ENVIRONMENTAL IMPACTS OF HOMELESS ENCAMPMENTS IN THE GUADALUPE RIVER RIPARIAN ZONE

BY

COURTENAY WHITE

MASTER OF SCIENCE

In

ENVIRONMENT AND MANAGEMENT

....
Dr. Anthony Boydell, Thesis Supervisor,
School of Environment and Sustainability
Royal Roads University

....
Dr. Matt Dodd, Thesis Coordinator,
School of Environment and Sustainability
Royal Roads University

....
Dr. Chris Ling, Director,
School of Environment and Sustainability
Royal Roads University

Abstract

Among the negative societal consequences of homelessness, its potential environmental impacts are largely unconsidered. This study examines the impacts of trash and riparian zone alterations associated with a homeless population inhabiting the area surrounding the Guadalupe River in San Jose, California. Literature was reviewed to determine the environmental effects of elevated trash and sediment loads in rivers, estuaries, and the marine environment. Building upon existing trash assessment protocols, a methodology was developed to increase the accuracy of source identification. Sampling of four predetermined areas took place between November 2012 and May 2013. Results showed elevated volumes of trash and occurrences of anthropogenic alteration in the areas of the riparian zone most heavily used by the homeless population. Using existing research, inferences were made regarding the environmental effects of these disturbances. It is subsequently recommended that new mitigation measures be empirically evaluated, including long-term benefit-cost analyses regarding permanent housing of homeless populations.

Table of Contents

List of Figures

List of Tables

Acknowledgements

Thank you to Tony Boydell, my thesis supervisor and Program Head of International Programs, School of Environment & Sustainability at Royal Roads University. I appreciate you taking the time to review this work section by section, and providing valuable insight and guidance.

Thank you to Chris Ling, Director of the School of Environment and Sustainability at Royal Roads University, for early recommendations about baseline quantification.

Thank you to Linda and Lillia White, for allowing me to escape the house to hunch over a laptop at the Martin Luther King Library, or to prowl the reaches of the Guadalupe River.

Thank you to the members of San Jose's homeless population, who were without exception tolerant of my presence in the riparian areas they call home. Larry, I hope you are well.

Introduction

Homeless populations have a long history of marginalization and outright exclusion from private and public spaces (Amster, 2008). This is particularly true in high-density urban environments in the United States, where as public spaces decrease and populations simultaneously increase, the homeless are forced to exist in increasingly tenuous areas. In California, a common refuge has emerged within the riparian zones of urban streams, where outdoor encampments housing individuals and groups have taken hold. The footprint accompanying such usage of rivers and riparian areas is visible to anyone who has seen such dwellings. The environmental impacts of homeless encampments, both within riparian zones themselves and in their oceanic receiving waters, are not sustainable.

Healthy riparian stream corridors are integral to the biological diversity and water-quality of the local ecosystem, and their degradation can cause social and economic problems at local and regional levels (Atkinson, Hunter & English, 2010). Such degradation can occur when humans make use of riparian zones for habitation, through actions such as terracing and vegetation removal, both of which can negatively affect stream temperature and physical structure (Poole & Berman, 2001). In addition to such physical alterations of the riparian zone, human habitation of natural areas requires the use and eventual disposal of large volumes of anthropogenic materials. Once introduced into the natural environment, either purposefully or accidentally, these materials are a pollutant commonly referred to as “trash.”

Trash comes in multiple forms: plastics, paper products, metals and glass are only the most obvious. The presence of such discarded debris is a conspicuous form of degradation in urban environments. While highly visible on streets and other public spaces, littered trash inevitably (and less visibly) makes its way into local waterways as a result of water and wind transfer (Santa Clara Valley Urban Runoff Pollution Prevention Program, 2013). Within riparian zones themselves, the materials used by homeless individuals can also be considered trash, since they almost invariably end up within the waterway. Whether the source of trash in the riparian zone is the general public or the homeless, once introduced to the area, "…this debris inevitably makes its way from the river to the ocean, where it is now considered a pollutant of global concern" (Sheavly & Register, 2007).

Materials associated with homeless usage of riparian zones include those used for shelter building and maintenance (tarps, blankets, cardboard, wood pallets and other construction materials), as well as day-to-day living (clothing, bicycles and shopping carts, food packaging and organic waste, pharmaceuticals and personal care products, cigarette and drug paraphernalia). This anthropogenic debris, and particularly the myriad forms of debris composed of plastic, has become a pervasive pollution problem affecting our oceans and inland waterways (Sheavly & Register, 2007). While much has been written on the subject of homelessness and its economic and human health effects, the purpose of this research is to shed light on a previously unconsidered consequence of homelessness: its environmental impact.

Municipalities across the United States, in attempts to satisfy the requirements of state-administered National Pollutant Discharge Elimination System (NPDES) permits, have been forced to respond to the growing problem of urban trash pollution. As a result, many jurisdictions have developed measures to quantify trash within their water bodies and Municipal Separate Storm Sewer Systems (MS4) (United States Environmental Protection Agency, 2013). Trash assessment protocols have evolved fairly rapidly in a short period of time, and have achieved reasonable success in the quantification and classification of trash. For example, it is now standard practice amongst many municipalities in the United States to quantify trash in terms of its volumes, rather than attempting to count individual pieces (Santa Clara Valley Urban Runoff Pollution Prevention Program, 2013). However, much more difficulty has been encountered in the area of source identification. Personal experience conducting trash assessments for a large municipal stormwater monitoring program has made clear that the vast majority of trash under evaluation is attributed to either "littering by the general public" or "illegal dumping." Similarly, research into environmental behavior has focused almost exclusively on littering by the general public and the circumstances that lead to it (Santos, Friedrich, Wallner-Kersanach & Fillmann, 2005; Seco Pon & Becherucci, 2012). Other studies have examined the nature of illegal dumping in urban areas, also by the general public (Situ, 1998). While these are important areas of assessment and study, they do not describe the entirety of the source populations of trash, particularly within the riparian zones of urban waterways.

This research will suggest that another source of anthropogenic debris in the environment be considered: that of homeless populations. Because homeless individuals fall outside of traditional census boundaries, reliable population statistics are essentially nonexistent, and estimates vary widely. Nevertheless, it has been proposed that in developed countries, homeless rates are approximately one percent of the urban population (Turnbull, Masters & Muckle, 2007). A recent estimate of the homeless population in the United States by Kanis, McCannon, Craig & Mergl (2012) is 405,000 people. In California’s Santa Clara County, the most recent enumeration of the homeless population placed the number at 7000 individuals (County of Santa Clara, 2013). San Jose, the largest city in the county and the tenth largest city in the U.S., is home to a significant proportion of this population. In consideration of these numbers, and the ubiquity of homelessness in many urban environments, it is notable that no studies have examined the extent and manner in which homeless populations make use of riparian areas, much less the impacts of that usage.

This study examined the environmental impacts of homelessness in the riparian zone of San Jose’s Guadalupe River, categorizing their types and quantifying their extent. Trash related to homeless encampments and transience within the Guadalupe’s riparian zone formed the focus of the data collection and analysis. Field-collected trash data was associated with environmental impacts based on correlations drawn from existing scientific literature. Inferences were made to associate trash volumes and types in the riparian zone with possible environmental impacts beyond that area, i.e., in the estuary and the marine environment. In addition, other homeless-related impacts on the riparian zone were examined, including stream-bank alteration and destruction of native vegetation, as well as increased incidence of wildfire.

This research represents an early iteration into the quantification of a largely unconsidered source of environmental damage. The data collection methodology developed for this study may contribute to subsequent research into riparian zone environmental impact assessments, particularly those involving unconstrained human usage. More importantly, it is anticipated that the results of this work will provide quantitative data and recommendations for planners, policy-makers, and community members as they confront the vexing issue of homelessness in western society.

Research Question

What are the environmental impacts of homeless encampments in the riparian zone of the Guadalupe River? In attempting to answer this broad question, this study focused on several associated, and more specific, questions.

- What anthropogenic debris (trash) is directly attributable to the homeless population? What are the types and volumes of this debris? What are the environmental impacts of these types and volumes of trash, based on current scientific understanding?
- How much of the visible alteration of the riparian zone (trailbuilding, terracing of streambanks and/or destruction of native vegetation) is directly attributable to the homeless population? What are the associated environmental impacts of these alterations?
- Where are the most and least heavily impacted areas located within the riparian zone of the Guadalupe River? Do these locations exhibit any temporal variability in their level of usage?

Literature Review

To date, there is no academic literature on the subject of homeless encampments as sources of environmental pollution or riparian zone damage. However, there is reference material that, taken together, helped guide this study. This review discusses academic research and writing on the following subjects: littering and other environmental crime; the extent of litter in the freshwater and marine environment and its environmental impacts, including health impacts upon wildlife and humans; and the environmental significance of anthropogenic riparian zone alterations. Finally, materials are reviewed that provide a background and framework for the development of this study's methodology. Much of the literature reviewed on these topics forms the empirical foundation for inferences between the data gathered as part of this research, and potential environmental impacts.

Littering, Dumping, and Socioeconomic Conditions

First, a body of academic work examines littering and other environmental crimes. Much of this literature suggests that socioeconomic factors play a role in littering, dumping, and overall environmental awareness (Santos et al., 2005; Seco Pon & Becherucci, 2012; Situ, 1998). Because illegal dumping and littering by the general public are the two most widely attributed sources of land-based anthropogenic debris, research has focused on these behaviors in particular. In the case of illegal dumping, Situ (1998) found that individuals who dump tires, rugs, used oil, furniture or construction materials are likely to be motivated by the desire to avoid the financial cost incurred from proper landfill disposal. A case study in Tehran, Iran's capital city, found that people's level of income was one of the major contributing factors to "environmentally-friendly behavior" (Kalantari, Fami, Asadi & Mohammadi, 2007). Due to a strong correlation between income and education level, it can be inferred from much of the literature that higher levels of education may be the more salient factor in the formation of environmentally-friendly habits. For example, in a study of littering behavior by beach users in southern Brazil, Santos et al. (2005) found that "litter generation is about twice higher in the area occupied by people with lower average annual income and literacy degree." Such information regarding the influence of socioeconomic characteristics on environmentalism is a useful starting point towards an understanding as to why a particular group of people (such as a homeless population) would be more likely to contribute disproportionately to environmental pollution.

Anthropogenic Marine Debris

Litter in the marine environment is the subject of a considerable amount of recent study. Anthropogenic marine debris is defined by Sheavly & Register (2007) as "…any manufactured or processed solid waste material (typically inert) that enters the ocean environment from any source." Recent attention by both the scientific community and major media has been paid to this issue, most notably as a result of revelations regarding so-called "garbage patches" in areas of open ocean. By some estimates, 70-80% of the debris in the North Pacific Gyre's so-called "Great Pacific Garbage Patch" is post-consumer waste from the land (Dumas, 2007). As a first step towards an understanding of the scale of the problem, efforts have been recently undertaken to quantify the amount of marine debris present in the world's oceans (Zhou et al., 2011). Much of this work has been conducted along the continental shelf (Keller, Fruh, Johnson, Simon & McGourty, 2008). However, it is now well established that anthropogenic debris exists in three distinct areas of the ocean: floating (surface) marine debris, seafloor (benthic) marine debris, and beached marine debris (Zhou et al., 2011). Most research has described and quantified debris that can be readily observed, either from a vessel or (in the case of beach litter surveys) on foot. However, a study by Browne et al. (2011) went further, bringing to light the issue of largely-unseen micro-plastics, which they defined as plastic particles less than 1mm in size. These pollutants result from both the degradation of larger plastic pieces and from their use in cleaning products and synthetic fibers (DiGregorio, 2012). Results of this study showed a strong spatial relationship between the abundance of micro-plastic on shorelines and human population density (Browne et al., 2011). The connection between trash accumulation areas and large centers of human population is also explored in a paper by Santos et al. (2009). This research examined the composition, quantity and distribution of debris along a 150km stretch of undeveloped beaches in northeast Brazil. The results showed that "…areas immediately south of the major regional embayments were the preferential accumulation sites, indicating that rivers draining populous areas are the major source of debris to the study site" (Santos et al., 2009).

Environmental Impacts of Anthropogenic Debris

The impact of anthropogenic debris on freshwater and marine life is the focus of other studies. For example, large debris items such as vehicle tires and anthropogenic woody debris (pallets, poles, construction debris, etc.) are the subject of research examining impacts upon a tidal marsh (Uhrin & Schellinger, 2011). These types of debris are commonly seen in the Guadalupe River, and frequently become entrained in the estuarine mudflats of South San Francisco Bay. The authors in this study found that several species of marsh vegetation were negatively impacted by the presence of these items in the habitat as a result of shading, crushing, and blocking access to substrate (Uhrin & Schellinger, 2011). Another recent study found that among intertidal filter-feeders such as gastropods, the presence of plastic cover (particularly plastic bags) in the habitat can decrease feeding efficiency (Aloy, Vallejo Jr., & Junio-Menez, 2011). Another paper showed that high frequencies of anthropogenic debris ingestion and associated green turtle mortality are attributable to plastic pollution of the marine environment (Bugoni, Krause & Petry, 2001).

Ingestion of plastics by sea turtles and other marine organisms can have multiple detrimental health effects: internal injuries and intestinal occlusion; reduction of stomach capacity and feeding stimulus, inhibiting growth; and chemical contamination (Plot & Georges, 2010). Loggerhead sea turtles (*Caretta caretta*) are considered to be among the marine organisms most vulnerable to plastic pollution, due to a highly opportunistic foraging strategy and frequent shifts in diet and habitat use (Lazar & Gracan, 2011). Another species, the endangered leatherback sea turtle (*Dermochelys coriacea*) was the subject of an observational study conducted in French Guiana. Virginie Plot and Jean-Yves Georges (2010) recounted their experience removing 2.6kg of plastic debris from the cloaca of a nesting female. Nearly all of the material they removed from this individual was found to be plastic bags, which are commonly ingested by sea turtles who mistake their floating forms for jellyfish, one of the animal’s primary prey items (Plot & Georges, 2010). Plastics, in their myriad forms, account for the vast majority of anthropogenic marine debris, be it in the water or on the beach. A recent study in the North Pacific Gyre

"…calculated that the amount of plastic in the Great Pacific Garbage Patch alone was about 100 million tons" (DiGregorio, 2012). Land-based research supports the notion that plastics are the dominant anthropogenic material in the marine environment. For example, a 2010 survey of debris on five beaches on a small island in Brazil found that 90% of the items collected were plastic materials (Widmer & Hennemann, 2010).

A particularly conspicuous threat to marine life associated with anthropogenic debris is entanglement. An animal that becomes entangled with fishing line, plastic six-pack rings, ropes or other debris can be strangled or drowned; entanglement can also limit an animal's mobility, preventing it from finding food and leading to eventual death (Sheavly & Register, 2007). A study by Emma Moore and colleagues (2009) investigated animal entanglement records for the period 2001–2005. Records of 454 entanglements were extracted from databases maintained by seven land-based scientific programs from central California to Washington State. Entanglements were found to have occurred in 31 bird and nine marine mammal species, including sperm and humpback whales (Moore et al., 2009). Another recent study conducted at one of the world's largest northern gannet (*Morus bassanus*) colonies provided evidence that the seabird commonly uses plastic debris as nesting material, and that this results in an average of 65 entanglement deaths every year (Votier, Archibald, Morgan & Morgan, 2011).

Though less visible, micro-plastics have the potential to affect a much wider range of organisms, including fish and invertebrates (Barnes, Galgani, Thompson & Barlaz, 2009). Research has shown that captive individuals of the mussel species *Mytulis edulis*, when fed micro-plastic fragments, accumulate the fragments in their guts (Betts, 2008). The health effects of animal ingestion of micro-plastics are only beginning to be understood. As recently as 2011, Browne et al. stated that "…once ingested by animals, there is evidence that micro-plastic can be taken up and stored by tissues and cells… with probable negative consequences for health."

One likely negative consequence of micro-plastic ingestion is the uptake of toxic chemical compounds used in the manufacture of plastic products. Chemicals that may leach from plastic in the ocean include "…phthalates from polyvinyl chloride (PVC), nonylphenol compounds from polyolefins, brominated flame retardants (BFR's) from acrylonitrile butadiene-styrene (ABS) or urethane foam, and bisphenol A (BPA) from polycarbonate" (Engler, 2012). Research has shown that "…marine lugworms can accumulate phenanthrene, a persistent anthropogenic compound commonly found in the ocean, when micro-plastic particles contaminated with a small amount of the contaminant are added to the sediments where the worms dwell" (Betts, 2008). It has further been documented that micro-plastics not only leach their constituent chemical compounds, they also act as a sink for toxic chemicals such as polychlorinated biphenyls (PCB's) and dioxins, which they sorb from water or sediment and then desorb once ingested by an animal (Engler, 2012). While the research discussed here has dealt with the effects of anthropogenic debris on wildlife, scientific attention has also been devoted to the study of health effects of micro-plastic-associated chemical contamination in humans.

A potentially significant effect of micro-plastic ingestion, in both animals and humans, is endocrine disruption (Shenoy & Crowley, 2011). Endocrine disrupting compounds (EDC's) are chemicals that cause alterations in human and animal endocrine systems by inhibiting or stimulating the production and metabolism of hormones, or changing the way hormones travel through the body (Schug, Janesick, Blumberg & Heindel, 2011). The issue of EDC's and their effects on humans and wildlife has been the focus of scientific study for some time. In a review of studies related to endocrine disruption and human health, Meeker (2010) cited "…experimental data demonstrating endocrine-related effects on reproduction, development, metabolism and cancer." The most common form of endocrine disruptor activity is by chemicals that mimic or antagonize the actions of naturally occurring estrogens, otherwise known as xenoestrogens (Yang, Yaniger, Jordan, Klein & Bittner, 2011). Endocrine disruptors can affect "…all aspects of the reproductive system, including gonadal formation, production of hormones and gametes, sex determination, formation of egg shells, and production and maintenance of mating signals and behaviors" (Shenoy & Crowley, 2011). While the connection between EDC's and male reproductive health has yet to be clearly demonstrated, "…both animal and human studies suggest a role of EDC's in altering female reproductive development" (Schug et al., 2011).

Xenoestrogens and other EDC's are present in many man-made plastic products that incorporate BPA, polypropylene (PP), and plasticizers such as phthalates (Meeker, 2010). Indeed, human health concerns have recently focused scientific and media attention on BPA, which has been found to accumulate in fish due to the compound's ubiquitous presence in the world's oceans (Engler, 2012). While this may be humanity's major dietary source of this contaminant, fears about the endocrine-disrupting effects of BPA in children have spawned the emergence of plastic products (such as baby bottles) that are marketed as "BPA free." However, in a recent study by Yang et al. (2011), it was reported that "…almost all commercially available plastic products that we sampled – independent of the type of resin, product, or retail source – leached chemicals having reliably detectable estrogenic activity, including those advertised as BPA free."

Endocrine disruption may therefore cause health problems for the affected individual, since hormones regulate so many bodily functions. However, the long-term consequences of degrading anthropogenic materials could go beyond the level of the individual organism. Due to the effects of EDC's on human and animal reproductive systems, individual effects may lead to larger-scale consequences for populations and species. For example, it has been suggested that "multi-generational changes in mating signals and behaviors in a local population can be of ecological significance if reproductive success is altered and of evolutionary significance if populations evolve genetic responses to these alterations" (Shenoy & Crowley, 2011).

The environmental effects of trash accumulation in freshwater is the subject of other research. A recent study by researchers in northeastern Turkey analyzed water quality parameters, and blood parameters of fish, in a reach of river subjected to runoff from an upstream trash dumping area. Their results showed that ammonia and orthophosphate levels were significantly higher than those found in a control reach; moreover, the concentrations of stress-indicator blood parameters such as cortisol, alanine, aspartate, lactate and magnesium in two species of cyprinids were significantly higher, suggesting that fish using the habitat below the trash dumping area were under stress (Akin, Polat, Yildirim, & Dal, 2011). It has been generally established that certain types of anthropogenic debris can negatively affect water quality, including discarded medical waste and human or pet feces; moreover, industrial or household waste items can introduce toxic substances, such as batteries containing acid or fluorescent light bulbs containing mercury (Santa Clara Valley Urban Runoff Protection Program, 2006).

Riparian Zone Alterations

Human usage of riparian zones can have adverse effects upon both the landscape and the river itself (Jowett, Richardson & Boubee, 2009). One of the more dramatic outcomes of people living in heavily vegetated and wind-exposed areas is the occurrence of wildfire. This is sometimes the unintended consequence of firebuilding for heating and cooking purposes; additionally, fires can be accidentally started as a result of careless use or disposal of cigarettes or illicit drug paraphernalia. Fires in riparian zones create canopy gaps and dry conditions, allowing subsequent buildup of dead wood and establishment of fire adapted species, which increases fuel loads and the probability of another fire; furthermore, the loss of native vegetation in a riparian zone can increase sediment loads to the stream via stimulation of erosion (Pettit & Naiman, 2007).

Sedimentation of freshwaters can result from other human activities. Healthy riparian zones entrap and retain small particles, reducing the sediment input to streams (Studinsky, Hartman, Niles & Keyser, 2012). Riparian areas that are subject to activities such as trail or road building, terracing, and vegetation removal can experience increased erosion and delivery of sediment to streams, particularly fine particles (Kaufmann, Larsen & Faustini, 2009). Increased inputs of sediment to streams can have numerous environmental effects, and can be particularly damaging to certain freshwater organisms. For example, shifts in aquatic invertebrate communities and decreased reproductive success of fish have both been observed as a result of sedimentation (Studinsky, et al., 2012). Compelling research on the subject of impaired fish reproduction as a result of sedimentation has been conducted in Finland. After applying varying sediment treatments to a section of gravelly stream, scientists documented that “high sedimentation caused detrimental effects on fitness-related traits of the emerging fry. For example, fish exposed to high sedimentation at the embryonic stage had, on average, a larger yolk sac at emergence than did fry receiving little or no sedimentation, independent of predator presence” (Louhi, Ovaska, Mäki-Petäys, Erkinaro, & Muotka, 2011).

The removal of riparian zone vegetation, while contributing directly to stream sedimentation, may have additional effects upon the water body. In particular, “…removal or alteration of riparian vegetation can have important implications for stream temperature” (Poole & Berman, 2001). Research in central British Columbia in the late 1990’s documented “…changes in stream temperature following timber removal” (Shrimpton, Bourgeois, Quigley & Blouw, 1999). More recently, a study conducted in southern England that compared water temperatures at shaded and open sites along the same stream found that “…the response of open sites to the marked diel fluctuation of air temperature (driven by insolation) leads to significantly higher temperature maxima in summer months” (Broadmeadow, Jones, Langford, Shaw & Nisbet, 2011). In addition to the temperature-regulating effect of riparian vegetation, plants and trees that overhang the water body provide other benefits to freshwater organisms, including predator avoidance and inputs of woody debris. In a study of predator-prey interactions between freshwater fish, it was found that bluegill sunfish (*Lepomis macrochirus*) “…initially chose the safer, higher-density cover plot significantly more often after being exposed to a predator” (Gotceitas, 1990). Finally, a study conducted in New Zealand elucidated the importance of large riparian vegetation in generating “…instream woody debris that creates habitat diversity, that includes pools and flow concentrations that provide feeding and resting locations for pool dwelling species” (Jowett et al., 2009).

Methodological Approaches

Information regarding trash quantification methods is mainly limited to studies conducted on beaches and coastal areas. Scientific methods of quantification of beach litter usually involve line-transect sampling, whereby individual items of trash along a designated transect (of selected width and length) are visually enumerated and classified. For example, Oigman-Pszczol & Creed (2007) used "…4m-wide belt transects above the high-tide mark and parallel to the coastline." The length of the transects in this study was established by the lengths of the beaches sampled, and litter abundance was expressed in terms of mean density of litter per area (number of items per 100m^2) for each beach (Oigman-Pszczol & Creed, 2007). This type of sampling not only generates accurate results, it usually includes the collection and proper disposal of the sampled litter. However, while such methods are useful in the context of a relatively flat, open area such as a beach, they are extremely difficult to apply to a riparian area characterized by varying topography, sinuosity, and levels of human habitation.

Several articles on the subject of riparian zone trash accumulation include basic methodological models. For example, Williams (2007) described the methods of his study in which trash in the riparian zone of the river Tawd in England was surveyed and quantified. Researchers divided the short river into five sections and enumerated trash items on both sides and "in-river." They developed five separate categories of trash, based upon likely sources: "pedestrian," "household," "industrial/office," "fast food," and "sewage." Research on another river in England by Balas, Williams, Simmons & Ergin (2001) provided further guidance into the predominant types of trash that can be categorized for sampling purposes. In this case, the authors generalized trash items into categories based upon their materials, including "plastic," "metal," "textiles," and "glass." Such generalizations are clearly useful when attempting to visually identify objects from the large variety of disposable anthropogenic materials. Indeed, the researchers in this study took the approach of enumerating individual pieces over the course of three 5m transects at 50 sites, on two occasions: their result was a total count of 8687 trash items (Balas et al., 2001).

Governments and non-governmental agencies (NGO's) have developed numerous templates for litter surveys, particularly in urban areas and on coastal beaches. For example, Keep America Beautiful (KAB), a U.S. nonprofit organization, uses a Litter Index as part of an annual "Great American Cleanup" event involving volunteers around the country (Keep America Beautiful, 2013). Many other organizations have developed similar litter quantification indexes. Due to their reliance on volunteer samplers, these indexes tend to be quite simple, foregoing the use of line transects and spatial distinction. Where beach cleanups involve participant documentation at all, it is in the enumeration and classification of individual trash items collected.

In an effort towards development of a more standardized and rigorous trash assessment methodology, the San Francisco Bay chapter of the California Regional Water Quality Control Board (RWQCB) developed, as part of its Surface Water Ambient Monitoring Program (SWAMP), a Rapid Trash Assessment (RTA) worksheet (California Environmental Protection Agency, 2013). This methodology was noteworthy for its establishment of a series of universal categories of trash types, and the development of a system of "scoring" the condition of assessment sites. However, the RTA continues to rely on enumeration of individual trash items, severely limiting its practical application in difficult-to-access riparian areas, including those subject to human habitation. More recently, the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP) made improvements to the RTA, including the conceptualization of a method of assessing amounts of trash using volume estimates rather than individual item counts (Santa Clara Valley Urban Runoff Pollution Prevention Program, 2013). The idea of estimating trash volumes led to the development, by the SCVURPPP and other agencies, of the Urban Rapid Trash Assessment (URTA) (California Environmental Protection Agency, 2013). It is this methodology that was incorporated into the data sheet created specifically for the sampling conducted as part of this study.

Finally, while methods have been developed for collection of data on trash in the environment, literature on data analysis methodologies for trash quantification is very limited. Most studies are generally confined to calculation of average and total trash volumes, and percentages by trash category. A study by Seco Pon & Becherucci (2012), however, used a two-way Analysis of Variance (ANOVA) to test hypotheses concerning the effects of sampling site and season on the mean abundance of litter. Another study conducted in Mexico took a different approach: in attempting to "…evaluate the spatial difference between the abundance and composition of the beach litter, the results were analyzed statistically using a Chart of Contingency, where "rows" included litter groups; "columns" were the abundance of litter present in the levels or beach transects, and "lines" included the areas" (Silva-Iniguez & Fischer, 2003). While the ambition of these types of approaches to trash quantification and classification is laudable, it is also somewhat impractical within a riparian area. As a result, sampling methods were developed exclusively for the sake of this research into homeless encampments within riparian zones.

Research Methodology

General Site Description

The Guadalupe River flows 23km from its origin in Almaden Lake, northward through downtown San Jose, to South San Francisco Bay (Fig.1). Headwaters in the Santa Cruz Mountains are the primary source feeding the river, and Los Gatos Creek is its major tributary (United States Department of the Interior, 2013). The Guadalupe drains an area of 257km², and with the exception of some protected estuarine habitat near San Francisco Bay and a stretch of the river north of downtown San Jose, the land surrounding the Guadalupe is developed, and includes a mixture of residential, commercial, and industrial land uses (United States Department of the Interior, 2013). San Jose International Airport, located approximately 3km north of the downtown core, directly parallels the river for a length of 4.4km.

The Guadalupe is a low-volume stream that exhibits seasonal flooding in response to heavy winter rains. Data from the United States Geological Survey (USGS) from the years 2003-2012 indicate that the average discharge recorded at one of two monitoring sites on the Guadalupe River was 22 Cubic Meters Per Second (CMS). The same data show that the rate of discharge may vary significantly from year-to-year, with an average of 43.3 CMS in 2006 and an average of 12.2 CMS in 2007 (United States Department of the Interior, 2013). In addition, discharge can vary dramatically throughout a given year, with winter months typically exhibiting the highest flows. Monthly data from 2011, for example, show a low of 10.1 CMS in September, and a high of 159.9 CMS in March (United States Department of the Interior, 2013).

Historic instances of elevated discharge in the Guadalupe resulted in significant flood events, and the economic impacts of such flooding eventually led to human-engineered changes in portions of the riparian zone. Flooding in San Jose has largely been attenuated with the construction of modern flood-protection structures along stretches of the Guadalupe, primarily in the heavily developed downtown core. Between this area and San Jose International Airport to the north, less development has taken place, flood control measures are largely absent, and the river is relatively unconstrained. As a result, seasonal flooding still occurs along this stretch of riparian zone, which is home to a population of homeless individuals. Such events cause the temporary displacement of homeless people from their encampments, and often result in the downstream transfer of large volumes of anthropogenic material associated with those shelters.

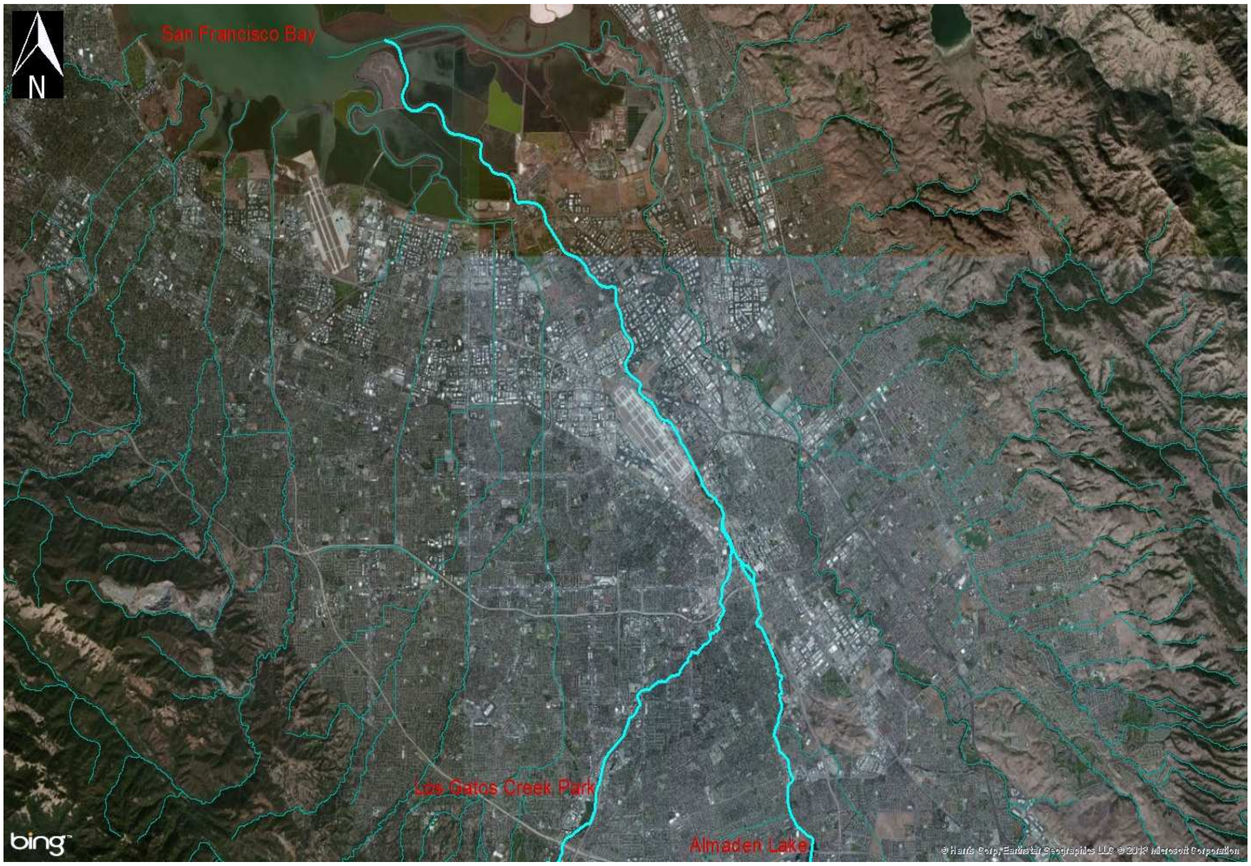


Figure 1: Los Gatos Creek and Guadalupe River. Map used under permission of Microsoft® Bing™ Maps Platform API's Terms Of Use Sections 1, 2, 5 & 8 (Educational or Non-Profit Use Only). Image copyright Harris corp. Earthstar Geographics LLC @ 2013 Microsoft Corporation.

Study Areas

The primary study area was chosen to be a 10km length of the Guadalupe River downstream of its confluence with Los Gatos Creek. For the establishment of baseline data, a 2km portion of Los Gatos Creek, 10.25km upstream of the confluence, was used as a secondary study area. Field reconnaissance of the two study areas was conducted sporadically over a 10-month period in 2011-2012. Four sample sites were ultimately chosen as a result of this field work. The riparian zone surrounding the primary and secondary study areas is entirely publically accessible, and two of the four chosen sample sites are accessible by paved walkway. Three of the four sites are located downstream of the confluence of the Guadalupe River and Los Gatos Creek.

The point where Los Gatos Creek enters the Guadalupe is noteworthy, for several reasons. First, the confluence is located in close proximity to the city's downtown core, where a large proportion of San Jose's homeless population is centered. This concentration is due to the presence of numerous resources for homeless individuals. Such resources include social services such as shelters, soup kitchens, and medical clinics. The urban environment also provides access to several forms of economic activity associated with homelessness, including panhandling; the collection and sale of recyclable materials such as bottles, cans, and scrap metal; and illicit trade in drugs, prostitution, and stolen goods such as bicycles and bicycle parts.

Second, the confluence of Los Gatos Creek and the Guadalupe River marks the beginning of the Guadalupe River Trail, a publically accessible system of paved walkways paralleling the river, at varying degrees of proximity, all the way to the estuary. Upstream of this point, much of the Guadalupe's riparian zone is lined with the backyards of private residences, commercial and industrial buildings, parking lots, and railway lines. Where the land is undeveloped, fencing exists or the stream is steeply incised, with no terracing of any kind. As a result, accessibility and usage of these areas for human habitation is impractical, and this was reflected in the lack of homeless encampments observed during early field reconnaissance.

Third, the input of flow and sediment from Los Gatos Creek results in a laterally expanded riparian area, including several stretches of wide, flat benches that remain dry outside of major flood events. This lateral expansion of the riparian zone reflects the formerly unconstrained, meandering nature of the Guadalupe, which at one time was the source for a large local fruit-growing industry (Dickinson, pers. comm., 2012). While the orchards are gone, and the river largely channelized for flood control, sections of the riparian zone downstream of the confluence with Los Gatos Creek provide flat ground, shade, and privacy for the local homeless population.

Sample Site Descriptions

For sampling purposes, emphasis was placed on three separate reaches of the Guadalupe between downtown San Jose and the estuary (Fig. 2). A reach of Los Gatos Creek, within the boundaries of Los Gatos Creek Park, was also selected for sampling. All four sample sites were chosen based upon extensive field reconnaissance of the primary and secondary sample areas conducted between August 2011 and October 2012. Over that period of time, distinct trends in spatial use of the riparian zones by the local homeless population were observed and documented. Observations were conducted by bicycle and on foot. As a result of these field observations, three sample locations within the primary study area were selected based upon their representativeness of different degrees of consistent usage by the homeless population: heavy usage (Fig. 3), moderate usage (Fig. 4), and minimal usage (Fig. 5).

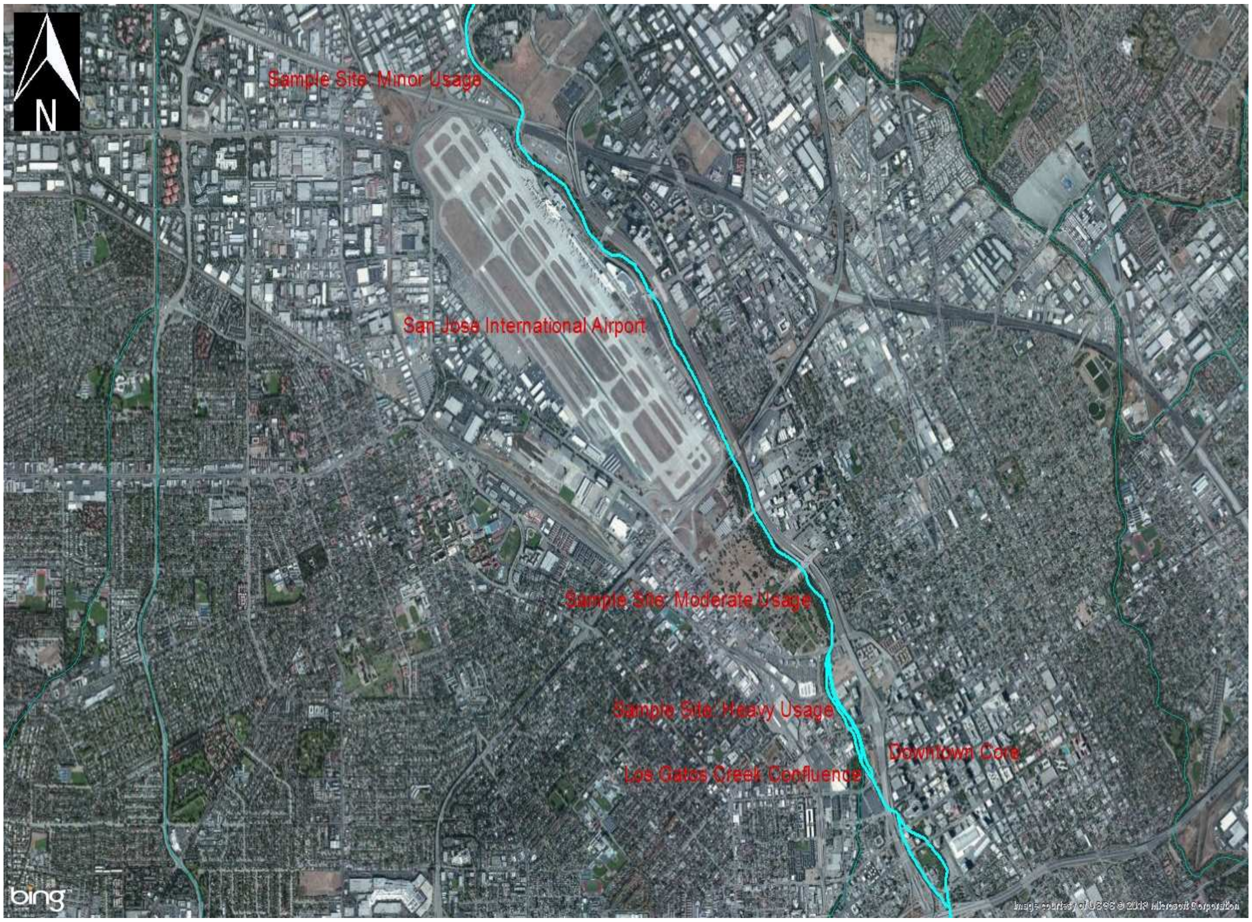


Figure 2: Primary study area (Guadalupe River). Map used under permission of Microsoft® Bing™

Maps Platform API's Terms Of Use Sections 1, 2, 5 & 8 (Educational or Non-Profit Use Only). Image copyright Harris corp. Earthstar Geographics LLC @ 2013 Microsoft Corporation.

Figure 3: Delineated riparian zone of Sample Site "Heavy," from St. John Street to 250m north. Map used under permission of Microsoft® Bing™ Maps Platform API's Terms Of Use Sections 1, 2, 5 & 8 (Educational or Non-Profit Use Only). Image copyright Harris corp. Earthstar Geographics LLC @ 2013 Microsoft Corporation.

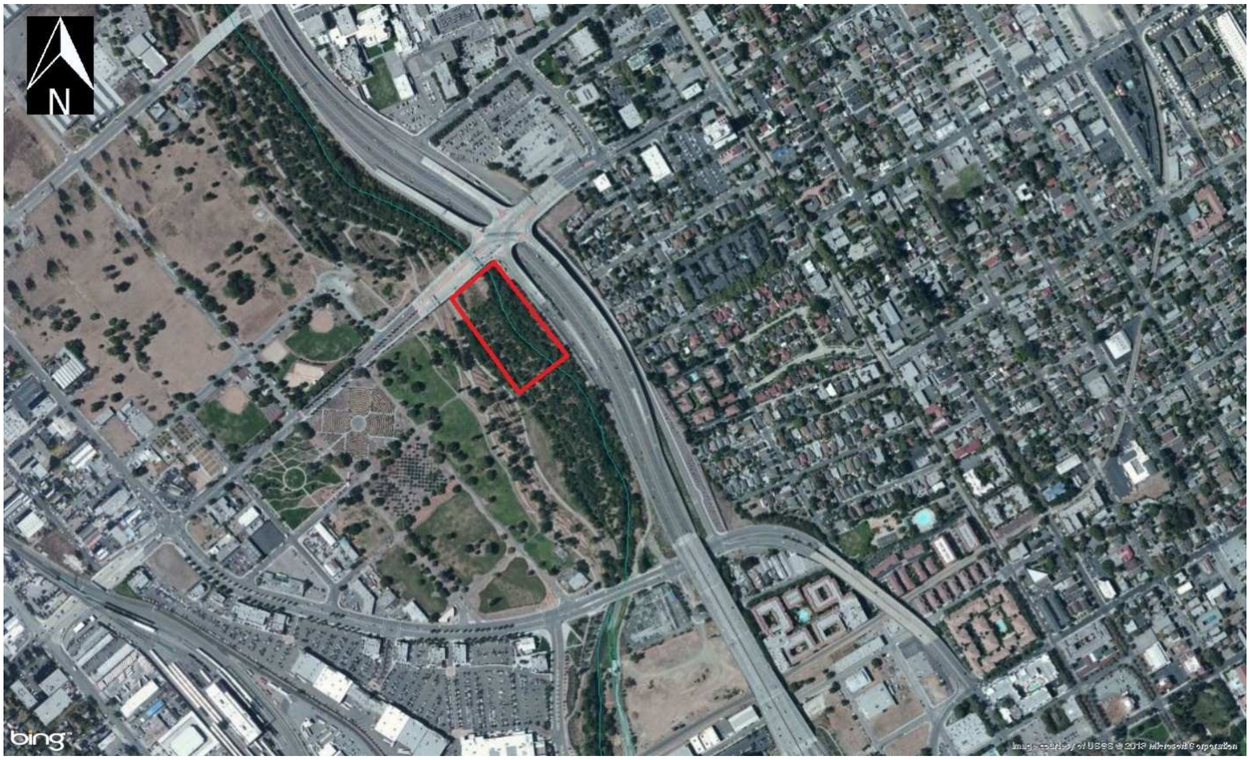


Figure 4: Delineated riparian zone of Sample Site "Moderate," from Taylor Street to 250m south. Map used under permission of Microsoft® Bing™ Maps Platform API's Terms Of Use Sections 1, 2, 5 & 8 (Educational or Non-Profit Use Only). Image copyright Harris corp. Earthstar Geographics LLC @ 2013 Microsoft Corporation.

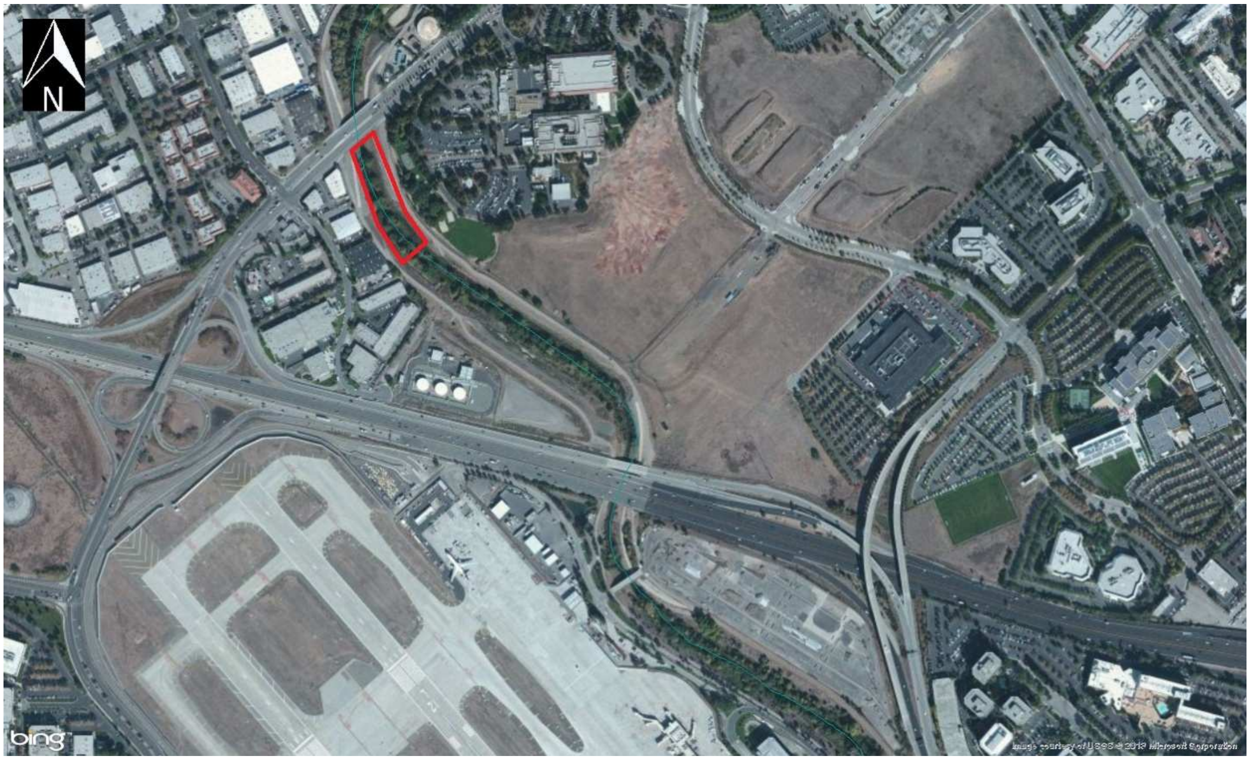


Figure 5: Delineated riparian zone of Sample Site “Minimal,” from Trimble Road to 250m south. Map used under permission of Microsoft® Bing™ Maps Platform API’s Terms Of Use Sections 1, 2, 5 & 8 (Educational or Non-Profit Use Only). Image copyright Harris corp. Earthstar Geographics LLC @ 2013 Microsoft Corporation.

The sample site labeled “heavy” was chosen because it consistently appeared to be the most heavily trafficked and debris-strewn of any stretch of river within the primary study area, and because of the presence of numerous small, scattered encampments. This is the closest site to San Jose’s downtown, and it includes two stretches of riparian zone covered by overpasses, thereby providing increased shelter and privacy. This site remained heavily used throughout the observation and sampling period.

The sample site labeled “minimal” was chosen because it was sparsely strewn with debris and because relatively little homeless-related activity was observed. This is the farthest site from San Jose’s downtown that remains within the primary study area, and its riparian zone is directly adjacent to channelization materials leading to a paved walkway. While single-occupancy encampments were observed in this area over the course of field reconnaissance and sampling, they were few and short-lived.

Finally, the sample site labeled “moderate” was chosen because its condition appeared, based on repeated field visits, to inhabit a middling condition compared to the two other sites. Several large and communal encampments exist within the boundaries of this site, in close proximity to the river. The site is in an area of relatively dense vegetation and is separated from the paved pathways along the west side of the river by a wide and flat grassy area, affording residents a high degree of privacy. Usage of this site was observed to be consistent throughout the observation and sampling period, with the exception of a displacement of the homeless population caused by a brief winter flood event in late 2012.

Because the river between downtown San Jose and the estuary is accessible by paved and unpaved walkways on one or both sides throughout its course, an assumption was made that there is always some degree of usage by homeless individuals, if only as a travel corridor. Indeed, the northern end of the Guadalupe River Trail affords access to the Bay Trail, which parallels San Francisco Bay all the way to the southern end of San Francisco County. Anecdotal evidence suggests that this system of trails serves as a conduit for homeless individuals traveling between San Jose and peninsula communities to the north (Ledesma, personal communication, 10 April 2012). As a result, no part of the Guadalupe River downstream of the confluence with Los Gatos Creek can be considered entirely unused by the population in question.

The Los Gatos Creek site was chosen because field reconnaissance indicated that no homeless population exists in that study area. Because of the potential significance of non-homeless environmental impacts to the riparian zone, it was desirable to establish a sampling location that, while unused by homeless people, nevertheless exhibited the physical characteristics of the other locations. In the interests of including a sample site that satisfied these criteria, it was necessary to look outside of the Guadalupe’s drainage area. Portions of Los Gatos Creek, approximately 10km upstream of its confluence with the Guadalupe, may be reliably considered unused by homeless individuals. This is due to several factors, including isolation of these stretches of the creek from heavily urbanized areas (and associated resources), and consistent usage by the general public for recreational purposes. As a result, a reach of this study area was used for the establishment of a baseline quantification of riparian zone characteristics (Fig. 6). This baseline data was collected at the same sampling frequency and in conjunction with the sampling of the Guadalupe River sections, in order to provide an estimate of, among other things, the amount of trash attributable to sources other than the homeless population.

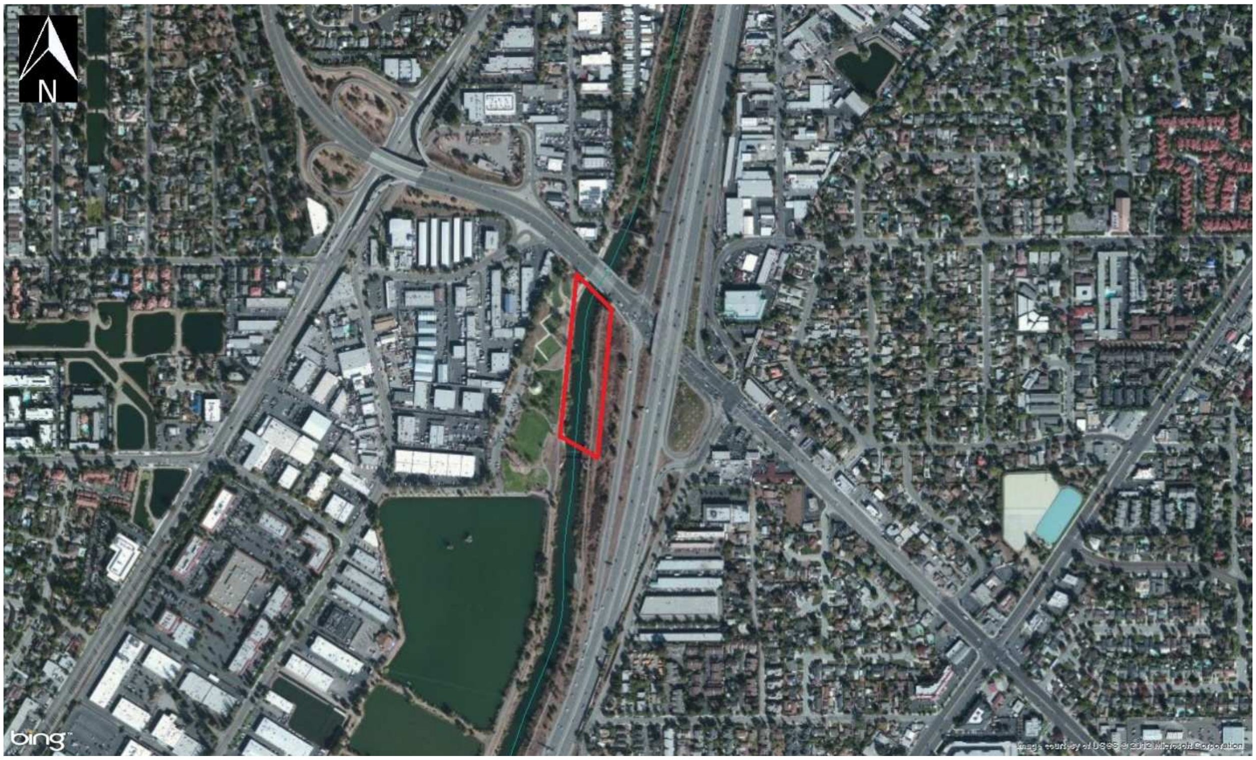


Figure 6: Delineated 250m riparian zone of Sample Site "Baseline," in Los Gatos Creek Park. Map used under permission of Microsoft® Bing™ Maps Platform API's Terms Of Use Sections 1, 2, 5 & 8 (Educational or Non-Profit Use Only). Image copyright Harris corp. Earthstar Geographics LLC @ 2013 Microsoft Corporation.

The four sampling locations were delineated in such a way as to provide spatial descriptions in units of volume. The selected locations were therefore measured for their width, their length, and their depth. These dimensions were chosen based upon cartographic research, field reconnaissance, and consistency and feasibility of sampling.

The width of the riparian zone of each of the reaches was determined with the use of topographical maps and aerial photographs, which were layered and output using ArcGIS computer software. These maps were ground-truthed and final riparian zone width delineations were established for each site, based on field observations of the boundary between riparian and non-riparian area on both sides of the stream. Riparian areas include terraces dominated by wetland plant species, the active floodplain, streambanks, and areas in the channel with emergent vegetation (Thompson, Ehrhart, Hansen, Parker & Haglan, 1998). In several cases, the lateral boundaries of the riparian areas were easily established by the presence of channelization materials such as rip-rap and gabions. The four width measurements were used to produce an average width, and this was established as the default width for all four areas. The average of the four sample area widths was calculated to be 40m.

The depth of each of the riparian zones was established during field reconnaissance of the sites. This was accomplished using a GPS unit equipped with an elevation measurement tool, and visual estimation of the wrack line or high-water mark. Once again, the four depth measurements were used to produce an average depth, and this was established as the default depth of the riparian zone for all four areas. The average sample area depth was calculated to be 3m.

The length of the riparian areas was chosen based on cartographic research and field reconnaissance. While Thompson et al. (1998) recommend that reach length be at least one full meander cycle, such delineation is impractical when evaluating a largely channelized stream such as the Guadalupe. Instead, the sample site lengths were chosen to be 250m. This was based on the feasibility of complete and accurate sampling of the sites, as well as the understanding that where a full meander cycle cannot be included, the reach should be a minimum of 200m (Thompson et al., 1998).

Sampling Strategy

The four chosen sites were sampled on five separate occasions. Data was collected for the following parameters:

- total trash volume and volume by category;
- number of distinct streamcourse alterations;
- number of distinct streambank alterations;
- presence/absence of destruction of vegetation;
- presence/absence of trail building;
- presence/absence of evidence of fire building;
- presence/absence of evidence of wildfire;
- presence/absence of homeless encampments.

Trash data was collected using techniques based on Urban Rapid Trash Assessment (URTA) protocols, as developed by biologists at SCVURPPP. This methodology is based on the premise that efficient estimation of trash volumes at a discharge location (e.g., stream channel, brow ditch, stormdrain outfall) is the most accurate means of assessment, due to the extremely high number (and often very small size) of trash items at sample sites, and also because of potential access issues. Application of URTA protocols begins with the delineation of the dimensions of the site to be sampled, in order to obtain that site's total volume. In other words, the sample site is conceptualized as inhabiting the confines of an imaginary box. This is accomplished using the following calculation:

(Sample Site Length) (Sample Site Width) (Sample Site Depth) = Sample Site Volume

A data sheet specific to this type of trash assessment, based upon those used by a number of municipal stormwater and urban runoff prevention agencies, was developed for this study, and includes all parameters outlined above. This data sheet was filled out for each of the four reaches studied during the sampling events. Both sides of the river were sampled and in-river trash data was also collected, where visually identifiable.

In the case of the Guadalupe River reaches, attention was also paid to homeless encampments: their locations, size, and potential hazards. This information was noted on the data sheets in an informal manner, largely for personal reference. However, all materials involved in the construction and maintenance of encampments located within the sample site were included within the trash assessment. It has been documented that homeless individuals seeking shelter have constructed encampments from anything and everything they could find, including camp tents, tarps, wood, rocks and even sun-baked mud (Amster, 2008). Due to the transient nature of these dwellings and their susceptibility to wind and water transfer to the river's main channel, these materials were considered, for the sake of this research, trash.

Sampling of the Los Gatos creek site followed the same methodology; however, because this reach is representative of a riparian zone that is unused by homeless individuals, all anthropogenic debris identified in the reach was attributable to littering by the general population, or illegal dumping. Where trail building was identified within this reach, it was attributed to local anglers.

Data Analysis

Quantitative analyses were conducted on data collected in the field. For each sampling event, total trash volume for each site was determined, along with the volumes of each type of trash; averages were calculated from this data. All quantitative analyses regarding trash accumulation in the sample sites first require calculation of the volumes of those sites. The dimensions of the sites were established and averaged as described above, with each site having a length of 250m, a width of 40m, and a depth of 3m. The total volume of the sites was therefore calculated as:

$$(250\text{m})\ (40\text{m})\ (3\text{m}) = 30{,}000\text{m}^3$$

Once this volume for the sites was established, the observed quantity of total trash was envisioned as an assembled collection within the confines of that space. The percentage of the total volume of the site occupied by that envisioned collection resulted in an estimate of the total volume of trash at the site. For example, where a site assessment determined that 1% of the total site volume was occupied by trash the calculation would result in a trash volume of 300m^3.

$$(.01)\ (30{,}000\text{m}^3) = 300\text{m}^3$$

The establishment of a total trash volume for the site then allowed for a more detailed quantitative description of the categories of trash present. Trash categories were chosen from 16 trash types that are listed on the field data sheet. Once a category of trash was identified within the sample site, its percentage of the total trash volume was estimated to the nearest one percent. The percentages of all documented categories of trash at the site must add up to 100%, i.e., the entirety of the total trash volume must be categorized. In so doing, estimates of the volume of each trash type can be calculated. For example, where it was recorded that food packaging makes up 10% of a site's 300m^3 of total trash, the volume of food packaging at the site would be 30m^3.

$$(.1)\ (300\text{m}^3) = 30\text{m}^3$$

The sampling event that took place in the primary study area following the December 2012 flood event was combined with data from the three sampling events in Los Gatos Creek. This baseline data was used to establish a value that represents impacts unrelated to the homeless population. This was designed to increase the accuracy of quantification of homeless-related trash data: baseline volumes of trash can be subtracted from the volumes identified in the primary study area in order to more accurately determine the volumes of trash that are the result of homelessness in the riparian zone. Using these figures, inferences were made regarding potential environmental impacts, as established in previously published scientific literature. The objective of the development of this methodology was to provide new insight into a source of environmental damage that has heretofore been inadequately accounted for.

Results

Four scheduled sampling events took place, each approximately two months apart. The first sampling event took place in early November 2012, the last in May 2013. All sites within the primary study area were sampled within the same day. Due to its distance from the other sites, the “Baseline” site was sampled one to two days before or after sampling of the other three sites. In addition to the scheduled sampling events, a series of storms in early December 2012 resulted in an opportunity to sample the three primary study area sites immediately following a flood event. Data from this fourth sampling event was used as baseline information, supplementing the data collected from the “Baseline” site.

Baseline Trash Quantification

Baseline data (all parameters) was collected at the “Baseline” sample site in the secondary study area. Baseline data (trash only) was collected at the three primary sample locations on Dec 4, 2012, immediately following a flood event. All raw data collected from the “Baseline” sample location are presented in Appendix A. Raw data collected on Dec 4, 2012 are presented in Appendix B.

At the “Baseline” sample site, alterations of the riverbed/streamcourse were not observed at any time during sampling; similarly, no streambank alterations were observed. Destruction of vegetation was observed on two occasions, while trail building was noted during all five sampling events. These alterations of the riparian zone were attributed to use of the area by local anglers, an activity which was observed on several occasions. At no time was evidence of homeless activity observed in the sampling area: no fire building, no evidence of wildfire, and no homeless encampments. The largest total volume of trash observed at the “Baseline” site over the course of the four sampling events was 300m^3. The average total volume was 225m^3. The average category volume was 14.06m^3, and trash was observed in 9 of the 16 possible categories. Average trash volumes by category for this site are presented in Table 1.

Table 1: Average trash volumes by category, sample site “Baseline”

Trash Category	**Average Volume, m³**
Automotive	0
Bicycle	0
Biohazard	0
Cig Waste	7.12
Constr. Material	0
Fabric/Clothing	16.5
Food Pkg.	50.62
Furniture	0
Misc. Glass	9
Misc. Paper	48.7
Misc. Plastics	46.87
Organics	3
Other (specify)	13.87
Plastic Bags	29.25
PPCP's	0
Shopping Cart	0

Baseline trash data was collected at the “Minimal” sample site on Dec 4, 2012. The total volume of trash was 300m³. The average category volume was 18.75m³, and trash was observed in 6 of the 16 possible categories. Raw baseline trash volumes from sample site “Minimal,” collected on Dec 4, 2012, are presented in Table 2.

Table 2: Trash volumes by category, sample site “Minimal,” Dec 4, 2012

Trash Category	Volume, m^3
Automotive	30
Bicycle	0
Biohazard	0
Cig Waste	15
Constr. Material	0
Fabric/Clothing	0
Food Pkg.	75
Furniture	0
Misc. Glass	0
Misc. Paper	75
Misc. Plastics	60
Organics	0
Other (specify)	0
Plastic Bags	45
PPCP's	0
Shopping Cart	0

Baseline trash data was collected at the “Moderate” sample site on Dec 4, 2012. The total volume of trash was 900m^3. The average category volume was 56.25m^3, and trash was observed in 12 of the 16 possible categories. Raw baseline trash volumes from sample site “Moderate,” collected on Dec 4, 2012, are presented in Table 3.

Table 3: Trash volumes by category, sample site “Moderate,” Dec 4, 2012

Trash Category	**Volume, m³**
Automotive	0
Bicycle	72
Biohazard	0
Cig Waste	27
Constr. Material	90
Fabric/Clothing	180
Food Pkg.	63
Furniture	90
Misc. Glass	45
Misc. Paper	72
Misc. Plastics	90
Organics	0
Other (specify)	0
Plastic Bags	63
PPCP's	18
Shopping Cart	90

Baseline trash data was collected at the “Heavy” sample site on Dec 4, 2012. The total volume of trash was 150m³. The average category volume was 9.37m³, and trash was observed in seven of the 16 possible categories. Raw baseline trash volumes from sample site “Heavy,” collected on Dec 4, 2012, are presented in Table 4.

Table 4: Trash volumes by category, sample site “Heavy,” Dec. 4, 2012

Trash Category	Volume, m³
Automotive	0
Bicycle	0
Biohazard	15
Cig Waste	7.5
Constr. Material	0
Fabric/Clothing	15
Food Pkg.	22.5
Furniture	0
Misc. Glass	0
Misc. Paper	15
Misc. Plastics	30
Organics	0
Other (specify)	0
Plastic Bags	45
PPCP's	0
Shopping Cart	0

The average total trash volume from the “Baseline” sample site (225m³) was combined with the total trash volume recorded at each of the primary sample locations on Dec 4, 2012 in order to produce an average baseline trash volume for each of the three sites, as follows:

- Minimal: 262.5m³
- Moderate: 562.5m³
- Heavy: 187.5m³

Total Trash Volumes

The single highest total trash volume recorded during scheduled sampling was 2700m³, on Jan 5, 2013 at sample site “Heavy.” The lowest total trash volume recorded during scheduled sampling was 300m³, on Mar 16, 2013 at sample site “Minimal.” Total trash volumes from the three primary sample locations for all scheduled sampling events are presented in Figure 7. Raw data from all scheduled sampling events in the primary study area are presented in Appendix C.

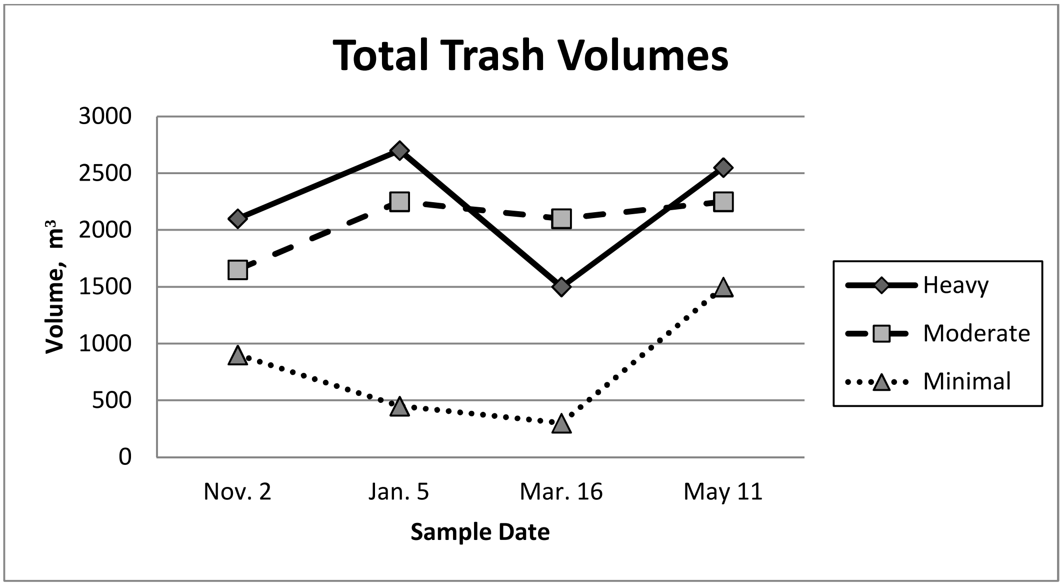


Figure 7: Total trash volumes at primary sample sites during scheduled sampling period

Average total trash volumes from the four scheduled sampling events at the primary sampling sites were calculated. Baseline trash volumes were subtracted from these average total trash volumes in order to produce an "adjusted" average total volume, more accurately reflective of the average volume of trash attributable to homeless activity. These results are presented in Table 5.

Table 5: Average and adjusted average total trash volumes at primary sample sites

	Average Total Trash Vol., m³	**Adjusted Average Total Trash Vol., m³**
Minimal	787.5	525
Moderate	2062.5	1500
Heavy	2212.5	2025

Trash Category Volumes

Trash from all 16 categories was observed during the course of sampling. The most frequently encountered categories of trash were cigarette waste, fabrics/clothing, food packaging, miscellaneous paper and miscellaneous plastics. Trash of these types was recorded at every sampling event in the primary sampling area. The most infrequently encountered category of trash was biohazard waste, which was recorded on three occasions. Biohazard waste also accounted for the lowest total volume by category, totaling 156m³. The highest total volume by category was fabrics/clothing, with 3295.5m³. Category volumes for each site and sampling event were totaled and averages were calculated. These results are graphically presented in Figures 7-9. Raw data from all scheduled sampling events in the primary study area are presented in Appendix C.

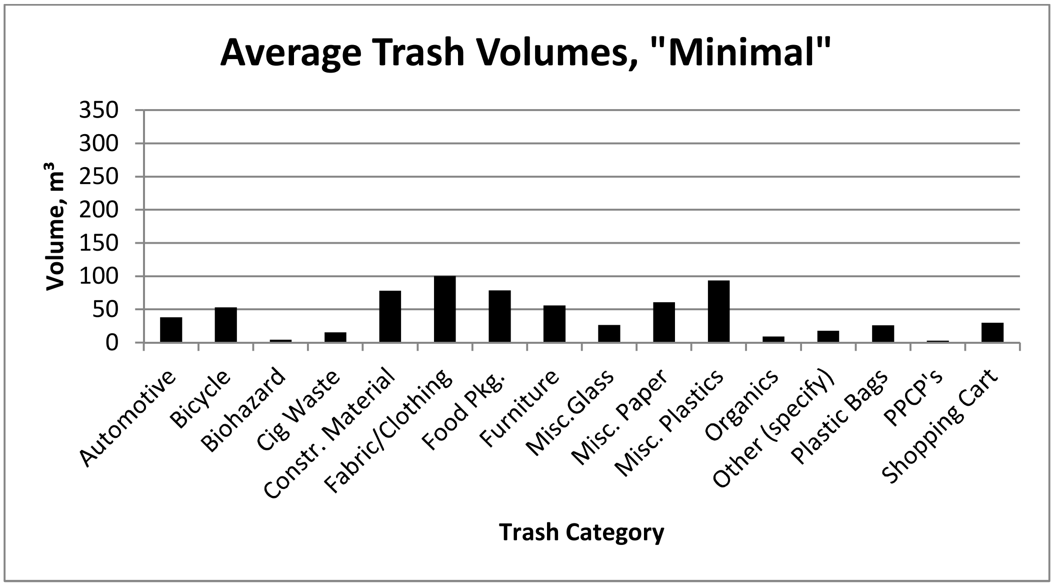


Figure 8: Average trash volumes by category, sample site “Minimal"

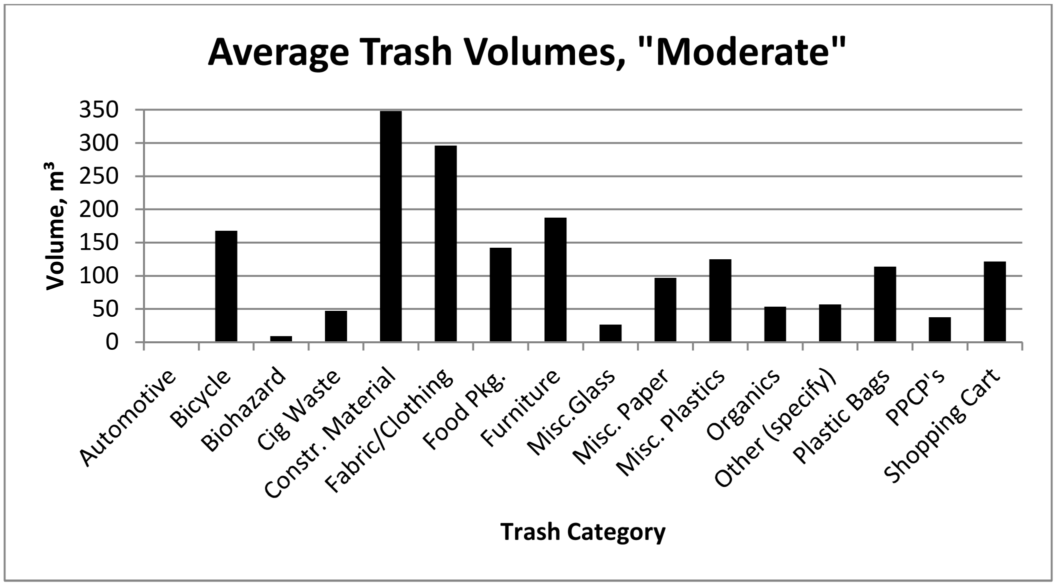


Figure 9: Average trash volumes by category, sample site "Moderate"

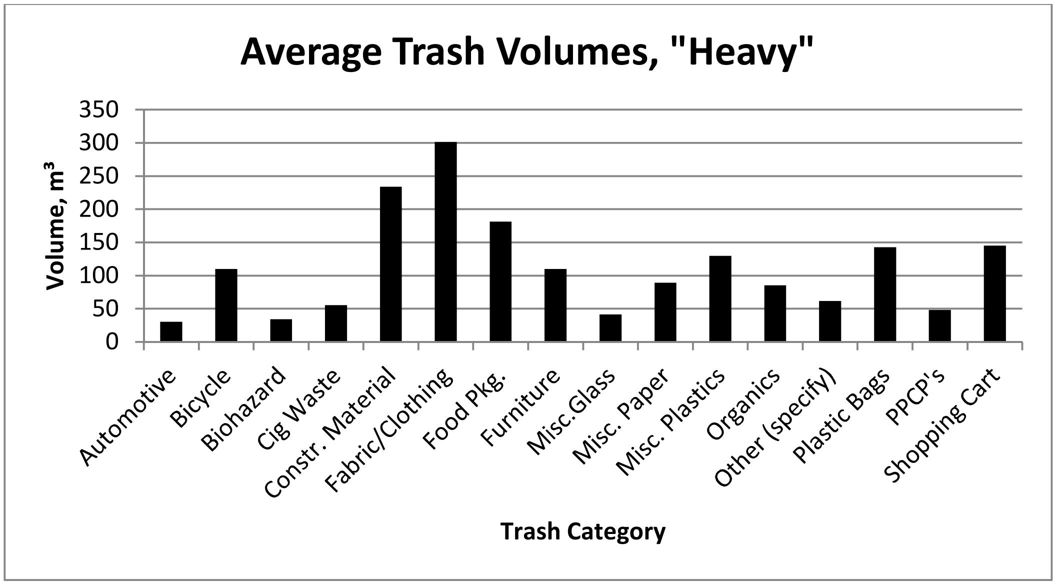


Figure 10: Average trash volumes by category, sample site "Heavy"

Riverbed/Streamcourse Alterations

Anthropogenic alterations of the riverbed and/or streamcourse were observed at sample site "heavy" on all but one of the scheduled sampling events. Four such alterations were observed in total, for an average of 1 riverbed/streamcourse alteration per sampling event. No other sites showed evidence of riverbed/streamcourse alterations at any time. Raw data from all scheduled sampling events in the primary study area are presented in Appendix C.

Streambank Alterations

Anthropogenic alterations of the streambank were observed at all sites in the primary sampling area, on all scheduled sampling events. Averages per sampling event were calculated from the total number of streambank alterations per site. These results are summarized in Table 6. Raw data from all scheduled sampling events in the primary study area are presented in Appendix C.

Table 6: Total and average streambank alterations at primary sample sites

	Total Streambank Alterations	Average per Sampling Event
Minimal	4	1
Moderate	23	5.75
Heavy	21	5.25

Other Parameters

Qualitative data (presence/absence) was collected for the following parameters: destruction of vegetation, trail building, evidence of fire building, evidence of wildfire, and existence of homeless encampments. The number of occasions during the four sampling events when each of these parameters was noted to be present was totaled, and this information is summarized in Table 7. Raw data from all scheduled sampling events in the primary study area are presented in Appendix C.

Table 7: Total number of observations of presence of "other parameters"

	Destruction of Veg'n.	Trail Building	Fire Building	Wildfire	Encampments
Minimal	2	2	0	0	2
Moderate	4	4	4	4	4
Heavy	4	4	3	0	4

Discussion

The results summarized above can be applied to several of the specific questions posed by this research, specifically: what are the types and volumes of anthropogenic debris (trash) that are directly attributable to the homeless population? What are their environmental impacts, based on current scientific understanding? How much of the visible alteration of the riparian zone (trailbuilding, terracing of streambanks and/or destruction of native vegetation) is directly attributable to the homeless population? What are the associated environmental impacts of these alterations?

Making direct attributions of the sources of individual pieces of anthropogenic debris in the environment is an inherently difficult task. This is exemplified by the rapidly changing templates of standardized trash assessments, as developed by municipalities and environmental organizations. The inclusion of baseline trash data in this study was an attempt at eliminating two of the more commonly attributed sources of trash in riparian zones, i.e., the general public and illegal dumping. The application of these baseline volumes (total trash and trash volumes by type) to the trash quantified within the sampling areas provided a method of more accurately determining the amounts and types of trash that is attributable to a third source, that of the homeless population. In this manner, trash of 16 different types was identified as originating from the population in question, in volumes ranging from156m³ to 3295.5m³.

The environmental impacts of these trash volumes can be considered in the context of previous research conducted with specific anthropogenic items in specific environmental media. While similar to the materials and the substrates that exist in the Guadalupe River, the conditions under which such research was conducted are not identical. Because of differences in climate, soil type and water quality (among other variables), direct conclusions cannot be made about the extent and severity of environmental impacts upon the Guadalupe estuary based on these studies, or any others. In particular, with respect to the impacts of physical alterations to the riparian zone, the soil type unique to the Guadalupe watershed – fine sandy loam – will not necessarily be the same as that found in the studies referenced below (University of California at Davis, California Soils Database, 2013). However, such work can form the basis for making informed comparisons between the results of those studies, and the results summarized above.

For example, the presence of litter items in brackish mudflats (such as those in an estuary like that found in south San Francisco Bay) has been found to negatively influence the foraging behavior of certain species of intertidal gastropods, by increasing their travel time to forage and by causing premature self-burying in response to perceived predation (Aloy et al., 2011). It can be inferred from such research that some of the anthropogenic materials observed in this study, once reaching the estuary, could have similar or greater effects upon the foraging and predator-avoidance behaviors of gastropods. Other research has found that large items such as vehicle tires and building materials impede the establishment and growth of wetland plants, which serve as habitat, refuge and food for ecologically important species (Uhrin & Schellinger, 2011). It can be theorized that some of the similarly bulky anthropogenic materials observed in this study would have equal or greater impacts upon estuarine plants.

The results summarized above demonstrate that plastic bags and fabrics/clothing are two of the most commonly encountered trash types in the riparian zone of the Guadalupe River. Large items such as lumber and shopping carts were also frequently observed. As previously noted, trash items found in the riparian zone, but outside the river itself, are assumed to eventually make their way into the stream channel by way of wind and water transfer. While such movement occurs in the riparian zone more or less continually, it was established during the course of this study that the Guadalupe River exhibits a significant seasonal water-borne transfer of materials, i.e., a winter flush. Once introduced into the main channel of the river, some proportion of these items will eventually make their way downstream to the estuary, where they will become entrained for a period of time. Indeed, casual observations of the Guadalupe River estuary have confirmed the presence of items such as plastic bags, fabrics and clothing, and shopping carts, along with myriad other forms of anthropogenic materials.

The research by Aloy et al. (2011) showed that a treatment area of one square meter, with 75% coverage by 19cm x 14cm plastic sheeting, resulted in significantly fewer gastropod individuals arriving at the bait within the area than an identical area with 25% coverage. It can be extrapolated by comparison that a similar-sized area covered by a large cloth tarp of the type used commonly in the construction of homeless encampments would have similar or greater consequences on gastropod foraging activity. Moreover, widely distributed large pieces of plastic (such as grocery bags or trash bags) or other items (such as fabrics and clothing) would also impact gastropod activity. In this study, it was found that homeless activity contributed 282.6m^3 of plastic bags and 698.1m^3 of fabrics and clothing to the riparian zone.

Similar comparisons can be made with research regarding anthropogenic materials as impediments to marsh plant growth. The study by Uhrin & Schellinger (2011) found impediments to native plant growth in the presence of coverage by vehicle tires (0.43m rim diameter, 9.1-10.9kg dry weight) and lumber (0.5m lengths of 0.5 x 0.1m). It can be extrapolated by comparison that the presence of bulky debris such as shopping carts and construction materials (items also commonly seen in homeless encampments), in an estuarine habitat such as that of South San Francisco Bay, would have similar or greater impacts. The results of this research showed that homeless activity within the Guadalupe River contributed a total of 296.7m³ of shopping carts, and 659.7m³ of construction materials, to the riparian zone.

Some speculative consideration of the environmental impacts of anthropogenic debris in the marine environment is warranted by the results of this study. While much has been written on the types, locations, and extent of trash in the ocean, little is known about the precise environmental impacts of this material. However, we can glean from previous research on the effects of marine debris on sea turtles some insight into the possible effects of, for example, "miscellaneous plastic," which was one of the more commonly observed categories of trash at the Guadalupe River sample sites. In one recent study, 54 dead loggerhead turtles were examined, and marine debris was found in the gut contents of 13 turtles, or 24%; moreover, plastics accounted for 70 of the 82 total pieces of debris, or 85% (Lazar & Gracan, 2011). Going further, it is possible to extrapolate that, if 24% of the study's turtles contained plastics 85% of the time, then there is a 20.4% chance of any one turtle having plastic in its digestive system. While the above-referenced study quantified marine debris in terms of individual pieces found in the guts of sea turtles, the proportions can still be used for comparative purposes. For example, with a 20.4% chance of ingestion by sea turtles of the average volume of plastic debris (plastic bags, miscellaneous plastic, and food packaging) found at the sample site "moderate," we can ascertain that those animals would ingest a total of 77.79m³ of material.

The physiological impacts of ingested plastic material on marine organisms are largely unknown. This is due in part to their relatively recent arrival in the oceans, and because of what will almost certainly be their long-term persistence in the environment. For example, while scientists can speculate with some credibility about the observed discomfort of a sea turtle attempting to expel several kilograms of plastic bags via the cloaca, it is much more difficult to gain a clearer understanding of the effects of, for example, microplastics. One area of significant current research is into the endocrine-disrupting compounds

(EDC's) that are present in virtually all types of commercially produced plastics. A comprehensive study done on an exhaustive array of widely available plastic products showed that without exception, all products had detectable amounts of estrogenic activity (EA), including those marketed as "BPA-free," such as baby bottles (Yang et al., 2011). It can therefore be assumed that the vast majority of the plastic material noted during the course of this study contains EDC's that are leached to the soil and water in which they reside.

While the main focus of attention has been on the potential for products to interfere with human endocrine systems, acutely or through chronic, (even genetic) effects, some research has been conducted on freshwater and marine organisms. For example, daphnids or water fleas, commonly used as test species in toxicological research, have been found to be the most susceptible to environmental pharmaceutical contaminants, followed by fish and algae (Pal et al., 2010). The recent attention paid to pharmaceuticals in wastewater is a result of the potential for these compounds to bypass even the most advanced municipal treatment systems, ending up in sensitive marine environments, such as San Francisco Bay. It was for this reason that the category of Pharmaceuticals and Personal Care Products (PPCP's) was included in the trash quantification portion of this study. While PPCP's only accounted for a relatively small volume of the observed debris – a total of $88.2m^3$ – their presence in homeless encampments is noteworthy, since the discharge of PPCP's directly into the freshwater environment has the potential to affect both freshwater and marine organisms, as well as infiltrate the alluvial aquifer.

The environmental impacts of riparian zone alterations can also be considered in the context of previous research. In so doing, it is again necessary to emphasize that the riparian soil conditions under which other studies have been conducted will not match those of the Guadalupe River watershed. Nevertheless, it has been established that anthropogenic alterations of the types seen in this study's sample sites (terracing, trailbuilding, and removal of vegetation) cause in-stream degradation in a number of ways. In particular, both terracing and trailbuilding result in the displacement of naturally occurring sediments, which are sent directly to the stream channel; moreover, the changes in slope stability from these activities causes increased erosion, leading to ongoing sedimentation (Poole & Berman, 2001). Increased sedimentation within streams has multiple impacts upon algal, invertebrate and fish populations, including decreased light penetration, increased smothering and scouring, and decreased habitat diversity (Wohl, 2004).

This study's observations of riparian zone alterations indicate that homeless activity within the Guadalupe results in some predictable changes to the naturally steep slopes leading to the river's main channel. The most commonly seen alteration was that of terracing, whereby sections of the streambank are manually dug out and abraded in order to create a flat surface for sleeping, cooking, cleaning, etc. A total of 48 such alterations were observed during the sampling period. Other observed alterations of the riparian zone included those intended to ease movement within the inhabited areas: 10 instances of trailbuilding and 10 instances of removal of vegetation. (Although these totals are identical, trailbuilding and removal of vegetation were considered separately. In other words, a recorded instance of trailbuilding, while it might destroy vegetation, is not recorded as an act of vegetation removal as well.) The most salient question regarding the removal of portions of the material making up the natural streambank (sediment and the vegetation growing within it) is: where does that material end up? Without having actually observed any active terracing, trailbuilding or removal of vegetation, it is nevertheless safe to assume that a significant portion of the material, and in particular the sediment, immediately or eventually is discharged to the watercourse. With numerous species of resident fish in the Guadalupe River, including an endangered run of steelhead salmon, it is reasonable to infer from research into the egg-smothering effects of large sediment loads that the streambank alterations observed in this study would have damaging effects on the Guadalupe's fish populations.

Several other parameters were considered during the sampling process, including the presence of homeless encampments. These were noted on 10 occasions, largely for purposes of safety and orientation. Evidence of firebuilding activity was noted on seven occasions. This usually took the form of fire rings or fire pits within the riparian areas, in close proximity or within the confines of homeless encampments.

Finally, evidence of wildfire was noted on four occasions within the sampling areas. None of these were associated with the locations where firebuilding was noted. This information was included in the study as a result of growing concern about fires resulting from human habitation of wildlands in urban areas. Indeed, recent and repeated fires in several heavily populated riparian zones in the city of San Jose have received coverage in the local media, and this has focused some degree of attention on the issue of homeless encampments. Large burnt sections of a greenbelt in a heavily developed urban area provide visible, and highly unwelcome, evidence of environmental damage. However, the less visible effects of riparian zone fires may be of greater environmental consequence. These have been found to include changes in nutrient fluxes and cycling, increased sediment loads, and stimulation of erosion (Pettit & Naiman, 2007).

Conclusions and Areas For Future Research

The results discussed in the previous section lead to several reasonable conclusions. First, it is clear that the areas of the Guadalupe River's riparian zone that are heavily inhabited and/or traveled by homeless individuals or groups are more impacted by trash, streambank alterations and wildfire than those areas that are less heavily used. Second, due to the movement of a portion of materials such as trash and sediment from the riparian zone to the estuary and eventually the marine environment, it can be concluded that environmental impacts extend beyond the observed areas. Finally, the areas that were the focus of this research were observed to be largely unchanged in terms of their degree of use throughout the length of the study. Although a period of flooding in early December 2012 resulted in an exodus of the riparian zone by the homeless population, those areas were almost immediately re-inhabited. As a result, it can be concluded that the conditions observed in this study's sample sites are representative of the longer-term situation in those areas.

While a certain degree of transience is an inherent aspect of homelessness, several large encampments in other riparian areas within San Jose (namely, those of Coyote Creek) have been observed to persist in the same location for more than 10 years (Ledesma, personal communication, 10 April, 2012). Such relative permanence implies that well-established areas of encampment in the Guadalupe watershed, such as those seen in this study's sample site "moderate," could remain in the observed conditions for years to come. Indeed, despite the occasional occurrence of forced displacement by city officials and law enforcement of long-term encampments within the Coyote Creek watershed, the same areas are quickly re-inhabited (Ledesma, personal communication, 10 April, 2012). Such precedence leads to the conclusion that riparian zone cleanups and evictions/removals of homeless people are of minimal consequence. In Santa Clara County, actions such as forced displacement and confiscation of property represent the controversial "last-ditch" efforts of cash-strapped local governments at dealing with a very high-profile issue. Leaving aside the question of their basic legality, the heavy-handedness of these efforts is emblematic of the level of desperation that exists among those dealing with just one of the societal consequences of homelessness. Clearly, new approaches and alternative frameworks for a long-term solution are needed.

The objective of this research was identification and quantification of the type, extent, and location of environmental impacts in the riparian zone of the Guadalupe River that are directly attributable to the homeless population. Inclusion of baseline data regarding the impacts of other source populations was intended as an original approach to increasing the accuracy of a historically inaccurate part of the trash assessment process, i.e., source identification. The continually evolving nature of urban trash assessment protocols suggests that the methodology developed for this study can serve as a framework for subsequent research into trash-related environmental damage. The techniques developed for pinpointing potential environmental effects of a homeless population's use of an area were not intended to further vilify that population. On the contrary, the objective was to establish yet another reason to work towards the eradication of homelessness, and attempt to quantify it in a unique and progressive manner. It is anticipated that this iteration of the trash assessment process may serve as a positive step forward in terms of source identification; however, other areas of social-science research may have more long-term meaning in regards to bringing about a solution to the issue of homelessness in general.

It is safe to conclude that if all attempts at eliminating or attenuating the issue of homeless encampments in urban waterways have been largely unsuccessful, then the next step is to empirically examine alternative approaches. Within certain agencies many of these approaches are widely discussed, and in some cases have been attempted, albeit on a very short-term and largely underfunded basis. One area of potential future research is the long-term benefit-cost analysis of permanent housing for homeless populations. An approach involving valuation methods could be taken, whereby the current and future costs of mitigation of the existing situation (e.g., salaries of city employees tasked with managing and conducting cleanups, materials used in construction of barriers/fencing, litigation arising from property confiscation and/or bodily harm) are compared to the costs associated with current and future housing of the homeless population. While speculation within some circles of municipal governments and homeless-outreach organizations has suggested that mitigation costs greatly exceed the costs of housing, no rigorous quantitative study has examined the question in the long-term. Further research could attempt to determine the actual long-term societal benefits that may accrue from permanent housing of otherwise chronically homeless individuals. In particular, studies could focus on the economic benefits associated with fewer withdrawals from the pool of social safety-net resources (health care, food stamps, welfare, temporary shelter), in addition to the potential added government revenue of taxable income from the otherwise unemployed. Such areas of future research warrant serious examination, if for no other reason than to move beyond the existing culture of exasperation amongst those attempting to confront the issue of homelessness in western society.

Works Cited

Akin, S, Polat, F., Yildirim, A., & Dal, T., (2011). The effects of pollutants on blood parameters of cyprinids in Yesilirmak river of Turkey: Are the fish at stress due to trash dumping area? *Fresenius Environmental Bulletin, 20*(8), 1993-2001.

Aloy, A. B.,Vallejo, B.M., & Junio Menez, M.A. (2011). Increased plastic litter cover affects the foraging activity of the sandy intertidal gastropod nassarius pullus. *Marine Pollution Bulletin, 62*(8), 1772-1779. doi: 10.1016/j.marpolbul.2011.05.021

Amster, R. (2008). *Lost in space: The criminalization, globalization, and urban ecology of homelessness*. New York: LFB Scholarly Publishing.

Atkinson, S.F., Hunter, B.A.,& English A.R. (2010). Prioritizing riparian corridors for water quality protection in urbanizing watersheds. *Journal of Water Resource and Protection*, *2*(7), 675-682.

Balas, C.E., Williams, A.T., Simmons, S.L., & Ergin, A. (2001). A statistical riverine litter propagation model. *Marine Pollution Bulletin, 42*(11), 1169-1176.

Barnes, D. K. A., Galgani, F., Thompson, R.C. & Barlaz, M. (2009). Accumulation and fragmentation of plastic debris in global environments. *Philosophical Transactions: Biological Sciences, 364*(1526), 1995-1998.

Betts, K. (2008). Why small plastic particles may pose a big problem in the oceans. *Environmental Science and Technology, 42*(24), 8995.

Broadmeadow, S.B., Jones, J.G., Langford, T.E.L., Shaw, P.J., & Nisbet, T.R. (2011). The influence of riparian shade on lowland stream water temperatures in southern England and their viability for brown trout. *River Research and Applications*, *27*(2), 226-237.

Browne, M. A., Crump, P., Niven, S.J., Teuten, E., Tonkin, A., Galloway, T., & Thompson, R. (2011). Accumulation of microplastic on shorelines worldwide: Sources and sinks. *Environmental Science & Technology*, *45*(21), 9175-9179. doi: 10.1021/es201811s

Bugoni, L., Krause, L., & Petry, M. V. (2001). Marine debris and human impacts on sea turtles in southern Brazil. *Marine Pollution Bulletin, 42*(12), 1330-1344. doi: 10.1016/S0025-326X(01)00147-3

California Environmental Protection Agency. California Regional Water Quality Control Board. (2013). *A rapid trash assessment method applied to waters of the San Francisco Bay region: Trash measurement in streams. Final technical report, 2005.* Surface Water Ambient Monitoring Program. Retrieved from http://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/planningtmdls/surfacemonitoring/rb2swamptrashrpt06152007.pdf

County of Santa Clara. Planning Office. (2013). Retrieved from http://www.sccgov.org/sites/planning/Facts

University of California at Davis, California Soils Database. (2013). Retrieved from http://casoilresource.lawr.ucdavis.edu/gmap/

DiGregorio, B.E. (2012). Tracking plastics in the oceans. *Earth, 57*(2), 28-35.

Dumas, D. (2007). Landfill-on-sea. *Ecologist, 37*(7), 34-37.

Earll, R.C., Williams, A.T., Simmons, S.L., & Tudor, D.T. (2000). Aquatic litter, management and prevention – the role of measurement. *Journal of Coastal Conservation (6)*1, 67-78.

Engler, R.E. (2012). The complex interaction between marine debris and toxic chemicals in the ocean. *Marine Pollution Bulletin, (46)*22, 12302-12315.

Gotceitas, V. (1990). Foraging and predator avoidance: A test of patch choice model with juvenile bluegill sunfish. *Oecologia, 83*(3), 346-351.

Jowett, I.G., Richardson, J. & Boubee, J.A.T. (2009). Effects of riparian manipulation on stream communities in small streams: Two case studies. *New Zealand Journal of Marine and Freshwater Research, 43*(3), 763-774.

Kalantari, K., Fami, H.S., Asadi, A. & Mohammadi, H.M. (2007). Investigating factors affecting environmental behavior of urban residents: A case study in Tehran city – Iran. *American Journal of Environemtnal Sciences, 3*(2), 67-74.

Kanis, R., McCannon, J., Craig, C., & Mergl, K.A. (2012). An end to chronic homelessness: An introduction to the 100,000 homes campaign. *Journal of Healthcare for the Poor and Underserved 23*(1), 321-326.

Kaufmann, P.R., Larsen, D.P. & Faustini, J.M. (2009). Bed stability and sedimentation associated with human disturbances in Pacific Northwest streams. *Journal of the American Water Resources Association,45*(2), 434-459.

Keep America Beautiful. Great American Cleanup. (2013). Retrieved from http://www.kab.org/site/PageServer?pagename=programs_gac

Keller, A. A., Fruh, E.L., Johnson, M.M., Simon, V., & McGourty, C. (2010). Distribution and abundance of anthropogenic marine debris along the shelf and slope of the US west coast. *Marine Pollution Bulletin, 60*(5), 692-700. doi: 10.1016/j.marpolbul.2009.12.006

Lazar, B. & Gracan, R. (2011). Ingestion of marine debris by loggerhead sea turtles, *Caretta caretta*, in the Adriatic Sea. *Marine Pollution Bulletin, 62*(1), 43-47.

Moore, E., Lyday, S., Roletto, J., Litle, K., Parrish, J.K., Nevins, H., Harvey, J., Mortenson, J., Greig, D., Piazza, M., Hermance, A., Lee, D., Adams, D., Allen, S., & Kell, S. (2009). Entanglements of marine mammals and seabirds in central California and the north-west coast of the United States 2001-2005. *Marine Pollution Bulletin, 58*(7), 1045-1051.

Oigman-Pszczol, S.S.& Creed, J.C. (2007). Quantification and classification of marine litter on beaches along Armação dos Búzios, Rio de Janeiro, Brazil. *Journal of Coastal Research, 23*(2), 421-428.

Pal, A., Gin, K. Y-H, Lin, A. Y-C, & Reinhard, M. (2010). Impacts of emerging organic contaminants on freshwater resources: Review of recent occurrences, sources, fate and effects. *Science of the Total Environment. 408*(24) 6062-6069.

Pellow, D. (2004). The politics of illegal dumping: An environmental justice framework. *Qualitative Sociology, 27*(4), 511-525. doi: 10.1023/B:QUAS.0000049245.55208.4b

Pettit, N.E. & Naiman, R.J. (2007). Fire in the riparian zone: Characteristics and ecological consequences. *Ecosystems, 10*(5), 673-687.

Plot, V. & Georges, J-Y. (2010). Plastic debris in a nesting leatherback turtle in French Guiana. *Chelonian Conservation and Biology, 9*(2), 267-270.

Poole, G.C. & Berman, C.H. (2001). An ecological perspective on in-stream temperature: Natural heat dynamics and mechanisms of human-caused thermal degradation. *Environmental Management, 27*(6), 787-802.

Santa Clara Valley Urban Runoff Pollution Prevention Program. (2013). *Trash ad-hoc task group: Development of urban rapid trash assessment, 2006.* P. Randall & J. Fusco. (Memorandum). Retrieved from http://www.scvurppp-w2k.com/pdfs/0506/RTA_Draft_Memo_031306-ALL.pdf

Santos, I. R., Friedrich, A. C., & Ivar do Sul, J.A. (2009). Marine debris contamination along undeveloped tropical beaches from northeast Brazil. *Environmental Monitoring and Assessment, 148*(1), 455-462. doi: 10.1007/s10661-008-0175-z

Santos, I. R., Friedrich, A. C., Wallner-Kersanach, M., & Fillmann, G. (2005). Influence of socio-economic characteristics of beach users on litter generation. *Ocean & Coastal Management, 48*(9–10), 742-752. doi: 10.1016/j.ocecoaman.2005.08.006

Shenoy, K. & Crowley, P.H. (2011). Endocrine disruption of male mating signals: ecological and evolutionary implications. *Functional Ecology, 25*(3), 433-448.

Schug, T.T., Janesick, A., Blumberg. B., & Heindel, J. (2011). Endocrine disrupting chemicals and disease susceptibility. *Journal of Steroid Biochemistry & Molecular Biology, 127*(2), 204–215.

Seco Pon, J. P. & Becherucci, M.E. (2012). Spatial and temporal variations of urban litter in Mar Del Plata, the major coastal city of Argentina. *Waste Management (Elmsford), 32*(2), 343-348. doi: 10.1016/j.wasman.2011.10.012

Silva-Iniguez, L. & Fischer, D.M. (2003). Quantification and classification of marine litter on the municipal beach of Ensenada, Baja California, Mexico. *Marine Pollution Bulletin, 46*(1), 132-138.

Situ, Y. (1998). Public transgression of environmental law: A preliminary study. *Deviant Behavior: An Interdisciplinary Journal, 19* (2), 137-155.

Sheavly, S.B. & Register, K.M. (2007). Marine debris & plastics: Environmental concerns, sources, impacts and solutions. *Journal of Polymers and the Environment*, *15*(4), 301-305. doi: 10.1007/s10924-007-0074-3

Studinsky, J.M., Hartman, K.J., Niles, J.M., & Keyser, P. (2012). The effects of riparian forest disturbance on stream temperature, sedimentation, and morphology. *Hydrobiologia*, *686*(1), 107-117.

Thompson, W.H., Ehrhart, R.C., Hansen, P.L., Parker, T.G. & Haglan, W.C. (1998). Assessing health of a riparian site. *American Water Resources Association Proceedings: Specialty Conference on Rangeland Management and Water Resources.* Retrieved from http://awra.org/~awra/proceedings/reno98/thompson

Turnbull, J., Muckle, W., & Masters, C. (2007). Homelessness and health. *CMAJ: Canadian Medical Association Journal = Journal De L'Association Medicale Canadienne*, *177*(9), 1065-1066.

Uhrin, A.V. & Schellinger, J. (2011). Marine debris impacts to a tidal fringing-marsh in North Carolina. *Marine Pollution Bulletin, 62*(1), 2605-2610.

United States Department of the Interior. United States Geological Survey. (2013). Retrieved from http://waterdata.usgs.gov/nwis/annual?referred_module=sw&site_no=11169025

United States Environmental Protection Agency. Office of Wastewater Management. (2013). Retrieved from http://cfpub.epa.gov/npdes/

Votier, S.C., Archibald, K., Morgan, G. & Morgan, L. (2011). The use of plastic debris as nesting material by a colonial seabird and associated entanglement mortality. *Marine Pollution Bulletin, 62*(1), 168-172.

Widmer, W.M. & Hennemann, M.C. (2010). Marine debris in the Island of Santa Catarina, south Brazil: Spatial patterns, composition, and biological aspects. *Journal of Coastal Research, 26*(6), 993.

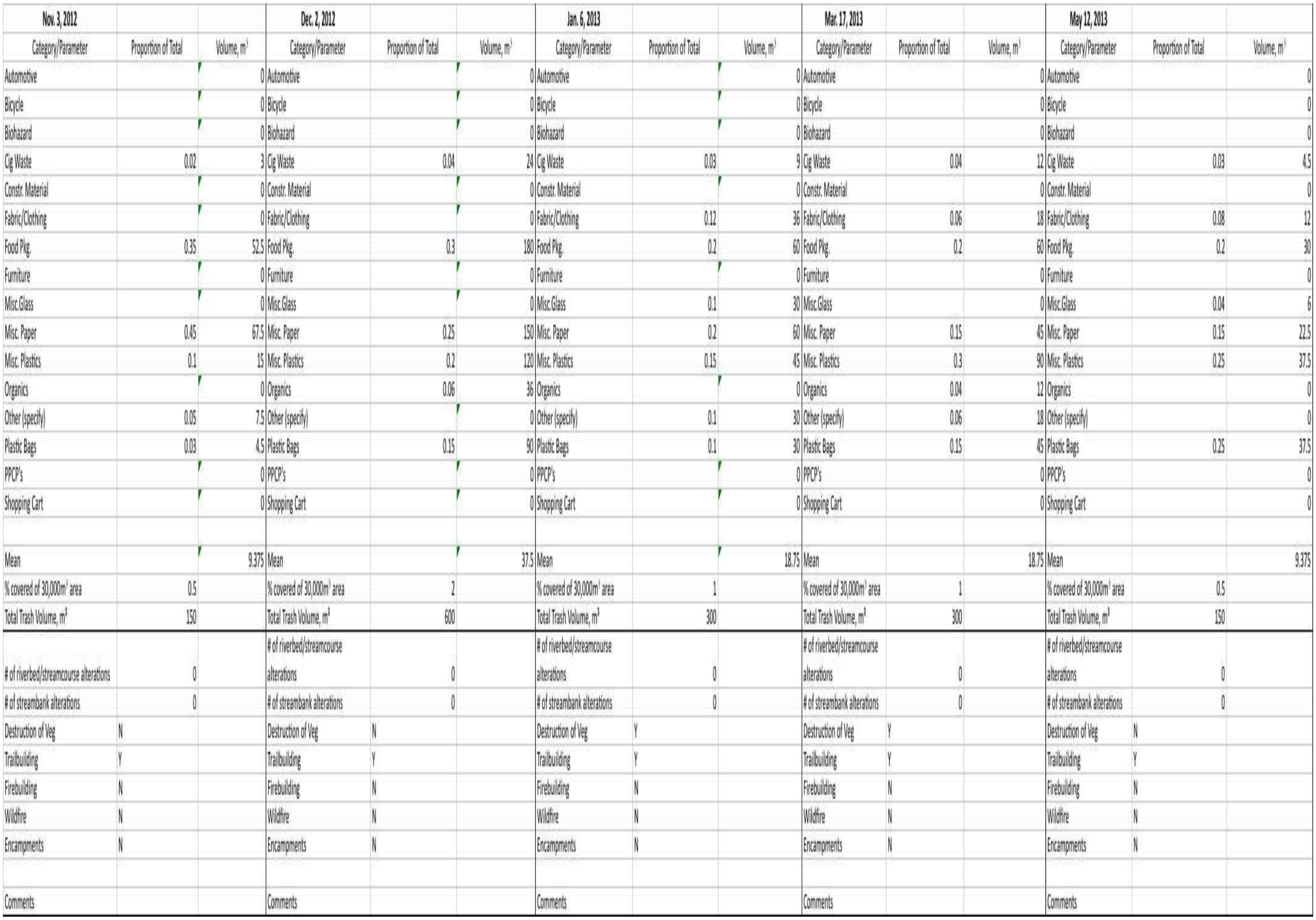
Williams, I. D. (2007). Littering of a watercourse in north-west England. *Proceedings of the Institution of Civil Engineers. Municipal Engineer, 160*(4), 201-207. doi: 10.1680/muen.160.4.201

Wohl, E. E. (2004). *Disconnected rivers: Linking rivers to landscapes.* New Haven: Yale University Press.

Yang, C.Z., Yaniger, S.I., Jordan, V.C., Klein, D.J., Bittner, G.D. (2011). Most plastic products release estrogenic chemicals: A potential health problem that can be solved. *Environmental Health Perspectives, 119*(7), 989-996. doi: 10.1289/ehp.1003220

Zhou, P., Huang, C., Fang, H., Cai, W., Li, D., Li, X., & Yu, H. (2011). The abundance, composition and sources of marine debris in coastal seawaters or beaches around the northern south China sea (China). *Marine Pollution Bulletin, 62*(9), 1998. doi: 10.1016/j.marpolbul.2011.06.018

Appendix A

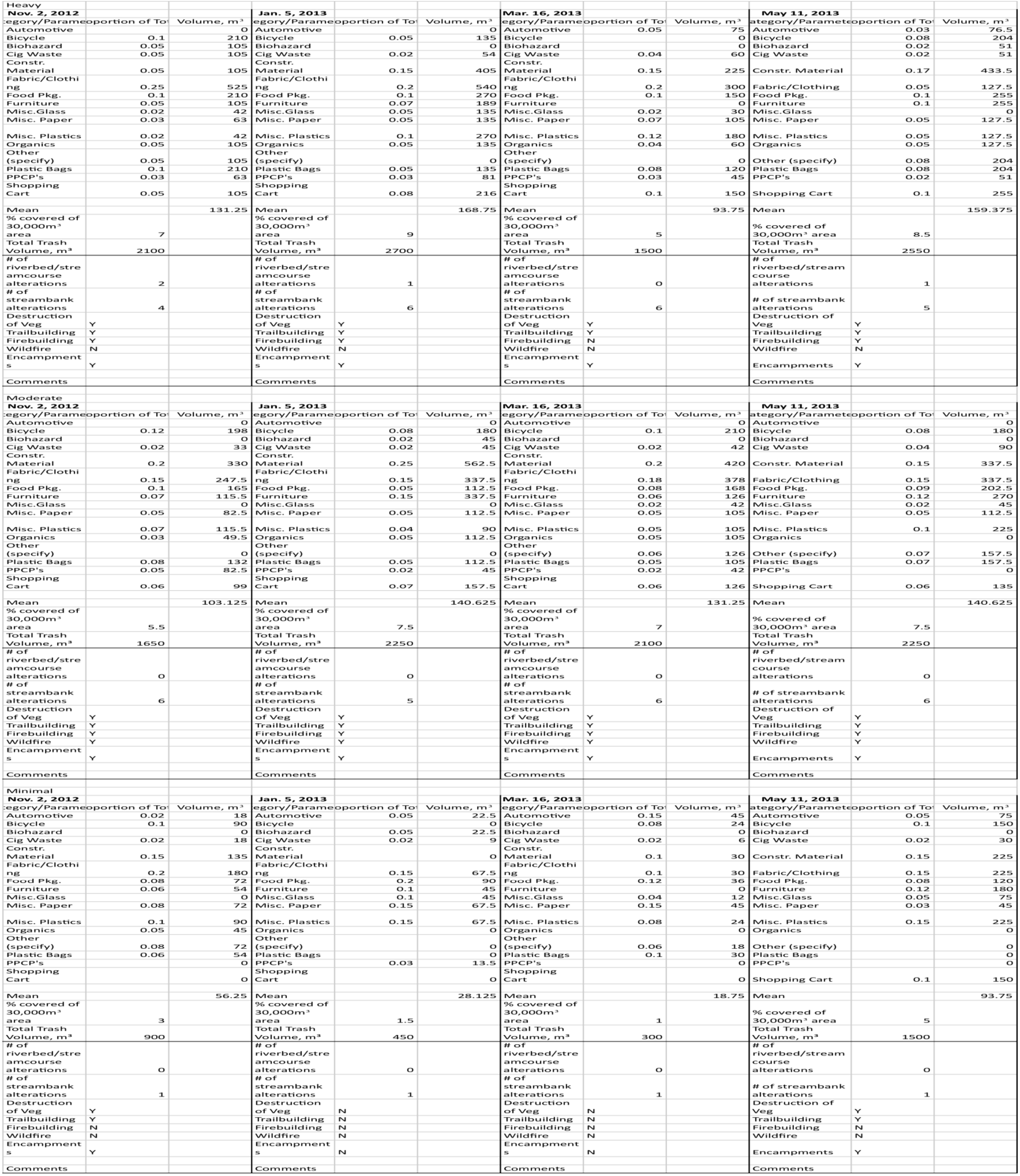


Nov. 3, 2012			Dec. 2, 2012			Jan. 6, 2013			Mar. 17, 2013			May 12, 2013		
Category/Parameter	Proportion of Total	Volume, m^3	Category/Parameter	Proportion of Total	Volume, m^3	Category/Parameter	Proportion of Total	Volume, m^3	Category/Parameter	Proportion of Total	Volume, m^3	Category/Parameter	Proportion of Total	Volume, m^3
Automotive		0	Automotive		0	Automotive		0	Automotive		0	Automotive		0
Bicycle		0	Bicycle		0	Bicycle		0	Bicycle		0	Bicycle		0
Biohazard		0	Biohazard		0	Biohazard		0	Biohazard		0	Biohazard		0
Cig Waste	0.02	3	Cig Waste	0.04	24	Cig Waste	0.03	9	Cig Waste	0.04	12	Cig Waste	0.03	4.5
Constr. Material		0	Constr. Material		0	Constr. Material		0	Constr. Material		0	Constr. Material		0
Fabric/Clothing		0	Fabric/Clothing		0	Fabric/Clothing	0.12	36	Fabric/Clothing	0.06	18	Fabric/Clothing	0.08	12
Food Pkg.	0.35	52.5	Food Pkg.	0.3	180	Food Pkg.	0.2	60	Food Pkg.	0.2	60	Food Pkg.	0.2	30
Furniture		0	Furniture		0	Furniture		0	Furniture		0	Furniture		0
Misc.Glass		0	Misc.Glass		0	Misc.Glass	0.1	30	Misc.Glass		0	Misc.Glass	0.04	6
Misc. Paper	0.45	67.5	Misc. Paper	0.25	150	Misc. Paper	0.2	60	Misc. Paper	0.15	45	Misc. Paper	0.15	22.5
Misc. Plastics	0.1	15	Misc. Plastics	0.2	120	Misc. Plastics	0.15	45	Misc. Plastics	0.3	90	Misc. Plastics	0.25	37.5
Organics		0	Organics	0.06	36	Organics		0	Organics	0.04	12	Organics		0
Other (specify)	0.05	7.5	Other (specify)		0	Other (specify)	0.1	30	Other (specify)	0.06	18	Other (specify)		0
Plastic Bags	0.03	4.5	Plastic Bags	0.15	90	Plastic Bags	0.1	30	Plastic Bags	0.15	45	Plastic Bags	0.25	37.5
PPCP's		0	PPCP's		0	PPCP's		0	PPCP's		0	PPCP's		0
Shopping Cart		0	Shopping Cart		0	Shopping Cart		0	Shopping Cart		0	Shopping Cart		0
Mean		9.375	Mean		37.5	Mean		18.75	Mean		18.75	Mean		9.375
% covered of 30,000m^3 area	0.5		% covered of 30,000m^3 area	2		% covered of 30,000m^3 area	1		% covered of 30,000m^3 area	1		% covered of 30,000m^3 area	0.5	
Total Trash Volume, m^3	150		Total Trash Volume, m^3	600		Total Trash Volume, m^3	300		Total Trash Volume, m^3	300		Total Trash Volume, m^3	150	
# of riverbed/streamcourse alterations	0		# of riverbed/streamcourse alterations	0		# of riverbed/streamcourse alterations	0		# of riverbed/streamcourse alterations	0		# of riverbed/streamcourse alterations	0	
# of streambank alterations	0		# of streambank alterations	0		# of streambank alterations	0		# of streambank alterations	0		# of streambank alterations	0	
Destruction of Veg	N		Destruction of Veg	N		Destruction of Veg	Y		Destruction of Veg	Y		Destruction of Veg	N	
Trailbuilding	Y		Trailbuilding	Y		Trailbuilding	Y		Trailbuilding	Y		Trailbuilding	Y	
Firebuilding	N		Firebuilding	N		Firebuilding	N		Firebuilding	N		Firebuilding	N	
Wildfire	N		Wildfire	N		Wildfire	N		Wildfire	N		Wildfire	N	
Encampments	N		Encampments	N		Encampments	N		Encampments	N		Encampments	N	
Comments			Comments			Comments			Comments			Comments		

Appendix B

Dec. 4, 2012	(Heavy)		**Dec. 4, 2012**	(Moderate)		**Dec. 4, 2012**	(Minimal)	
tegory/Parame	oportion of Tot	Volume, m^3	egory/Parame	portion of Tot	Volume, m^3	tegory/Parame	portion of Tot	Volume, m^3
Automotive		0	Automotive		0	Automotive	0.1	90
Bicycle		0	Bicycle	0.08	72	Bicycle		0
Biohazard	0.1	15	Biohazard		0	Biohazard		0
Cig Waste	0.05	7.5	Cig Waste	0.03	27	Cig Waste	0.05	45
Constr. Material		0	Constr. Material	0.1	90	Constr. Material		0
Fabric/Clothing	0.1	15	Fabric/Clothing	0.2	180	Fabric/Clothing		0
Food Pkg.	0.15	22.5	Food Pkg.	0.07	63	Food Pkg.	0.25	225
Furniture		0	Furniture	0.1	90	Furniture		0
Misc.Glass		0	Misc.Glass	0.05	45	Misc.Glass		0
Misc. Paper	0.1	15	Misc. Paper	0.08	72	Misc. Paper	0.25	225
Misc. Plastics	0.2	30	Misc. Plastics	0.1	90	Misc. Plastics	0.2	180
Organics		0	Organics		0	Organics		0
Other (specify)		0	Other (specify)		0	Other (specify)		0
Plastic Bags	0.3	45	Plastic Bags	0.07	63	Plastic Bags	0.15	135
PPCP's		0	PPCP's	0.02	18	PPCP's		0
Shopping Cart		0	Shopping Cart	0.1	90	Shopping Cart		0
Mean		9.375	Mean		56.25	Mean		56.25
% covered of 30,000m^3 area	0.5		% covered of 30,000m^3 area	3		% covered of 30,000m^3 area	1	
Total Trash Volume, m^3	150		Total Trash Volume, m^3	900		Total Trash Volume, m^3	300	
# of riverbed/streamcourse alterations	0		# of riverbed/streamcourse alterations	0		# of riverbed/streamcourse alterations	0	
# of streambank alterations	2		# of streambank alterations	2		# of streambank alterations	1	
Destruction of Veg	Y		Destruction of Veg	Y		Destruction of Veg	N	
Trailbuilding	Y		Trailbuilding	Y		Trailbuilding	Y	
Firebuilding	N		Firebuilding	N		Firebuilding	N	
Wildfire	N		Wildfire	Y		Wildfire	N	
Encampments	N		Encampments	N		Encampments	N	
Comments			Comments			Comments		

Appendix C



Heavy											
Nov. 2, 2012			**Jan. 5, 2013**			**Mar. 16, 2013**			**May 11, 2013**		
egory/Parame	oportion of To	Volume, m³	egory/Parame	oportion of To	Volume, m³	egory/Parame	oportion of To	Volume, m³	ategory/Paramete	oportion of To	Volume, m³
Automotive		0	Automotive		0	Automotive	0.05	75	Automotive	0.03	76.5
Bicycle	0.1	210	Bicycle	0.05	135	Bicycle		0	Bicycle	0.08	204
Biohazard	0.05	105	Biohazard		0	Biohazard		0	Biohazard	0.02	51
Cig Waste	0.05	105	Cig Waste	0.02	54	Cig Waste	0.04	60	Cig Waste	0.02	51
Constr. Material	0.05	105	Constr. Material	0.15	405	Constr. Material	0.15	225	Constr. Material	0.17	433.5
Fabric/Clothing	0.25	525	Fabric/Clothing	0.2	540	Fabric/Clothing	0.2	300	Fabric/Clothing	0.05	127.5
Food Pkg.	0.1	210	Food Pkg.	0.1	270	Food Pkg.	0.1	150	Food Pkg.	0.1	255
Furniture	0.05	105	Furniture	0.07	189	Furniture		0	Furniture	0.1	255
Misc.Glass	0.02	42	Misc.Glass	0.05	135	Misc.Glass	0.02	30	Misc.Glass		0
Misc. Paper	0.03	63	Misc. Paper	0.05	135	Misc. Paper	0.07	105	Misc. Paper	0.05	127.5
Misc. Plastics	0.02	42	Misc. Plastics	0.1	270	Misc. Plastics	0.12	180	Misc. Plastics	0.05	127.5
Organics	0.05	105	Organics	0.05	135	Organics	0.04	60	Organics	0.05	127.5
Other (specify)	0.05	105	Other (specify)		0	Other (specify)		0	Other (specify)	0.08	204
Plastic Bags	0.1	210	Plastic Bags	0.05	135	Plastic Bags	0.08	120	Plastic Bags	0.08	204
PPCP's	0.03	63	PPCP's	0.03	81	PPCP's	0.03	45	PPCP's	0.02	51
Shopping Cart	0.05	105	Shopping Cart	0.08	216	Shopping Cart	0.1	150	Shopping Cart	0.1	255
Mean		131.25	Mean		168.75	Mean		93.75	Mean		159.375
% covered of 30,000m³ area	7		% covered of 30,000m³ area	9		% covered of 30,000m³ area	5		% covered of 30,000m³ area	8.5	
Total Trash Volume, m³	2100		Total Trash Volume, m³	2700		Total Trash Volume, m³	1500		Total Trash Volume, m³	2550	
# of riverbed/streamcourse alterations	2		# of riverbed/streamcourse alterations	1		# of riverbed/streamcourse alterations	0		# of riverbed/stream course alterations	1	
# of streambank alterations	4		# of streambank alterations	6		# of streambank alterations	6		# of streambank alterations	5	
Destruction of Veg	Y		Destruction of Veg	Y		Destruction of Veg	Y		Destruction of Veg	Y	
Trailbuilding	Y		Trailbuilding	Y		Trailbuilding	Y		Trailbuilding	Y	
Firebuilding	Y		Firebuilding	Y		Firebuilding	N		Firebuilding	Y	
Wildfire	N		Wildfire	N		Wildfire	N		Wildfire	N	
Encampments	Y		Encampments	Y		Encampments	Y		Encampments	Y	
Comments			Comments			Comments			Comments		

Moderate											
Nov. 2, 2012			**Jan. 5, 2013**			**Mar. 16, 2013**			**May 11, 2013**		
egory/Parame	oportion of To	Volume, m³	egory/Parame	oportion of To	Volume, m³	egory/Parame	oportion of To	Volume, m³	ategory/Paramete	oportion of To	Volume, m³
Automotive		0	Automotive		0	Automotive		0	Automotive		0
Bicycle	0.12	198	Bicycle	0.08	180	Bicycle	0.1	210	Bicycle	0.08	180
Biohazard		0	Biohazard	0.02	45	Biohazard		0	Biohazard		0
Cig Waste	0.02	33	Cig Waste	0.02	45	Cig Waste	0.02	42	Cig Waste	0.04	90
Constr. Material	0.2	330	Constr. Material	0.25	562.5	Constr. Material	0.2	420	Constr. Material	0.15	337.5
Fabric/Clothing	0.15	247.5	Fabric/Clothing	0.15	337.5	Fabric/Clothing	0.18	378	Fabric/Clothing	0.15	337.5
Food Pkg.	0.1	165	Food Pkg.	0.05	112.5	Food Pkg.	0.08	168	Food Pkg.	0.09	202.5
Furniture	0.07	115.5	Furniture	0.15	337.5	Furniture	0.06	126	Furniture	0.12	270
Misc.Glass		0	Misc.Glass		0	Misc.Glass	0.02	42	Misc.Glass	0.02	45
Misc. Paper	0.05	82.5	Misc. Paper	0.05	112.5	Misc. Paper	0.05	105	Misc. Paper	0.05	112.5
Misc. Plastics	0.07	115.5	Misc. Plastics	0.04	90	Misc. Plastics	0.05	105	Misc. Plastics	0.1	225
Organics	0.03	49.5	Organics	0.05	112.5	Organics	0.05	105	Organics		0
Other (specify)		0	Other (specify)		0	Other (specify)	0.06	126	Other (specify)	0.07	157.5
Plastic Bags	0.08	132	Plastic Bags	0.05	112.5	Plastic Bags	0.05	105	Plastic Bags	0.07	157.5
PPCP's	0.05	82.5	PPCP's	0.02	45	PPCP's	0.02	42	PPCP's		0
Shopping Cart	0.06	99	Shopping Cart	0.07	157.5	Shopping Cart	0.06	126	Shopping Cart	0.06	135
Mean		103.125	Mean		140.625	Mean		131.25	Mean		140.625
% covered of 30,000m³ area	5.5		% covered of 30,000m³ area	7.5		% covered of 30,000m³ area	7		% covered of 30,000m³ area	7.5	
Total Trash Volume, m³	1650		Total Trash Volume, m³	2250		Total Trash Volume, m³	2100		Total Trash Volume, m³	2250	
# of riverbed/streamcourse alterations	0		# of riverbed/streamcourse alterations	0		# of riverbed/streamcourse alterations	0		# of riverbed/stream course alterations	0	
# of streambank alterations	6		# of streambank alterations	5		# of streambank alterations	6		# of streambank alterations	6	
Destruction of Veg	Y		Destruction of Veg	Y		Destruction of Veg	Y		Destruction of Veg	Y	
Trailbuilding	Y		Trailbuilding	Y		Trailbuilding	Y		Trailbuilding	Y	
Firebuilding	Y		Firebuilding	Y		Firebuilding	Y		Firebuilding	Y	
Wildfire	Y		Wildfire	Y		Wildfire	Y		Wildfire	Y	
Encampments	Y		Encampments	Y		Encampments	Y		Encampments	Y	
Comments			Comments			Comments			Comments		

Minimal											
Nov. 2, 2012			**Jan. 5, 2013**			**Mar. 16, 2013**			**May 11, 2013**		
egory/Parame	oportion of To	Volume, m³	egory/Parame	oportion of To	Volume, m³	egory/Parame	oportion of To	Volume, m³	ategory/Paramete	oportion of To	Volume, m³
Automotive	0.02	18	Automotive	0.05	22.5	Automotive	0.15	45	Automotive	0.05	75
Bicycle	0.1	90	Bicycle		0	Bicycle	0.08	24	Bicycle	0.1	150
Biohazard		0	Biohazard	0.05	22.5	Biohazard		0	Biohazard		0
Cig Waste	0.02	18	Cig Waste	0.02	9	Cig Waste	0.02	6	Cig Waste	0.02	30
Constr. Material	0.15	135	Constr. Material		0	Constr. Material	0.1	30	Constr. Material	0.15	225
Fabric/Clothing	0.2	180	Fabric/Clothing	0.15	67.5	Fabric/Clothing	0.1	30	Fabric/Clothing	0.15	225
Food Pkg.	0.08	72	Food Pkg.	0.2	90	Food Pkg.	0.12	36	Food Pkg.	0.08	120
Furniture	0.06	54	Furniture	0.1	45	Furniture		0	Furniture	0.12	180
Misc.Glass		0	Misc.Glass	0.1	45	Misc.Glass	0.04	12	Misc.Glass	0.05	75
Misc. Paper	0.08	72	Misc. Paper	0.15	67.5	Misc. Paper	0.15	45	Misc. Paper	0.03	45
Misc. Plastics	0.1	90	Misc. Plastics	0.15	67.5	Misc. Plastics	0.08	24	Misc. Plastics	0.15	225
Organics	0.05	45	Organics		0	Organics		0	Organics		0
Other (specify)	0.08	72	Other (specify)		0	Other (specify)	0.06	18	Other (specify)		0
Plastic Bags	0.06	54	Plastic Bags		0	Plastic Bags	0.1	30	Plastic Bags		0
PPCP's		0	PPCP's	0.03	13.5	PPCP's		0	PPCP's		0
Shopping Cart		0	Shopping Cart		0	Shopping Cart		0	Shopping Cart	0.1	150
Mean		56.25	Mean		28.125	Mean		18.75	Mean		93.75
% covered of 30,000m³ area	3		% covered of 30,000m³ area	1.5		% covered of 30,000m³ area	1		% covered of 30,000m³ area	5	
Total Trash Volume, m³	900		Total Trash Volume, m³	450		Total Trash Volume, m³	300		Total Trash Volume, m³	1500	
# of riverbed/streamcourse alterations	0		# of riverbed/streamcourse alterations	0		# of riverbed/streamcourse alterations	0		# of riverbed/stream course alterations	0	
# of streambank alterations	1		# of streambank alterations	1		# of streambank alterations	1		# of streambank alterations	1	
Destruction of Veg	Y		Destruction of Veg	N		Destruction of Veg	N		Destruction of Veg	Y	
Trailbuilding	Y		Trailbuilding	N		Trailbuilding	N		Trailbuilding	Y	
Firebuilding	N		Firebuilding	N		Firebuilding	N		Firebuilding	N	
Wildfire	N		Wildfire	N		Wildfire	N		Wildfire	N	
Encampments	Y		Encampments	N		Encampments	N		Encampments	Y	
Comments			Comments			Comments			Comments		

'Eye-popping' number of hypodermic needles, pounds of waste cleared from Orange County riverbed homeless encampment

By ANH DO

MAR 10, 2018 | 4:30 PM

A bicyclist rides past piles of trash from the Santa Ana River homeless camp after it was cleared and more than 700 people relocated in Anaheim in February. (Allen J. Schaben / Los Angeles Times)

Crews from the Orange County Public Works department have collected nearly 14,000 hypodermic needles and cleared more than 5,000 pounds of hazardous waste — including human waste — from the vast homeless encampment along the Santa Ana River trail.

The numbers, released last week, represent cleanup work done from Jan. 22 to March 3 along a two-mile stretch of trail spanning the 5 Freeway in Orange to Ball Road in Anaheim.

The tally — 404 tons of debris, 13,950 needles and 5,279 pounds of waste — is "simply eye-popping," said Shannon Widor, Orange County Public Works spokesman.

"Nothing of this magnitude involving our crews and homeless populations has ever been done before in the county," he said.

He said the waste included propane, pesticides, solvent and paint. "We've kind of seen it all. It's a good thing it's been hauled away. People tend to lose sight that this area is part of a flood control channel, and debris can keep spreading and impact water quality," he added.

Last month, county officials moved more than 700 people living at the encampment near Angel Stadium into motels and shelters temporarily, assigning workers from the Orange County Health Care Agency to conduct assessments of the homeless to help connect them to support services.

Through March 2, 221 clinical assessments have been completed — with 493 referrals given to social services, veterans services, public health and behavioral health and more, county spokeswoman Jen Nentwig said.

The cleanup at the trail is part of an environmental remediation project that will focus on tree trimming, removing 2 to 3 inches of soil and working with Orange County Parks to repair the bicycle path, Widor said.