

Trash In Creeks: Benchmarking Solution Space and Resources

RR-22-02, August 2022

Leila Gosselink, Andrew Clamann and Mateo Scoggins

Leila.Gosselink@austintexas.gov

Andrew.Clamann@austintexas.gov

Mateo.Scoggins@austintexas.gov

City of Austin, Watershed Protection Department
505 Barton Springs Road, Austin, Texas 78704

Abstract

At the request of Austin City Council (CIUR 2234), to address prevention and abatement of trash in waterbodies, the Watershed Protection Department (WPD) researched strategies available in literature and reached out to peer municipalities, organizations, and vendors. The City of Austin already implements many of the strategies employed by other entities. While there are novel technologies for the active and passive collection of trash, most have limitations that preclude efficient use in Austin's setting. Based on the research, recommendations for the City of Austin to address the problem of trash in creeks include a progressive and three-pronged strategy: the physical removal of trash at strategic locations, improved methods to prevent trash from getting to the waterways, and strategies to reduce the quantities of some types of items that typically become trash in our community such as single-use plastics. A companion report "Trash in Creeks: A Field Survey of Trash Intensity and Source Types in Austin, Texas" (RR-22-01) provides a high-resolution characterization of Austin's trash in creeks problem. Recommendations in this report integrate the findings of the Austin field survey with the results of comprehensive benchmarking.

Introduction

Due in part to public comments that 1) assert the increase of trash in creeks over time, 2) express concern of micromobility vehicles (i.e. scooters) in waterbodies, and 3) request the reinstatement of the public camping ban, Austin City Council passed Resolution No. 20200123-108 (CIUR 2234) directing the City Manager to "prepare a study with recommendations to improve the ecological health and safety of Austin's rivers, lakes, and creeks by addressing litter problems, prevention, and abatement in our watersheds...". The resolution further specified a list of deliverables to address litter problems and illegal dumping of electric micro-mobility devices in waterways. The Environmental Monitoring and Compliance (EMC) Division of the Watershed Protection Department (WPD), in response to one of these deliverables, committed to a research effort to identify practices by peer cities and organizations (nationally and globally) and provide recommendations for actions that Austin could take to substantially prevent and abate litter in our watersheds.

Litter, overflowing dumpsters at apartments, windblown garbage from the bed of a pickup truck, storm-washed floatables, illegal dumping, encampments in riparian areas, old commercial developments lacking proper stormwater controls, and historic buried trash and debris exposed by erosion are all examples of trash that ends up in waterways. The negative externalities of trash in creeks far exceeds aesthetics and includes many expensive costs (beyond the cost to simply remove) such as:

- Litter can decrease property values in residential areas and decrease customers/sales in commercial areas (Skogan, 1990).
- The risk to human health and safety imposed by trash is increased by sharps and trip hazards, but also includes indirect biological hazards through chemical pollution and increased mosquito habitat.
- Environmental degradation from microplastics, rotting textiles, decaying foam rubbers, paint, metals, etc., is difficult to quantify and may have effects on wildlife habitat, and/or morbidity/mortality to aquatic life.
- Trash can obstruct storm sewers increasing the risk of property damage from flooding and can exacerbate erosion by obstructions in flow paths diverting storm (University of Texas at Austin, 2022).

When fully realized, the cumulative costs to the community of trash in creeks may outweigh the costs of clean up and prevention.

Aesthetic degradation promotes a positive feedback loop that invites apathy and additional littering. A lack of ownership, or a belief that someone else will pick up the litter, or simple disregard because the area is already littered (University of Texas at Austin, 2022) are all reasons for littering. Once litter is in the waterway, it may take years, decades, or even centuries to resolve. The time improperly disposed trash spends in our environment can be staggering. An item as small as a cigarette butt may only take 2-5 years to decompose, but an aluminum can take 200-500 years (*The Brazos River Authority, 2021*).

It is important to evaluate solution opportunities along all parts of the waste stream path. For example, extracting trash once within creeks will only result in the need for additional removal effort if the pathway of the trash is not intercepted. Intercepting the trash before it enters the creek will only result in continued efforts to intercept if the source of the trash does not cease. Instead, reduction of the materials commonly littered is the only method that can reduce the time and expense of interception and removal. To effectively resolve the problem, a multifaceted strategy that attacks the problem from all parts of the waste stream is necessary.

Extraction: Removing Trash within the Waterway

Faced with an ever-increasing volume of trash in common areas and riparian corridors the initial reaction is to lean into the problem and orchestrate clean ups through volunteer organizations, contractors, and additional municipal staff. However, collecting trash within the waterways is extremely time consuming, logistically difficult, often hazardous, and expensive. The economic burden often falls on the local government's budget and ultimately the cost felt by the citizens through increased taxes or a reduction of other services. A 2009 study by Keep America Beautiful found that the U.S. spends about \$11.5 billion per year to clean up litter (KAB, 2021); however, this cost is likely spiraling upward due to inflation and increased waste load.

Options for trash removal in creeks are limited in many ways (e.g., physical access, cost, time, labor, hazard, etc.) and typically take the form of hand removal due to the complexity of natural waterways. This intense physical labor is spread over a large area; Austin has hundreds of miles of creeks and thousands of miles of contributing tributaries in its jurisdiction alone. If the trash is submerged or otherwise buried the difficulty in removal is increased. Private property, limited entry points, and the

logistics of trash disposal further limits cleanup efforts. Active and passive mechanical devices installed to detain trash still require physical removal by people. Trash booms, trash racks or other devices that detain/extract trash from creek flow are problematic in regions that experience extreme weather such as Central Texas because these mechanisms could cause increased localized flooding and/or exacerbate erosion of the stream bed or banks.

Interception: Preventing or blocking trash from entering waterways

Opportunities within a community to intercept trash prior to reaching creeks are available, but often underutilized. Stormwater controls in Austin are designed to capture the “first flush” of a storm event and detain a portion of floodwaters including some interception of trash carried by stormwater. These facilities can be effective at intercepting trash if the controls are regularly maintained but may not detain floatable debris if the storm event is large. Other physical containments such as trash cans/dumpsters are vulnerable to both improper use and overloading. Undersized capacity and/or inadequate emptying frequency can lead to trash overflowing to the landscape and creeks. Increased access to waste receptacles, education and outreach programs, enforced ordinances strengthening the prohibition/consequences of unrestrained trash, and efforts to collect trash on the ground can all reduce the amount of trash mobilizing to waterways.

Individuals and encampments of people experiencing homelessness are frequently a focal point for discussions about trash in and around creeks and were part of the discussion in the development of CIUR 2234. The association of discarded items with homelessness is apparent to observers but not directly linked to larger scale trash patterns. A recent survey identified that encampments were not consistently associated with high volumes of trash in creeks (Clamann et al. 2022). Some encampments in Austin were observed to maintain a clean perimeter and may not contribute significantly to the total load of trash in creeks. Other encampments are riddled with loose items and when located within the floodplain are subject to stormwater mobilization (e.g., tent, fabrics, possessions, trash). Homelessness is a complex and critical issue in Austin that needs to be addressed at many levels, with trash service, disposal and mitigation just one of them.

Diversion of trash prior to entering the creek is a more effective and less difficult endeavor than physical removal once in the creek. Regardless of the increased efficacy, it still requires constant diligence/expense and adaptation to changing social patterns.

Source Reduction: Reducing the Supply of Trash in Our Community

Worldwide, but particularly in cities, there is a trend toward single-use, disposable and overly packaged consumer goods. Even those who ensure their trash follows the proper disposal pathway are unable to avoid the single-use industry and ultimately contribute to the increasing supply of these items entering our creeks and lakes. Although some commercial establishments, with the encouragement of their customers and through Austin’s Zero Waste efforts, are switching to compostable alternatives and reusable containers, major reductions in materials most frequently found in the litter stream will require regulatory approaches. While comprehensive regulations are difficult to institute, restrictions on use of non-biodegradable materials and packaging are likely a key tool in keeping trash out of our creeks.

Methods: Research and Benchmarking

Efforts to benchmark a wide range of potential strategies to the litter problems in Austin began with contacting other large cities in the United States. City representatives were solicited to describe strategies,

effectiveness, maintenance, problems, costs, and additional contacts. As in Austin, numerous entities are often involved in litter management efforts, and each entity might focus on only one component (like cleanups). Research efforts evolved from generalized survey questions to a more targeted focus on successful, novel, and innovative strategies/tactics.

Internet research also yielded different methods and evaluations of effectiveness, along with some specific examples of implementation. The US Environmental Protection Agency Trash Free website (US EPA, 2021) provided information on funded programs and a list of municipalities who have identified trash as an impairment of beneficial uses (e.g., recreation) in a water body as part of the water quality assessments required under the Clean Water Act (CWA). In some instances, the EPA has delegated the authority to administer the CWA to the state, as is the case for the state of Texas. Texas has elected not to include trash as a constituent to be assessed and has therefore not identified trash as an impairment. As part of their cooperation with the EPA and the CWA, those states and municipalities that do identify an impairment are required to provide a Total Maximum Daily Load (TMDL) plan to reduce the constituent of concern and the amount that must be removed and have developed comprehensive guides for Best Management Practices (BMPs) for reduction, monitoring success, and identifying gaps.

Types of mechanized and passive trash collection products were grouped by type. Manufacturers of representative products within a type were contacted for information such as purchase cost, maintenance requirements, as well as cities where the product had been implemented and contact information. When provided, customers who had implemented the products for litter control were solicited for opinions on the success/failure, and relative value. Where available, independent published evaluation of device effectiveness was obtained. Some of the most recent mechanical and automated devices have not been implemented yet in the United States, have only been demonstrated but not permanently deployed, and/or have not been in place long enough for a reliable assessment of success.

Benchmarking also included compilation of available cost data. Equipment purchase price or other “up-front cost” was typically available; however, the true cost to implement (maintenance, staffing, ancillary, etc.) was quite difficult to obtain because of the scale of implementation, the level of effort, labor complexity, and frequent overlap with other programs/organizations. For example, labor for maintenance may be provided by a volunteer group, but management of those efforts and any associated risks are born by the governmental agency, but effectively undiscoverable. A breakdown of cost information was impossible to reliably acquire for individual strategies in most cases.

For a perspective of overall funding requirements in other cities, Austin costs were compared to those provided in a Pennsylvania litter study. Nine Pennsylvania cities were examined, but the two largest are shown in Table 1 (Burns & McDonnell, 2020); the complete results are included in Appendix A. Based on their description of the categories, costs for Austin, from the Trash in Creeks Program Inventory, Analysis and Outcomes 2022 were distributed between categories as best as possible.

Table 1. COA litter program costs (\$, except for population) compared to large Pennsylvania municipalities

City	Philadelphia*	Pittsburgh	Austin FY20 (avg costs FY18-20)
Population	1,584,138	301,048	1,028,225
Litter Prevention (Trash)	1,217,000	2,734,400	2,722,203
Dumping Prevention	2,163,400	246,800	6,609,111
Education & Outreach	547,300	57,700	123,500
Litter Abatement	36,314,700	2,706,900	8,384,434
Dumping Abatement	6,376,800	232,400	1,017,986
Enforcement	1,778,300	331,300	1,990,734
Total	48,397,500	6,309,500	20,847,968**
Cost/Person	\$ 30.55	\$ 20.96	\$ 20.28**
*Most costs from FY18 (Burns & McDonnell 2020)			
**Code Enforcement Costs not included.			

Philadelphia created the “Zero Waste and Litter Cabinet” in 2016 which was guided by an Action Plan (City of Pa 2017). Philadelphia used a litter index database, which in conjunction with litter reporting through their 3-1-1 system and surveillance, guides the placement of new public litter cans and optimizes routes for litter collection. The placement of surveillance cameras for illegal dumping and where to build enclosures on parkland for trash containment as well as coordination with their transportation authority is also directed by the index and reporting.

Results

The strategies explored in this research have been grouped into three categories:

- **EXTRACTION:** Litter removal from within waterways,
- **INTERCEPTION:** Preventing or blocking trash from getting to waterways, and
- **SOURCE REDUCTION:** Stemming the Flow Into our Community

EXTRACTION: Litter Removal from Within Waterways

Current Austin Waterway Cleaning Programs

The WPD maintains a perennial presence on Lady Bird Lake via the Field Operations Division (FOD) Lady Bird Lake crew which is responsible for removing litter, trash, and debris from the main body of the lake (485 acres) and along the shoreline (14.8 miles). FOD utilizes boats (Figure 1) to remove trash on Lady Bird Lake; some have a collector bin for trash below deck. However, the skimming function with the collector bins cannot be used as designed because it has a deleterious impact on lake vegetation/organic detritus which quickly fills the bin and was discontinued. The boats are currently still used by the lake crew for trash management, but the collector bins are not employed. Austin has installed floating trash booms at the mouths of the urban tributaries to capture litter from the creeks as they discharge into Lady Bird Lake; removal of captured debris from behind the booms is eased by the access provided from the lake itself. A boom, like those at creek mouths has also been installed at in East Austin at 38 ½ street on a small tributary below a shopping center, to facilitate trash removal by unhoused workers employed through “The Other Ones Foundation (TOOF).” Performance and maintenance requirements for this boom can direct whether more of these devices should be deployed in creeks to

concentrate trash for cleanup. From October 2021 through July 2022, the Lady Bird Lake crews have removed more than 18 tons of waste material. WPD also uses vendors to provide vegetation and litter management services along more than 80 miles of waterways and over 1,100 stormwater controls.



Figure 1. Elastec Omni Catamaran skimmer boat with collector bin (*Photos courtesy of Elastec*)

The Clean Creeks Program is a joint effort between Austin Resource Recovery (ARR) and WPD to provide general litter abatement in creeks and waterways. Efforts have been enhanced in the Waller Creek Project area downtown, including providing for screening of trash at the intake structure for the flood control tunnel. Collected litter must be removed from the intake structure screen and the stilling basin pond manually.

Currently, the resources Austin has allocated to trash and litter removal are extensive. All our parks and trail systems and their numerous trash receptacles are maintained through the Austin Parks and Recreation Department (PARC) geographic area. This major effort is supplemented in high use areas, such as downtown and the Waller Creek area, by many other agencies. In the downtown area this includes the Downtown Alliance, the Waterloo Greenway, the operators of concert venues, Adopt-a-Creek volunteer groups, ARR and the WPD, among others.

Several cities are having success with hiring from within the communities of people experiencing homelessness for litter control including Fort Worth, Texas; Portland, Oregon; Pueblo, Colorado; Stockton, California; San Jose, California; Tacoma, Washington and Oakland, California through the nonprofit Downtown Streets Team (individual city contacts and <https://www.pewtrusts.org/en/research-and-analysis/blogs/stateline/2021/10/13/cities-see-trash-cleanup-programs-as-a-way-to-combat-homelessness> accessed April 14, 2022). Austin has implemented two specific efforts to both address trash at homeless encampments and simultaneously provide employment. They have contracted through The Other Ones Foundation (TOOF) to employ people from the homeless community to pick up trash. They have also targeted areas for the [Violet Bag Program](#) to encourage proper disposal and provide pick up services in and around homeless communities in Austin. Each year since this effort was instituted staff have requested expansion to the program.

If the use of TOOF for boom maintenance is successful, Austin should also consider expanding that program and other incentive-based efforts. Churches or other nonprofits that work with the communities might attempt a trade program where clothing or bedding materials that might be discarded could be traded for clean materials, or these organizations could perhaps be required to collect equivalent waste materials when making donation deliveries. There are several different programs that use the “Trash for Treats” slogan or encourage appropriate disposal, primarily through schools. Smith College handed out 320 desserts during campus moveout and collected six boxes of unwanted clothing and 27 bins of recyclables in 2016 (<https://www.smith.edu/about-smith/news/trash-for-treats-2016>). However, very few innovative programs were identified that addressed the huge problem of discarded fabric (clothes, blankets, etc).

Solutions for our littered waterways include enhancement of these current City of Austin programs; each budget cycle, funding is requested to expand those programs found to be most effective. Programs and mechanisms used in other cities to remove litter from our waterways are described in the remainder of this section with a discussion of applicability to the City of Austin.

Volunteer Cleanup Programs for Waterways

Most cities have volunteer programs, sometimes an affiliate of Keep America Beautiful (KAB-America; an affiliate search is at <https://kab.org/search-result/>), sometimes as part of City or County efforts, and sometimes through a nonprofit. Many programs, like those in Austin, are providing organization and equipment, and sometimes these programs are the primary effort in less urban areas to address their trash problem. For example, WPD-supported KAB programs “Adopt A Creek” and the “Clean Lady Bird Lake” since 10/01/2021 have removed an additional 4.3 tons of waste material solely from the lake. These volunteer efforts have the added benefit of raising awareness of the litter problem and educating community members about how their product and disposal choices impact the environment.

Many states and areas have cleanup efforts at multiple nested layers, for example, a state chapter of Keep America Beautiful (KAB- America) and an affiliate organization at a county or city level; in Austin those are Keep Texas Beautiful (KTB) and Keep Austin Beautiful (KAB). Many cities, or other jurisdictions, that operate an affiliate program do not limit registration at events, and some provide equipment only “as available” (e.g. Keep Arkansas Beautiful). Sometimes the organization and scheduling of cleanups is left solely to the volunteers, or an organization provides instruction, guidance, and equipment only, similar to KAB-Austin’s ‘Love Where You Live” program. The KAB-Austin model for the lake appears to benefit from the easy sign-up, provision of equipment and trash hauling service. The one exception is the limitations to the number of people who can be involved. A contract with KAB-Austin with a high level of funding allows negotiations with them on service provided as that contract is renewed. KAB-Austin also provides Austin with regular reports, so the success of equipping a higher number of volunteers would be measurable by the amount of litter collected.

Expanding cooperative efforts with multiple groups is also an approach that other cities have demonstrated can maximize impact (e.g. “[Source to Sea](#)”); managing those efforts would require additional staffing and/or funding. Groups could be identified by their goals relative to the environment as well as groups who use the waterways regularly for recreation or exercise. The organization of these types of events and volunteers could be primarily provided by the identified groups, with equipment or other support supplied by Austin. Trash pickup from large cleanup efforts could be requested if enough advance notice is provided, as it is for “Love Your Neighborhood” cleanups. For example, the “Animal Safe Migration” organization reached out to the Watershed Protection Department about coordination of clean up events (details provided in Appendix B). One concept that has been identified is the coordination of clean-up events with a centralized schedule so that efforts are not duplicated, and they achieve as much

coverage as possible geographically as well as temporally. KAB-Austin already maintains a calendar of events; the system could be updated to include other efforts such as cleanups by the Trail Foundation, with links provided from the City of Austin's webpage, Chamber of Congress, and social media; increased funding to KAB or the entity managing would be required.

The City of San Marcos reached out to the [Leave No Trace](#) (LNT) Center for Outdoor Ethics for a week-long focused river clean-up effort. The Center assisted in getting stakeholders together and equipping them with the tools to effectively educate visitors about being better stewards of the river. The Center held workshops across San Marcos for tubing businesses, Texas State University, local non-profits, and city managers, ending with a cleanup. The City of San Marcos engaged with those efforts with educational tents, having games for children and items like litter bags near launch and take-out points for river goers. Similarly, Austin focuses on the well-known LNT ethic. Many City of Austin Park Rangers have received official LNT training and Austin's Barton Creek Greenbelt was selected as one of a few national LNT Hot Spot locations a few years ago. LNT Hot Spot locations are popular beautiful outdoor areas across the country that have been damaged due to heavy use. The program is designed to help reduce impacts in nature including excessive trash, damage to vegetation, trail erosion and more while allowing community members to enjoy our nation's shared outdoor places. Where signage is provided, as planned for concessionaires on the Lady Bird Lake, it should include links for volunteer efforts, perhaps promoting free canoe/kayaks for those events. Grant funding opportunities might be used to supplement existing programs or test new ones. KAB-America through KAB-Texas has awarded grants for litter control since Texas was an identified focus state from the Keep America Beautiful 2020 National Litter Study (KAB-America 2021). Although most nonprofit and city staff contacted felt that signage became unnoticed after it has been in place awhile, there are some parking areas near trails and lake launch points that might benefit from "Leave No Trace" signage.

Another way to encourage participation is providing incentives for actions. City staff have approached lakeside businesses in the past but had a low success rate in gaining cooperation. Many programs have tried a variety of incentives, usually these require working with local businesses to provide a discount or prizes. Sometimes encouragement can instead be in the form of gamification or drawing on competitive spirit for large cleanup efforts. For example, forming teams, (e.g. sports teams, companies), with each team getting bingo cards for types of trash collected and prizes awarded. The City of San Marcos and Keep San Marcos Beautiful instituted [Kudo Coins](#), where staff award coins for returning full litter bags at education tents at launch and takeout points. The coins can then be passed on to other people the recipient would like to reward when they observe someone contributing to cleanup efforts or redeemed for discounts or rewards at participating merchants. Costs for the coins themselves are minimal, but organization and recruitment for business participation would need to occur. The Chamber of Commerce might assist with coordination, and it could be modeled after or be part of the "Go Local" campaign, which provides discounts or perks at local businesses. Another opportunity for coordination might be with the Austin Chamber of Commerce "chamber bucks". The simplest method would be for Kudo Coin recipients to be able to redeem one or several for a Go Local card (currently they have a cost of \$15 for citizens wanting to purchase one).

There were two unique programs identified for litter retrieval from waterbodies by community members and visitors. The Urban Rivers nonprofit in Chicago had the most enthusiastic report on the effectiveness of a program from among all those interviewed. They had built constructed wetlands and were having the common problem of how to extract litter from the vegetation. They instituted a program where free kayaks were provided for volunteers who schedule a regular cleanup time, committing to a regular 1–2 hour time slot once a week; volunteers also collect scientific information on the constructed wetlands. They store kayaks with a crate attached for litter retrieval and grabbers and gloves in a riverside shipping container and provide a place for litter disposal. They report that this almost continuous daily manual cleaning does an excellent job in the focus area. This allows paddlers in the community who may not be

able to own a canoe/kayak/SUP or are unable to afford regular rentals, the use of kayaks, and was reported to be a highly effective motivator.

Another program which is beginning to be adopted in a few areas (mostly overseas) is Trash Fishing or Plastic Fishing (Figure 2). In the US, efforts have primarily been individuals or small groups, such as an effort by a father and son in the Detroit River, who encouraged a competitive spirit in their “fishing” cleanups. PETA endorses it as a way of protecting aquatic creatures from the hazards associated with litter in water bodies. In the Netherlands and the UK, the efforts have grown from cleanups to building a boat from discarded plastics. The Canary Wharf College used plastic fishing materials to build a boat. The Plastic Whale Foundation has a method to distribute equipment for online events, hold school educational plastic fishing trips, and Plastic Fishing tours available for anyone who will purchase a ticket. The proceeds are used in their many efforts including the production of furniture from used plastic in a collaborative effort ([Plastic Whale – Together for a plastic free land & sea](#)).



Figure 2. Trash Fishing outing in Amsterdam (Photo courtesy of Plastic Whale)

Finally, while venues, condominiums, and office buildings that are on the shore of a waterbody have a vested interest in beautifying their waterfronts, much of the litter that has already entered the water body is difficult to retrieve. There is often no enforcement for littered shorelines or a way to include shoreline maintenance for new developments. The adoption of waterway segments by businesses through the Adopt-A-Creek program could help with this gap. The adoption program could alternatively be a funding mechanism for City cleanup or contract crews, as it is for Texas Highways where a highway section is “adopted” through a funding mechanism only. The City of Oakland cited success with their “Adopt-A-Drain” program, where over 750 volunteers have adopted over 1,000 storm drains to maintain. Their program was estimated to offset staff time of 10 hours/week to assist with volunteer management after their sign-up website was improved. Equipment layout costs are low at \$40-100 to outfit a volunteer. Very recently, in the summer of 2022, Austin began an “Adopt-A-Drain” program (<https://www.austintexas.gov/AdoptAStormDrain>).

Waterway Litter Collection Devices

Many cities have tried a variety of devices for capturing litter within the waterways themselves.

However, there are many limitations to this approach, including the volatile flow conditions in our creeks and reservoirs. Booms are floating devices that must span the waterway to capture floating materials without obstructing flow (Figure 3); sometimes booms include a curtain or screen below the boom, but those do not function in shallow water bodies where they would also prohibit the movement of aquatic life. The materials entrapped behind booms must be removed manually and can be lost over the top of the boom in higher flows. Booms are also sometimes used to direct floating debris to a passive collection device. Booms do break-away if a large quantity of debris is retained or in high flow conditions; this is often a design feature so they can be reattached rather than replaced. Issues in deploying booms include the aesthetic impact of corralled debris between maintenance, the loss of collected debris in high-flow conditions, and the access within creeks and reservoirs required to manually remove trash.



Figure 3. Trash Booms and Maintenance Crew (*Photos courtesy of Elastec*)

While WPD deploys floating booms at the mouths of several urban creeks, it is not feasible to install booms that span whole reservoirs or that block areas that boats traverse. For example, at some locations like the mouth of Barton Creek and vicinities near rental vendors, booms would restrict passage of water vessels. Costs of booms vary widely from \$3,000-\$5,000 per boom and up to \$2000/10-foot section for more durable booms (Table 2). Booms can also be paired at creek mouths or deeper sections with traps or capture devices. If the booms at creek mouths could be retrofitted or replaced to incorporate a device like the Elastec bins which can be emptied directly into bins beneath the Lake Crew boats (Table 2, Figure 4), that may prevent the loss of material. However, the cost of the bins can be high (Table 3) .

Table 2. Trash Containment Booms and Estimated Costs

In-Stream Trash Capture Device	Manufacturer Info	Locations Installed	Initial Cost*	Annual maintenance costs**
Litter Boom	https://osprey.world/litter-collection-devices	Birmingham , AL (funded with USEPA grant to Freshwater Land Trust)	NA - Contracts included installation and maintenance	\$20K-\$45K. Osprey maintenance contract for several devices; Mobile, AL
Trash Boom - Elastec	https://www.elastec.com/products/floatin-g-boom-barriers/trash-debris-boom/bruteboom/	San Antonio, TX	\$1K-\$2k/10-ft section	Medium

WaterGoat Trash Barrier	https://www.watergoat.org/product-page.html	Tampa Bay, FL; Greenville, SC; Boston - Charles River, MA; Fundraiser for one as teaching tool - Columbus State Univ., GA	\$3K-\$5K	"The average Watergoat can be cleaned out in less than two hours with three Volunteers. Scoop Nets or Hooking Nets are used to easily remove debris" re manufacturer .
*Capital Cost Sources: Manufacturer or Agency installing device. Where range is provided: High = \$100K +; Medium = \$10K-\$100K; Low = <\$10K				
**Maintenance Cost: Agency who installed the device or estimates from (Shields, 2020) For maintenance, annual costs: High = \$80K+; Medium= \$20-\$80K; Low = <\$20K				



Figure 4. Skimmer Boat Used to Empty Trash Trap (*Photo courtesy of Elastec*)

The more robust group of devices for collection within or at the mouths of creeks function by passively allowing stormwater to carry the litter and debris into a trash trap device, usually a metal trap or mesh, or

other sturdy material, that does not impede flow while collecting debris. Frequently booms are used to funnel floating debris to devices that are narrower than the creek width (Figure 5). The devices basically screen the debris and allow the water to flow through. Most of these devices are quite costly (Table 3) with potentially high maintenance costs, and in some instances where large watersheds are served, they are part of a much larger structure. Many cities install devices and soon revert to contracting with the manufacturer for maintenance.



Figure 5. Booms directing Floatables into Trash Traps (Photos courtesy of Bandalong and Elastec)

Trash traps typically float so that surface litter is collected in a cage or mesh as creeks rise during storm events. Some have a breakaway function like that of booms. While that prevents flow obstructions, the device and its captured litter are lost downstream. Damage to the devices can also occur when large debris and branches impact them during storms. While these devices do concentrate the litter, they still require maintenance which is more difficult than for booms because of their more limited capacity and more complicated structure; for some depending on design, a concern has been entrapment of wildlife in the cages if debris prohibits their exit. For smaller structures vandalism has been a problem. Maintenance also requires that they be located where they can be accessed for maintenance; a few of the structures reviewed are deployed only at large culverts with a well-defined cross-section. Near creek mouths, as with the booms, maintenance access is more easily provided from the lake, but the benefit is offset by these locations receiving the highest flows (bottom of a watershed) and provide no benefit within the creeks upstream. Some devices have been installed and maintained by volunteers after storm events in several Alabama waterways (Bates, 2022). If survey data, reporting and neighborhood requests identify specific locations that may naturally accumulate litter due to the flow patterns, these areas may be locations where testing smaller in-stream capture devices, perhaps with volunteer litter removal, could prevent further litter dispersion downstream.

Table 3. In-Stream Trash Capture Devices

	Manufacturer Info	Locations Installed	Initial Cost*	Annual Maintenance Costs**
Bandalong Litter Trap; Stormwater Systems	Bandalong The Original Litter Trap - Storm Water Systems	Waycross, GA; Washington, DC; Little Rock, AK; Australia; Gainesville, GA; Prince George's County, MD; Mt. Rainier, WA; Athens, GA	\$50K-\$100K	\$28K-\$40K re District of Columbia SW Management
Bandalong-Bandit (small scale)	Introducing The Bandalong Bandit! - Storm Water Systems	Smaller waterways: Chattahoochee River Keeper, TN	\$14,000	Low
LitterGitter	https://osprey.world/litter-gitter	Mobile, AL: Mobile Bay National Estuary Program; East Baton Rouge Parish, LA; Birmingham, AL,	Medium	\$20K-\$45K. Osprey maintenance contract for several devices; Mobile, AL
Trash Trout Jr.	https://www.ashevillegreenworks.org/trash-trout.html	Asheville and other cities, NC; St. Louis, MO; Roan Mtn, TN; Elizabethton, TN	Large \$25,000 Small (bank width <50 ft.) \$7,500	Low - depending on site installation
Elastec Brute Bin Trash Collector	https://www.elastec.com/products/floating-boom-barriers/trash-debris-boom/brute-bin/		\$26,000	
Trash Cage; Clearwater Mills	https://www.clearwatermills.com/trash-cages.html	Baltimore, MD	\$75K-\$110K with installation	\$5K-\$20K
*Capital Cost Sources: Manufacturer or Agency installing device. Where range is provided: High = \$100K +; Medium = \$10K-\$100K; Low = <\$10K				
**Maintenance Cost: Agency who installed the device or estimates from (Shields, 2020) For maintenance, annual costs: High = \$80K+; Medium= \$20-\$80K; Low = <\$20K				

Cities that have a litter reduction requirement as part of their MS4 permits have invested significant resources including installation of a significant number of these types of expensive devices. These cities also can provide evaluation of the devices and their effectiveness. California has an approved list for devices that provide full pollutant capture including floatables, which is included in Appendix C. It is also highly recommended that before a large investment is made, results from testing by cities currently evaluating trash capture devices be reviewed to assess applicability to Austin based on similar flow,

climate and topography along with maintenance requirements. As an indication of the interest in litter nationwide, the American Society of Testing and Materials (ASTM) has just announced a new standard test method for trash capture performance of stormwater control measures, E3332 ([Standard Test Method for Determining Trash and/or Debris Capture Performance of Stormwater Control Measures \(astm.org\)](https://www.astm.org/standards/E3332.htm)).

Deep Water Litter Collection Devices

New technologies are being developed for automated removal by machines or robots; these efforts are spurred on by the attention to ocean waste and the profusion of plastics in our environment. Some devices for capturing litter will only function with a minimum water depth, excluding most Austin's creek locations. Many of these were developed for areas with deeper perennial creeks or tributaries entering a bay or are focused on plastic pollution in the ocean. Most automated devices for freshwater litter problems have a limited track record and there is a dearth of information on their effectiveness, ability to retrieve litter among vegetation, maintenance requirements, problems under high flow conditions and vandalism, but they are being demonstrated and tested in many locales. Automated litter collection devices have the same requirement to collect and dispose of collected litter, but they have the added complication of powering the devices. One benefit to consider for some of the more unique devices is the visibility and education value brought to the public, and in particular attention brought to the litter problem.

Another type of floating litter collector, applicable only in a deeper water setting, is a small skimming device like the "Sea Bin" that has been deployed in over 800 harbors and marinas worldwide. It acts as a floating garbage bin skimming the surface of the water by pumping water into the device. The Seabin V5 can intercept floating debris, plastics, and even microfibers with an additional filter. It requires power and thus must be moored to docks or boardwalks. Operational costs are estimated to be about \$3/day and the catch bag capacity is about 20 kg; the manufacturer recommends that it be checked twice a day. The SeaBins can collect and transmit data. The USEPA and the Partnership for the Delaware Estuary have just begun (summer 2022) a program to study a network of devices placed in the river for litter removal, data collection, trash monitoring and water quality monitoring. (<https://seabinproject.com/seabin-partners-with-us-epa-pde-philadelphia/> accessed June 15, 2022). SeaBins would only be a consideration at docks or on the boardwalk to keep those immediate areas free of litter and debris; they may become more attractive if solar charging for the pump can be incorporated.

There are many efforts to develop more automated litter collection devices (i.e., robotic devices). Most of these systems have been developed outside of the United States. The most fully developed litter robot appears to be the [WasteShark](https://wasteshark.com/). Multiple WasteSharks can be deployed, and plans indicate development of a station for emptying and recharging, but no station information was provided with the specifications from the manufacturer. The specifications indicate that each robot can recover up to 500 kg (1,100 lbs.) of trash per day, with a waste receptacle holding 180 liters (47.5 gallons). The WasteShark (Figure 6) can collect water quality information simultaneously and can be operated manually or autonomously with predefined routes.

Open Ocean Engineering based in Hong Kong has a similar device called a [Clearbot](https://clearbot.com/) which can collect up to 250 kg (550 lbs) of trash/trip and, uniquely, is solar powered. Open Ocean Engineering has recently partnered with the gaming company Razer to develop a detection system to identify trash for pickup. The Clearbot catalogues and categorizes trash as well. The biggest unknown and the biggest challenges for aquatic robots are operational. Most of these devices require recharging, and to facilitate a longer deployment-time the large trash volume capacity makes the devices bulky and difficult to transport. Lake access and variable flow velocities present some logistical issues for retrieving the litter robots for emptying and charging.



Figure 6. Waste Shark Aquatic Litter Robot and photo to show scale (Photos courtesy of RanMarine for Wasteshark photo and IADYS – Interactive Autonomous Dynamic Systems for Jellyfishbot photo)

Clear Blue Sea, a nonprofit based in Australia, has developed several solar powered prototypes of a “[FRED](#)” (Floating Robot for Eliminating Debris). They plan for FRED to be designed to be scaled up, modified, or replicated by anyone interested in improving marine waters. It is currently being piloted, but their plan is that it can be successfully constructed with readily available commercial products, and they will provide the design. Another nonprofit, the Urban Rivers program, has a [prototype aquatic trash robot](#), but software issues and maintenance have been ongoing problems; their plan was that it could be controlled remotely by users online. They have concerns with vandalism and the loss of the robot, thus the implementation of a safety tether and a virtual GPS cage which will limit the area that can be served. Based on these initiatives, it might be worth pursuing sponsoring contests or working with University of Texas engineering students to construct devices.

The Jellyfishbot from an overseas company is now being heavily marketed (Figure 7). An interesting feature of the Jellyfish bot is that it can also be equipped with a sampling net for scientific collection purposes. The makers of the Jellyfishbot have offered to provide a demonstration in Austin.

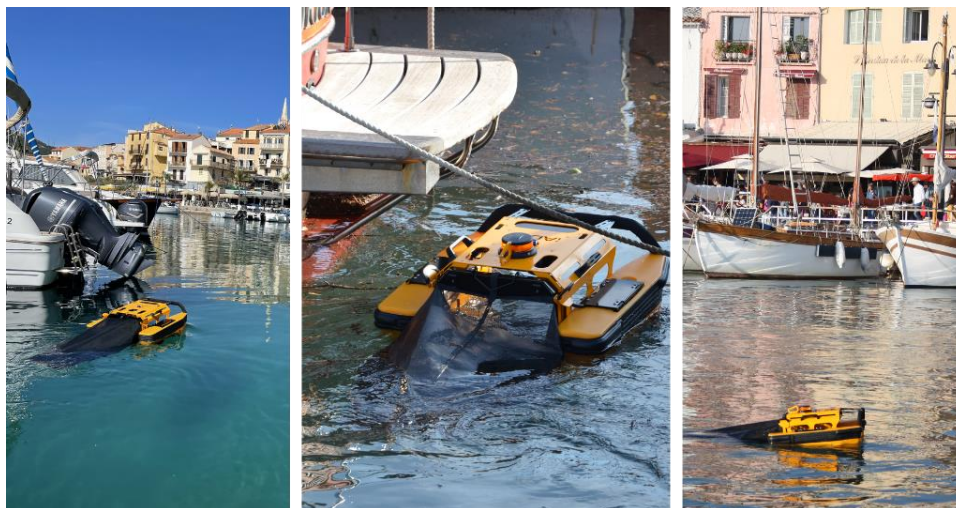


Figure 7. Trash Robot, Jellyfishbot, deployed in harbor area (Photo courtesy of IADYS – Interactive Autonomous Dynamic Systems for Jellyfishbot photo)

Some cities have piloted litter robots as part of community education campaigns and coordinated with sponsoring companies. IKEA introduced the “Good Ship IKEA” with its store opening in Greenwich, England, and Coca-Cola used pirate themed robotic vessels in London as part of the “Treasure your river campaign”; both had citizens pilot the boats. Implementation of the aquatic litter robots have not been extended on a long-term basis. Examples of other litter robots under development are a [Kickstarter for development of a litter robot](#) by the Urban Rivers program in Chicago with the intention of allowing remote online piloting by citizens and a very technologically advanced marine debris system using drones and autonomous robots called [SeaClear in Europe](#)

For some municipalities, large scale trash removal devices may offer the least ongoing operational and maintenance efforts, such as “Mr. Trash Wheel” (e.g., Figure 8) in Baltimore, Maryland. Several trash wheels prevent litter from entering the Baltimore harbor area or Chesapeake Bay, and one is proposed for Fort Worth, Texas to protect the Trinity River. Fort Worth intends to fund the initial \$600,000 cost as well as \$1,000,000 for 10 years of maintenance through donations. Baltimore’s Trash Wheel cost was \$800,000 with annual operating costs estimated at \$130,000. Several restrictions make them impractical for application in Lady Bird Lake. Areas for installation of these devices do not have boat traffic. The stationary device uses water flow to carry the debris to the collection area via large booms that direct floatables to the wheel for removal. In Austin, the tributaries are frequently dry, and there is insufficient space in the creek outflow to station a large device. Attempting to collect trash within the lake itself would require booms that impede recreational watercraft from passing. Additionally, while the manufacturer, Clearwater Mills, has offered to evaluate whether they might be able to scale down such a device (for installation at a location such as the mouth of Shoal Creek), the maintenance access for the volume of trash collected would be difficult. Trash Wheels thus far have been deployed in deep-water locations attached to a dock or other station with access for dumpster removal. In addition, Lady Bird has multiple urban creeks flowing in that contribute to the trash problem so each would need a device to be effective at reducing trash in the lake.



Figure 8. Mr. Trash Wheel in Baltimore, MD *(Courtesy of Waterfront Partnership, Baltimore, MD)*

One newly emerging technology to direct litter toward a collection device without obstructing flow uses a submerged air curtain. This technology is being tested in the Netherlands and is not yet available in the United States. This curtain of air might overcome constraints where a boom is not feasible, allowing the waterway to remain navigable yet still be able to divert the litter to a collection device or concentrate the litter in a confined area for collection. These devices, like many passive collection devices still rely on the water movement to transport the litter, so they must be placed in a flow-through system. It works by generating a screen of bubbles that block plastics and direct suspended plastics to the surface. The

bubble curtain is placed diagonally across the entire waterway and guides plastic waste to the side and into a catchment system. The benefit to this type of system is that it does not obstruct watercraft or interfere with biological life, it may benefit aquatic life by increasing dissolved oxygen. The primary costs include installation, and energy costs for the pumps that generate the bubblers. One of these systems has been deployed in an Amsterdam canal (Figure 9). [The Great Bubble Barrier](#) effectiveness is described in a company newsletter:

“Based on the results of the pilot at Deltares research institute, it has been calculated that the Great Bubble Barrier captures approximately 70-80% of top-surface floating plastic and 50% of plastic underwater. During the tests in the IJssel we looked at how these results translate in a river. We tested our Bubble Barrier at the IJssel in various weather conditions and came to the conclusion that it caught 86% of the (floating) test material. We can catch plastics with a size of 1mm and bigger, like granulate and Styrofoam. In the pilot at Wervershoof, we are investigating whether we can catch microplastics measuring 20 micrometers up to 500 micrometers (0.5 millimeters).”



Figure 9. Bubble barrier diverting flow to Containment Trap, Netherlands (*Photo courtesy of The Great Bubble Barrier*)

Another similar system is called [Azure, by Icthion](#). The costs of the systems were stated to be highly dependent on local conditions in width, depth, and flow velocity. The systems are comprised of a tube with openings along the bottom of the waterway through which air is pumped; the aeration has the added benefit of increasing oxygen in the water column.

INTERCEPTION: Preventing or blocking trash from getting to waterways

The City of Austin has sanitation codes to prevent trash from becoming litter as well as protecting our waterways from pet waste (Table 4). Currently in Austin there are several methods to physically intercept the litter before it enters the stormwater system. In new development water quality ponds capture stormwater and intercept trash but may not capture or retain floatables if the storm event is larger than the required water quality volume. Much of central Austin’s development occurred before those requirements or space is limited for placing devices. Austin does construct some retrofit facilities using the fee-in-lieu and other capital funds to construct water quality ponds to try and capture untreated flows. The Texas Department of Transportation has an [Adopt-A-Highway](#) program in place, and in a few particularly

vulnerable crossings in the recharge zone, traps to capture highway spills are in place. These traps are quite effective for capturing litter as they are designed to contain oil which also floats on the water's surface. Observation also indicates they are also very effective at containing cigarette butts. Maintenance of these devices would minimize loss of captured litter, and additional cooperative agreements with TxDOT might allow the installation of trash traps along road swales and easements.

Table 4. Applicable portion of City Code of Ordinances Title 10. Public Health Services and Sanitation and Pet Waste Sign	
<p>§ 10-5-42 - LITTERING PROHIBITED</p> <p>(A) A person commits an offense if the person deposits or throws litter on a street, alley, sidewalk, premises, vacant lot, or public property, including a park or playground.</p> <p>(B) A person commits an offense if the person deposits or throws litter along a street, alley, sidewalk, or public property, including a park or playground.</p> <p>(C) A person commits an offense if the person deposits or throws litter from cleaning the interior of a residence, business, or premises on a street, alley, sidewalk, or creek.</p>	 <p><i>(Ladybird Lake Trail near Statesman Bat Observation Center)</i></p>
<p>§ 10-5-43 - LITTER REMOVAL REQUIRED.</p> <p>The owner or occupant of a business or residence adjacent to a street, alley, sidewalk, or public property on which litter is located commits an offense if the owner or occupant fails to remove the litter from the one-half of the street adjacent to the owner or occupant's property not later than 24 hours after the owner or occupant becomes aware of the litter.</p>	
<p>§ 10-5-45 - PENALTY</p> <p>A person who violates this article commits a Class C misdemeanor, punishable in accordance with Section 1-1-99 (where this violation is punishable by a fine not to exceed \$2000).</p>	

Pathways on the watershed surface can sometimes be identified and litter intercepted before it enters the storm drain system. In the downtown area of Austin, inlet filters are in place to capture large trash in areas most heavily used by tourists and for entertainment. These filters do not capture all trash as an overflow is provided to prevent street flooding. The labor to empty these regularly is quite demanding as they must be manually removed and emptied into collection vehicles. Because they are within the inlet itself this process cannot be mechanized. If the inlet sumps are pumped out on a regular basis, installation of a mesh hood within the inlet would exclude the floatables from moving down into storm sewer pipes. These devices might also increase maintenance requirements to prevent any clogging within the inlets. Trials of several inlet types have led staff to conclude that the filters originally put in place in Austin are preferred for ease of maintenance (pers. comm. John Beachy, WPD). Expanding the area where inlet filters are used is cost prohibitive due to the intensive manual maintenance requirements and thus, their use is limited to areas of high foot traffic and tourist activity.

Prevent Litter from Reaching Waterways

Methods that prevent litter on the watershed surfaces from entering the waterways provide protection not only for the receiving water bodies (reservoirs in Austin) but also the creeks. Ensuring that residents, commercial developments, and construction areas comply with existing regulations is a first line of defense. Philadelphia has instituted the [Streets & Walkways Education and Enforcement Program](#) (SWEEP) that educates Philadelphia residents, businesses, and property owners about sanitation regulations and enforces code violations. SWEEP officers are trained, uniformed civilians. They educate local businesses and apartment managers about their responsibility for keeping their properties clean, work with communities on outreach efforts, patrol streets to enforce litter laws, and issue warnings and citations. Philadelphia states that their entire SWEEP program, education and enforcement, costs approximately \$2.3 million annually. This type of approach to keep watershed surfaces as clean and litter-free as possible, along with interception works to prevent litter from reaching waterways.

Some entities require the retention of litter when using the water bodies for recreation. One highly effective method on the Buffalo River in Arkansas is focused on requiring all river users to follow a set of National Park Service (NPS) rules for litter control (Table 5). Concessionaires on the river must have a permit from the NPS and display and enforce the rules as well as provide mesh litter bags. The provision of requiring mesh litter bags to be on watercrafts not only prevents the loss of trash into the water body but provides a place to contain any extra litter collected while recreating.

Table 5. National Park Service Watercraft Rules for Buffalo River, Arkansas

- **Glass Containers:** The possession or use of glass containers in caves, on trails or waterways within 100 feet (30.48 meters) of any river or stream is prohibited for public safety, except in designated campgrounds, picnic sites, or in vehicles on designated roads and parking areas.
- **Mesh Litter Bags:** All canoes, kayaks, tubes, rafts, and other vessels easily susceptible to swamping, tipping, or rolling must have an attached closeable mesh litter bag. All trash must be disposed of safely and legally. A mesh litter bag is not required for people traveling without food or beverages. If you rent your vessel from a park authorized concessioner a litter bag will be provided with each vessel. You may also purchase a litter bag from a concessioner for use in your privately owned vessel. Visit our park's **Canoe Rental** page for a list of park authorized concessioners.
- **Fasten Cooler Lids:** If you are transporting food and/or beverages in a vessel on the river, it must be kept in a sealed cooler or container that prevents the contents from spilling into the river.
- **Use a Floating Holder (Koozie) for Beverages:** All beverage containers not securely contained in a sealed cooler or mesh litter bag must be held in a floating holder that is designed to prevent it from sinking beneath the surface of the water.
- **Foam Coolers:** The possession of polystyrene coolers (commonly known as Styrofoam) is prohibited while floating or camping along the Buffalo River, except in developed campgrounds, picnic areas, landings, roads, and parking lots. This prohibition includes cups, plates, coolers, ice chests, and containers. High-density bait containers, used solely for that purpose, are allowed.

The City of Austin has similar parks rules, prohibiting concessionaires from selling refreshments in Styrofoam, and prohibiting glass and cigarettes in parks. Unfortunately, these rules do not apply to the waterbodies themselves and many citizens of Austin, but especially visitors, are unaware of the rules. Park rules should be published at parking areas and other access points to parks, creeks, and the river.

Currently the Parks and Recreation Department is working with concessionaires to develop “Leave No Trace” signs. Concessionaires could also be used as a vehicle to distribute mesh litter bags, even if not required, they could be offered. If informational tents are used by the City of Austin or other partners at launch and take-out points during high water traffic times, litter bags could be provided there as well. The link to parks rules on their webpage could benefit from a short rule summary as seen above for the Buffalo River.

One additional type of inlet protection are trash guards or curb inlet screens. Curb inlet guards simply block all trash from entering curb limits with screening or flaps (Figure 10), costs start at \$1,000 to \$1,500 per inlet for 3-5 foot inlets. Curb inlet guards differ from inlet filters as they do not capture or retain the trash, but rather allow stormwater to enter while blocking litter that is then washed down gradient along the street curb, thus avoiding clogging. They were evaluated in California as an alternative to having to provide full capture for trash reduction and achieved a 63–78% reduction in trash (Fusco & Fons, 2019). While these are a low cost retrofit, they must be used in conjunction with a rigorous street cleaning program to collect the litter before entering the waterway through another path. Their benefit is exclusion of trash from inlets, while reducing maintenance difficulty. The disadvantage of these devices is that the street litter would remain visible until cleaned and may just move litter to another location downgradient of areas with inlet protection.



Figure 10. Custom Curb Inlet Guard, Myrtle Beach and BioClean Curb Guard (Photo courtesy City of Myrtle Beach and BioClean)

Some municipalities require that businesses and residents provide maintenance of sidewalks and adjacent portions of the street surface. New York City inspects and enforces their requirement that both residential and commercial properties clean sidewalks and the surface 18 inches from the curb. Austin has the requirement (Table 4) that the owner or occupant of a property remove litter adjacent to the street centerline but may require a program like the SWEEP program in Philadelphia to educate and monitor compliance. Advertisement of our reporting system (3-1-1) might facilitate those activities, and neighborhoods who are having a problem with excessive litter in commercial areas could be encouraged to use the Austin 311 system.

Austin has an existing street sweeping program; the frequency of street sweeping varies by area type. Some cities have more structured street sweeping programs that post street sweeping dates and times scheduled so that parked vehicles can be relocated. Baltimore posts parking requirements to facilitate daily sweeping in their downtown area, while areas that are swept monthly do not have signs but there is a schedule and residents are encouraged to move their vehicles. Typically, one side of the street at a time is cleaned, enabling cars to be simply switched to the alternate side. New York City also uses an alternate street side parking system, with tickets issued for cars blocking street sweepers; informational signs note schedules. If responses to 3-1-1 litter complaints are too numerous to address, they could be tracked in a geographic database and that information used to target the street sweeping program. Logistics of varying schedules may be difficult to implement, but that may be a project that could use advanced technology and transportation optimization software for future implementation. Increased street sweeping

capabilities, including for curb inlet guards, comes at a capital cost of \$200,000 for new sweepers and an estimated \$60,000 for operating costs.

Other interception devices that were tested in the past that did not meet pollutant removal requirements, might be reconsidered as floatable controls. The devices that capture floatables within the storm drain system include those that can be inserted at junctions in the storm drain system. A Stormceptor was installed in a storm drain junction in the Rosewood neighborhood for testing its efficiency, and it did not meet requirements for sediment and pollutant removal. If used solely for the trash capture, they could be effective for retaining floatables but during the City testing the unit became clogged (Glick et al., 2013). Devices like hoods or trash guards within stormwater inlet catch basins can block trash from moving from the catch basin to the stormwater pipes. New York City has hoods installed in the catch basins to retain floatables in the sumps and inspects them on a regular basis or in response to complaints. Capital costs are comparable and maintenance requirements depend on maintenance of inlet catch basin sumps. A manhole must be removed, and the contents pumped out; if catch basin sumps are already being maintained using vacuum trucks maintenance should not be significantly increased. If certain storm drains are transporting trash from a highly developed area, a limited number might be employed. Consideration might be given to including them as part of large construction pollution control plans. These sites lead to increased litter in the area with the introduction of numerous trucks carrying supplies. If the closest storm sewer junction downstream of the site was required to have a temporary insert and maintained regularly, it would capture the materials not retained on the site.

Another example of devices which are better for capture of floatables than pollutants are the large underground vaults put in place at the Austin Recreation Center and as pre-treatment to capture litter and debris before discharge of stormwater to the Convention Center Wet Pond. This type of device has also been used at some commercial areas due to lack of sufficient area for above ground ponds. A big issue with underground treatment devices is the tendency to allow maintenance to cease; the lack of visibility of the devices or their condition leads to neglect.

End of pipe solutions considered by Austin for capturing trash at a pipe or other outfall structure suffer similar problems with clogging/increased risk of flooding, access, and maintenance. An example of an outfall capture device that was evaluated in Austin are netting trash traps, essentially netting bags attached to the pipe (Figure 11). The maintenance can be simple if not desiring to sort trash; the entire filled netting attached to a pipe end is removed and discarded as a whole. The capital is relatively small for the first bag (\$5,000 each for those tested in Austin) but since that cost must be repeated for each maintenance event, the long-term costs are enormous.



Figure 11. StormX Netting Trash Traps (Photos courtesy of [Stormwater Systems](#))

Large commercial retail locations with high customer traffic often results in littered parking surface which gets washed into a waterway. Another alternative or addition to an outfall capture device would be a requirement that these strip malls and large grocery establishments retain their litter on-site. These sites (defined by retail sales with parking area of a certain size) could be required to install fencing or other surface debris control of a specific height to contain blown material around their parking areas. This solution may lead to some unsightly areas of the enclosures, but the business would be required to retain their waste. Contrary to the Texas waste laws, this would be putting the onus of managing their waste on the proper entity rather than on the taxpayer. A requirement like this could be put in place as a development water quality control or it could be a negotiation for a frequently reported litter problem.

Each of these smaller scale solutions has the added benefit of improved litter conditions and the reduction in effort of removing litter after it enters the creeks. But, because these flows paths must be intercepted before reaching creeks, many more locations must be treated. The most comprehensive litter capture solutions would be locating them at outlets at each drainage area. The large number of locations and thus devices needed, if not instituted for each development, makes the capital cost and maintenance requirements substantial. Currently, volume exceeding the required capture for water quality ponds, bypasses or flow around the pond. Wet ponds in particular catch a lot of trash due to their flow-through design. These ponds do collect trash and must be maintained every 6 months per the Environmental Criteria Manual 1.6.3. Inspection reports will show if there is a trash/debris deficiency during commercial and residential inspections. Amending our development code to specify capture and treatment of floatables in all water control devices would be the most effective way to capture litter for new developments.

Increase Disposal Convenience

Trash cans, dumpsters, recycling bins and all manner of trash collection devices are ubiquitous in our urban areas, but they are vulnerable to lack of use and overloading (Figure 12). Their effectiveness is ultimately limited by the diligence of use and frequency of emptying. Convenience and sufficient capacity of trash receptacles can, however, greatly increase their effectiveness. In the 1950's Disney increased the number of trash bins until a can is never more than 30 feet away, based on the distance at which improper disposal increases. Keep America Beautiful (KAB America 2021) found that at the time of improper

disposal, the average distance to the nearest receptacle was 29 feet. Littering increases as the distance to a trash receptacle increases and more littering acts occur in areas that already have existing litter. An observation from a recent study on trash in Austin’s creeks found that the amount of trash in encampments was highly variable (Clamann et al., 2022); some areas have little to no peripheral trash and others have a dense amount of trash. Areas that did not have much trash were typically near serviced trash receptacles whereas encampments deep in floodplain/greenbelts displayed a dense accumulation of trash.



Figure 12 (a) Trash near paddling concession, Lady Bird Lake (left) and (b) PARD trash cans near paddling concession (right) (*Stephen F. Austin Dr. across from Austin High School*)

Concessionaires on City of Austin land could also be required to provide litter bags to customers. Litter bags could also be provided by Austin staff doing “Leave No Trace” education events. The Missouri Department of Conservation’s [Stream Team Program](#), provides mesh trash bags to river recreationists, including through canoe-rental operations as part of their “Stash Your Trash” program. The program has an annual operating budget of \$80,000 for the purchase of mesh bags to be distributed free of charge for the states more than 1.3 million visitors a year.

The simplest device to prevent trash from becoming litter on Ladybird Lake requires boaters to deposit their trash in a receptacle on the waterway itself. The City of San Marcos, Texas, deploys “Litter Boats” on their rivers during high use periods (Figure 13). Logistics to be considered include locations to avoid restricting boat traffic and maintenance requirements; San Marcos reported emptying boats several times a day during weekends and holidays (Amy Thomaides, City of San Marcos, pers. comm. 5/2/2022). This type of device is only applicable where people are recreating in the water without easy access to land-based trash receptacles. There is some concern that disposal as watercraft float by may miss the receptacles and rather than being retrieved and packed out, contribute to the litter problem.



Figure 13. Litter Boat in San Marcos, Texas (Photo courtesy of Pecan Park Riverside RV Park)

Potential locations for floating trash bins like the Trash Boats are areas where recreation and alcohol consumption are concentrated. During lake cleanups a high incidence of crushed cans and bottles and other beverage containers are seen below Barton Springs Pool and on the lake bottom where a delta has formed a shallow area as Barton Creek enters Lady Bird Lake. Barton Creek does not have a boom at that location because it would block the entrance of rented watercraft from the Zilker Park canoe/kayak rental venue as well as prohibit the regular recreational use of that lower portion of Barton Creek by standup paddleboarders. For the mouth of Barton Creek, a canoe or trash receptacle might be anchored or attached below Lou Neff Point, allowing emptying from the shore. Providing on-the-water receptacles not only provide a place close to the source for disposal of trash generated while enjoying the water, but also make it more convenient to dispose of other floating litter, thus encouraging litter collection during recreation.

Compacting trash receptacles are devices that have been incorporated in some programs because of their ability to contain 6-8 times as much waste as a regular bin (Figure 14). Austin Resource Recovery (ARR) had a trial of solar powered compacting trash bins on Guadalupe Street due to the problem of overfilling. It was determined that they would no longer be used for two primary reasons. The recycling side filled up quickly, but because of the nature of mixed recycling, the compaction was not ideal. The other reason was that ARR crews were already working on a regular fixed schedule, so the added benefit of a trash can that could alert staff when emptying was needed did not fit with routine maintenance. Philadelphia incorporated the installation of close to 1000 solar-powered Big Belly trash receptacles throughout downtown and the commercial district. At a cost of over \$4,000 per bin, major modifications to current maintenance programs would be required to offset the cost of the bins with any gain in reducing the emptying frequency due to compacting and directing efforts more towards high trash areas. Another added benefit of compactors is eliminating the ability to scavenge for trash. Two companies were identified that market these, both solar powered, [Big Belly](#) and [Ecube Labs](#) both offer optimization of bin maintenance and deployment.



Figure 14. Solar Powered Compacting Trash Cans (Photo courtesy of [Big Belly](#))

Another area of frequent overfilling are outdoor eating establishments and other areas used for that purpose (Figure 15). Rules may need to be revisited for these commercial businesses, or requirements through the MS4 program coordinated. One suggested requirement is a lidded garbage receptacle for every picnic table, potentially along with increased dumpster requirements.



Figure 15. Trash Area of Food Trailer Court (Photos from Juniper St., East Austin, TX)

Some areas tend to have a plethora of litter due to their role as transition areas, where citizens are moving from into an area where smoking, beverages, or food are not allowed. Parking lots of secondary schools and to-go food establishments are areas where trash needs to be discarded and frequently the bins are inconvenient (more than 30' spacing) or overfilled. Schools should be encouraged to maintain their parking areas and bus stops. The City of Austin could work with Austin Independent School District (AISD) to promote environmental efforts from their students. Education programs discussed in the following section would recruit student participation.

Cigarette butts are not as visually obvious in the creeks themselves, but still litter the ground around benches, trash cans, and particularly in transition areas where smokers are going into an area where smoking is prohibited. One device that has been implemented in numerous cities worldwide is a “cigarette butler” or “sidewalk butler”, a small disposal container that can be attached to a utility pole that is

specifically for cigarette debris. In entertainment districts, these are reported to be effective in keeping the butts off the sidewalk, providing a convenient alternative to “flicking” them into storm drain inlets. Corpus Christi’s downtown management district invested in these through a grant awarded by the Council of Governments and the Texas Commission on Environmental Quality (TCEQ). The UK organization Hubbub initiated a #neatstreets program with sectioned “ballot bins” (Figure 16), that “gamifies” cigarette butts by using them to vote on various topics (e.g., their favorite soccer player or sports team). Hubbub is a nonprofit that also provides [free resources and campaigns](#), only asking that they be informed of the projects.

Bus stops are a prime location for cigarette butlers. They would require maintenance but could be emptied with the waste receptacles. Allowing beverages on buses might lead to them being left on the buses but might reduce loss to the environment if a waste container was provided on the buses. Compacting trash cans or, if a bottle bill were instituted in Texas, refund stations for containers at the bus stops are additional alternatives. Several cities have positioned solar powered compacting stations at bus stops including San Francisco and Philadelphia.

[Terracycle](#) is an organization to which you can ship tobacco waste (butts, cigarette packaging) and will recycle the waste for free. There is no cost unless you purchase shipping containers from them, but you can use any container. Maintenance coordinated with the Downtown Alliance for the downtown area and south congress would be initial locations to investigate. A successful funding opportunity is a cigarette litter tax; a litter survey and analysis of data collected using the Litterati App was used to justify, and in fact increase, a litter tax for San Francisco (pers. comm Jeff Kirschner, Litterati). Although the state of Texas prohibits any other jurisdiction from charging a cigarette tax (Texas Tax Code Title 2. Subchapter J. Sec. 154.601STATE CODE CITATION). it may be worth pursuing an increase in the state cigarette tax with the proceeds being distributed to municipalities for litter abatement.

Philadelphia also created the “Community Cans” program to place over 50 wire mesh litter cans in the public right-of-way, in partnership with sponsors in commercial districts. Although cleanup at event sites might be sufficient, parking areas such as the Mopac Access Road, north of the river near Zilker Park, and other adjacent event parking areas, might be considered for temporary trash receptacles. Temporary trash receptacles could be coordinated with roadway barrier distribution and pickup after the event. The importance of the provision and maintenance of abundant litter receptacles is emphasized in almost every big city.



Figure 16. Vote with your Butt London “Neat Streets” project through Hubbub. *(Photo courtesy of Hubbub)*

Another source of litter is spilled trash during recycle and trash collection, both at commercial and residential locations, and illegal dumping. For commercial facilities, increasing inspection of waste areas may address this as well as reporting. For city collection, it may be another opportunity to coordinate with street sweeping on the same or next day which would also make it easier for residents to remember to relocate street parked vehicles if implemented. The City of New Orleans had a problem with illegal dumping near their ports, so they installed a dumpster in the area, which a contractor removes and replaces every two or three weeks for \$200; \$7,000 was spent to develop signage directing trucks to the location (USEPA 2016). Travis County funded a comprehensive study to identify strategies to address illegal dumping (TSU 2021). The study found that it is five times more expensive to cleanup than prevent illegal dumping. As a result, the county has established an online tool to help locate disposal methods more easily at www.traviscountyrecycles.com. Texas State University also recommended developing an illegal dumping online reporting tool, collecting data from that effort, and implementing pilot programs for reduced-cost options for waste disposal.

Community Education

The City of Austin has a robust community education strategy with programs in youth education, marketing and technology. The desired result is changing individual behavior patterns to properly dispose of waste and participate in cleanup programs. The Watershed Department has recently used new applications of statistical methods, collaborating with the University of Texas to analyze the response to outreach programs and identify programs that successfully move citizens from awareness of a problem, to gaining their interest and desiring to help, all the way to taking action. Use of that type of analysis would target programs that successfully change citizen and visitor patterns, from awareness to action. More information on this new effort can be obtained through the Data Analysis/Decision Support Team in the Watershed Protection Department.

KAB-America identified 85% of littering as the result of individual attitudes and state that changing individual behavior is key to preventing litter. Every jurisdiction contacted has community education programs and campaigns. Each jurisdiction, however, has consistently offered the opinion that while

education in schools is essential to establish a baseline understanding of an individual's impact on the community, anti-litter slogans and campaigns lose their influence over time. Some programs, tap into a community's identification and pride of place. "Don't Mess With Texas" has been repeatedly cited as an example of a highly effective campaign and efforts to replace it have met with resistance. However, enhancements to refresh a campaign, such as using native Texas actor Matthew McConaughey can bring new recognition to the issues. Signs, even those displaying rules, have the same problem of lack of notice when they have been in place for an extended time. Without enforcement action or notice of violations, they soon become ignored.

One program that many municipalities have adopted is marking storm drains. Markers or painted signs on stormdrain inlets inform citizens that anything discarded in the drains ends up in the creek. Austin has a [stormdrain marking program](#) that has marked approximately 12,000 stormdrains (Figure 17). This program educates citizens that the items that enter the inlets do not go to a treatment plant, which can be a perception for people from areas with a combined sewer system, that route stormwater and sewage to treatment plants. While these older combined sewer systems are being phased out, the perception that pipes lead to a treatment plant still lingers. In high tourist areas, [more eye-catching graphics might be employed](#) to attract attention and prohibit the casual disposal of items into the storm drains and onto the streets. Japan has a street decorated with a paint that is only visible when wet which brings a surprise element to the flow pathways on the street surface leading to the inlets.



Figure 17. Stormdrain Inlet Art (Photos courtesy of Friends of the River, Fort Wayne, IN)

The Don't mess with Texas campaign has an [app to report litterers](#) In Texas and in almost all jurisdictions reported violators receive a notification in the mail (identified by license plate number) stating the law and the potential fine if an officer observes them littering. Representatives from several jurisdictions have communicated that fines are primarily assessed only in the case of illegal dumping, which have higher penalties. When asked how likely it is for someone to get caught or fined because of littering in a Philadelphia study, approximately 80% of respondents said, "Not likely at all" (Pennsylvania Litte Research Study 2020). The City of Austin has incorporated a message about reporting people parking in handicapped spaces on some of their meter pay stations; there may be an opportunity to include the Report A Litterer program information there as well or on metering stations in severely littered areas.

A highly recognized slogan like "Leave No Trace" becomes an ethic that many people adopt and use to call out bad behavior. Incorporation of that nationally recognized slogan into Austin's education campaigns taps already established behaviors associated with the slogan. And although the slogan in the past was used for wilderness camping and hiking, the concepts should carry over to packing out and proper disposal even when visiting an urban trail or water feature as well as enjoying a park.

One enhancement to Austin efforts would encourage reporting of frequently overfilled trash cans. A model that could be used is the "How am I driving" sticker seen on commercial vehicles; a sign could be posted on prioritized trash cans with a QR code for reporting ("Am I too full? Please report here"). An

example priority area would be overfilled parkland trash receptacles and concessionaire trash facilities in parks. While contracts with concessionaires require that they manage their own trash, they are frequently overfilled and nearby park receptacles quickly become overfilled as well (Figure 12b). Combined prominent “Leave No Trace” signage (including how to report litter issues) and perhaps even litter fine reminders, would encourage proper disposal.

The City of Austin incorporates litter education into its youth programs at all education levels. These efforts have been expanded, revised, and evaluated over time, from sorting trash to examining waste streams (using a recycling relay game) to watershed models that teach how pollutants move through the watershed (using physical models and Trash Travels posters). One enhancement of the programs would be to encourage more schools to adopt a nearby creek segment or at least include a “Love Where You Live” cleanup as part of their program. Recruitment could be coordinated through school science programs and school clubs and community service hours could be used as an inducement for participation. Schools should be encouraged to provide opportunities and sanction time for students to perform cleanups, design signs, design a program, or even generate an app to help with cleanups. Sports events and litter generated there provide another opportunity for volunteer cleanups (by service clubs or for service hours) and education.

Litter education could also be expanded to include data and even geographic analysis depending on the grade level. Several Apps have been developed that allow the collection and analysis of litter collection data. One of the apps is discussed below, but app use could be incorporated in Austin’s environmental education. The City of Austin investigated the use of the Litterati App for their recent Trash in Creeks survey; this App includes a sophisticated program to quantify litter collected by type and even by brand, along with geographic location data. The software has a recognition function that identifies this information from a photograph of each piece of litter collected. Raw data can be downloaded free, but more selective retrieval and in-depth data analysis and visualization is done by Litterati under a contract or cooperative program. Some cities are participating in the efforts, but some have also identified difficulties with using the data. Over time, if many of the participants in cleanup activities entered their data into the same App, the data acquired might approach that achieved by a comprehensive random sampling plan. Some issues of concern are user bias in litter collection (sometimes biodegradable items or smaller fragments are not retrieved). The data may also be heavily weighted for more frequent users or locations that are more frequently visited. Franklin County in North Carolina has a contract with Litterati, but a county representative who works with cleanups noted that the biggest drawback is the substantial increase in time required for cleanups, since each individual cigarette butt or piece of paper is photographed. Most programs track general quantities, like number of trash bags, or for large City efforts pounds collected, which is easily comparable across programs and locations.

Cleanup programs for watershed surfaces are like those for creeks. KAB-Austin has the “Love Where You Live” program that provides equipment and trash pickup, if notified in advance, for individual or group cleanups at any location. A recent trend in the US is to engage people in litter pickup who are out frequently exercising or walking. Sweden began the trend called “plogging” and in Swedish it means pick up and run and it is catching on globally. You can even purchase backpacks and bags, or plogging kits (a bag and a folding grabber). A quick search of the hashtag #plogging on Instagram or social media shows the increasing popularity all over the planet. Some towns have embraced plogging and are organizing events. The Hillsborough Township Community in New Jersey frequently includes the fact that plogging burns about 22% more calories than jogging alone. To highlight and promote this new activity they sponsored events with the first 100 participants receiving plogging litter cleanup kits. Some communities have formed groups to “plog” together at a regularly scheduled time. “Plogging the Keys” meets on the same day each week at a different location. Individuals who prefer to “plog” on their own can still be involved in a community that shares their efforts such as the Facebook group “Plogging in the USA” (which has a #dontmesswithtexas entry). A plogging campaign could kick-off the sport in Austin by

providing equipment, perhaps as an extension of KAB-Austin's "Love Where You Live" program. Informational packets could be provided to institutions, schools, the YMCA, and other organizations who might use the activity for team building or as an additional summer camp activity.

As Austin continues to grow, its litter problem reflects the population increase which includes the large influx of visitors. Many of our programs focus on our citizens. More effort may need to be made to prevent improper waste disposal by visitors who don't have the same motivation as citizens to protect the environment they live in. A program expansion might focus on convenience and capacity of visitor areas, with reminders displayed, and highly visible events and cleanups that can be tied with tour activities and new experiences like plastic fishing or plogging. As cleanup efforts that include visitors have increasing participation, results should include not only a cleaner environment, but increased motivation of participants to be more careful to properly dispose of waste in our city.

All the efforts that prevent litter from entering our waterways are a better solution than perennial cleaning. An example of costs of a large-scale campaign was [Your Litter Hits Close to Home](#) in Maryland, Virginia and the District of Columbia including advertisement, visuals, communication, and community outreach. Over approximately six years, a total of about \$500,000 was spent on implementing the program, fronted by approximately \$300,000 in research and development of the program. A smaller scale example is the [Trash Free Schools Project](#) in Maryland and the District of Columbia sponsored by the Ferguson Foundation with an annual budget of \$15,000.

The Clean Water Fund developed a technical assistance program that partners with local governments to "ReThink Disposable" packaging. Their program costs are approximately \$300,000 per year. They found that the cost to businesses is the purchase of re-useable products with a proven payback period, but they save an average of \$3,000 to \$4,000 annually after the initial investment. In San Francisco, 112 food businesses and four institutions reduced disposable product usage by over 10 million products and prevented 120,000 pounds of waste. A case study with a high school resulted in annual savings of \$6,459 in food ware costs and a reduction of 3,376 pounds of waste. Case Studies can be found at <https://rethinkdisposable.org> along with resources opportunities to partner.

Even though preventing litter from entering our waterways is a more effective and less difficult than physical removal, it still requires constant diligence and ongoing expense and ultimately may do nothing to affect the flow of single use and disposable items into and throughout our community.

Source Reduction: Stemming the Flow Into our Community

Regulations

Regulating the production or use of materials or specific products are perhaps the most difficult solutions to implement. Although they may initially seem the least expensive solution with no initial capital investment or ongoing maintenance there are potential large development and implementation costs such as interfacing with impacted business communities and potential legal fees.

The most effective method of reducing litter is to eliminate availability of materials that are most frequently discarded and are most predominantly seen in our waterways. Austin has regulated some materials primarily based on health and safety. Cigarettes and glass are banned in our park system unless otherwise specified or if allowed for certain events. To aid in the litter problem, PARD has also banned the use of Styrofoam containers by concessionaires selling refreshments on City property. WPD's recent Trash in Creeks survey (Clamann et al., 2022) noted that plastics were numerically dominant in all watersheds. Polystyrenes and other floatables were also frequently amongst the most common materials

observed. These materials are used to produce most single use containers for beverages and to-go containers. Large fabric materials could, however, dominate the observed litter based on their greater volume. Besides the large physical size of fabric items found, from clothing to sleeping bags and blankets, when saturated in the creeks they become heavy. Their prevalence may be due to their lack of movement as they are weighed down or entangled and trapped on rocks, branches, and bridge structures. Plastic, polystyrenes and other floatables on the other hand are more easily transported through the creeks and to the Colorado River.

Some entities report a reduction in litter in areas that have bans/restrictions. The Marine Conservation Society (MCS), which runs the largest annual cleanup event in the United Kingdom (UK), found that litter on beaches has dropped to the lowest level in more than 20 years, after a ban on a few single-use plastic items (such as plastic bags and cotton ear buds). The reduction was significant even though plastics and polystyrene still made up 75% of all the litter collected (MCS 2014).

Cities and states in the US with various bans in place all reported success in reducing litter. The most banned materials are plastic grocery bags, single-use plastic water or beverage bottles and polystyrene food packaging. California's state agency said that they are seeing a substantial decline in plastic grocery bag litter on beaches, rivers, and parkways after a single-use plastic bag ban; this reduction is supported by data collected from the Coastal Clean-Up Day only a year after the ban went into effect. Sometimes additional measures are needed when only one specific product is banned. The University of Vermont saw an initial increase in consumption of other bottled beverages (Berman & Johnson, 2015); they are continuing their efforts by increasing water stations and stocking them with biodegradable cups. (Berman & Johnson, 2015). The overwhelming opinion of government and nonprofit representatives where bans were in place was that regulations have the most immediate and largest impact on litter. An added impetus for reduction of plastic materials is that they use large amounts of petroleum resources to produce as well as contributing to less visible microplastics in the environment and our drinking water.

Comprehensive bans of multiple litter materials or product types have even been put in place at a national scale. For example, India is banning 19 identified single-use plastics, including polystyrene and "expanded polystyrene" (aka Styrofoam), beginning July 1 of 2022. And, in India in August of 2021 the manufacturing, import, stocking, distribution, sale, and use of identified single-use plastic commodities was phased out because of their low utility and high littering potential. The Indian Environment Minister has said the ban will be strictly enforced with penalties including jail time.

Some jurisdictions have bans on multiple products, as separate or combined laws. Usually the bans were phased in, providing time for the products to be replaced with re-useable or compostable products. The bans that have been in place have faced several issues. For example, the definition of a single-use bag sometimes led to slightly thicker bags or the definition of compostable was not specific and led to containers that could not be accepted into the composting waste stream. The prevalence of single-use plastic/polystyrene beverage and food containers from the Trash in Creeks survey in Austin indicates that any reduction in their use would provide a significant reduction in litter.

Single Use Plastic Bags

The most widespread bans are on single-use plastic bags and on polystyrene products. Single-use plastic bags are used on average for 12 minutes. Humans use 5 trillion plastic bags per year; 160,000 a second; 700/year for every single person on the planet (<https://www.theworldcounts.com/challenges/planet-earth/waste/plastic-bags-used-per-year> accessed May 20, 2022). Recycling rates at different times and in different areas are cited as only between 1-5%.

If single-use plastic bags don't wind up in a landfill, the bags litter the landscape, clog storm drains, pollute rivers and oceans, and choke and kill wildlife. A six-week study of 80 random sampling points across Austin called Trashblitz by a partnership of organizations found that trash bags were among the top ten most frequently found waste materials (Trashblitz and Litterati 2021). Keep America Beautiful's 2020 National Litter Study cited it in the top twenty most frequent litter items, using a different categorization method. The City of Austin and at least ten other cities in Texas had instituted plastic bag bans or fees for their use. The Texas Supreme Court, however ruled that Laredo's ban conflicted with a 1993 solid-waste disposal state statute thus nullifying those efforts (<https://www.texasattorneygeneral.gov/news/releases/ag-paxton-warns-11-cities-their-bag-bans-are-illegal> accessed 5/10/2022). The Texas Solid Waste Disposal Act which states that local governments may not "prohibit or restrict, for solid waste management purposes, the sale or use of a container or package in a manner not authorized by state law" or "assess a fee or deposit on the sale or use of a container or package" was used to preempt local bag laws. This precedent would be hard to overturn for all containers or packaging as well as for fees or taxes used as disincentives. Although a bag ban is no longer an option in Texas it must be noted that it has been highly effective in other parts of the country as reported by representatives from several cities and follow-up studies. In Washington D.C. after institution of their bag bill, 67% of residents and businesses reported seeing fewer plastic bags as litter and 50% of businesses have saved money.

A data map on Plasticbaglaws.org shows that as of October 2021, 2020, 10 states have statewide bans and an additional eleven contain jurisdictional bans without state preemption while 19 states, including Texas, have laws preempting plastic bag laws as discussed above (<https://www.plasticbaglaws.org/bagmaps> accessed 4/13/2022); there are a total of over 300 municipalities that have banned plastic bags.

Looking at other bans, incentives, and disincentives options, like those provided in the Surfrider Foundation's Plastic Bag Law [Activist Toolkit](#) (Romer, 2019), may make alternative products (to plastic) more cost competitive or more attractive. Plastic bags do not have to be single use. They can be reused and the low-density polyethylene plastic (LDPE) they are made of can be recycled or burned with other things to produce energy. The low rates of recycling lead to the discard of 100 billion bags a year. Single use bags are hard to recycle because they jam sorting equipment at recycling facilities, thus requiring hand sorting. One approach suggested would be to require post-consumer recycled content in plastic bags as described in the following excerpt from the Plastic Bag Law Activist Toolkit:

"Most local bag laws in the U.S. require post-consumer content for paper bags. Post-consumer recycled content is material from products that people or businesses already used (e.g., shipping cartons, plastic bottles) versus pre-consumer recycled content, which is material from the manufacturing process (e.g., scraps left over when envelopes are cut). It's important to require post-consumer recycled content to drive a market for truly recycled materials and divert recyclable materials from landfill. Under most ordinances, paper carryout bags must be 100% recyclable and include a minimum of 40% post-consumer recycled content. Standard-sized paper shopping bags that meet these criteria are now widely available. Requiring post-consumer recycled content for paper bags is important in straight plastic bag bans, because environmental impacts of paper versus plastic bags are closely analyzed. Many ordinances also require that paper bags must contain no old growth fiber.

Until recently, most ordinances did not require post-consumer recycled content for plastic bags because plastic bags containing post-consumer recycled content were difficult to obtain. However, the California statewide law has created a market for post-consumer recycled content film plastic bags. The California statewide bag law requires that bags marketed as reusable that are made from plastic film must be made from a minimum of 20% post-consumer recycled material after January 1, 2016. As more and more jurisdictions require post-consumer content, the

percentage of post-consumer content readily available should be monitored and requirements should be adjusted accordingly.”

Other approaches attempting to include disincentives for plastic bags used by retail stores might be adding fees or justifying the required collection of single-use plastic bags by the retail stores using them as part of the City’s zero waste efforts. If used in conjunction with requiring recycled content in bags, stores might be more inclined to use alternatives.

Polystyrene

Polystyrene and Styrofoam are problematic for several reasons. They are light and therefore easily transported by wind or water, they are difficult to recycle, brittle and easily break into small pieces that are more difficult to retrieve from the environment and presents a danger to aquatic life. Dangers of polystyrene in the environment come from its ability to pick up contaminants, becoming a toxic material, the ingestion of tiny polystyrene pieces by wildlife, and its potential to cause obstructions to flow. Polystyrene is broken down to microplastics in the environment (Helmberger et al., 2022). These microplastics have now been identified in almost every type of environmental media: soil, air, and water, drinking water supplies, and in human blood. The EPA National Human Adipose Tissue Survey for 1986 identified styrene (used to produce polystyrene) in 100% of all samples of human fat tissue taken in 1982 in the US (El-Ziney et al., 2016).

Twenty-nine countries have regulations against polystyrene; in [France and Germany the ban is restricted to foam take-out containers](#) only. In Austin, some highly specific restrictions reduce the localized use of polystyrene such as a prohibition for use by concessionaires in City parks. Austin is prohibited from banning polystyrene containers city-wide due to State law. In the United States, as of 2021 [seven states have banned EPS foam](#), with three of those in effect in 2021 and the others being phased in at later dates. In addition, other smaller jurisdictions have also banned it, including San Marcos, CA, and Washington DC, which banned polystyrene foam take-out containers and then expanded it to include all retail sales. Florida municipalities and counties have attempted to ban polystyrene on beaches, but those rules have been challenged. In September 2021, however, Florida introduced a proposed phaseout of polystyrene foam food packaging. The Florida Legislature will consider the proposed rule this year. (Nikki Fried Press release September 24, 2021). Florida State Commissioner Fried cited the hidden danger to public health from these disposable consumer products citing the link to human and animal health concerns from the chemicals and the long period required for decomposition. The distinction of banning a material for health reasons rather than for the purposes of limiting litter may be important if a ban is pursued to avoid preemption of a ban at the state level. Alternatives to a ban, would be sustainability requirements around packaging and food service containers; an approach like requiring that single-use bags include some percent of recycled material. If packing and food service containers were required to be made of compostable materials, the market would quickly identify materials like the cardboard to-go containers or the mushroom packaging that IKEA has announced to replace its Styrofoam packaging. There are some voluntary programs for reduction. New York City Public Schools through an organization called [Cafeteria Culture](#), instituted “Trayless Tuesdays” in New York Public Schools, diverting 2.4 million plastic foam trays per month from the waste stream (USEPA 2016).

Beverage containers

Some bans have been very specific, banning for instance, plastic water bottles. They are usually smaller scale bans, proposed and enacted in several municipalities and campuses over such concerns as resource wastage, transportation emissions, plastic litter, and damage to affected aquifers.

Some municipalities in Australia and Canada have enacted bottled water bans. The Australian town of Bundanoon offers public drinking fountains and filtered water dispensers, and stores sell empty reusable bottles (BUNDANOON JOURNAL July 2009). Many municipalities in Canada and some in the U.S. have instead prohibited them only on city property. In Toronto, the ban prohibits the sale and distribution of water bottles in all civic centers, city facilities, and parks. San Francisco has stiff penalties if plastic water bottles are sold at events and are also installing outdoor water bottling refilling stations. In Cape Cod Massachusetts, the ban on city property extends to soft drinks in plastic bottles. Quite a few college campuses and some municipalities have banned the sale of beverages in single-use plastic, though there is some feeling that banning bottled water encourages drinking other less healthy beverages instead. A key component to the success in reducing plastic water bottles is availability of water stations including outside (for example, for the homeless population), and having readily available reusable bottles. Austin Water Utility is installing twelve water stations (Figure 18) in the Central Business District. Coordinating this increased availability of refill stations with efforts to encourage or provide reusable bottles could reduce one use bottles being discarded in public space.



Figure 18. New Austin Water Water Stations (at Trinity St. and E. Cesar Chavez St.)

Although the alternative of reusable water bottles and fill stations is a simple solution, in some instances, they are more inconvenient. The discard of plastic water bottles is ubiquitous on Austin's trails and high pedestrian traffic areas. Incentives for travelers to use reusable bottles is an area that needs to be investigated. Tourists use around [30 plastic bottles per person for a two-week trip](#). Perhaps large events that attract large numbers of participants, like SXSW, could be encouraged to supply both refillable bottles and large drinking water containers in event areas.

Another alternative to single use plastic bottled water is aluminum canned water. Aluminum cans are unique in that they are most often recycled directly, meaning that the average can has a very high percentage of recycled content. This means that aluminum cans have more than three times the recycled content than EPA estimates for glass or plastic, with 70% recycled content on average. Innovative alternatives to plastics continue to emerge. A group of students has managed to create a biodegradable

plastic bottle from algae and other natural materials. The implementation and use of a product like this could take a big cut in the use of plastics.

Container deposit legislation mandates [a refundable deposit on certain types of recyclable beverage containers](#). Deposit efforts are effective because it includes an incentive for the user not to discard their container and have been demonstrated to be highly effective, especially in homeless communities. Opinion polls show the public supports bottle bills, but the beverage and packaging industries have blocked bottle bills in nearly 40 states and even the successful programs are still threatened. There are ten U.S. states with these “bottle bills.” Studies show that the recycling rate for beverage containers is vastly increased with a bottle bill. The United States' overall beverage container recycling rate is approximately 33%, while states with container deposit laws have a 70% average rate of beverage container recycling. Michigan's recycling rate of 97% from 1990 to 2008 was the highest in the nation, as is its ten-cent deposit (Gitlitz & Franklin, 2006). Studies in seven states show that beverage container legislation has reduced beverage container litter from 69% to 84% and reductions in total roadside litter range from 30% to 64%.

[Texas](#) unsuccessfully attempted to introduce a bottle bill in 2011, 2013, and again in 2015. The bill set a redemption goal and deposit rates. Containers made of glass, plastic or aluminum with a capacity of 4 L (1.1 U.S. gal) or less would have been covered. The Texas bottle bill did not gather enough votes (https://en.wikipedia.org/wiki/Container_deposit_legislation_in_the_United_States#Repealed_legislation and <https://www.bottlebill.org/index.php/past-campaigns/texas-past-campaigns> accessed February 10, 2022). One interesting alternative are machines that entice recyclers to deposit beverage containers for the chance to win a prize, point cards or cash. Tomra [Reverse vending \(tomra.com\)](#) is a company that works with retailers where container deposits are accepted, but also could be used at those transition points on the watershed surface that collect large volumes of litter. And in another example, [a McDonalds in Stockholm lets you pay for food with recycled cans](#) (Figure 19).



Figure 19. McDonalds Stockholm, Food for Cans (Photo courtesy of DDB Stockholm Agency)

Comprehensive bans of specific materials for municipalities in the state of Texas or even container deposit legislation may not be feasible due to the Texas Supreme Court ruling preempting local bans, as described below for single-use plastic bags. However, it may be worth investigating other ways to achieve the same result. The Surf-rider Foundation has a [database of over 1,000 regulations](#) that have been in place regarding plastics and toolkits for making policy. Sources of data cited above include lists of those cities and states that have bans or restrictions in place. All the entities contacted that had bans in place

reported that they were highly effective in reducing those materials being discarded. Restrictions were frequently described as making the most significant difference in litter.

Use Restrictions

There are a few examples of more comprehensive rules that protect a particular natural resource. These restrictions appear to be more enforceable and sometimes easier to implement, particularly if they are related to health and safety. Beach communities frequently ban glass containers on their beaches. Parks ban alcohol. The State of Texas bans glass in riverbeds in counties within 85 miles of an international border. (Texas Health and Safety Code 365.035). The National Park Service has many parks with specific restrictions, sometimes relating to the wildlife habitat, but also in protecting a particular water body. As cited in Section 3, glass and Styrofoam coolers are banned on the Buffalo River in Arkansas and Denali National Park has extensive Leave No Trace rules.

Disposable items (e.g., cans, plastics, glass, foam or paper) and alcohol are prohibited by law on the Rainbow River in Dunnellon, Florida, however reusable containers are allowed. The City of New Braunfels bans single-use items on the Guadalupe and Comal Rivers, a ban so-called the “Can-Ban”. The ordinance also prohibits all glass and Styrofoam, limits cooler size, and assesses a \$2 River Management Fee for non-residents. New Braunfels’ original 2011 ordinance was challenged in court and suspended, but revived in October 2017, after the Texas Supreme Court refused to strike it down. Fines of \$500 are assessed and citations are regularly issued for those that have banned items.

As the population grows, so grows recreation on Lady Bird Lake (Figure 20), leading to increased littering of single use (glass, aluminum, plastic) beverage containers, discarded clothing, polystyrene coolers, and fishing gear, whether intentionally or inadvertently. Structural controls will not address the problem of litter released directly into the lake, and the City already has staff dedicated to cleanup of the surface as well as volunteer efforts. Any new and mechanized/robot devices will still require removal and disposal of the materials collected. Prohibition of single use containers (glass, plastic, and styrenes) would yield a significant decrease in some of the materials seen. If the City were to institute rules solely for Lady Bird Lake or the Colorado River within the city limits, restrictions could be published and enforced at concessions that rent watercraft as well as other launch points. An initial effort to educate local citizens with informational booths at launch points and perhaps staff at concessionaires as well and information provided to hotels and other venues could help inform compliance.

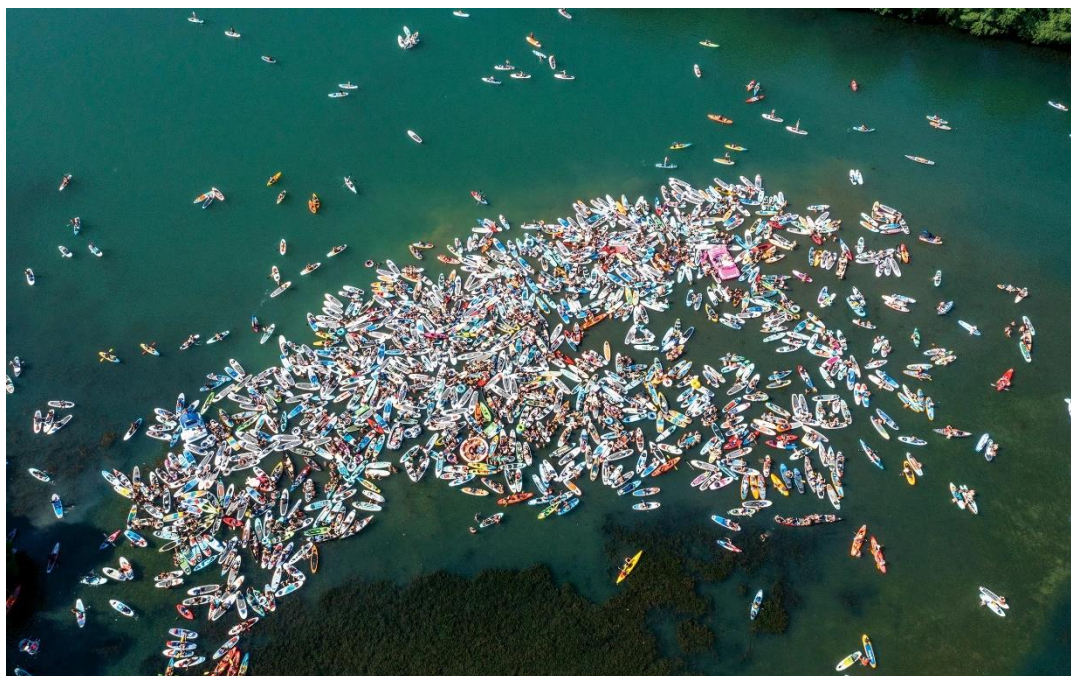


Figure 20. Recreation levels in Lady Bird Lake at Barton Creek confluence in peak use
(Photo courtesy of Texas Monthly, published in July 2022 issue)

Conclusions

Solutions were compiled from among those employed across the nation and listed in Tables 6, 7 and 8. The solutions are discussed here in a bottom-up approach, from clean-up in creeks and reservoirs (Table 6, Extraction) to preventing litter from entering our waterways (Table 7, Interception), and finally the most comprehensive approach of reducing litter sources (Table 8, Source Reduction); requirements for supporting actions are also identified. For each solution the first column provides a relative cost and benefit assessment. The cost level (\$-\$\$\$ or <\$10,000 to >\$100,000); a range is provided where the scale of implementation is the determining factor. Although maintenance is not included in cost estimates, an “M” is included to indicate frequent maintenance is required. Finally, a comparative benefit is estimated where “◇◇◇” indicates solutions recommended for implementation or trial, with the number of diamonds indicating the level of confidence. A “◆” is included where a solution is unsuitable for Austin or may cause clogging in storm drains or outfalls. Following each of the tables are some key findings about the most promising solutions, particularly as they relate to Austin.

Table 6. Extraction: Solutions to pull litter directly from waterways.			
Cost/ Benefit	Strategy	Current/potential use	Comments/Obstacles
\$\$-\$\$\$ ◇	Increased Manual (paid) cleanup	COA full-time crews plus additional efforts funded through volunteer and subcontractors	Coordination with other entities is lacking, which may be needed to target the critical areas.

Table 6. Extraction: Solutions to pull litter directly from waterways.

Cost/ Benefit	Strategy	Current/potential use	Comments/Obstacles
\$\$ 000	Violet bag program	COA promotes, distributes and actively uses during cleanups	Provision of trash collection for homeless encampment locations
\$\$\$ M ♦	Trash Wheel	Currently several installed in Baltimore and planned for Fort Worth.	Limited area of effectiveness. Potential for use with “bubble barrier”, new technology to divert floating litter without obstructing boat traffic. Maintenance and access issues.
\$-\$\$ M 0	Trash Booms	COA utilizes in Lady Bird	Trash lost during large storm events and inhibited watercraft access
\$\$ M 0	In-Stream Litter Traps [e.g. Litter Gitter, Bandalong]	Trash cages centered in current booms or additional locations to retain captured litter better and ease collection.	Medium Cost; Need to test for animal entrapment, esp. where creeks dry and for ease of emptying and durability in storm events.
\$\$-\$\$\$ M ♦	Trash Robots	One benefit would be high visibility and could be incorporated into a public campaign like “Treasure Your River” used by Coca Cola in the UK (https://www.hubbub.org.uk/Pages/Category/campaigns?Take=36)	Demonstration to be held August 31, 2022 to acquire additional information. High cost. Insufficient information on capability in highly vegetated areas and maintenance, charging, vandalism concerns and appropriate areal extent. Sales currently only from overseas companies
\$-\$\$ 0/00	Trash Fishing	Trash Collection as tourist attraction and/or team building exercise	Provides high visibility and awareness with limited litter removal. Establishment of venue may be major effort.
\$\$ M ♦	Small-scale Litter Skimmer [Sea-Bin]	Trash Collection at stationary location siphoning water into a straining device. Could provide information on devices to concessionaires.	Requires power and continual maintenance. Primarily used in marinas.
\$-\$\$ 00	Volunteer Cleanup Programs	In Place: Funding to Keep Austin Beautiful “Clean Lady Bird Lake” and “Adopt-A-Creek”	Possible enhancements would be to Increase allowed participation and advertisement to tourists, UT, and condominium dwellers; Coordinate with more local agencies like “Animal Safe Migration”. Increased efforts would require increased funding depending on effort level.

Table 6. Extraction: Solutions to pull litter directly from waterways.			
Cost/ Benefit	Strategy	Current/potential use	Comments/Obstacles
\$\$ ◇◇◇	Free Watercraft for Lake Maintenance	Free kayaks for regular committed volunteers like the Urban Rivers Program	Requires purchase of watercraft and provision of litter disposal, along with advertisement of the program and location to store watercraft and supplies. Maintenance for collected litter removal, some administrative costs.
\$\$ ◇	Trash Collection Incentives	Provide rewards or discounts, etc. for cleanup efforts “Kudo Coins” in San Marcos or other alternatives or other contests or gamification.	Incentives would need to be solicited from local businesses.
\$-\$\$ ◇◇	Use Litter Data for Trash Cleanup Direction	Target the 10% dense trash sites identified by the Trash Survey for cleanup efforts.	Need to revisit to observe whether accumulation returns and whether a device could facilitate collection. Increased staffing required.

- Cleanup efforts are a particularly effective use of volunteers if manual extraction is required and can be prohibitively expensive if using paid staff. Trials to assess the effectiveness of devices to concentrate trash for pickup should continue.
- Increased participation in volunteer efforts can be encouraged with incentives (like free watercraft), high visibility efforts (e.g. trash fishing) and soliciting cooperative support and publication, through businesses, schools, and other venues in high traffic areas. Approaching businesses for cooperative efforts (installing inlet guards if the business agrees to “adopt-a-drain”) could lessen the cost to the City directly.
- The concentration in creeks of 76% of the litter at only 10% of the sites is an opportunity to prioritize those areas for cleanup (Trash in Creeks Study, Clamann et al. 2022, interactive map: <https://arcg.is/0z48bj0>). Include scheduled revisits at strainer locations like the Johnson Creek bypass tunnel.
- Using devices in-stream to concentrate and retain litter, adding traps to booms at creek mouths or putting booms to concentrate litter, can make cleanup easier by creating an artificial “strainer” at a more easily accessible site/
- Extraction efforts can be particularly difficult in creeks due to access issues, difficulty in extraction from the streambed and vegetation, and the widely dispersed nature of our stream networks. In creek cleanups may be reduced if supplemental cleanup addresses high frequency illegal dumpsites and is paired with enforcement action and, if possible, equipment or reporting to identify the offenders.

- Note that trash robots and mechanized collection are only feasible on flat, deep water, like a reservoir or lake, while there are many obstacles to their use: vandalism, charging, and emptying.
- Waste service at encampments should be increased (Violet Bag Program) and discussions held with agencies providing support services. This may encourage minimizing single use food and beverage containers as well as increase the retrieval of containers that have been provided as well as the clothing and housing materials, to reduce abandonment.

Table 7. Interception: Solutions to Intercept Litter before it Enters Waterways. Costs are scalable to size of area or number of units.			
Cost/ Benefit	Strategy	Current/potential use	Comments/Obstacles
\$-\$\$\$ ♦♦ M	Curb Inlet Guards	In high pedestrian traffic and high litter areas.	Would require reprioritization or additional funding for street sweeping. Should be tested and monitored by appropriate City of Austin departments to ensure no clogging. Implementation where frequent street sweeping already occurs could reduce costs of inlet filter maintenance.
\$\$ M ♦	Catch Basin Inserts or Swirl Separators	Drop in or constructed insert that separates trash from stormflow within the stormsewer system. Possible temporary installation in high construction areas.	Many have high cost of installation, but primarily maintenance, requiring a vactor truck or manual removal of material after manhole removal. High clogging potential. Functional difficulty found when tested by Watershed (Glick et al. 2013)
\$\$ ♦	Enhanced Reporting of Litter Problems	Implement and advertise method to report litter problems through 3-1-1 or another program.	Staffing levels could be high to respond to reports. Also, response on public vs private locations would need to be addressed.
\$\$-\$\$\$ ♦♦	Increased Enforcement for littering: SWEEP (Philadelphia) type Program	Staff with the capability to educate businesses, etc. about trash requirements and authority to issue warnings and citation	Staffing requirements could be high.* * <i>Unable to acquire information from Pennsylvania with SWEEP program directly at this time, on staffing levels and whether fines are issued.</i>
\$\$ ♦♦	Refine and Enhance Street Sweeping Program	Prioritization and scheduling for high litter locations and hours when on-road vehicles are absent, or vehicle removal requirements.	Large difficulties in logistics for crew scheduling. Leaf litter during certain times needs to be considered and integrated.

Table 7. Interception: Solutions to Intercept Litter before it Enters Waterways. Costs are scalable to size of area or number of units.

Cost/ Benefit	Strategy	Current/potential use	Comments/Obstacles
\$-\$\$\$ ♦ M	End-of-pipe Nets or Traps at Outfalls	Nets or devices that strain the outflow from stormsewer outfalls at creeks.	High likelihood of obstructing flow causing flooding. High maintenance requirements associated with high flow events. High costs for replaceable nets that ease maintenance.
\$-\$\$\$ ♦♦	Physical Containment at Large Commercial Developments	Fencing or other retention around site to prevent movement of litter for collect if floatable treatment is not provided for stormwater.	Would probably require change in development rules. Include Shopping Cart retention
\$-\$\$\$ ♦♦	Floatable Capture In Water Quality Controls	Amend requirements for new ponds to require capture of floatables that are frequently lost in bypass systems.	Would require change in water quality pond requirements and ongoing maintenance.
\$\$ ♦♦♦ M	Increase litter disposal proximity and capacity.	Evaluate size and distance between litter bins on high use trails and high pedestrian areas; assess relative to 30' guideline. Possibility of bins in heavy parking locations during large events.	Increased costs, especially labor costs for maintenance. Contact Philadelphia re success of Community Cans program.
\$\$ ♦ M	Solar compacting bins	Possible installation only in areas where high use overwhelms capacity.	High costs for installation as well required changes to maintenance scheduling. Difficulty in either adapting current crew scheduling or complete overhaul to optimize the reporting capabilities of the bins.
\$\$\$ ♦	Provide Additional Water Stations	Encourage use of reusable water bottles, including by homeless citizens, by providing refill stations. Could supplement by providing reusable bottles at hotels and through homeless services.	Austin Water Utility recently installed 12 new stations. No data on the impact on reducing litter. May need an education campaign to discourage provision of single-use containers to homeless population.
\$ ♦♦♦	Lakeside and Park Concession Requirements	Ensure "Leave No Trace" Signage is posted and that sufficient litter disposal required and maintained.	Costs should be borne by concessionaires; Additional inspection may be required.
\$-\$\$ ♦ M	Cigarette Butlers	Provide cigarette butlers in transition areas and high pedestrian areas. Evaluate maintenance in cooperation with downtown alliance and others.	Cost of devices, maintenance required. Could be paired with campaign or gamified to attract attention.

Table 7. Interception: Solutions to Intercept Litter before it Enters Waterways. Costs are scalable to size of area or number of units.			
Cost/ Benefit	Strategy	Current/potential use	Comments/Obstacles
\$-\$\$\$ 00	Enhance Current Education Programs	Expand volunteer cleanup opportunities and creek adoptions, particularly through schools, condominiums, organizations	Advertising or information distribution costs can be high. Campaigns need to be refreshed.
\$-\$\$ 00	New education effort or partnership	Specific focus effort. Example: Rethink Disposable with Clean Water Fund.	Staff time might be high for the program to be effective.
\$\$ 000	Encourage landfill disposal	Free dump days, increased enforcement, monitoring (cameras) at frequently used dumping locations	Possible provision of containers for disposal for closed hours or additional locations
No Data	Program to retrieve Homeless Materials	Work with nonprofits to retrieve single-use containers and discarded clothing.	Programs using this approach were not identified, and merit further investigation. It may be that some existing programs retrieve materials, but not that we could document.
000	Mesh Litter Bags	Provide or Require Mesh Litter Bags for On-Water Recreation	Distribution and information must be provided at launch locations, as well as sufficient waste disposal for the return of trash. Could be required of lakefront concessionaires.
\$\$ M 000	Trash Boat bin in Ladybird Lake	Moored boats (s) to provide trash receptacle in lake to encourage proper disposal.	Active maintenance required during high use periods.

- Institutional or programmatic interception methods are already extensive in Austin, but additional focus on visitors, college students, and programs to report litter may provide opportunities for enhancement. High profile efforts at trails encouraging “Leave No Trace” and interactive activities like plogging are some approaches that can be pursued. On our waterways, ensuring that people recreating have a way to retain their trash could be accomplished by providing or requiring mesh litter bags or providing a “litter boat”
- While expensive, increasing waste capacity appears to be the most critical component for encouraging appropriate disposal. Picnic tables (in parks and commercial/multifamily properties) should have sufficient waste receptacles. Based on maintenance, solar compacting bins could be used to increase capacity, where schedules are flexible and locations remote. Maintenance costs are very high to significantly increase the number and capacity of trash cans, but the amount of litter distributed in heavily used pedestrian areas (South Congress), where no trash cans are within sight, shows that they are desperately needed.

- Ordinances and enforcement need to be updated to reduce the incidence of overflowing waste receptacles and dumpsters (similar to Philadelphia's SWEEP program). Improving monitoring of high frequency illegal dumping sites and reporting procedures for litter would result in increased enforcement of severe problem areas, penalties in turn would reduce littering and dumping behaviors. One specific issue to address is abandoned telecommunication lines. Increased funding for Code Enforcement would be required. Another issue is whether water quality ponds need additional control of floatables, or more frequent cleaning.
- Illegal dumping was associated with the highest litter areas in the Trash in Creeks study (Clamann 2022); high priority should be given not only to strategies that reduce dumping, but also those that ease appropriate disposal.
- Site specific solutions may need to be used to prevent trash movement to our creeks from high litter areas, such as combining curb inlet guards with targeted street sweeping or with the adopt-a-drain program. Strategies to retain shopping carts and debris in large retail shopping centers need to be developed.

Table 8. Source Reduction: Solutions that can reduce the sources of litter that are most frequently found in Austin waterways			
Poten tial	Strategy	Current/Potential Use	Comments/Obstacles
◇	Single use plastic bag ban	Previous failure due to state preemption	State pre-emption without a different goal.
◇◇	Retail bag post-consumer recycled material requirement	Require that bags that are provided by retailers contain a minimum of post-consumer recycled material.	Potential state challenge. Use of these requirements also increases the market and likelihood that plastic will be recycled.
◇◇	Single-use Plastic bag recycling bins at retail locations	Require that retailers provide plastic bag recycling opportunity	Legal requirements not determined.
◇	Ban sales of bottled water	Unusual, usually restricted to a college campus or other small environment.	Mixed results with possibility of other single-use beverage containers replacing plastic water bottles, although water in aluminum cans is more recyclable.
◇	Restrict sales and/or use of single-use water bottles on City property and/or lake		Same issue as a ban, replacement with alternatives. Concerns with heat and hydration.
◇	Container Deposit Legislation	Unsuccessfully proposed in Texas legislature in the past.	
◇◇	Polystyrene (Styrofoam) Ban	Increasing implementation worldwide. Ban could be comprehensive or specific; only at grocery markets and convenience stores, or only for takeout food containers.	State pre-emption ban could mean it would be challenged, but toxicity concerns may facilitate implemented as Florida has based their proposal.
◇◇◇	Restrict Use of Polystyrene (Styrofoam) in City Parks and/or Lakes & River	Further restrict current ban of the sale of food in parks in polystyrene to also prohibit possession, particularly of polystyrene coolers.	Education and enforcement would be required, at least initially, but concessionaires could easily ensure polystyrene coolers are restricted there.
◇◇	Single-Use Container Ban on Lady Bird Lake or River	Ban the Possession of Single-Use Containers	State preemption challenge possible, although New Braunfels ban upheld. Enforcement at concessionaires and at other launch points would be required.
◇◇◇	Prohibit Glass and Cigarettes on Lady Bird Lake and/or Colorado River	Extend the current prohibition in parks to the Colorado River or Lady Bird Lake.	Will require education, signage and enforcement.

- Table 8 lists measures other entities have put in place to would limit the use of the materials most frequently found littering our waterways. The relative feasibility of implementing these solutions in Texas are indicated by the number of symbols in the first column; with a greater number indicating a higher possibility that a rule might be put in place. The state of Texas previously

overturned a plastic bag ban, and it is anticipated that any bans would face the same challenge. Relative costs are not included because of the potential for high legal costs and unknown costs of enforcing the restrictions.

- Expansion of some current rules for Austin Parks may be most likely to be implemented. The prohibition on glass and cigarettes should be extended to the Colorado River system; safety concerns with glass make this a common ban on rivers, lakes and beaches.
- As the solution reported as most effective where instituted, reducing the materials that are frequently discarded could, even if on a small scale, reduce our litter. Prohibiting polystyrene and glass on the trails and waterways could address the most problematic materials for safety as well as for polystyrene decomposition and toxicity, in the most vulnerable locations (immediately adjacent to waterways with no interception opportunities).
- Recreators who have refreshments should have a mesh litter bag or other way to ensure they will “Leave No Trace”. Mesh bags could be provided, could be attached to all rental watercraft, could be encouraged or could be required. Informational booths would be in high traffic areas to educate hikers and boaters about the issue.

Although many bans and container deposit proposals have a low probability of success having previously failed in Austin and most cities in Texas, the two listed below are examples of successful precedents and could be reconsidered in the future.

- A ban of polystyrene as food service containers or other appropriate categories (coolers) could be pursued following the example of Florida, basing the need on public health. Lake Austin is a drinking water source and Austin creeks do contribute to the Edwards Aquifer, so polystyrene may impact public health as well as that of the aquatic community.
- A bold regulatory statement would be to follow the precedent set by New Braunfels and prohibit all single use containers in Lady Bird Lake. That ban was upheld by the state appeals court and the Texas Supreme Court denied an appeal, but such a rule would raise a lot of enforcement issues.

Selecting and compiling a suite of measures that pulls from all three solution spaces (Extraction, Interception and Source Reduction) will be necessary for Austin to effectively address the litter problem we are currently facing. Most large municipalities are struggling with the same issues, leading to the development of TMDLs, where appropriate, Action Plans such as Philadelphia’s and studies such as the Santa Ana Watershed’s Trash Assessment for Homeless Encampments (SAWPA 2021). Table 9 lists some municipal strategies that were used to develop a comprehensive action plan from watershed to river.

Table 9. Approaches for Comprehensive Litter Action Plan		
Approach	Description	Obstacles/Comments
Leave No Trace Hot Spot Effort	Solicit Assistance from Leave No Trace Center for Outdoor Ethics	Organization would need to approve; At least a week of multiple staff member time to organize stakeholder meetings, collect information requested. This is just one option for Action Plan Development.
Zero Waste and Litter Cabinet (Philadelphia)	A Committee to Take Solutions, Recommend the Phase I and Budgeting and Review Results	Alternatives of Staff Across Departments is an alternative, but either method has coordination, reporting, and evaluation difficulties.
Consultant Action Plan Development	Frequently consultants are used to develop a TMDL plan.	High Cost

The suite of solutions provided will allow layering of approaches to minimize the trash that becomes litter and to remove the litter from our waterways. The Trash Survey results identified large litter volumes associated with illegal dumping and encampments, but also located “hot spots” where cleanup efforts will have the most impact. Efforts using that information for the most short-term impact could begin promptly.

- ❖ High Priority Cleanups - The priority should be to extract litter from those areas with the highest volume to prevent further spread throughout our watersheds. It should include plans for follow-up visit at those high litter sites to see if they are an ongoing problem (versus historic dumping sites) .
- ❖ Increasing waste disposal convenience and capacity should also begin as soon as possible in high pedestrian activity areas. Current litter cleanup efforts like street sweeping can provide data to identify high litter areas. Possible actions are listed below.
 - If funding is available to increase waste service activities, Austin should provide more or higher volume litter bins in high pedestrian areas, particularly at high use times.
 - City code requirements should be reviewed and compared with those of other municipalities and an informational packet prepared, if not already available, for businesses denoting their responsibilities and possible penalties.
 - A review of enforcement actions and fines assessed would provide information on whether lack of penalties could be a factor in site management litter problems.
 - Identify who would be responsible for street litter, in high pedestrian areas and high-volume parking where no waste receptacles are located.

While addressing opportunities for immediate action, a long-term plan should be developed with solutions identified by geographic area and primary watershed surface litter sources. The plan should consider the time required to implement solutions; for example, code changes or source reduction measures will require policy planning. Development of a plan will assist in coordinating across the multiple departments involved in the efforts and in assessing the success of each component.

References

- Bates, D. (2022). Stormwater Conveyed Litter and How to Manage It. Presentation of Stormwater University, April 26, 2022. And personal communication during presentation Don Bates, president Osprey Initiative LLC.
- Berman, E. R., & Johnson, R. K. (2015). The unintended consequences of changes in beverage options and the removal of bottled water on a university campus. *American journal of public health*, 105(7), 1404-1408.
- Brazos River Authority. (2021). "Don't Let Your Trash Go Down the Drain – Preventing Stormwater Pollution." *The Brazos River Authority*, 25 Aug. 2021, <https://brazos.org/About-Us/News/News-Room/Resource-Library/Dont-Let-Your-Trash-Go-Down-The-Drain-Preventing-Storm-Water-Pollution>
- Burns & McDonnell. (2020). The Cost of Litter and Illegal Dumping in Pennsylvania, A Study of Nine Cities across the Commonwealth. January 2020. Submitted to Keep Pennsylvania Beautiful.
- Burns & McDonnell. (2020). Pennsylvania Litter Research Study, January 2020. Submitted To: Pennsylvania Dept. of Environmental Protection, Pennsylvania Dept. of Transportation, Keep Pennsylvania Beautiful and Keep America Beautiful
- City of Philadelphia. (2017). Zero Waste Litter Cabinet Action Plan 2017. (<https://www.phila.gov/media/20190821131753/Zero-Waste-Litter-Action-Plan-2017.pdf> (Accessed July 27, 2022))
- Clamann, A., Scoggins, M., Porras, A., Collins, J., and Walker, J. (2022). Trash in Creeks: A field survey Of trash intensity and source types in Austin, Texas. City of Austin. RR-22-01, August 2022.
- Clean Water Action (CWA) and Clean Water Fund (CWF). Retrieved March 7, 2022. <https://rethinkdisposable.org>
- El-Ziney, M. G., BaAbdoulah, H., & Tawfik, M. S. (2016). Monostyrene intake in albino rats: accumulation in organs and effects on growth performance and oxidative stress. *Int J Nutr Food Sci*, 5(1), p. 73.
- Foley, Meraiah. (2009). "Ban on Bottled Water, Apparently a First, Puts a Small Town on a Big State." In: BUNDANOON JOURNAL. Published July 17, 2009
- Funkhouser, D. (2019). "Banning Plastic Bags Town by Town, A Guide." In: Phys. Org February 20, 2019.
- Fusco, J. and E. Fons. (2019). Trash Reduction Effectiveness of Curb Inlet Screens – An Alternative to Full Capture Systems? CASQA Conference, October 8, 2019. Sponsors: City of Oakland, CA, Santa Clara Valley Pollution Prevention Program, EOA Inc.
- Gitlitz, Jenny & Franklin, Pat (2006). "The 10 Cent Incentive to Recycle". Container Recycling Institute.

- Glick, R., Zhu, T., Robinson, R., Bai, B., Mahmoud, S., Manning, S., Moezzi, A. 2013. Stormwater Control Measures in Austin, TX: Data Report. COA Report No: CM-13-01. City of Austin, Watershed Protection Department. September 2013.
- Helmberger, M. S., Miesel, J. R., Tiemann, L. K., & Grieshop, M. J. (2022). Soil Invertebrates Generate Microplastics From Polystyrene Foam Debris. *Journal of Insect Science*, 22(1), 21.
- Hubbub. (Accessed June 10, 2022) “Treasure Your River” Coca Cola with Hubbub at: <https://www.hubbub.org.uk/Pages/Category/campaigns?Take=36>
- Keep America Beautiful. (2021). *Keep America Beautiful National Litter Study Summary Report KAB America May, 2021*.
- Marine Conservation Society. (2021). Great British Beach Clean Results. <https://www.mcsuk.org/what-you-can-do/join-a-beach-clean/great-british-beach-clean/great-british-beach-clean-2021-results/> (Accessed March 15, 2022)
- University of Texas at Austin. (2022). “Pollution Prevention.” *Environmental Health & Safety (EHS)* / ehs.utexas.edu/environment-waste/waste-management/pollution-prevention. (accessed March 6, 2022)
- River Rules. (n.d.). Retrieved from <https://www.nps.gov/buff/planyourvisit/river-rules.htm> (Accessed April 30, 2022.)
- Romer, J. (2019). “Surfrider Foundation’s Plastic Bag Law Activist Toolkit for U.S. Cities & States.” Supplement to Surfrider’s: Rise Above Plastics Activist Toolkit. January 2019.
- Sanata Ana Watershed Project Authority (2021). Request for Proposal for Consulting Services: Monitoring water quality and trash assessment of homeless encampments in the Upper Santa Ana Watershed. May 2021
- Skogan, W. G. (1990). *Disorder and decline: Crime and the spiral of decay in American neighborhoods*. The Free Press, 1990.
- Texas State University (TSU). 2021. Travis County Improving Solid Waste Management. TSU Institute for Government Innovation.
- Thompson, R. C., Moore, C. J., Vom Saal, F. S., & Swan, S. H. (2009). Plastics, the environment and human health: current consensus and future trends. *Philosophical transactions of the royal society B: biological sciences*, 364(1526), 2153-2166.
- Trashblitz & Litterati. (2021) “Austin Report”. Provided by Litterati and currently available at <https://www.scribd.com/document/532795873/Trashblitz-Austin-Final-Report-5Gyres-x-Litterati>. <https://www.litterati.org/stories/engage-austin> Accessed July 22, 2022.
- United States Environmental Protection Agency (USEPA) 2021. Trash Free Waters. Retrieved from <https://www.epa.gov/trash-free-waters> (accessed December 30, 2021)
- United States Environmental Protection Agency (USEPA). 2016. Aquatic Trash Prevention National Great Practices Compendium. December 2016. Trash-Free Waters Program, US Environmental Protection Agency

Appendix A. Litter Abatement Costs, Nine Pennsylvania Cities (<https://www.keppabeautiful.org/wp-content/uploads/2020/02/KPB-Litter-Cost-Study-013120.pdf> Accessed August 10, 2022).

City	Population	Prevention of Litter: Trash Cans & Maintenance	Prevention of Illegal Dumping	Education & Outreach	Litter Abatemen incl. Encampment	Illegal Dumping Abatement	Code** Enforcement	Total	Cost/ Person
Allentown	121,433	\$1,291,700	\$8,900	\$35,000	\$2,192,100	\$370,200	\$669,300	\$4,567,200	\$37.61
Altoona	43,702	\$227,300	\$151,800	\$2,300	\$260,700	\$26,000	\$143,500	\$811,600	\$18.57
Erie	96,471	\$151,100	\$498,600	\$17,300	\$998,400	\$207,900	\$345,700	\$2,219,000	\$23.00
Harrisburg	49,229	\$73,400	\$34,700	\$102,200	\$1,242,700	\$235,500	\$49,000	\$1,737,500	\$35.29
Lancaster	59,420	\$20,000	\$1,000	\$5,500	\$1,393,300	\$7,200	\$704,500	\$2,131,500	\$35.87
Philadelphia	1,584,138	\$1,217,000	\$2,163,400	\$547,300	\$36,314,700	\$6,376,800	\$1,778,300	\$48,397,50	\$30.55
Pittsburgh	301,048	\$2,734,400	\$246,800	\$57,700	\$2,706,900	\$232,400	\$331,300	\$6,309,500	\$20.96
Reading	88,495	\$70,500	\$126,500	\$9,400	\$1,437,200	\$404,600	\$29,700	\$2,077,900	\$23.48
Austin FY20 + Avg FY18-20 Capital Cost	1,028,225	\$2,722,203	\$6,609,111	\$123,500	\$8,384,434	\$1,017,986	\$1,990,734	\$20,847,968	\$20.28
*Most costs from FY18 (Burns & McDonnell 2020)									
**Only litter specific Code Enforcement included									

Appendix B. Offer to Cooperate from “Safe Animal Migration”

Hello,

I am reaching out on behalf of Animal Safe Migration, a local 501 c 3 based here in Austin, TX. Our mission is to create coexistence between human and animal life by way of safe migratory pathways for all wildlife in their natural habitats. Right now we are focusing our efforts on habitat restoration and wildlife conservation. Since mid-December we have been going out with our volunteers and cleaning up Lady Bird Lake every Saturday for a minimum of two hours. You may have seen us along the Ann and Roy Butler Hike-and-Bike Trail. Over the course of our clean-ups we have collected over 500 gallons of trash, and that is only what is found around the lake beds and on the surface of the water closest to shore. In addition to the trash, we have pulled numerous drowned animals out of the water and disposed of dozens of hypodermic needles.

These past few months we have come to realize that the city we all love, is grossly polluted; The water ways that we spend our summers in, are not only polluted with trash, but have toxins in them that are harmful to people and wildlife alike. Our ecosystems are being destroyed, and we are seeing less wildlife because of it.

We have plans to plant native vegetation along the shorelines, reducing the amount of toxins in the water, and to install flood netting on storm drains that run into the lake, preventing garbage from flowing into the water off of the streets. But, we can not do this without your help.

As nature lovers and Austin locals alike, we feel that it is our responsibility to make sure people know their impact. It is our responsibility to educate our community on how they can help, how they can do better. We want to partner with the City of Austin in order to have the ability to continue to improve our community, your community. Would you consider funding our project?

Thank you so much, I hope to hear from you soon.

Best,

Caitlin Phillips

Director of Operations

Animal Safe Migration

www.animalsafemigration.org

caitlin@animalsafemigration.org / 206.355.6893

Appendix C.

California Stormwater Quality Association: Certified Full Capture System List of Trash Treatment Control Devices

(Last Updated July 7, 2022)

TABLE 1 - CATCH BASIN INSERTS AND OTHER DEVICES

Owner / Website	Full Capture System Trash Device Brand Name	Date Application Certified or Fact Sheet Updated	Date Vector Control Accessibility Verified
AbTech Industries	Ultra Urban Filter (UUF) Curb Opening and Drop-In	Application 25 5/1/20	4/8/2020
Advanced Drainage Systems, Inc. FLEXSTORM Division	FLEXSTORM PURE Full Trash Capture (FTC) Inserts	Application 3 3/15/2018 Updated 4/21/2021	3/30/2021
Advanced Drainage Systems, Inc. FLEXSTORM Division	FLEXSTORM Connector Pipe Screen	ADS-1 Updated 6/8/2021	3/30/2021
Bio Clean® Environmental Services, Inc.	Curb Inlet and Grate Inlet Filters	Application 4 3/15/2018 Updated 10/21/2021	10/20/2021
Bio Clean® Environmental Services, Inc.	Modular Connector Pipe Trash Screen	BC-3 Updated 4/30/2020	3/10/2020
BrightWater™	Connector Pipe Screen	Application 29 3/15/2018 Updated 12/28/2020	11/19/2020
BrightWater™	Curb Inlet Filter	Application 26 6/30/2020	4/17/2020
Ecology Control Industries	Debris Dam - Catch Basin Insert for Curb Inlet Design	ECI-1 Updated 6/17/2020	4/29/2020
Enviropod International: A Stormwater360 Group Company	Enviropod® LittaTrap™ FC	Application 27 10/15/2020	7/20/2020
Fabco Industries, Inc.	Fabco Connector Pipe Screen	Application 36 7/6/2022	6/16/2022
Filtrexx Sustainable Technologies	StormExx® Clean	Application 16 8/10/2018 Updated 11/25/2019	12/6/2019
Frog Creek Partners, LLC	Gutter Bin® Channel Filtration System & Mundus Bag® Water Filter	Application 22 6/26/2019	4/19/2019
Frog Creek Partners, LLC	Gutter Bin® Eco Curb Inlet Filter & Mundus Bag® Water Filter	Application 23 2/18/2019	10/11/2019
Frog Creek Partners, LLC	Gutter Bin® Eco Drop Inlet Filter & Mundus Bag® Water Filter	Application 24 2/18/2020	12/6/2019

G2 Construction, Inc.	G2 CPS-Mod™ and Removable CPS Mod™ Screen	Application 18 6/26/2019	3/15/2019
G2 Construction, Inc.	G2 GITS™ Grated Inlet Trash Screen	Application 19 6/26/2019	4/10/2019
Inventive Resources, Inc.	Water Decontaminator	Application 2 3/15/2018 Updated 2/5/2021	4/20/2020
Oldcastle Infrastructure™	FloGard® + Plus® Catchbasin Trash Screen Insert, Combination Inlet Style Drop in Basket	OI-1 Updated 6/9/2021	6/9/2021
Oldcastle Infrastructure™	FloGard® Catchbasin Trash Screen Insert, Flat Grated Inlet Style Drop in Basket	OI-2 Updated 6/9/2021	6/9/2021
Oldcastle Infrastructure™	FloGard® Catchbasin Outlet Trash Screen Insert Connector Pipe Screen	OI-3 Updated 11/29/2019	12/6/2019
Revel Environmental Manufacturing, Inc.	Triton™ Bioflex Inlet Trash Guard Catchbasin Polyester Fiber Mesh Trash Filter Insert	REM-1 9/10/2021	9/7/2021
Revel Environmental Manufacturing, Inc.	Triton™ CPS-FTC (Crescent Pipe Screen)	Application 12 7/10/2018	3/15/2019
Revel Environmental Manufacturing, Inc.	Triton Perf-FTC Insert	Application 13 7/10/18 Updated 12/21/2021	12/20/2021
Safe Drain Stormwater Holdings Inc.	Storm Vector Guard	Application 30 2/11/2021	12/17/2020
Stormtek	Stormtek ST3 & STEG Catchbasin Connector Pipe	AS-1, A1S-2 Updated 8/12/2021	8/4/2021
United Stormwater, Inc.	Connector Pipe Trash Screen	USW-1 Updated 1/29/2022	Updated 1/26/2022

TABLE 2 - HIGH FLOW CAPACITY TRASH DEVICES

Owner / Website	Full Capture System Trash Device Brand Name	Date Application Certified or Fact Sheet Updated	Date Vector Control Accessibility Verified
Advanced Drainage Systems, Inc.	Barracuda Hydrodynamic Separator	Application 21 6/26/2019 Updated 5/21/2021	3/15/2019
AquaShield™, Inc.	Aqua-Swirl® Stormwater Treatment System	Application 1 8/4/2017 Updated 11/6/2020	12/3/2020
Bio Clean® Environmental Services, Inc.	Debris Separating Baffle Box (DSBB)	Application 6 3/15/2018	7/28/2020
Bio Clean® Environmental Services, Inc.	BioClean Deflective Screening Device (DSD)	Application 20 6/26/2019	7/28/2020
Bio Clean® Environmental Services, Inc.	Modular Wetland System® (MWS)	Application 15 7/10/2018	3/15/2019
Coanda Inc.	Coanda Trash Screen and Debris Fence	COA-1 Updated 9/10/2021	9/7/2021
Contech Engineered Solutions	Continuous Deflective Separator (CDS) Hydrodynamic Separator	CCP-1HF Updated 5/27/2021	4/29/2021
Jensen® Stormwater Systems	Jensen® Deflective Separators (JDS)	Application 5 3/15/2018	12/6/2019
Hydro International®	Downstream Defender (In-Line and Off-Line Configurations)	Application 14 7/10/2018	3/16/2020
Hydro International®	First Defense® High Capacity Full Trash Capture Device (FDHC FTC)	Application 28 10/30/2020	8/20/2020
Hydro International®	Hydro DryScreen	Application 10 7/10/2018 Updated 5/5/2021	4/29/2021
Hydro International®	Hydro Up-Flo Filter®	Application 11 7/18/2018	3/16/2020
Oldcastle Infrastructure™	FloGard® NetTech	OI-11HF Updated 12/08/2020	12/3/2020
Oldcastle Infrastructure™	Nutrient Separating Baffle Box® (NSBB)	Application 17 10/12/2018 Updated 7/21/2020	5/1/2020
Roscoe Moss Company	Storm Flo® Trash Screen – Linear Radial Gross Solids Removal Device	RMC-1HF Updated 3/30/2021	3/11/2021
StormTrap	SiteSaver®	Application 9 3/15/2018 Updated 2/23/2021	3/18/2021

StormTrap	TrashTrap Net and Fixed Basket In-Line Systems	Application 34 6/21/2022	5/3/2022
StormTrap	TrashTrap Net and Fixed Basket End-of-Pipe Stormwater Treatment System	Application 35 7/6/2022	6/1/2022

[Certified Full Capture System Trash Treatment Control Devices | CASQA - California Stormwater Quality Association](#)