Puerto Creek (Weston et al., 2008). In addition, we have also reported that non-depositional areas are more abundant in an urban California stream (Arcade Creek) in 2009 based on sediment mapping work (Hall et al. 2009b).

Our results are important because current sampling methods for collecting sediment for both sediment chemistry and toxicity testing in wadeable California streams target depositional areas without considering the spatial context (representativeness) of these areas relative to the entire wetted stream bed area. Failure to determine the spatial extent of depositional area is in direct conflict with the California Surface Water Ambient Monitoring Program (SWAMP) protocols. These protocols clearly state that the collection of sediment is purposefully biased for fine materials, which therefore must be discussed thoroughly in any subsequent interpretative reporting of the data, in regards to "representativeness" of the collected sample to the environment from which it was collected (Puckett, 2002). To our knowledge this "representativeness" issue has not been addressed with previous sediment toxicity or sediment chemistry studies in California.

In order to address the representativeness issue required by SWAMP (Puckett 2002) and associated with targeted sampling of depositional areas in wadeable California streams, mapping of depositional and non-depositional areas using a random design as described in this study is needed. This type of sediment mapping data is not only valuable for assessing the spatial extent of depositional areas in the wetted stream bed but could also be used to design a targeted sampling program that would adequately represent both depositional and non-depositional areas within a wadeable lotic system. This sediment mapping design could also be a cost effective approach for prioritizing water bodies with suspected sediment linked impairment for management actions or further examination. For example, water bodies dominated by depositional areas and hydrophobic chemical impairment in sediment may have a higher priority.

The mapping of depositional and non-depositional areas in wadeable streams described in this report has an important role in determining the spatial extent of potential impairment in water bodies designated as impaired (i.e., included in 303(d) listings) when hydrophobic chemicals such as pyrethroids are identified as the pollutant responsible for the impairment. The results from this study in both Del Puerto Creek and Pleasant Grove Creek demonstrated that although depositional areas are rare from a stream wide perspective, these areas are nevertheless more abundant downstream. The finding that depositional areas are more abundant downstream is in agreement with our previous sediment mapping study in Arcade Creek (Hall et al. 2009b). The fact that depositional areas, although rare, were reported to be more abundant in downstream areas suggests that 303(d) listings for pyrethroids for the entire stream length of Del Puerto Creek, Pleasant Grove Creek and Arcade Creek (Hall et al. 2009b) may not be justified.

Pyrethroid concentrations measured throughout the entire wetted stream bed in Del Puerto Creek, from both depositional and non-depositional areas that were selected based on random sampling, demonstrated that pyrethroid concentrations were markedly higher in depositional areas than non-depositional areas. This result is not surprising and it is notable that depositional areas make up only 4% of Del Puerto Creek. Concentrations of total pyrethroids measured in non-depositional areas, the predominant type of stream bed material for this creek, were extremely low or below the level of detection. Although concentrations of pyrethroids measured in depositional areas were higher than in non-depositional areas, the measured pyrethroid concentrations we reported in this study were substantially lower than concentrations reported by Weston et al. 2008 in 2005 and 2006. Differences in analytically measured concentrations between the two studies may be related to the areas actually sampled or the time period selected for sampling.

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7.0 TABLES SECTION

TABLE 1. Sample site numbers, coordinates and water quality parameters measured during the Spring 2010 sediment characterizations of Del Puerto Creek (DLP) and Pleasant Grove Creek (PGC)

Site	Latitude	Longitude	Water Temperature (C°)	Specific Conductivity (µS)	pH	Dissolved Oxygen (mg/L)	Salinity (ppt)	Turbidity (NTU)
DLP-1	37.54090	-121.11739	13.1	975	8.82	10.77	0.6	31.8
DLP-11	37.53558	-121.12645	14.7	993	8.74	11.55	0.6	20.8
DLP-22	37.53022	-121.14035	18.4	1159	8.94	11.67	0.3	18.4
DLP-33	37.52240	-121.14750	19.5	1181	9.03	10.71	0.7	25.7
DLP-44	37.51413	-121.15930	13.4	978	8.84	12.41	0.6	16.33
DLP-55	37.49888	-121.16820	20.3	1006	9.02	12.16	0.6	6.17
DLP-66	37.49926	-121.17767	20.2	875	8.82	10.92	0.5	0.82
DLP-77	37.49614	-121.19189	19.6	875	8.82	10.72	0.5	0.66
DLP-88	37.48970	-121.20556	13.2	957	8.68	12.12	0.5	1.39
DLP-99	37.48170	-121.21519	19.7	858	8.67	9.54	0.5	0.65

TABLE 1. – continued.

Site	Latitude	Longitude	Water Temperature (C°)	Specific Conductivity (µS)	pH	Dissolved Oxygen (mg/L)	Salinity (ppt)	Turbidity (NTU)
PGC-1	38.80960	-121.49360	18.3	174	7.40	8.00	0.1	15.4
PGC-11	38.81117	-121.45716	22.1	322	7.75	9.75	0.2	8.54
PGC-22	38.8115	-121.41615	22.9	480	7.91	12.43	0.2	5.15
PGC-33	38.79416	-121.36637	20.2	185	7.68	6.46	0.1	4.78
PGC-44	38.80325	-121.32407	22.7	202	7.92	6.46	0.1	3.24
PGC-55	38.78678	-121.36150	17.8	120	6.67	7.71	0.1	4.79
PGC-66	38.79068	-121.33478	19.9	137	7.22	6.83	0.1	2.66
PGC-77	38.76770	-121.34191	20.0	89	6.71	2.64	0	6.68
PGC-88	38.78292	-121.32738	17.0	145	6.90	4.26	0.1	3.88
PGC-99	38.76900	-121.30282	15.9	194	7.27	9.04	0.1	2.91

TABLE 2. Del Puerto Creek sites, depositional categories, area sampled, depositional area, % depositional sediment, and site coordinates of transects sampled in Spring 2010. Samples with less than 50% depositional sediment were considered non-depositional.

Site ID	Depositional Category	Total Transect Area (m^2)	Depositional Area (m^2)	% Depositional Sediment	Latitude	Longitude
DLP-1	Non-depositional	2.25	0.00	0.0	37.54092	-121.11739
DLP-2	Non-depositional	2.70	0.15	5.6	37.54060	-121.11754
DLP-3	Non-depositional	3.40	0.20	5.9	37.54039	-121.11852
DLP-4	Non-depositional	2.50	0.13	5.0	37.54014	-121.11877
DLP-5	Non-depositional	2.80	0.90	32.1	37.54001	-121.11938
DLP-6	Non-depositional	3.70	0.13	3.4	37.53936	-121.12159
DLP-7	Non-depositional	1.80	0.54	30.0	37.53927	-121.12289
DLP-8	Non-depositional	2.20	0.55	25.0	37.53745	-121.12578
DLP-9	Non-depositional	2.30	0.74	32.2	37.53642	-121.12652
DLP-10	Non-depositional	3.10	0.51	16.5	37.53569	-121.12645
DLP-11	Non-depositional	2.30	0.83	36.1	37.53558	-121.12645
DLP-12	Non-depositional	1.70	0.04	2.1	37.53525	-121.12681
DLP-13	Non-depositional	2.05	0.45	22.0	37.53507	-121.12713
DLP-14	Non-depositional	2.50	0.03	1.0	37.53446	-121.12784
DLP-15	Non-depositional	1.80	0.14	7.8	37.53425	-121.12821
DLP-16	Non-depositional	1.40	0.45	32.1	37.53315	-121.13049
DLP-17	Non-depositional	3.30	1.28	38.8	37.53226	-121.13153
DLP-18	Non-depositional	2.05	0.10	4.9	37.53153	-121.13179
DLP-19	Non-depositional	3.05	0.48	15.6	37.53062	-121.13473
DLP-20	Depositional	2.85	2.80	98.3	37.53052	-121.13495
DLP-21	Non-depositional	2.80	0.31	11.1	37.53085	-121.13581
DLP-22	Non-depositional	1.40	0.25	17.9	37.53022	-121.14035
DLP-23	Non-depositional	1.30	0.58	44.6	37.52974	-121.14102
DLP-24	Non-depositional	2.10	0.35	16.7	37.52958	-121.14115
DLP-25	Non-depositional	2.00	0.50	25.0	37.52882	-121.14190
DLP-26	Non-depositional	1.90	0.36	18.9	37.52824	-121.14240
DLP-27	Depositional	2.05	1.11	54.1	37.52810	-121.14260
DLP-28	Non-depositional	1.80	0.60	33.3	37.52720	-121.14418
DLP-29	Depositional	2.30	1.70	73.9	37.52710	-121.14458
DLP-30	Non-depositional	1.80	0.40	22.2	37.52606	-121.14675
DLP-31	Non-depositional	1.60	0.22	13.8	37.52266	-121.14716
DLP-32	Non-depositional	1.80	0.40	22.2	37.52246	-121.14740
DLP-33	Non-depositional	1.80	0.52	28.9	37.52240	-121.14750
DLP-34	Non-depositional	1.20	0.30	25.0	37.52046	-121.14836
DLP-35	Non-depositional	1.40	0.50	35.7	37.52032	-121.14834
DLP-36	Non-depositional	2.00	0.30	15.0	37.51942	-121.14908
DLP-37	Non-depositional	1.20	0.40	33.3	37.51870	-121.15042

TABLE 2 - continued.

Site ID	Depositional Category	Total Transect Area (m^2)	Depositional Area (m^2)	% Depositional Sediment	Latitude	Longitude
DLP-38	Non-depositional	1.40	0.35	25.0	37.51859	-121.15068
DLP-39	Non-depositional	1.20	0.05	4.2	37.51844	-121.15096
DLP-40	Non-depositional	1.20	0.32	26.3	37.51587	-121.15480
DLP-41	Non-depositional	1.55	0.32	20.8	37.51459	-121.15775
DLP-42	Non-depositional	5.40	2.15	39.8	37.51417	-121.15918
DLP-43	Depositional	1.60	0.98	61.3	37.51564	-121.15524
DLP-44	Non-depositional	1.20	0.18	15.0	37.51412	-121.15930
DLP-45	Non-depositional	2.05	0.05	2.4	37.51372	-121.15999
DLP-46	Non-depositional	5.10	0.00	0.0	37.51151	-121.16179
DLP-47	Non-depositional	4.00	0.05	1.3	37.50897	-121.16538
DLP-48	Non-depositional	3.70	0.08	2.2	37.50876	-121.16555
DLP-49	Non-depositional	5.05	0.25	5.0	37.50500	-121.16695
DLP-50	Non-depositional	4.65	0.08	1.7	37.50493	-121.16696
DLP-51	Non-depositional	3.00	0.00	0.0	37.50317	-121.16741
DLP-52	Non-depositional	4.50	0.00	0.0	37.50296	-121.16746
DLP-53	Non-depositional	2.00	0.00	0.0	37.50067	-121.16706
DLP-54	Non-depositional	6.05	0.40	6.6	37.49947	-121.16768
DLP-55	Non-depositional	5.85	0.00	0.0	37.49888	-121.16820
DLP-56	Non-depositional	3.80	0.00	0.0	37.49865	-121.16838
DLP-57	Non-depositional	4.60	0.00	0.0	37.49833	-121.16860
DLP-58	Non-depositional	5.00	0.20	4.0	37.49797	-121.16928
DLP-59	Non-depositional	8.95	0.00	0.0	37.49783	-121.16987
DLP-60	Non-depositional	4.70	0.00	0.0	37.49777	-121.17027
DLP-61	Non-depositional	5.50	0.00	0.0	37.49774	-121.17199
DLP-62	Non-depositional	4.40	0.00	0.0	37.49795	-121.17340
DLP-63	Non-depositional	6.40	0.00	0.0	37.49804	-121.17372
DLP-64	Non-depositional	6.60	0.00	0.0	37.49809	-121.17385
DLP-65	Non-depositional	7.95	0.00	0.0	37.49904	-121.17621
DLP-66	Non-depositional	2.60	0.00	0.0	37.49927	-121.17766
DLP-67	Non-depositional	3.15	0.00	0.0	37.49857	-121.18040
DLP-68	Non-depositional	5.80	0.16	2.8	37.49657	-121.18375
DLP-69	Non-depositional	4.70	0.10	2.1	37.49656	-121.18385
DLP-70	Non-depositional	4.90	0.00	0.0	37.49649	-121.18430
DLP-71	Non-depositional	3.60	0.00	0.0	37.49631	-121.18501
DLP-72	Non-depositional	3.70	0.00	0.0	37.49628	-121.18520
DLP-73	Non-depositional	5.20	0.00	0.0	37.49620	-121.18564
DLP-74	Non-depositional	6.50	0.23	3.5	37.49618	-121.18691
DLP-75	Non-depositional	6.95	0.10	1.4	37.49613	-121.18827
DLP-76	Non-depositional	4.40	0.00	0.0	37.49586	-121.18926
DLP-77	Non-depositional	4.75	0.00	0.0	37.49614	-121.19189
DLP-78	Non-depositional	3.85	0.00	0.0	37.49604	-121.19204

TABLE 2 - continued.

Site ID	Depositional Category	Total Transect Area (m^2)	Depositional Area (m^2)	% Depositional Sediment	Latitude	Longitude
DLP-79	Non-depositional	8.00	0.00	0.0	37.49511	-121.19290
DLP-80	Non-depositional	8.50	0.20	2.4	37.49370	-121.19468
DLP-81	Non-depositional	4.70	0.00	0.0	37.49351	-121.19610
DLP-82	Non-depositional	3.00	0.50	16.7	37.49153	-121.19768
DLP-83	Non-depositional	3.35	0.00	0.0	37.49157	-121.19856
DLP-84	Non-depositional	4.90	0.00	0.0	37.49149	-121.20165
DLP-85	Non-depositional	5.50	0.18	3.3	37.49188	-121.20307
DLP-86	Non-depositional	7.00	0.00	0.0	37.49034	-121.20492
DLP-87	Non-depositional	9.75	0.00	0.0	37.48989	-121.20517
DLP-88	Non-depositional	12.00	0.00	0.0	37.48971	-121.20556
DLP-89	Non-depositional	13.40	0.00	0.0	37.48974	-121.20551
DLP-90	Non-depositional	4.00	0.00	0.0	37.48906	-121.20690
DLP-91	Non-depositional	6.10	0.00	0.0	37.48871	-121.20732
DLP-92	Non-depositional	5.20	0.00	0.0	37.48528	-121.20998
DLP-93	Non-depositional	5.20	0.10	1.9	37.48515	-121.20989
DLP-94	Non-depositional	14.20	2.21	15.6	37.48346	-121.21039
DLP-95	Non-depositional	3.10	0.10	3.2	37.48305	-121.21134
DLP-96	Non-depositional	3.60	0.27	7.5	37.48322	-121.21161
DLP-97	Non-depositional	6.05	0.20	3.2	37.48302	-121.21263
DLP-98	Non-depositional	3.90	0.00	0.0	37.48238	-121.21377
DLP-99	Non-depositional	6.95	1.38	19.8	37.48170	-121.21519

TABLE 3. Pleasant Grove Creek sites, depositional categories, area sampled, depositional area, % depositional sediment, and site coordinates of transects sampled in Spring 2010. Samples with less than 50% depositional sediment were considered non-depositional.

Sample ID	Depositional Category	Total Transect Area (m^2)	Depositional Area (m^2)	% Depositional Sediment	Latitude	Longitude
PGC-1	Depositional	10.10	6.75	66.8	38.81035	-121.49175
PGC-2	Non-depositional	12.30	1.65	13.4	38.80955	-121.48484
PGC-3	Depositional	6.30	4.05	64.3	38.81059	-121.48138
PGC-4	Non-depositional	14.00	0.70	5.0	38.81055	-121.47985
PGC-5	Non-depositional	12.90	1.20	9.3	38.81214	-121.47675
PGC-6	Non-depositional	11.00	0.00	0.0	38.81270	-121.47604
PGC-7	Non-depositional	11.40	2.60	22.8	38.81320	-121.46863
PGC-8	Depositional	5.20	2.80	53.8	38.81277	-121.46597
PGC-9	Depositional	3.80	2.20	57.9	38.81197	-121.46169
PGC-10	Non-depositional	13.85	0.05	0.4	38.81176	-121.45805
PGC-11	Non-depositional	12.35	0.80	6.5	38.81117	-121.45716
PGC-12	Non-depositional	5.40	0.71	13.1	38.81264	-121.45117
PGC-13	Non-depositional	4.95	0.00	0.0	38.81242	-121.44988
PGC-14	Non-depositional	3.40	0.00	0.0	38.81208	-121.44910
PGC-15	Non-depositional	4.70	0.00	0.0	38.81298	-121.44197
PGC-16	Non-depositional	8.00	0.90	11.3	38.81296	-121.43970
PGC-17	Non-depositional	7.80	0.80	10.3	38.81230	-121.43499
PGC-18	Non-depositional	10.00	0.20	2.0	38.81268	-121.42225
PGC-19	Non-depositional	5.75	0.40	7.0	38.81315	-121.41925
PGC-20	Non-depositional	14.50	0.00	0.0	38.81196	-121.42455
PGC-21	Depositional	14.90	8.50	57.0	38.80900	-121.40912
PGC-22	Depositional	14.90	14.70	98.7	38.80862	-121.40888
PGC-23	Non-depositional	16.00	3.00	18.8	38.80451	-121.39884
PGC-24	Depositional	16.40	11.30	68.9	38.80920	-121.40922
PGC-25	Non-depositional	14.00	0.55	3.9	38.80333	-121.39078
PGC-26	Non-depositional	5.50	0.25	4.5	38.79469	-121.37241
PGC-27	Non-depositional	15.40	2.40	15.6	38.80412	-121.39349
PGC-28	Non-depositional	4.00	0.00	0.0	38.79466	-121.37132
PGC-29	Non-depositional	2.50	0.00	0.0	38.79490	-121.37289
PGC-30	Non-depositional	4.20	0.55	13.1	38.79457	-121.37159
PGC-31	Non-depositional	2.30	0.00	0.0	38.79460	-121.37045
PGC-32	Non-depositional	6.40	0.00	0.0	38.79464	-121.37188
PGC-33	Non-depositional	8.30	0.00	0.0	38.79416	-121.36637
PGC-34	Non-depositional	6.10	0.00	0.0	38.79323	-121.36347
PGC-35	Non-depositional	4.90	0.00	0.0	38.79352	-121.36220
PGC-36	Non-depositional	6.85	0.37	5.4	38.79637	-121.35679
PGC-37	Non-depositional	5.90	1.83	31.0	38.79884	-121.34749
PGC-38	Non-depositional	9.80	0.00	0.0	38.79985	-121.34309
PGC-39	Non-depositional	7.00	1.10	15.7	38.80099	-121.34107
PGC-40	Non-depositional	4.10	0.00	0.0	38.79981	-121.33626
PGC-41	Non-depositional	3.55	0.81	22.8	38.80322	-121.33325
PGC-42	Non-depositional	6.50	0.00	0.0	38.80318	-121.33244

TABLE 3. - continued.

Sample ID	Depositional Category	Total Transect Area (m^2)	Depositional Area (m^2)	% Depositional Sediment	Latitude	Longitude
PGC-43	Non-depositional	4.00	0.00	0.0	38.80260	-121.32958
PGC-44	Non-depositional	10.90	2.71	24.9	38.80325	-121.32407
PGC-45	Non-depositional	5.40	0.36	6.7	38.80341	-121.32186
PGC-46	Non-depositional	7.40	0.25	3.4	38.80360	-121.31735
PGC-47	Non-depositional	4.10	0.40	9.8	38.80468	-121.31480
PGC-48	Non-depositional	5.50	0.00	0.0	38.80387	-121.31690
PGC-49	Non-depositional	3.50	0.00	0.0	38.80548	-121.31271
PGC-50	Non-depositional	9.60	0.00	0.0	38.80597	-121.30635
PGC-51	Non-depositional	2.10	0.00	0.0	38.79107	-121.36313
PGC-52	Non-depositional	1.70	0.00	0.0	38.79111	-121.36396
PGC-53	Non-depositional	1.10	0.00	0.0	38.79000	-121.36489
PGC-54	Non-depositional	2.70	0.00	0.0	38.78983	-121.36411
PGC-55	Non-depositional	3.40	0.40	11.8	38.78678	-121.36150
PGC-56	Non-depositional	0.60	0.00	0.0	38.78689	-121.36069
PGC-57	Non-depositional	3.50	1.50	42.9	38.78558	-121.36026
PGC-58	Non-depositional	6.00	0.90	15.0	38.78207	-121.35787
PGC-59	Non-depositional	1.00	0.00	0.0	38.79700	-121.35182
PGC-60	Non-depositional	1.00	0.00	0.0	38.79686	-121.34948
PGC-61	Non-depositional	1.20	0.00	0.0	38.79595	-121.34967
PGC-62	Non-depositional	3.50	0.70	20.0	38.79429	-121.34153
PGC-63	Non-depositional	5.10	1.70	33.3	38.79458	-121.33992
PGC-64	Non-depositional	2.10	0.08	3.8	38.79434	-121.33883
PGC-65	Non-depositional	2.80	0.00	0.0	38.79081	-121.33600
PGC-66	Non-depositional	5.60	0.80	14.3	38.79068	-121.33478
PGC-67	Non-depositional	1.90	0.00	0.0	38.77188	-121.35039
PGC-68	Non-depositional	2.55	0.00	0.0	38.77151	-121.35045
PGC-69	Non-depositional	0.20	0.00	0.0	38.77145	-121.34861
PGC-70	Non-depositional	1.60	0.00	0.0	38.77059	-121.34678
PGC-71	Depositional	1.10	0.65	59.1	38.77045	-121.34665
PGC-72	Non-depositional	1.50	0.00	0.0	38.77043	-121.34660
PGC-73	Non-depositional	1.70	0.00	0.0	38.77055	-121.34620
PGC-74	Non-depositional	0.50	0.00	0.0	38.77058	-121.34396
PGC-75	Non-depositional	2.40	0.30	12.5	38.76841	-121.34263
PGC-76	Non-depositional	14.60	6.60	45.2	38.76824	-121.34246
PGC-77	Non-depositional	0.40	0.00	0.0	38.76770	-121.34191
PGC-78	Depositional	1.50	1.00	66.7	38.76582	-121.33277
PGC-79	Non-depositional	0.80	0.20	25.0	38.76583	-121.33269
PGC-80	Non-depositional	3.10	1.25	40.3	38.76600	-121.32809
PGC-81	Depositional	3.15	3.15	100.0	38.76611	-121.32781
PGC-82	Non-depositional	0.90	0.24	26.7	38.77047	-121.34881
PGC-83	Non-depositional	2.50	0.00	0.0	38.76969	-121.34769
PGC-84	Non-depositional	1.45	0.00	0.0	38.76766	-121.34563
PGC-85	Non-depositional	1.50	0.00	0.0	38.76576	-121.34213
PGC-86	Non-depositional	9.20	2.00	21.7	38.76335	-121.34083
PGC-87	Non-depositional	4.90	0.64	13.1	38.78496	-121.32818
PGC-88	Non-depositional	5.70	0.50	8.8	38.78292	-121.32738

TABLE 3. - continued.

Sample ID	Depositional Category	Total Transect Area (m^2)	Depositional Area (m^2)	% Depositional Sediment	Latitude	Longitude
PGC-89	Non-depositional	2.85	0.10	3.5	38.77555	-121.32148
PGC-90	Depositional	1.75	1.21	69.3	38.77538	-121.32148
PGC-91	Non-depositional	4.25	1.45	34.1	38.77087	-121.31564
PGC-92	Non-depositional	7.35	0.95	12.9	38.76988	-121.31418
PGC-93	Non-depositional	5.00	2.00	40.0	38.77002	-121.31242
PGC-94	Non-depositional	4.80	1.80	37.5	38.77123	-121.31041
PGC-95	Non-depositional	6.20	0.35	5.6	38.77097	-121.30854
PGC-96	Depositional	6.10	3.80	62.3	38.77050	-121.30810
PGC-97	Non-depositional	1.45	0.05	3.3	38.76969	-121.30569
PGC-98	Non-depositional	4.00	1.00	25.0	38.76960	-121.30496
PGC-99	Non-depositional	1.20	0.00	0.0	38.76900	-121.30282

TABLE 4. TOC and grain size values for Del Puerto Creek lower, middle and upper sections for depositional (D) and non-depositional (ND) areas. There were 6 samples for each stream section.

Del Puerto Creek Sites	% TOC	% Gravel	% Sand	% Silt	% Clay
734m -ND	.127	46.4	49	4.3	0.3
1635m - ND	.158	35.4	63.2	1.3	0.1
2079m – D	.965	0	21.8	61.5	16.7
2506m – D	.766	0	12.2	70.7	17.1
3392m – D	.860	0	25.1	60.6	14.3
3852m – ND	.167	28.6	69.5	1.7	0.2
4744m – D	.813	0.3	19.1	58.0	22.6
4889m – ND	.191	25.3	72.2	2.3	0.2
5847m – D	1.51	1.1	20.3	64.1	14.5
5987m – D	1.01	0	13.8	67.1	19.1
8543m - ND	.133	8.1	85.6	5.9	0.4
8820m - ND	.172	31.6	67.7	0.7	0
9213m – ND	.132	10.8	87.8	1.3	0.1
11166m - D	.727	0	6.2	72.3	21.5
11522m – ND	.226	35.8	63.3	0.8	0.1
11663m – D	2.0	0	22.7	59.2	18.1
12937m – D	1.55	0	16.8	70.1	13.1
13041m - ND	.174	29.9	65.8	4.0	0.3
Mean	0.649	14.1	43.5	33.7	8.82

TABLE 5. Pyrethroid concentrations (ng/g dry weight) for Del Puerto Creek sites. Depositional (D) and non-Depositional (ND) samples are noted in the sample ID column.

Sample ID	% TOC	Bifenthrin ng/g	Bifenthrin @ 1% TOC	Fenpropathrin ng/g	Fenpropathrin @ 1% TOC	Lambda-cyhal. ng/g	Lambda-cyhal. @ 1% TOC	Permethrin ng/g	Permethrin @ 1% TOC
734mND	0.127	0.0286	0.225	0.0011	0.009	0.034	0.268	0	0
1635mND	0.158	0.0259	0.164	0	0	0.0532	0.337	0	0
2079mD	0.965	1.59	1.65	0.005	0.005	2.2	2.28	0.275	0.285
2506mD	0.766	0.975	1.27	0.006	0.008	8.14	10.63	0.130	0.169
3392mD	0.860	2.8	3.26	0.005	0.006	1.18	1.37	0.304	0.353
3852mND	0.167	0.0636	0.38	0	0	0.0821	0.492	0.0342	0.205
4744mD	0.813	0.492	0.610	0	0	0.283	0.348	0.233	0.287
4889mND	0.191	0.0328	0.172	0.00149	0.008	0.0945	0.495	0	0
5847mD	1.51	2.38	1.58	0.009	0.006	1.85	1.23	0.601	0.398
5987mD	1.01	7.81	7.73	0.006	0.006	1.18	1.17	0.967	0.957
8543mND	0.133	0	0	0	0	0.0428	0.322	0	0
8820mND	0.172	0.01	0.058	0.001	0.006	0.109	0.634	0	0
9213mND	0.132	0	0	0	0	0.0463	0.351	0	0
11166mD	0.727	0	0	0.001	0.001	0.0244	0.034	0	0
11522mND	0.226	0	0	0	0	0.0579	0.256	0	0
11663mD	2.0	0.0782	0.039	0.0124	0.006	1.37	0.685	0	0
12937mD	1.55	0.046	0.029	0.0105	0.007	0.146	0.094	0	0
13041mND	0.174	0	0	0.0008	0.005	0.0028	0.016	0	0

TABLE 5. – continued.

Sample ID	% TOC	Cyfluthrin ng/g	Cyfluthrin @ 1% TOC	Cyper-methrin ng/g	Cyper-methrin @ 1% TOC	Esfenvalerate ng/g	Esfenvalerate @ 1% TOC	Delta-methrin ng/g	Delta-methrin @ 1% TOC
734mND	0.127	0	0	0.0123	0.097	0.0136	0.107	0	0
1635mND	0.158	0	0	0.0114	0.072	0.0239	0.151	0	0
2079mD	0.965	0.0160	0.017	0.0397	0.041	1.08	1.12	0	0
2506mD	0.766	0.0128	0.017	0.0289	0.038	0.853	1.11	0	0
3392mD	0.860	0.0155	0.018	0.0482	0.056	3.02	3.51	0	0
3852mND	0.167	0	0	0.0157	0.094	0.0428	0.256	0	0
4744mD	0.813	0.0062	0.008	0.0271	0.033	0.799	0.983	0	0
4889mND	0.191	0	0	0.0157	0.082	0.0195	0.102	0	0
5847mD	1.51	0.145	0.096	0.0576	0.038	10.7	7.09	0	0
5987mD	1.01	0	0.025	0.0404	0.04	1.27	1.26	0	0
8543mND	0.133	0	0	0.0136	0.102	0.0875	0.658	0	0
8820mND	0.172	0	0	0.0129	0.075	0.159	0.924	0	0
9213mND	0.132	0	0	0.0130	0.098	0.0527	0.399	0	0
11166mD	0.727	0	0	0.0145	0.019	0.0032	0.004	0	0
11522mND	0.226	0	0	0.0223	0.099	0.0118	0.052	0	0
11663mD	2.0	0	0	0.0515	0.026	0.405	0.203	0	0
12937mD	1.55	0	0	0.0451	0.029	0.157	0.101	0	0
13041mND	0.174	0	0	0.0123	0.071	0.0026	0.015	0	0

TABLE 6. Toxic units (TU) calculations for pyrethroids (1% TOC normalized) by site for Del Puerto Creek sites. Depositional (D) and non-depositional (ND) samples are noted in the sample ID column. The sum of TUs by site and ranking by site is also included. Toxic units > 1.0 are in bold type.

Sample ID	% TOC	Bifen TU	Fen TU	Lam-cy TU	Perm TU	Cyflu TU	Cyper TU	Esfen TU	Delt TU	Sum TU	Rank Stream
734mND	0.127	0.043	NA	0.060	0	0	0.026	0.007	0	0.136	13
1635mND	0.158	0.032	NA	0.075	0	0	0.019	0.010	0	0.136	12
2079mD	0.965	0.317	NA	0.507	0.003	0.002	0.011	0.073	0	0.913	5
2506mD	0.766	0.244	NA	**2.362**	0.002	0.002	0.010	0.072	0	**2.692**	1
3392mD	0.86	0.627	NA	0.304	0.003	0.002	0.015	0.228	0	**1.179**	3
3852mND	0.167	0.073	NA	0.109	0.002	0	0.025	0.017	0	0.226	8
4744mD	0.813	0.117	NA	0.077	0.003	0.001	0.009	0.064	0	0.271	6
4889mND	0.191	0.033	NA	0.110	0	0	0.022	0.007	0	0.172	10
5847mD	1.51	0.304	NA	0.273	0.004	0.009	0.010	0.460	0	**1.06**	4
5987mD	1.01	**1.487**	NA	0.260	0.009	0.002	0.011	0.082	0	**1.851**	2
8543mND	0.133	0	NA	0.072	0	0	0.027	0.043	0	0.142	11
8820mND	0.172	0.011	NA	0.141	0	0	0.020	0.060	0	0.232	7
9213mND	0.132	0	NA	0.078	0	0	0.026	0.026	0	0.13	14
11166mD	0.727	0	NA	0.008	0	0	0.005	0	0	0.013	18
11522mND	0.226	0	NA	0.057	0	0	0.026	0.003	0	0.086	15
11663mD	2	0.008	NA	0.152	0	0	0.007	0.013	0	0.18	9
12937mD	1.55	0.006	NA	0.021	0	0	0.008	0.007	0	0.042	16
13041mND	0.174	0	NA	0.004	0	0	0.019	0.001	0	0.024	17

TABLE 7. Comparison of pyrethroid concentrations (ng/g dw) in Del Puerto Creek from Weston et al. 2008 study with the current University of Maryland (UMD) study.

Study Characteristic	Weston et al. 2008	UMD
Date of Study	December 2005 – March 2006	March 2010
Sampling Design	25 sample sites	18 sample sites; 9 depositional sites and 9 non-depositional sites
Areas sampled	Depositional areas in mainstem and irrigation laterals	Depositional and non-Depositional areas in mainstem
Pyrethroids measured	bifenthrin, cyfluthrin, cypermethrin[1], deltamethrin[1], esfenvalerate, lambda-cyhalothrin, permethrin	bifenthrin, cyfluthrin, cypermethrin, deltamethrin, esfenvalerate, fenpropathrin[2], lambda-cyhalothrin, permethrin
Range of pyrethroid concentrations from depositional areas[3] (ng/g dw)	bifenthrin (0 – 286) lambda-cyhalothrin (2.2 – 63) cyfluthrin (ND – 7.5) permethrin (ND – 20.2) esfenvalerate (1.5 – 22.3)	bifenthrin (0.05 – 7.8) lambda-cyhalothrin (0.2 – 8.1) cyfluthrin (0 – 0.15) permethrin (0 – 0.97) esfenvalerate (0.16 – 10.7) fenpropathrin (0 – 0.009) cypermethrin (0.03 – 0.06) deltamethrin (0)

[1]Concentrations were not reported in the publication.
[2]Fenpropathrin was not measured in the Weston et al. 2008 study.
[3]All pyrethroid concentrations measured in non-depositional areas by UMD were much lower than in depositional areas.

TABLE 8. Comparison of pyrethroid concentrations (ng/g dw) in Del Puerto Creek from Ensminger et al. 2009 study with the current University of Maryland (UMD) study.

Study Characteristic	Ensminger et al. 2009	UMD
Date of Study	Monthly sampling from December 2007 – June 2008	March 2010
Sampling Design	1 site (Vineyard Av) sampled 11 times over 7 months	18 sample sites sampled once; 9 depositional sites and 9 non-depositional sites
Areas sampled	Depositional areas[1] in mainstem	Depositional and non-Depositional areas in mainstem
Pyrethroids measured	bifenthrin, cyfluthrin, cypermethrin, deltamethrin, esfenvalerate, fenpropathrin, lambda cyhalothrin, permethrin	bifenthrin, cyfluthrin, cypermethrin, deltamethrin, esfenvalerate, fenpropathrin, lambda-cyhalothrin, permethrin
Range of pyrethroid concentrations from depositional areas[2] (ng/g dw)	bifenthrin (ND – 74.4) cyfluthrin (ND – 4.2) cypermethrin (ND) deltamethrin (ND) esfenvalerate (ND) fenpropathrin (ND) lambda cyhalothrin (ND – 9.0) permethrin (ND)	bifenthrin (0.05 – 7.8) cyfluthrin (0 – 0.15) cypermethrin (0.03 – 0.06) deltamethrin (0) esfenvalerate (0.16 – 10.7) fenpropathrin (0 – 0.009) lambda-cyhalothrin (0.2 – 8.1) permethrin (0 – 0.97)

[1]It was assumed that depositional areas were sampled although the methods were vague.
[2]All pyrethroid concentrations measured in non-depositional areas by UMD were much lower than in depositional areas.

8.0 FIGURES SECTION

FIGURE 1. Del Puerto Creek and Pleasant Grove Creek sampling locations in California.

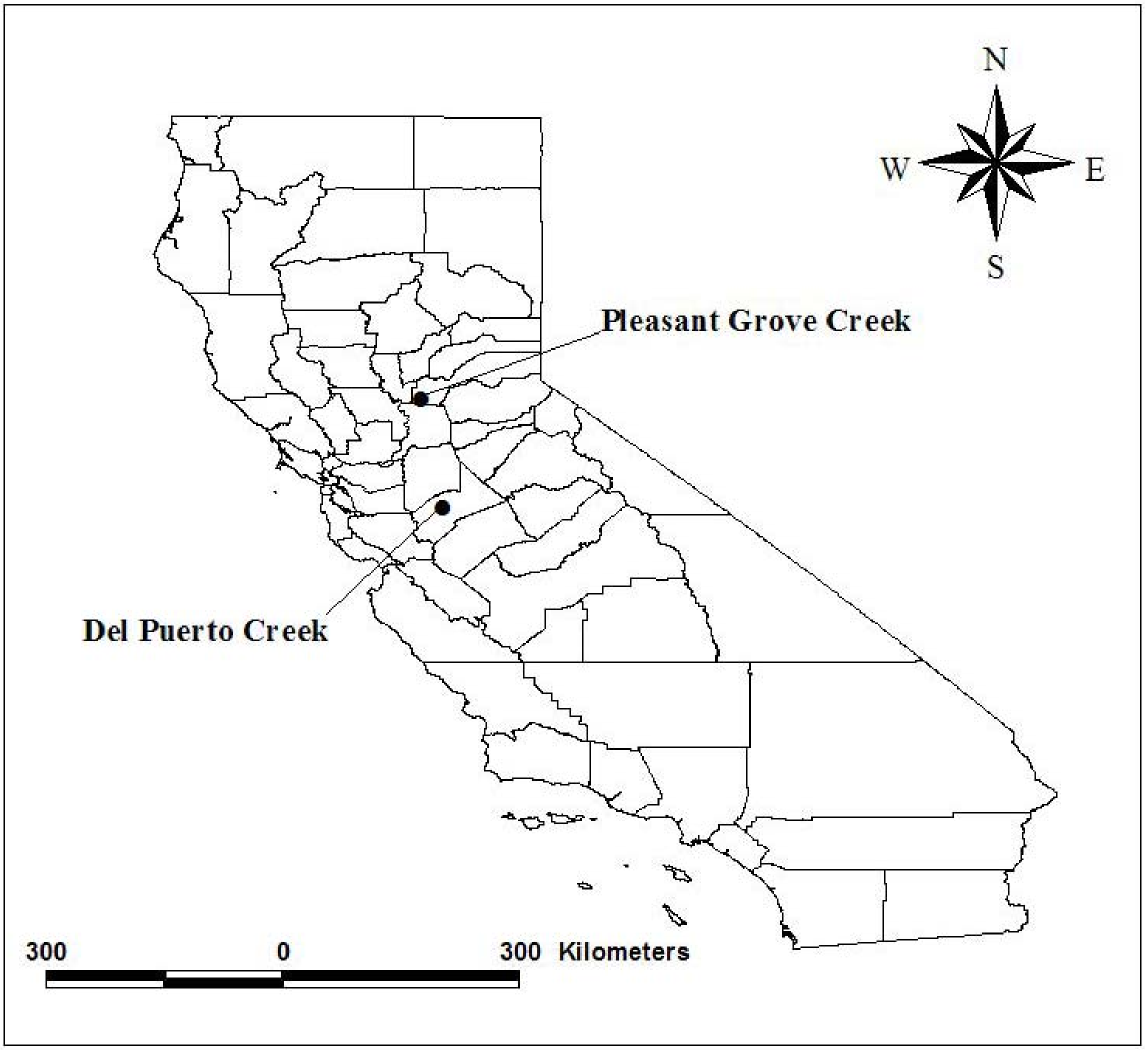

FIGURE 2. Del Puerto Creek showing the downstream and upstream extent of the 99 sediment sample sites.

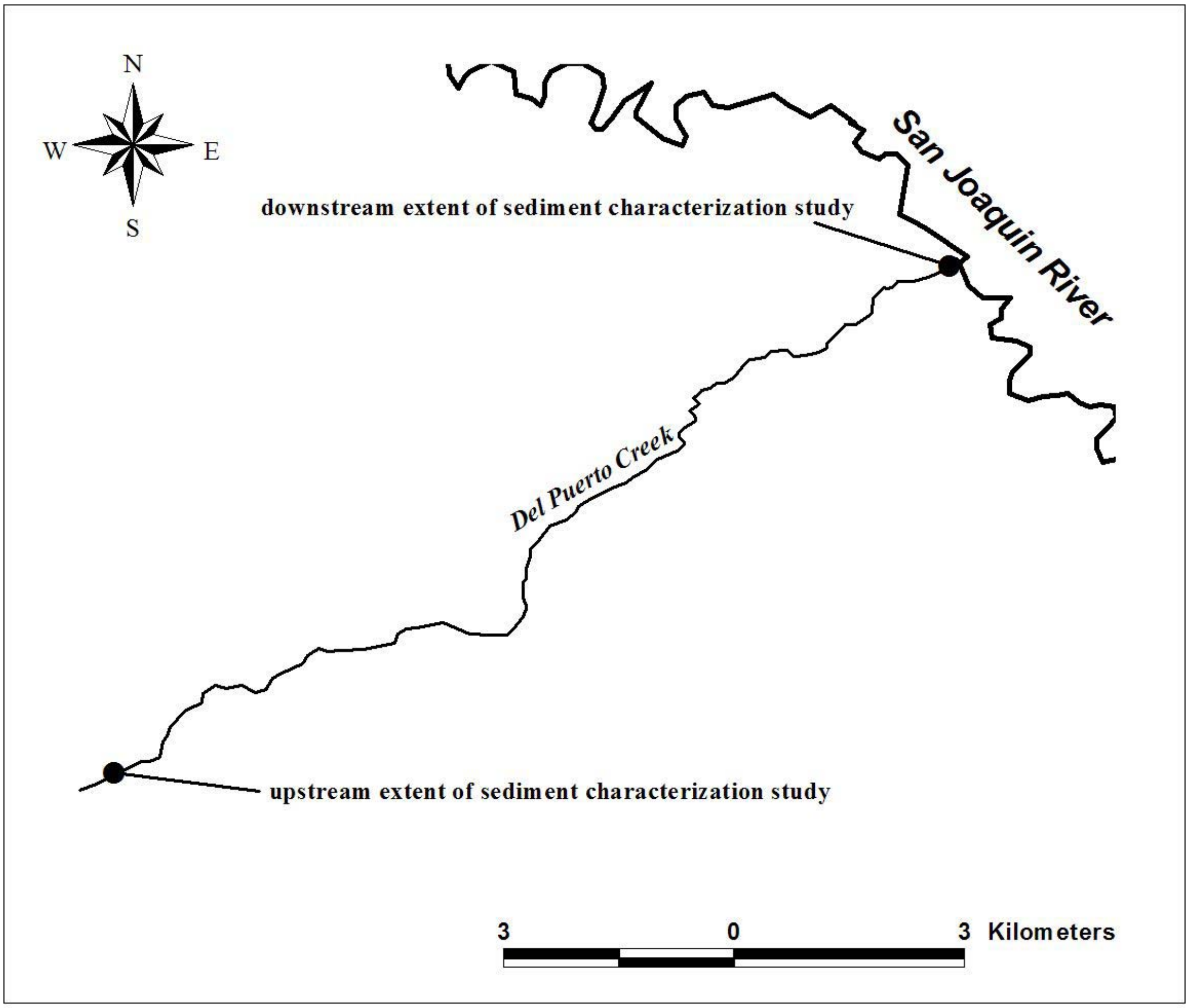

FIGURE 3. Pleasant Grove Creek showing the downstream and upstream extent of the 99 sediment sites.

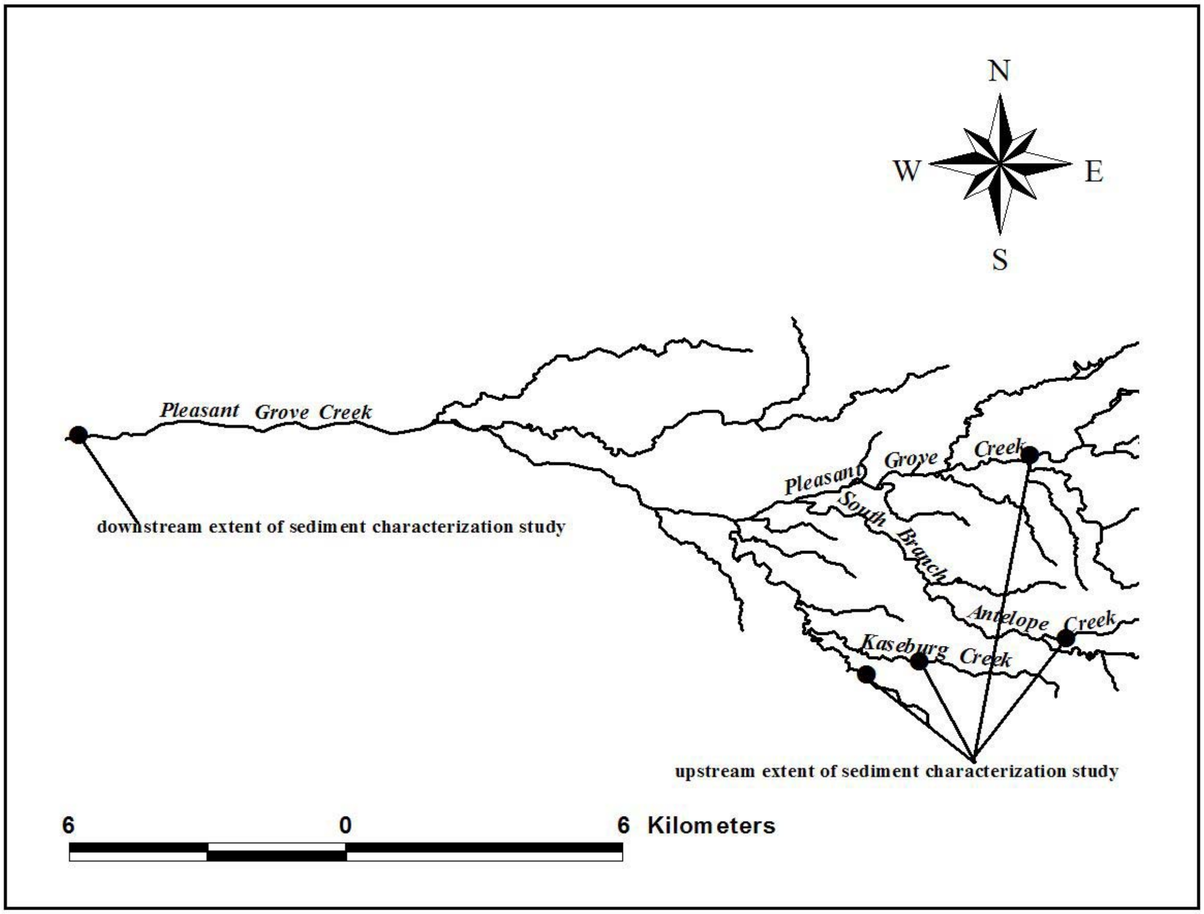

FIGURE 4a. Map showing lower section of Del Puerto Creek (~ 4.5 km) where sediment characterization was conducted at 33 sites. The dark section of each pie chart represents the % depositional area by site.

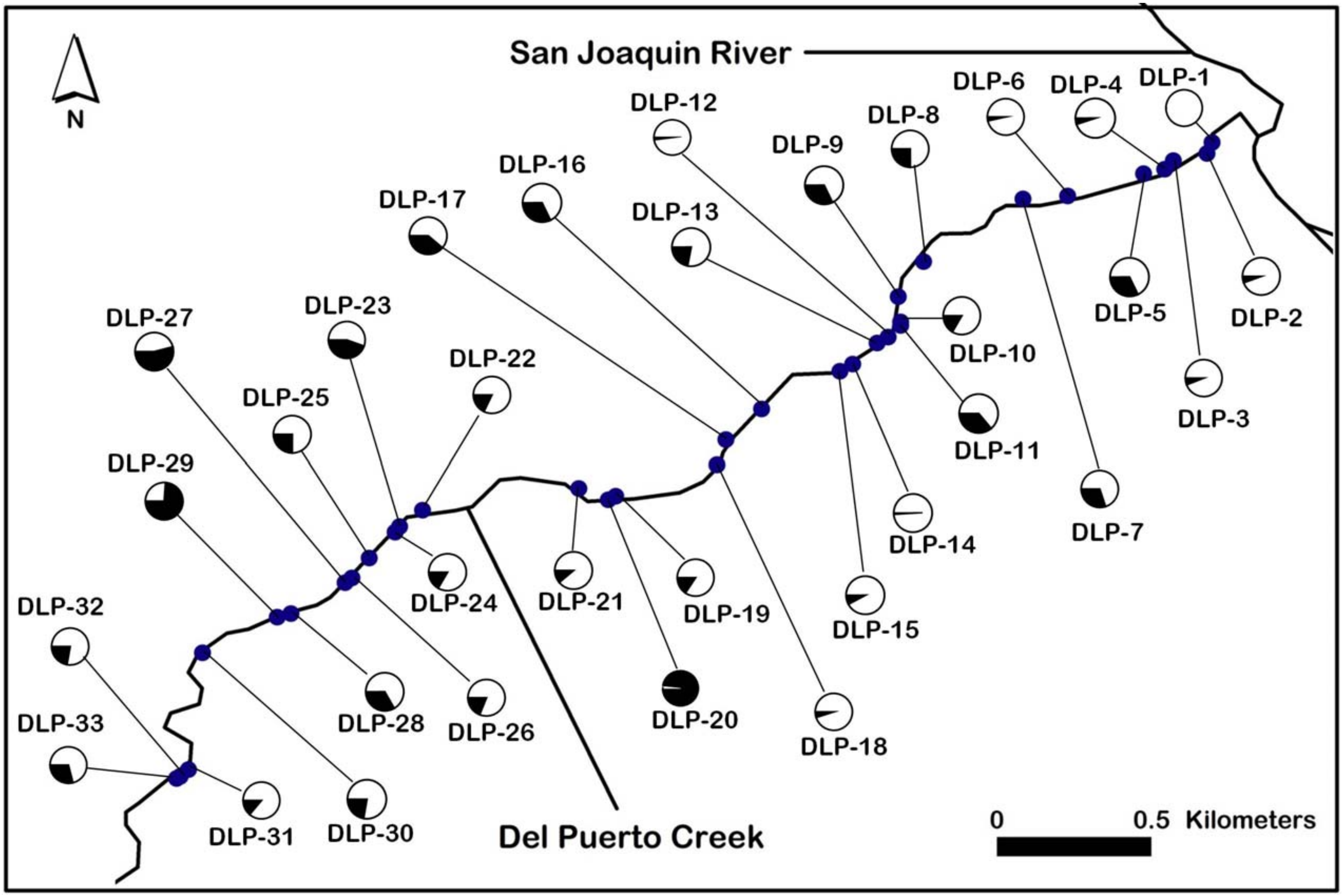

FIGURE 4b. Map showing middle section of Del Puerto Creek (~ 4.5 km) where sediment characterization was conducted at 33 sites. The dark section of each pie chart represents the % depositional area by site.

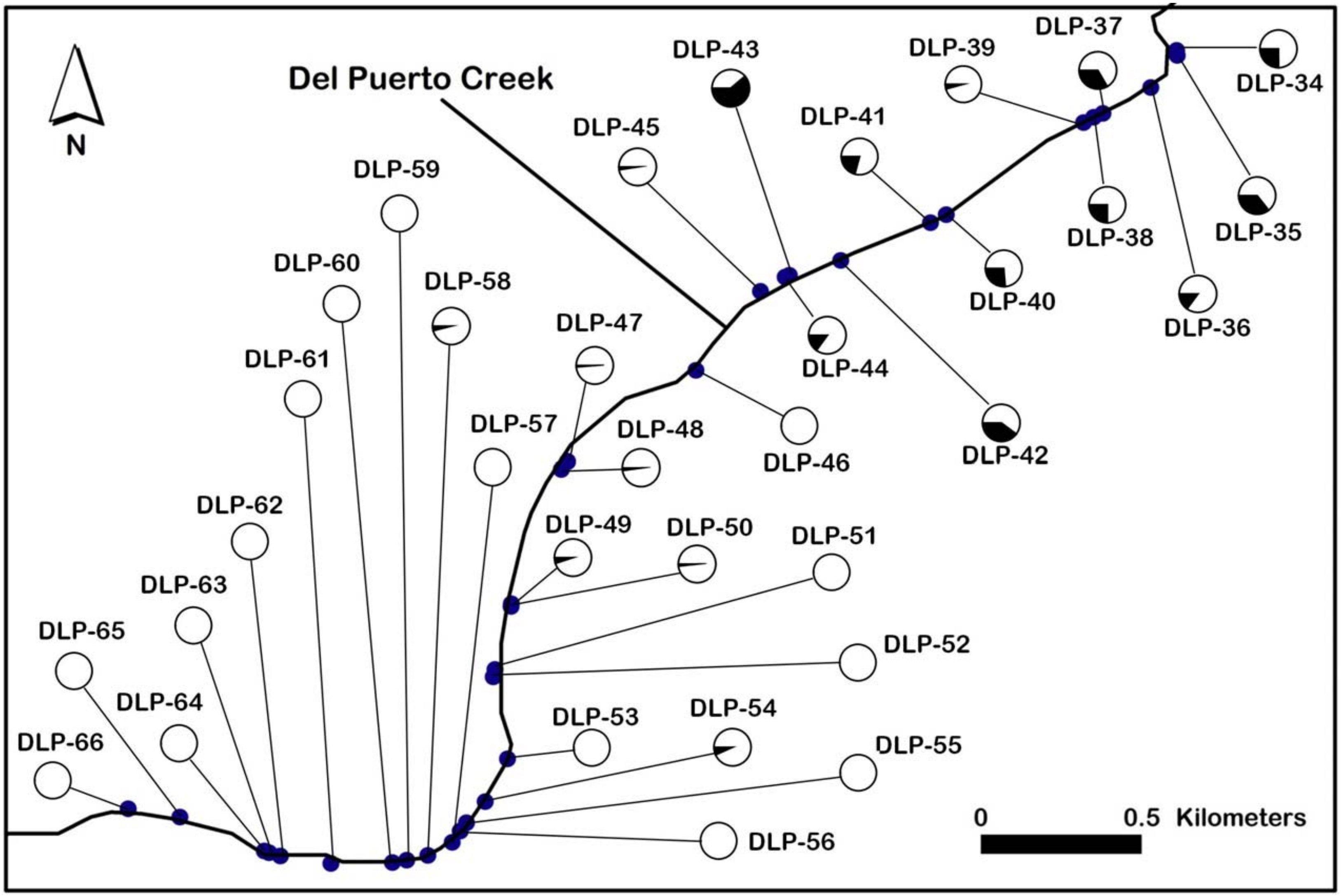

FIGURE 4c. Map showing upper section of Del Puerto Creek (~ 4.5 km) where sediment characterization was conducted at 33 sites. The dark section of each pie chart represents the % depositional area by site.

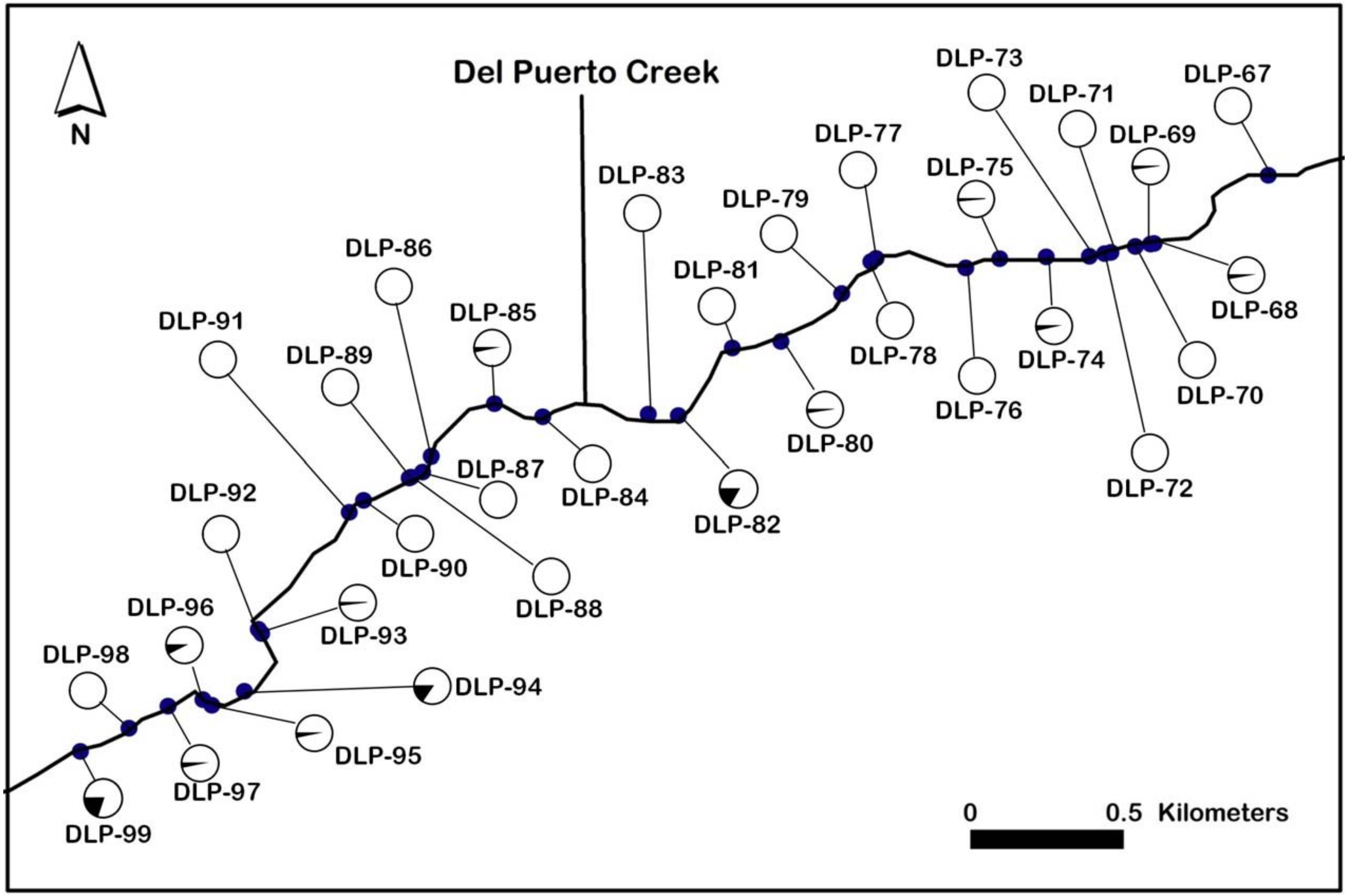

FIGURE 5. Mean total transect area for the lower, middle and upper sections of Del Puerto Creek. Statistical comparisons of total area indicate that the lower, middle and upper sections are all significantly different (P<0.05; Kruskal-Wallis One Way Analysis of Variance on Ranks with Tukey Test). Sections with different letters are significantly different.

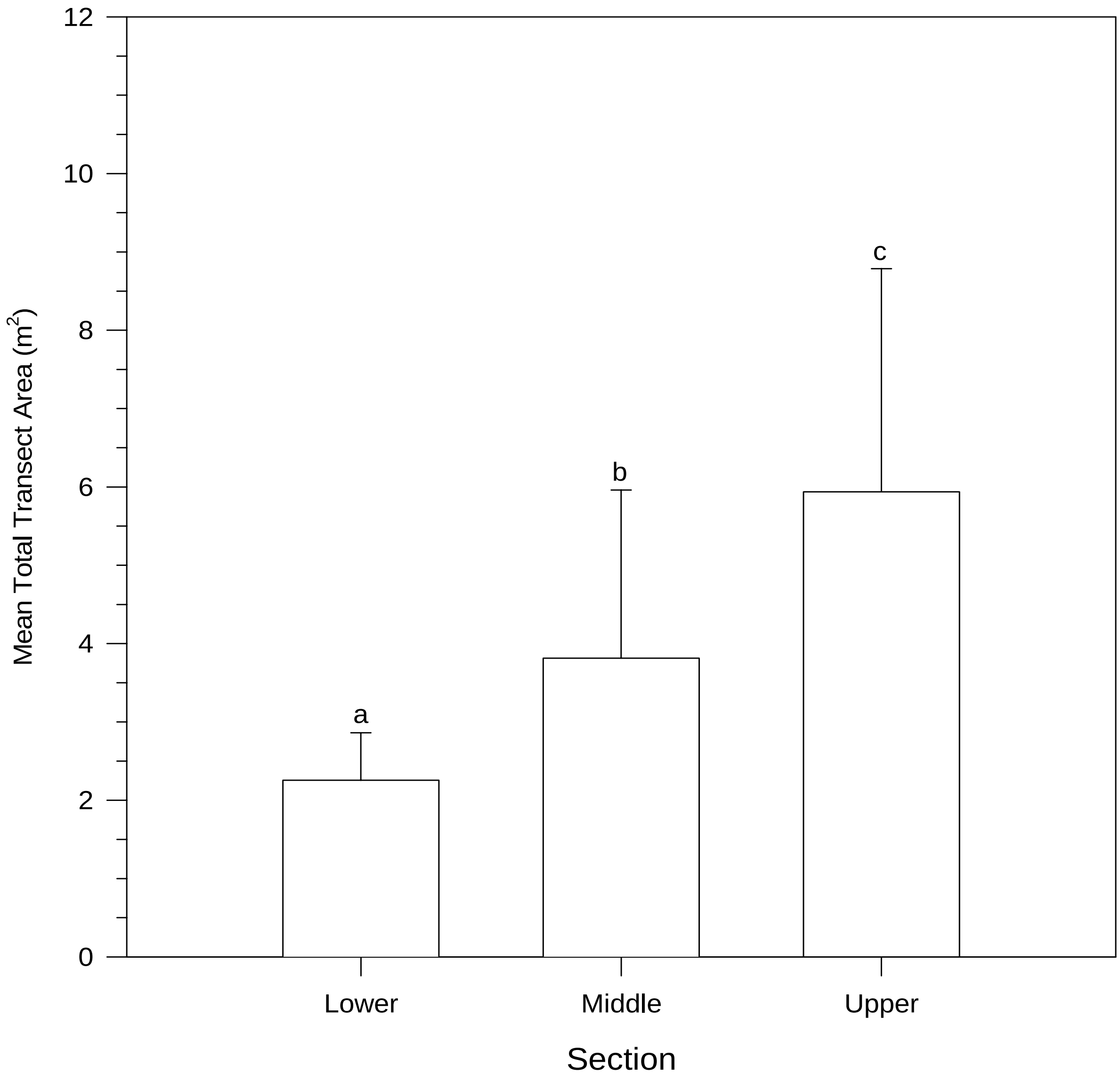

FIGURE 6. Mean depositional area per transect for the lower, middle and upper segments of Del Puerto Creek. Statistical comparisons of depositional area indicate that the lower segment has significantly more depositional area (P<0.05) than the middle and upper sections (Kruskal-Wallis One Way Analysis of Variance on Ranks with Tukey Test). Sections with different letters are significantly different.

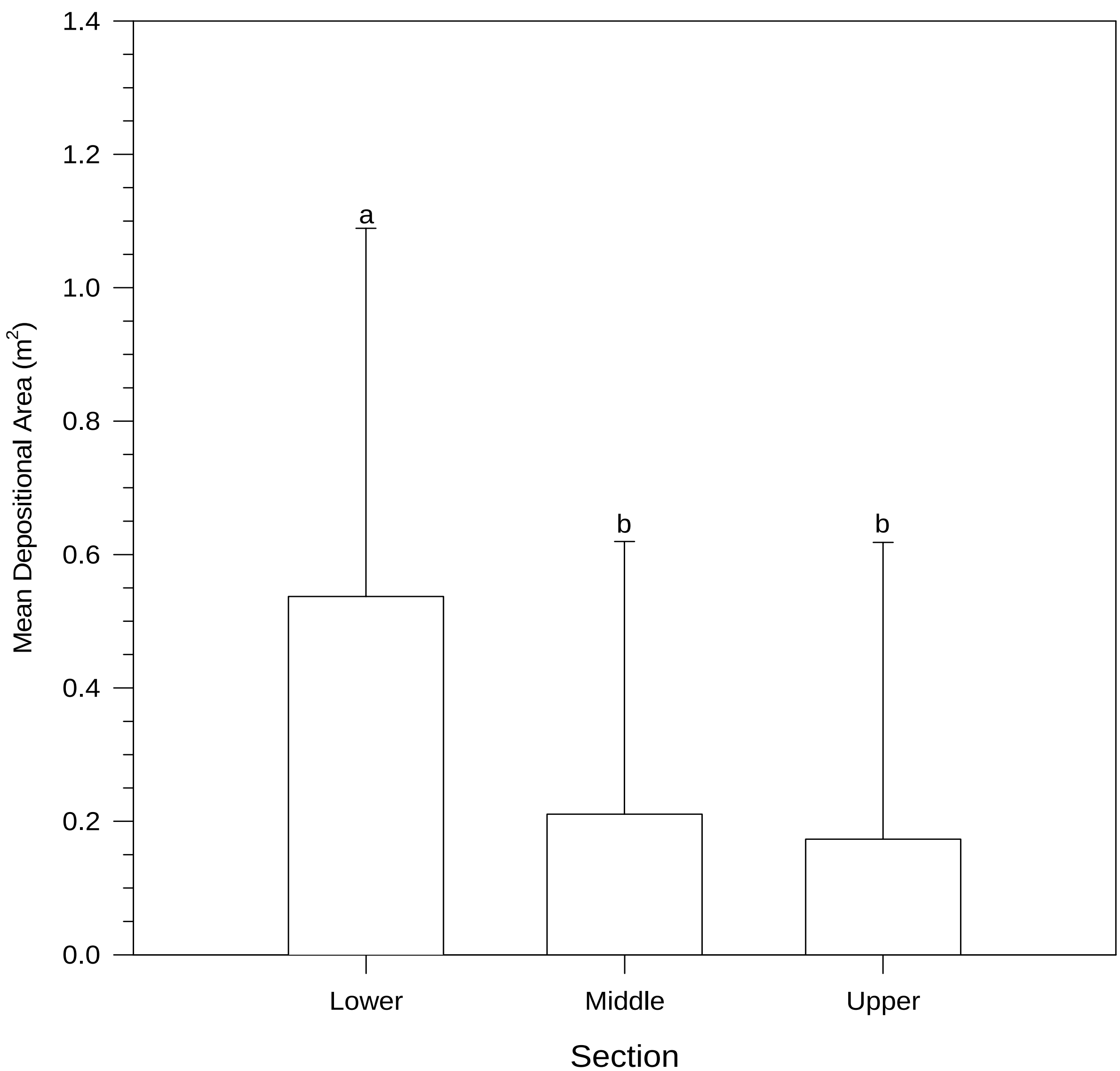

FIGURE 7. Mean % depositional area for the lower, middle and upper sections of Del Puerto Creek. Statistical comparisons of % depositional area indicate that the lower section has a significantly greater percentage of depositional area (P<0.05) than the middle and upper sections (Kruskal-Wallis One Way Analysis of Variance on Ranks with Tukey Test). Sections with different letters are significantly different.

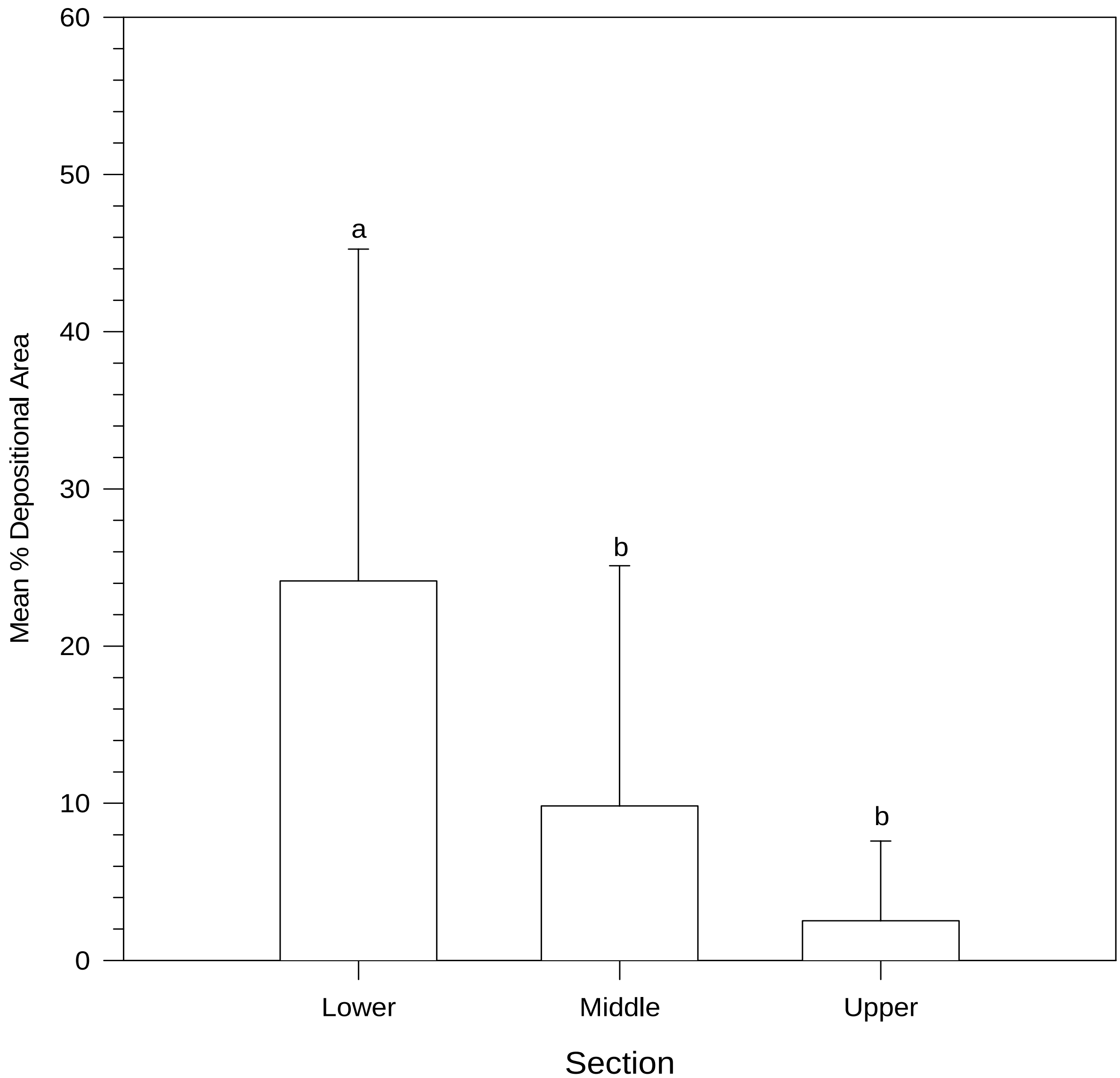

FIGURE 8a. Map showing lower section of Pleasant Grove Creek (~ 14 km) where sediment characterization was conducted at 33 sites. The dark section of each pie chart represents the % depositional area by site.

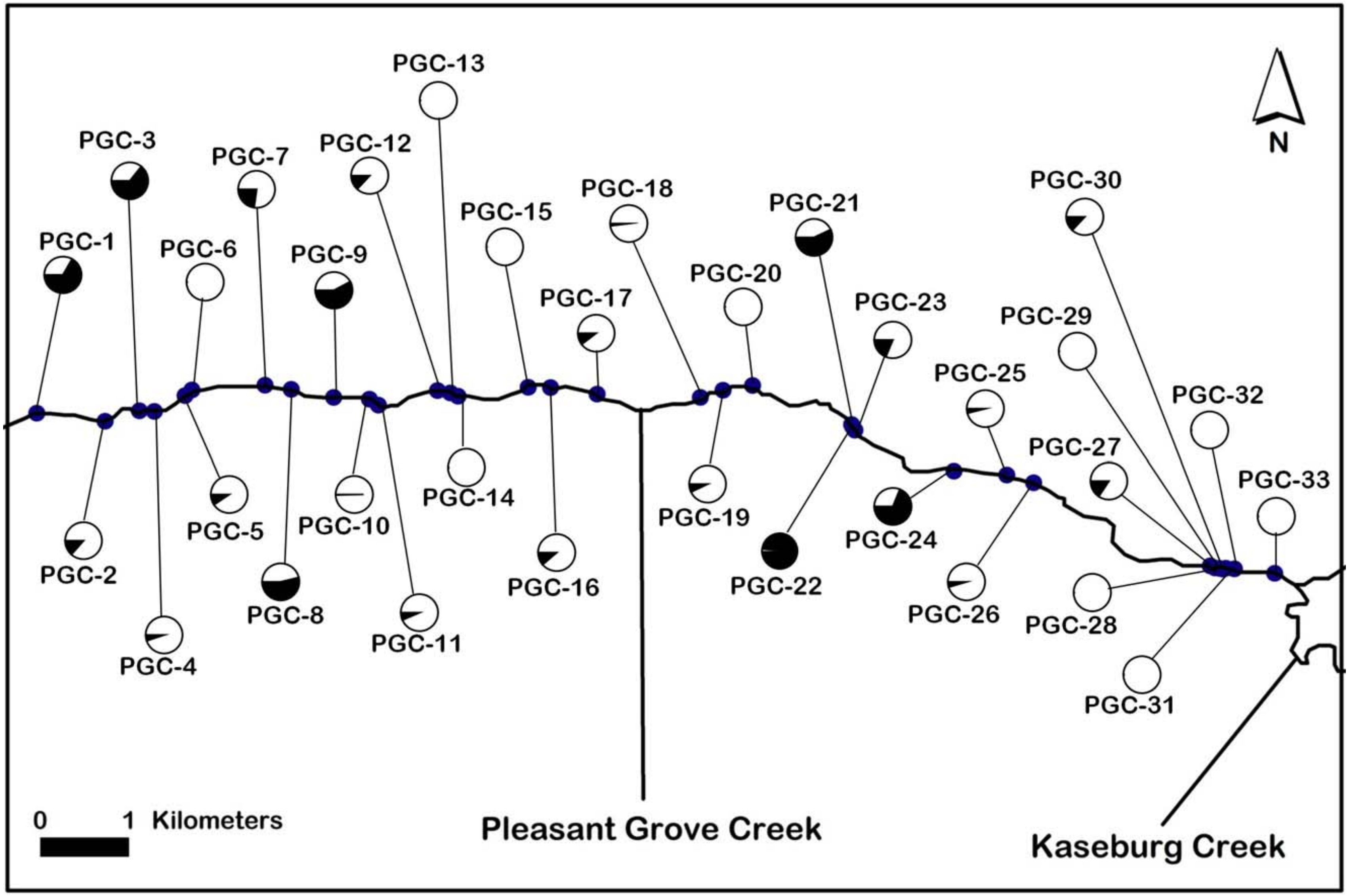

FIGURE 8b. Map showing middle section of Pleasant Grove Creek (~ 14 km) where sediment characterization was conducted at 33 sites. The dark section of each pie chart represents the % depositional area by site.

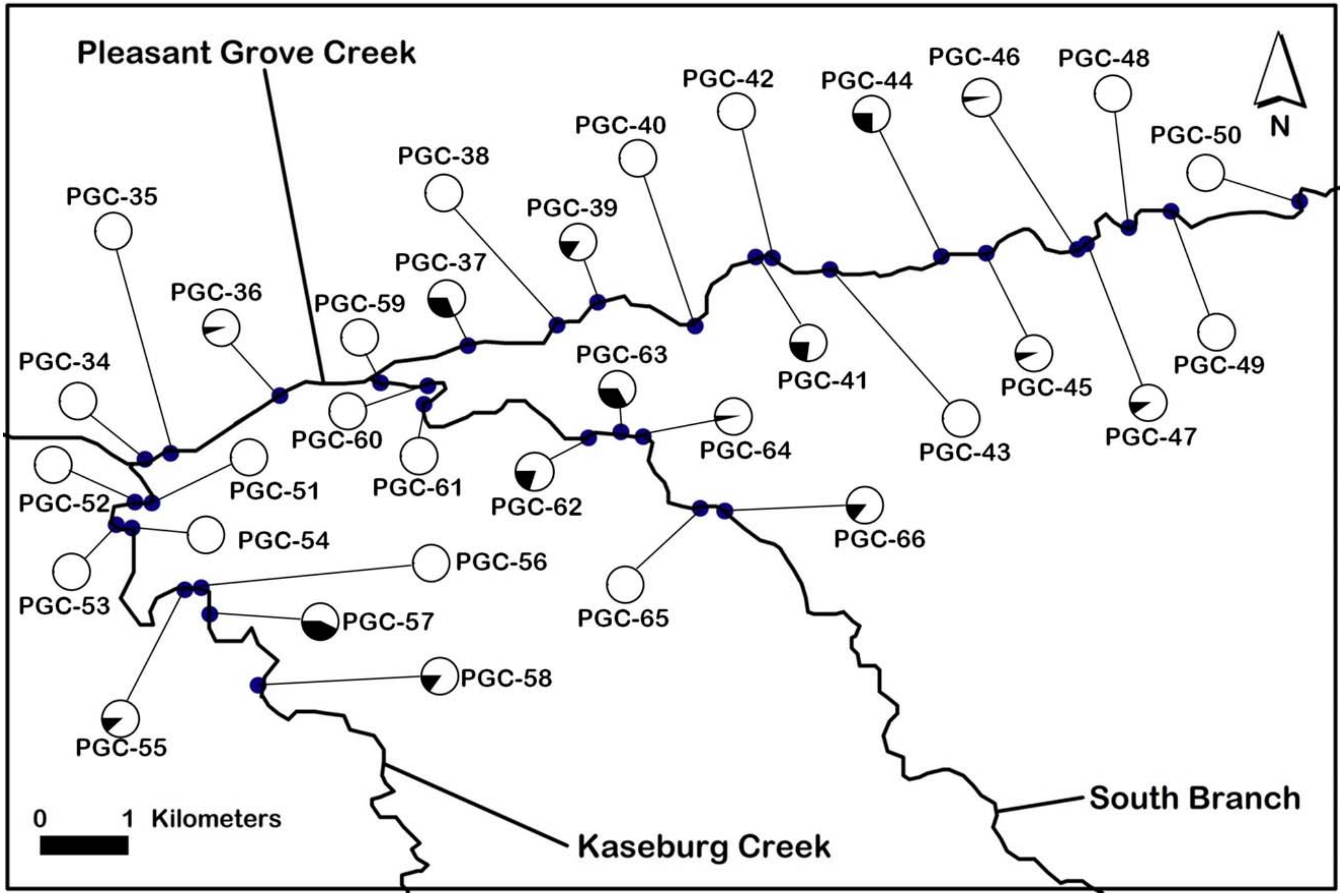

FIGURE 8c. Map showing upper section of Pleasant Grove Creek (~ 14 km) where sediment characterization was conducted at 33 sites. The dark section of each pie chart represents the % depositional area by site.

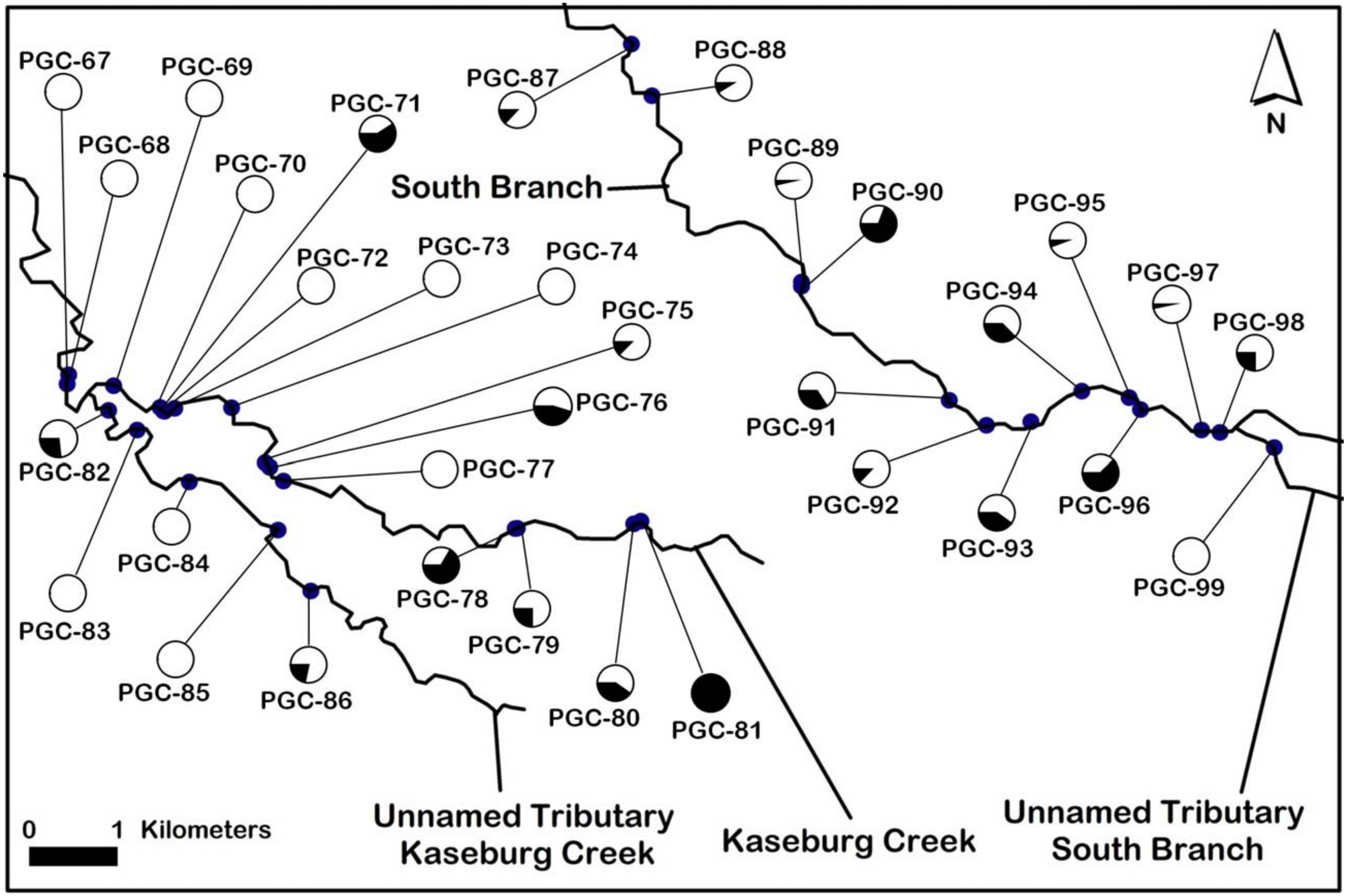

FIGURE 9. Mean total transect area for the lower, middle and upper sections of Pleasant Grove Creek. Statistical comparisons of transect area indicate that the lower section has significantly more total area (P<0.05) than the middle and upper sections (Kruskal-Wallis One Way Analysis of Variance on Ranks with Tukey Test). Sections with different letters are significantly different.

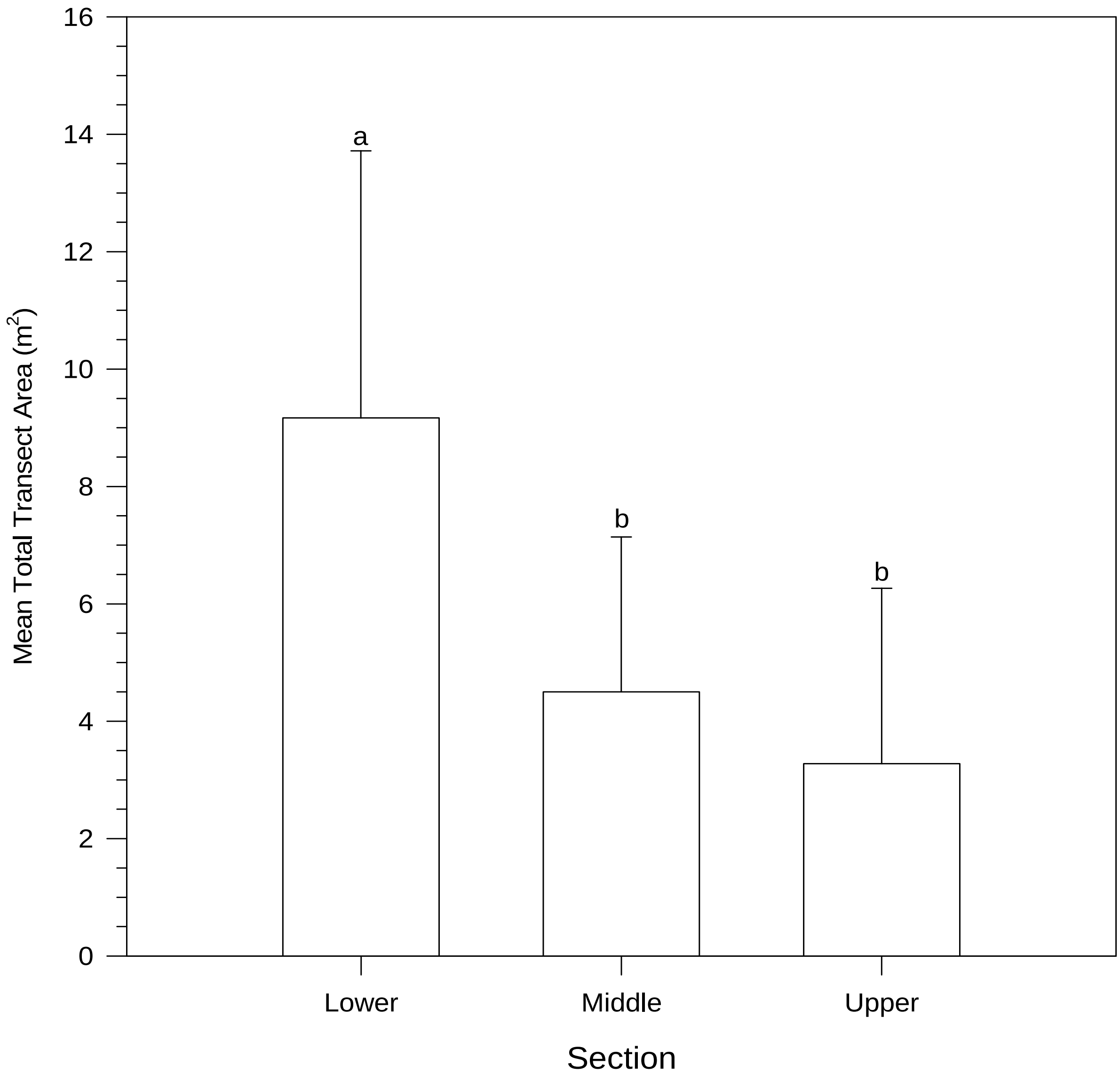

FIGURE 10. Mean depositional area for the lower, middle and upper sections of Pleasant Grove Creek. Statistical comparisons of depositional area indicate that the lower section has significantly more depositional area ($P<0.05$) than the middle section (Kruskal-Wallis One Way Analysis of Variance on Ranks with Tukey Test). Sections with different letters are significantly different.

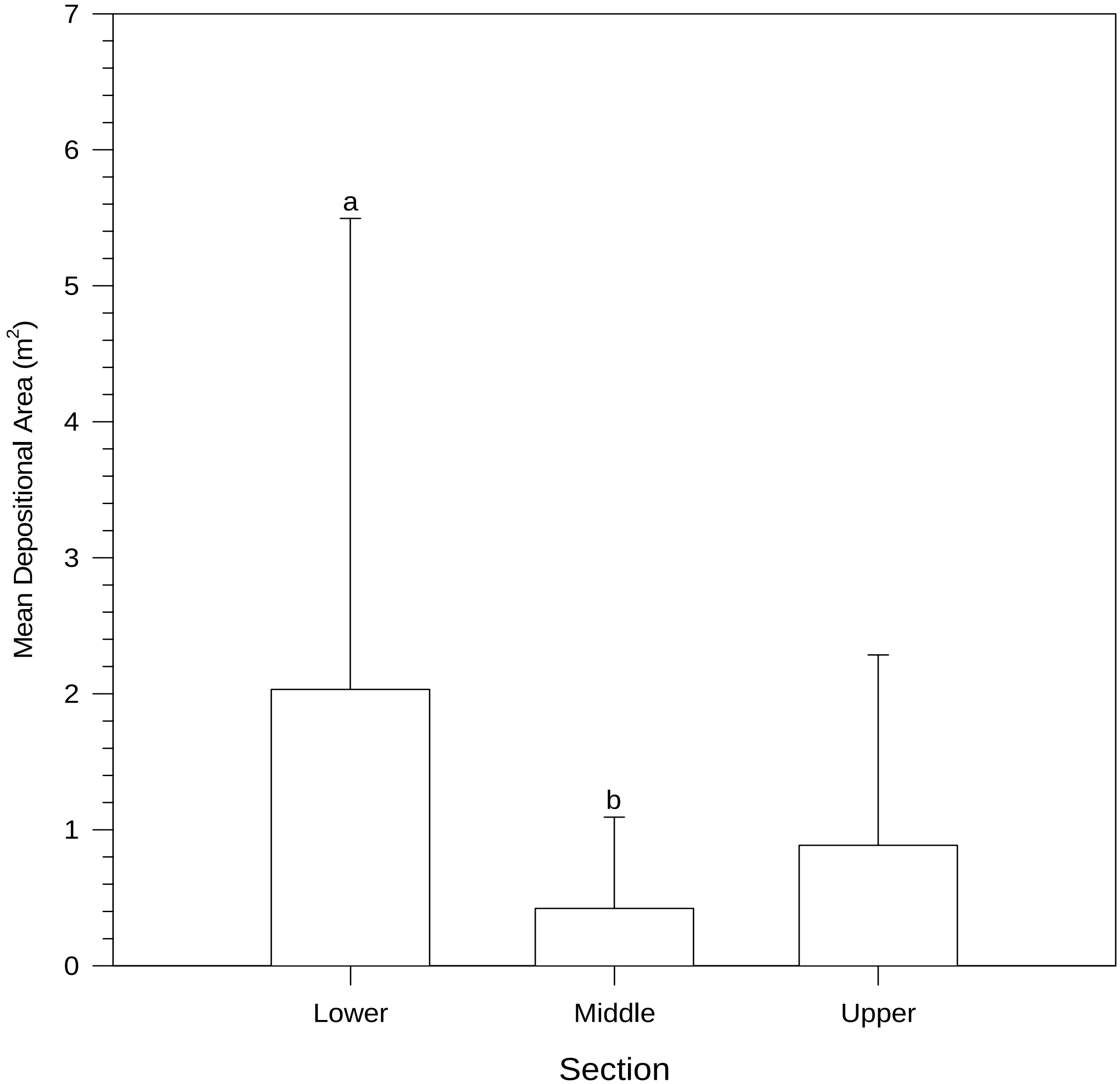

FIGURE 11. Mean % depositional area for the lower, middle and upper sections of Pleasant Grove Creek. Statistical comparisons of % depositional area indicate that no section has significantly more % depositional area than another segment (P<0.05; Kruskal-Wallis One Way Analysis of Variance on Ranks with Tukey Test).

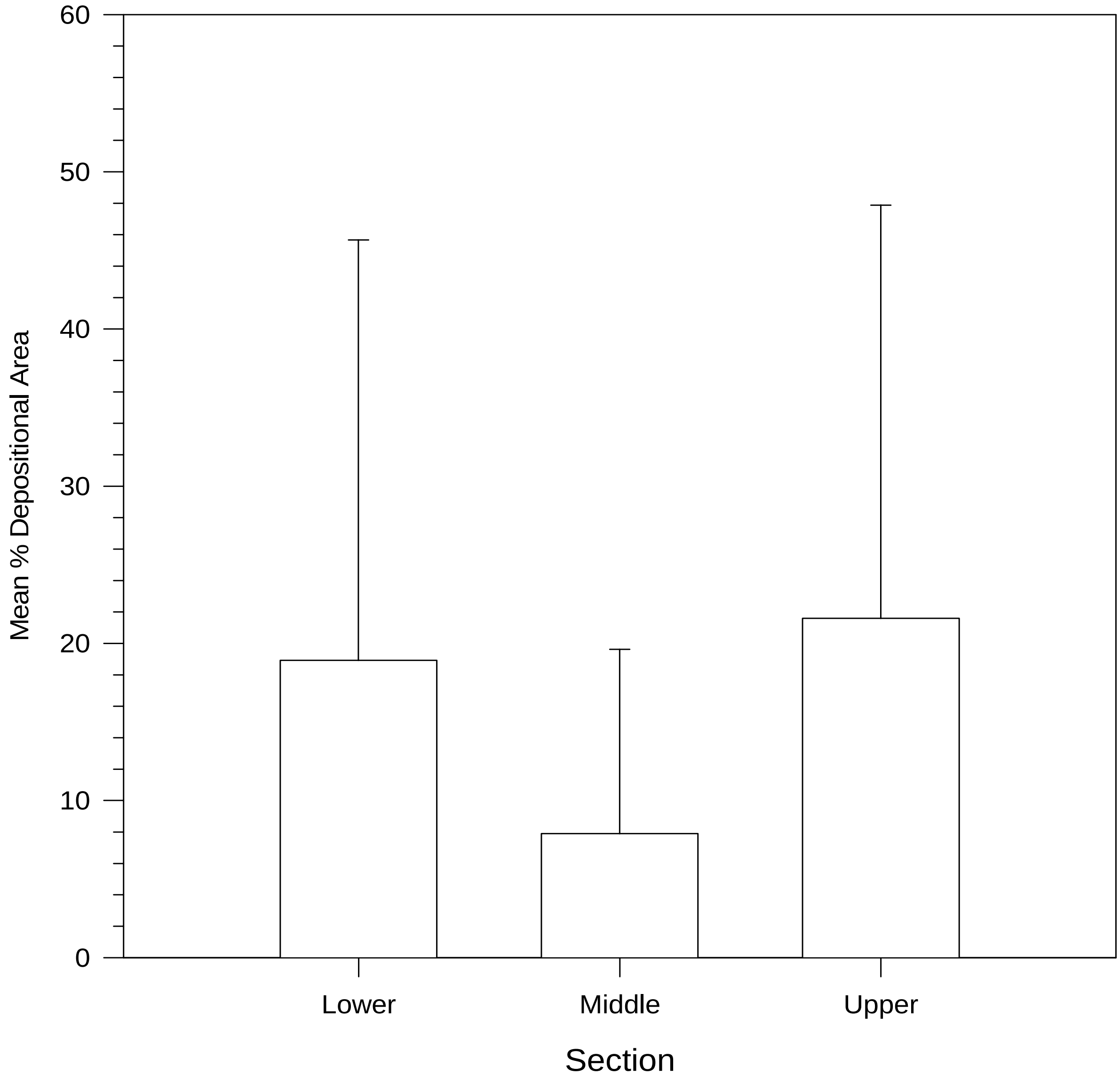

FIGURE 12. Mean total pyrethroid concentrations (ng/g) by section for Del Puerto Creek.