OPPORTUNITIES OF APPLYING SYSTEM ANALYSIS TO THE US WASTE MANAGEMENT SYSTEM; BIO-INSPIRED SOLUTIONS FOR A MORE CIRCULAR ECONOMY

A Thesis

by

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ABSTRACT

This thesis focuses on the data collection needed for and the application of a systems-level analysis to the US waste management system. A systems approach, in combination with ecological network analysis techniques, enables the flows and structure of the US waste management network to be compared with naturally sustainable ecological food webs. This comparison highlights areas of potential improvement in the waste management system's sustainability, uncovering biologically inspired network characteristics that shift its design closer to that of a true circular economy.

Circular economy addresses issues caused by limited resources, by campaigning for their continuous circulation. This circulation is analogous to the primary function of the detritivores and decomposers-type species in ecological food webs, a keystone for the strength and sustainability of their ecosystems. End-of-life materials introduced to the waste management network correspond to the supply of detritus in a food web. This dead organic or low-quality material makes up a large percentage of the material flow in ecosystems and can only be processed by detritivores. Despite their importance, previous applications of ecosystem structure to human network design has demonstrated that even heavily advertised "sustainable" networks lack an equivalency to these species in the form of reuse and recycling.

The tasks of this thesis analyze the overall design of the US waste management network, the detrital feedback streams provided through material recycling, and real-world waste movement based on facility information within the US. This research uncovers a hidden detrimental aspect of the current structure of the US waste management network, that it is organized to streamline materials to landfill disposal. Unlike the networks studied by ecologists, the waste management networks considered lack the material cycling needed to mimic the function of ecosystems, keeping them far from resembling any aspects of a circular economy. The results of the analyses are used to recommend changes to today's waste management practices to shift its design towards a more sustainably functioning system.

DEDICATION

I would like to dedicate this thesis to my family, who has provided significant guidance throughout my life and education. First and foremost, to my parents who have always provided me with every opportunity and supported me with unconditional love. Also, to my brother and best friend, who has been a source of unyielding support as well as tough competition throughout my life. I am forever grateful for your influences.

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Contributors

This work was supervised by a thesis dissertation committee consisting of Professor Astrid Layton PhD as the advisor, Professor Michael Moreno PhD of the Department of Mechanical Engineering and Professor Ahmed Ali PhD of the Department of Architecture. The literature review depicted in Chapter 2 was conducted in part by Shelby Warrington of the Department of Mechanical Engineering and some sections were published in 2019. The student completed all other work conducted for the thesis independently. The data analyzed for Chapter 6 was provided in part directly through the Texas Commission of Environmental Quality.

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NOMENCLATURE

Co	Connectance ecological metric
λmax	Cyclicity ecological metric
CE	Circular Economy
COG	Councils of Government
EIP	Eco-Industrial Parks
ENA	Ecological Network Analysis
EPR	Extended Producer Responsibility
EREF	Environmental Resource and Education Foundation
[F]	Food Web Structural Matrix
FCI	Finn's Cycling Index ecological metric
FW	Food Web
G	Generalization ecological metric
H	Shannon Index ecological metric
Hc	Non-dimensional total system overhead ecological metric
ISRI	Institute of Scrap Recycling Industries, Inc.
L_D	Linkage Density ecological metric
LF	Landfill
MRF	Material Recovery Facility
MSW	Municipal Solid Waste
Npredator	Number of predators (consumers) ecological metric

Nprey	Number of prey (producers) ecological metric
OEM	Original Equipment Manufacturer
P_R	Prey to predator ratio ecological metric
P_S	Specialized predator ratio ecological metric
$P_{S,prey}$	Specialized prey ratio ecological metric
R	Robustness ecological metric
RCRA	Resource Conservation and Recycling Act
[T]	Food Web Flow Matrix
TF	Transfer Station
V	Vulnerability ecological metric
WG	Waste Generator
WTE	Waste-to-Energy

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CHAPTER I

INTRODUCTION

Motivation

The Global Waste Network

Now, more than ever, the world is in need of organized and global waste management reform. Today's consumption trends put future generations at risk with the rapid elimination of natural resources and waste generation [1]. With the current conditions, new studies estimate that the US will have only 15 years of landfill capacity by 2021[2]. For decades, the volume of waste generation has been on the rise, resulting in a growing concern for the impacts this growth will have on future generations [3]. Recent changes, such as the implementation of "National Sword" (closure of China's market) and an overall loss in waste exportation options, made to the waste management infrastructure have drastically reduced disposal options, further spurring an immediate need for global attention. A study done by Waste Business Journal now suggests that in the 5 years following the Chinese import ban (2018-2023) the total landfill capacity in the US is predicted to decrease by over 15% as a result of increased landfilling[2]. For regions like the Northeast and Midwest, the loss will be closer to 30% and life expectancy dwindles down to about 8 and 11 years by 2021[2].

The recent surge of landfilled waste is due to the 2018 Chinese importation ban known as "National Sword" that took effect in January of 2018. Prior to this ban, China had been the largest consumer of global waste since the 1980's, importing materials from every developed country on the planet [4]. China imported half of all global exports by 2016, 45 million tons of materials, equating to $18 billion dollars in commodity value [5]. The continuation of that rate would have resulted in the estimated global displacement of 111 million metric tons of plastic material waste by the year 2030 [4].

The consequences of the National Sword have been felt at global, national, and local levels. Countries in South East Asia have scrambled to import the sudden glut of plastics, demonstrated in Figure 1 alongside other changes to the exportation of plastic waste from 2017 to 2018.

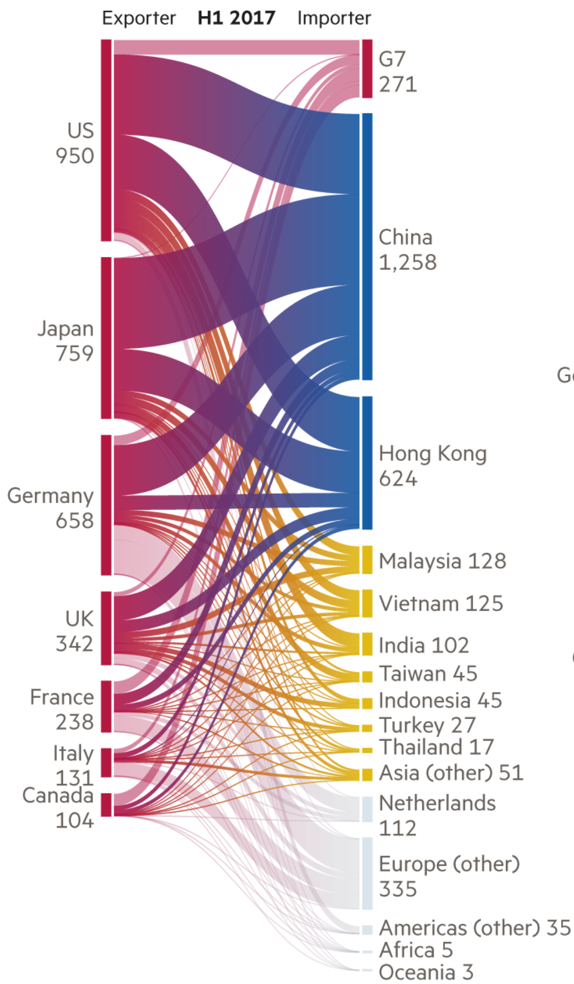

Figure 1: Global change in plastic waste before (left) and after (right) the Chinese crackdown on imports of plastic waste deemed the "National Sword". *Figure used with permission of David Blood and Financial Times*[6].

An unfortunate result of the new material flow routes is that countries like Malaysia, Vietnam, and Thailand have been overwhelmed with the volume of imports spurring many of these countries to implement importation bans of their own [7, 8]. Compounding this, China announced in 2018 its intent to ban *all* waste imports by the year 2020 [5]. The dwindling export options are especially threatening to the US waste management structure, which exports approximately 1/3 of its recycling commodities [5]. Already, recycling rates have dropped from the national average of 9.1% to 4.4% in 2018, and may even go as low as 2.9% in 2019 if the rest of Southeast Asia follows in China's footsteps[9].

Among other global responses, some countries have taken measures to alleviate the impact by responding with their own environmental legislation that address the production of waste rather than the issue of where to send that waste. For example, England, Canada, and Japan have elected to ban the *production* of single-use plastics in an effort to reduce displaced material.

The United States Waste Network

National legislation in response to this change in circumstance has not yet been seen within the United States. As the largest contributor to exported waste, the US faces the most serious repercussions from the loss of China as an export consumer. Prior to National Sword, the US alone accounted for approximately 1/3 of China's waste imports, valued at $5.6 billion dollars [5]. Jim Fish, the CEO and present of Waste Management (the largest waste management company in the US) commented after the announcement of the National Sword policy: "The world is changing more rapidly than ever. To sustain and succeed in the face of this change requires agility, adaptability and, above all, a resilient spirit [10]." In the short term, waste management companies within the US are adjusting to the loss of a consumer for their recyclable materials through slower processing (allowing for a more diligent sorting process in the effort to achieve a greater percentage of decontamination in recyclable waste), upgraded processing technology, new markets (Malaysia, Thailand, Vietnam), stockpiling, incineration for gas recovery (also known as waste to energy), and increased landfilling [5]. The majority of these activities are only temporary solutions however, leaving the growing problem of: *what to do with American-made recyclable waste?* Slowing down processing and coupled with the sudden high supply and low demand has caused a sharp decrease in the value of recyclable materials, resulting in over 65% of recyclable material streams becoming a *cost liability*, or at risk of forfeiting economic benefits as a result processing costs exceeding future returns. Equipped facilities, such as large recycling companies with the infrastructure to support urban areas, are restricting the materials they will accept and stockpiling excess material. This is done to prioritize the more valuable material streams and as a result of low commodity prices. Pete Keller, the public face of Republic Services (the second largest waste management company within the US), has said that they have over 2,000 tons of paper in inventory that they have been unable to move "at any price or cost"[11]. Smaller recycling companies that serve significant portions of their state's population have had operations upended, in many cases collections of recycling have been sent directly to landfills [11].

With the demand for and stresses on domestic waste management being greater than ever, it is essential to recognize the limitations of landfilling. The current methods of calculating remaining landfill life (in years) does not take into consideration the predicted increased annual rate of waste production, the recent increase in landfilled recyclables, or the impacts of nearby landfills closing [12]. Every state also handles their waste management independently (adhering to a few EPA regulations that set the national standard), which limits access to uniform information and analysis from a national perspective. The resultant fragmented network prevents an impactful design solution from being uncovered, a solution that requires a system level model that takes into account the many components making up the US waste network.

Circular economy (CE) is one method proposed towards alleviating the challenges introduced by both limited resources and excessive waste generation [13]. CE seeks to improve material cycling through the principals known as the 3R's: reduce, reuse, and recycle [14]. Research on sustainability practices has made great improvements in the last decade. However, the emphasis has been placed on recycling, which has been put in jeopardy by China's recent actions and misses the potentially significant opportunities of reduce and reuse [15].

The Biological Waste Network

Biological ecosystems are in a constant R&D phase, and those millions of years of research and development have resulted in networks that are able to survive disturbances and effectively use available energy. While most common expressions of biomimicry are in the realm of product design (self-cleaning surfaces and Velcro are two very well-known examples [16, 17]), using ecosystems to better design human networks has a lot of value. Figure 2 plots the sustainability of ecosystems as a function of their balance between efficiency and diversity, illustrating the "maximized" position that real-life ecosystems have been able to obtain. Prior work has used ecosystems as inspiration for the redesign of human networks towards more sustainable industrial resource networks [14, 18, 19] and power grids [20] and more resilient power grids [21] and water distribution networks [22]. The practice of mimicking Nature in design is known as biomimicry or bio-inspired design [23].

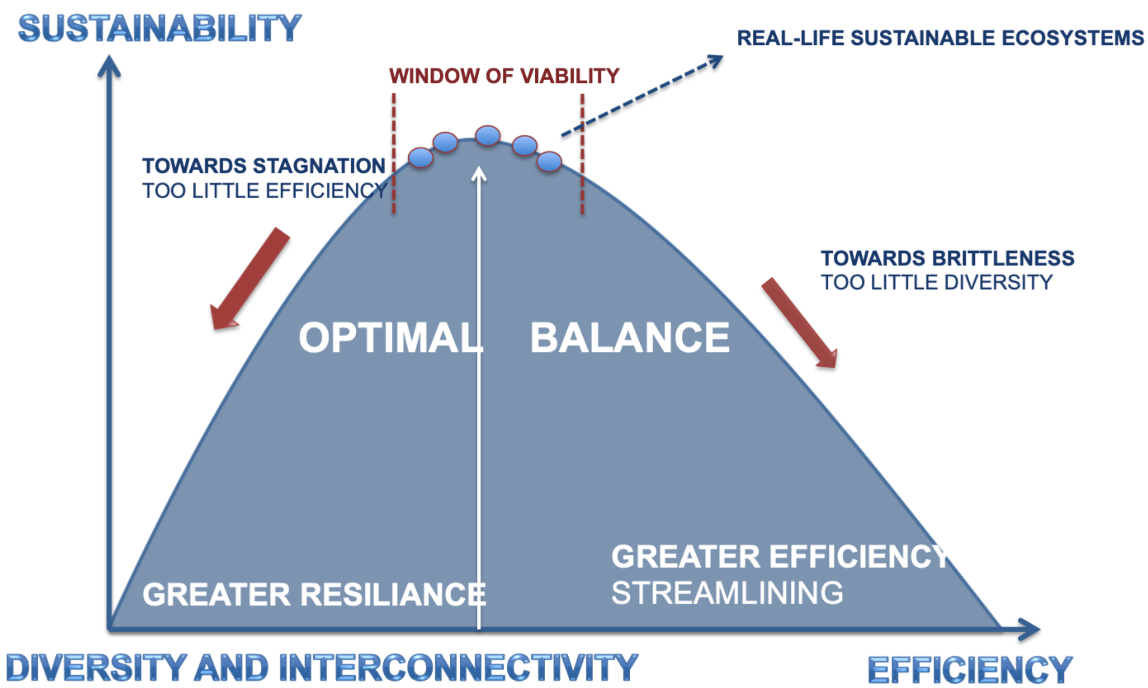

Figure 2: Sustainability graph demonstrating efficiency vs diversity and interconnectivity.

The ability of ecosystems to maximize their sustainability is thought to be partially the result of detritivores and decomposers [24]. Detritivores and decomposers are unique food web actors (a food web models the predator-prey based interactions within an ecosystem) that process low quality energy from dead organic matter (DOM), enabling its use by the rest of the system. This behavior has led to the term “recyclers of the biosphere.” These actors (species such as earthworms, fungi, and bacteria) make up what is known as the “brown food web,” which actually processes a large percentage of the total energy and connects with over half of the actors within an ecosystem [25, 26]. The processing of DOM by detritivores creates the characteristic complex cyclic structure of ecosystems. This cyclic structure has been found to correlate with thermal efficiency in thermodynamic power cycles, relating to the increase in thermal efficiency in these cycles that is activated through the addition of components that are able to use low quality energy [27], and is a desirable property for sustainably minded human networks [28].

Waste management has yet to be considered from a network flow perspective that includes all actors within the system. No cohesive network model is currently available and the data is sporadic and hard to follow, with each actor reporting what they want using their own terminology. A network model for the waste management system in the US would enable bio-inspired characteristics to be incorporated into the redesign, with the goal of learning from and mimicking the extremely successful waste network of ecosystems. Building this network would also enable fully informed decisions to be made that consider all network aspects: the independently run actors of the waste management network, their costs, their locations and permits, and their fill rates.

The Broader Impact and Intellectual Merit of a Waste Model

This thesis details the solid waste flow network specifically of regions within Texas and the larger network of the entire USA, creating a baseline model and analysis tool for future researchers. The developed tool supports the decision-making process faced by the waste management industry by incorporating previously overlooked factors such as cost of transportation, limitations of nearby landfills, predicted commodity prices and availability, increased waste generation and more, enabling decision makers to reach well-informed solutions.

The analysis of waste from a network perspective also improves its design for the future of waste management. The development of such a network would allow for algorithms and optimization processes to be applied by future researchers to aid in all aspects of waste management organization. For example, the information collected could be used to determine where to implement a new landfill or recycling facility to have the greatest impact by identifying what areas of the network have the greatest need. The current trends in the waste management industry are identified and tracked to circular economy initiatives, enabling the system's sustainability to be analyzed and methods for improvement to be identified. The results enable the necessary changes to today's waste practices to be clearly and intelligently determined.

Research Task Outlines

Task 1 & 2: ***Build a theoretical network representing 1) material flows based on actual waste generation and disposal practices in the US and 2) the US recycling industry practices***

Waste management practices within the US currently lack sufficient methods of National (or top-level organization). Decisions in the waste management industry are most often made by municipalities or private companies within the industry, who are required to adhere to regulations set by the state.

Objective

The objective of Task one is the generation of a theoretical network based on the US's actual waste generation and disposal data that originates with sectors of waste generation and ends with methods of disposal. The network will call out the steps waste materials follows before reaching the disposal destination and analyze the feedback loops of various recycling methods. A result of Task 1 is provided within the literature review in Chapter 2. A high-level example highlighting the steps of a waste network is shown in Figure 3.

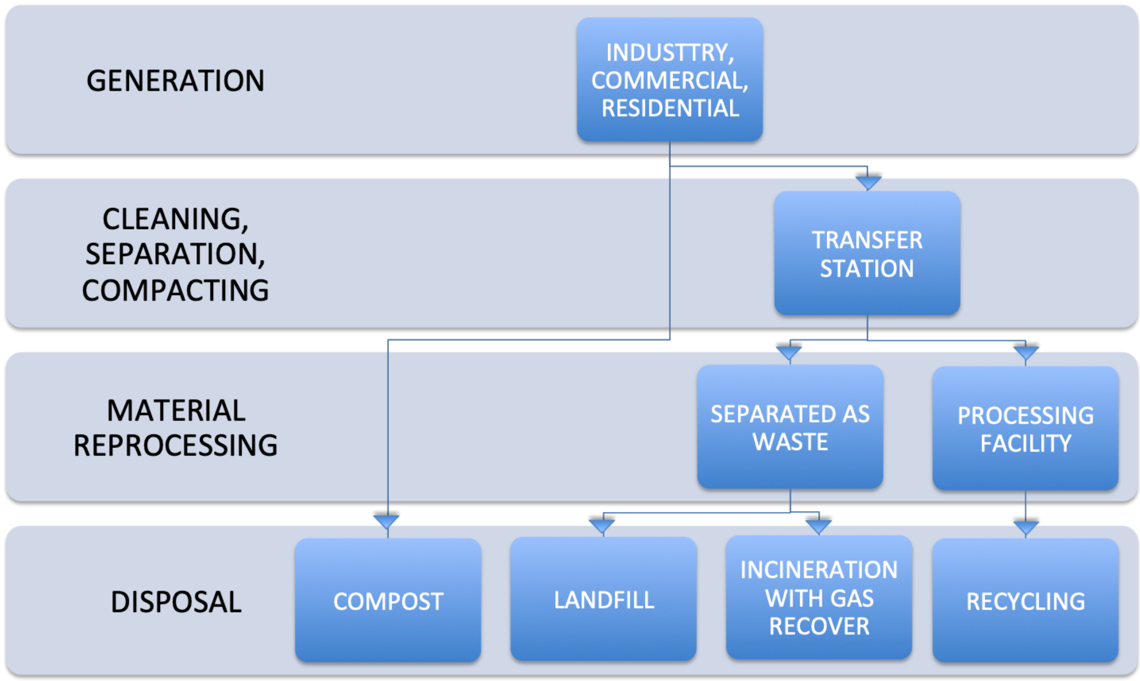

Figure 3: The process for waste disposal in the US, starting from the top-level at generation moving down to ultimate disposal in a variety of settings.

Figure 3 demonstrates the general waste flow for the most common disposal methods within the US. Generation is often considered as industrial, commercial, or residential. Industrial waste is generated through mass production processes seen in manufacturing. Sectors that contribute to industrial waste include agriculture, automotive, textiles, construction & demolition. Commercial waste is defined differently based on the local or industry standards. Commercial waste is a term that can be: 1) included as industrial waste, 2) defined by generation volume, or 3) defined by the generation source. For the purposes of this network, the third option will be used and commercial waste will be considered waste generated by industry that is not a result of manufacturing. An example would be the waste generated by hospitals, restaurants, car dealerships, etc. Lastly, residential waste encompasses municipal solid waste generated by the general population.

Besides materials set aside for composting, all waste is first delivered to a transfer station for separation, cleaning, and compacting. Composting is a unique disposal method because most composting companies organize their own pick up and transportation (not including landfills that compost). This does not mean that composting facilities do not need to conduct some waste separation, but most (if not all) companies are privately owned and provide strict instructions on acceptable materials. Transfer stations can be landfill focused, recycling focused, and in some cases capable of handling both. The majority of facilities that interact with the public are operating as transfer stations, although many promote or title themselves as recycling. When waste arrives at these stations, it is first separated into recycling materials and general waste. General waste is then typically compacted and transferred to landfills or for incineration with gas recovery. Depending on the capabilities of the individual transfer station, recycling materials are first separated into categories (ex. Paper & paperboard, low grade/high grade plastic, metals, or glass), then cleaned, and occasionally treated to increase the material value (for example, shredded paper can be sold at a higher value than regular paper because it is ready for direct reprocessing). The practices of the transfer station depend largely on the local climate with regards to environmental awareness. Rural transfer stations are likely to not separate for recycling and some cities may only have the ability to handle higher grade plastics or select materials. These problems and considerations are further explored in later chapters of this thesis.

Once a material has been set aside by transfer stations for recycling, it can be sold to a processing facility that will conduct the material recovery. Most processing facilities are capable of handling at most a hand full of different materials. The selectiveness is due to different equipment being needed for metal, glass, paper, etc. Often times it is more cost effective to focus on a selected few, although this can create challenges as commodity values are unpredictable and sometimes volatile. For example, blended commodity value was reported to be down nearly 50% after the China's importation ban due to a glut of materials available for the remaining processing facilities [5].

In addition to the connections in Figure 3, the network generated in Task 1 will also include the feedback flows from recycling, compost, and gas recovery. These feedback loops create material cyclicity in the system, an essential characteristic towards achieving circular economy as well as towards mimicking the behavior of natural food webs.

Each type of actor within the network (waste generator (sectors), transfer station, processing facility, landfill) operates using a basic set of "rules". The connectivity matrix representing the groups with broad categories is given below.

$$
\begin{array}{c|cccc}
 & \overset{\textbf{WG}}{\uparrow} & \overset{\textbf{TF}}{\uparrow} & \overset{\textbf{P}}{\uparrow} & \overset{\textbf{LF}}{\uparrow} \\
\hline
\textbf{WG} \rightarrow & 0 & 1 & 0 & 0 \\
\textbf{TF} \rightarrow & 0 & 0 & 1 & 1 \\
\textbf{P} \rightarrow & 1 & 0 & 0 & 1 \\
\textbf{LF} \rightarrow & 0 & 0 & 1 & 0
\end{array}
$$

Figure 4: Task 1 Basic Waste Material Connectivity Matrix. Arrows represent direction of material flow.

The above matrix demonstrates that facilities registered with a transfer station permit (TF) are the only actors allowed to interact with the waste generators (WG) (in the form of waste collection). Transfer stations can then send materials to either landfill (LF) or to a process facility (P). From the process facility, a minimum of 10% of the materials gathered should be returned to the sectors, the rest can be sent to landfill[12]. Landfills can return energy to the generators through gas collection (or waste to energy) practices or to processing facilities through further diverting material waste. For this material flow matrix, only materials diverted will be considered. No actors will send material to an alternate facility of the same function (for example, transfer stations will not send waste to other transfer stations), however landfills are capable of generating energy that is used at the same site. This type of behavior is known as cannibalism within a representative food network.

To better understand the simple feedback stream provided through the process facility actor above, the recycling industry is analyzed through Task 2; maintaining similar research questions and goals towards better understanding the functionality and structure of this waste management sub-industry.

Primary Research Question

T1&2.1 What routes of waste disposal are available in the US waste management industry?

The evolution of waste management in the US has resulted in a system with little coordination, making it very difficult to track and improve. The lack of this information has led to the network being widely misunderstood, even by professionals within the waste management industry[29]. Task 1 aims to address this need by developing a theoretical network of the top-level waste management actors, including routes for specialized materials, such as: medical waste, construction and demolition waste, and the primary recyclable materials. As well as including the various transfer stations, processing plants, and value of material cycling achievable through the various methods of disposal.

T1&2.1 Research Question Goals:

The goal of the theoretical network is to shed light on an often-misconceived system as well as provide general understanding of waste management practices with emphasis on the recycling industry through Task 2. The organized theoretical networks will allow for the analysis and comparison with sustainable systems such as natural food networks. These investigations will illuminate possible areas for improvement and provide a base model that decision makers within the industry and local officials can utilize when considering the organization waste management.

T1&2.2 What are the primary areas where changes be made to improve the current system?

Significant research on the implementation of sustainability in industry with a system-level approach has been previously applied to manufacturing tactics and organization. Sustainability research has focused on reducing overall waste from these systems and as a result the waste still generated is overlooked. Executing some of the same sustainability analysis methods to the waste management model developed in T1&2.1 will identify negative and positive trends, determining the potential sustainability effects of proposed changes to the overall performance of the US waste-system. An example of this would be creating greater separation of waste materials (one method proposed towards creating a circular economy) within the theoretical system and observing the effected results.

T1&2.2 Research Question Goals:

By looking at system-level metrics for internal material cycling, network efficiency, and network robustness, discussions can be developed on the impact of popular sustainability methods to a waste network. Implementing the methods of circular economy will result in improved system metrics (such as cyclicity and sustainability) and will support the implementation of these changes on the real-world network. These observations will create recommendations for system alterations and methods for higher sustainability performance of the US waste management system.

Task 1 & 2 Initial Findings and Hypotheses

The initial research confirms a clear lack of interconnectivity within the waste management sectors. Industry generators of waste appear to be highly unregulated, which makes it difficult to collect wholesome information. Based on these findings, the following hypothesizes have been formed:

Hypothesis #1: *The waste management network will have high pathway efficiency and low robustness*.

High efficiency and low diversity are cornerstone traits seen in most industry networks today as a result of streamlining processes. Waste management is organized by the origin and type of waste materials primarily. This cascades into four or five clearly separated processes available to waste generators such as: residential and commercial liquid waste management, residential and commercial solid waste management, construction and demolition waste management, etc.

Hypothesis #2: *Models designed through Task 2 modified to represent sustainable practices will result in new metrics that are closer to metrics seen in natural food webs.* Sustainable efforts hope to achieve higher material efficiency, most often through the promotion of circular economy. As such, waste generation is curbed through the continuous use of materials and energy. In this way, models are designed to create more cyclicity, a known trait of biological food networks.

Task 3: ***Collect and analyze the essential information required to develop a realistic model of Texas waste flows***

The current US protocols for documentation of information from waste management facilities do not provide sufficient details, preventing the necessary broad-viewed analysis of the system. Although research has been conducted, these industry analyses can cost as much as $4,500 to obtain.

Objective

The objective of Task 2 is to have a complete collection of data that quantitatively describes the Texas waste flow network, including facility information, volume metrics, location (GPS) of facilities, and costs of feasible waste routes. This information will be the basis of the model design in Task 3 and functions as the primary source of data for this dissertation.

Primary Research Questions

T3.1 What actors, decisions chains, and connections does a realistic waste management network include?

Moving on from the theoretical model of Task 1, the solid waste management network of Texas is used to create a small-scale representational model of a real-life waste management network using a region within Texas. Factors such as: what actors contribute to the network, how does responsibility break down, and what determines the connections within the network will all be determined.

T3.1 Research Question Goals:

The collection of the data is a large feat: much of the information needed to build a model for municipal solid waste (which is the easiest waste system to ascertain data for) is not readily available. Significant work to collect accurate and complete information will ensure that improvements made when analyzing solid waste management from a network perspective can be demonstrated. The collected data will also provide a data source for future researchers to continue to explore municipal solid waste management, as well as make recommendations for future data collection methods.

T3.2 What gaps exist in the monitoring and reporting by current waste management actors regarding waste generation, treatment, and disposal?

The data collection will highlight discrepancies in waste management published materials. This has already become apparent; a revelation that is troubling as the reports used for data here are also employed by many policy-makers when making decisions on the future of solid waste management. Improving upon the method of gathering information will create better practices, enable new and more sustainable network designs, and have a positive effect on the public's understanding of waste management.

T3.2 Research Question Goals:

Identifying the gaps in the current data acquisition and analysis methods will improve upon the approaches used for gathering such information in the future. One immediately noticeable breakdown in the Texas Commission on Environment Quality's (TCEQ) report is the calculation for total remaining MSW landfill capacity (in years).

The report for 2017 suggests that Texas has 55 years of landfill capacity left, however only 3 years earlier TCEQ published there were 60 remaining years for landfilling. The numbers provided by the facilities do not always align with their consumption rates and do not consider the predicted increases in consumption or the closing of landfills.

T3.3 What information is needed to build a decision-making model that might accurately resemble changes made in waste management?

What are the initial connections within the network? When the local landfill reaches capacity, what are the variables considered when rerouting the region's waste? The answer is simple: cost and risk. However, when a system-level approach is taken "cost and risk" quickly evolve into a complex decision process that includes the numerous costs contributing to waste management. This Task will address the various influencing factors that the US waste management industry faces today, contributing to a system-level model.

T3.3 Research Question Goals:

The analysis of costs and risks related with the transportation and disposal of municipal solid waste will be used to towards the future work utilizing the data and developing models that resemble a realistic change in network connections. The information gathered will be the basis for the optimization model developed in Task 3.

Task 3 Initial findings and Hypotheses

The data available through the Texas Commission on Environmental Quality is an excellent basis from which to build a network, however it lacks pertinent information needed to build the model in Task 3[12]. Research is needed to be able to accurately estimate the behaviors expected from this network. Based on the initial findings, the following hypotheses were developed:

Hypothesis #1: *The published remaining number of years available for landfilling will be reduced significantly*. Past reports have already been found to overestimate the actual value expected. Including predicted increases in consumption due to the growth rate of Texas, the closing of landfills is predicted here to result in a much lower number of remaining landfill years in Texas.

Hypothesis #2: *Factors outside of cost and risk will play a role in the decision-making process executed in the real-life waste network.* Initial investigations suggest that the lack of coordination within the waste management system has resulted in various inefficiencies. This suggests that decisions were made based on unidentified external factors that the thesis aims to clarify. Possible additional factors are hypothesized to include company relationships, public initiatives, and strict permitting regulations.

Task 4: ***Create a scaled down version of the Texas waste network model that accounts for flow connections between actors***

Currently, no method is available that incorporates all facility information (including transfer station, processing station, and transportation to disposal) to optimize decision-making or evaluate comprehensive costs of waste transportation. Even using all of the data Texas has collected on these facilities, many aspects are left unknown which make it difficult to design a full-scale network. To perform an optimization, real-world facilities will be analyzed for their material flow types and volumes to determine connection matrices and flow matrices for the regional waste management networks.

Objective

The objective of Task 4 is to use the collected data from Task 3 and organize the data in a manner that would allow for the development of a dynamic version of the Texas waste network model that is capable of considering various cost and risk elements. This will be done using information gathered in Task 1 and 2 along with regional segments of the data to create accuracy within the theoretical model. The flow and structural matrices of the designed model will enable investigations into what changes can improve the sustainability of future waste management networks based on their comparisons with naturally sustainable food webs.

Research Question and Goals

T4.1 What additional information can the network analysis of solid waste management provide?

Very little research has been done on the tracking of solid waste, none considering the system from an overall network perspective. This novel approach is expected to uncover significant findings and provide opportunities for advancement.

T4.1 Research Question Goals:

The model developed in Task 4 will demonstrate the advantages of analyzing waste management from a network perspective. The network designed will provide a basis for the future development of an optimization that can prioritize the costs and risks associated with connection changes in the network. The future model will illuminate possibilities and create better informed processes. The goal of Task 4 is to organize the data from Task 3 in a manner in which it can be analyzed using ecological metrics and ready for implementation with future optimization tools.

T4.2 What adjustments can be made to improve the current waste management network?

Can altering waste management practices result in an improved outlook for waste disposal? Will implementing sustainable policies extend the life expectancy of our current system? At what level will alterations maximize their impact? These questions currently do not have a standardized means of analysis. The model developed in Task 4 targets such questions for further investigation.

T4.2 Research Question Goals:

Adaptations supporting various sustainability initiatives will be understood from a real-world perspective. The waste management networks' current sustainability will be tested utilizing ecological metrics and trends in the model will be identified. The model will create a basis for future researchers to engage with when addressing the topic of waste management.

Task 4 Initial Findings and Hypotheses

The flow considerations in Task 4 will include facility specifications, material type and volume recorded, as well as the shared sources of waste generation. The material flow will be able to be adjusted to accurately represent predicted growth in both waste generation and populations utilizing similar tactics as demonstrated in the analysis of the data in Task 3.

Hypothesis #1: *The decisions made by a future optimization model will be more informed than most decisions are in the real world of waste management.* Most decisions on the handling of municipal solid waste are made by local government officials. These officials are directed by the EPA to make their decision based on cost and risk. However, because only the blanket cost of removal and disposal are available to them, decision makers are ignorant to the real costs of their decisions. By including transportation costs calculated down to number of trucks as well as limitations on landfill intake, the optimization model will improve the decision-making process.

Hypothesis #2: *The priorities exercised in the decision-making process will be partially dependent on the environmental awareness and education exercised from the associated region.* Consider the comparison between Austin (a city in the Capital Area Council of Governments) and the towns located within the West Central Texas Council of Governments. Today, Austin leads Texas cities in terms of environmental awareness and education. There exist multiple options for material recycling and reuse within its city limits. Many Austinites choose to pay more for their wastes to be recycled and, as a result, the recycling industry has grown. Conversely, the West Central Texas Council of Governments has no regionally available material recycling facilities. Four of their 12 landfills are Monofills, meaning they service cities with populations below 12,000 and are only granted waste disposal permits for 5-year increments. It is very unlikely that the two regions will exercise the same priorities when planning local waste management design.

Dissertation Layout

This dissertation is organized to follow the Tasks outlined. Chapter 1 serves as motivation for the thesis topic as well as a top-level introduction to the objectives and goals of the dissertation research. Chapter 2 is the literature review for this thesis and introduces the topics of circular economy, natural food web contributions to this research and various sustainability practices to provide the reader with the pertinent background information. Chapter 3, 4, 5, and 6 are dedicated to Tasks 1, 2, 3, and 4. These chapters introduce specific topics pertinent to the Task problems, discuss the methods that were used to gather information and complete each Task, analyze and discuss the significance of the results, and finally summarize the take away statements for each Task. Finally, Chapter 7 will be a brief conclusion to the thesis, where the final take-away messages will be reiterated for the thesis as a whole. In addition, future work will be presented focusing on a broader level of consideration. The Conclusions chapter will combine the information gathered in the literature review and the results of each Task to discuss overarching themes and tie any loose ends. Following Chapter 9 will be the appendices and references list.

CHAPTER II

LITERATURE REVIEW*

Introduction

Current industry operations rely heavily on virgin materials and generate an exorbitant amount of waste: in 2015 the US Environmental Protection Agency (EPA) estimated that 2.24 kg of waste was generated per person per day within the US, with containers and packaging contributing 77.9 million tons (29.7 percent of 2015's total generation) [30]. This rate of waste generation and the planet's finite resources negate the long-term sustainability of this linear production-to-waste model [13, 31]. One potential solution for minimizing the environmental impacts of our waste generating society is to increase the efficiency with which available resources are used. Resource use efficiency is one of the main goals of Circular Economy (CE), which seeks to "close the loop" in production processes by promoting the minimization of raw material inputs and waste outputs [14].

Circular Economy

The fundamentals of sustaining human life rely on the understanding that the planet has a finite source of capital stock [1]. Recognizing the reality of these limitations, where existing production and consumption are organized to reflect limitless raw materials, became the prerequisite to a framework outlining a shift from open-ended

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economics to the circular economic system [32], a system derived from materials and energy conservation laws in thermodynamics [33]. This change in viewpoint in environmental and ecological economics has since evolved into a focus on three central actions, referred to as the 3Rs Principle: reduction, reuse, and recycle [14, 34]. Reduction aims to minimize the energy and material inputs to production processes, thereby increasing resource efficiency at production and consumption levels [14, 35]. Reuse focuses on preventing products and components from being labeled “waste,” encouraging reuse in their original roles [36]. Recycle seeks to reduce environmental impacts through recovery processes, where material waste is reprocessed into new products, materials, or substances [14, 37].

Despite this triple pronged approach, circular economy efforts have primarily focused on recycling [14]. Recycling has become the primary component of material decomposition networks set out to reduce landfill waste. Current recycling however is highly inefficient and most efforts are more symbolic than practical. Markets for recycled materials are notoriously volatile, contributing to costs that often exceed the cost to simply dump recyclable materials in landfills [15, 38-40]. Only 9% of the world’s plastic produced from 1950 to 2017 has been recycled [41]. Reuse, an activity that was once so common it was done without thinking, may hold greater potential for creating and supporting material pathway for byproducts that prevent waste. Reuse is traditionally viewed as extending the life of a product in its original role, for example a reusable ceramic coffee cup (vs. a single use paper cup). The single use cup only has value with regards to the original drink it contains, the ceramic coffee cup's value however is tied to its ability to hold both current and future drinks. In this paper we discuss the potential benefits of investing in traditional reuse and byproduct reuse. Byproduct reuse, which turns a byproduct into an input for a secondary process, is a less-explored alternative to traditional "original function" reuse. Challenges such as producer habits in manufacturing processes (for example a lack of enforced extended producer responsibility, EPR), regulations favoring virgin material use, and liabilities derived from using secondary materials, all make large-scale byproduct reuse a challenge that needs more research to overcome [42-48].

Biological Food Networks

Naturally sustainable, biological food web networks present a method for identifying flaws in and potential solutions for the current linear industry model to move closer to a circular economy. Biological food webs are networks of species that connect via predator-prey interactions, or for the purposes of the analogy with industry, they are made up of actors that exchange and transform materials and/or energy. These biological networks have developed a non-linear structure that enables the efficient use of low quality and waste material in a way that is reminiscent of an ideal circular economy [24, 49].

Food webs are able to increase their resource-use efficiency and minimize wasted product through decomposition networks [49]. These networks center on low quality energy, allowing food webs to reuse and retain energy and material flows that would otherwise be lost [50]. Detritivores and decomposers function as the "recyclers of the biosphere," aiding nutrient cycling and conversion by breaking down the larger organic materials. Decomposers specialize in consuming and metabolizing the smaller dead organic matter, known as detritus, enabling it to be reintroduced as nutrients that fertilize the growth of plant-based species [49]. Figure 1 shows the four primary energy sources in a food web: energy produced by plant life or the "primary producers" as they are known in ecology (PP), the live consumer system which processes energy from a living state (LC), the decomposer system made up of decomposers (actors that breakdown the lowest quality energy sources in an ecosystem) and detritivores (actors that consumer energy in a dead state), and dead organic matter. The relative size of the arrows and boxes provide insight into the sources and flows of energy that dominate ecosystem functioning. The primary energy flow is of dead organic matter that is processed by decomposers, a flow that can be up to 5 times the energy flux of the other major pathways in an ecosystem [51]. The interactions between the decomposer system actors (things like earthworms, fungi, and bacteria) and the rest of the food web have been linked to the overall dynamics and stability of food webs [52] as well as the ability of the web to support species diversity and larger predators [50]. The detrital feedback loops that occur in biological food webs have also been shown to increase resource use efficiencies [53].

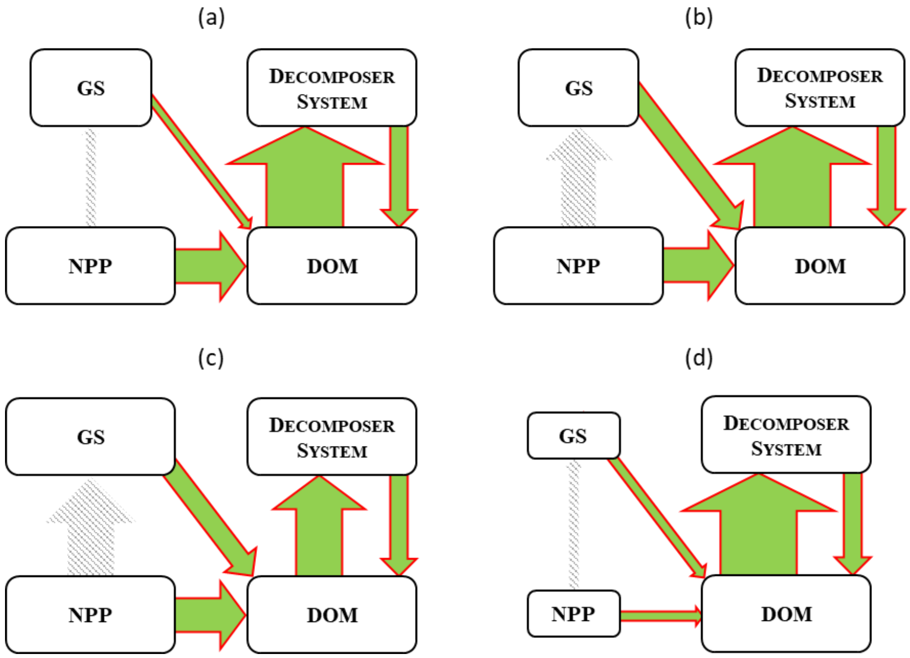


Figure 5: General Patterns of Energy Flow Between Subgroups in Four Ecological Cycles: (A) Forest; (B) Grassland; (C) Plankton Sea Community; (D) Stream of Small Pond. The relative size of the boxes and arrows represent relative magnitudes of the energy produced in each compartment and flowing between. NPP= Net Primary Production; GS= The Grazer System, also known as the Live Consumer System; DOM= Dead Organic Matter; Decomposer System= Decomposers and Detritivores. ***Adapted from Townsend and Colleagues (2008) with permission of John Wiley & Sons*****, INC. COPYRIGHT © 2008 BY JOHN WILEY & SONS, INC.**

The lack of equivalent and identified detritivore and decomposer opportunities in industry is a challenge to mimicking food web behaviors. However, recognizing areas that can be adapted to provide these functions would mitigate the issue and further the goal of translating the desirable properties of food webs to circular economy. One example of this is implementing the decomposer/detritivores functional role in industrial networks; an approach investigated in some newer industrial symbiosis research [28, 49].

Industrial symbiosis is a subset of industrial ecology that focuses on the optimization of resource use through business relationships resulting in two or more companies supporting industrial waste utilization or other forms of resource sharing [54-56]. Current industrial systems have been shown to lack an active decomposition network, limiting the potential for the reuse of materials [28]. The General Motors "Blueprint for Zero Waste" is an example of industrial synergy where focus is placed on working both internally and with a network of suppliers to directly use byproducts as a system input, in place of sending materials to be melted or chemically repurposed [57]. GM's value recovery success involves (1) cardboard shipping materials recycled into sound-damping material in the headliners of the Buick Lacrosse, (2) paint sludge used as a plastic material for shipping containers that are durable enough to hold Chevrolet Volt engine components, and (3) selling steel sheets remains to local steel fabricators to stamp out small brackets for heating and air conditioning equipment for other industries [57]. Continuing to translate the lessons learned from food web design to industrial practices, with a focus on reuse and recycling networks, is a promising route to move closer towards circular economy goals.

Work is being done towards industry implementation of detritus and decomposer-type actors, however analyzing the functional differences between industrial waste and detritus has not yet been investigated. As the significance of detrital pathways become recognized for their beneficial effect on ecosystem energy flows, empirical research in ecology has expanded to include detritivore-type animals as well as to consider the resource nutrient content of detritus itself [50, 58-61]. Although the composition of detritus can vary significantly across food webs, research has found that the nutritional content of detritus can have a significant effect on the consumption rates and assimilation rates of detritivores [61, 62]. Low-quality, recalcitrant detritus is therefore commonly assumed to slow/reduce consumption and assimilation rates, leading to slower detritivore growth while high-quality, nutritious detritus has been shown to contribute towards higher consumption rates and growth efficiencies [61, 63-66]. With this in mind, an important comparison to consider is the quality of industry-generated waste and its corresponding effect on waste feedback loops.

Methods

Literature Selection Methods

The following review was written using both academic and non-academic sources. The collection of published studies was executed utilizing several associated criteria: (1) topics of interest (detritus, brown food chain, circular economy, origins, principles, methods of implementation, byproduct reuse, etc.), (2) comparison to contemporary articles (many sources with valuable claims were over 10 years old, in these cases more relevant papers were found to corroborate), and (3) objections and challenges. The search was done through Google Scholar and the Texas A&M Library website using keyword searches such as: “detritivore actors”, “circular economy”, “recycling”, “reuse”, “byproduct reuse”, “lean manufacturing.” Sources were screened through their abstracts to determine if their focus aligned with our interests. After selecting sources pertinent to our study, 84 journal articles and book excerpts were used. Popular journals were the Journal of Cleaner Production (4 papers), Resources, Conservation, and Recycling (8 papers), Journal of Industrial Ecology (3), and the Journal of Remanufacturing (3 papers). Books were found based on the same search methods above, the literature draws information from 36 different books, with 6 from university publishing presses (John Hopkins University Press (1 paper), Harvard University Press (1 paper), etc.).

Online information was used for current figures, news updates, and statistics. The recent news on China's ban of recycling imports has already had a major impact on the US recycling network, however very little information has been published academically on this event and its impacts. Statistics and figures were primarily found through publications by the US EPA (7 sources), with additionally information from news outlets such as NPR, BBC News, and CNBC. Company websites were used for real-world examples, including General Motors and Boeing. One hundred and fifteen references were collected in total.

Waste

Waste generation in the United States has increased over the years at a rate of 3.5% while the rate of waste that is recycled or composted has leveled off after interest in recycling in the 80s and 90s waned, leaving a growing amount of waste being dumped in landfills (shown in figure 2) [3]. This rate of increase is expected to continue growing worldwide as populations increase and developing countries modernize [67, 68].

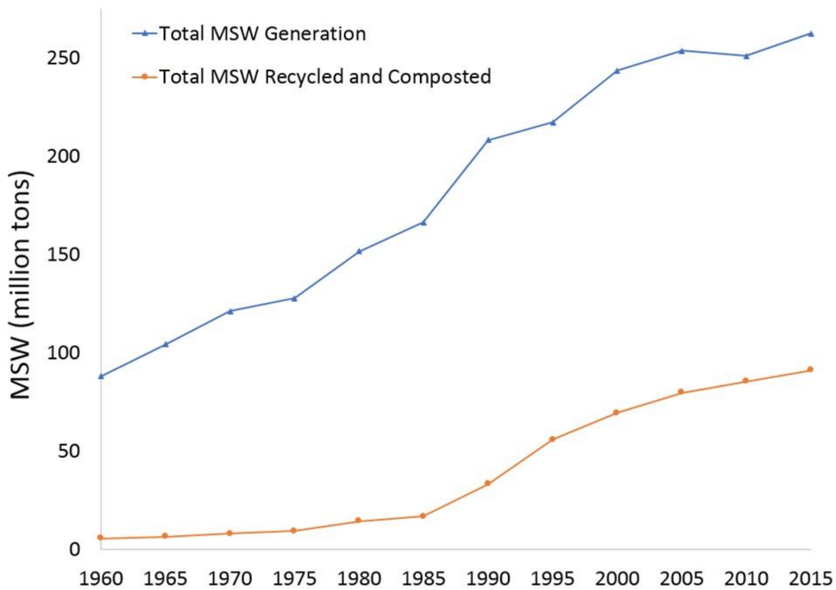


Figure 6: Total Municipal Solid Waste (MSW) Generation (Blue Triangles) and Amount Recycled and Composted (Orange Circles) in Millions of Tons in the US from 1960 to 2015. ***Figure adapted with permission from the EPA*** **[44].**

These concerning trends in waste production worldwide warrant a focus on waste-reduction strategies at both the consumer and producer level. Well-known strategies such as recycling and design for disassembly focus on one side or the other. However, product and byproduct reuse are under realized strategies that involve both the customer and manufacturer. As such, product and byproduct reuse are presented here as a unique reduction strategy due to it being functional at both the consumer and producer levels.

The process of distinguishing a material as a by-product or waste plays an important role in the resulting end-of-life treatment. A by-product mislabeled as waste faces significantly more regulations and limited opportunities as a result of regulations associated with the title [69]. The European Commission (EC) established the difference between wastes and by-products as a part of its 2005 Thematic Strategy on the Prevention and Recycling of Waste [36]. Production leftovers with valuable characteristics are singled out as by-products [70]. The food industry presents a clear example as to the negative effect that regulations attached to the term “waste” can have: a third of edible material generated each year in the US is not consumed and only 5% of this can be donated due to waste-related policies [71]. A three-part evaluation was created by the European Commission to aid in distinguishing useful by-products from waste: a material is waste if there is a possibility that the material is unusable, it fails to meet the technical specifications that are required to make it useable, or there is no known market for the material [36]. Hazardous waste, a highly regulated stream of waste, has been further defined by the EPA as: waste that has the potential to be dangerous or harmful to humans or the environment [72]. Electronic and electrical equipment is a common household hazardous waste when components contain lead, plastic housing, etc. that can be released to ground water or air when thrown into a landfill [73]. Outside of hazardous waste, it is sometimes desirable to remove the label of waste from an item that has, since having been originally labeled, found a market. The EC has established steps for waste recovery:

1. “the substance or object is commonly used for specific purposes
2. there is an existing market or demand for the substance or object
3. the use is lawful (substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products)
4. the use will not lead to overall adverse environmental or human health impacts [74].”

Dealing with Waste: Consumer Initiatives

In the last 40 years, environmental policies within the United States have gone from “top-down” federal environment regulations (allowing state power to limit pollution at its source of production) to individualized environmental tactics that instead place injunctions on the individual to “do their part” [15]. As such, over the years American waste reduction and sustainability have shifted from being the responsibility of the manufacturer to the responsibility of consumer [15, 75]. Although there is no comprehensive sociological explanation for this trend in policy, many scholars believe that corporate actors and foundations funding environmental NGOs (non-government organization) have taken advantage of the US’ environmental regulatory vacuum to frame socio-economic issues in a perspective that allows them to promote solutions directing responsibility away from themselves [76, 77]. As a result of policy trends, consumer-level environmental responsibility and awareness has been the focus of the majority of sustainability efforts since the 1980s [15]. Although discussed here with specifics related to the US, this policy issue is relevant in many countries worldwide. Plastic packaging for example made up 59% of all plastic waste in the EU in 2015 and the recycling of this material is solely dependent on the actions taken by EU customers [78]. As a result, high quality packaging material ends up in landfills: in the same year less than 30% of used plastic was recycled in the EU [78]. Consumer culture that emphasizes “more, newer, better” increases the difficulties facing all waste reduction efforts [79]. Research has shown that a majority of consumers believe that remanufactured products are of lesser quality than new products [80]. Negative consumer perceptions of remanufactured products can create difficulty to find support in industry.

Recycling

Recycling is defined as the extraction of valuable material from used products for use in new products [81]. The benefits of recycling include lower energy requirements compared to the extraction of virgin material, lower emission production, and diverted waste from landfills [82, 83]. The US EPA in 2015 disclosed that 181 million metric tons of carbon dioxide equivalent emissions were saved through recycling and composting [84]. The average benefits and cost savings associated with recycling have supported its steady rise in popularity [81]. Recycling a ton of aluminum cans for example saves 21,000 kilowatt hours of energy, a 95% saving in energy when compared to the amount of energy required to mine, process and transport aluminum ore [85]. The recycling of all materials removes them from landfills however not all materials are significantly more energy efficient [86]. Recycled glass for example uses only 13% less energy than creating virgin glass [87, 88]. Materials such as aluminum and steel have high recovery rates (36.4% and 71.3% respectively in 2015) due to cost savings for recycling vs. raw material manufacture [89]. Cost savings is not always enough to encourage recycling however: precious metals such as gold, silver and platinum have high environmental and economic value and low recovery rates [90, 91]. Retrieving precious metals from electronics, despite their high concentrations and high value is still unpopular due to hazardous waste concerns [92, 93]. Gold for example costs approximately $900 per ounce and is found in concentrations of 250 grams per metric ton in printed circuit boards as opposed to concentrations of less than 10 grams per metric ton in mines [94].

Recycling is often touted as reducing emissions; however, it can be difficult to determine whether this is true of today's recycling practices. Emissions created during collection-transportation, removal and disposal, as well as those generated during the recycling processes can quickly offset potential benefits[29, 40]. Waste and recycling networks have become complex and widespread over the years, making use of economies of scale to reduce costs [95]. Operations are often poorly documented, making it difficult to quantify the environmental impacts. An estimated 50%-80% of the total electronic waste volume generated in the US is suspected to be exported to developing countries [92, 96]. As much as 50% of the US's electronics waste is guessed to make its way to China, India, Pakistan, Vietnam, Philippines, Malaysia, Nigeria, Ghana, and Mexico or Brazil through illegal exportation means [90]. The lack of empirical data makes it impossible to calculate the true emissions savings (or costs) of today's recycling [40].

The percentage of municipal solid waste recycled or composting annually in the United States increased from 10.1% in 1985 to 34.7% in 2015 [3], however this slow but steady increase has hit a roadblock recently due to policy changes. Over the last twenty-six years the US exported thousands of tons of recyclable material to China, however as of January 1st, 2018 China has stopped accepting recyclable material from foreign countries. This policy change has had a huge impact on US recycling practices, resulting in large amounts of recyclable materials being stored in the hope of policy reversal or simply sending them to landfills [11, 97].

Remanufacturing

Remanufacturing creates a like-new product from an end-of-life product by disassembling, updating and fixing where needed, and reassembling the components [80, 98]. Distinction is sometimes made between remanufacturing and reconditioning, where reconditioning involves the replacement of key components and remanufacturing involved restoration of a product to like-new condition [81]. The engine of a car for example, can be removed and disassembled. Once cleaned and reconditioned, the engine is reassembled to be sold again as a *remanufactured* engine. Research has suggested that remanufacturing is more energy-sustainable than recycling: it requires less energy than recycling and produces a new product rather than just the base materials for a new product [99]. There are cases where remanufacturing is not desirable, such as in the healthcare field where sterility must be ensured or with hazardous materials. The medical industry relies heavily on disposable products and equipment due to contamination concerns [100]. A single hospital bed in the US generates on average 8.4 kg/day of waste [101]. Small electronics and products containing hazardous materials see increased difficulties in remanufacturing efforts [93]. Despite these difficulties remanufacturing is an underutilized route to waste-reduction: current remanufacturing efforts make up only 2% of production in the United States and only 1.9% in Europe [102].

Remanufacturing depends on the consumers: products must be returned by consumers to either the original producer (original equipment manufacturers or OEMs) or companies that specialize in remanufacturing. A large portion of remanufacturers fall into the latter category, especially in markets where the original manufacturers lack remanufacturing incentives [80]. OEM's fear that the sales of remanufactured products could reduce the sales of new products and therefore discourage or set up roadblocks to remanufacturing [58, 80]. The main drivers for OEMs to remanufacture is long-term environmental and economic incentives. Economic incentives include increased profits, a 'green' image, product cost reductions, improved market value and control of the secondary remanufactured product market [58].

Dealing with Waste: Producer Initiatives

Waste-reduction strategies on the manufacturing side of things focus on waste generated during the manufacturing and production processes and therefore do not require participation of consumers. These initiatives include design for disassembly, reverse supply chain, and lean manufacturing.

Environmental policy, specifically within the US, does little to hold current producers accountable for their role in waste generation [15]. 'Extended producer responsibility' (EPR) is a strategy designed to associate with and hold the producer responsible for all of the environmental costs that arise from their product [91, 103, 104]. Some of the more environmentally conscious producers have developed and adopted EPR practices. The intergovernmental Organization for Economic Co-operation and Development (OECD) has implemented EPR in an effort to move responsibility for disposal up-stream, from municipalities to producers, using incentivized-encouragement [103]. Without governmental incentives however, it is unlikely that the approach will be adopted worldwide

Design for Disassembly

Design for disassembly is the purposeful incorporation of disassembly-based-concerns into product design. The result of design for disassembly measures focus on making the disassembly process non-destructive, as well as quicker and easier [84, 105]. Proprietary concerns can work against making disassembly easier, as original manufacturers will oftentimes make products difficult to disassemble, preventing independent remanufacturers from reselling their products or product parts [80, 93]. Remanufacturing, requires that products be disassembled without damage and thus disassembly is often done by hand, adding danger associated with hazardous materials [106]. This first step of remanufacturing has increased interest in design for disassembly.

Recycling does not require a product's components to remain intact, extracted materials are returned to their original state as a raw material. This destructive disassembly allows automated machines to be used for recycling processes [106]. However, some sources have stated that design for disassembly can increase the amount of material from a product that can be recovered for recycling. For instance, small amounts of metals found in electronics can be recovered more easily when disassembly is considered beforehand [107]. Considering disassembly during the design phase can also reduce the time it takes to disassemble, making it possible to recycle or remanufacture more products in a shorter amount of time.

Due to design decisions at the producer level having the largest impact on waste generation, the decision to minimize the responsibility at this level overlooks the largest opportunity for reduction [108]. Wastes such as component packaging and material by-products retain no value once a product is produced. The Extended Producer Responsibility (EPR) is a model created to address this disconnect, suggesting that product producers should take responsibility for the environmental impacts of their products throughout the product life cycle [44]. This would require producers to consider sustainability impacts of everything from selection of materials, the production process, product use, and disposal of products at their end of life cycle [104]. Considering sustainability at the producer level enables decisions to be made during design that shift the waste-management focus from recycling to a combination of reduce and plan-for-reuse [109].

Reverse Supply Chain

Reverse supply chain, also known as 'reverse logistics' or 'green supply chain management,' centers around a manufacturer taking responsibility for the end-of-life stage of their product [58]. This involves purposefully planning for product take-back measures to retrieve products from customers, enabling additional value to be extracted from products after a consumer is done [58, 106, 110]. A reverse supply chain may include one of many recovery strategies, including reuse, recycling or remanufacturing. There is no set format for how a reverse supply chain should be created, since each one must be designed with the target product in mind: a reverse supply chain for car tires looks very different than one for small electronics [110].

Reverse supply chains have been found to emerge in cases with favorable (1) economic and environmental incentives for both consumers and producers, (2) product design that facilitates remanufacturing, and (3) certainties with regards to time, quality, quantity and cost in waste-product procurement [58]. Fuji Film, a single-use camera manufacturer from Japan, for example supported their reverse supply chain with an in-house remanufacturing facility, resulting in an 82% (by weight of all cameras) recycling or remanufacturing success. Their fully automated remanufacturing line enables them to make use of design for disassembly, improving recycling efficiency and decreasing associated costs, in addition to avoiding disposal costs charged by film developing centers [106].

Lean Manufacturing

Lean manufacturing seeks to specifically eliminate waste through efficient production planning, with the mentality of “don’t accept waste as unavoidable” [111]. Waste in a “lean” system concerns: waste of complexity, labor, overproduction, space, energy, defects, materials, time and transport [112, 113]. The identification of waste is essential to implementing lean manufacturing and determining which needs addressing is the primary Task.

The Toyota Production System, designed by Taiichi Ohno and Shigeo Shingo of Toyota to minimize waste [114], has since been shown to have considerable cost and quality advantages over standard mass production practices [115]. Now known as lean manufacturing, these efforts reduce inputs by adapting mass production to craft production, using tools to reduce wait time between processes, increasing manufacturing velocity with just-in-time manufacturing, inventory management, standardized work, workplace organization, and scrap reduction [116]. Challenges to and failures in implementation, despite the desirable benefits, have prevented lean manufacturing from becoming a mainstream manufacturing technique. Successful application requires complete dedication from personal, extensive planning, strong leadership, and sufficient knowledge of lean manufacturing tools and techniques. Failure to apply the methods correctly can often create more problems than solutions [117].

Reuse

Reuse refers to a product that is able to avoid disposal by repeating its original function for multiple iterations. The End-Of-Life vehicle directive, a strategy aimed at reducing the amount of waste vehicles generated in the EU each year, defines reuse as "any operation by which components of the end-of-life vehicles are used for the same purpose for which they were conceived [69]." This definition encourages the reduction of waste by extending value in a product over an increased period. The United Nations and the EU have both put forth efforts to encourage the implementation of reuse due to its practical simplicity and effectiveness at waste reduction. A study sponsored by the EU Commission showed that the single use plastic material made up 49% of marine litter on European beaches in 2016 [118]. The UN Environment Program additionally estimates that 89% of marine plastic is a single-use plastic item, such as plastic bags, straws, and disposable utensils [119]. The European Parliament has since recently voted in favor of banning single use plastic [120].

Unfortunately, reuse has yet to gain worldwide consideration. The US leads the world in waste generation, producing 254 million tons of waste in 2013, about 2.5 times larger than what was produced in 1960 and all studies point to that volume continuing to increase (as seen in Figure 3) [3]. Figure 3 shows the relative growth from 1960 to 2015 of personal consumer expenditure (PCE), municipal solid waste (MSW) generated, and municipal solid waste per capita. The values measured in 1960 are used as a baseline unit value to demonstrate the changes over time, for example if a value of 200 was seen in 1960 and the index for a later year is 3 then the value for that year would be 600. PCE is a metric used to quantify the US household spending on items such as food, clothing, vehicles, and recreation services [3]. The overall rise in MSW generated per capita between 1960 and 2015 has an index value of 1.6; however, the PCE indicates a dramatic increase in household spending on goods and services.

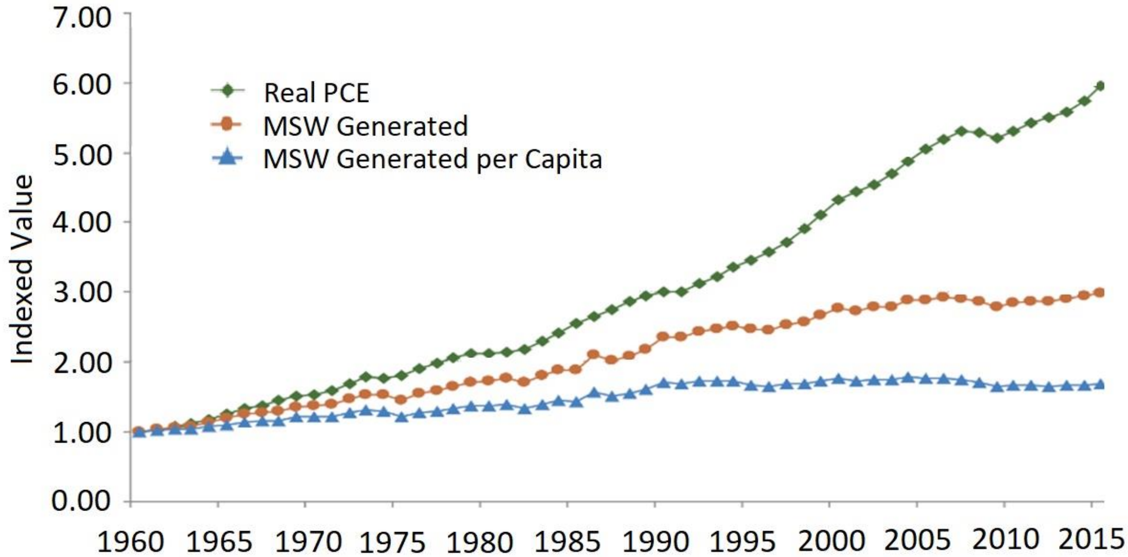


Figure 7: Indexed (Based on 1960 values) Real Personal Consumer Expenditure (PCE), Municipal Solid Waste Generated, and MSW Generated Per Capita in the US from 1960-2015. ***Figure used with permission from (2018 EPA "2015 FACT SHEET).***

A widespread reduction in waste generation through traditional, single function reuse would require an increase in environmental responsibility felt by both individual and industry producers. Decisions to create and purchase higher quality products as well as a commitment to the process are important components of successful reuse. To the average consumer, this can be seen in the decision to wash kitchenware instead of opting for the "easy clean up" that disposable products offer. The concept of reuse can be expanded beyond the traditional single function definition to include the application of by-product materials in secondary processes. The broader and relatively new definition holds potential in the production process.

By-Product Reuse

By-product reuse (also seen discussed as beneficial reuse) recognizes value in a potential waste item, turning would-be waste into a valuable commodity. By-product refers to materials produced as a direct result of manufacturing that are not a part of the final product. By-product reuse has been implemented with some success in programs such General Motors' Zero Waste Initiative and the Kalundborg EIP in Denmark, where companies and industries reduce their overall material usage through synergistic exchanges and practices. GM has diverted by-product materials from landfills by 1) reusing cardboard packaging in Buick Verano headliners, reducing noise in the passenger compartment, 2) converting 1,000 scrap Chevrolet Volt battery covers into nesting boxes for a range of birds and bats, and 3) reusing 1,600 shipping crates as raised garden beds to support urban farming initiative supporting soup kitchens [57]. By-product reuse has seen some success in commercial products that tout their sustainable characteristics: the Swiss company Freitag creates stylish messenger bags, wallets, and purses from old tractor trailers' side-panel tarps and "Garbage Bowls" made from recycled pieces of broken glass have been made popular by The Food Network host Rachel Ray [121].

There are two main challenges to successful by-product reuse: 1) finding a cost-effective secondary purpose where the by-product has "as-is" value and 2) delivery infrastructure to get by-products to the secondary market. The cost of shipping by-products beyond a company's proximal region presents economic obstacles [42] and reapplications are not always clear, forcing the byproduct to be labeled waste. These types of obstacles in action can be seen with electronic packaging materials used in automated manufacturing, known as plastic “matrix trays” [122]. Every day, millions of these trays are produced, used and discarded worldwide [122]. The trays have unique characteristics and remain undamaged after use however a cost-effective alternative function has yet to be identified [122].

By-product reuse is further hindered in the US by the low cost of landfilling, a lack of standards and specifications remaining attached to the by-products, poor awareness and marketing of available by-products, and varying state requirements and government resources [42]. The lack of government drivers coupled with the low cost of landfilling cause industries to choose the cheaper option of disposal of materials rather than finding applications for reuse [42]. The loss of specifications when used materials become by-products discourages manufacturers as well due to what is seen as an increased risk in loss of quality due to the material uncertainties [42].

Discussion

Table 1: Waste-Reduction Strategies at the Consumer and Producer Level. Reuse is Unique that it is a strategy that can be used at either stage.

<table>
<tr><th>Consumer</th><th>Producer</th></tr>
<tr><td>Recycle</td><td>Design for Disassembly</td></tr>
<tr><td rowspan="2">Remanufacture</td><td>Reverse Supply Chain</td></tr>
<tr><td>Lean Manufacturing</td></tr>
<tr><td colspan="2">Reuse</td></tr>
</table>

The many waste-reduction strategies discussed in this paper are organized in Table 1 by their consumer versus producer dependence. Design for disassembly, reverse manufacturing, and lean manufacturing are all producer driven waste reduction efforts that through planning are able to increase the value extracted from materials. Reducing consumption, recycling, and remanufacturing are consumer driven conservation efforts that all have relatively high rates of value preservation. These processes require investment in a reclamation process, there are inherent losses involved, and the final product often still requires further manufacturing. Reuse, both traditional single-function reuse and by-product reuse, is unique in that it can be done by either the consumer or producer, without a dependence on the other. By-product reuse is a sustainability practice that can be implemented at the producer level. One of the main advantages of by-product reuse is that, unlike recycling and remanufacturing, no additional waste is generated in the process of reusing a by-product since the material is used directly as-is as a material input for a secondary process, recognizing and extending inherent value.

Reuse vs. Recycling

Recycling and reuse both work towards reducing overall waste generation. Recycling has been the popular focus of environmental efforts, but may not be the most impactful solution. Recent events, namely the importation ban ("National Sword") imposed by China, have shown that the viability of recycling greatly relies on conditions outside industry control. With the loss of China as the primary customer of recycling goods, the recycling industry has faced a difficult reality in which many facilities are unable to operate at a profit [97, 123]. Previously China (the largest importer of plastic recycling) accepted more than half the planet's generated waste, but since January 2018 has imposed broad importation bans, delivering a shock to the global recycling industry [124]. By-product reuse may be able to fill this gap left by China in the recycling industry. Many products that are recycled, especially those recycled at the manufacturing level, have a potentially high value as a new raw material. New and stable by-product customers are needed to bypass the label "waste" by deriving value from these materials.

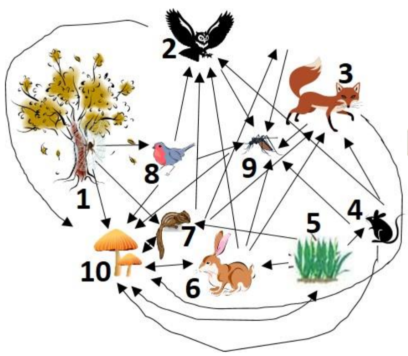
Eco-industrial parks (EIPs) are an excellent example of the power of reuse. These networks of industries are built upon by-product reuse. Industries interact via the exchange of materials and energy that would be waste, but with the right industries these "waste" streams are able to become industry inputs, reducing the need for virgin raw materials. The Kalundborg EIP in Denmark is a highly successful example, reducing yearly carbon emissions by 240 kilotons and their freshwater usage by 264 million gallons over more than 50 years of symbiotic interactions [56].

Reuse in Nature: Detritivores and Decomposers

The reuse of by-products and waste materials increases use-efficiency, ensuring that all value in a product is used. This process of using low quality materials and energy rather than disposing of them strongly mimics decomposer type-species in biological food webs. The decomposer network, the group of species in food webs whose primary function is to break down low quality materials and energy to return it for use, consists of two fundamental actors: detritivores and decomposers [51]. Detritivores consume larger and more complex dead materials just as remanufacturing and recycling in industry break down existing waste into its basic parts so it can be used again to create a product of value. The decomposer actor in natural food webs reuse of byproducts, or beneficial reuse, is more similar to because it generates value directly from a source of waste. While decomposers may not achieve 100% recovery of energy and materials, they are essential in achieving the higher cyclicity typical of natural food webs.

$$\det(\mathbf{F}^{-1} - \lambda\mathbf{I}) = 0 \qquad (1)$$

Cyclicity (λ_{max}, the maximum real eigenvalue solution to Eq. 1) is a metric from ecology used for quantifying the presence and complexity of cycles in the structure of food webs [125]. Figure 3-left shows a hypothetical food web network and on the right is the food web matrix [$\mathbf{F}$] representing connections in the network using a one in F_{ij} where there is an interaction from i to j and a zero otherwise. Cyclicity is calculated as the maximum real eigenvalue solution to Eq. 1. Research has shown that food webs are characteristic of very high cyclicity values, and this structural characteristic of food webs may relate to the high efficiency and robustness that biological food webs also display. Changes the design of a network with the purpose of increasing a network's cyclicity has been shown to correspond to increasing the efficiency with which a network's resources are used [126]. Detritivores and decomposers are the species in biological food webs that enable the structural cycling that results in high cyclicity values. These species provide basic nutrition to the rest of the food web by breaking down dead organic matter, or detritus, and converting it to inorganic nutrients that provide fertilization to plants [51]. Research has shown that industrial networks and cities see similar efficiency improvements when they better incorporate decomposer-type actors and their associated cyclic feedback loops [28, 49].



$$
[\mathbf{F}] = \textit{prey} \quad
\begin{array}{c}
\\ 1\\2\\3\\4\\5\\6\\7\\8\\9\\10
\end{array}
\begin{array}{c}
\textit{predators}\\
\begin{array}{cccccccccc}
1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10
\end{array}\\
\left[\begin{array}{cccccccccc}
0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 1\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1\\
0 & 1 & 1 & 0 & 1 & 0 & 0 & 0 & 1 & 1\\
0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 1\\
0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 1\\
0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1\\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1\\
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1\\
0 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 1
\end{array}\right]
\end{array}
$$

Figure 8: A Hypothetical Food Web with 11 Actors, including a Decomposer/Detritivore-Type Actor (11), Drawn as a Directional Graph (Right) and the Associated Structural Food Web Matrix [F] quantifying information about connections from Prey to Predator in the Network (Left). ***Used with permission from Astrid Layton*** **[18].**

Figure 8 illustrates a possible connection between the amount of byproduct reuse in industrial networks and an increase in the ecological metric cyclicity. The industrial networks plotted were selected as those best realized from a dataset presented in [28], to which additional networks have been added. The industry networks were investigated to determine which interactions were those of reuse rather than an actual commercial output. By-product streams in Figure 8 were counted based on available EIP information [28, 127, 128] of streams of materials that, without the EIP actor's presence, would be sent to a landfill (excluding strict recycling). This focuses on materials that wouldn't normally (in normal economic conditions) have value, things like ash produced by a cogeneration or coal power plant, bagasse produced from sugar refineries that can be used as a biofuel, and glass waste from a car glass producer used for glass fiber production. The results suggest that industries that wish to increase their robustness to disturbances and the efficiency with which they use available resources, among other potentially beneficial characteristics of ecological food webs, can achieve this by increasing their engagement with others through reuse-type interactions.

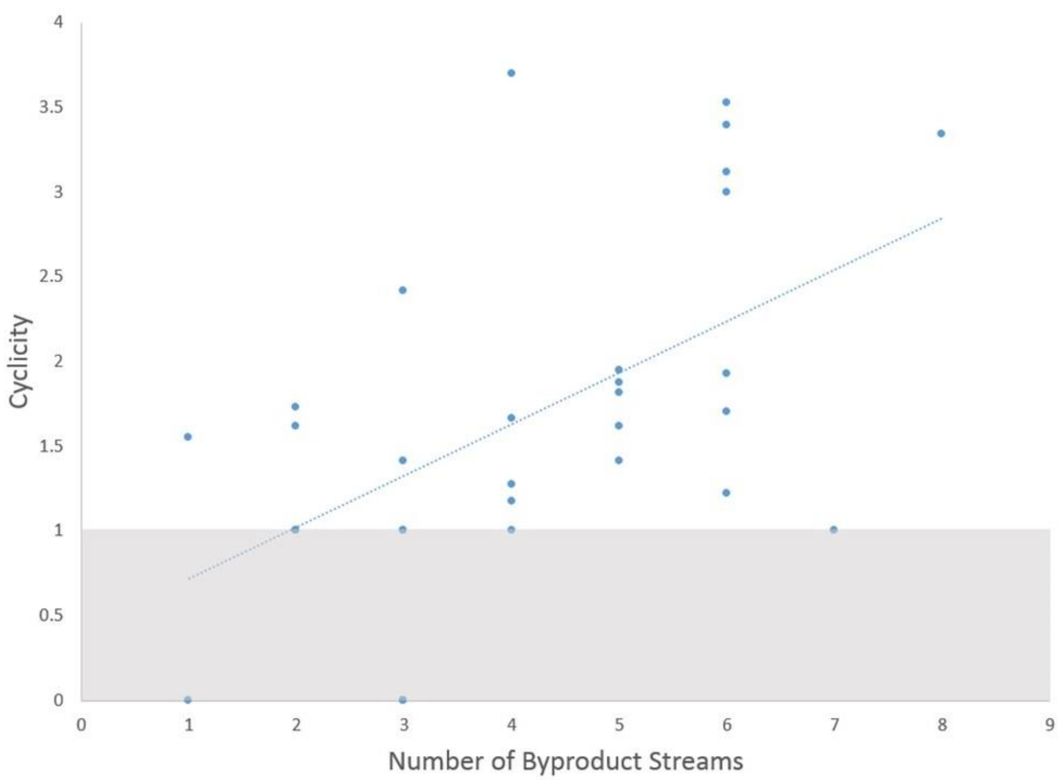


Figure 9: The number of byproduct streams in a set of 31 EIPs vs. their cyclicity. The grayed-out portion reiterates that the cyclicity cannot be a value between zero and one. ***Adapted with permission from [28] with additional data from [127, 128].***

The nutritional value of detritus contributes to the success of food webs' detrital actors [61-66]. As such, the *quality* of industry waste should be scrutinized as an important element in the ability to implement detrital feedback loops. One route is through the adoption of an extended producer responsibility approach by industry producers, the result of which will be a greater retention of value in the design of products, byproducts, and packaging. This and other industry-based changes will mimic the introduction of high-quality detritus that has shown to positively change food webs. Greater diversity in detritivore-equivalent actors in industry will additionally aid in increasing the cyclicity of materials before they reach end-of-life.

Future Outlook

Equating waste industry products, by-products, and packaging to detritus in the food web, first needs an identified consumer. Successfully implementing this practice will see participating companies' profit, whether fiscally or in other methods, through the reuse/recycling/repurposing of waste materials. Two categories of by-products and packaging must be considered to determine viability: 1) products whose original function could benefit from improved quality and 2) byproducts that cannot be conveniently used again in the same application.

Some household products that apply to our first category of materials, such as reusable grocery bags or straws, have already achieved successful reuse by being redesigned for multiuse functionality. These redesign tactics however have not yet made an impact on industry manufacturers. Producers are currently not required to reduce waste at their end: it is rare to see packaging or by-products achieve multiple life cycles before arriving as an end-of-life product.

While extending the producer responsibility will not necessarily affect the bottom line, value should be assigned in terms of environmental importance. A real-life example of creating new business from waste can be seen in the UK with the adapted treatment of the previously mentioned JEDEC Matrix Trays. Several British recycling companies now accept used JEDEC Matrix Trays, reprocess these trays (clean and check for damages/impurities), and then sell the trays for their originally designed function [129]. There are many places where this practice can be adopted. For example, imagine if a company like Amazon were to invest in more durable packages: the packaging could be returned to Amazon and used again. A drastic reduction would be seen in the total cardboard and plastic amount sent to landfill. In 2017 alone, Amazon shipped over 5 billion items through Prime worldwide [130]. Collection of the packaging could be managed to create little cost to the company by using local pickup/drop-off centers and delivery workers. Customers could be incentivized using a small returned fee to their account with the return of the used packaging in good condition. A company called LimeLoop is one of the first companies to provide a reusable packaging system for ecommerce companies [131]. When you order a product and select “reuse” on the checkout screen, the package arrives with a reversible label that can be used to send the reusable package back [132]. Amazon already participates in a joint program with Goodwill known as “Give Box Back,” where Amazon covers the cost of shipping for items mailed to Goodwill in a reused Amazon box [133].

Consumer and profit generation must also be investigated for the second category of materials, those that cannot be conveniently reused in their original function. Materials such as the sheet metal left from the window space of a stamped-out car body, wheat germ from wheat milling, sawdust from the lumber industry, and more [57, 134, 135]. “Recycling Art” competitions put on by city and state organizations also add value to these materials: the state of Nevada, Marin County, CA, Beaufort County, SC, the city of Phoenix, and many more all hold such events. These competitions promote Circular Economy through creative designs that use everyday household waste, including straws, bottles, and cans. Reimagine such a contest funded by corporate sponsors, with the constraint that designs must utilize the designated materials provided by the sponsors. Such a competition was held at Texas A&M University using the JEDEC Matrix Trays as the project’s materials. Students generated designs for acoustic ceilings, lampshades, artistic window blinds, solar energy collection, and aquaponics. Beyond the generation of ideas, lacking a viable customer still prevent this by-product reuse from becoming a real-world success. An event held to showcase byproduct reuse designs where the products are seen by industry representatives may help create customers. Corporate involvement in such an event could result in fiscal savings and a positive investment towards the future environmental outlook, creating good publicity, as well as reduce their landfilling numbers and promote any green initiatives

Conclusions

The review of current sustainability methods presented here focuses on circular economy, identifying areas of potential improvement. Sustainability practices are compared to functions in biological ecosystems, breaking these practices down into those that can be accomplished at the producer and consumer levels. This method highlights that recycling and remanufacturing efforts are driven by consumer activities. Design for disassembly, reverse manufacturing, and lean manufacturing on the other hand are driven by producers. The value of detritus in biological ecosystems and the direct effect that this flow has on the detrital actors can be translated into inspiration for the processing of material waste in industry. This helps shift the focus from the more popular waste reduction method of recycling, to the potential value of reuse and byproduct reuse. These later methods hold a potentially greater ability to expand industry's "detrital feedback loop," shifting the current system to a more bio-inspired structure. By-product reuse from this perspective is potentially a highly underutilized and underappreciated asset in creating a close-loop system, supporting future work in identifying secondary applications for common industry by-products.

CHAPTER III

TASK 1

Introduction

Most Americans do not have to think about the destination of their waste: a quick switch of the garbage disposal or rolling a bin out for garbage collection once a week solves the problem. The actual endpoint of this waste however, is unknown to the public. This lack of understanding leads to problems for the waste management industry and allows the public to remain ignorant of the impact their waste is having on their surrounding environment. Problems resulting from a misinformed or uninformed public include aspirational recycling (putting non-recyclables or contaminated materials in the recycling bin), low environmental awareness during purchase, and disengagement in local waste management initiatives.

This chapter introduces the complex system that is the US waste management sector, providing a brief history of the US waste management system as well as a top-level breakdown of US waste management. A hypothetical-realistic network model of the primary actors within the waste management industry is built using this detailed understanding of the waste management system. The network model demystifies waste management operations and defines the functions and limitations of the network actors. A connectivity matrix of the network model is creating, from which equations are developed to define the relationships between actors. This connectivity matrix is expanded upon using data provided by the US EPA on municipal solid waste generation and disposal. This data includes material flows and waste origins, enabling a flow model of MSW management in the US to be built. The results of this Task 1 are used in Tasks 2-4, providing essential background information on actual waste management practices in the US

Methods

Literature Review

A Brief History of US Solid Waste Management

Up until the industrial revolution, the US's relatively small amount of city dwellers and the bounty of land and water available prevented the large-scale waste and sanitation issues that had become common in Europe [136]. However, with the industrial revolution, the number of cities grew by 10-fold and the population shifted from majority rural dwellers to 51% urban [136]. As a result a number of epidemic outbreaks occurred, and combined with the public's belief that filth, pollution, and poor living conditions were contributors to disease, public health officials began to organize municipal sanitation [136].

The public's demand for change brought solid waste management to wide-spread focus in the 1880's. Water sanitation and sewer systems were the primary concerns prior to this and waste had not yet garnered institutional attention. Unfortunately, at this time there was no national funding for regional infrastructure. The responsibility thus fell to municipalities, who disposed local waste using nearby municipal dumps [136]. Sanitation methods including street sweeping, refuse collection, transportation, resource recovery, and disposal were developed and adopted nationwide in the following decades.

The practice of using *open* municipal landfills ended with the implementation of The Resource Conservation and Recovery Act of 1976 (RCRA) [136]. This legislation forced the closure of open municipal dumps within the US and demanded regionally organized municipal solid waste management (MSWM). After the implementation of the RCRA, a 'garbage crisis' in the late 80's and early 90's prompted private companies to assume the role of waste management [136]. Still today a significant part of waste management within the US is handled through privately organized enterprises [136]. MSWM has expanded to include the recycling industry, combustion with energy recovery, compost, and larger landfills, utilizing a complex transportation network to move waste across state and country lines.

These historical developments have shaped the current waste management practices within the US. The US waste management industry formed through local municipalities and private companies addressing a need in their communities. Communication between facilities or states is only minimally needed from this perspective; brokered contracts determine the management of waste regardless of where the waste is generated. The agreements determine whether recycling is processed locally or shipped to developing countries, where it often is not recycled. States also each create their own landfill/process facility legislation, resulting in policy differences preventing comparisons or analyses to be made at the national level and making it difficult to implement top-level changes. All of these challenges combine, resulting in a lack of facility understanding and management at a national level.

As the beaches of Thailand and the ports of Malaysia fill up with American waste, someone in the US is throwing away food-covered Styrofoam with the belief that they are recycling. To make matters worse, the waste management industry operates with intricacies that make it difficult for even researchers to comprehend. To address this issue, this chapter provides a comprehensive understanding of the US waste management industry and addresses the current standards of waste management analysis.

Data Acquisition

The Basic Model

The functions of the primary actors must first be understood, before the connections within the network can be analyzed. The primary actors within the municipal waste network (MWN) are designated based on their functional role within the larger network, following the method used by ecologists to aggregate the species within an ecosystem into the actors within a food web. Four actors make up the MWN, the waste generator (WG), transfer facility (TF), processing (P), and landfill (LF). These groupings are generalized to cover a broad range of sub-functions and to be applicable to both solid and liquid waste. One facility may provide several of these functions in practice, but for the purpose of the basic network model here they are considered separately. The routes for compost and combustion with energy recovery are not modeled as unique interactions due to these options only being available in select regions. Composting is aggregated into the processing facility function and combustion with energy recovery is counted towards landfilling, as it is an end-of-life disposal method. The basic model represents the standard options available to most local waste management networks as a result of these modeling decisions. The network created in Task 1 provides visualization and understanding of the primary actors within the system, as well as a base for increasing the complexity of future models.

Waste Generator

The **waste generator** of the network represents the source of *any* waste handled in the US waste management infrastructure. The waste generators are modeled as providing the material and the amount they put into the system must be equivalent to the total waste disposed of or processed. The generators are here separated based on sector (for the case of MSW the sectors are residential, commercial, and construction and demolition), but there are a variety of methods used in waste management to identify the role of waste generator. Task 3 represents the waste generators as counties, but generation can also be grouped through material type. As in ecology, the use of various aggregation techniques aids in harnessing a full understanding of the resultant network by considering several perspectives [137].

Transfer Stations

The movement of waste from the generating source to a processing facility or landfill is done by **transfer stations**, who collect, sort, and send waste to disposal. Transfer stations can be specific to waste classifications such as solid, liquid, industrial, and medical. Transfer stations require *transfer permits* that indicate they comply with the regional regulations (i.e. the facilities in Texas meet the standards set by the Texas Commission of Environmental Quality). Some facilities have transfer permits as well as landfilling or processing permits. The model created here however considers the transfer function separately. Transfer stations are the first stop after collection for municipal solid waste and typically provide the collection services commonly seen in residential and commercial areas.

Transfer stations are a temporary stop for waste and often do not provide any sorting or processing. These facilities are included in the model here despite often being overlooked to emphasize the importance of waste *collection*. Collection and transportation account for the majority of waste management costs and each disposal material has specific transportation needs. Figure 10 illustrates the market share cost breakdown of waste management in the US, highlighting that the cost of collection makes up 62% of the total waste management cost. An average of 63,000 standard size garbage trucks are filled every day in the US based an average American producing roughly 4.4lbs of waste a day [3]. This all supports the selection of transfer stations as their own functional actor in the network model created in Task 1.

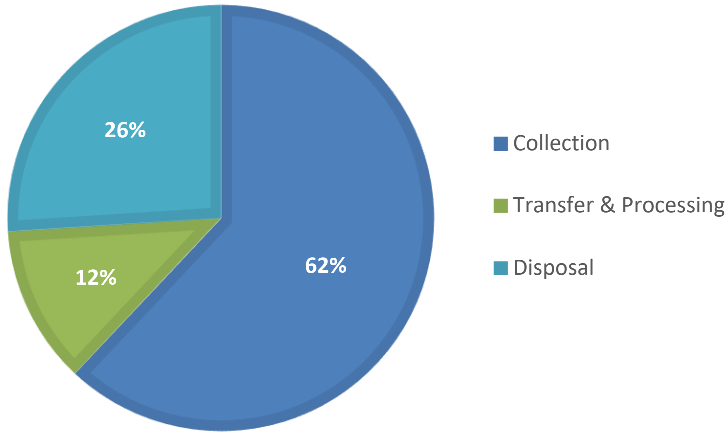


Figure 10: Waste Management Cost Breakdown (MSW Sector) [3]. Transfer refers to the operation of transfer facilities, not the transportation of materials.

A transfer station that *separates* waste is considered a **material recovery facility (MRF)**. Many recycling companies are actually MRFs. These facilities do not perform recovery processes, rather they sort materials and sometimes further prepare it (shredding, baling, etc.) for future processing. A material recovery facility that serves the MSW sector is known as a **"dirty" MRF** due to the level of material intermixing within the waste stream. The leading MRFs can achieve a recovery rate as high as 80%, however most MRFs achieve much lower rates of 15-20%, heavily relying on manual sorters [138].

Processing

Processing represents any waste treatment that has the potential to return materials back to the initial waste generator, including material recycling, composting, and liquid waste treatment. These operations can be carried out by one facility or several, depending on the development of the region. Materials that are not returned to are still sent to disposal, modeled as the landfill here, as waste.

The processing facilities are modeled here are performing *restorative* processes on any materials received. For example, shredding metal for recycling preparation does not qualify as processing, but melting that material in a foundry to be used as a raw material does. This broad category is an immense simplification of the real network involved within this feedback stream. Task 2 provides the breakdown of this function, while Task 1 is simplified to give introductory understanding.

Landfill

Landfills are the final destination for the majority of waste generated within the US. Some landfills sort and divert materials, some compost, and others do neither. The majority of waste remains at a landfill once it arrives. Landfill gas can additionally be collected to generate power. The network model built in Task 1 only considers the movement of waste material within the system and therefore this energy return is not taken into account in the basic material flow.

Known Variables

Using the results of the literature review, several values were chosen as the known variables for the basic network. These values include: annual recycling average for the US (as reported by the EPA), total material processed (reported by processing facility), total material landfilled and total material diverted by landfills (reported by the landfill). These values are commonly recorded by most states (although not collected as a national sum yet) and therefor chosen to represent the given variables for this network.

For the total material diverted by landfills, the composting value provided by the EPA is used; this value was designated due to landfills commonly composting material (which in many states they can do without separate facility registrations) and because *the true national value has yet to be determined*. Although this is an educated guess, it is a realistic estimation given the domain knowledge of the industry. It also provides for the inclusion of composting data in the basic model. The variable values are shown with their references in the following table. These values will be used with the basic network to conduct calculations and analyze the governing equations.

Table 2: Known Variables for Basic Model

Known Variables		
Variable	Volume	Ref
Total Disposed:	262 million metric tons	[3]
Annual Recycling Average (2015):	34.7% (with compost) 25.8% (w/o compost)	[3]
Total Material Recycled (2015):	67.8 million metric tons	[3]
Total Material Processed (2018):	13 million metric tons	[139]
Materials Diverted by Landfill (composted):	23.4 million metric tons	[3]

MSW Disposal Routes

The flow magnitudes making up the MSW network enable existing waste disposal alternatives in the US to be demonstrated. This data provides an encompassing understanding of the various disposal options for typical MSW. The Environmental

Protection Agency's (EPA) figures for MSW management in 2015 are used as a starting point to track various materials from their end-of-life treatment back to their possible origins. The four disposal processes available to the MSW sector are: recycling, composting, combustion with energy recovery, and landfilling. The percentage disposed using each of these methods are shown in Figure 11. This breakdown highlights the heavy dependence on landfills in the US, also ominous of the impact that any disturbance to landfills would have to the MSW network. The EPA also provides figures outlining the MSW-specific breakdown of each disposal method by their material make-up and the percent material dissection of total waste generated, providing the information needed to build the realistic MSW network model. This information was used to establish the connections between a MSW actor and landfilling, recycling, combustion with energy recovery, and compost.

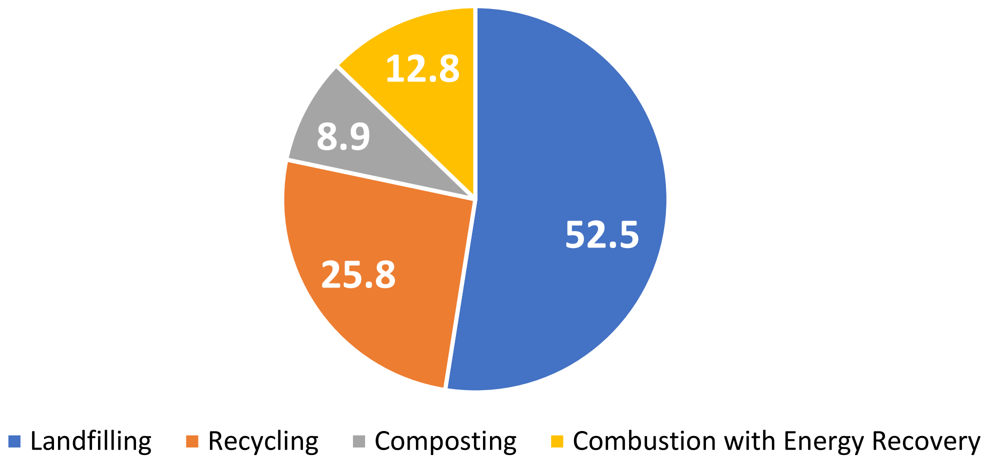


Figure 11: Management of MSW in the United States according to the EPA in 2015. Figure duplicated with the permission of the EPA [3].

Recycling

Recycling facilities typically focus on a small selection of materials to minimize the required specialized equipment investments and maximize profitability. Material processing facilities can buy sorted and cleaned materials from transfer stations that operate as material recovery facilities, or directly from industry sources. The actors and operations used within recycling are broken down in Chapter IV, providing additional analysis of the feedback streams within the overall MSW network.

Combustion with Energy Recovery

Incineration as a means of providing waste-to-energy (WTE) benefits uses gas collection to generate power. Non-recyclable waste materials are converted into usable heat, electricity, or fuel through confined and controlled burning. The EPA ranks this alternative just above landfilling in the waste management hierarchy, shown in Figure 12. The combustion with energy recovery process produces a usable byproduct from waste, decreasing the volume of landfill waste and generating a renewable energy source. The amount of energy recovered has been claimed as offsetting the carbon emissions produced in the burn[140].

Figure 12: Waste Management Hierarchy according to the EPA. ***Used with permission from the EPA*** **[3].**

While this argument for waste incineration with energy recover is good, it’s not the full story. Plastic for example does not breakdown or generate methane in landfills, but it does release harmful dioxins when burned. Modern incinerators claim to have solved this issue with gas containment methods, but in cases like plastics landfilling waste may still be preferable[141].

Landfilling

The most popular national and global means of waste disposal is the **landfilling** of materials. Landfills provide permanent waste storage. The indiscriminate and indefinite storage ability has downsides however, including land degradation and methane emissions. Some facilities mediate the emissions by recovering the gas generated. Many countries have strict regulations on the operation of landfills to reduce the environmental and social impact of the facilities. Unfortunately, many developing counties, such as Thailand or India, end up dumping waste in poor areas where people live among piles of waste.

Composting

Composting is the least popular method of waste disposal due to the material selectiveness required. This process utilizes the breakdown of organic matter as a means of providing nutrition to soil that can later be used for agricultural purposes. Composting can be done at an individual level (for example saving compost for fertilizer in the garden), by specific compost facilities, and sometimes through landfill facilities that provide material separation.

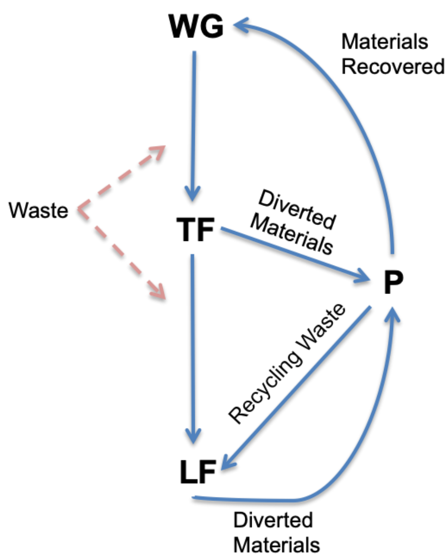
Procedure

Excel was used throughout Task 1 to analyze data. The results of the literature review are used to create the following models. The basic network is developed using information on the waste management sector resulting from the literature review in Chapter 2. The three disposal methods outlined (recycling, landfill, compost) are traced back to their origin of waste generation using EPA data. The material breakdown of the disposed waste for each of the three disposal methods is used to determine its likely origin.

Results and Discussions

Basic Material Flow Model

The basic connectivity matrix that represents material flows between waste generators (WG), transfer facilities (TF), processing (P) and landfills (LF) is shown in Figure 13.



A)

$$
\begin{array}{c c}
 & \begin{array}{cccc} WG & TF & P & LF \end{array} \\
\begin{array}{c} WG \\ TF \\ P \\ LF \end{array} & \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{bmatrix}
\end{array}
$$

B)

Figure 13: A) Flow Diagram of Waste Materials. B) Connectivity Matrix for Material Flow of Basic Waste Management Network.

Ones and zeros indicate whether or not material is being passed from the left column of actors (producers/prey) to the top row of actors (consumers/predators). The connectivity (or coincidence) matrix is developed into equations for a flow matrix to define the network relationships. The basis for the flow network analysis is the mass matrix, M shown below:

$$M = \begin{bmatrix} 0 & x_1 & 0 & 0 \\ 0 & 0 & x_2 & x_3 \\ x_4 & 0 & 0 & x_5 \\ 0 & 0 & x_6 & 0 \end{bmatrix}$$

The given values are the annual recycling rate within the US, the total material processed, the total material landfilled, and the total material diverted from landfill facilities. Assigning these values as y_1, y_2, y_3, and y_4 yields Eqs. 1-6.

$$Annual\ Recycling\ Rate = y_1 = \frac{x_4}{x_1} \quad (1)$$

$$Total\ Material\ Processed = y_2 = x_2 + x_6 \quad (2)$$

$$Total\ Material\ Landfilled = y_3 = x_3 + x_5 - x_6 \quad (3)$$

$$Landfill\ Diverted\ Materials = y_4 = x_6 \quad (4)$$

Eqs. 1-4 assume no losses between actors. For example, the processing facility is assumed to process the total material delivered from both transfer stations and landfills. In reality, some of this material may be rejected and sent again to landfill. However, in the state of Texas, a facility can apply as a recycling facility if it diverts a minimum of 10% of the material it collects. Assuming worst case, the following equation is defined:

$$y_2 = [0.1 * (x_2 + x_6)] + [0.9 * x_5] \quad (5)$$

Lastly, the sum of the material delivered to processing centers or landfills from the transfer facility (x_2 and x_3) must be equivalent to the total waste generated by WG. This equation is based on the assumption that as the network is a closed system, therefor there are no external imports or exports. With this Eq. 6 the network has 6 equations and 5 unknowns.

$$Total\ Waste\ Generated = x_1 = x_2 + x_3 \tag{6}$$

Findings

Using the EPA's value for total landfilled waste to balance the equations, the following flow diagram for the basic model is shown in Table 3.

Table 3: Flow Matrix for Basic Flow Model (in millions of metric tons) [142].

	WG	TF	P	LF
WG	-	302.8	-	-
TF	-	-	67.8	235.0
P	40.8	-	-	27.0
LF	-	-	23.4	-

This table indicates that the amount of waste generated is approximately 302.8 million metric tons and that, *of the 67.8 million tons of recycled material, over half - 40.8 million tons - was returned to the waste generator*. Compost here is considered to be separated by the landfills to not confuse the recyclable materials with compost materials, but this does not necessarily have to be the case.

performing MRF's), and assuming that 70% of processed materials is returned to the waste generator (average recovery rate provided by ISRI[139]).

Table 4: Flow Matrix for Basic Model using ISRI processed value as the fixed variable (in millions of metric tons) [142].

	WG	TF	P	LF
WG	-	99.7	-	-
TF	-	-	13.0	86.7
P	9.1	-	-	3.9
LF	-	-	23.4	-

Starting with the value for domestic processing provided by the ISRI (13 million) and using the assumptions that have been developed here, we find that the total landfilled material falls short of the EPA estimated value (*262 million metric tons) by 171.43 million metric tons* of waste[3, 142]. When the EPA recycling value is used and the other assumptions are maintained, the calculation for total landfill becomes much greater than the estimated value as seen in Table 4, at *142.5 million metric tons of waste*. This value is assuming that *all* waste, besides the waste separated for recycling, is sent to the landfill – a kind of worst-case scenario. The additional assumption that only 52% of the waste that passes through the transfer facilities is sent to landfill (based on the disposal breakdown provided by the EPA[3]), brings the flow table values closer to the numbers published by the EPA, *255.4 million metric tons,* as seen in Table 6. This is only 6.6 million metric tons off from the recorded value of *262 million metric tons*.

Table 5: Flow Matrix for Basic Flow Model using EPA recycling as the fixed value (in millions of metric tons) [3].

	WG	TF	P	LF
WG	-	519.8	-	-
TF	-	-	67.8	384.2
P	47.5	-	-	20.3
LF	-	-	23.4	-

Table 6:Flow Matrix for Basic Model using EPA recycling value as fixed and assuming 52% of waste is sent to landfill (in millions of metric tons) [3].

	WG	TF	P	LF
WG	-	302.8	-	-
TF	-	-	67.8	235.0
P	47.5	-	-	20.3
LF	-	-	-	-

The only difference between Table 6 and the originally calculated basic model of Table 3 is the division of processed materials sent to the waste generator and landfill. Table 5 assumes 70% of processed materials return to the waste generator as recycled material [142]; in the original Table 3 these numbers are calculated to satisfy the summation value set by the total landfilled material. However, according to Table 5 and Table 6, the volume of processed material should be much higher in comparison to the 13 million tons recorded by the ISRI[139]. The discrepancies here illuminate a *serious flaw* with the way that recycling is recorded in the US: **a biased inclusion of exports**. This discovery will be elaborated on in the US waste management analysis following.

	WG	TF	P	LF
WG	-	302.8	-	-
TF	-	-	67.8	235.0
P	40.8	-	-	27.0
LF	-	-	23.4	-

A) Scenario utilizes the EPA's value for total landfilled waste to balance equations

	WG	TF	P	LF
WG	-	99.7	-	-
TF	-	-	13.0	86.7
P	9.1	-	-	3.9
LF	-	-	23.4	-

B) Utilizes ISRI value for processed material (13 mil tons) assuming national recovery rate is 15% and 70% of processed material is returned to the waste generator

	WG	TF	P	LF
WG	-	519.8	-	-
TF	-	-	67.8	384.2
P	47.5	-	-	20.3
LF	-	-	23.4	-

C) Utilized EPA recycling number (67.8 mil tons) and compost (23.4 mil tons) as fixed values

	WG	TF	P	LF
WG	-	302.8	-	-
TF	-	-	67.8	235.0
P	47.5	-	-	20.3
LF	-	-	-	-

D) Utilized EPA recycling value and assuming 52% of waste is sent to landfill (disregards compost)

Figure 14: Flow Matrixes for US MSW and their scenario assumptions

MSW Disposal Model

The disposal tracks (i.e. the routes to various disposal methods such as landfilling, recycling, etc.) are divided by their material classifications and provided as percentages of the partial total (ex. % of total for recycling, compost, etc.) in Table 7.

Table 7: MSW Disposal Method by Material. Data provided by the EPA [3].

Material	Recycling	Composting	Combustion w/ Energy Recovery	Landfill	Total Waste Generated
Paper & Paperboard	66.9%	0.0%	13.3%	13.3%	25.1%
Metals	12.1%	0.0%	8.1%	9.5%	8.9%
Glass	4.5%	0.0%	4.4%	5.1%	4.3%
Plastic	4.6%	0.0%	15.9%	18.9%	12.7%
Wood	3.9%	0.0%	7.6%	8.0%	6.0%
Rubber, Leather, Textiles	5.9%	0.0%	16.5%	10.9%	9.1%
Food	0.0%	9.0%	22.0%	22.0%	15.0%
Yard Trimmings	0.0%	91.0%	7.8%	7.8%	15.6%
Other	2.1%	0.0%	4.4%	4.5%	3.4%

Using these values as a basis for connections between waste generator and final disposal, realistic assumptions are made regarding the likely origin of each material. The TCEQ has historically broken down the majority of the MSW waste into Construction and Demolition, Commercial, and Residential, although the more recent annual reports consider municipal (residential and commercial waste considered together) and construction and demolition. From 2003-2012, these waste origins made up roughly 85% of MSW waste generated, 1/5 being from construction and demolition and the other 4/5 split between commercial and residential waste. Figure 15 illustrates a theoretical network for MSW waste disposal using Table 7 and this TCEQ breakdown.

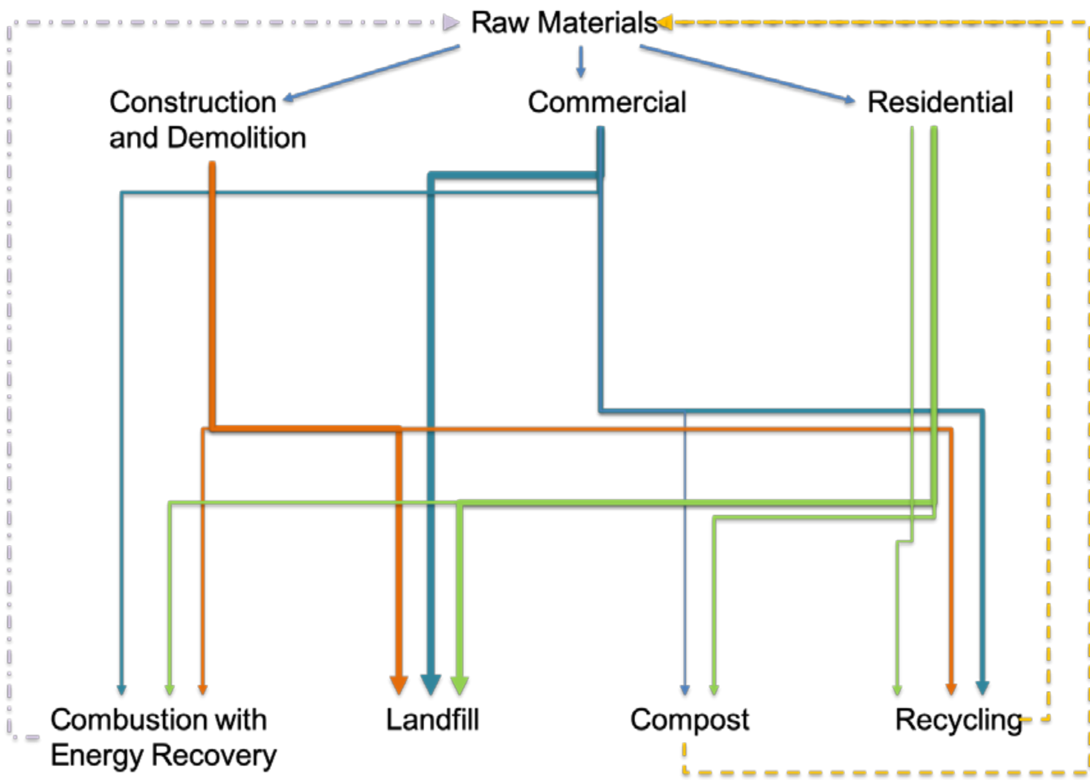


Figure 15: A theoretical network highlighting the possible MSW disposal routes in the US. The relative line thickness indicates the relative volume of materials and energy being moved.

The network in Figure 15 represents not just a strict material flow, but also an energy flow of the network. The relative thickness of the line indicates the relative volumes being directed to each disposal end point. Due to the materials being inconsistent in measurements, the optimization of this flow network currently cannot be conducted using a flow matrix. For example, energy returned in kW-hrs from the combustion with energy recovery actor (shown as a grey dotted arrow) cannot be easily translated to tons of waste material (solid lines) that are delivered to this actor. The orange-dotted line represents material returned to the system. Both the compost and recycling feedback streams involve losses such as: operational costs, processes emissions, and losses involved in the chemical breakdown of materials. Future work will seek to develop improved algorithms and additional input-output relationships to enable these considerations to be addressed

US Waste Management Analysis

Task 1 breaks down the waste management methods across the US by basic function, building a network model that is general enough so that it can represent the waste management system in any given US region. The model highlights the four standard routes for waste disposal within the US. The US in 2015 advertised 67.8 million metric tons MSW waste was recycled, however the findings of Task 1 have uncovered that over ¾ of this, 54.7 million metric tons, was actually exported as a scrap material to be recycled outside of the US. The reported recycling rate of 35.4% is technically *incorrect*, this rate instead represents the US recovery rate. *Recovery rates* are used to measure the percentage of a specific recyclable material (or group of materials) that is collected for recycling and sold to end users. Recovery rates can be dependent on the material types and include only that material in the rate calculations. The processor actor (P) is the only actor within this system that is able to cycle material back to consumers via recycling.

Material scrap as an export is theoretically advantageous for the nation, if the countries receiving this material are *actually* processing it. Today, exported material is not required to be recorded in most states. The problem of waste management is thus solved by making it someone else's problem. Unfortunately, the US sends 78% of their exported waste to poor, developing countries. This is primarily a result of the free and easy export of waste material allowed by lax US regulations. The poorest of which are buying the lowest quality materials (plastics). The most valuable pieces are picked out (thicker plastics and metals) on arrival and the remainder is landfilled, incinerated, or dumped, creating a health crisis for communities. Lightweight materials like plastic wind up in the local waterways that send the waste straight out to sea. Most of these plastics are produced using petroleum and will last thousands of years. The sun and waves of the ocean break down most plastic into microparticles, which *never* biodegrade. Current research estimates that these are 5.25 trillion particles of “plastic smog,” or 270,000 tons, in our oceans[143]. These micropollutants have been linked to several human health problems, including cancer. The best alternative for exported waste, after recycling, is landfilling or safe incineration. The mismanagement of waste due to US generated waste is further investigated as a result of these findings in following chapter on Task 2.

The conflicting values found during data acquisition and the poor and selective reporting of waste management values were major challenges to the efforts of Task 1, to create a simple representation of a complex network. Conflicting data includes the recycling values reported by the EPA versus the processed material reported by the ISRI. This was discovered to be due to considering exported materials as part of the volume that is included when calculating the US recycling rate. The EPA only records waste for the MSW and construction and demolition sectors, meaning industry generated waste goes unrecorded. This is because much of the domestic waste generation and processing volume is held with privately-controlled companies who generally do not share their data with the public.

The data collection and results presented here lay the groundwork for the system analysis applications that promote the development of a self-sufficient waste management network.

Future work:

Task 1 sheds light on the inner workings of solid waste management, which has been a largely misunderstood by the public and misrepresented by documenting agencies. Future work will create a more developed model using data from cities, with expanded actors and flows. The long-term goal for the network model is one that enable solid waste management exportation and global movement to be tracked and alternate designs optimizations to be tested.

Conclusion

The analysis of the waste management system as a network provides better principal understanding of a complex network that is commonly misunderstood. The results of this Task demonstrated large discrepancies between domestic material processed and corresponding EPA recycling rates published. By depending on exports as a waste management alternative, the US's governing entities enable the public to ignore both the US waste generation/management as well as the impact their waste generation is having on the environment. The methods of waste management in the developing countries who receive exported waste are often inferior to recommended standards. These same materials, which are damaging local and global communities, are counted towards US material recycling. Additional investigations are made in Task 2 as a result of the findings of this chapter to better understand the extent of the problem.

The basic MSW network of Task 1 can be developed further to create an encompassing model of waste management in the US and provide an influential tool for key decision makers within the waste management industry. The *proposed* future network connections and calculations can determine waste flows and provide a more comprehensive understanding of the US waste management than has ever been achieved. The following Tasks will continue investigations into the US waste management practices as well as further the development of the proposed future model.

CHAPTER IV

TASK 2

Introduction

This chapter takes a closer look at the feedback stream provided through the recycling process. The US Environmental Protection Agency published the rate of recycling as 25.8%, not including compost material [3]. As discussed in Task 1, the calculation of this rate *includes* scrap material sold as an export commodity. The approach of inflating recycling numbers by counting sold exports as recycled material is not only done in the US. Figure 16 illustrates the percentage of *total plastic waste that is mismanaged* by country. These inadequate waste management practices include disposal in dumps or otherwise branded open, uncontrolled landfills, both of which have high likelihoods of polluting rivers and oceans. Figure 16 does not consider littered waste, which makes up approximately 2% of total waste of low- and high-income countries.

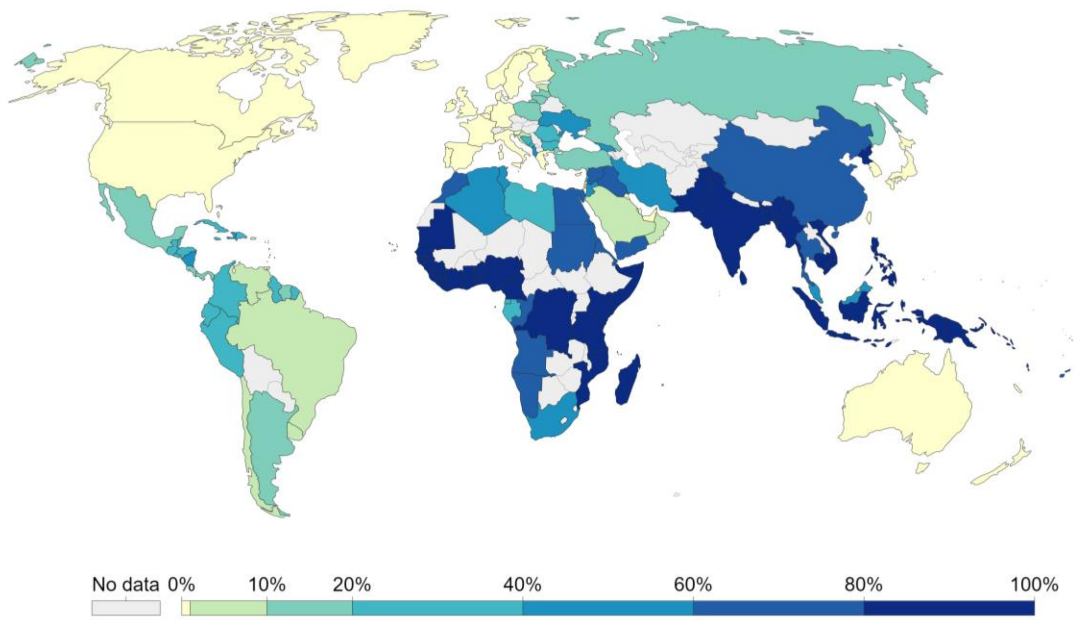


Figure 16: Share of plastic waste that is inadequately managed worldwide in 2010. Darker colors represent a higher percentage mismanaged and lighter colors represent a lower percentage. Grey signifies that no data was available. ***Used with permission and slightly modified from Our World in Data and Jambeck*** **[68].**

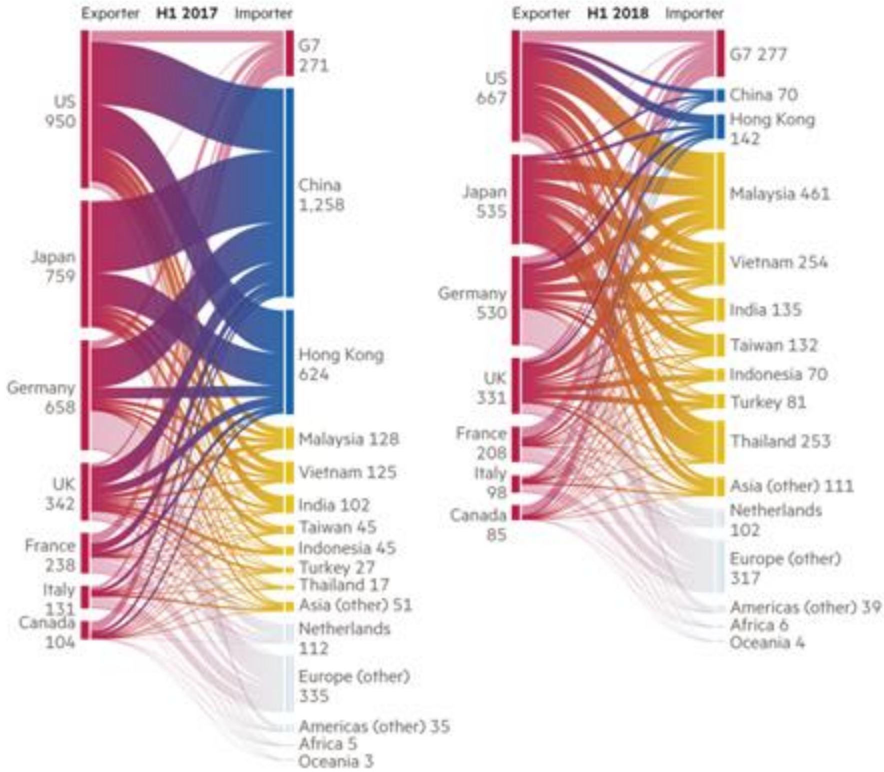


Figure 17: Global change in plastic waste before (left) and after (right) the Chinese crackdown on imports of plastic waste deemed the "National Sword". ***Figure used with permission of David Blood and Financial Times*** **[6].**

Revisiting the exportation flow of plastic exports from 2017 to 2018 as seen in Figure 17, a shift in those countries exporting and countries importing is evident. The countries touting a 0% share of mismanaged waste in Figure 16 are also the *primary exporters* of plastic scrap material in Figure 17. Eight of the nine largest exporters of plastic waste in 2018 report 0% mismanaged waste in the study generating Figure 16 [68, 144]: in 2018, the US reported 0% mismanaged waste but sent 78% of its plastic waste to countries who had a greater than 5% mismanagement rate [145]. The main importers of low-quality material waste (i.e. materials with low market price as a recycled product, for example paper and plastic) are among the counties with the highest percentage of mismanaged waste.

Table 8: Primary US plastic export destinations with mismanaged waste[68].

Country	% Mismanaged
Malaysia	55%
Thailand	73%
Vietnam	86%
India	85%
China	74%

Table 8 shows the mismanagement rates for some of the primary destinations for US exported waste in 2017 and 2018 [68, 146]. The countries listed account for (at a minimum) 44.9% of the annual US plastic exports and 72% of US global plastic exports from January to June of 2018 [145, 147]. The values in reality are likely even higher, as both Mexico and Canada also imported US that gets sent overseas [145]. With this information, *is it fair to report that the US mismanagement rate is 0%?* This chapter analyzes the US methods of recycling to gain an understanding that is closer to reality.

To understand capabilities and restrictions of the recycling processes, the recycling industry will be analyzed here in Task 2 and compared to the structure and functioning of successful biological food webs using *food web metrics* from ecology. Flow-magnitude information is collected for non-ferrous metals, ferrous metals, plastics, and paper to create connectivity matrixes and flow matrices from where their structure and functioning can be analyzed using Ecological Network Analysis (ENA) techniques.

Special focus is given to the simple feedback recycling streams from Task 1's basic model, which are actually several various routes that can be separated based on material and processes. These parallel feedback streams are *analogous to the detrital feedback streams seen in ecological food webs*. The biological and human systems are compared to understand their similarities and differences, with the goal of finding food web characteristics to mimic as a potential solution route for MSW networks. MATLAB (version R2016b) is used to take the findings one step further, with a biologically-inspired optimization pf the non-ferrous (aluminum) and plastic networks using the ecosystem metric Finn Cycling Index (FCI).

Methods

Literature Review

Ecological Food Networks

Ecological networks are represented using a graph-based organization of the quantitative fluxes of nutrients and/or energy passing between the various species or nutrient pools [137]. The analysis of these networks involves representing the actors within an ecosystems as species or trophospecies that are connected by directed flows of matter [148]. An example of an analogous human network representation of this would be the grouping of waste generators into a single "waste generator" actor, all the transportation facilities into a single "transportation facility" actor, and the same for processing facilities and landfills in the basic models created in Task 1.

Detritus Consumers

Detritivore and decomposer actors in an ecosystem control the material and energy circulation for the entire ecosystem. Although this feedback group is made up of a vast and diverse number of species, it is often represented by only one or very few actors in ecology. The degree of aggregation (*species-resolution*) can have a large effect on properties of the resulting food web representation of the complex ecosystem [137]. Considering the further breakdown of the detritus role and its significance on the sustainability of the network is thus extremely important.

The diversity, maintenance, and evolution of the corresponding detrital component of the food web is dependent on the quantity and type of resources available within the network [26]. Many studies have shown a strong link between the diversity of resources (detritus and primary producers) and the diversity of consumers and predators [148, 149]. The detritivore species and the available detritus affect the detrital processing rate within the network [150-153], so for low quality nutrients or slow-metabolizing species, the reintroduction of nutrients into the primary food chain takes longer. Countering this are the large number of detritivore and decomposer who create multiple energy/matter feedback streams in parallel. These parallel streams vary in their speed and efficiency of energy turn over, each contributing towards a more stable availability of resources within the network.

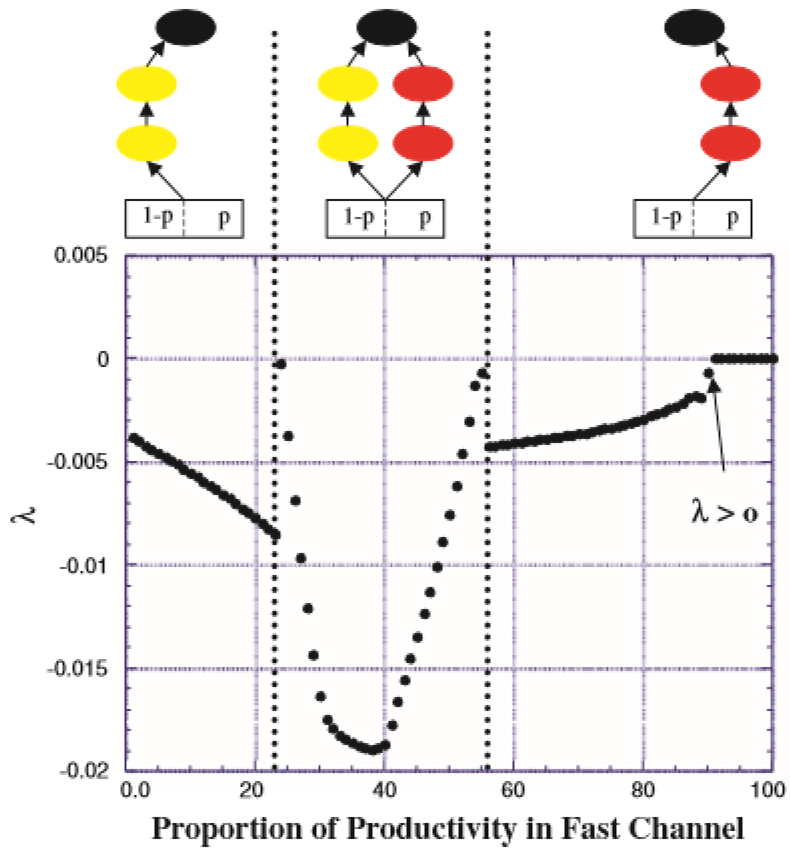


Figure 18: The dominant eigenvalues for a series of cascade models along gradient of resource allocation. ***Used with permission of John C. Moore*****[26].**

The significance of these parallel streams is best understood by looking at the dominant eigenvalues vs the proportion of productivity for a series of 'cascade models' (a class of models in ecology that are used to represent cascading effects triggered by exogenous perturbations). The results of this study, conducted by the ecologist John Moore[26], can be seen in Figure 18. The figure shows a red and yellow stream, representing two parallel food chains that are linked by a common predator (black oval) who has a heterogeneous source of nutrition. The two steams have different process rates and efficiencies; the red pathway represents the “fast” feedback loop while the yellow is “slow.” The x-axis represents the proportion of resources taking the fast channel and the y-axis shows the dominant eigenvalue for the system at each iteration of partitioning the resource. The *total* energy passing through the system is the same for every iteration. The *most stable* configuration takes place when the two feedback streams are coupled, suggesting that *the presence of multiple detrital feedback loops has a stabilizing effect on the performance of the overall system*.

The reutilization of materials within a system creates *cycling* [154]. Cycling is not directly measurable, but ecological network analysis (ENA) has a metric called *cyclicity* that quantifies the presence and strength of cycling. The cycling of energy in ecosystems is mainly accomplished through dead organic matter (detritus) that is processed by the detritus feeders who extract all remaining value and return it to the system [53, 125]. Some ecologists considered cycling in ecosystems an indicator of system *maturity*, revealing an ecosystem’s capability of retaining matter and energy and its ability to endure during resource scarcity [154, 155]. Studies have shown that increasing material cycling also increases the probability that the ecosystem will achieve local stability [154]. An ecology study found that increasing the amount of recycled matter in the system tended to increase the transfer efficiencies and *reduce dependence on external resources* [156]. This achievement is synonymous with the *goals of circular economy*: minimizing dependence on new materials.

There are several ENA metrics that measure different aspects of cycling. This thesis considers two methods: Finn’s Cycling Index and cyclicity[154]. Finn’s cycling index (FCI) quantifies the proportion of the *total* system throughflow of matter that is generated through cyclic pathways [154]. Cyclicity (λ_{max}) measures the presence and strength of cyclic (closed loop) pathways. The latter metric has the additional advantage that it *only* requires knowledge of the network pathways, whereas FCI also requires flow magnitudes passing along all pathways [126].

These and the metrics are combined with a few other ENA metrics that are able to quantify ecosystem characteristics, a comparison can be made between the networks that represent industrial systems and the above mentioned naturally sustainable food networks[18, 19, 157].

Data Acquisition

Detrital Feedback Streams in Industry

Much like in biological food webs, there are various methods of achieving material feedback streams within industry. These streams, similar to their food web counterparts, are dependent upon the quantity and type of material available and provide different efficiencies of material turnover. Instead of dead leaves, these streams are made up of materials such as paper and paperboard, plastic, ferrous and non-ferrous metals, yard trimmings and brush, and glass. Recycling of each has its own unique processes that all act in parallel.

Comprehensive Industrial Detrital Feedback

The specifics needed with regards to material acceptance and flow magnitude information, a MSW model of the complete detrital feedback is not possible using the currently available data. As a substitute, the efficiency and production rates of these streams are considered and compared to the findings of ecology, as well as the rate of mismanaged waste for the US.

Recycling

Recycling is the most popular method of achieving material feedback. This thesis questions whether this this needs to change: *Is recycling a viable solution towards achieving circular economy?* Task 2 provides a breakdown of different material streams and analyzes the "health" of the current network. As recycling processes are specific to a material, the streams considered are reduced to non-ferrous metals, ferrous metals, plastic, and paper. Other processes exist for medical waste, organic waste (yard trimmings, brush, and green waste), electronic waste, etc. however these are not included in the results.

Non-Ferrous Metal

Non-ferrous metals are metals without iron (ferrite), such as aluminum, copper, lead, nickel, tin, titanium, and zinc. Non-ferrous scrap is generated through sources such as industrial equipment, parts and products, and aluminum cans. Non-ferrous materials are unique in that they do not degrade or lose their chemical or physical properties during the recycling process. Non-ferrous metals account for more than half of US scrap industry earnings by value despite making up less than 10% of US's recycling by volume [158, 159]. The energy saved by recycling non-ferrous metals offer the highest efficiency rates in comparison to other materials, recycled aluminum saves 95% of energy while recycling copper saves 75% and paper, steel, and glass offer 60%, 50%, and 34% [139, 158, 159].

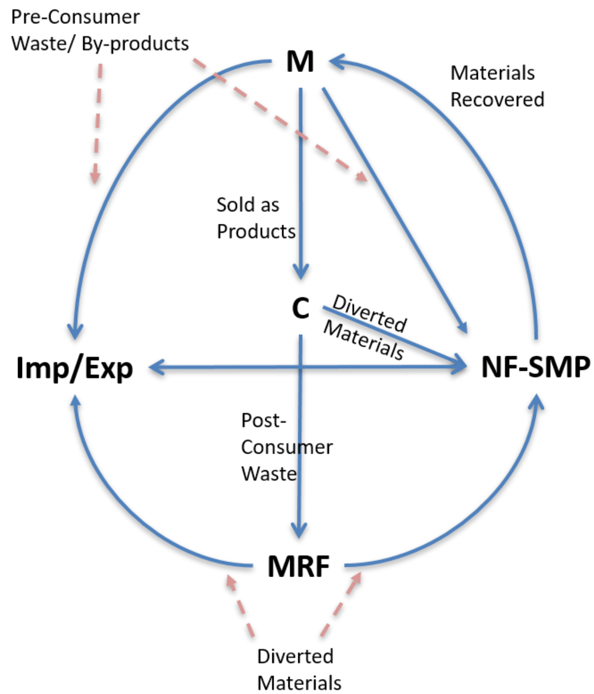


Figure 19: Material Flow of NF-Metal Recycling. M- Manufacturer, C- Consumer, NF-SMP- Non-ferrous Scrap Metal Processor, MRF- Material Recovery Facility, Imp/Exp- Imported or Exported recycled materials.

Figure 19 illustrates the recycling pathways for non-ferrous metals. Some post-consumer items, such as aluminum cans, are first processed by a material recovery facility (MRF) which sorts waste, while other non-ferrous scrap is collected by scrap metal processors (SMP). Figure 42 illustrates the separation techniques of an MRF in Appendix B. There are facilities available within the US that are capable of handling non-ferrous metals, however many states including Texas do not have large non-ferrous metal processors available and export out of state.

Non-ferrous metals are somewhat difficult to track because the focus is on the highest volume materials aluminum, copper, nickel, zinc, and lead. The information that was found on non-ferrous metals can be found in Table 52 on page 246 in Appendix B.

Table 9: Scenario 1 Supply and Demand Values in units of metric tons. N, M, C, SMP stand for new material, manufacturer, consumer, material recovery facility, and non-ferrous scrap metal processor. The first column are the actors in the material flow network of non-ferrous metals seen in Figure 19.

Aluminum				
	Supply	*Demand*	Supply Ref	Demand Ref
N	741,000	-	[160]	-
M	6,580,000	8,245,400	[139]	[142]
C	670,000	3,610,000	[3]	[3]
MRF	600,000	600,000	-	-
NF-SMP	3,700,000	5,268,000	[158]	[158]
Imp/Exp	4,800,000	2,900,000	[142]	[142]

Due to the missing information, the recycling supply and demand values and the network pathways considered here are specific to *aluminum* in the US. Aluminum is also the most profitable material to recycle. Table 9 gives an example of the supply and demand values of each actor in Figure 19. These values are those used in the case denoted as Scenario 1 in the results. The supply from an actor (second column Table 9) designates how much material each actor (first column) adds to the system and the demand (third column Table 19) determines how much material each actor receives. The scenario described by Figure 19 is realistic even though the values highlighted are educated guesses. The results are within the problem's solution space (feasible region that is the set of all possible points) and represent a possible scenario based on the assumptions used. A list of assumptions and a short description of the scenarios are included in Table 53 on page 247 in Appendix B as a reference for the results of this chapter.

Ferrous Metal

Ferrous metals include iron in their composition, which results in a deterioration of material quality with each iteration of recycling. This is mediated through chemical processes and by mixing recycled material with fresh material. Figure 20 shows the recycling streams for ferrous metals.

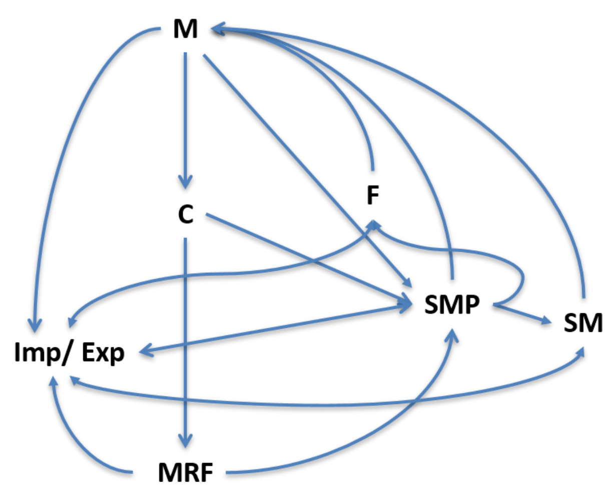


Figure 20: Material Flow for Ferrous Metal Recycling. M- Manufacturer, C-Consumer, MRF- Material Recovery Facility, SMP- Scrap Metal Processor, SM-Steel Mill, F- Foundry, Imp/Exp- Imported or exported recycled materials.

Sources of ferrous metal include auto bodies, industrial equipment, appliances, and other discarded parts, products, and packaging. Similar to NF-metals, a relatively small amount of materials recycled are diverted through MRFs and the rest are collected by SMPs. Many of these SMPs are small and sell their materials to larger processors. Ferrous metal flows from MRFs/SMPs to a steel mill or foundry to be returned to the system as a raw material. Ferrous metal is the *second* largest exported material due to recycling (behind paper and paperboard) and is the only material that experienced an *increase* in exports after the implementation of China's National Sword policy.

Combining data from the EPA, ISRI (International Research Services, Inc.), OECD (Organization for Economic Co-operation and Development), and BIR (Bureau of International Recycling) the assumptions listed in Table 10 are created. These assumptions provide the basis for the ferrous metal network analysis.

Table 10: Table of Assumptions with references for ferrous metal analysis

Assumption	Reference
• 17% of total domestic processed material is exported, while 83% returns to US manufacturing	[142]
• Sum of all domestic processed materials is equal to 66 million	[142]
• Sum of material sent to exports is 14,955,411	[146]
• Domestic Processors purchased 46,343,561 metric tons from international sources	[161]
• 18,170,000 tons of ferrous metal was sent from manufacturing to the customer	[3]
• Post-Consumer recycling accounted for 6.06 million tons	[3]
• 95% of materials from the consumer go to the MRF, while 5% goes directly to processing	Assumption
• Inputs to the manufacturer should be approximately 60% of total material sent to M	[37]
• The total amount of scrap sent to manufacturer will be at least 58.8 million	[159]
• Sum of inputs into manufacturer actor is 81.6 million tons	[162]
• 80% of US production of steel/ferrous metals relies of virgin materials	[163]
• 70% of processing was done through large steel mills, 30% through foundries	[159]

Plastic

The plastic recycling industry in the US strongly relies on *exportation*. This dependence has created a weak US network with insufficient domestic processing facilities to handle the immense volume of the US's plastic waste. Figure 21 illustrates the material flows in the plastic recycling process. The material flow diagram represents plastic waste flow between the actors: manufacturer (M), consumer (C), material recovery facility (MRF), plastic recovery facility (PRF), manufacturer and plastics recovery facility (MPRF), and the importation and exportation of plastic materials.

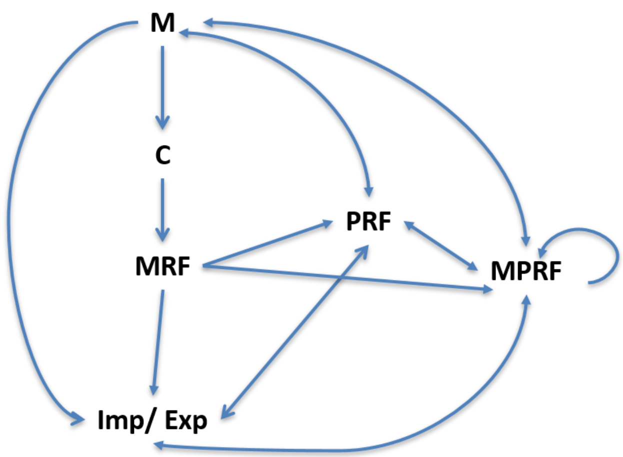


Figure 21: Material Flow for Plastic Recycling. M- Manufacturer, C- Consumer, MRF- Material Recovery Facility, PRF- Plastic Recovery Facility, MPRF- Manufacturer with Plastics Recovery Facility, Imp/Exp- Imported or exported recycled materials.

Recycling plastic is more challenging than most materials due to the variety of applications and blends. Only thermoplastics, out of the two types thermoset and thermoplastic, can be re-melted and re-molded into new products (due to chain complexity thermosets will not melt regardless of the temperature). ISRI advertises the energy savings for plastic to be 88% [139]. This is based on the recycling of plastic *bottles*.

Paper

Paper makes up the largest volume of recycled material within the US [3] and has the most complex network of recycling. It is incredibly difficult to attempt to organize the actors within this network in a flow diagram. However, Figure 22 attempts to visualize the network (without the connectivity matrix) do demonstrate the extreme complexities in comparison to the previously discussed networks. Following the figure, the industry operations between actors are described to remove any confusion.

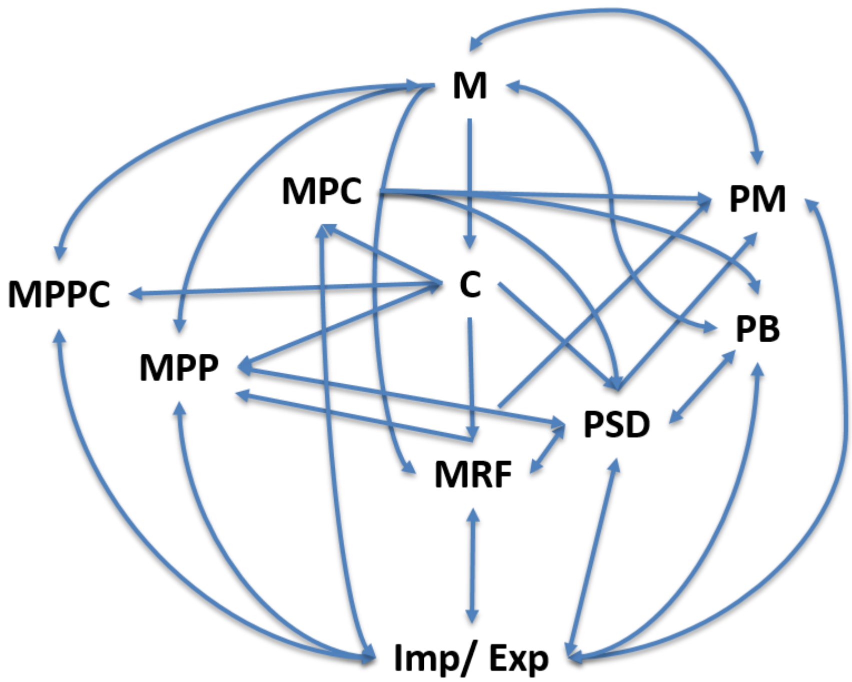


Figure 22: Material flow for paper recycling industry. M- Manufacturer, C- consumer, MRF- material recovery facility, PSD- paper stock dealer, PB- Paper broker, PM- Paper mill, MPPC- Manufacturer with collection and processing, MPP- manufacturer with processing, MPC- manufacturer with collection, imp/exp- import and export of paper.

Based on the visualization provided by Figure 22, it can be easily concluded that it would be near impossible to begin to guestimate the supply or demand values for each individual actor. Recycled paper, including newspaper, cardboard, office paper, and food cartons can be generated by residences and collected through curb-side and drop off recycling programs where most of the material will be sorted at an MRF or paper stock dealer (small scale brokers who procure supply for processing facilities) [164]. Significant amounts of paper recycling (primarily cardboard) is also recovered and baled at large retailers and grocery stores and sent directly to paper mills (processing facilities) or paper brokers (can include paper stock dealers, however normally refers to larger operations) [164]. Paper and paperboard mills within the US can consume recovered paper from both domestic and external sources. From there, the material may undergo a secondary sorting or primary process and then be sold as an export. Many paper manufacturers also operate their own collection and/or processing, while others rely on brokers for a steady supply [164]. Regardless, the complexity of this system prevents it from being included in the recycling flow optimization analysis.

Paper remains the greatest volume of recycled material in the US as well as the greatest export of recycled material. Much like plastics, recycling via exportation has been the most popular form of separated paper waste management. China and several southeast Asian countries have declared their intention to ban the importation of paper and paperboard in the near/immediate future, following their ban on plastics. However, the success of these implementations (specifically in China) is called into question by industry experts due to the paper recycling industry within China carrying much more political influence than its plastic counterpart [165]. Where the plastic recycling sector is far more horizontal (made up of many small producers) the paper recycling is led by Chinese industry giants (Nine Dragons, Lee & Man, etc.) who provide recycled containerboard for companies like Nike, Walmart, Target, etc. whom would be motivated to take their orders elsewhere if they can no longer buy large quantities of cheap boxes [165]. Still, the export of paper recycling products to China fell 18% from 2017 to 2018, while the exports to India rose by 24% [165]. Using national values for processing and export/import, the paper industry is considered further in the results section of this chapter.

Glass, E-waste, and miscellaneous recycling

For the analysis of this thesis, glass, electronic waste, and other various sources of recyclable materials are not considered independently. For the case of glass, although the material can be recycled an infinite number of times, the energy savings (only 10-15%) and profitability (poor) prevent it from making up a large portion of the recycling industry [142]. Instead, the main streams: non-ferrous and ferrous metal, plastic, and paper are chosen for further analysis.

Procedure

To consider the system as most US environmental enterprises would like, first the recycling networks are considered utilizing the import/export option as an additional actor in the system. This replicates the manner in which exported material is considered towards the recycling rate for the country. In addition to import/export, new (virgin) material is designated as an actor that supplies to the system, but doesn't consume. This is done to provide a realistic flow volume to the manufacturing actors as well as to remain consistent (i.e. if imports/exports is chosen to represent an actor, so will new materials).

To complete this, MATLAB (version R2016b) was used to optimize the recycling routes using Finn Cycling Index (FCI). Information on supply and demand generated the flow matrices required for ENA and the limiting equations (governing the network connections) created the model. The values for several food web metrics were calculated, including the following Eqs. 1-8.

- *N* is the number of species/actors in the network.
- *L* is the number of links in the network.

$$L = \sum_{i=1}^{m} \sum_{j=1}^{n} f_{ij} \tag{1}$$

- *Linkage Density* (L_D) is the ratio of the total number of links to the total number of species in a food web.

$$L_D = {}^{L}\!/_{N} \tag{2}$$

- *Nprey* is the number of prey/producers in the network. This is the sum of rows in the food web matrix [**F**] with nonzero entries.
- *Ns,prey* is the number of specialized prey, or those producers who interact with only one type of consumer. This is the sum of rows in the food web matrix [**F**] with *only one* nonzero entry.
- *Ps,prey* is the specialized prey fraction, or the ratio of specialized prey to total prey.

$$P_{s,prey} = {}^{N_{s,prey}}\!/_{N_{prey}} \tag{3}$$

- *Npredator* is the number of predators/consumers in the network. This is the sum of columns in the food web matrix [**F**] with nonzero entries.

- $N_{s,predator}$ is the number of specialized predators, or those consumers who interact with only one type of producer. This is the sum of columns in the food web matrix [**F**] with *only one* nonzero entry.
- *Ps* is the specialized fraction of predators.

$$P_s = {}^{N_{s,predator}}\!/_{N_{predator}} \tag{4}$$

- P_R is the prey to predator (producer to consumer) ratio.

$$P_R = {}^{N_{prey}}\!/_{N_{predator}} \tag{5}$$

- *G*, generalization (links divided by number of predators) is the average number of prey available to any one predator in the network.

$$G = {}^{L}\!/_{N_{predator}} \tag{6}$$

- *Vulnerability* (*V*) is the average number of predators per prey in a web.

$$V = {}^{L}\!/_{N_{prey}} \tag{7}$$

- *Cyclicity* (λ_{max}) is a measure of the presence and strength of cyclic pathways present in a system [18, 19]. Cyclicity is calculated as the maximum real eigenvalue of the adjacency matrix [**A**], the transpose of the food web matrix. Figure 23 outlines the calculation of λ_{max}. It can be a value of zero (no cycles), one, (a single basic cycle), and greater than one (increase number and complexity of cycles).

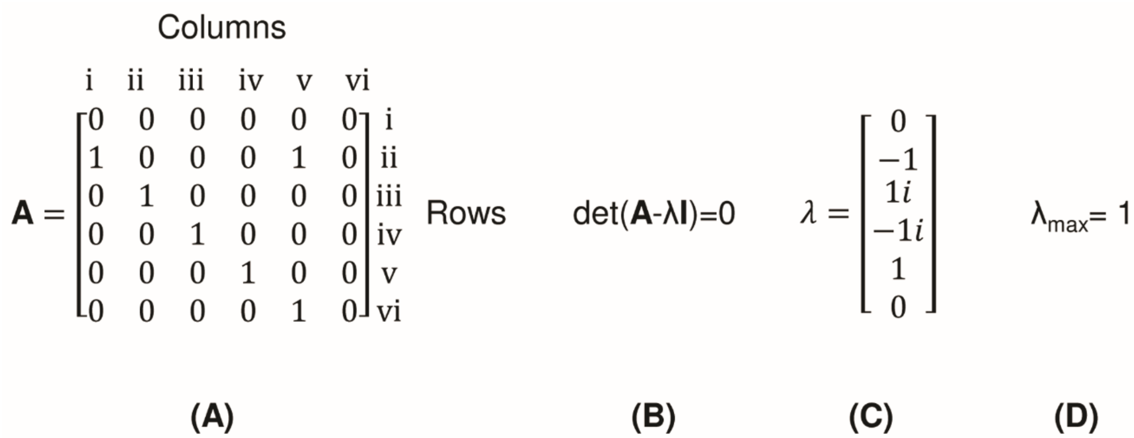


Figure 23: The process for calculating the cyclicity of a system with six species. (a) Labeled adjacency matrix for the system– rows represent flow *to* a node, columns *from* a node. (b) Equation for the calculation of the eigenvalues for the adjacency matrix. (c) Eigenvalues. (d) The cyclicity of the cycle as the maximum real eigenvalue of the adjacency matrix. *Figure used with permission from* [27].

- *Connectance* (*Co*) is the ratio of actual direct interactions to total possible interactions within a network.

$$Co = {}^{L}\!/_{N^2} \tag{8}$$

The optimization generates new flow matrices that maximize FCI while still meeting the supply and demand/governing equations. Wherever possible, the known values were used to calculate the unknown values within the network, however several networks did not have enough information available and realistic assumptions are made. The MATLAB (versionR2016b) code, a small section of which is included below describing the calculations for the above metrics, is in Appendix B starting on page 247.

```
n = size(A,1); %number of actors
L = nnz(A); %number of links
```

```
prey= sum(F~=0,2); %how many predators eat each prey
Nsprey = sum(prey==1); %Specialized number of preys
Nprey = nnz(prey);  %number of preys
Psprey = Nsprey/Nprey; %specialized prey fraction


predator = sum(F~=0,1);  %how many preys are eaten by each predator
Nspredator = sum(predator==1); %specialized number of predators
Npredator = nnz(predator); %number of predators
Pspredator = Nspredator/Npredator; %specialized predator fraction


PR = Nprey/Npredator; %prey to predator ratio
G = L/Npredator; %Generalization

cyclicity = max(abs(eig(A)));
```

Using the flow matrices generated by the above optimization, the system is then analyzed using the standard practices of ecological network analysis: where imports/exports and new materials are considered in the flow matrix, but are not considered as part of the structural matrix. To do this, the matrices generated in the previous optimization are modified to resemble the format shown below in Figure 24.

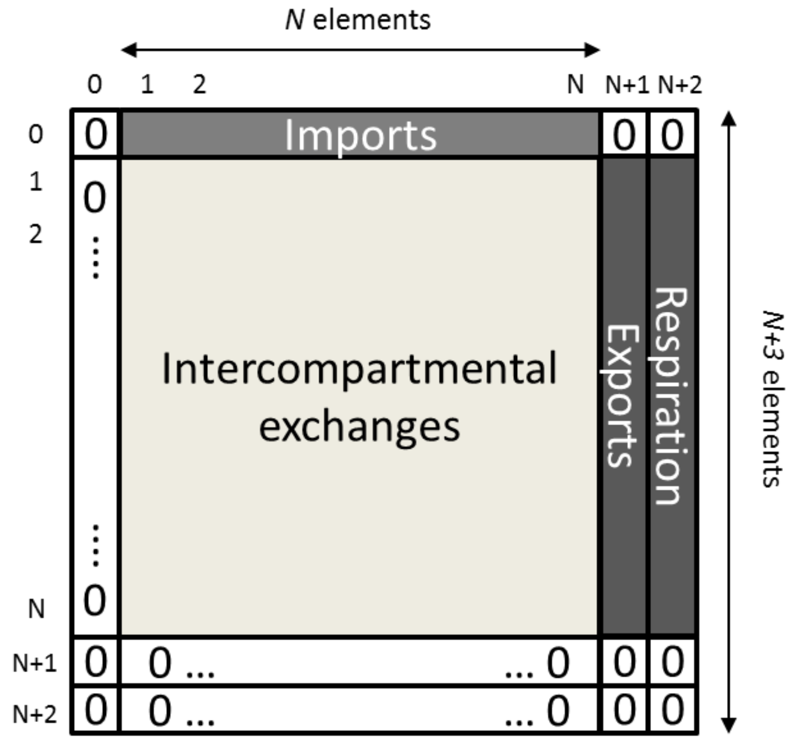


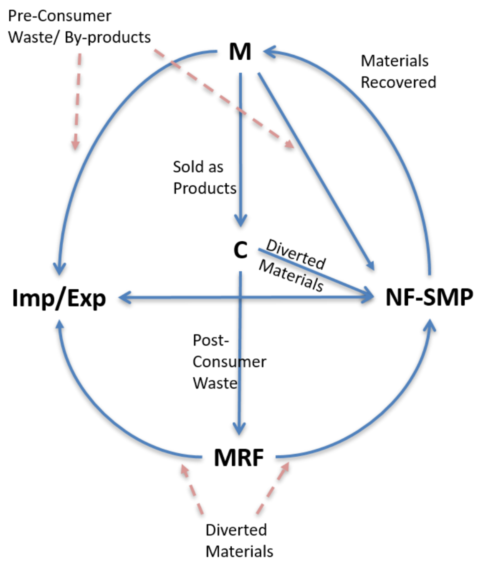
Figure 24: A squared (*N*+3) x (*N*+3) flow matrix where *N* is the number of species represented in the food web, the zeroth row/column entry represents imports to the system across the systems boundaries, the *N*+1 row/column entry represents exports across the system boundaries, and the *N*+2 row/column entries represent respiration or dissipation to the surroundings. ***Figure adapted with permission from*** **[166].**

To modify these matrices, a zero column and row were added to the ends to represent zero dissipation. Although each recycling operation does have some dissipation, it is difficult to quantify values for this and the results focus on structural metrics for comparison between the inclusion of the additional actors and without. For this reason, these values are assumed to be zero.

Using the results of these operations, discussions are made based on the effect that these alterations had. Unfortunately, due to the complexity of the paper and the ferrous metal network, these analyses were unable to be performed. Instead, the basic flow matrix is considered in Excel for ferrous metal and the research conducted for both material flows contributes to the overall analysis of the US recycling industry.

Results and Discussions

Non-Ferrous



$$
\begin{array}{c}
 \\ \mathbf{M} \\ \mathbf{C} \\ \mathbf{NF\text{-}MRF} \\ \mathbf{SMP} \\ \mathbf{Imp.}
\end{array}
\begin{array}{c}
\begin{array}{ccccc} \mathbf{M} & \mathbf{C} & \mathbf{MRF} & \mathbf{NF\text{-}SMP} & \mathbf{Exp.} \end{array} \\
\begin{bmatrix}
1 & 1 & 0 & 1 & 1 \\
0 & 1 & 1 & 1 & 0 \\
0 & 0 & 0 & 1 & 1 \\
1 & 0 & 0 & 1 & 1 \\
1 & 0 & 0 & 1 & 1
\end{bmatrix}
\end{array}
$$

Figure 25: Material Flow and Connectivity Matrix for Non-Ferrous Metal Recycling. M are the Manufacturers, C are the Consumers, MRF are the Material Recovery Facility, NF-SMP is the non-ferrous scrap metal processors, and Imp/Exp are the imported or exported recycled materials.

Figure 25 illustrates the network relationships between manufacturer (M), consumer (C), non-ferrous scrap metal processor (NF-SMP), material recovery facility (MRF), and the import and export of *recycled non-ferrous metals*. The connectivity matrix includes additional *possible* flows not pictured in the digraph, such as a connection to/from the consumer and to/from the manufacturer to represent reuse/ by-product reuse. These additions ensure the solution space for the optimization is not limited and highlights the effects that these return streams can have on the ENA metrics.

The aluminum recycling network analysis bases the supply of the manufacturer actor (M) on IRSI's published value for the US consumption of aluminum in 2017 of 6,580,000 metric tons[139]. The demand for M was set as the Congressional Research Service value for US aluminum consumption in 2017, of 8,245,400 metric tons[161, 167]. The process supply value is the recovered aluminum material *in use*, reported by ISRI. The process demand is based on ISRI's processing consumption figures. Import and export values are from ISRI's online data sheets[161]. There is no sure way of knowing how much aluminum is handled by MRFs, thus two scenarios are considered based on: 1) the MRF consuming less material than is produced by the consumer (suggesting most material is post-consumer waste going through these facilities) and 2) that the MRF consumes more material than the consumer produces (meaning that the MRF must also work with manufacturers and their waste streams include both pre-consumer and post-consumer waste). Table 11 shows *Scenario 1* where supply and demand are set to 600,000 metric tons and Table 12 shows *Scenario 2* where supply and demand is set to 1,300,000 and 1,500,000 metric tons, respectively. The values for MRF assume that the facilities' receive their materials from the consumer, that there is zero loss (unlikely, but since the material that is sent to landfill is not considered here, the assumption can be made that this value represents the recycled material *after* separation), and that the consumer can send material directly to the processor (a reasonable assumption for scrap metal processors).

Table 11: Supply and Demand Values for *Scenario 1* of Aluminum Recycling (representative non-ferrous metal). N is the New material introduced, M are the Manufacturers, C are the Consumers, MRF are the Material Recovery Facility, NF-SMP is the non-ferrous scrap metal processor, and Imp/Exp are the imported or exported recycled materials. References where available for the values are listed in the right two columns. Highlight values indicate that these values were designated as educated guesses and not found directly through research.

Aluminum- Scenario 1				
	Supply	*Demand*	Supply Ref	Demand Ref
N	741,000	-	[160]	-
M	6,580,000	8,245,400	[139]	[142]
C	670,000	3,610,000	[3]	[3]
MRF	600,000	600,000	-	-
NF-SMP	3,700,000	5,268,000	[158]	[158]
Imp/Exp	4,800,000	2,900,000	[142]	[142]

The MRF receives material from more than just the consumer and there is some loss from consumption and production modeled in Scenario 2 (Table 12). The loss represents material that is either too contaminated (mixed in with other materials or dirty) to be separated any other miscellaneous aluminum that is rerouted to the landfill. Scenarios 1 and 2 are both realistic, but Scenario 1 is more likely to occur when very few recycling facilities are available regionally and Scenario 2 is more likely when the local MRFs are larger and well equipped.

Table 12: Supply and Demand Values for *Scenario 2* of Aluminum Recycling. N is the New material introduced, M are the Manufacturers, C are the Consumers, MRF are the Material Recovery Facilities, NF-SMP is the non-ferrous scrap metal processors, and Imp/Exp are the imported or exported recycled materials.

Aluminum				
	Supply	*Demand*	S. Ref	D. Ref
N	741,000	-	[160]	-
M	6,580,000	8,245,400	[139]	[142]
C	670,000	3,610,000	[3]	[3]
MRF	1,300,000	1,500,000	-	-
NF-SMP	3,700,000	5,268,000	[158]	[158]
Imp/Exp	4,800,000	2,900,000	[142]	[142]

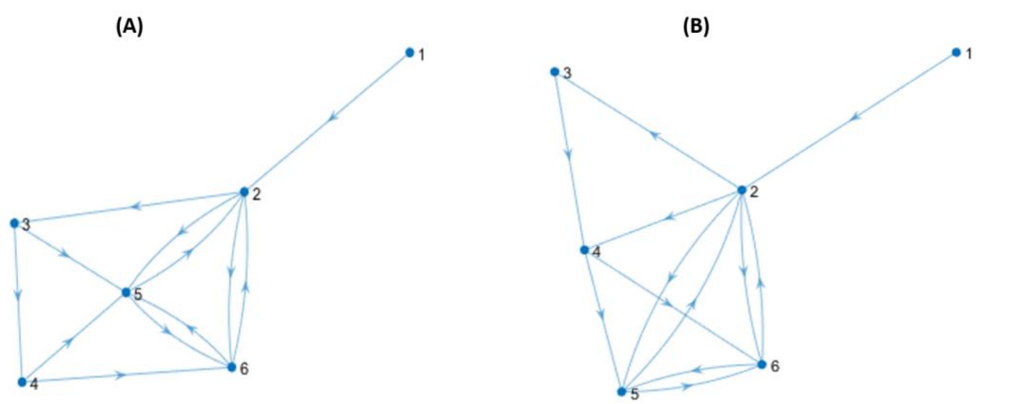


Figure 26: The FCI optimized flow networks of Scenario 1 (A) and Scenario 2 (B).1) The actors are 1) primary production (new material), 2) manufacturing (M), 3) consumer, 4) materials recovery facility, 5) non-ferrous metal processor, and 6) imported and exported aluminum.

Figure 26A and B represent the expected flow path of the networks described by Figure 26 and Table 12. Reuse has been prohibited in both scenarios and thus by-product reuse is not allowed (M to M) and consumer reuse is prevented (C to C). The connection between consumers to manufacturer is blocked representing no extended producer responsibility. The effect of these types of beneficial connections on the system is highlighted by rerunning the optimization without these limitations, as shown by the runs, assumptions, and corresponding food metric values listed in Table 13. Scenarios 1 and 2 (run 1 and 2 in Table 13) are the baseline cases. For both scenarios the metrics were analyzed allowing all types of reuse and without all types of reuse. These relationships are dictated in the equality and inequality section of MATLAB (version R2016b) in Appendix B on page 248. The flow diagrams of these runs are shown in Figure 27 and the flow tables for these runs are provided in Table 54 on page 257 as a part of Appendix B.

Table 13: Run number, Food Web Metrics, and scenarios for the Aluminum recycling network's FCI Optimization. All scenarios here allow for manufacturer by-product reuse, consumer reuse, and extended producer responsibility (EPR).

Run	Cyclicity	FCI	Ld	G	V	PR	Scenario
1	2.2567	1.9833	2	2.4	2	1.2	Scenario 1; does not allow reuse
2	2.3593	1.8807	2	2.4	2	1.2	Scenario 2; does not allow reuse
3	2.804	1.436	2.33	2.8	2.33	1.2	Scenario 1 with all reuse and EPR
4	2.8933	1.3467	2.33	2.8	2.33	1.2	Scenario 2 with all reuse and EPR
5	2.9354	1.3046	2.5	3	2.5	1.2	Scenario 1, C does not send all to MRF, and includes all reuse/EPR
6	3.098	1.142	2.5	3.2	2.5	1.2	Scenario 2, C does not send all to MRF, and includes all reuse/EPR

The cyclicity of each scenario is improved when the manufacturer and consumer are permitted to reuse materials. These metrics will be considered in more detail with the values found assuming that the new materials and import/export do not represent system actors, however it can be seen that the theoretical practice of reuse has a significant impact on the cyclicity of these recycling networks. Interestingly, the Finn cycling index decreases as the cyclicity increases in this simulation. This is likely due to the unusual inclusion of exports and new materials as actors. By increasing reuse, material is required to travel less (since the actors deliver to self) and this value is compromised. The flow diagrams generated by the optimization are shown below in Figure 27.

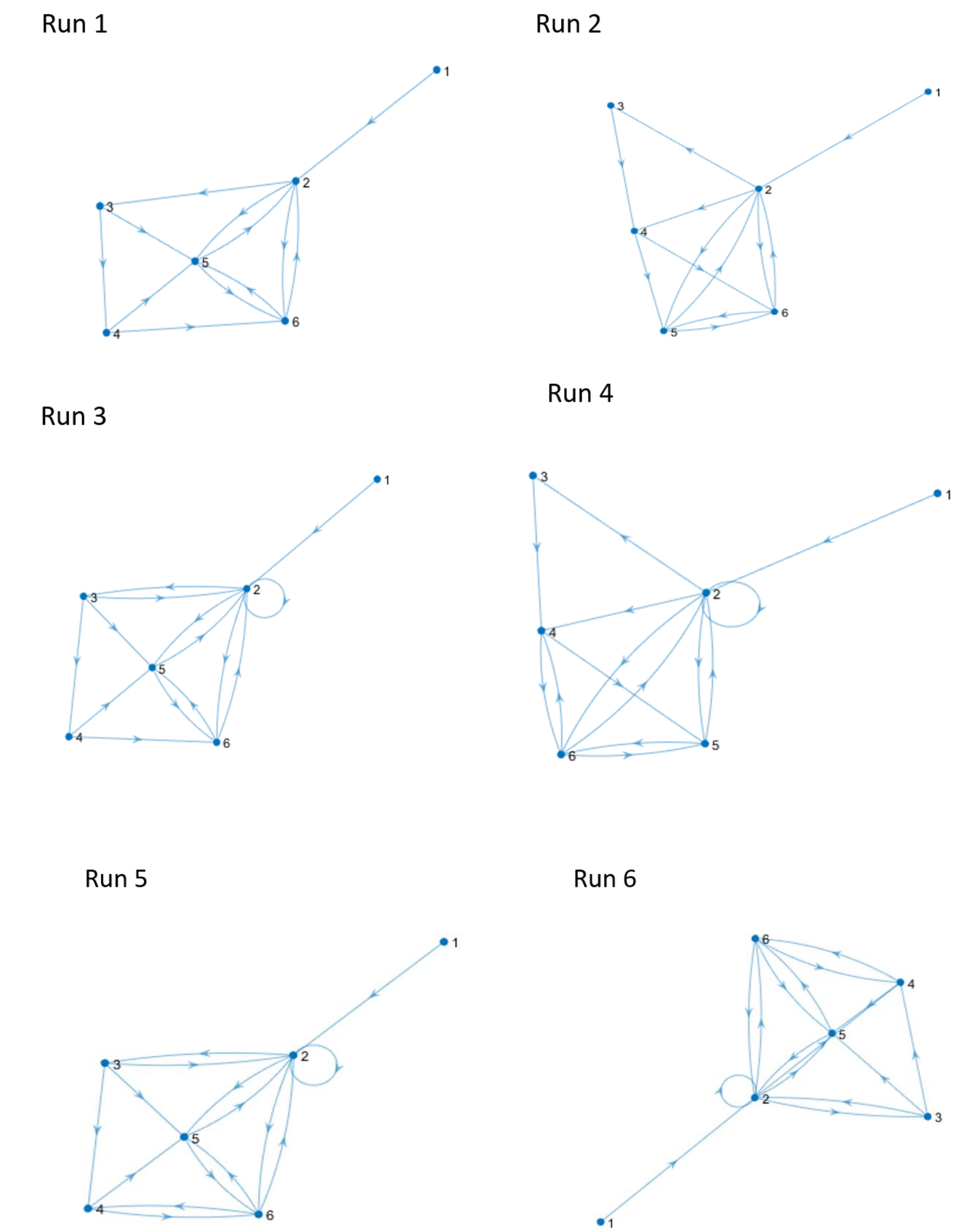


Figure 27: Runs 1-6 (corresponding with Table 13) of the flow diagram for aluminum recycling. Point 1 denotes new materials being introduced into the system, point 2 is the manufacturer actor, point 3 is the consumer, 4 is the material recovery facility, 5 is the non-ferrous scrap metal processor, and 7 is the imp/exp.

Runs 3-6 allow for reuse and by-product reuse, as well as extended producer responsibility (demonstrated through a return flow from consumer, 3, to manufacture, 2). All 6 networks can be considered to be realistic flows, depending on the facility practices involved in the network. Following the principal that network functions are a resultant of the structure or form of the system, through mimicking the structural metrics seen in ecological food webs, known for their sustainability, the end result should provide a network capable of higher sustainability. This process is further elaborated during the cumulative analysis of the US Recycling Industry on page 127.

Next, the flow matrix was used to recalculate the cyclicity of the system assuming that the structure for domestic recycling followed the standard practices for ecological metrics. The values that are calculated considering export as an actor within the system will represent the ecological metrics for the *advertised system*, while the values utilizing only the domestic processing in the structure matrix will represent the *actual values*. The results of both are shown in Table 14 below and visualized in the following Figure 28.

Table 14: Calculated cyclicity values considering advertised recycling structure and actual recycling structure

	Cyclicity	
Run	*Advertised*	*Actual*
1	2.2567	1.4656
2	2.3593	1.4656
3	2.804	2.2056
4	2.8933	1.9276
5	2.9354	2.2056
6	3.098	2.3165

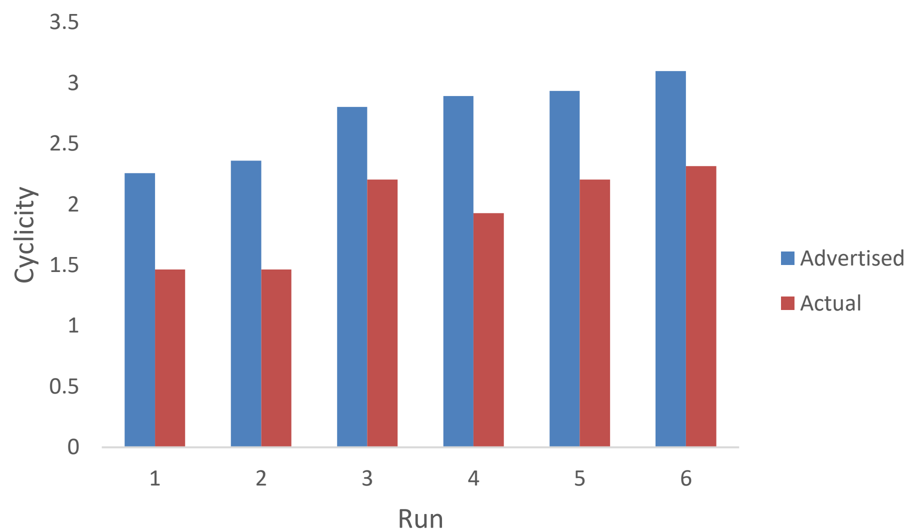


Figure 28: Advertised versus Actual Recycling Cyclicity in the US Aluminum Recycling Industry

As shown in Figure 28, the inclusion of export into the domestic recycling values has a significant impact on the overall perception and structure of the system. Cyclicity, being the measure of strength for a system, has been directly rated to the maturity and sustainability of ecological food networks. This value can be 0, 1, or greater than 1; a cyclicity measurement greater than one indicates the system has more developed pathways between the actors. As this is the analysis of the recycling industry, values greater than 1 should be given. The significance of cyclicity and considerations for the additional ecological metrics calculated will be further elaborated in the Analysis of US Recycling section of the results on page 127.

Ferrous Metals

The number of actors and lack of information when evaluating the material flow of ferrous metal within the US creates a large amount of uncertainty. This uncertainty is reduced here by aggregating the domestic processing facilities (DP) into one actor. Excel was used to determine the missing flow values. This is not ideal for the network analysis; the relatively small number of actors will affect the food web metrics. The grouping of domestic processors reverts the flow diagram back to the same number of actors as in the original, basic flow diagram as seen in Figure 29.

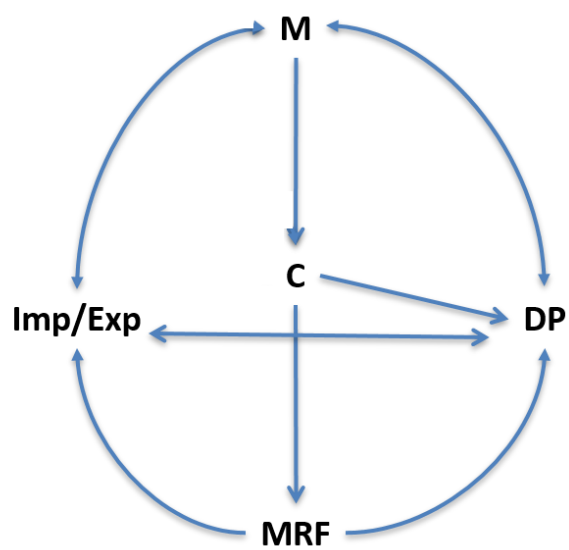


Figure 29: Modified Flow for Ferrous Metal Recycling. M are the Manufacturers, C are the Consumers, MRF are the Material Recovery Facility, DP are the domestic processing facilities, and Imp/Exp are the imported or exported recycled materials.

Again, the reuse and by-product reuse feedback loops are not shown in this version similar to aluminum flow diagrams. However, a feedback loop from M to M and form C to C could be added to demonstrate the possibility for reuse. This reuse could be applicable to the consumer and manufacturer, as well as some reuse/cannibalism from the import/export actor. However, cannibalism is prohibited with regards to import/export actor due to the material never entering the bounds of this network considered; thus, is disregarded. Table 15 is generated using this network set up and the **exact** values published from resources found in the data acquisition. Using the volume for the exportation of ferrous metal exports in 2017 (*14,955,411 metric tons*), the volume of imported ferrous scrap (*4,643,561 metric tons*; assumed to be sold to processors) the ISRI published values for domestic processed ferrous metal (*66 million metric tons*), and the assumption that of the ferrous material processed within the US, only 17% is exported the following flow table, Table 15, was constructed.

Table 15: Ferrous Metal Flow Table with Exact Values (creating inaccurate flows). N are the new materials introduced, M are the Manufacturers, C are the Consumers, MRF are the Material Recovery Facility, DP are the domestic processing facilities, and Imp/Exp are the imported or exported recycled materials.

	N	**M**	**C**	**MRF**	**DP**	**exp**
N	-	47,040,000	-	-	-	-
M	-	-	18,170,000	1,243,000	54,062,439	8,124,561
C	-	-		6,060,000	303,000	-
MRF	-	-	-		7,000,000	(4,389,150)
DP	-	54,780,000	-	-	-	11,220,000
imp/exp	-	4,020,000	-	-	4,634,561	-

The numbers in Table 15 are from several sources (EPA, IRSI, OECD, etc.; references provided in Table 10 in the data acquisition section of this chapter) and create a flow table that has *negative* flows as well as values that contradict some published statements, such as the value for US ferrous consumption (*81.6 million metric tons*) does not match this networks calculation of *105.84 million metric tons* of consumption. The 66 million tons of processed material is assumed here to be indicative of the processing production (versus consumption) and that the exported scrap is the only loss of steel. These exports from M and DP combine to cause the value for exported material by MRF to become negative.

The assumptions are adjusted according to the ISRI and the International Trade Administration (ITA). ISRI reports that materials processed (all types) are reintroduced into the material stream, reducing the values sent by the domestic processor (DP) by 30%[142]. The International Trade Administration estimates that 10.1 million metric tons of steel were exported in 2017[168], which was added to the export total. These changes result in revised flows seen in Table 16.

Table 16: Ferrous Metal Flow Table Adjusted. M are the Manufacturers, C are the Consumers, MRF are the Material Recovery Facility, DP are the domestic processing facilities, and Imp/Exp are the imported or exported recycled materials.

	N	M	C	MRF	DP	exp
N	-	46,400,000	-	-	-	-
M	-	-	18,170,000	1,243,000	47,862,439	14,324,561
C	-	-		6,060,000	303,000	-
MRF	-	-	-		13,200,000	2,776,850
DP	-	38,346,000	-	-	-	7,854,000
imp/exp	-	3,000,000	-	-	4,634,561	-

The values in Table 16 come much closer to matching the reported total production of ferrous metal in the US, 87.4 million tons (vs. 81.6 million actual). Table 15 resulted in a value of 105.8 million tons. These results demonstrate the *importance of assumptions* and improve the realism of the ferrous metals analysis. Unfortunately, the system does not have enough internal data to support the development of a flow matrix for this material flow. The future work for this research will include solidifying values for these various flows as well as analyzing the structural metrics found using the connectivity (or adjacency) matrix. The research developed on the recycling of ferrous metals is used towards the cumulative analysis of the US Recycling Industry on page 130.

Plastic

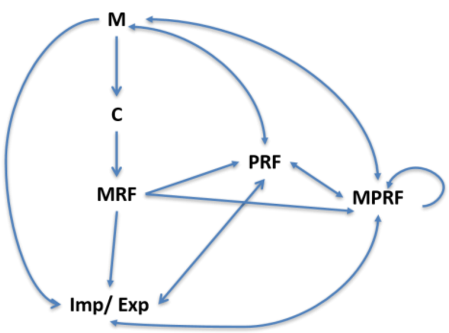
An unfortunate amount of guesswork is needed for the plastic material recycling Network. Roland Geyer (associate professor in UCSB's Bren School of Environmental Science and Management):

"You can't manage what you don't measure [169]."

Although the disposal of plastics has had significant public attention, data on production and consumption values are difficult to find when compared to the data on metals for example. The only plastic importation data available is given in US dollars, making it near-impossible to determine volumes. In addition, the data (used through most of Task 2) provided by the American International Scrap Trade Industries (ISRI) is pulled from data collected by UN stats made available through the UN Comrade's database[170].

While the ISRI acts as an aggregator of publicly available data, this means that there is **no governmental or private enterprise within the US responsible for tracking the production of material generation or recycling, especially in the case of recycling exact data is undeterminable**. Currently, the ISRI is still determining whether or not their states level processing numbers are accurate enough to begin publishing; even then, this research is focusing on the metal industry for which there is better industry participation[170]. The figures occasionally shown for US plastic production most often uses values published by the EPA that do not include construction or demolition waste or significant manufacturing waste streams protected by the private corporations generating these volumes[3].

Plastic recycling has had been impacted the most by the current bans put in place in China and southeast Asia: the US exportation of plastic recycling material dropped 92% in 2018 alone[9].



$$\begin{array}{cc} & \begin{array}{cccccc} \text{M} & \text{C} & \text{MRF} & \text{PRF} & \text{MPRF} & \text{Exp.} \end{array} \\ \begin{array}{c} \text{M} \\ \text{C} \\ \text{MRF} \\ \text{PRF} \\ \text{MPRF} \\ \text{Imp.} \end{array} & \begin{bmatrix} 1 & 1 & 0 & 1 & 1 & 1 \\ 0 & 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 1 & 1 \\ 1 & 0 & 0 & 0 & 1 & 1 \\ 0 & 1 & 0 & 1 & 1 & 1 \\ 1 & 0 & 0 & 1 & 1 & 1 \end{bmatrix} \end{array}$$

Figure 30: Material Flow (left) and Connectivity Matrix (right) for Plastic Recycling. M are the Manufacturers, C are the Consumers, MRF are the Material Recovery Facility, PRF are the plastic recovery facilities, MPRF are the manufacturers with plastics recovery, and the Imp/Exp actor demonstrating Imp for imported materials (column) or Exp (row) showing the exports of recycled materials.

The material flow digraph and connectivity matrix for plastic waste in the US are shown in Figure 30. The digraph highlights the flow routes in the US plastic recycling industry. The actors included are the manufacturers (M), consumers (C), material recovery facilities (MRF), plastic recovery facilities (PRF), manufacturers with plastics recovery (MPRF), and the import and export of recycled materials (shown separated on the row and column for clarification).

Unfortunately, the assumptions made for plastic are insufficient to provide the supply and demand values for plastic. This is due to plastic (although it is the second largest material stream of our waste) being relatively unregulated within the US. Without information on the US production or accurate consumption values of plastic materials, the estimation of these values is based on domain knowledge. The supply and demand values (shown in Table 17) are based on EPA information on consumption, ISRI information on the import and export of plastic scrap, and Statistica figures published from ISRI values for the total production of plastic[171]. The scenario represented by Table 17 only considers scrap imports and exports, these only represent a fraction of the real imports and exports; however, values on the remaining material are unavailable.

Table 17: Supply and Demand Values for Plastic Recycling. Highlight values are estimates.

	Plastic	
	Supply	**Demand**
	(in metric tons)	
N	56,487,000	-
M	34,830,000	60,000,000
C	34,500,000	3,140,000
MRF	4,000,000	2,000,000
PRF	1,400,000	1,300,000
MPRF	1,400,000	1,300,000
Imp/Exp	1,667,736	390,000

The estimated values Table 17 are highlighted in grey. The missing value with the largest impact is the manufacturing production of plastics. The only estimate available is based on the EPA's measurement for volume of waste generation within the US, but that does not consider construction or demolition plastic nor many plastic wastes generated through manufacturing processes. Nevertheless, these values were designated to understand the network flow and the impacts that reuse can have within the system.

The network described by Table 17 was optimized for FCI without and with reuse, resulting in the two solutions shown in Figure 31.

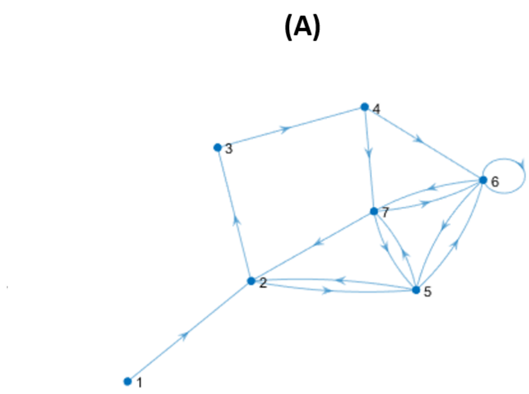


Figure 31: Optimized Flow Diagram for Plastic Recycling without (A) and with (B) reuse. The actors here are 1) primary production (new material), 2) manufacturer, 3) consumer, 4) material recovery facility, 5) plastic recovery facility, 6) plastic and manufacturing recovery facility, and 7) import/export of plastic.

This network solution is very close (or identical) to the directional flows expected from the plastic recycling industry utilizing these actors. Notice that actor 6 is the only one with reuse and this facility operates both manufacturing and processing. This optimization resulted in the following metrics, shown in Table 18.

Table 18: Metrics for plastic recycling optimization without and with reuse (assuming the inclusion of import and export as a separate actor).

	Without reuse	With reuse
FCI	1.5613	1.3967
Cyclicity	2.6787	2.8433
Npredator	6	6
Nprey	7	7
Generalization	2.5	2.83
Links	15	17

These values include the export and production of new material as separate actors, which skews their values from the standard calculations according to ecological network analysis. However, it can still be seen that reuse improves the cyclicity of the system by providing increased linkages between the network actors. With the increase in connections, the generalization for the system has also improved. This result indicates that reuse can have a notable impact on the sustainability and strength of the US waste management system. While volumes for recycling can be increased with no effect on the structural values, adjusting waste management behaviors to encourage reuse can strengthen the network and have an immediate impact on the form of the waste management network where consumers are involved.

Using the flow matrices generated through the optimization technique above, the domestic network (with exports and the introduction of virgin materials considered outside of the structural matrix) was created. The following results were calculated for the cyclicity values of plastic domestic recycling. Similar to the section on non-ferrous, inclusion of exports will represent the advertised metrics, while limiting the consideration to domestic values is considered the actual values.

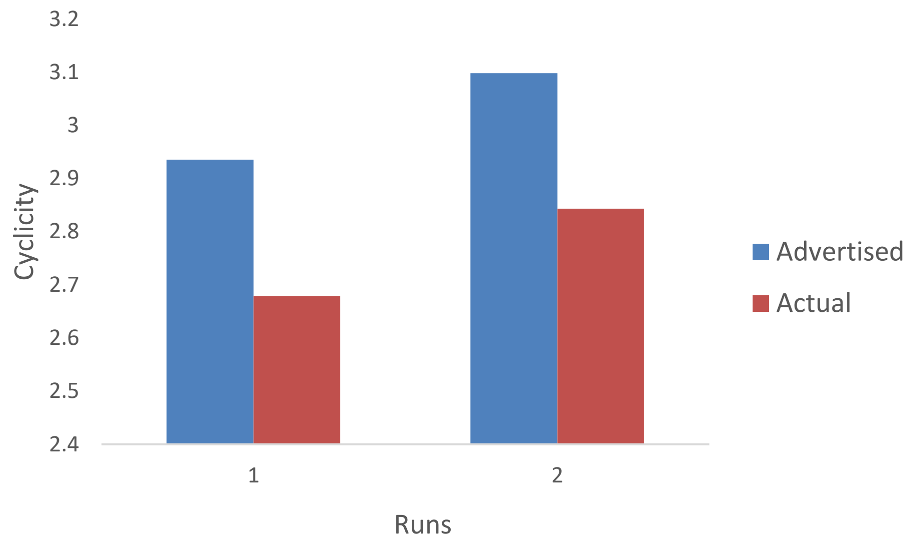


Figure 32: Cyclicity calculations for advertised and actual performance of domestic plastic recycling

The values found for the actual network are much lower than those found with exportation included. This is shown again to demonstrate that the trend will hold regardless of material considered. By including exportation as recycling, there is a clear and intentional skewing of the system structure. Likely thanks to corporately funded environmental programs, many Americans have been taught that recycling is the solution to circular economy and assume that the reason it has not been successful up to this point is due to a lack of participation[15]. However, the analysis of the advertised versus actual cyclicity demonstrates the gap between the advertised material cycling present versus the actual; the results of this comparison (with the knowledge of mismanaged waste rates) should call into question the legitimacy of the US recycling network as well as the morality standards of the American enterprises responsible for educating the public on the impact of their waste. While the plastic recycling industry can save energy, most plastic material is incapable of being processed and even durable plastics are limited to 1-2 recycling processes[86]. As a result, this material makes up the largest percentage (which is unknown) of waste exported to counties with mismanagement rates greater than 55%.

These results are collected and further elaborated on in the section for Analysis of the US recycling System on page 127 with the discussion and analysis in comparison to ecological food web metric values.

Paper

Paper is one of the most complex recycling networks within the US, as well as the largest volume of recycled material. Without basing the network on a known set of recycling facility actors and without cooperation and data sharing between these facilities, it is nearly impossible to collect realistic supply and demand values for the entire US paper recycling network. A network based almost entirely on assumptions was optimized using MATLAB (version R2016b), however the results were insufficient for analysis. Additionally, it is difficult to encourage the reuse of most paper and paperboard products as their deterioration rate impedes reuse applications. Nonetheless, the values that could be found through research are provided in Table 19 below.

Table 19: Known Values for the US Paper Recycling Industry

Values for 2017	Volume (metric tons)	Ref
New US Production	77,269,000	[139]
US Consumption	72,120,000	[139]
MSW Consumption	68,050,000	[3]
Total Processed	46,100,000	[142]
Exported Scrap Paper	18,261,334	[171]
Imported Scrap Paper	4,900,000	[146]

Because it was impossible to determine the flow matrix, instead research done on the paper recycling industry is used towards the Analysis of US Recycling on page 127.

Analysis of *US Recycling*

Mismanagement Rate of Waste in the US

The US touts a 0% waste mismanagement rate and the waste that is *exported* to countries with poor management is counted towards the countries recycling rates. Consider Table 20 shows countries' mismanagement rates and their volume of imported plastic waste from the US. The exportation values shown are for the months January to June 2018, thus these volumes represent only half of the year's US exports. Plastic waste values are used because values on total material flow are not readily available and would require detailed data collection. The mismanagement rates in Table 20 are still *optimistic* values for plastic since plastic is much more likely than other imported wastes to be mismanaged. This is due to the level of contamination involved in plastic waste as well as the much lower commodity prices.

Table 20: US mismanaged volume of waste by country[68, 171].

Country	% mismanaged	US Export Volume from Jan to June (in 1,000 metric tons) 2017	2018	Resulting mismanaged waste from January to June (in metric tons) 2017	2018
Malaysia	55%	42.17	157.3	23,194	86,515
Thailand	73%	4.39	91.51	3,205	66,802
Vietnam	86%	48.9	71.22	42,054	61,249
India	85%	66.71	69.71	56,704	59,254
China	74%	257.66	60.45	190,668	44,733
Hong Kong	74%	379.38	30.25	280,741	22,385
SUM		799.21	480.44	**596,565**	**340,938**

The volume of exports and each receiving country's mismanagement rates, it can be conservatively estimated that the US mismanaged *596,565 metric tons of plastic* waste from Jan-June 2017 and *340,938 metric tons* from Jan-June 2018 through exports. According to this analysis, that means that the US inadequately disposed of more plastic in the *first half of 2017* than it processed domestically for the *entire year of 2017* (466,929 tons [161]). This means that while the US reports a waste mismanagement rate of 0%, it in fact has more.

Although US exportation of solid waste significantly reduced from 2017 to 2018, the reduction failed reduce consumption or waste production. Attention was instead drawn to blame Asia for polluting the ocean, while the US has refrained from taking part in worldwide initiatives to lessen the impact of single use products and exportation to countries with waste mismanagement[172]. With the loss of exportation as an alternative for plastic waste, some reports have determined that 211 million tons of plastic waste will be displaced by the year 2030[9]. Without an alternative destination and if the values for production and consumption remained the same, landfilling rates within the US are expected to increase dramatically in the years following the implementation of the National Sword. The landfilling numbers have yet to be published for the year of 2018, but recycling companies who previously sent their plastic material to Asia have already reported as much as 100% of their material streams have had to be diverted directly to landfill or their operations supported only through government funding[173].

Comprehensive Industrial Detrital Network

Each of the aforementioned recycling methods makes up one stream of an industrial detrital feedback network. Each of these feedback loops operates using specific material requirements and returns energy with varying efficiencies. Table 21 summarizes the findings here, highlighting the major results and discussions with regards to the industrial detrital feedback stream. Figure 33 shows a high-level flow diagram of these detrital feedback steams. The color of the line (green to red) indicates the energy saved in comparison to the production of raw materials. The dashed lines indicate limitations to recycling material due to “decycling,” or the degradation of the product after the processing operations. The line thickness reflects the recycling rate. The thickest lines (plastic and steel) have recovery rates of over 70% and the thinnest (plastic and glass) have recovery rates of less than 35%.

Table 21: Recycling statistics based on material stream [139, 142, 158].

Material	*Recycling Rate*	*Energy Saved*
Non-ferrous metal		
Aluminum (total)	43%	95%
Aluminum (cans)	67%	95%
Copper	unknown	75%
Lead	unknown	75%
Ferrous metal		
Steel (automotive)	100%	60%
Steel (appliances)	90%	60%
Steel (cans)	67%	60%
Paper Products		
Paper and Paperboard	69%	60%
Corrugated Cardboard	92%	75%
Glass bottles and jars	33%	10-15%
Plastic Bottles	29%	88%

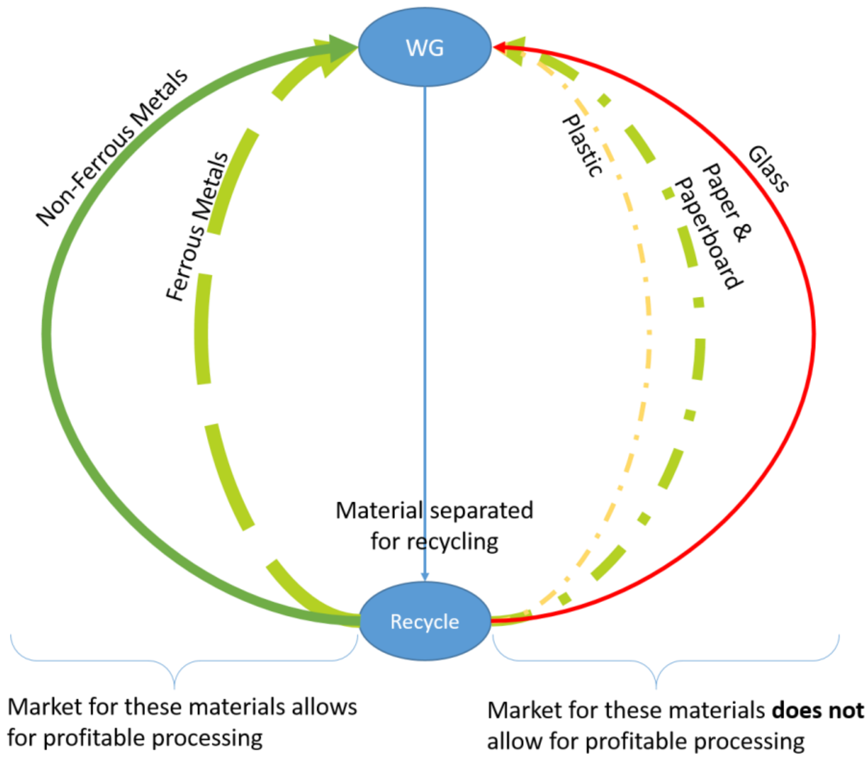


Figure 33: Visualization of detrital feedback loop provided by varuous recycling streams. Materials with a solid line can be recycled infinitely, dark green steam materials have >75% energy savings, light green have energy savings > 50% energy savings, yellow shows plastic because although bottles have 88% energy savings, average is approximated at lower than 50%, red stream shows materials with less than 25% energy savings when recycled in comparison to creating virgin materials. Materials on the right be recycled at a profit in the 2018-2019 recycling market, while materials on the right are cost liabilities[54, 142].

Using the detrital research done by Moore, demonstrating the advantages of multiple detrital feedback loops, the assumption can be drawn that the various recycling processes provide greater stability to the material consumption network within the US. In addition, understanding the limitations of recycling, more restrictions should be applied on the production of materials such as plastic or paper packaging that can be replaced with more durable materials. By investing in higher value materials, the recycling industry will have greater support and retain higher profitability.

Recycling and Food Web Metric Comparisons

Utilizing the results developed through the optimization and structural analysis of aluminum and plastic, Table 22 was created to compare the two recycling industry metrics with those of known sustainable food webs.

Table 22: Ecological Food Metrics Found for US Recycling of Aluminum and Plastic with Food Web Metrics for Comparison

Considering Export within the System							
Run	Cyclicity	FCI	Ld	G	V	PR	Material
1	2.2567	1.9833	2	2.4	2	1.2	Aluminum
2	2.3593	1.8807	2	2.4	2	1.2	
3	2.804	1.436	2.33	2.8	2.33	1.2	
4	2.8933	1.3467	2.33	2.8	2.33	1.2	
5	2.9354	1.3046	2.5	3	2.5	1.2	
6	3.098	1.142	2.5	3.2	2.5	1.2	
1	2.6787	1.5613	2.1429	2.5	2.1429	1.1667	Plastic
2	2.8433	1.3967	2.4286	2.83	2.4286	1.1667	
Considering the network without exports							
Run	Cyclicity	FCI	Ld	G	V	PR	Material
1	1.4656	0.4222	1.50	1.50	1.50	1.00	Aluminum
2	1.4656	0.4094	1.50	1.50	1.50	1.00	
3	2.2056	0.3579	2.00	2.00	2.00	1.00	
4	1.9276	0.3605	1.70	1.75	1.75	1.00	
5	2.2056	0.4459	2.00	2.00	2.00	1.00	
6	2.3165	0.4428	2.25	2.25	2.25	1.00	
1	1.8668	0.23	1.60	1.60	1.60	1.00	Plastic
2	2.1204	0.69	2.00	2.00	2.00	1.00	
Values for Food Webs							
	Cyclicity	FCI	Ld	G	V	PR	
	4.240	0.125	5.040	6.180	5.340	1.090	

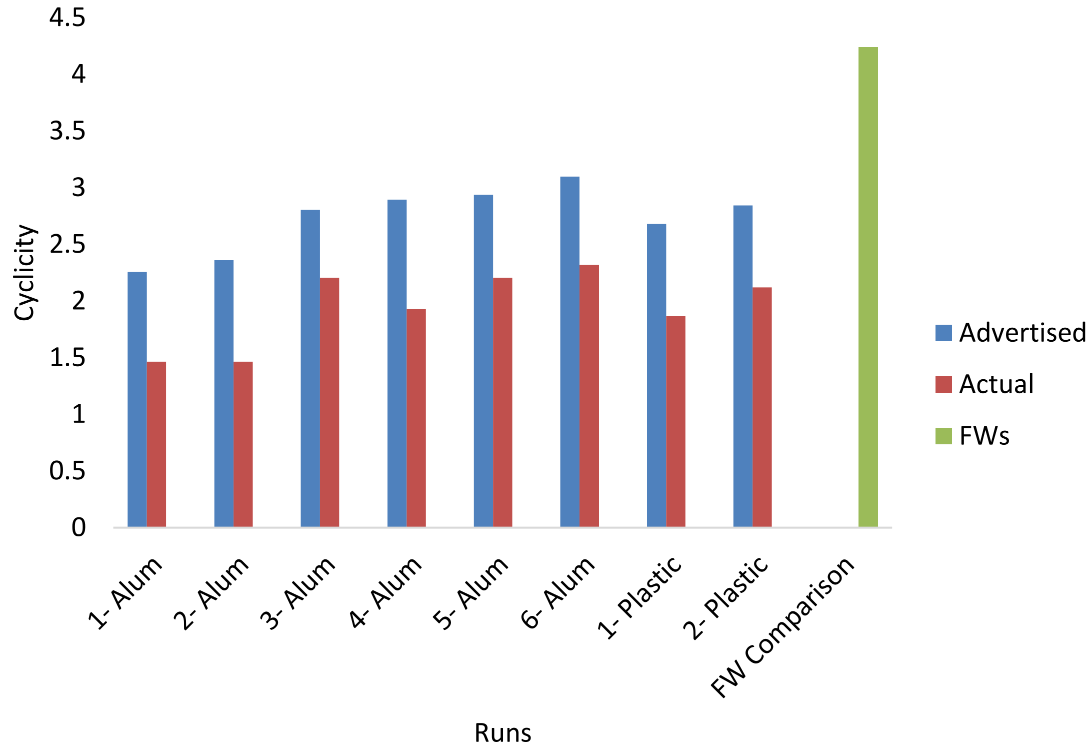


Figure 34: Cyclicity Values for US Aluminum and Plastic Advertised and Actual for Comparison with those of FWs

Based on the comparison between the recycling industry and the metrics for natural food webs, the recycling industry should be organized with more actors providing material feedback if it aims to achieve the cyclicity values seen in the FW's naturally sustainable system. This translates to investing in the development of additional processing facilities within the US as well as promoting numerous methods of collection for recycled materials. Notice that runs 5 and 6 for aluminum are the highest for recycling; in these scenarios all reuse, as well as extended producer responsibility and MRF collection, are permitted. Providing more options for collection increases the linkages and as a result, the system cyclicity.

Future Outlook

Challenges

The challenges to Task 2 were primarily due to a lack of available information. In addition, theorizing the structure of a complex network that is dependent on regional government decisions and the market for materials requires guesswork. ISRI reports in one place that the US alone processed 66 million metric tons and in another the place that it estimates 65 million metric tons were processed around the world[139, 142]. Inconsistencies like these in the reported data create significant challenges for data acquisition that Task 2 dealt with through detailed research to improve the accuracy of needed assumptions.

Future Work

Future work will seek to develop a more concrete and well-defined model for the complex material recycling networks. More accurate data will be sought after for supply and demand values for all of the materials to more accurately represent the system flows. In addition, real world recycling networks can be considered as a basis for future flow models and actor development.

Conclusions

Although the implementation of National Sword did not change the importation regulations on metals, slow global economic growth has been diminishing Chinese demand for ferrous and non-ferrous metals since 2011[158]. In addition, China has threatened to ban the importation of all solid waste, including metals, by 2020. Although the restricted import bans may not come to fruition, improvements must be made to the US recycling network to reduce dependencies on exports for *all* material streams. Importation bans affect the recycling industry by creating a glut of recyclable materials, without sufficient demand this results in decreases of the material commodity prices. An insufficient market for recycled materials will make it extremely difficult for domestic facilities to operate at a profit. In addition, the networks' structural analysis completed through the comparison of cyclicity values demonstrates that the domestic recycling industry is seriously lacking in its capacity to provide material cycling. Based on the principal: function follows form, development must be made towards improving the domestic capabilities of separating and processing facilities if recycling hopes to be a productive method towards achieving a circular economy. By considering exportation as a form of recycling, the US is diverting responsibility for its pollution; meanwhile touting the false representation of 0% rate of waste mismanagement and shaming developing countries for their inadequate disposal methods.

In conclusion, recycling energy efficiency rates are not the only factors that need to be considered when discussing the effectiveness of recycling. The success of the US recycling industry relies on the development of domestic facilities, the investment in higher quality materials, and an increase in consumer and producer responsibility. This can provide profitability, increase return, and reduce material demands for virgin materials.

CHAPTER V

TASK 3

Introduction

The lack of organized information is one of the largest challenges in understanding waste management. The up-to-date information has only been collected through private companies and therefor is not readily available to the general public. These databases can cost anywhere from $120 (for facility information of all 50 states) to $4,500 (in-depth market research done by professionals)[174-176].

As it stands, the movement of waste after collection is difficult to study due to the lack of documentation required from corresponding facilities. Although some states do compile various facility data on waste transportation, the EPA does not require the documentation of non-hazardous municipal waste nor do they include any transportation data into their annual MSW reports [3, 177]. Furthermore the absence of uniform terminology, the confusion surrounding roles of federal and local government, and the inadequacy of enforcement standards all contribute to a considerable amount of waste going unreported in national MSW totals[40]. Equally detrimental is the variations in policy and regulation across state lines which result in uneven comparisons that prevent predictable trends and convenient analysis at a national level [29]. Especially as the cost of transportation grows, the lack of empirical data surrounding waste movement creates a challenge in understanding the environmental impacts of trash collections, removal and disposal [29].

This chapter collects the available facility data for all of the waste management facilities within Texas. This includes: transfer facilities, processing facilities, and landfills. The collection of this information provides data for analysis, which determines the potential achievements and limitations of a model built using the current data. Identifying the missing, pertinent information needed to construct a full-scale network model provides the bases on which recommendations are developed and organized in the Conclusions chapter this thesis.

In addition to analysis of the data for network purposes, the calculations used by the TCEQ are investigated to test the validity of their methods. For example, the values given for remaining landfill capacity in years is used to make important decisions within waste management, yet it is unlikely that these numbers represent a realistic expectation. Changes should be implemented using domain knowledge of the waste management system in order to better predict the data's future behavior.

The empirical data considered is state-specific to provide consistency. Texas was chosen because it represents a large market for waste disposal partly due to its low cost of electricity and landfilling prices [12]. Within Texas, waste is identified first by its source (the waste generator) and then by the properties of the waste materials [12]. Texas defines solid waste as: "solid waste resulting from incidental to municipal, community, commercial, institutional, and recreational activities, including garbage, rubbish, ashes, street cleanings, dead animals, abandoned automobiles, and all other solid waste other than industrial solid waste" [12]. This definition is more encompassing than ones used by the US Environmental Protection Agency (USEPA) and some other states[3].

Methods

Data Acquisition

The data collected is representative of all the permitted, waste management facilities within the state of Texas. The Texas Commission on Environmental Quality (TCEQ) sets the state's regulations in addition to the national regulations provided by the EPA. Within the state, waste management is separated further into 24 Regional Planning Commissions, also known as Councils of Governments (COGs). These councils are responsible for MSW management planning on a regional basis. The raw data tables received from the TCEQ can be found in Appendix E on page 328. The various regions are shown and provided in the table and figure below.

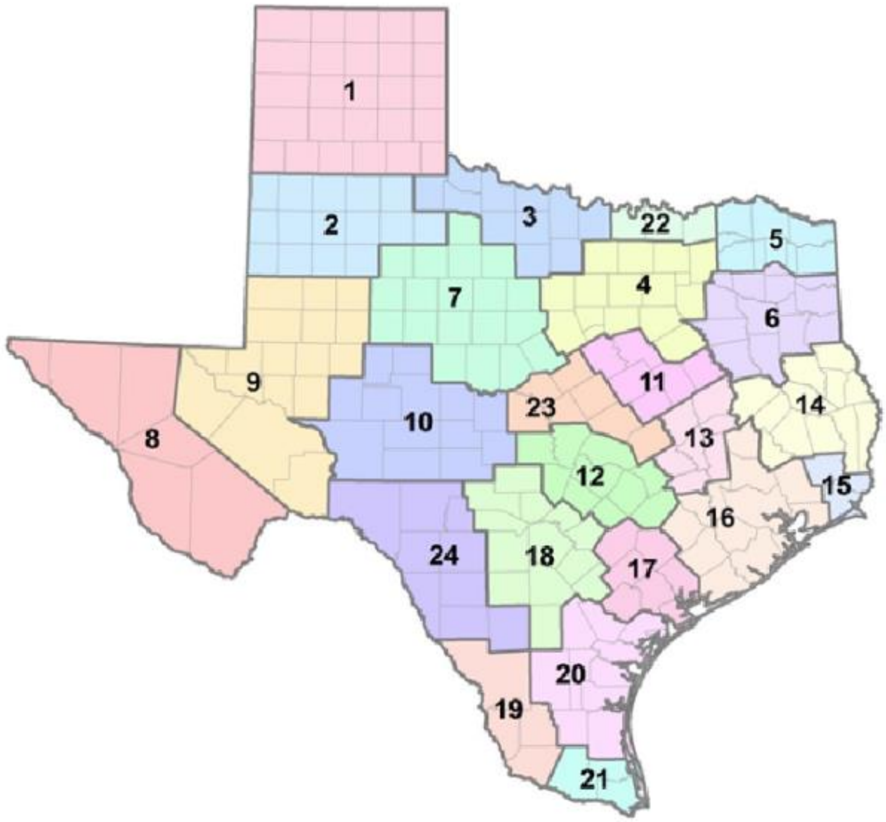


Figure 35: Texas divided by Councils of Governments. Used with permission of TCEQ[12].

The TCEQ collects facility information for all COGs on an annual basis. The facilities are sorted as: processing, landfill, or landfill with gas recovery. Facilities can have permits for multiple functions and are listed separately by each. In addition, facilities with landfill permits can operate as compost facilities and divert material for reprocessing. An example of this can be seen in the City of Kerrville Landfill, which is registered as a transfer station, compost facility, and landfill in addition to diverting materials for reprocessing.

An overview of the facilities analyzed in this Task 2 can be found within the Texas Commission on Environmental Quality (TCEQ) in their "Municipal Solid Waste in Texas: A Year in Review" which outlines 2017's waste data summary and analysis [12]. However, much of the information collected by these facilities is recorded but not published. By reviewing the official annual forms required of facilities, the gaps in the published data were identified and the information requested from the TCEQ directly. As a result, the original Excel files used to generate the annual reports for: landfills, processing facilities, and landfills with gas recovery were provided directly.

Landfill Facilities

The TCEQ report provides the region, permit number, site name, county, landfill type, annual tonnage for 2017, remaining tons, and the site's estimation for remaining years for 196 MSW Landfills across Texas. These landfills are segregated into categories depending on their permit for waste disposal. The facility type and count in Texas are: I (97), IAE (31), IV (23), IVAE (21), IAE& IVAE (18), and Monofill (6). The below figure shows this information mapped.

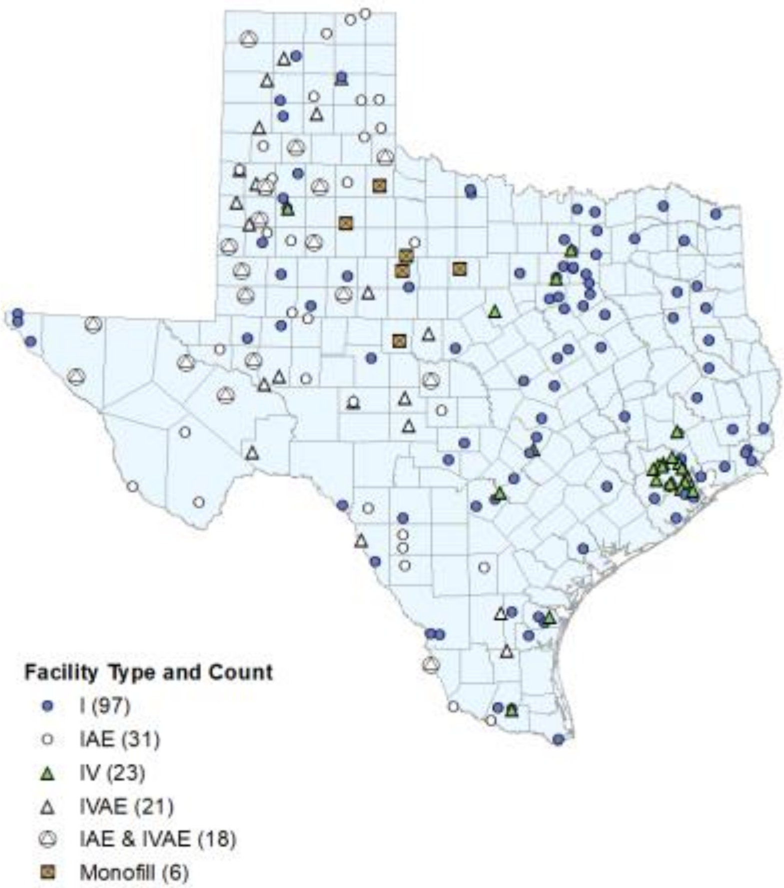


Figure 36: TCEQ Facility Type Map of Texas. Used with permission from the TCEQ[12].

This map provides the location of every active landfill within Texas in 2017. The landfill types determine what materials the landfill can accept, as well as the waste treatment style being used. Such landfills may also operate a gas recovery facility on-site, however these facilities are listed independently as processing facilities through the TCEQ.

Landfill Facility Type: I & IAE

The facilities designated as type I landfills are standard for MSW disposal within Texas. They represent 49% of all active landfills and the TCEQ estimates about 89% of waste is disposed of through these facilities[12]. A type I landfill can be an IAE landfill if it is qualified as arid-exempt, meaning the facility does not need to adhere to liner and ground water testing requirements. This is common for relatively dry parts of the state. If the facility qualifies for arid-exempt, limitations are put on the volume of waste acceptance[12].

Landfill Facility Type: IV & IVAE

If a landfill is designated as type IV, this location is specialized and should only accept brush, construction and demolition, and non-putrescible waste. Non-putrescible wastes are those that do not decompose easily, a list of these materials is provided in Appendix B for reference. In the same manner as type I landfills, type IV can qualify for arid-exempt and become IVAE if they meet the regional requirements.

Monofills

Monofills are unique in that they do not operate with the same permit requirements as the other types of landfills. These relatively small landfills, meant to service a rural town with 12,000 people or less, and are awarded five-year permits before needing to renew or close. These facilities handle demolition and are operated by a county or municipality. Only 3 COGs have monofills and 60% of all monofills are located within COG 7: West Central Texas Council of Governments.

Processing Facilities

In addition to landfills, the region, permit number, site name, county, type and 2017 tons is also provided for 183 processing facilities within the state. Unlike in Task 1, transfer facilities are included in this definition of process facilities, but the function remains unchanged. The various types of process facilities, as defined by the TCEQ, can be seen in the table below.

Table 23: Active MSW Processing Facilities Types in 2017 According to TCEQ

Facility Type
Autoclave (5AC)
Liquid Waste Processor (5GG)
Medical Waste Processor (MWG)
Recycling and Recovery (5RR)
Liquid Waste Transfer Station (5TL)
Transfer Station (5TS)
Waste Incinerator (5WI)
Composting (5RC)
Gas Recovery (9GR)

The processing facilities are aggregated by function and material. For example, transfer stations are separated based on their function of waste transport, but also into liquid waste, solid waste, and medical waste transfer stations.

In addition to liquid, solid, and medical waste processing, the processing facility list includes: Autoclave facilities- use pressure and steam to sterilize medical waste, waste incinerators- convert waste into ash through combustion, composting- uses decomposers and detritivores to process organic matter into a form that plants can absorb as nutrients, and gas recovery- these are the landfills with gas processing and are listed separately.

Landfill with Gas Recovery

The 26 landfill facilities that recover landfill gas for beneficial reuse are also reported, their listed information includes: region, permit number, name, county, landfill reference, gas processed (ft^3), gas distributed off site(ft^3), power generated and sold (kWh), as well as power generated and used on-site (kWh).

Additional Facility Information

Tipping Prices

The tipping price of a facility refers to the amount they charge for disposal. Although the TCEQ does collect information on the average rate charged by all landfill and processing facilities, only the average is provided in their yearly annual report. After receiving the raw data, many (but not all) facilities had listed typical pricing for their facility. However, these rates can be set according to either weight or volume depending on the facility. In the annually required form, landfill and processing facilities can provide the average cost per unit in any of the following measurements: tons, gallons, pounds, compacted cubic yard, and uncompacted cubic yard. The table below demonstrates this by providing a small section of the data with all facility pricing for COG3, the Nortex region of Texas.

Table 24: Tipping Prices Provided by TCEQ for COG 3

COG 3 Facility Tipping Prices					
Facility Type	**By Tons**	**By Gallon**	**By Pound**	**By Comp. CY**	**By Un-Comp. CY**
5TS	$50.00	$ -	$ -	$ -	$ -
5TS	$68.19	$ -	$ -	$ -	$ -
5TS	$40.15	$ -	$ -	$ -	$ -
5GG	$ -	$ 0.20	$ -	$ -	$ -
5TS	$51.78	$ -	$ -	$ -	$ -
Monofill	$ -	$ -	$ -	$ -	$ -
I	$30.80	$ -	$ -	$ -	$ -
I	$28.00	$ -	$ -	$ -	$ -

In this example, all of the facilities have provided information minus the monofill and most have done so using tons as their unit of measurement. However, many facilities do not submit a value for tipping prices and of the ones that do, TCEQ reported that 74% of landfills and 52% of processing facilities utilized scales to measure their accepted waste, while the rest used estimated volume[12].

For a few facilities that did not provide tipping prices, information on the tipping prices was found online, however this process was time intensive and did not always yield results. Instead, the Analysis of MSW Landfill Tipping Fees, published by the

Environmental Research & Education Foundation (EREF), was used to derive a relationship between tipping fee and landfill size. The database surveyed 1,540 active MSW landfills across the US to draw a sample for analysis of MSW landfill tipping fees. Of these companies, 55 companies (14%) were large (accepting over 390,000 tons per year), 181 companies (45%) were medium (accepting between 65,000 and 390,000 tons per year), and 164 (41%) were small (accepting less than 65,000 tons annually). With this information, they analyzed the relationship between tipping fee and landfill size, landfill ownership, availability of MSW waste-to-energy (WTE) within the state, and landfill gas collection and beneficial reuse. These results suggested that the cost difference between public and private landfills grew as landfill sizes became larger, that landfills with beneficial reuse charge higher tipping fees on average, and that the smaller the landfill is, the higher the tipping fee.

With this data, the average tipping price was provided based on the landfill's annual acceptance rate, ownership type, and beneficial reuse factors. These values were calculated as averages for the US. In order to adjust the prices to Texas values, proportionalities were used to determine the equivalent ratio given the known averages for Texas (provided in the TCEQ's annual report) to provide realistic values for the facilities in the data used for the future work of this research. Unfortunately, there is no equivalent study done to cover processing facilities, so in some cases the tipping information unfortunately remains missing.

GPS Coordinates

Although the GPS coordinates for each facility are not fully utilized within the Tasks of this thesis, future work plans to utilize this information for waste transportation optimization. As such, the latitude and longitude for each facility was recorded. A portion of the site's latitude and longitude were found using Google Maps; however, a large percentage of these locations were unlisted there. For these cases, the facility site was found through the Waste Bits database. This database provided an interactive image of the pinned location which was used in combination with the "drop pin" application in Google Maps to identify the latitude and longitude. In a few cases, a landfill or transfer/treatment station was unlisted in both databases and required looking up by its permit identifier through the TCEQ's Central Registry Query to try and determine more information.

The raw data provided by the TCEQ directly does include facility addresses. However, some of the addresses are mailing addresses for the company instead of actual addresses for the landfills. These were only a few of the challenges faced when collecting information on the facility locations. In addition to this, several facilities gave GPS locations that were in the middle of nowhere with no facilities visible through Google Maps. A few of these examples are included for demonstration and can be seen in Appendix C.

Procedure

To garner a full understanding of the data, the three Excel sheets of raw data were combined to list all facilities (processing, landfill, and landfill with gas recovery) by their COG. This was done to try and identify the most likely connections between facilities within the perspective network. The raw data sheets provide a large amount of data that is not needed for the purposes of this thesis, so only the pertinent information was transferred from these files to the new excel sheets. This information includes tipping prices, counties or states/countries served and the quantity of: transferred material, composted material, chemically processed material, chipped material, diverted material, liquid waste material treatment, landfilled material, remaining landfill capacity, and gas recovered at the landfill.

Analysis Using Current Data

From there, the sum of the diverted material, total tons disposed, total remaining capacity, and estimated capacity in years were calculated for each COG. This was done to calculate the individual recycling rate for the region and analyze the accuracy for which the remaining capacity in years is calculated. Monofills were removed from the facility information, as they do not provide remaining capacity in years and they are also neglected in the analysis done by the TCEQ. In addition, the population for each COG (in 2017) was added to the data, as well as the estimated growth rate of the population based on the 2000 and 2010 census changes. Population information will be used to determine projected growth for waste generation.

The equations used for the analysis of the data using current population and generation values are provided below.

$$COG\ total\ (generation, diverted, capcity, etc) = \sum All\ individual\ facility\ values\ within\ COG - Monofill\ values \qquad (1)$$

$$Avg\ Remaining\ Years = \frac{Sum\ of\ all\ remaining\ years}{\#\ of\ Landfilling\ Facilities\ in\ COG} \quad (2)$$

This summation is used for the calculation of total: diverted material, waste disposed, remaining capacity in tons, and remaining years of capacity. The average years remaining for COG utilized the values provided by the individual facility. This was done in order to compare these estimations to the remaining capacity in years that can be calculated using the consumption data.

$$Recycling\ Rate\ (\%) = \frac{Total\ Diverted\ (tons)}{Total\ Disposed\ (tons) + Total\ Diverted\ (tons)} \quad (3)$$

This calculation is used to determine the overall recycling rate for the individual COG as well as the entire state of Texas based on the annual report for 2017.

$$Calculated\ Remaining\ Capacity\ (in\ Years) = \frac{Total\ Remaining\ Capacity\ (tons)}{Annual\ Total\ Disposed\ (tons)} \quad (4)$$

This calculation is done to gain an understanding of the regional and state-wide capacity left in years, assuming the annual rate for 2017 will remain consistent in the following years. It is also calculated to identify the differences between the calculated numbers and the values provided by the facilities.

$$Annual\ Rate\ needed\ to\ achieve\ given\ years = \frac{Total\ remaining\ capacity\ (tons)}{Total\ Provided\ Years} \quad (5)$$

This calculation uses the provided years remaining reported by the facilities to determine what the necessary annual disposal rate would need to be in order to achieve the remaining years that have been estimated. For example, COG 1 has 41,845,313 tons of remaining landfill capacity and a total of 1,203 remaining years (given) of capacity within the region. To achieve this predicted total of years, the new annual rate of disposal would have to be 34,790 tons. The value will be used in the following equation to visualize how far off the estimations are based on the measured disposal rates of 2017.

$$Improvement\ Needed = \frac{(Current\ Annual\ Disposed - Annual\ Rate\ Needed)}{Diverted\ Materials} \tag{6}$$

The “improvement needed” is calculated to emphasize the irregularities between the estimated years remaining for the landfill and the measured disposal rates. The value calculated is an index. Using the example of COG 1, the annual rate needed (calculated) was 34,790 tons and the current annual rate is 551,400 tons. To achieve the estimated number of years, the diverted materials (as well as the recycling rate) would need to improve by 34.8 times or 3480% to achieve the new annual rate as well as survive the given remaining years. This is clearly an unlikely scenario, demonstrating the extent of inaccuracy in the remaining years values provided by the facilities. These results will be compared with the calculations provided by the TCEQ to better understand their methods of analyzing the data.

Predictive Analysis

The population and growth rates have been collected to include projected increase in waste generation. The detailed census information (for COG) is only conducted every 10 years. However, the Texas Demographic Center conducted population projections based on the years 2010-2015 and the following figure summarized their results.

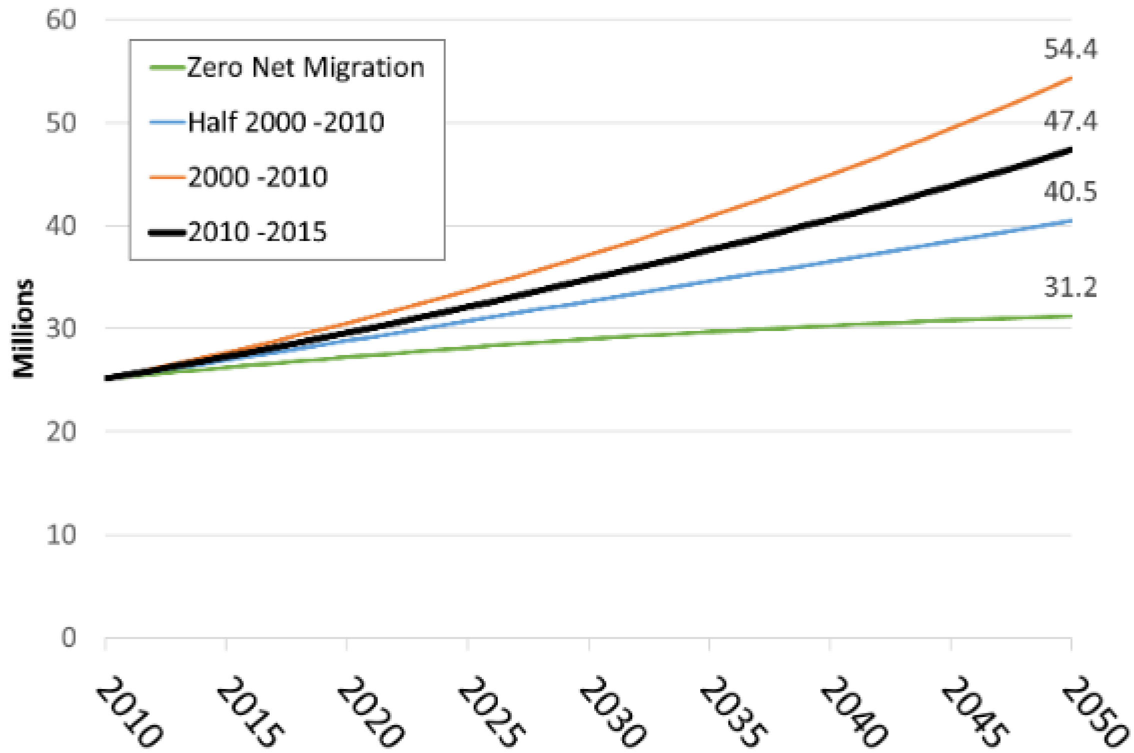


Figure 37: Projected Distribution of the Population. ***Used with permission from the Texas Demographic Center*****[178].**

Based on these results, the projected increase in population was calculated for 100%, 75%, and 50% of the rate predicted from 2000-2010. Using Figure 37 above, it can be assumed that the figures for 100% of the 2000-2010 rate can be considered the worst case scenario, 50% calculations will be considered the best scenario, and 75% rate is likely the most accurate based on the 2010-2015 values. These calculations were used to predict the future total waste generation for the area and consider the repercussions pertaining to remaining landfill capacity values. For remaining years calculations, Monofills have been excluded as they work on a different permit system and therefor are not taken into account in the TCEQ annual analysis of remaining capacity. The equations used for the values discussed in this chapter are given below.

$$Estimated\ 2023\ Pop.(worst\ case) = population * \left(1 + P_g\right) \quad (6)$$

$$Estimated\ 2023\ Pop.(best\ case) = population * \left(1 + \frac{P_g}{2}\right) \quad (7)$$

$$Estimated\ 2023\ Pop.(moderate\ case) = population * \left(1 + (0.75 * P_g)\right) \quad (8)$$

These calculations will provide us with a range of realistic values in order to consider population growth within the calculations for remaining capacity. Lastly, the new annual tonnage will be calculated and the total remaining years adapted for these values using Equations X and X below.

$$New\ Annual\ Waste\ Generation = Waste\ per\ person\ \left(\frac{tons}{person}\right) * Predicted\ Population \quad (9)$$

$$New\ Remaining\ Capacity\ (years) = \frac{Total\ Remaining\ Capacity\ (tons)}{New\ Annual\ Waste\ Generation} \quad (10)$$

These findings will be used to consider the future outlook as well as make recommendations in Task 4 on potential improvements.

Lastly, the GPS information was taken from the first Excel documents (that were created before receiving the raw data, using the annual report from 2017) and added to the organized raw data. Both the raw data and the organized Excel are used in combination to complete Task 2 and 3.

Results

Recycling Rate Analysis

Using the data for diverted materials and total disposed, Table 25 was organized.

Table 25: Recycling Rate Analysis for Task 2

COG	Recycling Rate (RR)	Total Tons Disposed	Total Material Diverted	Total Years Rem.	Remaining Capacity (tons)	Calc. Years Rem	Annual Rate needed to achieve yrs	RR Growth Req (x)
1	2.62%	551,400	14,845	1202.8	41,845,313	75.89	34,789.92	34.80
2	3.74%	545,709	21,180	1542.8	85,430,404	156.55	55,373.61	23.15
3	6.06%	309,020	19,923	350.0	51,698,564	167.30	147,710.18	8.10
4	9.21%	10,694,434	1,085,517	1007.8	415,523,055	38.85	412,307.06	9.47
5	0.005%	443,200	24	408.0	66,264,547	149.51	162,413.11	11,699.5
6	0.086%	653,536	560	476.0	108,822,740	166.51	228,619.20	759.46
7	1.26%	561,655	7,143	563.1	91,487,100	162.89	162,470.43	55.88
8	1.63%	501,244	8,324	242.0	53,094,861	105.93	219,400.25	33.86
9	1.07%	706,187	7,664	452.7	37,696,168	53.38	83,269.64	81.28
10	0.05%	205,659	98	644.0	5,002,185	24.32	7,767.37	2,011.09
11	2.11%	671,798	14,480	221.9	39,323,170	58.53	177,211.22	34.16
12	8.07%	2,457,321	215,660	146.3	65,865,833	26.80	450,210.75	9.31
13	2.62%	392,956	10,593	64.0	25,148,481	64.00	392,945.02	0.00
14	1.03%	513,067	5,320	235.3	35,670,254	69.52	151,594.79	67.94
15	1.39%	694,700	9,801	171.8	30,213,307	43.49	175,863.25	52.94
16	5.87%	9,106,967	568,261	990.9	328,558,267	36.08	331,575.61	15.44
17	3.17%	152,074	4,972	28.0	5,975,550	39.29	213,412.50	(12.34)
18	0.99%	2,894,705	28,959	193.6	161,841,146	55.91	835,956.33	71.09
19	4.45%	424,464	19,790	144.9	51,275,358	120.80	353,867.20	3.57
20	2.00%	755,016	15,447	358.3	85,898,210	113.77	239,738.24	33.36
21	1.99%	1,235,104	25,103	301.9	110,595,594	89.54	366,331.88	34.61
22	2.47%	214,300	5,436	147.0	15,288,038	71.34	104,000.26	20.29
23	2.47%	453,487	11,501	39.0	6,086,083	13.42	156,053.41	25.86
24	5.77%	139,080	8,511	408.0	8,117,573	58.37	19,896.01	14.00
Total	**5.64%**	**35,277,082**	**2,109,109**	**10,340**	**1,926,721,801**	**54.62**	**5,482,777**	**15,087**
AVG	2.92%	1,469,878	87,880	430.8	80,280,075	81.75	228,449	628.62

The table here uses the information organized by COG to pull the values for: total tons disposed, total materials diverted, total remaining years, and total remaining capacity in tons. With these values, the recycling rate, calculated remaining years, annual rate needed to achieve proposed years, and improvement needed to achieve these estimations have been calculated. Monofills have been removed from COG 2, 3, and 7.

Of the COGs, only one region's predicted annual years matches the mathematical values calculated: COG 13, Brazos Valley Council of Governments. There is only one landfill facility within this COG. There is also only one COG that underestimates the years remaining and again this facility includes only one landfill.

TCEQ Calculated Remaining Capacity

Fortunately, the TCEQ is not ignorant to the error introduced by the facility provided estimation of remaining years. Instead, their values for remaining years, waste generation per person, and statewide annual years remaining are consistent with the values calculated above in Table 25. The TCEQ created a table of their own with COG breakdown, this can be found in Appendix C for comparison.

By disregarding the individual facility estimations and using the material data to calculate the years remaining, the bias (error introduced by the individual facility mis-judging their facility's remaining capacity) is considerably reduced. In addition, using the average values (calculated for COGs) reduces the variance (error introduced by extraneous factors, such as measurement imprecision) of the data by dividing total COG values by the number of facilities within the COG. Through the reduction of bias and variance, the TCEQ has mediated the overall error of their analysis and provides a reasonable method of calculating remaining capacity in years.

Predictive Analysis

Although the TCEQ's calculations are not unsound, these values are unlikely to be representative of the realistic expectations. This is due to factors such as: population growth, increased consumption, volatility within the recycling industry, and more. Currently, it is difficult to include all of these considerations due to unorganized information. However, some considerations can be easily considered, such as population.

Using the methods described within the procedure section of this chapter, the following table, Table 26, was created using estimated population growth.

Table 26: Predictive Population Analysis

				Calculated for projected values of year 2027						
COG	**Population (2017)**	**Waste Gen. per Person (lb/day)**	**Projected growth rate (2000-2010)**	**Best-Case (50%) Est. Pop.**	**New "Best-Case" Waste Generation (tons)**	**Moderate (75%) Est. Pop.**	**Moderate Growth Waste Generation (tons)**	**Worst-Case (100%) Est. Pop.**	**Worst Case Waste Generation (tons)**
1	437,985	6.9	6.2	451,56	568,493.4	577,040	726,463.0	585,587	737,223
2	434,744	6.8	8.9	454,09	569,993.1	582,135	730,720.5	594,277	745,962
3	220,528	7.6	-0.7%	219,756	307,938.4	307,398	430,748.1	306,857	429,990
4	7,518,902	7.7	23.2	8,391,095	11,934,988.8	12,555,266	17,857,856.0	13,175,543	18,740,101
5	283,772	8.5	4.2	289,73	452,507.2	457,161	714,001.6	461,814	721,270
6	860,334	4.1	11.3	908,94	690,460.8	708,923	538,519.7	727,386	552,544
7	328,919	9.3	0.8	330,23	563,901.5	565,025	964,824.0	566,148	966,742
8	865,822	3.1	17.3	940,71	544,601.1	566,280	327,831.9	587,959	340,382
9	476,304	8.1	10.9	502,26	744,674.2	763,918	1,132,614.5	783,161	1,161,146
10	159,608	7.0	4.0	162,80	209,772.2	211,829	272,946.8	213,885	275,597
11	366,026	10.0	8.6	381,76	700,685.3	715,129	1,312,535.8	729,573	1,339,045
12	2,237,922	6.0	35.9	2,639,629	2,898,410.1	3,118,955	3,424,727.4	3,339,499	3,666,894
13	352,634	6.1	19.6	387,19	431,465.7	450,721	502,258.3	469,975	523,715
14	383,784	7.3	6.4	396,06	529,485.1	537,694	718,824.0	545,903	729,798
15	398,485	9.5	0.9	400,27	697,826.2	699,389	1,219,282.3	700,952	1,222,007
16	7,064,712	7.0	25.4	7,961,930	10,263,551.8	10,841,844	13,975,986.2	11,420,137	14,721,450
17	197,376	4.2	2.6	199,94	154,051.0	155,039	119,454.6	156,028	120,216
18	2,587,905	6.1	24.4	2,903,629	3,247,858.8	3,424,436	3,830,407.4	3,601,013	4,027,918
19	358,772	6.4	0.9	360,38	426,373.7	427,329	505,573.2	428,284	506,703
20	596,853	6.9	4.2	609,38	770,871.3	778,799	985,176.8	786,727	995,205
21	1,305,970	5.1	30.1	1,502,518	1,420,987.2	1,513,929	1,431,778.2	1,606,870	1,519,676
22	205,481	5.7	8.4	214,11	223,300.6	227,801	237,577.8	232,301	242,271
23	488,128	5.0	20.1	537,18	499,062.4	521,850	484,816.0	544,638	505,986
24	173,630	4.3	8.2	180,74	144,782.3	147,633	118,256.4	150,485	120,540
			Totals:	31,325,959	38,996,042	40,855,522	52,563,181	42,715,002	54,912,384
New Remaining Capacity					49.41		47.16		45.11

Using the worst-case scenario, a more accurate estimation of the remaining landfill years would be 45.1 years. The nearly decade difference between this value and the value calculated using current data demonstrates the downfalls of using such a basic model. With this information being tracked annually, it is perfectly reasonable to utilize these trends to improve upon the data analysis.

Discussions

There are several interesting findings when considering the TCEQ provided facility data. The most interesting perhaps being the dismal recycling rates. The TCEQ has published that the recycling rate for 2015 was 22.7% based on information provided from recycling facilities within the state. However, according to the 2017 facility data, the best recycling rate for COG was not even half of this value.

There are three main possibilities for why the facility's diverted values do not produce the recycling rates estimated by the TCEQ: exported recycling, using processing facility information, and including values besides those for diverted materials. Often times the material exported for the purposes of recycling is counted towards the total recycling rate. In fact, without this inclusion, the EPA recycling rate values would plummet across the board for nearly every material. If this is the primary reason that the numbers calculated within Task 2 do not match the TCEQ figures, this means that 7.42 million tons of material was exported as recycling from Texas in 2017 alone (22.7% of total disposed- total diverted in 2017). This is not an inherently negative contribution, as the sales of recycled material help to balance the international trade within the US. However, with exportation options being significantly reduced in the years following this analysis, it indicates that domestic markets will soon have a glut of recycling materials that they are not capable of handling. This means increased landfilling while the US recycling industry attempts to regain control.

Another possibility that could be affecting the recycling rate within the US is surveying the total material processed from the standpoint of the material recovery and production facilities. These facilities often import materials from out of state as well as from international sources.

The analysis of the remaining years provided by the facilities introduces some distrust with regards to the recording of information. Although there are likely several scenarios where the annual capacity in years was adjusted with good reason, there is too much variance between estimated years and calculated years remaining for this to be the case for all of the values. As such, the provided values are subject to some level of individual interpretation on behalf of the facilities. The TCEQ does not trust these values enough to be used in their own calculations. Perhaps an improved method of record keeping may aid in reducing these downfalls in the data.

Facility Trends

Medical waste transfer and processing facilities coordinate with the highest number of waste generators with an average of accepted waste from 66.2 counties and 4.3 other states. However, one facility alone (Sharps Environmental Service, COG6) claims to service 57 other states/territories and 254 (all) of Texas counties, which appears to be unlikely based on the volume of material processed. Even without the inclusion of this facility, the average number of counties served is 55.7 and 1.3 other states for medical waste facilities. This is most likely due to these companies being larger corporations that have specialized facilities to handle medical waste, but market access across the US.

The liquid waste transfer and processing facilities served the second largest number of counties on average with 22.4 counties and .2 states (not all facilities serve other states). Only 3 of 36 liquid waste facilities (transfer or processing) recorded any diverted materials. Of the counties who responded on tipping prices, most facilities (29) charged by gallon with the average price being $0.19 per gallon.

For solid waste transfer stations, the average number of counties served was 2.9 and only two facilities serviced either New Mexico or Oklahoma. 46% of the active landfills within Texas service only one county, so many transfer stations serve one county as well.

Regional Implications

Regulations on waste management are typically created at the state level, so waste trends can often vary depending on location. For example, the landfill tipping fees have been increased in states like Washington and California to encourage reuse and recycling. However, although these states are individually landfilling less materials, cities and industries have opted to transport their waste out of state (occasionally, out of the country) to be managed. As a result, transportation is becoming an increasingly important variable to consider when weighing the costs of waste management.

Challenges

Data Acquisition

Challenges in collecting this data include the facilities using multiple aliases, difficulty in finding information online, and vague location markers. As well as unfamiliar and inconsistent terminology prevented the clear interpretation and searching of this material.

Future Impact

The organization of this material is a tedious and time-consuming Task. As such, the gathered data provides value to future research as a source for comparison and inspiration. With improved records regarding waste management in the US, more can be done to optimize and analyze our current management practices. In addition, the data used here provides numbers for the year before China's importation ban was imposed and will provide a baseline for future research. Such future research may aim to determine the extent at which China's ban impacted the US waste management industry. In addition, the loss of exportation options may illuminate the exported waste that is unaccounted for within this data.

Conclusion

In conclusion, based on the facility data provided by the TCEQ, 95.36% of waste generated within Texas is not separated for recycling. This material can be either landfilled, composted/treated, or incinerated. The majority of waste generated within Texas is sent to landfill. Calculations used by the TCEQ do a sufficient job of analyzing the analysis, however more can be done to provide a comprehensive analysis of the data.

CHAPTER VI

TASK 4

Introduction

Many factors are attributed to the decisions facing the waste management industry, the two most encompassing are cost and risk. These considerations in most scenarios are only taken into account on an *individual* or *local* level because much of the domestic processing and disposal data is held within privately-controlled companies who generally do not share their data with the public. Currently, *there is **no** tool* that can consider various waste management scenarios to search for improved solutions. Task 3 provided a basis from which solutions can be developed, but to allow for the consideration of various cost and risk factors in a system analysis, the real-world facilities must still be organized into a network. Unfortunately, unknowns in the available data make it insufficient for building a complete model of the waste management network. Regions of Texas are used instead as a starting point, and along with the results of Task 2 (Chapter 5) a rudimentary network can be developed. These results will further the objectives of Task 4, which focus on looking towards future work and go into further depth on what decisions are supported by using a system analysis approach for the waste management system.

The COGs of Task 3 are considered as possible bases for designing a realistic waste management network to develop a model using the *data from real facilities*. Several metrics adopted from ecology network analysis are considered as a means of narrowing down the regions ideal for analysis, by eliminating those without ecological characteristics. Once selected, connectivity matrices are constructed using the information available. The networks are then analyzed and discussions are made regarding the impact of the organized system. Task 4 uses these results to discuss future opportunities of a system analysis of the waste management system using *facility-specific* data.

Methods

Data Acquisition

Facility information regarding materials transferred, processed, and landfilled is taken from the TCEQ data where possible in addition to information gathered outside of TCEQ such as specific facility research in order to better understand the functionality of the various companies used within the network. This information is used for the creation of a realistic network, testing different designs, and analyzing select food metrics on real-world facilities.

COG Analysis

Task 2's COG breakdown in Excel is used to construct a representative network that provides values comparable to those of sustainable food webs. To determine which COGs were best for creating a network, several sizes and variety of COGs were used to attempt the network design. Using the most successful of these trials, a range of values was chosen to select additional COGs for analysis. In addition, the minimum number of actors was chosen as to not skew the ecological metrics analyzed in the results of this section[137]. For the intended network design, it was determined that an ideal network for food web analysis has more than 13 actors, a balanced number of prey and predators, information to provide sufficient linkage within the actors, and the majority of actors share the same primary producer. These characteristics prevent skewed metrics and improve comparisons with real world sustainable systems found in food networks.

These requirements outline that a COG must have the following characteristics to be selected for analysis: more than 13 facilities and counties (total actors), a balanced number of transfer facilities, processing facilities, and landfills, good information on types of material transferred, and the COG facilities share a common grouping of counties served.

A balanced prey to predator ratio (P_R) in ecology is a constant derived from functional response equations that represents the ratio of producer to consumer [149, 179]. Due to varying predator behaviors, defining an "ideal" ratio is difficult because this ratio must meet the demands of the species in question [179]; a lionfish for example eats twice his body weight in juvenile fish daily, while a lion feeds on a shared prey once every 3-4 days resulting in very different needs with regards to a prey to predator ratios. Additional variables like foraging time and hunting success rate will also have an effect on the prey to predator ratio [179]. To determine what an "ideal" ratio is for designing a waste network from facility information, the relationship between the producers (counties, transfer stations, and processing facilities) and the consumers (landfills, processors, and transfer facilities) is analyzed. The goal of designating a threshold for predator ratio (P_R) is to eliminate COGs that do not have enough waste generators (prey) or disposal alternatives (predators) to realistically support the internal network alone. If a

COG is prey heavy, this is indicative that the region's waste is handled through facilities outside of their region. If a COG is predator heavy, this indicates that the facilities within the region are more likely to be importing waste from other COGs. To design a network that can use the COG area as system bounds, it is important that the region can handle its waste independently without over supplying for the generation.

The ideal prey to predator ratio for a waste management network should consider the number of transfer stations, processing facilities, and landfills within the region. When analyzing the COGs independently, in most cases the total transported material recorded is much less than the total amount of waste landfilled. This is a problem because it prevents the tracking of waste and provides no way to determine the origin of the material that makes up the difference between waste landfilled and waste transported. COGs such as 5, 7, and 9-11 do not have any registered transfer stations within their regions at all, making it likely that these landfills are either operating their own waste transfer while not recording it, or they are receiving materials from transfer stations outside of their COG. The landfills in these COGs service only one county in most cases, indicating that they are a municipal run landfill that transfers its own waste. This information is not reported publicly so linkages in these networks between transfer and landfill are impossible to confirm without additional cooperation from the facilities.

Every landfill needs a source of waste transportation; however, one transfer station can service several landfills if the region's waste generation is sufficient in waste type and quantity to demand a need for multiple facilities. Conversely, several transfer stations can deliver to the same landfill, which is often the case for larger (often meaning cheaper) landfills [180]. The average COG prey to predator ratio is 0.80, meaning most regions have fewer transfer and processing facilities than landfills and processing facilities. Based on the analysis of the COGs, a prey to predator ratio threshold of $0.5 \leq P_R \leq 1.5$ was chosen as a basis for elimination. COGs that did not meet this requirement were discarded as options for analysis. The COGs with a prey to predator ratio of less than 0.5 generally were found to have a lack of information, making it difficult to determine the linkages between actors. The COGs with a prey to predator ratio over 1.50 were found to service too large a variety of counties creating too many unknowns in the network and reducing the accuracy in which

After the prior selection criteria were implemented, "common counties served" were highlighted for the remaining COGs. If the region serviced a large and diverse number of counties the facilities are less likely to be connected. In addition, it is much more difficult to determine the origins of waste because the number of variables introduced. It is much easier to start with a common grouping of counties and follow the waste from the common generators. Thus, COGs with a shorter list of common counties served were chosen.

Procedure

COG Selection

The number of transfer stations, number of processing facilities, number of landfills, and resulting number of prey and predators are all considered to narrow down the list of COGs considered for building a network model. COGs with less than 11 facilities were eliminated (since 2 counties at a minimum are additionally included as actors COGs with 11 facilities will have 13 actors). This requirement eliminated 10 COGs. The 3 COGs with over 23 facilities were also eliminated because this high number of actors makes it difficult to differentiate possible linkages, and the majority of the actors did not serve a common source of primary actors (counties).

Any COGs with zero transfer facilities or zero processing facilities were also eliminated, as well as any COGs that did not meet the threshold for prey to predator ratio of $0.5 \leq P_R \leq 1.5$. Removing the regions outside of this prey to predator ratio limits the number of unknown linkages within the corresponding network. Consider the connections boxed in red in Table 27.

Table 27: Connectivity Matrix for COG 21 demonstrating unknown but possible connections within COG 21. Ones indicate the actors from the vertical access (left) are providing materials to the actors on the horizontal axis (top). The actors of this network include: four counties, three transfer stations, four processing facilities, and five landfills.

	C	H	S	W	1	2	3	4	5	6	7	8	9	10	11
C	0	0	0	0	1	1	1	0	0	1	1	1	1	0	1
H	0	0	0	0	1	1	0	0	1	1	0	1	1	1	1
S	0	0	0	0	1	0	0	0	1	1	0	1	1	0	1
W	0	0	0	0	1	0	1	0	0	1	0	1	1	0	1
1	1	0	0	0	0	0	0	0	0	0	1	0	1	0	0
2	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1
3	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1
4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
6	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0
7	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

These 1's show the possible connections between five transfer stations, four counties, and one landfill. The connections between the facilities were made depending on the type of material transferred and landfilled; if the two facilities share the same materials and serve a similar selection of counties, they are assumed to have a *possible* linkage. However, that may not be the case. In reality, transfer station 2 may deliver all of its waste to 9, while transfer station 6 delivers none at all. Unfortunately, that data is not available or required of current reporting standards. In addition, the transferred volume of waste is insufficient in volume to provide for the recorded landfilling figures. This means that the landfill must be either working with facilities outside the COG or collecting waste that is not reported as transported. As a result, there is greater uncertainty in flow volumes for facilities serving a wide range of counties or transfer stations. To limit the uncertainty of the flow matrix resulting from the network analysis, COGs with a reasonable number of shared counties and a balanced number of transfer facilities and landfills were chosen.

The *remaining 5 COGs* are considered for comparison to network versions designed based on naturally occurring food webs. The three networks that meet the chosen network characteristics through their combination of actors and linkages are then chosen for further results development.

Building the Network Model

To identify the actor-types within each COG-based network, multiple listings of one facility were condensed where possible based on *facility function* unless contradicting data discouraged this. For example, the Kerrville City Landfill is referred to in the literature with a variety of facility descriptions, as shown in Table 28. None of these descriptions contradict each other so this facility is condensed from three to the single entry in Table 29.

Table 28: A multiple entry example of Kerrville City Landfill. Green facilities are registered as processing facilities, blue entries are landfills. The red entries highlight double counting. TF- transfer volume, RC- composted volume, DV- diverted volume (removed from landfill volume for some method of processing), LD- landfilled volume, Rem_Cap CY- remaining capacity in cubic yards, Rem Cap Tn- remaining capacity in tons, YR- facility indicated remaining capacity in years- $/Tn- tipping price charged per ton of material. The label identifies what type of facility it is registered as (5TS- transfer station, 5RC- compost, 1- Type I landfill).

Permit	Name	Label	TF (tons)	RC (tons)	DV (tons)	LD (tons)	Rem_Cap CY	Rem_Cap Tn	YR	Counties Served	$/Tn
40240	CITY OF KERRVILLE LANDFILL	5TS	74,388	-	-	-	-	-	-	Kerr	$67.21
42028	CITY OF KERRVILLE LANDFILL	5RC	-	8,850	-	-	-	-	-	Kerr	$67.21
1506A	CITY OF KERRVILLE LANDFILL	1	-	8,850	116	9,078	675,827	340,955	13	Kerr	$67.21

Table 29: Single Entry Example of Kerrville. Purple indicates facility with combined registrations. TF- transfer volume, RC- composted volume, DV-diverted volume (removed from landfill volume for some method of processing), LD- landfilled volume, Rem_Cap CY- remaining capacity in cubic yards, Rem Cap Tn- remaining capacity in tons, YR- facility indicated remaining capacity in years- $/Tn- tipping price charged per ton of material. New label indicates the function of the facility, in this case that the facility is a landfill that has a transfer permit and also performs composting as well as diverts materials for recycling.

Name	Label	TF (tons)	RC (tons)	DV (tons)	LD (tons)	Rem_Cap CY	Rem_Cap Tn	Rem YR	Counties Served	$/Ton
CITY OF KERRVILLE LANDFILL	LF_TF _RC_DV	74,388	8,850	116	9,078	675,827	340,955	12.7	Kerr	$67.21

Although none of the numbers for Kerrville City Landfill contradict, this example brings up another issue that is extremely common within waste management practices: double counting. *Double counting* refers to when two facilities list processing for the *same* physical material (resulting in a material group being counted twice for a single process), which in this case has been done for composting by the last two listings (both document 8,850 tons being composted) of.

The same amount of compost material was registered for the composting facility permit AND for the landfilling facility permit. This is legally allowed because landfilling permits provide the right to compost material. Depending on the area it can actually be more beneficial for a facility to divert/compost material as a landfill versus under their transfer permit as a result of landfill-specific incentives. Unfortunately, this leads to inaccuracies when calculating total recycling values for a state. The damage done in the

Kerrville case is relatively harmless (counting only 8,850 composting tons twice), however when transfer facilities and processing facilities publish recycled material twice it can lead to incredibly misleading overall calculations. The already poor recycling rates for residential recycling can with confidence be labeled as an over-estimation due to the common occurrence of double counting. Double counting has been corrected here wherever possible, like in the case of the Kerrville facility. However, with the number of possible connections as well as missing information on the volume of flow between each facility, it is impossible to completely correct for double counting.

Another challenge presents itself when two facilities are named the same but their individual values prevent them from being condensed. For example, the Edinburg Regional Disposal facility of COG 21 was unable to be condensed into one actor. The two listing from the Excel created are shown in Table 30. The inconsistencies in the remaining capacity, total material landfilled, and quantity of materials diverted all indicate the *operation of two separate facilities*. The points of contact and addresses given also do not match between the facilities. These facilities thus were *not* condensed into one operation. Only the gas recovery facility was able to be combined within the landfill with permit 956B. Table 31 shows the results of condensing Table 30 actors.

Table 30: Edinburg Multiple Entry Example. Blue entries are landfills and orange entries are gas recovery facilities that are attached to landfill facilities. TF- transfer volume, RC- composted volume, DV-diverted volume (removed from landfill volume for some method of processing), LD- landfilled volume, GR_G- estimated annual gas processed, GR_G_S- estimated annual gas distributed off site, Rem_Cap CY- remaining capacity in cubic yards, Rem Cap Tn- remaining capacity in tons, YR- facility indicated remaining capacity in years, Tipping Fee by U_CY is the cost of disposal, which here is given by un-compacted yard. Lastly landfill permit attached refers to which facility the gas recovery sight has been attached to.

Permit	Name	Label	DV (tons)	LD (tons)	GR_G (ft^3)	GR_G_S (ft^3)	Rem_Cap CY	Rem_Cap Tn	YR	Counties Served	Tipping Fee by U_CY	Landfill Permit Attached To (9GR)
956B	EDINBURG REGIONAL DISPOSAL FACILITY	1	0	123,136	-	-	10,309,433	5,639,260	32	Brooks Cameron Hidalgo Starr Willacy	$10	
2302	EDINBURG REGIONAL DISPOSAL FACILITY	4	805	494,515	-	-	5,179,505	3,348,550	6	Brooks Cameron Hidalgo Starr Willacy	$10	
48038	CITY OF EDINBURG REGIONAL LANDFILL	9GR	0	-	4.60E+08	8.36E+08	-	-		-	-	956B

Table 31: Condensed Labels of Edinburg. Blue entries are landfills and purple indicates facility with combined registrations. TF- transfer volume, RC- composted volume, DV-diverted volume (removed from landfill volume for some method of processing), LD- landfilled volume, GR_G- estimated annual gas processed, GR_G_S- estimated annual gas distributed off site, Rem_Cap CY- remaining capacity in cubic yards, Rem Cap Tn- remaining capacity in tons, YR- facility indicated remaining capacity in years, Tipping Fee by U_CY is the cost of disposal, which here is given by un-compacted yard. Lastly landfill permit attached refers to which facility the gas recovery sight has been attached to. New label indicates the function of the facility, in this case the first facility is a landfill that diverts materials for recycling and the second is a landfill that diverts materials for recycling and collects gasses for waste to energy purposes.

Permit	Name	Label	DV	LD	GR_G	GR_G_S	Rem_Cap CY	Rem_Cap Tn	YR	Counties Served	Tipping Fee by U_CY
2302	EDINBURG REGIONAL DISPOSAL FACILITY	LF_DV	805	494,515	-	-	5,179,505	3,348,550	6	Brooks, Cameron, Hidalgo, Starr, Willacy	$10
956B	EDINBURG REGIONAL DISPOSAL FACILITY	LF_IX_DV	-	123,136	459,646,000	835,720,000	-	-	32	Brooks, Cameron, Hidalgo, Starr, Willacy	$10

Table 32: Facility Labels for Task 2 and 3. Labels designated by function of the facility.

Name	Label
Counties	Starting Letters
States/Countries	OWG_#
Transfer Stations	TF_I
Medical Waste Transfer Station	TF_MW
Liquid Waste Transfer Station	TF_LQ
Liquid waste transfer and processing	TF_P_LQ
Autoclave Facility	P_AC
Medical Waste Processing Center	P_MW
Recycling and Recovery	P_RR
Waste Incinerator	P_WI
Compost Facility	P_RC
Liq. Waste Processor	P_LW
Landfill Type I and IV	LF
Reg Landfill w Med Waste	LF_MW
Landfill with Compost	LF_RC
Reg Landfill, Diverts, Med Waste	LF_MW_DV
Landfills that Divert Materials	LF_DV
Landfill Type IX that Divert Material	LF_IX_DV
Landfills with transfer	LF_TF
Landfill with transfer and compost	LF_TF_RC
Landfill w Transfer, compost, and Diverted materials	LF_TF_RC_DV
Landfill with compost and material diversion	LF_RC_DV
Landfill with on-site processing (chipping, grinding, etc.)	LF_CHGR
Landfill with compost, chipping/grinding, material diversion	LF_RC_CHGR_DV

Each of the facility types included in the five final COGs selected for analysis in Task 3, as well as all of the facilities within for COG 16 (which has the largest and most diverse number/type of actors) is given a new label that defines the capabilities. This is done to provide a basis of understanding for the regional facility capabilities. All labels used throughout this thesis (using the facility data from TCEQ) are provided in Table 32. The inclusion of COG 16 was done to explore the various actor types within the network of Texas to gain a more in-depth understanding of the system as it has the largest number of actors and greatest variety within its system.

Once the actors were condensed where possible, the number of counties (the waste generators of the system) served by the COG facilities were analyzed. A similar grouping of counties represents a similar nutrient base in corresponding food webs (i.e. indicates all actors share a primary source of energy- a commonality for all ecological food webs). However, having too many counties shared between actors increases the number of unknowns within the network because it is impossible to accurately determine the origins of the waste attributed. This is because there is no information on generation values, nor a method developed to determine generation values. As a result, to reduce the uncertainty, a facility grouping with a smaller base of shared counties is most likely to reflect the real-world flow network. Using the information on shared counties, three final COGs were selected for a full analysis. The results of this chapter go into greater detail with regards to the final selection process.

The final selection of three COGs only still requires that the linkages between the networks are identified. This is done by determining which facilities accept the same type and volume of waste as well as which facilities serve the same counties. This process is described in further detail in the following *Results and Discussions*. The resulting flow matrices and structural matrices are used for analysis of the systems' ecological metrics for comparison with real world sustainable food webs. The ecological metrics considered for comparison are: cyclicity, Finn's Cycling Index (*FCI*), non-dimensional Total System Overhead (*Hc*), Shannon Index (*H*), Linkage Density (L_D), Prey to Predator Ratio (P_R), Generalization (*G*), Vulnerability (*V*), and Connectance (*Co*). Table 33 defines these metrics for reference.

Table 33: Ecological Metric Definition for those used throughout Task 4 analysis.

	Label	**Definition**
R	Robustness	Balance between pathway efficiency and redundancy
FCI	Finn Cycling Index	Ratio of flows going through cycle in the system to the total flow going through a system
Hc	Non-dimensional total system overhead	Non-dimensional value pertaining to redundant flows in the network
H	Shannon Index	Characterizes species diversity in a community
cyclicity	Cyclicity	A measure of strength and presence of cyclic pathways in the network
Ld	Linkage Density	Ratio of the total number of links to total number of species
Pr	Prey to Predator Ratio	Ratio of producers (prey) to consumers (predators)
G	Generalization	The average number of prey eaten per predator in the network
V	Vulnerability	The average number of predators per prey in a web
Co	Connectance	Number of actual direct interactions divided by total number of possible interactions

The calculation of these metrics was done using MATLAB (version R2016b), the code for which is provided in Appendix D in section D.1 on page 260. The ecological metrics calculated using the network flow (*R*, *FCI*, *Hc*, and *H*) are more complex in nature and require the several other metrics to be defined before providing these equations. In addition, these metrics much contribute less to the discussions for this Task as the focus here is on system structure. For these reasons, the flow metric equations are provided on page 260 in Appendix D. Conversely, the structural metrics used for calculations and discussions are further elaborated on and defined by their mathematical denotation in Figure 38 and Eqs. 1-5 of this chapter.

Cyclicity (λ_{max}) measures the presence of cycling within a network, which is often also considered as the strength of the system. This value is calculated by finding the maximum eigenvalue of a network's connectance or structural adjacency matrix [**A**][18, 19]. The structural depiction with a sample cyclicity for a network with six species is shown in Figure 38.

Columns

$$\mathbf{A} = \begin{array}{c} \begin{array}{cccccc} \mathrm{i} & \mathrm{ii} & \mathrm{iii} & \mathrm{iv} & \mathrm{v} & \mathrm{vi} \end{array} \\ \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \end{bmatrix} \end{array} \begin{array}{l} \\ \mathrm{i} \\ \mathrm{ii} \\ \mathrm{iii} \\ \mathrm{iv} \\ \mathrm{v} \\ \mathrm{vi} \end{array} \text{ Rows} \qquad \det(\mathbf{A}\text{-}\lambda\mathbf{I})=0 \qquad \lambda = \begin{bmatrix} 0 \\ -1 \\ 1i \\ -1i \\ 1 \\ 0 \end{bmatrix} \qquad \lambda_{max} = 1$$

(A) (B) (C) (D)

Figure 38: The process for calculating the cyclicity of a system with six species. (a) Labeled adjacency matrix for the system– rows represent flow to a node, columns from a node. (b) Equation for the calculation of the eigenvalues for the adjacency matrix. (c) Eigenvalues. (d) The cyclicity of the cycle as the maximum real eigenvalue of the adjacency matrix. ***Figure used with permission from*** **[27]**

Cyclicity can be either 0, 1, or greater than 1. A system with a cyclicity value of zero has no internal cycling; a system with a value of 1 has one loop or cycle present. Systems with various internal cycles or material feedback streams will have a cyclicity value greater than 1. This is ideal for a network aiming to achieve circular behaviors or sustainable characteristics. Food webs are prominent for having high cyclicity values, provided by their various detrital feedback steams and notorious sustainability.

Linkage density (L_D) divides the number of links (L), or direct connections between species in a network) by the number of species (N) and is shown in Eq. 1[18, 19].

$$L_D = {}^{L}/_{N} \tag{1}$$

Prey to predator ratio (P_R) is the ratio of producers (n_{prey}) to consumers ($n_{predator}$) and is given in Eq. 2 [18, 19].

$$P_R = {}^{n_{prey}}/_{n_{predator}} \tag{2}$$

Generalization (G) divides the number of links (L) by the number of predators ($n_{predator}$) in a system to determine the average number of prey eaten per predator in the network, as seen in Eq. 3[18, 19].

$$G = {}^{L}/_{n_{predator}} \tag{3}$$

Similar to generalization, vulnerability (V) calculates the number of predators a prey can defend by dividing linkages (L) by the number of prey (n_{prey}) in the system, as seen in Eq. 4[18, 19].

$$V = {}^{L}/_{n_{prey}} \tag{4}$$

Connectance (*Co*) is a ratio of actual interactions versus total possible interactions. By limiting the system to exclude cannibalism (receiving materials from self) as shown in Eq. 5[18, 19].

$$Co = {}^{L}\!/_{N^2} \tag{5}$$

COG Analysis

The five COGs that complied with the requirements set for the comparative analysis are shown in Table 34. Their facility lists were condensed if needed and the number of actors and number of different actor types were changed accordingly, as seen in Table 35. The shared counties in each COG are also investigated by determining the most frequently listed counties by the COG facilities. Table 36 shows the counties that were mentioned more than seven times and shared by two or more COGs. This emphasizes the various lengths that waste can travel before reaching end destinations. Consider county Jim Wells in COG 20 and colored royal blue in Figure 39. The final results of this analysis are provided in Table 36. This was done to understand which COGs support counties outside of their region and is used as support for the Cumulative COG analysis on page 201.

Table 34: COGs selected for Task 3. Prey indicates facilities that send materials to another facility and predators indicate facilities that accept waste from a facility. Transfer stations are prey, landfills are predators, and processing facilities are both prey and predators. When counties are included into the network, transfer stations will be considered prey and predators as well. The prey to predator ratio is given by # of prey/ # of predators. Sum of the actors is the total number of facilities involved.

COG	# of Transfer Facilities	# of Processing Facilities	# of Landfills	# of Prey	# of Predators	Prey to Predator Ratio	Sum of Actors
12	6	6	4	12	10	1.20	16
18	6	6	6	11	11	1.00	18
20	3	2	7	5	9	0.56	12
21	3	4	5	7	9	0.78	12
23	5	4	2	9	6	1.50	11

Table 35: Actor considerations for selected COGs. Different number of actor types indicates functionality variation in actors, total number of actors is the number of condensed facilities, and average number of counties served is calculated by dividing the number of counties served by the number of facilities.

COG	Avg. Num. of Counties Served	Num. of Different Actor Types	Total Num. of Actors
12	11.44	10	16
18	13.28	11	16
20	7.5	5	12
21	4.5	9	11
23	4.27	6	11

Table 36: County repetition in final COG selection. Numbers indicate the amount of facilities within that COG that service the listed county. Sum indicates the total number of facilities within these five COGs that service the one county.

	Number of Facilities Serving each County					
County	**COG 12**	**COG 18**	**COG 20**	**COG 21**	**COG 23**	**SUM**
Atascosa	2	7	-	-	-	9
Aransas	-	-	7	1	-	8
Bandera	2	6	-	-	-	8
Basdrop	9	6	-	-	-	15
Bee	-	5	6	1	-	12
Bell	6	4	-	-	9	19
Bexar	4	9	-	-	-	13
Blanco	6	5	-	-	-	11
Brooks	-	-	5	4	-	9
Burnet	11	3	-	-	2	16
Caldwell	6	3	-	-	-	9
Cameron	-	-	1	10	-	11
Comal	5	9	-	-	-	14
Duval	-	-	9	1	-	10
Gillespie	4	5	-	-	-	9
Guatalupe	4	8	-	-	-	12
Hays	11	4	-	-	-	15
Hildago	-	3	-	9	-	12
Jim Wells	1	3	9	1	-	14
Karnes	2	5	1	-	-	8
Kendall	4	4	-	-	-	8
Kenedy	-	4	4	2	-	10
Kleberg	-	-	7	2	-	9
Lampasas	3	2	-	-	6	11
Mclennan	2	-	2	-	3	7
Medina	2	6	-	-	-	8
Nueces	-	4	-	2	-	6
Refugio	1	2	5	1	-	9
San Patricio	-	-	7	1	-	8
Starr	-	2	-	6	-	8
Travis	14	5	-	1	1	21
Webb	-	5	1	1	-	7
Willacy	-	2	2	6	-	10
Williamson	13	3	-	-	4	20

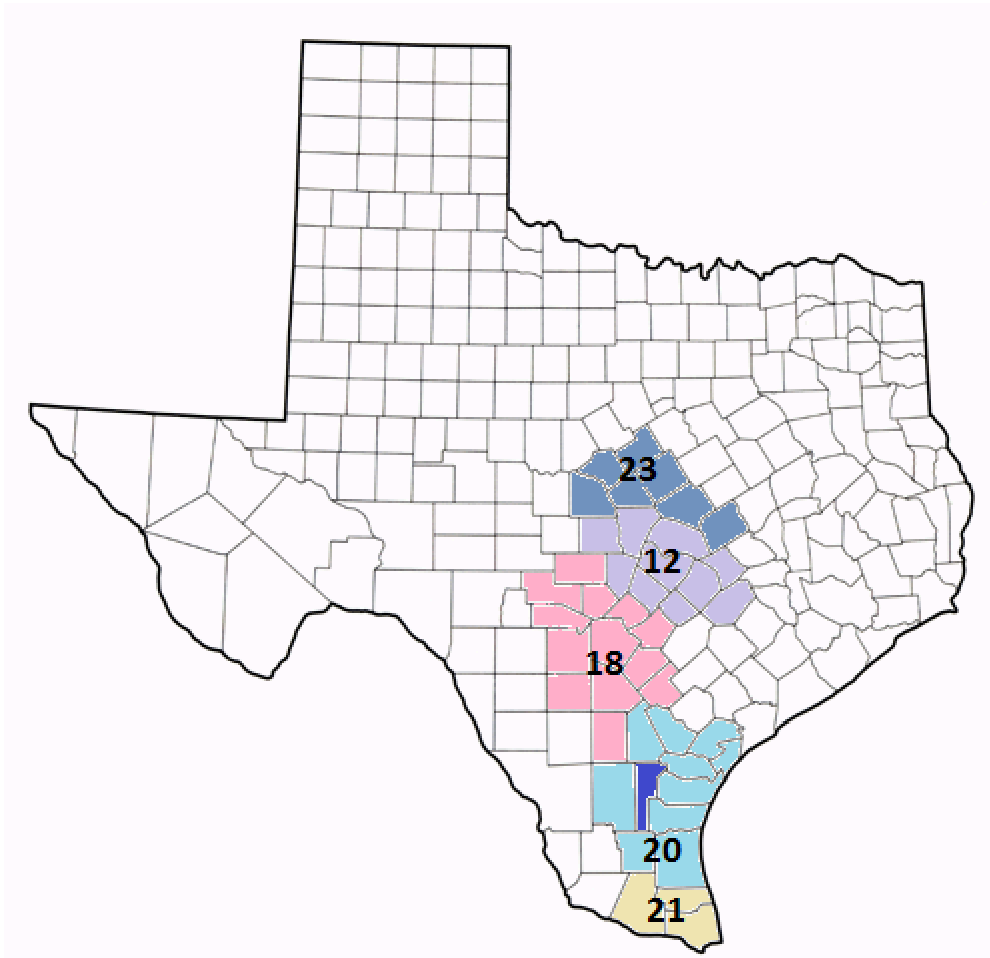


Figure 39: Texas Map of Selected COGs for Jim Wells example.

Figure 39 highlights the five COGs that were chosen for analysis. Jim Wells County (royal blue) is served by COG 12, 18, 20, and 21. Therefore waste, depending on its type, generated within this COG can have a wide range of distances that it will travel before disposal in a Texas landfill or processing center. This analysis only considers the five final COGs, so these are certainly not the only COGs that offer services to this county. Although this demonstrates that waste has a wide range of possible distances waste can travel, currently *nothing is done to consider or track the expenditures created by waste transportation*. The COGs for analysis were further reduced to COGs 20, 21, and 23 for their manageable number of actors (they serve a lower average number of counties) to aid in the creation of flow matrices.

County Selection

Table 36 highlights the possible travel distances of waste and can also be used to determine which counties to include in the network analysis of each COG. For example, COG 21 uses four counties (Cameron, Hildago, Starr, and Willacy) shared by over nine facilities. The excess counties for each network were removed, as well as any columns that were filled with zeros. The resulting counties for the COGs selected are shown in Table 37. These counties represent the waste generators of this system.

Table 37: Selected Counties for COG Network Development. County Mentions indicates number of facilities that list this county as a customer.

COG 20		COG 21		COG 23	
Name	**County Mentions**	**Name**	**County Mentions**	**Name**	**County Mentions**
Aransas	7	Cameron	10	Bell	9
Brooks	5	Hidalgo	9	Coryell	8
Duval	9	Starr	6	Lampasas	6
Jim Wells	9	Willacy	6	Mclennan	3
Live Oak	6			San Saba	2
Nueces	7			Williamson	4
San Patricio	7				
Total Mentions	**50**	**Total Mentions**	**31**	**Total Mentions**	**32**

COG 20

Table 38: Connectivity Matrix for COG 20. Ones indicate the actors from the vertical access (left) are providing materials to the actors on the horizontal axis (top). The actors of this network include: four counties, three transfer stations, four processing facilities, and five landfills. The actors are summarized in Table 39.

	ASP	B	DJW	LO	N	TF 1	TF 2	TF 3	PAC	PRC	LF 1	LF 2	LF 3	LF 4	LF 5	LF 6	LF 7
ASP	0	0	0	0	0	1	0	1	1	1	0	0	0	0	1	1	1
B	0	0	0	0	0	0	0	0	1	0	1	0	1	1	1	0	0
DJW	0	0	0	0	0	0	0	1	1	1	0	1	1	1	1	1	1
LO	0	0	0	0	0	0	1	1	1	0	0	0	0	0	1	1	1
N	0	0	0	0	0	0	0	1	1	1	0	0	0	1	1	1	1
TF 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
TF 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
TF 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
P AC	1	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0
P RC	1	0	1	0	1	0	0	0	0	0	0	0	0	1	1	1	0
LF 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LF 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LF 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LF 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LF 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LF 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LF 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 39: Label Key for Connectivity Matrix of COG 20

Actor Label	***Actor***
ASP	Aransas & San Patricio
B	Brooks
DJW	Duval & Jim Wells
LO	Live Oak
N	Nueces
TF 1	Aransas County Transfer Station Facility
TF 2	Live Oak County
TF 3	J C Elliott Landfill
P AC	Envirotech Waste Solutions Medical Waste Processing And Storage Facility
P RC	Texas Sludge Disposal
LF 1	Brooks County
LF 2	Duval County Landfill
LF 3	City Of Alice Landfill
LF 4	City Of Kingsville Landfill
LF 5	El Centro Landfill
LF 6	City Of Corpus Christi Landfill
LF 7	Gulley Hurst

Letter labels instead of numbers were used for COG 20 due to the ordering by facility type. The counties Aransas and San Patricio as well as Duval and Jim Wells were each aggregated into one actor for the connectivity matrix, as every county that serves one, serves both.

The Brooks County landfill is not serviced by a transfer station due to the facility only collecting construction and demolition waste. For this reason, this is the only landfill that is permitted to receive material directly from the county. Whether the construction and demolition companies deliver this material or the landfill transfers the material itself is unknown based on the available data.

Using online research, it was also determined that the Texas Sludge Disposal actor is permitted to collect its own waste. These values are not recorded as transportation numbers but it is assumed that the volumes are received directly from the counties serviced.

The "JC Elliott Landfill" was found online to be *JC Elliott Collection Services*. Research here determined that this company services the same counties and charges the same prices as the *City of Corpus Christi Landfill*. Although the point of contacts and company locations are different, it is assumed that the landfill actor here likely contracts out some of the transportation services, in this case to the JC Elliott facility. Based on this assumption, all of the material collected through the transfer facility is assumed to go to the City of Corpus Christi Landfill.

The process of autoclaving material produces incinerator ash. Only one landfill reports the disposal of incinerator ash and it services the county in which the Autoclave facility is located. This data allows for the assumption that the autoclave processing facility sends material to El Centro Landfill.

Based on the reported landfilled or transferred values, the following governing Eqs. 6-17 were established for the calculation of the network's flow matrix. The subscript of these equations determines the actor being specified and i or j determines whether it's the sum of the exports (row) or inputs (column) for the corresponding actor. For example, F_1 refers to the inputs or exports of actor 1, or in this case the Aransas County Transfer Station. These equations define that the material imported must equal the material exported and this value is defined by the data provided by the facilities to the TCEQ through their annual report for the year of 2017[12].

$$\sum_{i=1}^{N} F_{TF1} = \sum_{j=1}^{N} F_{TF1} = 7{,}373\ tons \quad (6)$$

$$\sum_{i=1}^{N} F_{TF2} = \sum_{j=1}^{N} F_{TF2} = 1{,}290\ tons \quad (7)$$

$$\sum_{i=1}^{N} F_{TF3} = \sum_{j=1}^{N} F_{TF3} = 94{,}296\ tons \quad (8)$$

$$\sum_{i=1}^{N} F_{P\ AC} = \sum_{j=1}^{N} F_{P\ AC} = 116\ tons \quad (9)$$

$$\sum_{i=1}^{N} F_{P\ RC} = \sum_{j=1}^{N} F_{P\ RC} = 14{,}417\ tons \quad (10)$$

$$\sum_{i=1}^{N} F_{LF\ 1} = \sum_{j=1}^{N} F_{LF\ 1} = 541\ tons \quad (11)$$

$$\sum_{i=1}^{N} F_{LF\ 2} = \sum_{j=1}^{N} F_{LF\ 2} = 3{,}960\ tons \quad (12)$$

$$\sum_{i=1}^{N} F_{LF\ 3} = \sum_{j=1}^{N} F_{LF\ 3} = 26{,}322\ tons \quad (13)$$

$$\sum_{i=1}^{N} F_{LF\ 4} = \sum_{j=1}^{N} F_{LF\ 4} = 34{,}869\ tons \quad (14)$$

$$\sum_{i=1}^{N} F_{LF\ 5} = \sum_{j=1}^{N} F_{LF\ 5} = 153{,}451\ tons \quad (15)$$

$$\sum_{i=1}^{N} F_{LF\ 6} = \sum_{j=1}^{N} F_{LF\ 6} = 476{,}927\ tons \quad (16)$$

$$\sum_{i=1}^{N} F_{LF\ 7} = \sum_{j=1}^{N} F_{LF\ 7} = 63{,}094\ tons \quad (17)$$

The assumptions discussed and several more were used. Shown Table 40, to determine the flow matrix for COG 20. Filling all the knowns volumes into the resulting connectivity matrix results in Table 41.

Table 40: Assumptions used to calculate flow matrix for COG 20

Assumptions
• All medical waste types are received from regional medical waste facility • All liquid waste is received from regional liquid waste facility • JC Elliot Collection Services (TF 3) delivers all waste to LF 6 • (Recorded landfilled waste- assigned transferred volume)*population proportion of the county= waste contributed by the county to the landfill (red in the flow matrix) • Return material (compost or medical in COG 20) is returned to the county in which the facility is located in the exact volume as reported • TF 1 is more likely to deliver waste to LF 6 based on waste consumption volume and material type as well as counties served • Transfer stations receive their material based on the population percentage make up the counties served • Incinerator ash is received from regional Auto Clave facility
COG Facility Specifics
• The P RC actor is registered as compost but also processes liquid waste • TF 1, TF 2, LF 1, and LF 2 serve single actors in the network

Table 41: Flow Matrix Determined for COG 20. Yellow highlight- exact values assumed from transfer station data, blue- exact values determined from facility, green- calculated based on population proportion (available in Appendix D), red- calculated based on population proportion of counties served after transfer materials was removed from total, no highlight-known volume flows that do not need assumptions to be determined. RO represents material sent to an actor outside the region facilities for some sort of recycling process.

	A SP	B	DJW	LO	N	TF 1	TF 2	TF 3	P AC	P RC	LF 1	LF 2	LF 3	LF 4	LF 5	LF 6	LF 7	RO
ASP	-	-	-	-	-	7,373	-	16,880	20.46	2,043	-	-	-	-	26,096	67,527	11,295	-
B	-	-	-	-	-	-	-	-	1.60	-	541	-	3,207	600	2,035	-	-	-
DJW	-	-	-	-	-	-	-	9,486	11.50	1,603	-	3,960	23,115	4,323	14,665	37,948	6,347	-
LO	-	-	-	-	-	-	1,290	2,215	2.68	-	-	-	-	-	3,424	8,860	1,482	-
N	-	-	-	-	-	-	-	65,714	79.66	11,105	-	-	-	29,946	101,592	262,882	43,970	-
TF 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3,972	-	3,401
TF 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,290	-	-
TF 3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	86,378	-	7,899
P AC	-	-	-	-	116	-	-	-	-	-	-	-	-	269	-	-	-	-
P RC	1,143	-	-	-	-	-	-	-	-	-	-	-	-	708	5,639	8,069	-	-
LF 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	205
LF 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LF 3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	441
LF 4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3,425
LF 5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LF 6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	77
LF 7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

The highlighted yellow values indicate the values that were provided directly from the data as materials sent to each specific landfill that limit the possible origins. For example, if a landfill reported a certain amount of medical waste, it is assumed that that exact amount was provided by the regional medical waste transfer station or processing facility. The light blue values are also directly taken from the data. In these cases, the landfill or transfer station serves only one county, meaning all of the recorded waste must be coming from this actor. The green values were calculated based on the percentage make-up of the counties served. This assumption may not represent the realistic network because it does not consider the amount of industrial activity in the area; however, in general the larger counties should be supplying more waste and this accounts for that likelihood. The light red values represent the proportional generation based on the counties' population after some amount has already been supplied via transfer stations. Grey spaces indicate connection areas that *may* be present based on counties served and materials transferred, but have been designated as zero's based on one of the later assumptions discussed above. These connection spaces are set as 1's when calculating the ecological metrics for comparison to account for these possible connections.

The results of the ecological analysis are discussed with the remaining COGs in the cumulative analysis section of this chapter's Results and Discussions on page 202.

COG 21

Table 42: Connectivity Matrix for COG 21: Lower Rio Grande Valley Council of Governments. Ones indicate the actors from the vertical access (left) are providing materials to the actors on the horizontal axis (top). The actors of this network include: four counties, three transfer stations, four processing facilities, and five landfills. The actors are summarized in Table 43 below.

	C	H	S	W	1	2	3	4	5	6	7	8	9	10	11
C	0	0	0	0	1	1	1	0	0	1	1	1	1	0	1
H	0	0	0	0	1	1	0	0	1	1	0	1	1	1	1
S	0	0	0	0	1	0	0	0	1	1	0	1	1	0	1
W	0	0	0	0	1	0	1	0	0	1	0	1	1	0	1
1	1	0	0	0	0	0	0	0	0	0	1	0	1	0	0
2	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1
3	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1
4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
6	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0
7	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 43: Label Key for COG 21 Connectivity Matrix

Actor Type	Label	Name
County	C	Cameron
County	H	Hidalgo
County	S	Starr
County	W	Willacy
Medical Waste Processing Facility	1	Stericycle Harlingen Processing Facility
Transfer Station (standard)	2	La Feria Transfer Station
Transfer Station (standard)	3	City of Harington Transfer Station Facility
Compost Processing Facility	4	City of Brownsville Composting Facility
Transfer Station (standard)	5	Pharr Transfer Station
Liquid Waste Processing Facility	6	Valley Dewatering Services
Landfill (with diversion and MW)	7	City of Brownsville Municipal Landfill
Landfill	8	Edinburg Regional Landfill
Landfill (with MW)	9	La Gloria Ranch Landfill
Landfill	10	Penitas
Landfill (with gas recovery & diversion)	11	Edinburg Regional Disposal Facility

The equations governing the relationship between the facilities are shown below, in Eqs. 18-24. The subscript determines which actor is being specified and i or j determines whether it's the sum of the exports (row) or inputs (column) for the corresponding actor. For example, F_1 refers to the inputs or exports of actor 1, or in this case the medical waste processing facility.

$$\sum_{i=1}^{N} F_1 = \sum_{j=1}^{N} F_1 = 3{,}014\ tons \tag{18}$$

$$\sum_{i=1}^{N} F_2 = \sum_{j=1}^{N} F_2 = 155{,}445\ tons \tag{19}$$

$$\sum_{i=1}^{N} F_3 = \sum_{j=1}^{N} F_3 = 66{,}178\ tons \tag{20}$$

$$\sum_{i=1}^{N} F_4 = \sum_{j=1}^{N} F_4 = 24{,}209\ tons \tag{21}$$

$$\sum_{i=1}^{N} F_5 = \sum_{j=1}^{N} F_5 = 52{,}358\ tons \tag{22}$$

$$\sum_{i=1}^{N} F_6 = \sum_{j=1}^{N} F_6 = 31{,}032\ tons \tag{23}$$

$$\sum_{i=1}^{N} F_7 = \sum_{j=1}^{N} F_7 = 317{,}665\ tons \tag{24}$$

$$\sum_{i=1}^{N} F_8 = \sum_{j=1}^{N} F_8 = 123{,}136\ tons \qquad (23)$$

$$\sum_{i=1}^{N} F_9 = \sum_{j=1}^{N} F_9 = 29{,}994\ tons \qquad (24)$$

$$\sum_{i=1}^{N} F_{10} = \sum_{j=1}^{N} F_{10} = 8{,}179\ tons \qquad (23)$$

$$\sum_{i=1}^{N} F_{11} = \sum_{j=1}^{N} F_{11} = 494{,}515\ tons \qquad (24)$$

Ideally, if the network were a closed system (i.e. no material is being provided from counties outside of this list, which is known to be untrue) these equations would not be difficult to use in order to solve for the unknowns (represented by 1's in the connectivity matrix) of the flow diagram. Unfortunately, without information from the facility, which is most often not made open to the public, these results cannot be calculated with certainty. For this reason, the material types of the transfer stations and the populations of the counties served are used to determine the missing values. The assumptions used for COG 21 and the facility specific details are provided in Table 44.

Table 44: Assumptions used for the flow matrix calculation of COG 21

Assumptions
• All medical waste types are received from regional medical waste facility • All liquid waste is received from regional liquid waste facility • If the volume of a transfer station exceeds the recorded landfill value, there is no connection between the two actors • (Recorded landfilled waste- assigned transferred volume)*population proportion of the county= waste contributed by the county to the landfill (red in the flow matrix) • Return material (compost, liquid, or medical in COG 21) is returned to the county in which the facility is located in the exact volume as reported • 2 (TF) is more likely to deliver waste to 7 (LF) based on waste consumption volume and material type as well as counties served • In the same way, 3 (TF) is more likely to deliver waste to 11 (LF) based on material and volume recorded, and 5(TF) is more likely to deliver all of its waste to 9 (LF) • Transfer stations receive their material based on the population percentage make up the counties served
COG Facility Specifics
• Actor 7 (landfill for Brownsville) recorded the *exact* same volume of chipped material as actor 4 (Brownsville compost) recorded for compost, so this connection has been assumed • Actor 10 (landfill Penitas) serves one county and no transfer stations, actor 5 (Pharr transfer station) serves one county in combination with 9 (La Gloria Ranch Landfill), who services this county and more

Applying the governing equations with these assumptions, the following flow matrix was calculated shown in Table 45. The population breakdowns used for calculations are provided in Appendix D on page 266.

Table 45: Flow Matrix calculated for COG 21. RO represents material sent to an actor outside the region facilities for some sort of recycling process. Yellow highlight- exact values assumed from transfer station data, blue- exact values determined from facility, green- calculated based on population proportion (available in Appendix D), red- calculated based on population proportion of counties served after transfer materials was removed from total, no highlight-known volume flows that do not need assumptions to be determined.

	C	H	S	W	1	2	3	4	5	6	7	8	9	10	11	RO
C	-	-	-	-	932	51,282	62,970	-	-	9,595	151,148	38,073	71,422	-	132,439	-
H	-	-	-	-	1,893	104,163	-	-	52,358	19,489	-	77,333	145,070	8,179	269,006	-
S	-	-	-	-	142	-	-	-	-	1,460	-	5,791	10,864	-	20,146	-
W	-	-	-	-	47	-	3,208	-	-	489	-	1,939	3,638	-	6,746	-
1	212	-	-	-	-	-	-	-	-	-	1,015	-	1,787	-	-	-
2	-	-	-	-	-	-	-	-	-	-	155,445	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	66,178	-
4	24,209	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-	-	52,358	-	-	-
6	-	15,810	-	-	-	-	-	-	-	-	10,047	-	5,175	-	-	-
7	-	-	-	-	-	-	-	24,209	-	-	-	-	-	-	-	89
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	805

COG 23

The assumptions listed in Table 48, the connectivity matrix in Table 46 (key shown in Table 47), the Eqs. 25-34 enabled COG 23 to follow the same process as for COG 20 and 21. The percentage breakdowns for COG 23 are shown on Page 319 in Appendix D. The resultant flow matrix for COG 23 is shown in Table 49.

Table 46: Connectivity Matrix for COG 23. Ones indicate the actors from the vertical access (left) are providing materials to the actors on the horizontal axis (top). The actor labels are defined below in Table 47.

	B	C	L	M	SB	W	1	2	3	4	5	6	7	8	9	10
B	0	0	0	0	0	0	1	1	1	1	1	1	1	0	1	1
C	0	0	0	0	0	0	1	1	1	0	1	1	1	0	1	1
L	0	0	0	0	0	0	1	1	1	0	1	1	0	0	1	0
M	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0
SB	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
W	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0
1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
6	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 47: Key for Connectivity Matrix of COG 23

Actor Label	*Actor*
B	Bell
C	Coryell
L	Lampasas
M	McLennan
SB	San Saba
W	Williamson
1	S & M Vacuum & Liquid Waste Processing Facility
2	Killeen Transfer Station
3	Stericycle Temple
4	Bell County WCID 1 Regional Compost Facility
5	City Of Copperas Cove Transfer Station Facility
6	City Of Copperas Cove Composting Facility
7	Fort Hood Bio treatment Facility
8	City Of San Saba Municipal Solid Waste Processing
9	Temple Recycling And Disposal Facility
10	Fort Hood Landfill

Table 48: Assumptions used for the flow matrix calculation for COG 23

Assumptions
• All medical waste types are received from regional medical waste facility • All liquid waste is received from regional liquid waste facility • If the volume of a transfer station exceeds the recorded landfill value, there is no connection between the two actors • Transfer Stations 1, 2, 3, and 5 send all waste to landfill 9. Transfer stations 7 and 8 send all waste to landfill 10 • (Recorded landfilled waste- assigned transferred volume)*population proportion of the county= waste contributed by the county to the landfill (red in the flow matrix) • Return material (compost or liquid in COG 23) is returned to the county in which the facility is located in the exact volume as reported • Transfer stations receive their material based on the population percentage make up the counties served
COG Facility Specifics
• Actor 8 (San Saba waste processing) serves one county and no transfer stations. In addition, no material is processed here, only diverted.

$$\sum_{i=1}^{N} F_1 = \sum_{j=1}^{N} F_1 = 4{,}568\ tons \quad (25)$$

$$\sum_{i=1}^{N} F_2 = \sum_{j=1}^{N} F_2 = 112{,}956\ tons \quad (26)$$

$$\sum_{i=1}^{N} F_3 = \sum_{j=1}^{N} F_3 = 441\ tons \quad (27)$$

$$\sum_{i=1}^{N} F_4 = \sum_{j=1}^{N} F_4 = 6{,}798\ tons \quad (28)$$

$$\sum_{i=1}^{N} F_5 = \sum_{j=1}^{N} F_5 = 30{,}977\ tons \quad (29)$$

$$\sum_{i=1}^{N} F_6 = \sum_{j=1}^{N} F_6 = 1{,}284\ tons \quad (30)$$

$$\sum_{i=1}^{N} F_7 = \sum_{j=1}^{N} F_7 = 317\ tons \quad (31)$$

$$\sum_{i=1}^{N} F_8 = \sum_{j=1}^{N} F_8 = 3{,}792\ tons \quad (32)$$

$$\sum_{i=1}^{N} F_9 = \sum_{j=1}^{N} F_9 = 433{,}986\ tons \quad (33)$$

$$\sum_{i=1}^{N} F_{10} = \sum_{j=1}^{N} F_{10} = 19{,}501\ tons \quad (34)$$

Table 49: Flow Matrix calculated for COG 23. RO represents material sent to an actor outside the region facilities for some sort of recycling process. Yellow highlight- exact values assumed from transfer station data, blue- exact values determined from facility, green- calculated based on population proportion (available in Appendix D), red- calculated based on population proportion of counties served after transfer materials was removed from total, no highlight-known volume flows that do not need assumptions to be determined.

	B	C	L	M	SB	W	1	2	3	4	5	6	7	8	9	10	RO
B	-	-	-	-	-	-	1,279	39,634	123	2,641	15,503	643	261	-	145,909	12,756	-
C	-	-	-	-	-	-	275	8,536	27	-	3,339	138	56	-	31,424	2,747	-
L	-	-	-	-	-	-	77	2,396	7	-	937	39	-	-	8,820	-	-
M	-	-	-	-	-	-	924	-	89	-	-	-	-	-	105,398	-	-
SB	-	-	-	-	-	-	-	-	-	-	-	-	-	3,792	2,500	-	-
W	-	-	-	-	-	-	2,013	62,390	194	4,157	-	-	-	-	-	-	-
1	180	-	-	-	-	-	-	-	-	-	-	-	-	-	4,388	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	106,897	-	6,059
3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	441	-	-
4	6,798	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28,209	-	2,768
6	-	1,284	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	317	-
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3,681	111
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,084

Cumulative COG Analysis

The structure and flow matrices created throughout Task 4 were used to calculate the ecological metrics shown in Table 50. Variable definitions for each are listed in Table 51.

Table 50: Ecological Metric Results for Task 4, Facility Analysis

	Facility Analysis						
	COG 20	**COG 21**	**COG 23**	***COG 20 likely***	***COG 21 likely***	***COG 23 likely***	**FWs**
R	0.283	0.365	0.349	0.283	0.365	0.349	0.519
FCI	2.07E-05	0.105	2.82E-04	2.07E-05	0.105	2.82E-04	0.125
Hc	1.592	1.301	1.976	1.592	1.301	1.975	2.886
H	1.870	2.238	2.655	1.870	2.238	2.655	4.576
cyclicity	2.676	1.859	1.618	1.414	1.815	1.618	4.240
Ld	2.533	2.800	2.938	2.067	2.533	2.563	5.040
Pr	0.533	0.846	1.167	0.583	0.846	1.167	1.090
G	4.750	3.818	3.357	4.429	3.455	2.929	6.180
V	2.533	3.231	3.917	2.583	2.923	3.417	5.340
Co	0.169	0.187	0.184	0.138	0.169	0.160	0.153

Table 51: Variable Definition for Ecological Metrics

	Label	Definition
R	Robustness	Balance between pathway efficiency and redundancy
FCI	Finn Cycling Index	Ratio of flows going through cycle in the system to the total flow going through a system
Hc	Nondimensional total system overhead	Nondimensional value pertaining to redundant flows in the network
H	Shannon Index	Characterizes species diversity in a community
cyclicity	Cyclicity	A measure of strength and presence of cyclic pathways in the network
Ld	Linkage Density	Ratio of the total number of links to total number of species
Pr	Prey to Predator Ratio	Ratio of producers to consumers
G	Generalization	The average number of prey eaten per predator in the network
V	Vulnerability	The average number of predators per prey in a web
Co	Connectance	Number of actual direct interactions divided by total number of possible interactions

The results of the COGs and their more likely configurations are compared to averages for a set of food web that represent general food web structural and functional characteristics. The comparison can be found for all selected metrics in The structure and flow matrices created throughout Task 4 were used to calculate the ecological metrics shown in Table 50. Variable definitions for each are listed in Table 51.

Table 50 and for the metric cyclicity in Figure 40. The COGs shown in light red in Figure 40 assume a "best case scenario," that the gray connections between the actors in the flow matrices representing advertised connections that could not be confirmed (8 entries are grayed-out in Table 41 for COG 20, 4 entries in Table 45 for COG 21, 6 entries in Table 49 for COG 23) *do have* a connection, hence designating these entries as

1s. The more realistic case however, is that these actors *do not have* a connection, and thus these gray highlighted values remain as zeros resulting in the “COG Likely” cases highlighted in blue in Figure 40 and The structure and flow matrices created throughout Task 4 were used to calculate the ecological metrics shown in Table 50. Variable definitions for each are listed in Table 51.

Table 50. These connections are believed to likely not exist because it does not make sense for one facility to send materials to multiple landfills if one can suffice. The decreased values shown through the “likely” entries reflect the expected recycling success based on *actual confirmed* connections, while the calculations for COG 20-23 reflect the *advertised* connections.

Figure 40 shows the values for cyclicity for each COG, both realistic and ideal, alongside food web averages. Cyclicity is determined by finding the maximum real eigenvalue of a network’s structural adjacency matrix (the connectivity matrices shown for COG 20, 21, and 23). Cyclicity is indicative of the number and complexity of cyclic pathways within a system, as the number of steps within the path approaches infinity[18, 19]. The larger the cyclicity, the more complexity and number of the paths are between the network actors. Cyclicity has been found by ecologists to significantly influence the dynamics and stability of FWs. The important decomposer and detrital actors in FWs provide the system structure that enables the high cyclicity values by reintroducing material as nutrients. Notice that the cyclicity values for the COGs shown in Figure 40 consistently drop between the advertised network scenarios (red) to the realistic scenarios (blue). The significance is that, a recycling/processing facility that advertises serving a generous area realistically will not serve most of these counties, reducing the beneficial cyclic structure introduced by having prolific recycling in a system and reflecting the limited reach hidden by false advertisements.

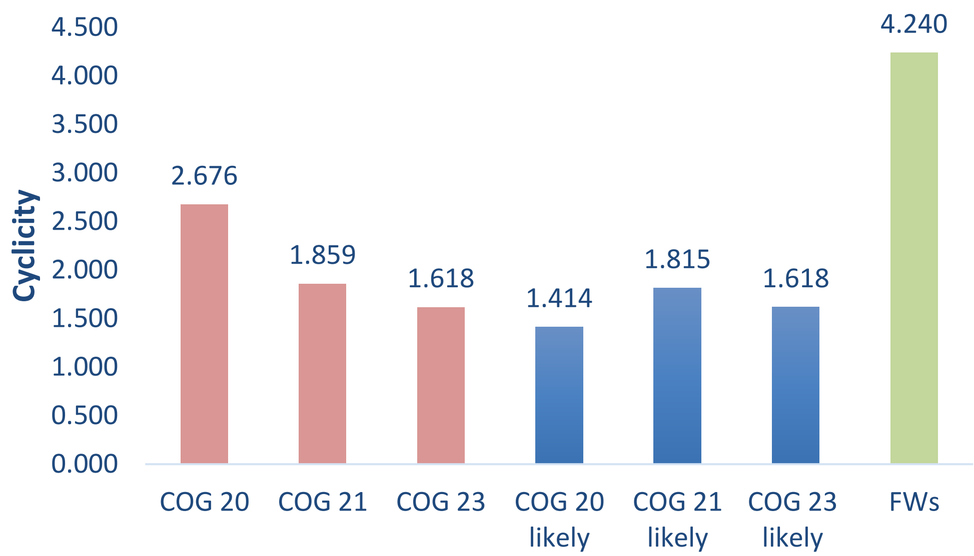


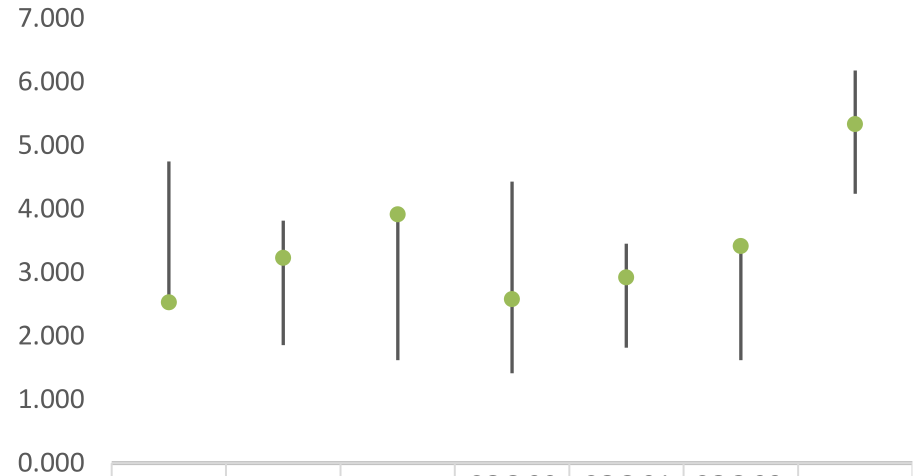
Figure 40: Cyclicity for Waste Networks in Comparison with values found from naturally sustainable FW's.

The values seen for cyclicity within the waste management networks are significantly lower when compared to the values found for FWs. This indicates that these detritus-based networks lean towards network efficiency instead of material recycling, a telling finding considering these are recycling networks. This network efficiency is reflected by the strong, streamlined waste-to-landfill paths and weakly designed material diversion for recycling. Most of the material that is diverted for recycling does not aid in increasing the network cyclicity because it is often sent to facilities *outside* of the COG region, where the material *may or may not be recycled*. Revisiting the *mismanaged waste* of Task 2, only a fraction of the material counted towards recycling is actually processed into new materials. Task 4 takes this one step further, showing that many counties do not even have infrastructure to support recycling. This means that *all the waste* generated within these counties is sent *directly* to landfill and considerable portions of “recycling” waste (collected by transfer stations as material recovery facilities) are separated immediately and *redirected again to landfills*.

The goal of mimicking the values found in FW metrics is based on the concept that the *structure leads to functionality*. Thus, a network designed to mimic sustainable FW structures has a greater likelihood of achieving sustainability through similar material cycling (a fundamental goal in circular economy practices). This characteristic FWs cycling is particularly desirable for the objective of a *sustainable waste management network*. The failure to achieve the EPA published recycling values is partially the result of a lack of sufficient domestic processing facilities. Without a detritus-equivalent in our waste networks we will be unable to reproduce the structure or function characteristic of FWs.

Developing additional processing facilities to service these regions is one way to increase the cyclicity within a waste management network. Processing facilities, such as material recycling, compost, and liquid processing facilities, utilize incoming waste as a source to create raw materials to return to the consumers/waste generators. These actors are thus providing the detrital feedback streams seen in FWs. If processing facilities are considered the detrital actors within the waste management network, then the COGs considered have *no* detrital consumers for materials, aside from liquid, medical, and compostable waste, meaning that the largest portions of these networks' waste streams (municipal solid waste and construction and demolition) are *not capable* of becoming a cycle.

The FW metrics generalization and vulnerability also quantify important aspects of FW structure. Generalization, Eq. 3 in this chapter, is calculated by adding the column sums of the food web matrix and dividing this figure by the number of columns with non-zero elements (i.e. the number of existing predators). Generalization thus quantifies the average number of prey that a predator can consume. Vulnerability, Eq. 4 in this chapter, is calculated by adding the row sums and dividing them by the number of rows with non-zero elements (i.e. existing number of prey). Vulnerability thus quantifies the average number of predators that a species must defend against. Cyclicity, Generalization, and Vulnerability are illustrated in a high-low graph in Figure 41, demonstrating the facility trends as well as statistically significant difference between the facility networks and the FWs.



	COG 20	COG 21	COG 23	COG 20 likely	COG 21 likely	COG 23 likely	FWs
Cyclicity	2.676	1.859	1.618	1.414	1.815	1.618	4.240
Generalization	4.750	3.818	3.357	4.429	3.455	2.929	6.180
Vulnerability	2.533	3.231	3.917	2.583	2.923	3.417	5.340

Figure 41: High-low demonstration of cyclicity, generalization, and vulnerability values for the facility analysis for comparison with natural FW. The upper limit of the bar is set by the value for generalization, the lower limit is set by cyclicity, and the green point is determined by the value for vulnerability

The values for *G* and *V* follow the trend of cyclicity, where the FW metrics greatly exceed that of the facility networks, further emphasizing the waste management network's failure to reproduce the network structure of FWs. Transfer and processing facilities can accept waste from numerous sources, but typically waste generators have a more limited selection of predators (waste collectors) at their disposal. The exception for this trend can be seen in COG 23, with 6 counties (prey) and only two top level predators (landfills). This exception is better understood using the analysis demonstrating *shared counties served*, shown in Table 36 on page 180, where it can be seen that the counties included in COG 23 (Bell, Coryell, Lampasas, McLennan, San

Saba, Williamson) are serviced by approximately *twice* as many facilities *outside* of the region than inside. This has broader implications regarding the greater distances that this waste must travel prior to eventual processing or disposal, resulting in additional emissions and energy consumption.

One method to shift the values for cyclicity, generalization, and vulnerability closer to that of food webs could be to establish co-existing facilities capable of handling multiple steams of waste materials. An example that suggests the success of this option is the cooperation between the Brownsville landfill and compost facility. This cooperation improves the cyclicity of the overall system and reduces the difference between generalization and vulnerability by providing facilities that operate as both prey and predator.

Challenges

The major challenge faced during Task 4 was making reasonable assumptions for facility linkages based only on the material type recorded. The volume landfilled greatly exceeded the volume transferred in the region. If the landfills are conducting collection on their own, these numbers are not recorded as transferred material. In addition, by limiting the number of counties in consideration, the excess landfill generation attributed by those counties is then credited to the narrowed down counties. This prevents accuracy when calculating flow volumes. Finally, several of these counties are serviced by facilities in other COGs, so parts of their generation volume are being routed to facilities not listed within this network. During the elimination phase it became apparent that a large number of COGs rely on facilities outside of their region to provide services to the counties within. This further compounds the difficulties of tracking waste as well as increasing the distances waste must be transported.

Conclusions

In conclusion, current waste management networks do not provide the necessary infrastructure to create a similar structure seen in natural food webs. In most regions, there is no equivalent to the detrital and decomposer actors for the majority of the waste stream volumes. Insufficient regional processing and facility cooperation greatly limits the cyclicity, generalization, and vulnerability values found for the waste management networks. In failing to duplicate the structure of sustainable systems, the waste management networks have been designed to streamline materials for landfill disposal. In consequence, the true MSW recycling rates for these regions (and most regions) are astoundingly poor, which is presumably why most governmental institutions promote the diversion or recovery rate as the recycling rate in place of more realistic values. To improve the structure of these networks and promote circular economy, the development of regional facilities that increase material cycling must be supported.

CHAPTER VII

CONCLUSIONS & FUTURE WORK

Research Goals

The overarching goal of this thesis is to apply system analysis from an ecological perspective to the US waste management network in order to promote a more circular economy. Previous sustainability research has yet to consider the US waste management network from a system analysis standpoint. The US waste management system is notorious for being difficult to understand, even by professionals within the industry. The absence and misuse of domain terminology, confusion surrounding waste management roles of federal and local governments, and the inadequacy in the enforcement of environmental standards all attribute to the majority of the US waste stream going miss-reported and unregulated. The discrepancies between policy and regulation across state lines hinder analysis of the network from a national perspective and top-level implementation of circular economy tactics.

To address these issues and begin to organize waste management data for system analysis, Tasks 1-4 build upon the results of the literature review in Chapter 2 LITERATURE REVIEW* and provide results that support recommendations towards achieving a more circular economy. The objectives of these Tasks are summarized in the following sections and their various results are concluded as support for the final bio-inspired recommendations.

Task 1

Task 1 furthered the goals of this research by illuminating a misconceived network and provided a general understanding of the four main disposal alternatives to municipal waste. These investigations created a base model that highlighted the four standard routes for waste disposal within the US. The results determined that, while the US in 2015 advertised that 67.8 million metric tons MSW waste was recycled, in reality over ¾ of this, 54.7 million metric tons, was actually exported as a scrap material to be "recycled" outside of the US. The reported recycling rate of 35.4% is technically *incorrect*, this rate instead represents the US recovery rate. These results prompted additional investigations into the recycling industry and mismanaged waste in Task 2.

Task 2

The recycling industries for non-ferrous metal, ferrous metal, plastic, and paper were analyzed in Task 2 and compared to the structure and functioning of successful biological food webs using *food web metrics* from ecology. This work highlighted the capabilities and restrictions of US domestic recycling processes. The structural analyses, focusing on cyclicity, of these networks were comparison demonstrated that the domestic recycling industry is lacking in its infrastructure and capacity to provide material cycling sufficient to meet the demands of domestic production. In addition, the discrepancies between the advertised recycling and actual recycling values were highlighted to demonstrate the impact that these misleading figures can imply.

Finally, the global mismanagement of waste was explored as a result of the findings in Task 1 that the majority of waste recorded for recycling is actually exported as waste material, where its recycling fate cannot be known. The results of Task 2 highlighted that the US *indirectly* mismanages significantly more than advertised: more plastic were mismanaged in the *first half of 2017* than processed domestically for the *entire year of 2017* via exporting waste to counties with high mismanagement values. The results of Task 2 provide references for several of the bio-inspired recommendations.

Task 3

Task 3 collected the available facility data for all of the waste management facilities within Texas, as provided by the Texas Commission of Environmental Quality (TCEQ). This included transfer facilities, processing facilities, and landfills. The collection of this data enabled the analysis that determined the potential achievements and limitations of a model built using published data. The calculations enabled the investigation of metrics such as landfill capacity in years and recycling rate, finding that based on the facility data provided by the TCEQ, 95.36% of waste generated within Texas is *not* separated for recycling. Population grown was also considered, finding a reduction in the advertised landfill capacity by approximately 6 years with just a moderate growth scenario. The data collected through Task 3 provided the facility information for the network analysis conducted in Task 4.

Task 4

Task 3 provided the COGs' facility data used as a basis for designing a realistic waste management network, made using *data from real facilities*. Several ecology network metrics quantitatively aided in the understanding of the functionality and structure of the current waste networks in Texas, and made recommendations for bio-inspired circular economy initiatives.

The results of Task 4 determined that current waste management networks do not provide the necessary infrastructure to create a similar structures seen in natural food webs. In most regions, there is no equivalent to the detrital/decomposer actors in ecosystems for the majority of the waste stream volumes. Insufficient regional processing and facility cooperation greatly limits the cyclicity, generalization, and vulnerability values found for the waste management networks. The departure from the structure of sustainable ecosystems systems highlighted that waste management networks are designed to streamline materials *for landfill disposal*.

Future Work

There are many ways in which the results and discussions of Tasks 1-4 can be used towards and strengthened through the development of further research. By investigating previously unmentioned challenges facing the waste industry market, an understanding can be gained concerning how the future work can improve the outlook for decision makers in industry. The additional work stemming from this thesis should include consideration for more applications utilizing this method of system analysis and other needs that can be addressed.

The models developed in Task 2 allow an optimization to test possible decisions for the recycling network model including flow volume, network connections (aside from those prevented), and actor reuse. Additionally, the network designed in Task 4 organizes real-world facility information in a manner that can lead to a system analysis.

Decisions similar to those made by the optimization in Task 2 are made every day at the local, state, national, and even international level for the facility networks of the waste management system. The lack of aggregated information however can make it difficult to implement well-rounded decision-making. To mediate this, the possibilities of applying the optimization tactics seen in Task 2 on a network similar to the one developed in Task 4 of Chapter VI is considered through the development of a possible future work Task for this thesis.

Future Work: ***Make recommendations towards improving the future waste management networks using the theoretical, dynamic waste network model and information of Task 1 & 2***

Objectives

The objective for a future "next step" is to use the scaled, system network developed in Task 3 as well as information gathered as a result of Task 1 and 2 to create a dynamic optimization took that can make recommendations for decision makers in the industry and for future researchers. This Task can explore the problems faced by the decision makers in waste management, the influencing factors on the industry and investigate the priorities of the stakeholder's in play.

Primary Research Question and Goals

RQ: What additional information should be collected by environmental government agencies in order to build a complete version of the model in Task 4?

Even with the TCEQ provided data that includes information from every facility in Texas, the resulting network has too many unknowns to be modeled completely. For example, information such as volume or weight of exported waste (to either another state or country), is not required and creates large inequalities within the flow network. The documentation of more values is needed in order to build a full-scale network of the model created in Task 4.

Research Question Goals:

Researchers and policy makers will be encouraged to adapt the information gathered during the annual reports for each facility. With the inclusion of this information, the future work of this research will have the ability to analyze the waste management networks using a complete and accurate flow network. This will allow for the future application of algorithms and optimization models in order to consider the design of the overall system and provide decision-making tools in the future.

RQ: What additional decisions can be influenced using a network analysis model similar to the one developed in Task 3? Who can benefit from the development of such a model?

More problems face solid waste management than just the ones outlined in this thesis. Task 4 and 4 confirm that landfill capacity will run out long before the US achieves perfect circular economy. Questions such as: Where would adding a landfill be most impactful? And what regions would receive the most benefits from investing in recycling? will be considered and solution methods developed. The proposed solutions will be based on a system-level model and information that is the most comprehensive available. Who is likely to benefit most from the development of this model and why? Decision makers of the industry will be addressed to determine what the specific needs are from their perspective.

Research Question Goals:

Researchers and policy makers will be encouraged to continue to investigate waste management analysis and to consider enforcing regulations that would require improved facility documentation to allow for an eventual national-level evaluation and assessment of waste management.

The goal of this research question is to emphasize the impact the proposed tool can have on society today. This will clarify who could implement this model and why it is advantageous for them to do so.

Initial Findings and Hypotheses

Interviews with various industry participants have been conducted throughout this thesis to understand what factors are most important to industry and waste management. These interviews lead to the following two hypotheses for this future work:

Hypothesis #1: *The information needed to complete the network would not be difficult to provide, if it were required of the facility*. Much of the information needed to complete a full-scale network of the version in Task 3 is likely already tracked by individual facilities. Knowing the volume or weight of materials sent to different facilities is already recorded for book keeping purposes. Providing this information would ideally create little additional strain to the facilities, but still have a resounding impact on the potential achievements of this research.

Hypothesis #2: *Creating a model that is available to the public will impact how decisions are made in waste management.* If a municipality were to learn that in 10 short years, their local landfill will be the only regional landfill left to service the area, how would they react? Most likely, local government officials and private landfills would be interested in making adjustments in tipping prices and transportation fees to protect their assets from becoming quickly depleted. Today's local governments already often include an in-county and out-of-county standard price for waste disposal. When faced with the impending increase in annual consumption, out-of-county prices may be inflated to the point that it is no longer cost effective for neighboring regions. This would aid in extending the time that the specific city/region has before also needing to transfer waste out-of-county. In addition, higher tipping prices encourage material recycling by closing the cost gap between disposal and recovery processes.

Bio-Inspired Recommendations

Steps to Achieving a Circular Economy

1. Promote Reuse *before* Recycling

The value of detritus in biological ecosystems and the direct effect that this flow and structure has on the detrital actors can be translated into inspiration for the processing of material waste in industry. This helps shift the focus from the more popular waste reduction method of recycling, to the potential value of reuse and byproduct reuse. These underutilized methods hold a potentially greater ability to expand industry's "detrital feedback loop," shifting the current system to a more bio-inspired structure. By-product reuse from this perspective is potentially a highly underutilized and underappreciated asset in creating a close-loop system, supporting future work in identifying secondary applications for common industry by-products.

2. Implement changes to encourage structural changes to the waste management network; Support the development of facilities that can handle various material streams

Based on the principal: function follows form, development must be made towards improving the domestic capabilities of separating and processing facilities if recycling hopes to be a productive method towards achieving a circular economy

In most regions analyzed throughout Task 3 of this thesis, there is no equivalent to the detrital and decomposer actors for the majority of the waste stream volumes. Insufficient regional processing and facility cooperation greatly limits the cyclicity, generalization, and vulnerability values found for the waste management networks. In failing to duplicate the structure of sustainable systems, the waste management networks have been designed to streamline materials for landfill disposal. In consequence, the true MSW recycling rates for these regions (and most regions) are astoundingly poor, which is presumably why most governmental institutions promote the diversion or recovery rate as the recycling rate in place of more realistic values. To improve the structure of these networks and promote circular economy, the development of regional facilities that increase material cycling must be supported.

In addition, landfilling prices that are much lower than recycling prices discourages this behavior from a consumer perspective. Disposal methods should be priced based on their environmental impacts to force a redesign of the waste management structure by influencing consumer behavior.

3. Obligate extended producer responsibility

Much like the nutritional value of detritus contributes to the success of food webs' detrital actors [61-66]. As such, the *quality* of industry waste should be scrutinized as an important element in the ability to implement detrital feedback loops in the recycling industry. One route is through the adoption of an *extended producer responsibility* approach by industry producers, the result of which will be a greater retention of value in the design of products, byproducts, and packaging. This and other industry-based changes will mimic the introduction of high-quality detritus that has shown to positively change food webs. Greater diversity in detritivore-equivalent actors in industry will additionally aid in increasing the cyclicity of materials before they reach end-of-life.

Additionally, the results of the optimization of the aluminum recycling industry achieved its highest levels of cyclicity when a return stream from consumer to manufacturer was included into the network model. Suggesting that the strength and sustainability of the recycling network would be improved with the implementation of these practices.

4. Ban the production of single use products

Packaging makes up nearly one third of the materials thrown away by residences and businesses in the US. The majority of packaging materials are made of paper or plastic; the two lowest value material commodities.

According to the results of Task 2, "Most of plastic waste however cannot be profitably recycled due to low initial quality, rendering the actual savings for all plastics much lower. Recycling plastic does consume less energy than creating new plastic, without a market for recycled plastic there is insufficient motivation to process plastic waste [163]. The implementation of the National Sword policy has made this worse, flooding the plastic recycling market and further reducing the market value of recycled plastic. As a result most plastic waste (80% [181]) is either landfilled or lost, contaminating the environment."

Policy should be implemented to tax, limit, or ban products with limited usefulness that are more likely to end up as nearly immediate waste.

5. Outlaw the exportation of waste to countries with mismanagement

The results of Task 2 discovered that the US indirectly mismanaged more plastic in the *first half of 2017* than it processed domestically for the *entire year of 2017* by exporting waste to counties with high mismanagement values. While the exportation of waste may provide a quick fix to the US's waste problems, all of the countries share in the environmental damage caused by the mismanagement of waste in southeast Asia- for which the US is the largest volume contributor. On May 10, 2019, more than 180 countries agreed to control plastic exportation to developing countries, requiring governmental permissions to gain control of the plastic waste pouring into the world's oceans. However, the US was not one of them.

Meanwhile, the Malaysian minister of energy, technology, science, climate change and environment has pleaded with American's to recognize the impact that the US's waste (alone) is having on her country[7].

With no promising response, many southeast Asian countries have taken matters into their own hands and plan to ban imports of low-quality waste. If the end result is an inevitable loss of exportation options (for the good of the environment) the US should take the initiative to join the countries attempting to protect our oceans and focus on domestic disposal options as well as ban the export of waste to developing countries.

6. Implement regulations on governmental and private enterprises responsible for educating the public preventing misrepresentation of waste statistics

Government enterprises responsible for educating the public are often funded by large corporations, and are generally not made more popular for promoting how poorly the US is succeeding with regards to its *true* recycling rate. However, reports published by these same entities are utilized by governmental decision makers and misleading figures can lead to a detrimental false sense of security.

The material cycling results found in Task 2 through the analysis of the aluminum and plastic recycling network for the *actual* network are **significantly** lower than those calculated with exportation included. By including exportation as recycling, there is a clear and intentional skewing of the system structure. The results of Task 2's comparison with the knowledge of mismanaged waste rates should call into question the legitimacy of the US recycling network as well as the morality standards of the American enterprises responsible for educating the public on the impact of their waste.

Regulations should be made and nomenclature should be used clearly by governing entities responsible for promoting environmental efforts within the US.

7. Develop uniform methods for waste management enterprises within the US and enforce documentation of waste generation by the private sector

The absence of uniform terminology, the confusion surrounding roles of federal and local government, and the inadequacy of enforcement standards all contribute to a considerable amount of waste going unreported in national MSW totals[40]. Equally detrimental is the variations in policy and regulation across state lines which result in uneven comparisons that prevent predictable trends and convenient analysis at a national level [29]. Currently, the lack of empirical data available makes it impossible for anyone to know the extent of environmental impacts resulting from the waste generation created by the US. Much less for the average American to understand where and how their personal waste generation will be disposed of.

In addition, values recorded by the EPA are often used to represent the US waste generation as a whole, when in reality MSW generated waste makes up an estimated value of only 30% of the US waste generation. Private corporations are given the autonomy to operate waste management without disclosing their data.

Without a clear idea of the waste generation, system analysis cannot successfully be applied to the entire system and the US remains ignorant of the generation volumes it may soon need to handle domestically. To benefit waste management and the recycling industry, standards need to be set defining uniform nomenclature and generation volumes should be traceable to better mediate disruptions to the network and predict commodity fulgurations in the future.

Conclusion

The literature review and Tasks 1-4 have provided a broad knowledge base focused on the US waste management system, and have been used to make these biologically inspired recommendations. These recommendations move the US towards developing a zero-waste system, improving the prospects of a truly circular economy in the US.

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APPENDIX A

TASK 1 ADDITIONAL RESOURCES

Appendix A.1: MRF Layout

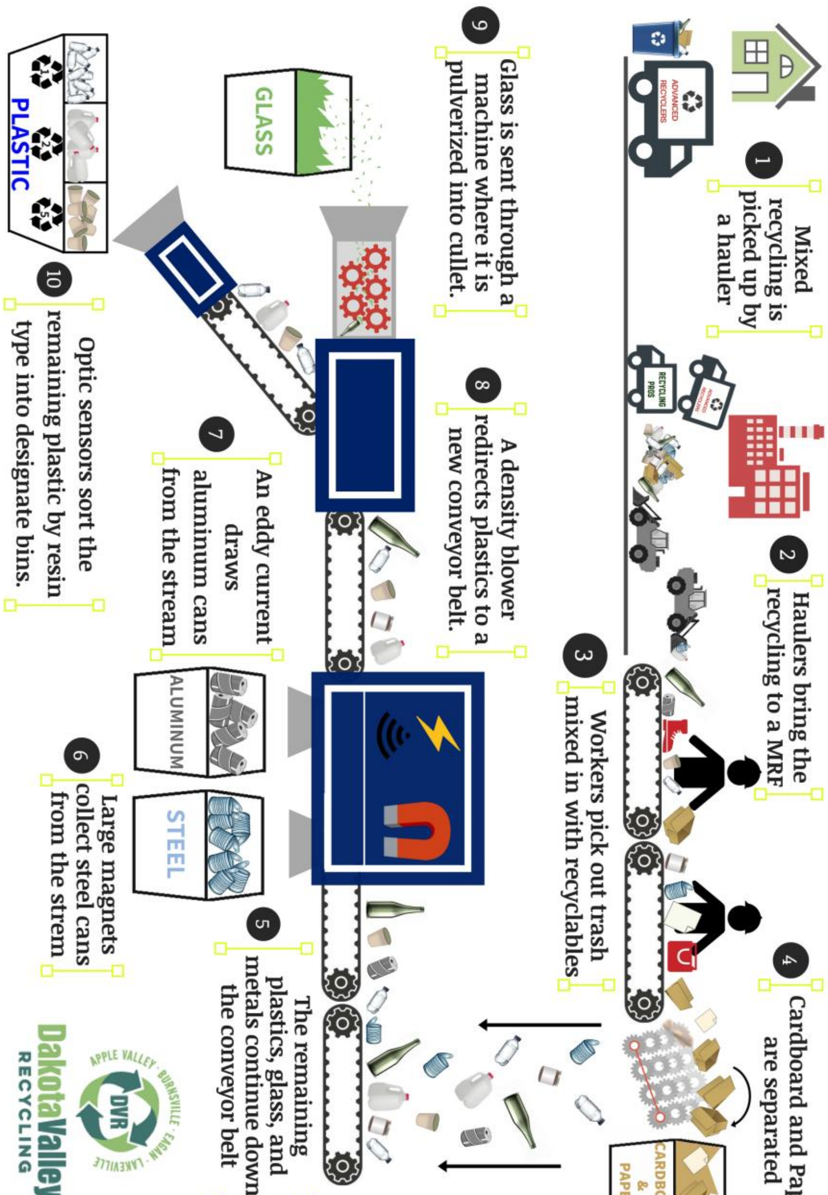

Figure 42: Material Recovery Facility (MRF) Layout [182]**. Used with permission of Dakota Valley Recycling.**

APPENDIX B

TASK 2 ADDITIONAL RESOURCES

Appendix B.1: Non-Ferrous Metal Data

Table 52: Non-Ferrous Metal Information found from various ISRI reports. [139]

2017	processed volume	Import Scrap	Export Scrap	
aluminum	5,268,000	671,946	1,524,346	
copper	1,862,000	165,372	1,004,215	
lead	1,056,000	9,852	57,634	
zinc	67,000	11,825	33,642	
nickel	120,000	33,773	29,994	
Non-Ferrous	>8500000			
	Recovered	**Consumption**	**export from 2018 Year Book**	**2017 World Scrap Trade Export Flow**
aluminum	3,700,000	6,580,000	1,568,000	8,110,129
copper	860,000	2,565,000	1,002,000	5,777,896
lead	1,000,000	1,680,000	56,000	430,426
zinc	67,000	870,000	34,000	327,340
nickel	90,000	231,000	488,000	123,111

Table 53: Assumptions for Runs in MATLAB (version R2016b) done for Aluminum

Assumptions
Scenario 1, Run 1
Consumer sends all 670 thousand tons to MRF MRF receives all its material from the consumer No reuse, by-product reuse, or extended producer responsibility (consumer does not return material to manufacturer
Scenario 2, Run 2
MRF receives material from more than just consumer No reuse, by-product reuse, or extended producer responsibility (consumer does not return material to manufacturer Consumer sends all 670 thousand tons to MRF
Scenario 1, Run 3
Consumer sends all 670 thousand tons to MRF MRF receives all its material from the consumer Reuse permitted as well as consumer return
Scenario 2, Run 4
MRF receives material from more than just consumer Consumer sends all 670 thousand tons to MRF Reuse permitted as well as consumer return
Scenario 1, Run 5
MRF consumes less than consumer produces Reuse permitted as well as consumer return
Scenario 1, Run 6
MRF receives material from more than just consumer, consumer does not send all to MRF Reuse permitted as well as consumer return

Table of info for NF- Metals

Appendix B.3: MATLAB (version R2016b) code used for network optimization

Aluminum

<u>Optimization Script</u>

```
clear
clc
```

```
%demand- what the actor consumes
%supply- what the actor produces
Nd=0; Ns=741;
Md=8245 ; Ms=6580;%Md= demand of M and Ms= supply of Ms
Cd=3610; Cs= 670;
MRF_d=1500; MRF_s=1300;
PRF_d= 5268; PRF_s=3700 ;
Exp_d=2900 ; Exp_s=4800;

demand = [Nd Md Cd MRF_d PRF_d Exp_d];
supply = [Ns Ms Cs MRF_s PRF_s Exp_s];

N=6; %total number of industries

%Equality constraints
k = 1;
for i = 1:N:(N*N)
    for j=0:N-1
        Aeq(k,i+j)=supply(j+1);
    end
    k = k+1;
end
%   N  M  C   Tf  P   I/E
%N  1  7  13  19  25  31
%M  2  8  14  20  26  32
%C  3  9  15  21  27  33
%T  4  10 16  22  28  34
%P  5  11 17  23  29  35
%I  6  12 18  24  30  36

Aeq(k,14)=1;


Aeq(k+1,13)=1; %N does not five to C
Aeq(k+2,19)=1; %N does not send to Tf
Aeq(k+3,25)=1; %N does not send to P
Aeq(k+4,31)=1; %N does not send to I/E
Aeq(k+5,33)=1; %C does not send to exp
Aeq(k+6,10)=1; %MRF does not send to Manufacturer
Aeq(k+7,16)=1; %MRF does not send to Customer
Aeq(k+8,22)=1; %T does not send to T
Aeq(k+9,23)=1; %SMP does not send to MRF
Aeq(k+10,17)=1; %P doesnt sent to C
Aeq(k+11,18)=1; %I doesnt sent to C
Aeq(k+12,36)=1; %Exp does not sent to Imp
Aeq(k+13,29)=1; %P does not sent to P
%Aeq(k+14,21)=1;
%Aeq(k+15,15)=1;     %No consumer reuse
%Aeq(k+16,9)=1;       %No manufacturer return

%Aeq(k+17,8)=1;       %No byproduct reuse
```

```
%%
beq=demand';
beq(k,1)=3610;

beq(k+1,1)=0;
beq(k+2,1)=0;
beq(k+3,1)=0;
beq(k+4,1)=0;
beq(k+5,1)=0;
beq(k+6,1)=0;
beq(k+7,1)=0;
beq(k+8,1)=0;
beq(k+9,1)=0;
beq(k+10,1)=0;
beq(k+11,1)=0;
beq(k+12,1)=0;
beq(k+13,1)=0;
%beq(k+14,1)=670;
%beq(k+15,1)=0;
%beq(k+16,1)=0;

%beq(k+17,1)=0;

%%

%bounds
lb = zeros((N*N),1);
ub = ones((N*N),1);


for j=1:N
    for i=0:N-1
        A(j,j+i*N)=1;
    end
end
b = ones(N,1);

%objective function
f = @(x) Alum(x);
x0 = ones(N*N,1);

%Optimization
options = optimoptions('fmincon','Display','iter','Algorithm','sqp');
[x, fval] = fmincon(f,x0,A,b,Aeq,beq,lb,ub,[],options)

%%
%Analysis
```

```
%Plastic = [x(1) x(6) x(11) x(16) x(21); x(2) x(7) x(12) x(17) x(22);
x(3) x(8) x(13) x(18) x(23); x(4) x(9) x(14) x(19) x(24); x(5) x(10)
x(15) x(20) x(25)];
Alum = [x(1) x(7) x(13) x(19) x(25) x(31); x(2) x(8) x(14) x(20) x(26)
x(32); x(3) x(9) x(15) x(21) x(27) x(33); x(4) x(10) x(16) x(22) x(28)
x(34); x(5) x(11) x(17) x(23) x(29) x(35); x(6) x(12) x(18) x(24) x(30)
x(36)];

for i = 1:N
    for j =1:N
        if Alum(i,j)>0.0001
            D(i,j)=1;
        else
           D(i,j)=0;
        end
    end
end

F =D;
A = F';
n = size(A,1); %number of actors
L = nnz(A); %number of links
prey= sum(F~=0,2); %how many predators eat each prey
Nsprey = sum(prey==1); %Specialized number of preys
Nprey = nnz(prey);  %number of preys
Psprey = Nsprey/Nprey; %specialized prey fraction


predator = sum(F~=0,1);  %how many preys are eaten by each predator
Nspredator = sum(predator==1); %specialized number of predators
Npredator = nnz(predator); %number of predators
Pspredator = Nspredator/Npredator; %specialized predator fraction


PR = Nprey/Npredator; %prey to predator ratio
G = L/Npredator; %Generalization

cyclicity = max(abs(eig(A)));

plot(digraph(F));

%%
%multiplying fraction with output
for i =1:N:N*N
    for j = 1:N
        xy(i+j-1) = x(i+j-1)*supply(j);
    end
end

Alum_real_flow = [xy(1) xy(7) xy(13) xy(19) xy(25) xy(31); xy(2) xy(8)
xy(14) xy(20) xy(26) xy(32); xy(3) xy(9) xy(15) xy(21) xy(27) xy(33);
```

```
xy(4) xy(10) xy(16) xy(22) xy(28) xy(34); xy(5) xy(11) xy(17) xy(23)
xy(29) xy(35); xy(6) xy(12) xy(18) xy(24) xy(30) xy(36)];
```

<u>Function Script</u>

```
function f = Alum(x)
%demand- what the actor consumes
%supply- what the actor produces
Nd=0; Ns=741;
Md=8245 ; Ms=6580;%Md= demand of M and Ms= supply of Ms
Cd=3610; Cs= 670;
MRF_d=1500; MRF_s=1300;
PRF_d= 5268; PRF_s=3700 ;
Exp_d=2900 ; Exp_s=4800;
N=6;

Alum = [x(1) x(7) x(13) x(19) x(25) x(31); x(2) x(8) x(14) x(20) x(26)
x(32); x(3) x(9) x(15) x(21) x(27) x(33); x(4) x(10) x(16) x(22) x(28)
x(34); x(5) x(11) x(17) x(23) x(29) x(35); x(6) x(12) x(18) x(24) x(30)
x(36)];

for i = 1:6
    for j =1:6
        if Alum(i,j)>0.0001
            D(i,j)=1;
        else
           D(i,j)=0;
        end
    end
end

F =D;
A = F';
n = size(A,1); %number of actors
L = nnz(A); %number of links
prey= sum(F~=0,2); %how many predators eat each prey
Nsprey = sum(prey==1); %Specialized number of preys
Nprey = nnz(prey);  %number of preys
Psprey = Nsprey/Nprey; %specialized prey fraction


predator = sum(F~=0,1);  %how many preys are eaten by each predator
Nspredator = sum(predator==1); %specialized number of predators
Npredator = nnz(predator); %number of predators
Pspredator = Nspredator/Npredator; %specialized predator fraction


PR = Nprey/Npredator; %prey to predator ratio
G = L/Npredator; %Generalization

cyclicity = max(abs(eig(A)));
```

```
%target values
cyclicity_target = 4.24;
G_target = 6.18;
Pspred_target = 0.10;
PR_target = 1.09;

f1 = abs(cyclicity-cyclicity_target);
f2 = abs(G-G_target);
f3 = abs(Pspredator - Pspred_target);
f4 = abs(PR- PR_target);
f = f1;
end
```

Plastic

Optimization Script

```
clear
clc

%demand- what the actor consumes
%supply- what the actor produces
Nd=0; Ns=56487;
Md=55000 ; Ms=34830;%Md= demand of M and Ms= supply of Ms
Cd= 34500; Cs=31400;
MRF_d=4000 ; MRF_s=2000 ;
PRF_d= 1400; PRF_s=1300 ;
MPRF_d=1400; MPRF_s=1300;
Exp_d=1667.7 ; Exp_s=390;


demand = [Nd Md Cd MRF_d PRF_d MPRF_d Exp_d];
supply = [Ns Ms Cs MRF_s PRF_s MPRF_s Exp_s];

N=7; %total number of industries

%Equality constraints
k = 1;
for i = 1:N:(N*N)
    for j=0:N-1
        Aeq(k,i+j)=supply(j+1);
    end
    k = k+1;
end

%   N  M  C   Tf  P   MP  I/E
%N  1  8  15  22  29  36  43
```

```
%M  2  9  16  23  30  37  44
%C  3  10 17  24  31  38  45
%T  4  11 18  25  32  39  46
%P  5  12 19  26  33  40  47
%MP 6  13 20  27  34  41  48
%I  7  14 21  28  35  42  49

Aeq(k,2)=1;
Aeq(k,3)=1;
Aeq(k,4)=1;
Aeq(k,5)=1;
Aeq(k,6)=1;
Aeq(k,7)=1;

Aeq(k+1,15)=1; %N does not five to C
Aeq(k+2,22)=1; %N does not send to Tf
Aeq(k+3,29)=1; %N does not send to P
Aeq(k+4,36)=1; %N does not send to I/E
Aeq(k+5,45)=1; %C does not send to exp
Aeq(k+6,31)=1; %C does not sent to P
Aeq(k+7,32)=1; %C does not sent to MP
Aeq(k+8,25)=1; %T does not send to T
Aeq(k+9,11)=1; %T does not sent to M
Aeq(k+10,18)=1; %T does not sent to C
Aeq(k+11,26)=1; %P does not send to TF
Aeq(k+12,19)=1; %P does not sent to C
Aeq(k+13,33)=1; %P does not sent to P
Aeq(k+14,27)=1; %MP does not send to T
Aeq(k+15,28)=1; %exp does not sent to T
Aeq(k+16,49)=1; % exp does not sent to imp
Aeq(k+17,20)=1; %MP does not send to C
Aeq(k+18,49)=1; %imp does not send to C
Aeq(k+19,13)=1; %MP doesnt send to M
Aeq(k+20,23)=1;     %M does not sent to TF
Aeq(k+21,10)=1;       %No manufacturer return
%
Aeq(k+22,21)=1;       %exp does not send to C
% Aeq(k+23,17)=1;       %No Consumer reuse
% Aeq(k+24,9)=1;       %No byproduct reuse
%%
beq=demand';
beq(k,1)=0;

beq(k+1,1)=0;
beq(k+2,1)=0;
beq(k+3,1)=0;
beq(k+4,1)=0;
beq(k+5,1)=0;
beq(k+6,1)=0;
beq(k+7,1)=0;
beq(k+8,1)=0;
beq(k+9,1)=0;
beq(k+10,1)=0;
```

```
beq(k+11,1)=0;
beq(k+12,1)=0;
beq(k+13,1)=0;
beq(k+14,1)=0;
beq(k+15,1)=0;
beq(k+16,1)=0;

beq(k+17,1)=0;
beq(k+18,1)=0;

beq(k+19,1)=0;
beq(k+20,1)=0;
beq(k+21,1)=0;
beq(k+22,1)=0;
% beq(k+23,1)=0;
% beq(k+24,1)=0;
%%

%bounds
lb = zeros((N*N),1);
ub = ones((N*N),1);


for j=1:N
    for i=0:N-1
        A(j,j+i*N)=1;
    end
end
b = ones(N,1);

%objective function
f = @(x) Plasticc(x);
x0 = ones(N*N,1);

%Optimization
options = optimoptions('fmincon','Display','iter','Algorithm','sqp');
[x, fval] = fmincon(f,x0,A,b,Aeq,beq,lb,ub,[],options)

%%
%Analysis
%Plastic = [x(1) x(6) x(11) x(16) x(21); x(2) x(7) x(12) x(17) x(22);
x(3) x(8) x(13) x(18) x(23); x(4) x(9) x(14) x(19) x(24); x(5) x(10)
x(15) x(20) x(25)];
Plasticc = [x(1) x(8) x(15) x(22) x(29) x(36) x(43); x(2) x(9) x(16)
x(23) x(30) x(37) x(44); x(3) x(10) x(17) x(24) x(31) x(38) x(45); x(4)
x(11) x(18) x(25) x(32) x(39) x(46); x(5) x(12) x(19) x(26) x(33) x(40)
x(47); x(6) x(13) x(20) x(27) x(34) x(41) x(48); x(7) x(14) x(21) x(28)
x(35) x(42) x(49)];

for i = 1:N
    for j =1:N
        if Plasticc(i,j)>0.0001
```

```
            D(i,j)=1;
        else
            D(i,j)=0;
        end
    end
end

F =D;
A = F';
n = size(A,1); %number of actors
L = nnz(A); %number of links
prey= sum(F~=0,2); %how many predators eat each prey
Nsprey = sum(prey==1); %Specialized number of preys
Nprey = nnz(prey);  %number of preys
Psprey = Nsprey/Nprey; %specialized prey fraction


predator = sum(F~=0,1);  %how many preys are eaten by each predator
Nspredator = sum(predator==1); %specialized number of predators
Npredator = nnz(predator); %number of predators
Pspredator = Nspredator/Npredator; %specialized predator fraction


PR = Nprey/Npredator; %prey to predator ratio
G = L/Npredator; %Generalization

cyclicity = max(abs(eig(A)));

plot(digraph(F));

%%
%multiplying fraction with output
for i =1:N:N*N
    for j = 1:N
        xy(i+j-1) = x(i+j-1)*supply(j);
    end
end

Plasticc_real_flow = [xy(1) xy(8) xy(15) xy(22) xy(29) xy(36) xy(43);
xy(2) xy(9) xy(16) xy(23) xy(30) xy(37) xy(44); xy(3) xy(10) xy(17)
xy(24) xy(31) xy(38) xy(45); xy(4) xy(11) xy(18) xy(25) xy(32) xy(39)
xy(46); xy(5) xy(12) xy(19) xy(26) xy(33) xy(40) xy(47); xy(6) xy(13)
xy(20) xy(27) xy(34) xy(41) xy(48); xy(7) xy(14) xy(21) xy(28) xy(35)
xy(42) xy(49)];
```

Function Script

```
function f = Plasticc(x)
%demand- what the actor consumes
%supply- what the actor produces
```

```
Nd=0; Ns=56487;
Md=60000 ; Ms=34830;%Md= demand of M and Ms= supply of Ms
Cd= 34500; Cs=31400;
MRF_d=4000 ; MRF_s=2000 ;
PRF_d= 1300; PRF_s=1400 ;
MPRF_d=1300; MPRF_s=1400;
Exp_d=120 ; Exp_s=2000;


N=7;

Plasticc = [x(1) x(8) x(15) x(22) x(29) x(36) x(43); x(2) x(9) x(16)
x(23) x(30) x(37) x(44); x(3) x(10) x(17) x(24) x(31) x(38) x(45); x(4)
x(11) x(18) x(25) x(32) x(39) x(46); x(5) x(12) x(19) x(26) x(33) x(40)
x(47); x(6) x(13) x(20) x(27) x(34) x(41) x(48); x(7) x(14) x(21) x(28)
x(35) x(42) x(49)];

for i = 1:7
    for j =1:7
        if Plasticc(i,j)>0.0001
            D(i,j)=1;
        else
           D(i,j)=0;
        end
    end
end

F =D;
A = F';
n = size(A,1); %number of actors
L = nnz(A); %number of links
prey= sum(F~=0,2); %how many predators eat each prey
Nsprey = sum(prey==1); %Specialized number of preys
Nprey = nnz(prey);  %number of preys
Psprey = Nsprey/Nprey; %specialized prey fraction


predator = sum(F~=0,1);  %how many preys are eaten by each predator
Nspredator = sum(predator==1); %specialized number of predators
Npredator = nnz(predator); %number of predators
Pspredator = Nspredator/Npredator; %specialized predator fraction


PR = Nprey/Npredator; %prey to predator ratio
G = L/Npredator; %Generalization

cyclicity = max(abs(eig(A)));


%target values
cyclicity_target = 4.24;
```

```
G_target = 6.18;
Pspred_target = 0.10;
PR_target = 1.09;

f1 = abs(cyclicity-cyclicity_target);
f2 = abs(G-G_target);
f3 = abs(Pspredator - Pspred_target);
f4 = abs(PR- PR_target);
f = f1;
end
```

Appendix B.4: Additional Results

Table 54: Flow matrices generated when considering the aluminum recycling industry in run 1-6

Run 1	N	M	C	TF	P	Imp/Exp
N	0.0	741.0	0.0	0.0	0.0	0.0
M	0.0	0.0	3610.0	0.0	4318.6	2183.4
C	0.0	0.0	0.0	600.0	70.0	0.0
TF	0.0	0.0	0.0	0.0	308.9	291.1
P	0.0	3274.6	0.0	0.0	0.0	425.4
Imp/Exp	0.0	4229.4	0.0	0.0	570.6	0.0
Run 2	N	M	C	TF	P	Imp/Exp
N	0.0	741.0	0.0	0.0	0.0	0.0
M	0.0	0.0	3610.0	830.0	4005.3	1866.7
C	0.0	0.0	0.0	670.0	0.0	0.0
TF	0.0	0.0	0.0	0.0	691.7	608.3
P	0.0	3274.9	0.0	0.0	0.0	425.1
Imp/Exp	0.0	4229.1	0.0	0.0	570.9	0.0
Run 3	N	M	C	TF	P	Imp/Exp
N	0.0	741.0	0.0	0.0	0.0	0.0
M	0.0	2860.5	3610.0	0.0	2597.8	1043.7
C	0.0	36.4	0.0	600.0	33.6	0.0
TF	0.0	0.0	0.0	0.0	306.5	293.5
P	0.0	2137.2	0.0	0.0	0.0	1562.8
Imp/Exp	0.0	2469.9	0.0	0.0	2330.1	0.0
Run 4	N	M	C	TF	P	Imp/Exp
N	0.0	741.0	0.0	0.0	0.0	0.0
M	0.0	3092.7	3610.0	180.9	2629.9	798.5
C	0.0	0.0	0.0	670.0	0.0	0.0
TF	0.0	0.0	0.0	0.0	685.7	614.3
P	0.0	2212.7	0.0	0.0	0.0	1487.3

Table 54 Continued..						
Imp/Exp	0.0	2198.6	0.0	649.1	1952.3	0.0
Run 5	N	M	C	TF	P	Imp/Exp
	0.0	741.0	0.0	0.0	0.0	0.0
	0.0	2860.5	3610.0	0.0	2597.8	1043.7
	0.0	236.4	0.0	200.0	233.7	0.0
	0.0	0.0	0.0	0.0	306.5	293.5
	0.0	2137.2	0.0	0.0	0.0	1562.8
	0.0	2269.9	0.0	400.0	2130.1	0.0
Run 6	N	M	C	TF	P	Imp/Exp
N	0.0	741.0	0.0	0.0	0.0	0.0
M	0.0	2954.8	3610.0	484.9	2484.7	777.5
C	0.0	233.5	0.0	207.9	228.6	0.0
TF	0.0	0.0	0.0	0.0	683.3	616.7
P	0.0	2194.2	0.0	0.0	0.0	1505.8
Imp/Exp	0.0	2121.5	0.0	807.2	1871.3	0.0

APPENDIX C

TASK 3 ADDITIONAL RESOURCES

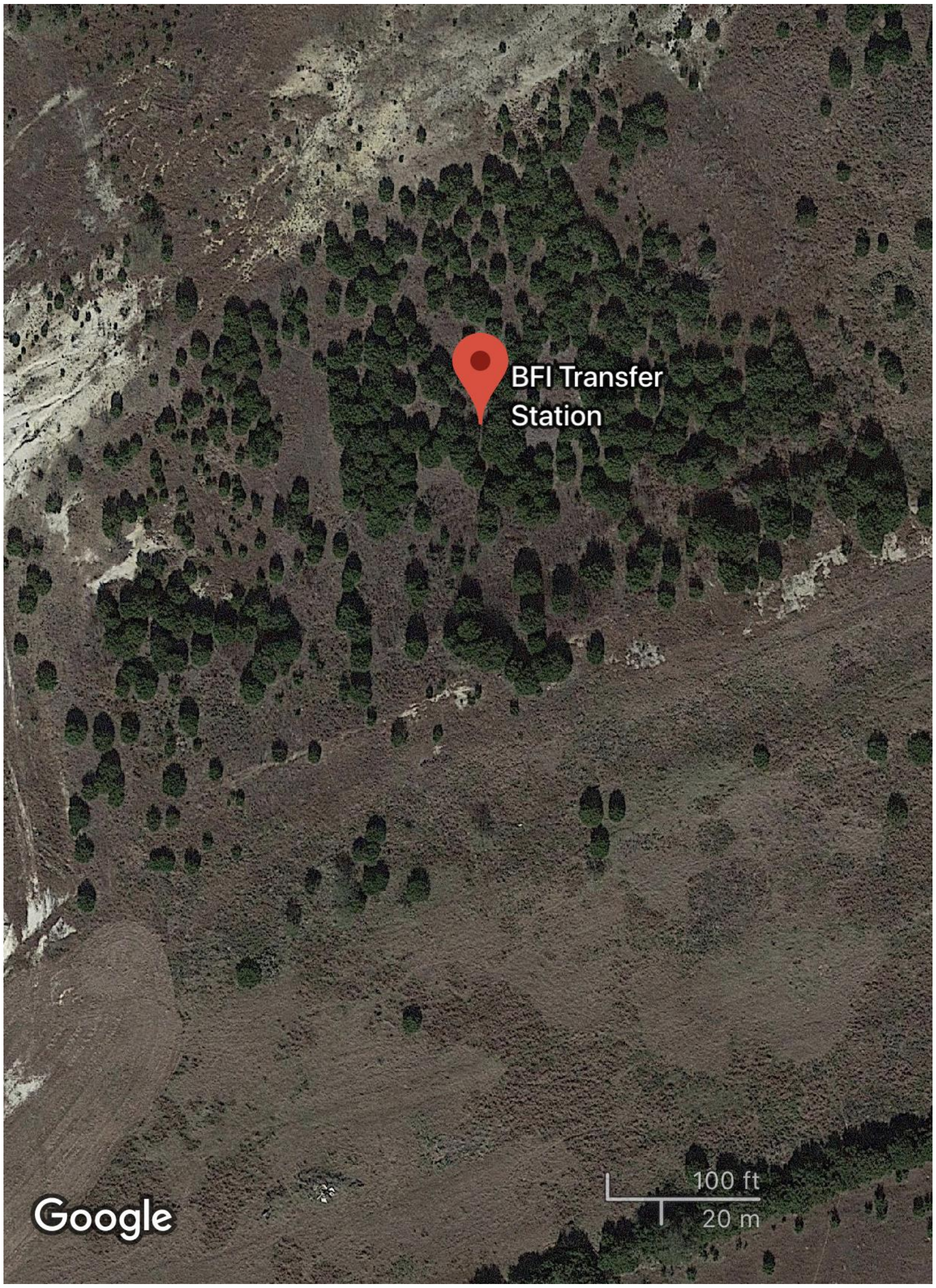

Figure 43: Example of Location listed incorrectly

APPENDIX D

TASK 4 ADDITIONAL RESOURCES

Appendix D.1 MATLAB (version R2016b) code for calculating ecological Metrics

Flow Metrics Code

```
%T = xlsread('redoo.xlsx', 'Sheet4', 'A1:R18')
%T = xlsread('redoo.xlsx', 'Sheet6', 'A1:T20')
%T = xlsread('redoo.xlsx', 'Sheet3', 'A1:S19')
T = xlsread('yikes.xlsx', 'Sheet6', 'A1:G7')


%food web matrix (structural matrix) from the flow matrix, flow is
represented row to columns (i to j)
N = size(T,1)-3;
F = T([2:N+1],:);
F = F(:,[2:N+1]);
F(F>0)=1;

%total system throughput
TSTp = sum(sum(T));

T_colsum = sum(T,1);
Q_colsum=T_colsum/TSTp;
T_rowsum=sum(T,2);
Q_rowsum = T_rowsum/TSTp;

%Host Coefficient Matrix [HC]
HC = diag(1./sum(T,2))*T;
HC(isnan(HC))=0;
HC_trans = HC';

%ascendency
A=log2((HC)./(Q_colsum));
A(isinf(A))=0;
A(isnan(A))=0;
ASC = sum(sum(T.*A));

%average mutual information
AMI = ASC/TSTp;

%development capactiy
B = Q_rowsum.*log2(Q_rowsum);
B(isnan(B))=0;
DC = -1*TSTp*sum(B(1:N+1));

%internal development capacity
DCi = -TSTp*sum(B(2:N+1));
```

```
%shannon index
H = DC/TSTp;

%total system overhead
TSO = DC - ASC;

%nondimensional total system overhead
Hc = TSO/TSTp;

To = T(1,:);
To_sum = sum(To);
Te = T(:,N+2);
Te_sum = sum(Te);
Ts = T(:,N+3);
Ts_sum = sum(Ts);

%imports system overhead
AA =
HC_trans(:,1).*Q_rowsum(1).*(log2(HC_trans(:,1).*((Q_rowsum(1))./(Q_col
sum'))));
AA(isnan(AA))=0;
TSOo = -TSTp*sum(AA);

%exports system overhead
AAA =
HC(:,N+2).*Q_rowsum.*(log2(HC(:,N+2).*(Q_rowsum./(Q_colsum(N+2)))));
AAA(isnan(AAA))=0;
TSOe = -TSTp*sum(AAA(2:N+1));

%dissipation system overhead
BB =
HC(:,N+3).*Q_rowsum.*(log2(HC(:,N+3).*(Q_rowsum./(Q_colsum(N+3)))));
BB(isnan(BB))=0;
TSOs = -TSTp*sum(BB(2:N+1));

%internal system overhead
TSOi = TSO - TSOo - TSOe - TSOs;

%exports ascendency
EE=HC(:,N+2).*Q_rowsum.*log2(Q_rowsum);
EE(isnan(EE))=0;
E = -TSTp*sum(EE);
ASCe = E - TSOe;

%dissipation ascendency
SS=HC(:,N+3).*Q_rowsum.*log2(Q_rowsum);
SS(isnan(SS))=0;
S = -TSTp*sum(SS);
ASCs = S - TSOs;
```

```
%internal ascendency
ASCi = DCi - E - S - TSOi;

%imports ascendency
ASCo = ASC - ASCi - ASCe - ASCs;

%Fractional Inflow Matrix [G]
G = T(2:N+1,2:N+1)./T_colsum(2:N+1);

%Output Structure Matrix [S]
I = eye(N);
S = (I - HC(2:N+1,2:N+1))^-1;
S_diag = S.*I;

%Leontief Inverse Matrix [L]
L = (I - G)^(-1);
Cmatrix = (S_diag-I)./S_diag;
Cmatrix(isnan(Cmatrix))=0;
%cycling and non-cycling versions of [L]
Lc = Cmatrix*L;
Lnc = L - Lc;

%Equivalent Trophic Position (ETP) of each actor:
ETP = sum(L,1);

%cycling total system throughput (TSTp,c)
CC = T_colsum(1,2:N+1).*((S_diag-I)./S_diag);
CC(isnan(CC))=0;
TSTpc = sum(sum(CC));

%Finn Cycling Index (FCI)
FCI = TSTpc/TSTp;

%Robustness (R) uses natural log
R = -(ASC/DC)*log(ASC/DC);

%Comprehensive Cycling Index (CCI)
M = zeros(4,1);

M = [R; FCI; Hc; H];

xlswrite('yikes.xlsx',M,'Sheetrec6')
```

Convert Flow to Structure

```
function F = flow_to_struc(T)

N = size(T,1);
```

```
A = T(2:N-2,2:N-2);

Z = size(A,1);

F = 0;

for i = 1:Z

    for j = 1:Z

        if  A(i,j) ~= 0
            F(i,j) = 1;

        else
            F(i,j) = 0;

        end
    end
end
```

Structural Metrics

```
function[lambda_max,N,L,Ld,G,V,Co,Pr,Prs,Pre,As,Ae,Prey_s,Pred_s,Prey_e
,Pred_e]=structural_metrics(ST)

f=ST;

%foodweb to adjacency matrix
fb=f';

%cyclicity
lambda_max=max(real(eigs(fb)));

%Number of species
N=size(f,1);

%Number of links
L=nnz(f);

%number of prey
np=0;
for x=1:N
  if  fb(:,x)==0     % if the entire column is zero, then it means that
actor is not a prey
      np=np+1;
  end
end
nprey=N-np; % subtracting number of actors that are not prey from total
number of actors gives the number of prey
```

```
%number of predators
npred=0;
for y=1:N
   if  fb(y,:)==0   % if the entire row is zero, then it means that
actor is not a predator
       npred=npred+1;
  end
end
npredator=N-npred;  % subtracting number of actors that are not
predators from total number of actors gives the number of predators

%number of specialized prey
%number of specialized predators
%number of double specialized actors
nsprey = 0;
nspred = 0;
ndspec = 0;

for z = 1:size(f,1)
     m(z) =  nnz(f(z,:));

     if m(z) == 1
         nsprey = nsprey +1;
     end

end

for p = 1:size(f,1)
     q(p) =  nnz(f(:,p));

     if q(p) == 1
         nspred = nspred +1;
     end

end

for n = 1:size(f,1)

    if m(n) == 1 && q(n) == 1
        ndspec = ndspec + 1;
    end
end


%number of exclusive prey
nep=0;
for o= 1:size(f,1)
    if columncheck(f,o) && rowcheck(f,o)    %columncheck function tests
if that column is all zeros and rowcheck tests if there is atleast one
non-zero element in that row meaning that actor is an exclusive prey
```

```
            nep=nep+1;
    end
end
neprey=nep;

%number of exclusive predators
nepr=0;
for r= 1:size(f,1)
    if rowcheck1(f,r) && columncheck1(f,r)  %rowcheck1 tests if that
row is all zeros and columncheck1 tests if there is atleast one non-
zero element in that column meaning that actor is an exclusive predator
            nepr=nepr+1;
    end
end
nepredator=nepr;


% Cyclicity %
lambda_max


% #Species %
N;


% #Links %
L;


% Link Density%
Ld=L./N


% #Prey %
nprey;


% #Predator %
npredator;


% Prey to predator ratio %
Pr=nprey./npredator


% Generalization %
G=L./nprey


% Vulnerability %
```

```
V=L./npredator


% Connectance %
Co=L./(N.^2)


% #Specialized prey %
nsprey;
%Specialized prey fraction
Prey_s = nsprey./npredator;

% #Specialized predators %
nspred;
% Specialized predator fraction %
Pred_s=nspred./npredator;

% #double specialized actors%
ndspec;
% #Specialized actors %
Nspec=nsprey+nspred-ndspec;
% Specialized actor fraction %
As=Nspec./N;

% Specialized prey to specialized predator ratio %
Prs=nsprey./nspred;


% #Exclusive prey %
neprey;
% Exclusive prey fraction %
Prey_e=neprey./npredator;

% #Exclusive predators %
nepredator;
% Exclusive predator fraction %
Pred_e=nepredator./npredator;

% #Exclusive actors %
Nexcl=neprey+nepredator;
% Exclusive actor fraction %
Ae=Nexcl./N;


% Exclusive prey to exclusive predator ratio %
Pre=neprey./nepredator;

end
```

Additional Function Files Needed

Column Check

```
function g=columncheck(a,i)
g=0;
count=0;
for j=1:size(a,2)
            if a(j,i)==0
                count=count+1;
            end
end
    if count==size(a,1)
        g=1;
    end
end
```

Column Check 1

```
function r=columncheck1(a,i)
r=0;
for j=1:size(a,1)
            if a(j,i)==1
                r=1;
                break
            end
end
end
```

Row Check

```
function f=rowcheck(a,i)
f=0;
for j=1:size(a,1)
            if a(i,j)==1
                f=1;
                break
            end
end
end
```

Row Check 1

```
function p=rowcheck1(a,i)
p=0;
count=0;
for j=1:size(a,1)
            if a(i,j)==0
```

```
                    count=count+1;
                end
    end
        if count==size(a,1)
            p=1;
        end
    end
```

Organized COG Data

		Identification
COG #	**Permit Number**	**Facility Name**
12	2260A	STERICYCLE
12	2300	IESI BLANCO COUNTY TRANSFER STATION
12	40035	BFI BURNET TRANSFER STATION
12	1787	HAYS COUNTY TRANSFER STATION
12	119	TEXAS DISPOSAL SYSTEM ECO DEPOT
12	2250	LIQUID ENVIRONMENTAL SOLUTIONS OF TEXAS
12	2310	J-V DIRT + LOAM
12	2250	LIQUID ENVIRONMENTAL SOLUTIONS OF TEXAS

		Identification
COG #	Permit Number	Facility Name
12	2250	LIQUID ENVIRONMENTAL SOLUTIONS OF TEXAS
12	2310	J-V DIRT + LOAM
12	2384	AUSTIN WASTEWATER PROCESSING FACILITY
12	40212	TOM DYE CONTRACTOR
12	40243	RIVER CITY ROLLOFFS
12	42016	TEXAS ORGANIC RECOVERY
12	466A	CITY OF GEORGETOWN TRANSFER STATION
12	2123	TEXAS DISPOSAL SYSTEMS LANDFILL
12	1841A	IESI TRAVIS COUNTY LANDFILL
12	249D	WASTE MANAGEMENT OF TEXAS AUSTIN COMMUNITY RECYCLING & DISPOSAL FACILITY
12	1405B	WILLIAMSON COUNTY RECYCLING AND DISPOSAL FACILITY
Subtotal		

		Identification	
COG #	**Permit Number**	**Facility Type**	**County Name**
12	2260A	P_AC	BASTROP
12	2300	TF_I	BLANCO
12	40035	TF_I	BURNET
12	1787	TF_I	HAYS
12	119	TF_I	TRAVIS
12	2250	P_LQ	TRAVIS
12	2310	P_RC	TRAVIS
12	2384	P_LQ	TRAVIS
12	40212	TF_LQ	TRAVIS
12	40243	P_RR	TRAVIS
12	42016	P_RC	TRAVIS
12	466A	TF_I	WILLIAMSON
12	2123	LF_RC_DV	TRAVIS
12	1841A	LF_DV	TRAVIS
12	249D	LF_IX_DV	TRAVIS
12	1405B	LF_CHGR_DV	WILLIAMSON
Subtotal			

		Facility Fees				
COG #	Permit Number	Was Waste or Feedstock Measured by Weight?	Was Waste or Feedstock Measured by Volume?	By Tons	By Gallon	By Pound
12	2260A	YES	NO	-	-	-
12	2300	NO	YES	-	-	-
12	40035	NO	YES	-	-	-
12	1787	NO	YES	-	-	-
12	119	NO	YES	-	-	-
12	2250	NO	YES	-	0.3	-
12	2310	YES	YES	28	0.1	-
12	2384	NO	YES	-	0.1	-
12	40212	NO	YES	-	-	-
12	40243	YES	YES	-	-	-
12	42016	NO	YES	-	0.1	-
12	466A	YES	YES	40	-	-
12	2123	YES	YES	45	-	-
12	1841A	YES	YES	31	-	-
12	249D	YES	NO	29	-	-
12	1405B	YES	NO	34	-	-
Subtotal				**207**	**0.5**	**-**

		Facility Fees		
COG #	Permit Number	By Compacted CY	By UnCompacted CY	Counties Served
12	2260A	-	-	Bastrop, Bell, Blanco, Burnet, Caldwell, Llano, Travis, Williamson
12	2300	30	30	Blanco, Burnet, Hays, Llano, Travis, Williamson
12	40035	-	35	Burnet, Llano
12	1787	15	25	Hays,Travis
12	119	-	40	Burnet, Hays, Llano, Travis, Williamson
12	2250	-	-	Bastrop, Bell, Blanco, Caldwell, Hays, Llano, Travis, Williamson
12	2310	-	15	Bastrop, Burnet, Hays, Travis, Williamson
12	2384	-	-	Bastrop, Bell, Blanco, Burnet, Caldwell, Hays, Llano, Travis, Williamson
12	40212	-	-	Hays, Travis
12	40243	-	-	Bastrop, Hays, Travis, Williamson
12	42016	-	10	Bastrop, Blanco, Burnet,Caldwell, Hays, Travis, Williamson
12	466A	-	26	Bell, Burnet,Travis, Williamson
12	2123	-	10	Bastrop, Bell, Burnet,Caldwell, Llano, Williamson
12	1841A	-	21	Bastrop, Blanco, Caldwell, Hays, Travis, Williamson
12	249D	-	-	Bastrop, Burnet, Hays, Llano, Travis, Williamson
12	1405B	-	-	Bell, Burnet, Travis, Williamson
Subtotal		**45**	**211**	

COG #	Permit Number	Total Counties Served	DV	AutoClave Total	Composting Total	Chipping/ Grinding Total
12	2260A	48	0	6830	0	0
12	2300	10	0	0	0	0
12	40035	2	0	0	0	0
12	1787	3	295	0	0	0
12	119	5	1739.5	0	0	0
12	2250	19	0	0	0	0
12	2310	5	0	0	183784	0
12	2384	19	0	0	0	0
12	40212	2	0	0	0	0
12	40243	4	28509.9	0	0	427.39
12	42016	15	0	0	8660.32	0
12	466A	5	11361.4	0	0	702
12	2123	24	149942.7	0	44887.32	0
12	1841A	10	23549.4	0	0	0
12	249D	7	0.4	0	0	0
12	1405B	5	261.7	0	0	4680.79
Subtotal		**183**	**215,660**	**6,830**	**237,332**	**5,810**

			Solid Waste Transfer	
COG #	**Permit Number**	**LWT Total Tons**	**Municipal In State**	**Municipal Out State**
12	2260A	0	0	0
12	2300	0	18608	0
12	40035	0	30267.4	0
12	1787	0	555.65	0
12	119	0	7314.94	0
12	2250	53646	0	0
12	2310	0	0	0
12	2384	87063	0	0
12	40212	147	0	0
12	40243	0	0	0
12	42016	0	0	0
12	466A	0	59960.15	0
12	2123	0	0	0
12	1841A	0	0	0
12	249D	0	0	0
12	1405B	0	0	0
Subtotal		**140,856**	**116,706**	**-**

		Solid Waste Transfer				
COG #	Permit Number	Municipal_ Total	Industrial_ Total	Brush_ Total	Construction Demo_Total	Total Tons Total
12	2260A	0	0	0	0	1390
12	2300	18608	0	0	185	18793
12	40035	30267.4	0	0	52	30319
12	1787	555.65	0	0	1232.01	1788
12	119	7314.94	0	0	167	7482
12	2250	0	0	0	0	0
12	2310	0	0	0	0	0
12	2384	0	0	0	0	0
12	40212	0	0	0	0	0
12	40243	0	0	0	5741.41	5741
12	42016	0	0	0	0	0
12	466A	59960.15	0	0	13386.84	73347
12	2123	0	0	0	0	0
12	1841A	0	0	0	0	0
12	249D	0	0	0	0	0
12	1405B	0	0	0	0	0
Subtotal		**116,706**	**-**	**-**	**20,764**	**138,860**

COG #	**Permit Number**	**Grease Total**	**Septage Total**	**Total Tons Total**
12	2260A	0	0	-
12	2300	0	0	-
12	40035	0	0	-
12	1787	0	0	-
12	119	0	0	-
12	2250	237	0	11,241
12	2310	0	0	-
12	2384	0	0	-
12	40212	0	146.63	147
12	40243	0	0	-
12	42016	0	0	-
12	466A	0	0	-
12	2123	0	0	-
12	1841A	0	0	-
12	249D	0	0	-
12	1405B	0	0	-
Subtotal		**237**	**147**	**11,388**

		Landfill Specific Data			
COG #	Permit Number	Muncipal_ Total	Brush_ Total	Construction_ Demo_Total	MedicalWaste_ Total
12	2260A	-	-	-	-
12	2300	-	-	-	-
12	40035	-	-	-	-
12	1787	-	-	-	-
12	119	-	-	-	-
12	2250	-	-	-	-
12	2310	-	-	-	-
12	2384	-	-	-	-
12	40212	-	-	-	-
12	40243	-	-	-	-
12	42016	-	-	-	-
12	466A	-	-	-	-
12	2123	846,060	-	15	-
12	1841A	-	-	190,435	-
12	249D	715,248	-	250,625	-
12	1405B	280,974	4,681	121,122	-
Subtotal		**1,842,281**	**4,681**	**562,197**	**-**

		Landfill Specific Data			
COG #	Permit Number	Sludge_ Total	GreaseTrap_ Total	Septage_ Total	IncineratorAsh_ Total
12	2260A	-	-	-	-
12	2300	-	-	-	-
12	40035	-	-	-	-
12	1787	-	-	-	-
12	119	-	-	-	-
12	2250	-	-	-	-
12	2310	-	-	-	-
12	2384	-	-	-	-
12	40212	-	-	-	-
12	40243	-	-	-	-
12	42016	-	-	-	-
12	466A	-	-	-	-
12	2123	458	-	-	-
12	1841A	-	-	-	-
12	249D	2,069	-	-	-
12	1405B	7,919	-	-	-
Subtotal		**10,446**	**-**	**-**	**-**

		Landfill Specific Data		
COG #	Permit Number	Total Tons_ Total	A) Total Tons Disposed	B) Estimated Compaction Rate (lbs/yd3)
12	2260A	-	-	-
12	2300	-	-	-
12	40035	-	-	-
12	1787	-	-	-
12	119	-	-	-
12	2250	-	-	-
12	2310	-	-	-
12	2384	-	-	-
12	40212	-	-	-
12	40243	-	-	-
12	42016	-	-	-
12	466A	-	-	-
12	2123	848,106	848,106	1,360
12	1841A	190,435	190,435	1,200
12	249D	999,836	999,836	1,500
12	1405B	418,944	418,944	1,450
Subtotal		**2,457,321**	**2,457,321**	**5,510**

		Landfill Specific Data		
COG #	Permit Number	H) Current FY's Remaining Capacity (yd3)	I) FY's Remaining Capacity (Tons)	J) Remaining Years at Current Performance (years)
12	2260A	-	-	-
12	2300	-	-	-
12	40035	-	-	-
12	1787	-	-	-
12	119	-	-	-
12	2250	-	-	-
12	2310	-	-	-
12	2384	-	-	-
12	40212	-	-	-
12	40243	-	-	-
12	42016	-	-	-
12	466A	-	-	-
12	2123	20,365,129	13,848,288	16
12	1841A	2,042,605	1,225,563	6
12	249D	10,297,663	7,723,247	11
12	1405B	59,405,152	43,068,735	113
Subtotal		**92,110,549**	**65,865,833**	**146**

		LGR Facility Information		
COG #	**Permit Number**	**LF Authorization No. where facility is located**	**Estimated Annual Gas Processed (ft3)**	**Estimated Annual Gas Distributed Off-Site (ft3)**
12	2260A	-	-	
12	2300	-	-	
12	40035	-	-	
12	1787	-	-	
12	119	-	-	
12	2250	-	-	
12	2310	-	-	
12	2384	-	-	
12	40212	-	-	
12	40243	-	-	
12	42016	-	-	
12	466A	-	-	
12	2123	-	-	
12	1841A	-	-	
12	249D	249D	1,399,677,000	
12	1405B	-	-	
Subtotal		**-**	**1,399,677,000**	**-**

		LGR Facility Information		
COG #	Permit Number	Power Generated and Sold this FY (kWh)	Power Generated and Used on Site (kWh)	Estimated Annual Gas Processed (ft3)
12	2260A			N/A
12	2300			N/A
12	40035			N/A
12	1787			N/A
12	119			N/A
12	2250			N/A
12	2310			N/A
12	2384			N/A
12	40212			N/A
12	40243			N/A
12	42016			N/A
12	466A			N/A
12	2123			N/A
12	1841A			N/A
12	249D			N/A
12	1405B			N/A
Subtotal		-	-	

COG #	Permit Number	Estimated Annual Gas Distributed Off-Site (ft3)	Power Generated and Sold this FY (kWh)	Power Generated and Used on Site (kWh)
12	2260A	N/A	N/A	N/A
12	2300	N/A	N/A	N/A
12	40035	N/A	N/A	N/A
12	1787	N/A	N/A	N/A
12	119	N/A	N/A	N/A
12	2250	N/A	N/A	N/A
12	2310	N/A	N/A	N/A
12	2384	N/A	N/A	N/A
12	40212	N/A	N/A	N/A
12	40243	N/A	N/A	N/A
12	42016	N/A	N/A	N/A
12	466A	N/A	N/A	N/A
12	2123	N/A	N/A	N/A
12	1841A	N/A	N/A	N/A
12	249D	N/A	N/A	N/A
12	1405B	N/A	N/A	N/A
Subtotal				

		Identification		
COG #	Permit Number	Facility Name	Facility Type	County Name
18	1443	CITY OF SAN ANTONIO TRANSFER STATION	TF_I	BEXAR
18	2248	LIQUID ENVIRONMENTAL SOLUTIONS OF TEXAS SAN ANTONIO FACILITY	P_LQ	BEXAR
18	2317	SOUTHWASTE DISPOSAL SAN ANTONIO FACILITY	P_RC	BEXAR
18	40085	LIQUID ENVIRONMENTAL SOLUTIONS OF TEXAS SAN	TF_I	BEXAR
18	40157	SOS LIQUID WASTE HAULERS	TF_LQ	BEXAR
18	40280	STERICYCLE	TF_MW	BEXAR
18	42032	NEW EARTH	P_RC	BEXAR
18	40244	MEDSHARPS SCHERTZ FACILITY	P_AC	COMAL
18	43011	LACOSTE WWTP	P_LQ	MEDINA
18	1410C	TESSMAN ROAD LANDFILL	LF_IX	BEXAR
18	2093B	COVEL GARDENS LANDFILL GAS POWER STATION	LF_IX_DV	BEXAR
18	66B	MESQUITE CREEK LANDFILL	LF	COMAL
18	1995	CITY OF FREDERICKSBURG LANDFILL	LF_DV	GILLESPIE
18	1848	BECK LANDFILL	LF_DV	GUADALUPE
18	1506A	CITY OF KERRVILLE LANDFILL	LF_TF_RC_DV	KERR
18	571	MCMULLEN COUNTY	LF_DV	MCMULLEN
18	48039	NELSON GARDENS	9GR	BEXAR
Subtotal				

		Facility Fees				
COG #	Permit Number	Was Waste or Feedstock Measured by Weight?	Was Waste or Feedstock Measured by Volume?	By Tons	By Gallon	By Pound
18	1443	YES	YES	60	-	-
18	2248	NO	YES	-	0	-
18	2317	NO	YES	-	0	-
18	40085	NO	YES	-	0	-
18	40157	NO	YES	-	-	-
18	40280	NO	YES	-	-	-
18	42032	YES	YES	17	-	-
18	40244	YES	NO	-	-	0.7
18	43011	NO	YES	-	0	-
18	1410C	YES	NO	45	-	-
18	2093B	YES	NO	29	-	-
18	66B	YES	NO	25	-	-
18	1995	YES	NO	55	0	-
18	1848	YES	YES	26	-	-
18	1506A	YES	NO	67	-	-
18	571	NO	YES	-	-	-
18	48039	0	0	-	-	-
Subtotal				**323**	**1.0**	**1**

		Facility Fees	
COG #	Permit Number	By UnCompacted CY	Counties Served
18	1443	40	Atascosa, Comal, Gillespie, Guadalupe, Kerr, Wilson
18	2248	-	Atascosa, Bexar, Comal, Gillespie, Guadalupe, Kerr, Wilson
18	2317	-	Atascosa, Bexar, Comal, Guadalupe, Kerr
18	40085	-	Atascosa, Bexar, Comal, Kerr, Wilson
18	40157	-	Bexar, Comal, Gillespie, Guadalupe, Kerr, Mcmullen, Wilson
18	40280	-	Atascosa, Bexar, Comal, Guadalupe, Wilson
18	42032	4	Bexar
18	40244	-	Atascosa, Bexar, Comal, Gillespie, Guadalupe
18	43011	-	Bexar, Comal, Gillespie, Guadalupe, Kerr, Mcmullen, Wilson
18	1410C	-	Atascosa, Bexar, Comal, Guadalupe, Wilson
18	2093B	-	Atascosa, Bexar, Guadalupe, Wilson
18	66B	-	Bexar, Comal, Guadalupe
18	1995	-	Gillespie
18	1848	-	Bexar, Comal, Guadalupe
18	1506A	-	Kerr
18	571	-	Mcmullen
18	48039	-	
Subtotal		**44**	

COG #	**Permit Number**	**DV**	**AutoClave Total**	**Composting Total**	**Chipping/ Grinding Total**
18	1443	3867.8	0	0	0
18	2248	0	0	0	0
18	2317	0	0	59371	0
18	40085	0	0	0	0
18	40157	0	0	0	0
18	40280	0	0	0	0
18	42032	16000	0	97031	16000
18	40244	0	3407	0	0
18	43011	0	0	0	0
18	1410C	0	0	0	0
18	2093B	10.6	0	0	0
18	66B	0	0	0	0
18	1995	2655.9	0	0	0
18	1848	6281.2	0	0	0
18	1506A	115.9	0	8849.76	0
18	571	27.6	0	0	0
18	48039	0	0	0	0
Subtotal		**28,959**	**3,407**	**165,252**	**16,000**

			Solid Waste Transfer		
COG #	**Permit Number**	**LWT Total Tons**	**Municipal_ Total**	**Construction Demo_Total**	**Total Tons Total**
18	1443	0	133446.82	10187.77	143635
18	2248	35777	0	0	0
18	2317	0	0	0	0
18	40085	0	0	0	0
18	40157	0	0	0	0
18	40280	0	0	0	3702
18	42032	0	0	0	0
18	40244	0	0	0	0
18	43011	66303	0	0	0
18	1410C	0	0	0	0
18	2093B	0	0	0	0
18	66B	0	0	0	0
18	1995	0	0	0	0
18	1848	0	0	0	0
18	1506A	0	74387.86	0	83238
18	571	0	0	0	0
18	48039	0	0	0	0
Subtotal		**102,080**	**207,835**	**10,188**	**230,575**

				Landfill Specific Data	
COG #	**Permit Number**	**Grease Total**	**Total Tons Total**	**Muncipal_ Total**	**Brush_ Total**
18	1443	0	-	-	-
18	2248	0	-	-	-
18	2317	0	-	-	-
18	40085	0	4,463	-	-
18	40157	592	592	-	-
18	40280	0	-	-	-
18	42032	0	-	-	-
18	40244	0	-	-	-
18	43011	0	-	-	-
18	1410C	0	-	567,386	18,880
18	2093B	0	-	707,847	3,689
18	66B	0	-	212,348	-
18	1995	0	-	32,357	-
18	1848	0	-	-	-
18	1506A	0	-	5	3,303
18	571	0	-	500	-
18	48039	0	-	-	-
Subtotal		**592**	**5,055**	**1,520,444**	**25,872**

		Landfill Specific Data			
COG #	Permit Number	Construction_ Demo_Total	MedicalWaste_ Total	Sludge_ Total	GreaseTrap_ Total
18	1443	-	-	-	-
18	2248	-	-	-	-
18	2317	-	-	-	-
18	40085	-	-	-	-
18	40157	-	-	-	-
18	40280	-	-	-	-
18	42032	-	-	-	-
18	40244	-	-	-	-
18	43011	-	-	-	-
18	1410C	50,168	6,165	11,695	68
18	2093B	215,110	-	3,904	-
18	66B	82,384	-	14,006	-
18	1995	-	-	1,780	375
18	1848	395,123	-	-	-
18	1506A	-	-	4,492	-
18	571	-	-	-	-
18	48039	-	-	-	-
Subtotal		**742,786**	**6,165**	**35,877**	**443**

		Landfill Specific Data			
COG #	**Permit Number**	**Septage_ Total**	**A) Total Tons Disposed**	**B) Estimated Compaction Rate (lbs/yd3)**	**H) Current FY's Remaining Capacity (yd3)**
18	1443	-	-	-	-
18	2248	-	-	-	-
18	2317	-	-	-	-
18	40085	-	-	-	-
18	40157	-	-	-	-
18	40280	-	-	-	-
18	42032	-	-	-	-
18	40244	-	-	-	-
18	43011	-	-	-	-
18	1410C	61,049	939,912	1,639	70,456,792
18	2093B	-	1,063,232	1,750	103,403,670
18	66B	-	452,245	1,750	10,929,112
18	1995	-	34,614	1,180	1,560,737
18	1848	-	395,123	1,300	4,301,661
18	1506A	-	9,078	1,009	675,827
18	571	-	500	750	7,336
18	48039	-	-	-	-
Subtotal		**61,049**	**2,894,705**	**9,378**	**191,335,135**

		Landfill Specific Data		
COG #	Permit Number	I) FY's Remaining Capacity (Tons)	Total Tons Total	J) Remaining Years at Current Performance (years)
18	1443	-	-	-
18	2248	-	-	-
18	2317	-	-	-
18	40085	-	-	-
18	40157	-	-	-
18	40280	-	-	-
18	42032	-	-	-
18	40244	-	-	-
18	43011	-	-	-
18	1410C	57,739,341	871,237	45
18	2093B	90,478,211	1,058,107	77
18	66B	9,562,973	452,245	17
18	1995	920,835	34,614	22
18	1848	2,796,080	395,123	14
18	1506A	340,955	9,078	13
18	571	2,751	500	6
18	48039	-	-	-
Subtotal		**161,841,146**	**2,820,904**	**194**

		LGR Facility Information		
COG #	**Permit Number**	**LF Authorization No. where facility is located**	**Estimated Annual Gas Processed (ft3)**	**Estimated Annual Gas Distributed Off-Site (ft3)**
18	1443	-	-	-
18	2248	-	-	-
18	2317	-	-	-
18	40085	-	-	-
18	40157	-	-	-
18	40280	-	-	-
18	42032	-	-	-
18	40244	-	-	-
18	43011	-	-	-
18	1410C	1410C	1,285,169,317	-
18	2093B	2093B	1,561,475,418	-
18	66B	66B	2,353,480,900	-
18	1995	-	-	-
18	1848	-	-	-
18	1506A	-	-	-
18	571	-	-	-
18	48039	1,237	610,687,000	-
Subtotal		**1,237**	**5,810,812,635**	**-**

		LGR Facility Information		
COG #	**Permit Number**	**Power Generated and Sold this FY (kWh)**	**Power Generated and Used on Site (kWh)**	**LGR Permit Number**
18	1443	-	0	-
18	2248	-	0	-
18	2317	-	0	-
18	40085	-	0	-
18	40157	-	0	-
18	40280	-	0	-
18	42032	-	0	-
18	40244	-	0	-
18	43011	-	0	-
18	1410C	58,742,508	4339582	48005
18	2093B	59,072,437	4181593	48015
18	66B	23,367,114	661558	48029
18	1995	-	0	-
18	1848	-	0	-
18	1506A	-	0	-
18	571	-	0	-
18	48039	19,247,891	15574	-
Subtotal		**160,429,950**	**9,198,307**	

		Identification		
COG #	Permit Number	Facility Name	Facility Type	County Name
20	40027	ARANSAS COUNTY TRANSFER STATION FACILITY	TF_I	ARANSAS
20	40002	LIVE OAK COUNTY	TF_I	LIVE OAK
20	40228	J C ELLIOTT LANDFILL	TF_I	NUECES
20	40270	ENVIROTECH WASTE SOLUTIONS MEDICAL WASTE PROCESSING AND STORAGE FACILITY	P_AC	NUECES
20	2319	TEXAS SLUDGE DISPOSAL	P_RC	SAN PATRICIO
20	379	BROOKS COUNTY	LF_DV	BROOKS
20	1481	DUVAL COUNTY LANDFILL	LF	DUVAL
20	262C	CITY OF ALICE LANDFILL	LF_DV	JIM WELLS
20	235B	CITY OF KINGSVILLE LANDFILL	LF_DV	KLEBERG
20	2267	EL CENTRO LANDFILL	LF	NUECES
20	2269	CITY OF CORPUS CHRISTI LANDFILL	LF_DV	NUECES
20	2349	GULLEY HURST	LF	NUECES
Subtotal				

		Facility Fees				
COG #	Permit Number	Was Waste or Feedstock Measured by Weight?	Was Waste or Feedstock Measured by Volume?	By Tons	By Gallon	By Pound
20	40027	YES	NO	100	-	
20	40002	NO	YES	-	-	
20	40228	YES	NO	37	-	
20	40270	YES	NO	-	-	
20	2319	NO	YES	-	0	
20	379	NO	YES	-	-	
20	1481	NO	YES	-	-	
20	262C	YES	NO	46	-	
20	235B	YES	NO	27	-	
20	2267	YES	NO	32	-	
20	2269	YES	YES	37	-	
20	2349	NO	YES	-	-	
Subtotal				**278**	**0.2**	**-**

		Facility Fees		
COG #	Permit Number	By Compacted CY	By UnCompacted CY	Counties Served
20	40027	-	-	Aransas, San Patricio
20	40002	-	-	Live Oak
20	40228	13	10	Aransas, Duval, Jim Wells, Live Oak, Nueces, San Patricio
20	40270	-	-	Aransas, Brooks, Duval, Jim Wells, Live Oak, Nueces, San Patricio
20	2319	-	15	Aransas, Duval, Jim Wells, Nueces, San Patricio
20	379	-	3	Brooks
20	1481	-	12	Duval, Jim Wells
20	262C	-	-	Brooks, Duval, Jim Wells
20	235B	-	-	Brooks, Duval, Jim Wells, Nueces
20	2267	-	-	Aransas, Brooks, Duval, Jim Wells, Live Oak, Nueces, San Patricio
20	2269	13	10	Aransas, Duval, Jim Wells, Live Oak, Nueces, San Patricio
20	2349	-	4	Aransas, Duval, Jim Wells, Live Oak, Nueces, San Patricio
Subtotal		**26**	**54**	

COG #	**Permit Number**	**Total Counties Served**	**DV**	**Composting Total**	**Chemical Disinfection Total**
20	40027		3400.6	0	0
20	40002		0	0	0
20	40228		7898.5	0	0
20	40270		0	0	115.9
20	2319		0	1443	0
20	379		205	0	0
20	1481		0	0	0
20	262C		441	0	0
20	235B		3424.7	0	0
20	2267		0	0	0
20	2269		76.7	0	0
20	2349		0	0	0
Subtotal		**-**	**15,447**	**1,443**	**116**

				Solid Waste Transfer	
COG #	Permit Number	Chipping/ Grinding Total	LWT Total Tons	Municipal_ In State	Municipal_ Out State
20	40027	2958	0		
20	40002	0	0		
20	40228	0	0		
20	40270	0	0		
20	2319	0	12974		
20	379	0	0		
20	1481	0	0		
20	262C	0	0		
20	235B	0	0		
20	2267	0	0		
20	2269	0	0		
20	2349	0	0		
Subtotal		**2,958**	**12,974**	**-**	**-**

		Solid Waste Transfer				
COG #	Permit Number	Municipal Total	Industrial Total	Brush Total	Construction Demo Total	Total Tons Total
20	40027	3972	0	0	0	3972
20	40002	1290	0	0	0	1290
20	40228	59594.28	0	17.76	26765.84	86378
20	40270	0	0	0	0	0
20	2319	0	0	0	0	0
20	379	0	0	0	0	0
20	1481	0	0	0	0	0
20	262C	0	0	0	0	0
20	235B	0	0	0	0	0
20	2267	0	0	0	0	0
20	2269	0	0	0	0	0
20	2349	0	0	0	0	0
Subtotal		**64,856**	**-**	**18**	**26,766**	**91,640**

		Liquid Waste Transfer				
COG #	**Permit Number**	**Sludge_ Total**	**Grease_ Total**	**Grit_Total**	**Septage_ Total**	**Total Tons_Total**
20	40027	0	0	0	0	0
20	40002	0	0	0	0	0
20	40228	0	0	0	0	0
20	40270	0	0	0	0	0
20	2319	0	0	0	0	0
20	379	0	0	0	0	0
20	1481	0	0	0	0	0
20	262C	0	0	0	0	0
20	235B	0	0	0	0	0
20	2267	0	0	0	0	0
20	2269	0	0	0	0	0
20	2349	0	0	0	0	0
Subtotal		**-**	**-**	**-**	**-**	**-**

		Landfill Specific Data				
COG #	Permit Number	Muncipal Total	Brush Total	Construction Demo Total	Medical Waste Total	Sludge Total
20	40027	-	-	-	-	-
20	40002	-	-	-	-	-
20	40228	-	-	-	-	-
20	40270	-	-	-	-	-
20	2319	-	-	-	-	-
20	379	-	-	336	-	-
20	1481	-	3,666	294	-	-
20	262C	22,185	2,066	1,575	-	-
20	235B	24,048	-	6,374	-	708
20	2267	61,202	3,014	8,311	-	5,639
20	2269	338,720	10,121	93,034	-	34,458
20	2349	-	17,464	45,630	-	-
Subtotal		**446,155**	**36,331**	**155,555**	**-**	**40,806**

		Landfill Specific Data			
COG #	Permit Number	GreaseTrap_ Total	Septage_ Total	Incinerator Ash Total	Total Tons_ Total
20	40027	-	-	-	-
20	40002	-	-	-	-
20	40228	-	-	-	-
20	40270	-	-	-	-
20	2319	-	-	-	-
20	379	-	-	-	336
20	1481	-	-	-	3,960
20	262C	-	-	-	25,881
20	235B	-	-	269	31,444
20	2267	-	-	-	153,451
20	2269	-	-	-	476,850
20	2349	-	-	-	63,094
Subtotal		**-**	**-**	**269**	**755,016**

		Landfill Specific Data		
COG #	Permit Number	A) Total Tons Disposed	B) Estimated Compaction Rate (lbs/yd3)	H) Current FY's Remaining Capacity (yd3)
20	40027	-	-	-
20	40002	-	-	-
20	40228	-	-	-
20	40270	-	-	-
20	2319	-	-	-
20	379	336	400	291,917
20	1481	3,960	800	10,218
20	262C	25,881	1,200	689,843
20	235B	31,444	827	3,043,714
20	2267	153,451	1,924	14,449,609
20	2269	476,850	1,074	123,169,630
20	2349	63,094	750	10,988,381
Subtotal		**755,016**	**6,975**	**152,643,312**

		Landfill Specific Data	
COG #	**Permit Number**	**I) FY's Remaining Capacity (Tons)**	**J) Remaining Years at Current Performance (years)**
20	40027	-	-
20	40002	-	-
20	40228	-	-
20	40270	-	-
20	2319	-	-
20	379	58,383	27
20	1481	4,087	6
20	262C	413,906	16
20	235B	1,258,576	43
20	2267	13,900,524	70
20	2269	66,142,091	139
20	2349	4,120,643	57
Subtotal		**85,898,210**	**358**

		Identification		
COG #	Permit Number	Facility Name	Facility Type	County Name
21	2334	STERICYCLE HARLINGEN PROCESSING FACILITY	P_MW	CAMERON
21	2375	LA FERIA TRANSFER STATION	TF_I	CAMERON
21	40248	CITY OF HARLINGEN TRANSFER STATION FACILITY	TF_I	CAMERON
21	42015	CITY OF BROWNSVILLE COMPOSTING FACILITY	P_RC	CAMERON
21	748	PHARR TRANSFER STATION	TF_I	HIDALGO
21	2343	VALLEY DEWATERING SERVICES	P_LQ	HIDALGO
21	2346	LIQUID ENVIRONMENTAL SOLUTIONS WESLACO FACILITY	P_LQ	HIDALGO
21	1273A	CITY OF BROWNSVILLE MUNICIPAL LANDFILL	LF_DV	CAMERON
21	2302	EDINBURG REGIONAL DISPOSAL FACILITY	LF	HIDALGO
21	2348	LA GLORIA RANCH LANDFILL	LF	HIDALGO
21	1727A	PENITAS	LF	HIDALGO
21	956B	EDINBURG REGIONAL DISPOSAL FACILITY	LF_IX_DV	HIDALGO
Subtotal				

		Facility Fees				
COG #	Permit Number	Was Waste or Feedstock Measured by Weight?	Was Waste or Feedstock Measured by Volume?	By Tons	By Gallon	By Pound
21	2334	YES	NO	-	-	
21	2375	YES	NO	50	-	
21	40248	YES	NO	43	-	
21	42015	YES	NO	15	-	
21	748	YES	NO	-	-	
21	2343	NO	YES	-	0	
21	2346	NO	YES	-	0	
21	1273A	YES	YES	30	-	
21	2302	YES	YES	30	-	
21	2348	YES	NO	65	-	
21	1727A	NO	YES	-	-	
21	956B	YES	YES	30	-	
Subtotal				**263**	**0.4**	**-**

		Facility Fees		
COG #	Permit Number	By Compacted CY	By UnCompacted CY	Counties Served
21	2334		-	Brooks, Cameron, Hidalgo, ,Starr, Willacy
21	2375		-	Cameron, Hidalgo
21	40248		-	Cameron, Willacy
21	42015		-	Cameron
21	748		-	Hidalgo
21	2343		-	Cameron, Hidalgo, Starr, Willacy
21	2346		-	Brooks, Cameron, Hidalgo, Starr
21	1273A		-	Cameron
21	2302		10	Brooks, Cameron, Hidalgo, Starr, Willacy
21	2348		-	Cameron, Hidalgo, Starr, Willacy
21	1727A		-	Hidalgo
21	956B		10	Brooks, Cameron, Hidalgo, Starr, Willacy
Subtotal		**-**	**20**	

COG #	**Permit Number**	**Total Counties Served**	**DV**	**AutoClave Total**	**Composting Total**	**Chipping/ Grinding Total**
21	2334		0		0	
21	2375		0		0	
21	40248		0		0	
21	42015		0		24209.06	
21	748		0		0	
21	2343		0		0	
21	2346		0		0	
21	1273A		24298		0	
21	2302		0		0	
21	2348		0		0	
21	1727A		0		0	
21	956B		805		0	
Subtotal		**-**	**25,103**	**-**	**24,209**	**-**

			Solid Waste Transfer			
COG #	Permit Number	LWT Total Tons	Municipal In State	Municipal Out State	Municipal Total	Industrial Total
21	2334	0			0	
21	2375	0			155444.5	
21	40248	0			52702.45	
21	42015	0			0	
21	748	0			42808	
21	2343	15810			0	
21	2346	17231			0	
21	1273A	0			0	
21	2302	0			0	
21	2348	0			0	
21	1727A	0			0	
21	956B	0			0	
Subtotal		**33,041**	**-**	**-**	**250,955**	**-**

		Solid Waste Transfer		
COG #	**Permit Number**	**Brush_ Total**	**Construction Demo_Total**	**Total Tons Total**
21	2334	0	0	212
21	2375	0	0	155445
21	40248	0	11246.3	66178
21	42015	0	0	0
21	748	9550	0	52358
21	2343	0	0	764
21	2346	0	0	0
21	1273A	0	0	0
21	2302	0	0	0
21	2348	0	0	0
21	1727A	0	0	0
21	956B	0	0	0
Subtotal		**9,550**	**11,246**	**274,957**

		Liquid Waste Transfer				
COG #	**Permit Number**	**Sludge_ Total**	**Grease_ Total**	**Grit_Total**	**Septage_ Total**	**Total Tons_ Total**
21	2334	0	0	0	0	0
21	2375	0	0	0	0	0
21	40248	0	0	0	0	0
21	42015	0	0	0	0	0
21	748	0	0	0	0	0
21	2343	0	0	0	0	0
21	2346	0	0	0	0	0
21	1273A	0	0	0	0	0
21	2302	0	0	0	0	0
21	2348	0	0	0	0	0
21	1727A	0	0	0	0	0
21	956B	0	0	0	0	0
Subtotal		-	-	-	-	-

		Landfill Specific Data			
COG #	**Permit Number**	**Muncipal_ Total**	**Brush_ Total**	**Construction_ Demo_Total**	**MedicalWaste_ Total**
21	2334	-	-	-	-
21	2375	-	-	-	-
21	40248	-	-	-	-
21	42015	-	-	-	-
21	748	-	-	-	-
21	2343	-	-	-	-
21	2346	-	-	-	-
21	1273A	238,456	33,215	18,792	1,015
21	2302	-	53,195	69,933	-
21	2348	226,603	18,783	3,967	1,787
21	1727A	3,258	100	4,571	-
21	956B	476,632	4,633	4,121	-
Subtotal		**944,949**	**109,926**	**101,384**	**2,802**

		Landfill Specific Data			
COG #	Permit Number	Sludge_ Total	GreaseTrap_ Total	Septage_ Total	IncineratorAsh_ Total
21	2334	-	-	-	-
21	2375	-	-	-	-
21	40248	-	-	-	-
21	42015	-	-	-	-
21	748	-	-	-	-
21	2343	-	-	-	-
21	2346	-	-	-	-
21	1273A	10,047	-	-	-
21	2302	-	-	-	-
21	2348	5,175	3,339	771	-
21	1727A	-	-	-	-
21	956B	7,429	-	-	1,143
Subtotal		**22,651**	**3,339**	**771**	**1,143**

		Landfill Specific Data		
COG #	Permit Number	Total Tons_ Total	A) Total Tons Disposed	B) Estimated Compaction Rate (lbs/yd3)
21	2334	-	-	-
21	2375	-	-	-
21	40248	-	-	-
21	42015	-	-	-
21	748	-	-	-
21	2343	-	-	-
21	2346	-	-	-
21	1273A	317,655	317,655	1,508
21	2302	123,136	123,136	1,094
21	2348	290,314	291,619	1,480
21	1727A	8,179	8,179	1,000
21	956B	494,515	494,515	1,293
Subtotal		**1,233,799**	**1,235,104**	**6,375**

		Landfill Specific Data		
COG #	Permit Number	H) Current FY's Remaining Capacity (yd3)	I) FY's Remaining Capacity (Tons)	J) Remaining Years at Current Performance (years)
21	2334	-	-	-
21	2375	-	-	-
21	40248	-	-	-
21	42015	-	-	-
21	748	-	-	-
21	2343	-	-	-
21	2346	-	-	-
21	1273A	27,641,110	20,841,397	49
21	2302	10,309,433	5,639,260	32
21	2348	109,129,915	80,756,137	214
21	1727A	20,500	10,250	1
21	956B	5,179,505	3,348,550	6
Subtotal		**152,280,463**	**110,595,594**	**302**

		LGR Facility Information		
COG #	**Permit Number**	**LF Authorization No. where facility is located**	**Estimated Annual Gas Processed (ft3)**	**Estimated Annual Gas Distributed Off-Site (ft3)**
21	2334	-	-	-
21	2375	-	-	-
21	40248	-	-	-
21	42015	-	-	-
21	748	-	-	-
21	2343	-	-	-
21	2346	-	-	-
21	1273A	-	-	-
21	2302	-	-	-
21	2348	-	-	-
21	1727A	-	-	-
21	956B	956B	459,646,000	835,720,000
Subtotal			**459,646,000**	**835,720,000**

		LGR Facility Information		
COG #	**Permit Number**	**Power Generated and Sold this FY (kWh)**	**Power Generated and Used on Site (kWh)**	**LGR Permit Number**
21	2334	-	-	-
21	2375	-	-	-
21	40248	-	-	-
21	42015	-	-	-
21	748	-	-	-
21	2343	-	-	-
21	2346	-	-	-
21	1273A	-	-	-
21	2302	-	-	-
21	2348	-	-	-
21	1727A	-	-	-
21	956B	-	-	48038
Subtotal		**-**	**-**	

		Identification		
COG #	Permit Number	Facility Name	Facility Type	County Name
23	2368	S & M VACUUM & LIQUID WASTE PROCESSING FACILITY	P_LQ	BELL
23	40209	KILLEEN TRANSFER STATION	TF_I	BELL
23	40234	STERICYCLE TEMPLE	TF_MW	BELL
23	42035	BELL COUNTY WCID 1 REGIONAL COMPOST FACILITY	P_RC	BELL
23	40145	CITY OF COPPERAS COVE TRANSFER STATION FACILITY	TF_I	CORYELL
23	42017	CITY OF COPPERAS COVE COMPOSTING FACILITY	P_RC	CORYELL
23	42040	FORT HOOD BIOTREATMENT FACILITY	P_RC	CORYELL
23	40004	CITY OF HICO TRANSFER STATION FACILITY	TF_I	HAMILTO N
23	40160	CITY OF SAN SABA MUNICIPAL SOLID WASTE PROCESSING	TF_I	SAN SABA
23	692A	TEMPLE RECYCLING AND DISPOSAL FACILITY	LF	BELL
23	1866	FORT HOOD LANDFILL	LF_DV	CORYELL
Subtotal				

		Facility Fees				
COG #	Permit Number	Was Waste or Feedstock Measured by Weight?	Was Waste or Feedstock Measured by Volume?	By Tons	By Gallon	By Pound
23	2368	NO	YES	-	0	
23	40209	YES	NO	62	-	
23	40234	NO	YES	-	-	
23	42035	YES	NO	-	-	
23	40145	YES	NO	65	-	
23	42017	YES	NO	-	-	
23	42040	NO	YES	-	-	
23	40004	NO	YES	-	-	
23	40160	NO	YES	-	-	
23	692A	YES	NO	29	-	
23	1866	YES	NO	103	-	
Subtotal				**258**	**0.3**	**-**

		Facility Fees		
COG #	Permit Number	By Compacted CY	By UnCompacted CY	Counties Served
23	2368	-	-	Bell, Coryell, Lampasas, Mclennan, Williamson
23	40209	-	-	Bell, Coryell, Lampasas, Williamson
23	40234	-	-	Bell, Coryell, Lampasas, Mclennan, Williamson
23	42035	-	7	Bell, Williamson
23	40145	-	-	Bell, Coryell, Lampasas
23	42017	-	-	Bell, Coryell, Lampasas
23	42040	-	-	Bell, Coryell
23	40004	-	14	Hamilton
23	40160	23	12	San Saba
23	692A	-	-	Bell, Coryell, Lampasas, Mclennan, San Saba
23	1866	-	-	Bell, Coryell
Subtotal		**23**	**33**	

COG #	**Permit Number**	**DV**	**Composting Total**	**Chipping/ Grinding Total**	**LWT Total Tons**
23	2368	180.1	0	0	4213
23	40209	6059	0	0	0
23	40234	0	0	0	0
23	42035	0	6798	0	0
23	40145	2768.4	0	0	0
23	42017	1284	0	475	0
23	42040	0	0	0	0
23	40004	14.6	0	0	0
23	40160	110.8	0	0	0
23	692A	0	0	0	0
23	1866	1084.5	3091.91	0	0
Subtotal		**11,501**	**9,890**	**475**	**4,213**

		Solid Waste Transfer		
COG #	**Permit Number**	**Municipal Total**	**Construction Demo_Total**	**Total Tons Total**
23	2368	0	0	175
23	40209	99870.42	6976.11	106897
23	40234	0	0	441
23	42035	0	0	0
23	40145	28209	0	28209
23	42017	0	0	0
23	42040	0	0	317
23	40004	105.49	0	105
23	40160	3681.1	0	3681
23	692A	0	0	0
23	1866	0	0	0
Subtotal		**131,866**	**6,976**	**139,825**

		Liquid Waste Transfer				
COG #	**Permit Number**	**Sludge_ Total**	**Grease_ Total**	**Grit_Total**	**Septage_ Total**	**Total Tons_ Total**
23	2368	0	0	0	0	0
23	40209	0	0	0	0	0
23	40234	0	0	0	0	0
23	42035	0	0	0	0	0
23	40145	0	0	0	0	0
23	42017	0	0	0	0	0
23	42040	0	0	0	0	0
23	40004	0	0	0	0	0
23	40160	0	0	0	0	0
23	692A	0	0	0	0	0
23	1866	0	0	0	0	0
Subtotal		-	-	-	-	-

		Landfill Specific Data			
COG #	Permit Number	Muncipal_ Total	Construction_ Demo_Total	MedicalWaste_ Total	Sludge_ Total
23	2368	-	-	-	-
23	40209	-	-	-	-
23	40234	-	-	-	-
23	42035	-	-	-	-
23	40145	-	-	-	-
23	42017	-	-	-	-
23	42040	-	-	-	-
23	40004	-	-	-	-
23	40160	-	-	-	-
23	692A	284,113	81,556	1,791	12,476
23	1866	17,786	32	-	-
Subtotal		**301,899**	**81,588**	**1,791**	**12,476**

		Landfill Specific Data			
COG #	Permit Number	GreaseTrap_ Total	Total Tons_ Total	A) Total Tons Disposed	B) Estimated Compaction Rate (lbs/yd3)
23	2368	-	-	-	-
23	40209	-	-	-	-
23	40234	-	-	-	-
23	42035	-	-	-	-
23	40145	-	-	-	-
23	42017	-	-	-	-
23	42040	-	-	-	-
23	40004	-	-	-	-
23	40160	-	-	-	-
23	692A	-	433,986	433,986	1,400
23	1866	16	19,501	19,501	1,100
Subtotal		**16**	**453,487**	**453,487**	**2,500**

		Landfill Specific Data		
COG #	Permit Number	H) Current FY's Remaining Capacity (yd3)	I) FY's Remaining Capacity (Tons)	J) Remaining Years at Current Performance (years)
23	2368	-	-	-
23	40209	-	-	-
23	40234	-	-	-
23	42035	-	-	-
23	40145	-	-	-
23	42017	-	-	-
23	42040	-	-	-
23	40004	-	-	-
23	40160	-	-	-
23	692A	6,608,681	4,626,077	10
23	1866	2,654,556	1,460,006	29
Subtotal		**9,263,237**	**6,086,083**	**39**

APPENDIX E

TCEQ DATA PROVIDED

Monofills

		Identification			
COG #	**Permit Number**	**Facility Name**	**Facility Type**	**County Name**
1	40271	Tri-State Recycling	5TS	Dallam
1	40192	City of Clarendon Msw Transfer Station	5TS	Donley
1	43030	City of Pampa Liquid Waste Processing	5GG	Gray
1	40026	City of Canadian Transfer Station	5TS	Hemphill
1	40015	City of Borger Transfer Station	5TS	Hutchinson
1	40031	City of Cactus Transfer Station	5TS	Moore
1	40263	Biocycle	5AC	Potter
1	76A	City of Amarillo Municipal Solid Waste Transfer Station	5TS	Potter
1	40109	City of Stratford Msw Transfer Station	5TS	Sherman
1	414	Claude Armstrong County Landfill	4AE	Armstrong
1	1164	City of Panhandle Municipal Solid Waste	1AE	Carson
1	445A	City of Dimmitt Municipal Solid Waste	1AE	Castro
1	2263	City of Childress Municipal Solid Waste	1 AE & 4	Childress
1	955	City of Wellington Municipal Solid Waste	1AE	Collingswor
1	1038A	City of Dalhart Municipal Solid Waste	1 AE & 4	Dallam
1	215A	City of Hereford Municipal Solid Waste	4AE	Deaf Smith
1	570	City of Mclean Landfill	1AE	Gray
1	2238	City of Pampa Municipal Solid Waste	1	Gray
1	589A	City of Pampa	4AE	Gray
1	2266	City of Memphis Municipal Solid Waste	1AE	Hall
1	2352	City of Spearman Municipal Solid Waste	1AE	Hansford
1	1943	City of Booker Landfill	1AE	Lipscomb
1	2279	City of Dumas Landfill	1	Moore
1	2285	City of Dumas Municipal Solid Waste	4AE	Moore
1	876A	Perryton Municipal Solid Waste Landfill	1AE	Ochiltree
1	791	Cal Farleys Boys Ranch Landfill	4AE	Oldham
1	73A	City of Amarillo Landfill	1	Potter
1	1663B	Southwest Landfill Tx	1	Randall
1	1009A	City of Tulia Landfill	1 AE & 4	Swisher
1	2281	City of Shamrock Municipal Landfill	1AE	Wheeler
2	40051	City of Levelland Transfer Station Facility	5TS	Hockley
2	2231	South Waste Disposal South Plains Facility	5GG	Lubbock
2	40176	Caliche Canyon Transfer Station	5TS	Lubbock
2	40279	Stericycle Lubbock	5MWTS	Lubbock
2	564	City of Muleshoe Landfill	4AE	Bailey
2	2291	City of Muleshoe Type 1-AE Landfill	1AE	Bailey
2	2268	Morton Municipal Solid Waste Landfill	4AE	Cochran
2	9017	City of Spur House Disposal Site	MONOFIL	Dickens
2	2207	City of Floydada	1 AE & 4	Floyd
2	2227	City of Post Landfill	1 AE & 4	Garza

		Identification		
COG #	Permit Number	Facility Name	Facility Type	County Name
2	2157	City of Plainview Landfill	1	Hale
2	1733	City of Sundown Landfill	4AE	Hockley
2	2369	City of Levelland Landfill	1 AE & 4	Hockley
2	1298	City of Littlefield Landfill	4AE	Lamb
2	2274	Littlefield Municipal Landfill	1 AE & 4	Lamb
2	363A	City of Amherst Landfill	4AE	Lamb
2	583A	City of Olton Landfill	1AE	Lamb
2	69	City of Lubbock Landfill	1	Lubbock
2	2252	City of Lubbock West Texas Regional Disposal Fac	1	Lubbock
2	2323	C & D Waste Landfill	4	Lubbock
2	2328A	City of Tahoka	1AE	Lynn
2	549A	City of Matador Landfill	1AE	Motley
2	2170	City of Brownfield Landfill	1	Terry
2	2293	City of Meadow Landfill	1AE	Terry
2	2217	Yoakum County Landfill	1 AE & 4	Yoakum
3	40144	City of Seymour Transfer Station Facility	5TS	Baylor
3	2295	IESI Bowie Transfer Station	5TS	Montague
3	1429	City of Wichita Falls Transfer Station	5TS	Wichita
3	2229A	IMC Waste Disposal	5GG	Wichita
3	40059	City of Vernon Transfer Station	5TS	Wilbarger
3	9001A	City of Paducah	MONOFIL	Cottle
3	1428A	City of Wichita Falls Landfill	1	Wichita
3	1571A	IESI Buffalo Creek Landfill	1	Wichita
4	1494	Parkway Transfer Station	5TS	Collin
4	40284	Town And Country Recycling	5TS	Collin
4	2045A	Custer Solid Waste Transfer Station	5TS	Collin
4	53A	Lookout Drive Transfer Station	5TS	Collin
4	12	City of Garland Transfer Station Facility	5TS	Dallas
4	60	City of Dallas Transfer Station	5TS	Dallas
4	227	City of University Park Transfer Station	5TS	Dallas
4	1145	Harry Hines Transfer Station	5TS	Dallas
4	1263	City of Mesquite Service Center	5TS	Dallas
4	1421	PSC Recovery Systems	5GG	Dallas
4	1453	City of Dallas Transfer Station	5TS	Dallas
4	40196	Community Waste Disposal Transfer Station	5TS	Dallas
4	40265	Stericycle Garland	5AC	Dallas
4	2069A	Dallas Facility	5GG	Dallas
4	40080	Harrington Environmental Services	5TL	Johnson
4	40168	Cleburne Transfer Station	5TS	Johnson
4	40181	Somervell County Transfer Station	5TS	Somervell
4	2275	North Texas Recycling Complex	5TS	Tarrant
4	2306	IESI Minnis Drive Transfer Station	5TS	Tarrant

		Identification		
COG #	Permit Number	Facility Name	Facility Type	County Name
4	2379	Liquitek Arlington Liquid Waste Facility	5GG	Tarrant
4	40052	Southwest Paper Stock	5TS	Tarrant
4	40186	Westside Transfer Station	5TS	Tarrant
4	1225D	Cold Springs Processing	5GG	Tarrant
4	2256A	Southwaste Disposal Dallas Facility	5GG	Tarrant
4	40241	Oncore Technology	5MW	Tarrant
4	2294	121 Regional Disposal Facility	1	Collin
4	62	City of Dallas Mccommas Bluff Landfill	1	Dallas
4	1394B	Hunter Ferrell Landfill	1	Dallas
4	1895A	Charles M Hinton Jr Regional Landfill	1	Dallas
4	996C	City of Grand Prairie Landfill	1	Dallas
4	1025B	Dfw Recycling And Disposal Facility	1	Denton
4	1312B	Camelot Landfill	1	Denton
4	1590A	City of Denton Landfill	1	Denton
4	1749B	Lewisville Landfill	4	Denton
4	1209B	CSC Disposal And Landfill	1	Ellis
4	1745B	Ellis County Landfill	1	Ellis
4	42D	Waste Management Skyline Landfill	1	Ellis
4	664	City of Stephenville Landfill	4	Erath
4	1195A	Republic Maloy Landfill	1	Hunt
4	534	City of Cleburne Landfill	1	Johnson
4	1417B	IESI Turkey Creek Landfill	1	Johnson
4	2190	City of Corsicana Landfill	1	Navarro
4	47A	IESI Weatherford Landfill	1	Parker
4	1983C	IESI Fort Worth C And D Landfill	4	Tarrant
4	218C	City of Fort Worth South East Landfill	1	Tarrant
4	358B	City of Arlington Landfill	1	Tarrant
4	48012	City of Arlington Landfill Gas Processing	9GR	Tarrant
4	48016	City of Denton Landfill	9GR	Denton
4	48018	Waste Management Skyline Landfill	9GR	Dallas
4	48027	Westside Recycling And Disposal Facility	9GR	Tarrant
4	48028	Camelot Landfill Gas To Energy Facility	9GR	Denton
4	48032	IESI Turkey Creek Landfill	9GR	Johnson
4	48033	Mccommas Bluff Lfg Processing Facility	9GR	Dallas
4	48042	121 Rdf Lfg Treatment Facility	9GR	Collin
4	1025B	Dfw Recycling And Disposal Facility	1	Denton
5	2382	Stouts Creek Compost	5RC	Hopkins
5	576C	New Boston Landfill	1	Bowie
5	2358	Blossom Prairie Landfill	1	Lamar
5	797B	Pleasant Oaks Landfill	1	Titus
6	2389	IESI Palestine Transfer Station	5TS	Anderson
6	40005	TDCJ Beto Unit	5TS	Anderson
6	40006	TDCJ Coffield Unit	5TS	Anderson

		Identification		
COG #	Permit Number	Facility Name	Facility Type	County Name
6	40040	IESI Palestine Transfer Station	5TS	Anderson
6	40174	Pittsburg Transfer Station Facility	5TS	Camp
6	2365	Edwards Construction	5GG	Gregg
6	40172	City of Carthage	5TS	Panola
6	40267	Sharps Environmental Service	5MW	Panola
6	356	Vital Earth Resources	5RC	Upshur
6	40266	City of Canton Transfer Station Facility	5TS	Van Zandt
6	40102	Upper Sabine Valley Swmd Transfer Station	5TS	Wood
6	1614A	Royal Oaks Landfill	1	Cherokee
6	1327B	Pinehill Landfill	1	Gregg
6	1249B	IESI TX Landfill	1	Rusk
6	1972A	Greenwood Farms Landfill	1	Smith
6	48026	Greenwood Farms Landfill	9GR	Smith
6	48041	Pine Lfg Treatment Facility	9GR	Gregg
7	1562A	Brownwood Regional Landfill	1	Brown
7	1302	City of Coleman Landfill	4AE	Coleman
7	9009	City of Stamford Building Demolition	MONOFIL	Haskell
7	1604B	City of Haskell Landfill	1AE	Haskell
7	2325	Abilene Environmental Landfill	1	Jones
7	1469A	Abilene Landfill	1	Jones
7	9004	City of Anson Abandoned & Nuisance Building Disposal Site	MONOFIL L	Jones
7	420A	Colorado City Municipal Landfill 420	1 AE & 4	Mitchell
7	50B	City of Sweetwater Type IV AE Landfill	4AE	Nolan
7	9013	City of Ballinger Abandoned Building	MONOFIL	Runnels
7	1463B	City of Snyder Landfill	1	Scurry
7	9000A	City of Breckenridge Monofill	MONOFIL	Stephens
8	728	City of El Paso Delta Transfer Facility	5TS	El Paso
8	2355	Liquid Environmental Solutions	5GG	El Paso
8	40237	El Paso C&D Recycling Plant	5RR	El Paso
8	40261	Stericycle Medical Waste Transfer Station	5MWTS	El Paso
8	40262	Mediwaste Medical Waste Treatment Facility	5AC	El Paso
8	1276	Panther Junction Landfill	1AE	Brewster
8	2197	City of Alpine Landfill	1AE	Brewster
8	1422	Usaadacenfb Fort Bliss	1	El Paso
8	2284	Greater El Paso Landfill	1	El Paso
8	729B	City of El Paso Landfill	1	El Paso
8	495	Hudspeth County Dell City Landfill	1 AE & 4	Hudspeth
8	957A	Hudspeth County Sierra Blanca	1 AE & 4	Hudspeth
8	1737A	City of Presidio Landfill	1AE	Presidio
9	2373	Affordable Dewatering Service	5GG	Midland
9	43028	City of Stockton Type V Lwp	5GG	Pecos
9	171	City of Andrews Landfill	1 AE & 4	Andrews

		Identification		
COG #	Permit Number	Facility Name	Facility Type	County Name
9	427	City of Crane	1 AE & 4	Crane
9	517A	City of Lamesa Landfill	1	Dawson
9	2158	Odessa Landfill	1	Ector
9	39	City of Seminole Landfill	1 AE & 4	Gaines
9	2154	Glasscock County Landfill Nw	1AE	Glasscock
9	288A	City of Big Spring Landfill	1	Howard
9	2189	City of Stanton Landfill	1AE	Martin
9	1605B	City of Midland Municipal Solid Waste	1	Midland
9	976	City of Fort Stockton Landfill	1 AE & 4	Pecos
9	2120	City of Pecos Landfill	1 AE & 4	Reeves
9	673	Terrell County Landfill	4AE	Terrell
9	566	City of Mccamey Landfill	4AE	Upton
9	691	Upton County Rankin Landfill	4AE	Upton
9	772	City of Monahans Landfill	1AE	Ward
10	2357	San Angelo Pro Pump Dewatering & Compost Facility	5RC	Tom Green
10	2359	Ds Recycling	5RC	Tom Green
10	42022	Kickapoo Composting Facility	5RC	Tom Green
10	26B	City of Junction Landfill	4AE	Kimble
10	195	City of Mason Landfill	1AE	Mason
10	1732	City of Brady Landfill	1 AE & 4	Mcculloch
10	1404	City of Menard Landfill	4AE	Menard
10	86B	City of Big Lake Landfill	1AE	Reagan
10	349	City of Eldorado Landfill	4AE	Schleicher
10	2264	City of Eldorado Landfill	1AE	Schleicher
10	79	San Angelo Landfill	1	Tom Green
11	241D	Itasca Landfill	1	Hill
11	1558A	BFI Mexia Landfill	1	Limestone
11	1646A	Lacy-Lakeview Recycling And Disposal	1	Mclennan
11	948A	City of Waco Landfill	1	Mclennan
11	48020	City of Waco Landfill	9GR	Mclennan
12	2260A	Stericycle	5AC	Bastrop
12	2300	IESI Blanco County Transfer Station	5TS	Blanco
12	40035	BFI Burnet Transfer Station	5TS	Burnet
12	1787	Hays County Transfer Station	5TS	Hays
12	119	Texas Disposal System Eco Depot	5TS	Travis
12	2250	Liquid Environmental Solutions of Texas	5GG	Travis
12	2310	J-V Dirt + Loam	5RC	Travis
12	2384	Austin Wastewater Processing Facility	5GG	Travis
12	40212	Tom Dye Contractor	5TL	Travis
12	40243	River City Rolloffs	5RR	Travis
12	42016	Texas Organic Recovery	5RC	Travis
12	466A	City of Georgetown Transfer Station	5TS	Williamson

		Identification		
COG #	Permit Number	Facility Name	Facility Type	County Name
12	2123	Texas Disposal Systems Landfill	1	Travis
12	1841A	IESI Travis County Landfill	4	Travis
12	249D	Waste Management of Texas Austin Community Recycling & Disposal Facility	1	Travis
12	1405B	Williamson County Recycling And Disposal Facility	1	Williamson
12	48019	Waste Management of Texas Austin Community Recycling & Disposal Facility	9GR	Travis
13	42003	Bryan Composting Facility	5RC	Brazos
13	43026	Still Creek WWTP	5GG	Brazos
13	2381	L&G Environmental	5GG	Washington
13	40018	City of Brenham Transfer Station Facility	5TS	Washington
13	40173	Washington County Transfer Station	5TS	Washington
13	2292	Twin Oaks Landfill	1	Grimes
14	40033	Hutto Garbage Service	5TS	Houston
14	40044	City of Jasper Landfill	5TS	Jasper
14	43007	City of Nacogdoches	5GG	Nacogdoche
14	40277	Pro Star Waste	5TS	Polk
14	40054	Don General Services	5TS	Sabine
14	40024	City of San Augustine Transfer Station	5TS	San
14	40013	City of Woodville Transfer Station Facility	5TS	Tyler
14	40038	Tyler County Transfer Station	5TS	Tyler
14	2105A	Angelina County Waste Management Center	1	Angelina
14	720	City of Nacogdoches Landfill	1	Nacogdoche
14	2242A	Western Waste of Texas Newton Complex	1	Newton
14	1384A	Polk County Landfill	1	Polk
15	40164	JTB Recycling Facility	5TL	Jefferson
15	40225	Triangle Waste Solutions	5TS	Jefferson
15	40268	Biomedical Waste Solutions	5AC	Jefferson
15	43000	JTB Recycling Facility	5GG	Jefferson
15	2214A	IESI Hardin County Landfill	1	Hardin
15	2027	BFI Golden Triangle Landfill	1	Jefferson
15	1486B	City of Beaumont Landfill	1	Jefferson
15	1815A	City of Port Arthur Landfill	1	Jefferson
16	40191	Country Waste	5TS	Austin
16	2235	Brazoria County Recycling Center Transfer Station Facility	5RR	Brazoria
16	2239A	Paragon Southwest Medical Waste	5WI	Chambers
16	40282	City of Weimar Transfer Station	5TS	Colorado
16	40053	Best Septic Tank Cleaning	5TL	Fort Bend
16	40264	Stericycle	5MWTS	Fort Bend

		Identification		
COG #	Permit Number	Facility Name	Facility Type	County Name
16	164	City of Galveston	5TS	Galveston
16	2232A	Utmb Galveston	5WI	Galveston
16	1471	Sam Houston Recycling Center	5TS	Harris
16	1578	Hardy Road Transfer Station	5TS	Harris
16	1697	City of Deer Park	5TS	Harris
16	2298	Br Perrin Plant	5GG	Harris
16	2350	Big K Environmental	5GG	Harris
16	2370	Wastewater Residuals Management	5GG	Harris
16	2386	10217 Wallisville Rd Unit C	5RR	Harris
16	40098	BFI Wastes Services of Texas	5TS	Harris
16	40131	Houston Southeast Transfer Station Facility	5TS	Harris
16	40132	Houston Southwest Transfer Station Facility	5TS	Harris
16	40133	Houston Northwest Transfer Station Facility	5TS	Harris
16	40189	Egbert Type V Ts Transfer Station	5TS	Harris
16	40211	Sprint Recycling Center Northeast	5TS	Harris
16	40217	Tanner Road Facility	5TS	Harris
16	40236	Excell Disposal Waste Containers	5TS	Harris
16	40249	Lone Star Recycling & Disposal	5TS	Harris
16	40250	Lone Star Srd Shredding Recycling Disposal	5AC	Harris
16	40273	Excel Medical Waste	5AC	Harris
16	40275	R&J Transfer Station	5TS	Harris
16	40283	Daniels Houston Facility	5MWTS	Harris
16	43034	Liquid Environmental Solutions of Texas	5GG	Harris
16	1355A	Ruffino Hills Transfer Station	5TS	Harris
16	1483A	Koenig Street Transfer Station	5TS	Harris
16	2234D	Liquid Environmental Solutions	5GG	Harris
16	2241A	Southwaste Disposal Hurst Facility	5GG	Harris
16	40028	Matagorda County	5TS	Matagorda
16	2222	Stericycle	5AC	Montgomer
16	2309	Mid America Contractors	5TS	Montgomer
16	42037	New Earth	5RC	Montgomer
16	2387	City of Huntsville Transfer Station Facility	5TS	Walker
16	40014	City of Hempstead Transfer Station Facility	5TS	Waller
16	2318	Don Tol Compost Facility	5RC	Wharton
16	1708	Dixie Farm Road Landfill	4	Brazoria
16	1539A	Seabreeze Environmental Landfill	1	Brazoria
16	1502A	Chambers County Landfill	1	Chambers
16	1535B	Baytown Landfill	1	Chambers
16	203A	Altair Disposal Services Landfill	1	Colorado
16	2270	Fort Bend Regional Landfill	1	Fort Bend
16	1505A	Blue Ridge Landfill	1	Fort Bend
16	1797A	Sprint Fort Bend County Landfill	4	Fort Bend
16	1149B	Galveston County Landfill	1	Galveston

		Identification		
COG #	Permit Number	Facility Name	Facility Type	County Name
16	1721A	Coastal Plains Recycling And Disposal	1	Galveston
16	1849B	North County Landfill	4	Galveston
16	1193	Whispering Pines Landfill	1	Harris
16	1301	Addicks Fairbanks Landfill	4	Harris
16	1403	Casco Hauling And Excavation Landfill	4	Harris
16	2185	Hawthorn Park Landfill	4	Harris
16	2304	Waste Corporation Tall Pines Lf	4	Harris
16	2344	Lone Star Recycling & Disposal	4	Harris
16	1307D	Atascocita Recycling And Disposal Facility	1	Harris
16	1540A	Greenshadows Landfill	4	Harris
16	1565B	Fairbanks Landfill	4	Harris
16	1586A	Wct Greenbelt Landfill	4	Harris
16	1599A	Greenhouse Road Landfill	4	Harris
16	1921A	Cougar Landfill	4	Harris
16	2240B	Ralston Road Landfill	4	Harris
16	261B	Mccarty Road Landfill Tx	1	Harris
16	2324	Sprint Montgomery Landfill	4	Montgomer
16	1752B	Security Landfill Rdf	1	Montgomer
16	1777	Mccarty Road Landfill Gas Recovery Facility	9GR	Harris
16	48006	Atascocita Recycling And Disposal Facility	9GR	Harris
16	48008	Security Landfill Rdf	9GR	Montgomer
16	48009	Coastal Plains Lfgte Facility	9GR	Galveston
16	48025	Ameresco Mccarty Energy	9GR	Harris
16	48034	Fort Bend Landfill Gas Treatment Facility	9GR	Fort Bend
16	48035	Republic Services Blue Ridge Energy Development	9GR	Brazoria
17	40017	City of Yoakum Transfer Station	5TS	Dewitt
17	2181	Jackson County Solid Waste Transfer Station	5TS	Jackson
17	40011	City of Hallettsville Transfer Station Facility	5TS	Lavaca
17	2330	Victoria Environmental	5GG	Victoria
17	2366	Victoria Regional WWTP	5GG	Victoria
17	42034	Victoria Compost Facility	5RC	Victoria
17	1522A	City of Victoria Landfill	1	Victoria
17	48036	City of Victoria Landfill	9GR	Victoria
18	1443	City of San Antonio Transfer Station	5TS	Bexar
18	2248	Liquid Environmental Solutions of Texas San Antonio Facility	5GG	Bexar
18	2317	Southwaste Disposal San Antonio Facility	5RC	Bexar
18	40085	Liquid Environmental Solutions of Texas San Antonio Facility	5TS	Bexar
18	40157	SOSLiquid Waste Haulers	5TL	Bexar
18	40280	Stericycle	5MWTS	Bexar

		Identification		
COG #	Permit Number	Facility Name	Facility Type	County Name
18	42032	New Earth	5RC	Bexar
18	40244	Medsharps Schertz Facility	5AC	Comal
18	40240	City of Kerrville Landfill	5TS	Kerr
18	42028	City of Kerrville Landfill	5RC	Kerr
18	43011	Lacoste WWTP	5GG	Medina
18	1410C	Tessman Road Landfill	1	Bexar
18	2093B	Covel Gardens Landfill Gas Power Station	1	Bexar
18	66B	Mesquite Creek Landfill	1	Comal
18	1995	City of Fredericksburg Landfill	1	Gillespie
18	1848	Beck Landfill	4	Guadalupe
18	1506A	City of Kerrville Landfill	1	Kerr
18	571	Mcmullen County	1AE	Mcmullen
18	48005	Tessman Road Landfill Gas Power Station	9GR	Bexar
18	48015	Covel Gardens Landfill Gas Power Station	9GR	Bexar
18	48029	Mesquite Creek Landfill	9GR	Comal
18	48039	Nelson Gardens	9GR	Bexar
19	40103	Jim Hogg County Transfer Station	5TS	Jim Hogg
19	40238	Starr County Transfer Station	5TS	Starr
19	954	City of Roma Landfill	1AE	Starr
19	2286	Ponderosa Regional Landfill	1	Webb
19	1693B	City of Laredo Landfill	1	Webb
19	783A	San Ygnacio Msw Landfill	1 AE & 4	Zapata
20	40027	Aransas County Transfer Station Facility	5TS	Aransas
20	40002	Live Oak County	5TS	Live Oak
20	40228	J C Elliott Landfill	5TS	Nueces
20	40270	Envirotech Waste Solutions Medical Waste Processing And Storage Facility	5AC	Nueces
20	2319	Texas Sludge Disposal	5RC	San Patricio
20	379	Brooks County	4AE	Brooks
20	1481	Duval County Landfill	4AE	Duval
20	262C	City of Alice Landfill	1	Jim Wells
20	235B	City of Kingsville Landfill	1	Kleberg
20	2267	El Centro Landfill	1	Nueces
20	2269	City of Corpus Christi Landfill	1	Nueces
20	2349	Gulley Hurst	4	Nueces
21	2334	Stericycle Harlingen Processing Facility	5MW	Cameron
21	2375	La Feria Transfer Station	5TS	Cameron
21	40248	City of Harlingen Transfer Station Facility	5TS	Cameron
21	42015	City of Brownsville Composting Facility	5RC	Cameron
21	748	Pharr Transfer Station	5TS	Hidalgo
21	2343	Valley Dewatering Services	5GG	Hidalgo
21	2346	Liquid Environmental Solutions Weslaco	5GG	Hidalgo
21	1273A	City of Brownsville Municipal Landfill	1	Cameron

		Identification		
COG #	**Permit Number**	**Facility Name**	**Facility Type**	**County Name**
21	2302	Edinburg Regional Disposal Facility	4	Hidalgo
21	2348	La Gloria Ranch Landfill	1	Hidalgo
21	1727A	Penitas	1AE	Hidalgo
21	956B	Edinburg Regional Disposal Facility	1	Hidalgo
21	48038	City of Edinburg Regional Landfill	9GR	Hidalgo
22	1030	City of Gainesville Transfer Station	5TS	Cooke
22	1136	City of Sherman Transfer Station	5TS	Grayson
22	2290	Texoma Area Solid Waste Authority Landfill	1	Grayson
22	523B	Waste Management Hillside Landfill	1	Grayson
23	2368	S & M Vacuum & Liquid Waste Processing Facility	5GG	Bell
23	40209	Killeen Transfer Station	5TS	Bell
23	40234	Stericycle Temple	5MWTS	Bell
23	42035	Bell County Wcid 1 Regional Compost	5RC	Bell
23	40145	City of Copperas Cove Transfer Station	5TS	Coryell
23	42017	City of Copperas Cove Composting Facility	5RC	Coryell
23	42040	Fort Hood Biotreatment Facility	5RC	Coryell
23	40004	City of Hico Transfer Station Facility	5TS	Hamilton
23	40160	City of San Saba Municipal Solid Waste Processing	5TS	San Saba
23	692A	Temple Recycling And Disposal Facility	1	Bell
23	1866	Fort Hood Landfill	1	Coryell
24	40057	City of Rock Springs Transfer Station	5TS	Edwards
24	40170	City of Brackettville Msw Transfer Station	5TS	Kinney
24	40178	Fort Clark Springs	5TS	Kinney
24	40251	City of Cotulla Transfer Station	5TS	La Salle
24	40034	City of Sabinaltransfer Station	5TS	Uvalde
24	2225	City of Carrizo Springs Landfill	1AE	Dimmit
24	2354	Fort Clark Springs Association Landfill	1AE	Kinney
24	1918	City of Eagle Pass And Maverick Landfill	4AE	Maverick
24	2316	Maverick County El Indio Msw Landfill	1	Maverick
24	1725	City of Uvalde Landfill	1	Uvalde
24	207A	City of Del Rio Landfill	1	Val Verde
24	2303	Zavala County Mswf Landfill	1AE	Zavala
24	1308A	City of Crystal City Landfill	1AE	Zavala
Subtotal				

COG #	Permit Number	Facility Fees: Was Waste or Feedstock Measured by Weight?	Was Waste or Feedstock Measured by Volume?	By Tons	By Gallon	By Pound	By Compacted CY	By Un-Compacted CY
1	40271	Yes	No	85	-	-	-	-
1	40192	No	Yes	-	-	-	-	12
1	43030	Yes	No	40	-	-	-	-
1	40026	Yes	No	85	-	-	-	-
1	40015	Yes	No	45	-	-	-	-
1	40031	Yes	No	-	-	-	-	-
1	40263	Yes	No	-	-	1	-	-
1	76A	Yes	No	-	-	-	-	-
1	40109	No	Yes	-	-	-	-	-
1	414	No	Yes	-	-	-	-	3
1	1164	No	Yes	23	-	-	-	-
1	445A	Yes	No	34	-	-	-	-
1	2263	Yes	Yes	-	-	-	-	9
1	955	No	Yes	25	-	-	-	2
1	1038A	Yes	No	26	-	-	-	-
1	215A	No	Yes	-	-	-	-	10
1	570	No	Yes	-	-	-	-	10
1	2238	Yes	No	40	-	-	-	-
1	589A	Yes	No	40	-	-	-	-
1	2266	No	Yes	-	-	-	11	-
1	2352	Yes	No	40	-	-	-	-
1	1943	Yes	Yes	75	-	-	-	47
1	2279	Yes	No	36	-	-	-	-
1	2285	Yes	No	36	-	-	-	-
1	876A	Yes	No	26	-	-	-	-
1	791	No	Yes	-	-	-	-	-
1	73A	Yes	No	30	-	-	-	-
1	1663B	Yes	Yes	34	0	-	19	19
1	1009A	Yes	No	30	-	-	-	-
1	2281	Yes	No	39	-	-	-	-
2	40051	Yes	No	-	-	-	-	-
2	2231	No	Yes	-	0	-	-	-
2	40176	Yes	No	33	-	-	-	-
2	40279	Yes	No	-	-	-	-	-
2	564	Yes	Yes	35	-	-	-	18
2	2291	Yes	No	35	-	-	-	18
2	2268	No	Yes	70	-	-	-	-
2	9017	No	No	-	-	-	-	-
2	2207	Yes	Yes	36	-	-	-	-
2	2227	No	Yes	-	-	-	-	35
2	2157	Yes	No	43	-	-	-	-

		Facility Fees						
COG #	Permit Number	Was Waste or Feedstock Measured by Weight?	Was Waste or Feedstock Measured by Volume?	By Tons	By Gallon	By Pound	By Compacted CY	By Un-Compacted CY
2	1733	No	Yes	-	-	-	-	7
2	2369	Yes	No	28	-	-	-	-
2	1298	Yes	No	35	-	-	-	-
2	2274	Yes	No	35	-	-	-	-
2	363A	Yes	No	-	-	-	-	-
2	583A	Yes	No	35	-	-	-	-
2	69	Yes	No	33	-	-	-	-
2	2252	Yes	No	33	-	-	-	-
2	2323	Yes	No	30	-	-	-	-
2	2328A	Yes	No	35	-	-	-	-
2	549A	Yes	No	39	-	-	-	-
2	2170	Yes	No	48	-	-	-	-
2	2293	Yes	No	30	-	-	-	-
2	2217	Yes	No	20	-	-	-	-
3	40144	Yes	No	50	-	-	-	-
3	2295	Yes	No	68	-	-	-	-
3	1429	Yes	No	40	-	-	-	-
3	2229A	No	Yes	-	0	-	-	-
3	40059	Yes	No	52	-	-	-	-
3	9001A	No	No	-	-	-	-	-
3	1428A	Yes	No	31	-	-	-	-
3	1571A	Yes	No	28	-	-	-	-
4	1494	Yes	No	45	-	-	-	-
4	40284	Yes	No	27	-	-	-	-
4	2045A	Yes	No	45	-	-	-	-
4	53A	Yes	No	45	-	-	-	-
4	12	Yes	No	26	-	-	-	-
4	60	Yes	No	-	-	-	-	-
4	227	No	Yes	-	-	-	-	-
4	1145	Yes	No	51	-	-	-	-
4	1263	No	Yes	-	-	-	-	-
4	1421	No	Yes	-	0	-	-	-
4	1453	Yes	No	-	-	-	-	-
4	40196	Yes	No	-	-	-	-	-
4	40265	Yes	No	-	-	-	-	-
4	2069A	No	Yes	-	0	-	-	-
4	40080	No	Yes	-	-	-	-	-
4	40168	Yes	No	28	-	-	-	-
4	40181	Yes	No	85	-	-	-	-
4	2275	Yes	No	-	-	-	-	-
4	2306	Yes	No	36	-	-	-	-

		Facility Fees						
COG #	Permit Number	Was Waste or Feedstock Measured by Weight?	Was Waste or Feedstock Measured by Volume?	By Tons	By Gallon	By Pound	By Compacted CY	By Un-Compacted CY
4	2379	No	Yes	-	0	-	-	-
4	40052	Yes	No	-	-	-	-	-
4	40186	Yes	No	48	-	-	-	-
4	1225D	No	Yes	-	0	-	-	-
4	2256A	No	Yes	-	0	-	-	-
4	40241	Yes	No	-	-	1	-	-
4	2294	Yes	No	32	-	-	-	-
4	62	Yes	No	25	-	-	-	-
4	1394B	Yes	No	40	-	-	-	-
4	1895A	Yes	No	26	-	-	-	-
4	996C	Yes	No	32	-	-	-	-
4	1025B	Yes	No	22	-	-	14	11
4	1312B	Yes	Yes	30	-	-	-	-
4	1590A	Yes	No	44	-	-	-	-
4	1749B	Yes	Yes	26	-	-	-	-
4	1209B	Yes	Yes	-	-	-	-	80
4	1745B	Yes	Yes	31	-	-	-	-
4	42D	Yes	No	22	0	-	22	11
4	664	Yes	No	50	-	-	-	-
4	1195A	Yes	No	29	-	-	-	-
4	534	No	Yes	-	-	-	-	-
4	1417B	Yes	No	32	0	-	-	-
4	2190	Yes	Yes	-	-	-	9	8
4	47A	Yes	Yes	41	-	-	23	23
4	1983C	Yes	No	38	-	-	-	-
4	218C	Yes	Yes	22	-	-	17	17
4	358B	Yes	No	31	-	-	-	5
4	48012							
4	48016							
4	48018							
4	48027							
4	48028							
4	48032							
4	48033							
4	48042							
4	1025B							
5	2382	No	Yes	-	-	-	-	-
5	576C	Yes	No	51	-	-	-	-
5	2358	No	Yes	-	-	-	8	8
5	797B	Yes	Yes	34	-	-	-	36
6	2389	No	Yes	-	-	-	17	25
6	40005	Yes	No	-	-	-	-	-

		Facility Fees						
COG #	Permit Number	Was Waste or Feedstock Measured by Weight?	Was Waste or Feedstock Measured by Volume?	By Tons	By Gallon	By Pound	By Compacted CY	By Un-Compacted CY
6	40006	Yes	No	-	-	-	-	-
6	40040	No	Yes	-	-	-	17	25
6	40174	No	Yes	-	-	-	12	12
6	2365	No	Yes	-	-	-	-	-
6	40172	Yes	No	-	-	-	-	-
6	40267	Yes	No	-	-	1	-	-
6	356	Yes	Yes	-	0	-	-	-
6	40266	No	Yes	-	-	-	19	16
6	40102	No	Yes	-	-	-	8	13
6	1614A	Yes	Yes	34	-	-	8	11
6	1327B	Yes	Yes	38	0	0	-	-
6	1249B	Yes	Yes	26	0	-	14	-
6	1972A	Yes	Yes	25	-	-	-	8
6	48026							
6	48041							
7	1562A	Yes	No	40	-	0	18	8
7	1302	No	Yes	-	-	-	-	-
7	9009	No	No	-	-	-	-	-
7	1604B	Yes	No	24	-	-	9	9
7	2325	Yes	No	40	0	-	-	38
7	1469A	Yes	Yes	26	0	-	9	9
7	9004	No	No	-	-	-	-	-
7	420A	No	Yes	28	-	-	-	15
7	50B	No	Yes	-	-	-	-	7
7	9013	No	No	-	-	-	-	-
7	1463B	Yes	No	33	-	-	-	-
7	9000A	No	No	-	-	-	-	-
8	728	Yes	No	-	-	-	-	-
8	2355	No	Yes	-	0	-	-	-
8	40237	Yes	Yes	33	-	-	-	12
8	40261	No	Yes	-	-	-	-	-
8	40262	Yes	No	-	-	2	-	-
8	1276	No	Yes	-	-	-	-	-
8	2197	Yes	Yes	55	-	-	-	14
8	1422	Yes	No	-	-	-	-	-
8	2284	Yes	No	26	-	-	-	-
8	729B	Yes	No	26	-	-	-	-
8	495	No	Yes	-	-	-	13	15
8	957A	No	Yes	-	-	-	13	15
8	1737A	Yes	No	60	-	-	-	-
9	2373	No	Yes	-	0	-	-	-

		Facility Fees						
COG #	Permit Number	Was Waste or Feedstock Measured by Weight?	Was Waste or Feedstock Measured by Volume?	By Tons	By Gallon	By Pound	By Compacted CY	By Un-Compacted CY
9	43028	Yes	Yes	-	0	0	-	-
9	171	Yes	No	35	-	-	-	-
9	427	No	Yes	-	-	-	2	-
9	517A	Yes	No	30	-	-	-	-
9	2158	Yes	Yes	46	0	-	-	51
9	39	Yes	No	25	-	-	-	-
9	2154	No	Yes	-	-	-	-	-
9	288A	Yes	No	45	-	-	-	-
9	2189	No	Yes	-	-	-	-	-
9	1605B	Yes	No	32	-	-	-	-
9	976	Yes	No	65	0	0	-	-
9	2120	Yes	No	-	-	-	-	-
9	673	No	Yes	-	-	-	-	-
9	566	No	Yes	50	-	-	-	-
9	691	No	Yes	-	-	-	-	-
9	772	Yes	No	42	-	-	-	-
10	2357	No	Yes	-	0	-	-	-
10	2359	No	Yes	-	0	-	-	-
10	42022	No	Yes	-	-	-	-	-
10	26B	Yes	Yes	-	-	-	-	20
10	195	Yes	No	-	-	0	-	-
10	1732	Yes	No	25	-	-	-	-
10	1404	No	Yes	-	-	-	-	-
10	86B	Yes	No	30	-	-	-	-
10	349	Yes	No	40	-	-	-	-
10	2264	Yes	No	40	-	-	-	-
10	79	Yes	No	42	0	-	-	-
11	241D	Yes	Yes	30	-	-	-	-
11	1558A	Yes	Yes	-	-	-	-	13
11	1646A	Yes	No	28	-	-	-	-
11	948A	Yes	No	31	-	-	-	-
11	48020							
12	2260A	Yes	No	-	-	-	-	-
12	2300	No	Yes	-	-	-	30	30
12	40035	No	Yes	-	-	-	-	35
12	1787	No	Yes	-	-	-	15	25
12	119	No	Yes	-	-	-	-	40
12	2250	No	Yes	-	0	-	-	-
12	2310	Yes	Yes	28	0	-	-	15
12	2384	No	Yes	-	0	-	-	-
12	40212	No	Yes	-	-	-	-	-

		Facility Fees						
COG #	Permit Number	Was Waste or Feedstock Measured by Weight?	Was Waste or Feedstock Measured by Volume?	By Tons	By Gallon	By Pound	By Compacted CY	By Un-Compacted CY
12	40243	Yes	Yes	-	-	-	-	-
12	42016	No	Yes	-	0	-	-	10
12	466A	Yes	Yes	40	-	-	-	26
12	2123	Yes	Yes	45	-	-	-	10
12	1841A	Yes	Yes	31	-	-	-	21
12	249D	Yes	No	29	-	-	-	-
12	1405B	Yes	No	34	-	-	-	-
12	48019							
13	42003	Yes	No	21	-	-	-	-
13	43026	No	Yes	-	0	-	-	-
13	2381	No	Yes	-	0	-	-	-
13	40018	Yes	No	59	-	-	44	90
13	40173	Yes	No	-	-	-	-	-
13	2292	Yes	No	24	-	-	-	-
14	40033	No	Yes	-	-	-	17	25
14	40044	No	Yes	-	-	-	12	16
14	43007	No	Yes	-	0	-	-	-
14	40277	No	Yes	-	-	-	-	-
14	40054	No	Yes	-	-	-	-	11
14	40024	No	Yes	-	-	-	15	8
14	40013	No	Yes	-	0	-	-	-
14	40038	No	Yes	-	-	-	11	9
14	2105A	Yes	Yes	22	-	-	8	7
14	720	Yes	Yes	-	-	-	7	6
14	2242A	Yes	Yes	27	-	-	-	-
14	1384A	Yes	Yes	18	-	-	7	6
15	40164	No	Yes	-	-	-	-	-
15	40225	No	Yes	-	-	-	6	6
15	40268	Yes	No	-	-	0	-	-
15	43000	No	Yes	-	-	-	-	-
15	2214A	No	Yes	-	-	-	10	7
15	2027	Yes	Yes	29	1	-	12	8
15	1486B	No	Yes	-	-	-	6	5
15	1815A	No	Yes	-	-	-	7	7
16	40191	No	Yes	-	-	-	-	-
16	2235	Yes	Yes	-	-	-	-	-

		Facility Fees						
COG #	Permit Number	Was Waste or Feedstock Measured by Weight?	Was Waste or Feedstock Measured by Volume?	By Tons	By Gallon	By Pound	By Compacted CY	By Un-Compacted CY
16	2239A	Yes	No	836	-	-	-	-
16	40282	Yes	No	51	-	-	-	-
16	40053	No	Yes	-	0	-	-	-
16	40264	No	Yes	-	-	-	-	-
16	164	Yes	No	40	-	-	-	-
16	2232A	Yes	No	-	-	0	-	-
16	1471	Yes	Yes	37	-	-	-	-
16	1578	Yes	No	28	-	-	-	-
16	1697	No	Yes	-	-	-	-	-
16	2298	No	Yes	-	0	-	-	-
16	2350	No	Yes	-	0	-	-	-
16	2370	No	Yes	-	0	-	-	-
16	2386	No	Yes	-	-	-	-	-
16	40098	Yes	No	-	-	-	-	-
16	40131	Yes	No	36	-	-	-	-
16	40132	Yes	No	36	-	-	-	-
16	40133	Yes	No	41	-	-	-	-
16	40189	No	Yes	-	-	-	-	8
16	40211	No	Yes	-	-	-	-	6
16	40217	No	Yes	-	-	-	-	10
16	40236	No	Yes	-	-	-	15	10
16	40249	Yes	No	22	-	-	-	-
16	40250	Yes	No	-	-	0	-	-
16	40273	Yes	No	-	-	0	-	-
16	40275	Yes	No	40	-	-	-	-
16	40283	Yes	No	-	-	-	-	-
16	43034	No	Yes	-	0	-	-	-
16	1355A	Yes	No	33	-	-	-	-
16	1483A	Yes	Yes	36	-	-	-	-
16	2234D	No	Yes	-	0	-	-	-
16	2241A	No	Yes	-	0	-	-	-
16	40028	Yes	No	43	-	-	-	-
16	2222	Yes	No	-	-	-	-	-
16	2309	Yes	No	39	-	-	-	-
16	42037	No	Yes	-	-	-	-	21
16	2387	Yes	No	67	-	-	-	-
16	40014	No	Yes	-	-	-	-	15
16	2318	No	Yes	-	-	-	-	10
16	1708	No	Yes	-	-	-	-	9
16	1539A	Yes	Yes	43	-	-	13	12
16	1502A	Yes	No	-	-	0	-	-
16	1535B	Yes	Yes	26	-	-	13	10

		Facility Fees						
COG #	Permit Number	Was Waste or Feedstock Measured by Weight?	Was Waste or Feedstock Measured by Volume?	By Tons	By Gallon	By Pound	By Compacted CY	By Un-Compacted CY
16	203A	Yes	Yes	27	-	-	-	16
16	2270	Yes	No	32	-	-	-	-
16	1505A	Yes	No	26	-	-	-	-
16	1797A	No	Yes	-	-	-	11	10
16	1149B	Yes	Yes	37	-	-	-	-
16	1721A	Yes	Yes	35	-	-	13	10
16	1849B	No	Yes	-	-	-	-	120
16	1193	No	Yes	42	-	-	-	-
16	1301	No	Yes	-	-	-	-	10
16	1403	No	Yes	-	-	-	-	7
16	2185	Yes	Yes	-	-	-	-	10
16	2304	No	Yes	-	-	-	-	7
16	2344	No	Yes	-	-	-	-	5
16	1307D	Yes	Yes	27	-	-	14	11
16	1540A	No	Yes	-	-	-	-	9
16	1565B	No	Yes	39	-	-	-	11
16	1586A	No	Yes	-	-	-	-	10
16	1599A	No	Yes	-	-	-	-	10
16	1921A	No	Yes	-	-	-	-	10
16	2240B	No	Yes	-	-	-	-	12
16	261B	Yes	No	42	-	-	-	-
16	2324	No	Yes	-	-	-	-	-
16	1752B	Yes	Yes	34	-	-	13	9
16	1777							
16	48006							
16	48008							
16	48009							
16	48025							
16	48034							
16	48035							
17	40017	Yes	Yes	66	0	0	-	14
17	2181	Yes	Yes	-	-	0	-	3
17	40011	No	Yes	-	-	-	-	30
17	2330	No	Yes	-	1	-	-	-
17	2366	No	Yes	-	0	-	-	-
17	42034	Yes	No	27	-	-	-	-
17	1522A	Yes	No	43	-	-	-	-
17	48036							
18	1443	Yes	Yes	60	-	-	-	40

COG #	Permit Number	Facility Fees						
		Was Waste or Feedstock Measured by Weight?	Was Waste or Feedstock Measured by Volume?	By Tons	By Gallon	By Pound	By Compacted CY	By Un-Compacted CY
18	2248	No	Yes	-	0	-	-	-
18	2317	No	Yes	-	0	-	-	-
18	40085	No	Yes	-	0	-	-	-
18	40157	No	Yes	-	-	-	-	-
18	40280	No	Yes	-	-	-	-	-
18	42032	Yes	Yes	17	-	-	-	4
18	40244	Yes	No	-	-	1	-	-
18	40240	Yes	No	67	-	-	-	-
18	42028	Yes	No	67	-	-	-	-
18	43011	No	Yes	-	0	-	-	-
18	1410C	Yes	No	45	-	-	-	-
18	2093B	Yes	No	29	-	-	-	-
18	66B	Yes	No	25	-	-	-	-
18	1995	Yes	No	55	0	-	-	-
18	1848	Yes	Yes	26	-	-	-	-
18	1506A	Yes	No	67	-	-	-	-
18	571	No	Yes	-	-	-	-	-
18	48005							
18	48015							
18	48029							
18	48039							
19	40103	No	Yes	-	-	-	-	5
19	40238	Yes	No	28	-	-	-	-
19	954	Yes	No	36	-	-	-	-
19	2286	Yes	No	30	-	-	-	-
19	1693B	Yes	No	32	-	-	-	-
19	783A	No	Yes	32	-	-	-	-
20	40027	Yes	No	100	-	-	-	-
20	40002	No	Yes	-	-	-	-	-
20	40228	Yes	No	37	-	-	13	10
20	40270	Yes	No	-	-	-	-	-
20	2319	No	Yes	-	0	-	-	15
20	379	No	Yes	-	-	-	-	3
20	1481	No	Yes	-	-	-	-	12
20	262C	Yes	No	46	-	-	-	-
20	235B	Yes	No	27	-	-	-	-
20	2267	Yes	No	32	-	-	-	-
20	2269	Yes	Yes	37	-	-	13	10

		Facility Fees						
COG #	Permit Number	Was Waste or Feedstock Measured by Weight?	Was Waste or Feedstock Measured by Volume?	By Tons	By Gallon	By Pound	By Compacted CY	By Un-Compacted CY
20	2349	No	Yes	-	-	-	-	4
21	2334	Yes	No	-	-	-	-	-
21	2375	Yes	No	50	-	-	-	-
21	40248	Yes	No	43	-	-	-	-
21	42015	Yes	No	15	-	-	-	-
21	748	Yes	No	-	-	-	-	-
21	2343	No	Yes	-	0	-	-	-
21	2346	No	Yes	-	0	-	-	-
21	1273A	Yes	Yes	30	-	-	-	-
21	2302	Yes	Yes	30	-	-	-	10
21	2348	Yes	No	65	-	-	-	-
21	1727A	No	Yes	-	-	-	-	-
21	956B	Yes	Yes	30	-	-	-	10
21	48038							
22	1030	Yes	No	49	-	-	-	-
22	1136	No	Yes	-	-	-	-	-
22	2290	Yes	No	35	-	-	-	-
22	523B	Yes	No	32	-	-	-	-
23	2368	No	Yes	-	0	-	-	-
23	40209	Yes	No	62	-	-	-	-
23	40234	No	Yes	-	-	-	-	-
23	42035	Yes	No	-	-	-	-	7
23	40145	Yes	No	65	-	-	-	-
23	42017	Yes	No	-	-	-	-	-
23	42040	No	Yes	-	-	-	-	-
23	40004	No	Yes	-	-	-	-	14
23	40160	No	Yes	-	-	-	23	12
23	692A	Yes	No	29	-	-	-	-
23	1866	Yes	No	103	-	-	-	-
24	40057	No	Yes	-	-	-	-	25
24	40170	No	Yes	-	-	-	25	-
24	40178	Yes	No	-	-	-	-	-
24	40251	Yes	No	-	-	-	-	-
24	40034	No	Yes	40	-	-	-	-
24	2225	Yes	No	50	-	-	-	25
24	2354	Yes	No	-	-	-	-	-
24	1918	No	Yes	24	-	-	8	8
24	2316	Yes	No	45	-	-	-	-
24	1725	Yes	No	45	-	0	-	8

		Facility Fees						
COG #	Permit Number	Was Waste or Feedstock Measured by Weight?	Was Waste or Feedstock Measured by Volume?	By Tons	By Gallon	By Pound	By Compacted CY	By Un-Compacted CY
24	207A	Yes	No	42	-	-	-	-
24	2303	Yes	No	50	-	-	10	10
24	1308A	Yes	Yes	45	-	-	-	-
Subtotal				**8,158**	**11**	**7**	**668**	**1,806**

COG #	Permit Number	Counties Served	Total Counties Served
1	40271	Dallam,Hartley,Hutchinson,Moore,Sherman	5
1	40192	Donley	1
1	43030	Donley,Gray,Hemphill,Hutchinson,Lipscomb,Roberts,Wheeler	7
1	40026	Gray,Hansford,Hemphill,Lipscomb,Ochiltree,Roberts,Wheeler	7
1	40015	Carson,Hansford,Hutchinson	3
1	40031	Moore	1
1	40263	Anderson,Andrews,Angelina,Archer,Armstrong,Bastrop,Bell,Bexar,Bosque,Brazoria,Burleson,Burnet,Cass,Childress,Collin,Comal,Comanche,Cooke,Dallas,Denton,Duval,El Paso,Fort Bend,Hale,Harris,Hill,Hunt,Lamb,Lubbock,Mclennan,Parker,Red River,San Saba,Tarrant,Travis,Van Zandt,Wise	37
1	76A	Potter,Randall	2
1	40109	Sherman	1
1	414	Armstrong	1
1	1164	Carson	1
1	445A	Castro	1
1	2263	Childress	1
1	955	Collingsworth	1
1	1038A	Dallam,Hartley	2
1	215A	Deaf Smith	1
1	570	Gray	1
1	2238	Donley,Gray,Hemphill,Hutchinson,Lipscomb,Roberts	6
1	589A	Donley,Gray,Hemphill,Hutchinson,Lipscomb,Roberts,Wheeler	7
1	2266	Donley,Hall	2

COG #	Permit Number	Counties Served	Total Counties Served
1	2352	Hansford,Moore,Ochiltree	3
1	1943	Lipscomb	1
1	2279	Moore	1
1	2285	Moore	1
1	876A	Ochiltree	1
1	791	Oldham	1
1	73A	Potter,Randall	2
1	1663B	Armstrong,Briscoe,Carson,Childress,Collingsworth,Dallam,Deaf Smith,Donley,Floyd,Gray,Hall,Hansford,Hartley,Hemphill, Hockley,Howard,Hutchinson,Lamb,Lipscomb,Lubbock,Moore,Randall	22
1	1009A	Briscoe,Swisher	2
1	2281	Wheeler	1
2	40051	Hockley	1
2	2231	Crosby,Donley,Floyd,Hale,Hockley,Lamb,Lubbock	7
2	40176	Lubbock	1
2	40279	Andrews,Armstrong,Bailey,Castro,Childress,Cochran,Collingsworth,Crane,Crosby,Dallam,Dawson,Deaf Smith,Donley,Floyd,Gaines,Garza,Gray,Hale,Hardin,Hartley,Hockley,Howard,Hutchinson,Lamb,Lubbock,Lynn,Martin,Midland,Moore,Motley,Parmer,Pecos,Randall,Reeves,Roberts,Scurry,Swisher,Terry,Ward,Wheeler,Winkler,Yoakum	42
2	564	Bailey,Lamb	2
2	2291	Bailey,Cochran,Lamb,Parmer	4
2	2268	Cochran	1
2	9017	Dickens	1
2	2207	Crosby,Dickens,Floyd,Motley	4
2	2227	Garza	1
2	2157	Floyd,Hale	2

COG #	Permit Number	Counties Served	Total Counties Served
2	1733	Hockley	1
2	2369	Hockley	1
2	1298	Hockley,Lamb	2
2	2274	Lamb	1
2	363A	Lamb	1
2	583A	Bailey,Castro,Floyd,Hale,Hockley,Lubbock,Swisher	7
2	69	Bailey,Cochran,Crosby,Dickens,Floyd,Garza,Hale,Hockley,King, Lamb,Lubbock,Lynn,Motley,Scurry,Terry,Yoakum	16
2	2252	Bailey,Cochran,Crosby,Dickens,Floyd,Garza,Hale,Hockley,King, Lamb,Lubbock,Lynn,Motley,Scurry,Terry,Yoakum	16
2	2323	Lubbock	1
2	2328A	Dawson,Garza,Lubbock,Lynn,Terry	5
2	549A	Briscoe,Cottle,Dickens,Hall,Kent,Motley	6
2	2170	Andrews,Cochran,Dawson,Ector,Gaines,Hockley,Lubbock,Terry, Yoakum	9
2	2293	Gaines,Garza,Hockley,Lubbock,Lynn,Terry	6
2	2217	Gaines,Yoakum	2
3	40144	Baylor	1
3	2295	Clay,Cooke,Denton,Jack,Montague,Wise	6
3	1429	Archer,Clay,Wichita	3
3	2229A	Anderson,Archer,Austin,Bastrop,Baylor,Bell,Burleson,Calhoun,Callahan,Childress,Clay,Collin,Collingsworth,Cooke,Dallas,Denton,Dickens,Dimmit,Donley,Eastland,Ellis,Erath,Fannin,Fisher,Foard,Gray,Grayson,Gregg,Hale,Hall,Hamilton,Hardeman,Haskell,Hays,Henderson,Hill,Hockley,Hood,Howard,Hunt,Jack,Johnson,Kaufman,King,Knox,Llano,Mitchell,Montague,Navarro,Nolan,Orange,Palo Pinto,Parker,Polk,Potter,Rockwall,San Saba,Shackelford,Sherman,Smith,Stephens,Stonewall,Tarrant,Taylor,Terrell,Throckmorton,Wheeler,Wichita,Wilbarger,Williamson,Wilson,Wise,Young	73
3	40059	Cottle,Foard,Hardeman,Wilbarger	4

COG #	Permit Number	Counties Served	Total Counties Served
3	9001A	Cottle	1
3	1428A	Archer,Clay,Wichita	3
3	1571A	Archer,Baylor,Clay,Cottle,Denton,Foard,Hardeman,Jack,Montague,Wichita,Wilbarger,Wise,Young	13
4	1494	Collin,Dallas	2
4	40284	Collin,Dallas,Grayson	3
4	2045A	Collin,Dallas,Denton	3
4	53A	Collin,Dallas	2
4	12	Dallas	1
4	60	Dallas	1
4	227	Dallas	1
4	1145	Dallas	1
4	1263	Dallas	1

COG #	Permit Number	Counties Served	Total Counties Served
4	1421	Anderson,Austin,Bandera,Bastrop,Bell,Bosque,Bowie,Brazos,Brooks,Brown,Burleson,Burnet,Caldwell,Calhoun,Callahan,Cameron,Camp,Carson,Cass,Castro,Chambers,Cherokee,Childress,Clay,Cochran,Coke,Coleman,Collin,Collingsworth,Colorado,Comal,Comanche,Concho,Cooke,Coryell,Cottle,Crane,Crockett,Crosby,Culberson,Dallam,Dallas,Dawson,Deaf Smith,Delta, Denton,Dewitt, Dickens, Dimmit, Donley, Duval,Eastland, Ector,Edwards,El Paso, Ellis, Erath, Falls,Fannin, Fayette, Fisher,Floyd,Foard,Fort Bend,Franklin, Freestone,Frio,Gaines, Galveston,Garza,Gillespie, Glasscock, Goliad, Gonzales,Gray,Grayson,Gregg,Grimes, Guadalupe,Hale,Hall, Hamilton, Hansford, Hardeman, Hardin,Harris,Harrison, Hartley, Haskell, Hays,Hemphill, Henderson, Hidalgo,Hill,Hockley, Hood, Hopkins, Houston, Howard, Hudspeth,Hunt,Hutchinson, Irion,Jack, Jackson,Jasper, Jeff Davis,Jefferson,Jim Hogg,Jim Wells, Johnson, Jones, Karnes, Kaufman,Kendall,Kenedy, Kent, Kerr, Kimble,King, Kinney,Kleberg, Knox,La Salle, Lamar,Lamb, Lampasas, Lavaca, Lee,Leon, Liberty, Limestone,Lipscomb,Live Oak,Llano, Loving, Lubbock, Lynn,Madison, Marion,Martin, Mason,Matagorda, Maverick, Mcculloch, Mclennan,Mcmullen, Medina, Menard, Midland, Milam,Mills,Mitchell, Montague, Montgomery, Moore, Morris,Motley, Nacogdoches,Navarro, Newton, Nolan, Nueces, Ochiltree,Oldham, Orange,Palo Pinto, Panola, Parker, Parmer, Pecos, Polk,Potter, Presidio, Rains,Randall, Reagan, Real,Red River, Reeves,Refugio, Roberts, Robertson, Rockwall, Runnels, Rusk, Sabine, San Augustine,San Jacinto, San Patricio,San Saba, Schleicher, Scurry, Shackelford,Shelby, Sherman, Smith, Somervell, Starr,Stephens, Sterling, Stonewall,Sutton, Swisher, Tarrant, Taylor, Terrell, Terry, Throckmorton,Titus,Tom Green, Travis, Trinity, Tyler, Upshur, Upton,Uvalde,Val Verde,Van Zandt, Victoria, Walker,Waller, Ward,Washington, Webb,Wharton, Wheeler, Wichita,Wilbarger,Willacy,Williamson, Wilson, Winkler, Wise, Wood, Yoakum, Young, Zapata, Zavala	239
4	1453	Dallas	1
4	40196	Collin,Dallas,Denton,Ellis,Kaufman,Tarrant	6

COG #	Permit Number	Counties Served	Total Counties Served
4	40265	Anderson,Andrews,Angelina,Aransas,Archer,Armstrong,Atascosa,Austin,Bailey,Bandera,Bastrop,Baylor,Bee,Bell,Bexar,Blanco,Borden,Bosque,Bowie,Brazoria,Brazos,Brewster,Briscoe,Brooks,Brown,Burleson,Burnet,Caldwell,Calhoun,Callahan,Cameron,Camp,Carson,Cass,Castro,Chambers,Cherokee,Childress,Clay,Cochran,Coke,Coleman,Collin,Collingsworth,Colorado,Comal,Comanche,Concho,Cooke,Coryell,Cottle,Crane,Crockett,Crosby,Culberson,Dallam,Dallas,Dawson,Deaf Smith,Delta,Denton,Dewitt, Dickens,Dimmit, Donley,Duval, Eastland,Ector,Edwards,El Paso,Ellis,Erath, Falls,Fannin, Fayette,Fisher,Floyd,Foard,Fort Bend,Franklin, Freestone, Frio,Gaines,Galveston,Garza, Gillespie,Glasscock, Goliad,Gonzales, Gray,Grayson,Gregg,Grimes,Guadalupe,Hale,Hall,Hamilton,Hansford,Hardeman,Hardin,Harris,Harrison,Hartley,Haskell,Hays,Hemphill,Henderson,Hidalgo,Hill,Hockley,Hood,Hopkins,Houston, Howard,Hudspeth,Hunt,Hutchinson,Irion, Jack,Jackson, Jasper,Jeff Davis, Jefferson,Jim Hogg,Jim Wells,Johnson Jones, Karnes, Kaufman, Kendall,Kenedy,Kent,Kerr, Kimble,King, Kinney,Kleberg, Knox,La Salle, Lamar, Lamb, Lampasas, Lavaca,Lee,Leon,Liberty, Limestone,Lipscomb, Live Oak,Llano,Loving, Lubbock,Lynn, Madison,Marion,Martin, Mason,Matagorda, Maverick, Mcculloch, Mclennan,Mcmullen,Medina,Menard, Midland,Milam, Mills,Mitchell, Montague, Montgomery, Moore,Morris, Motley,Nacogdoches, Navarro, Newton, Nolan,Nueces, Ochiltree,Oldham,Orange,Palo Pinto,Panola, Parker,Parmer, Pecos,Polk,Potter,Presidio, Rains,Randall, Reagan, Real,Red River, Reeves,Refugio, Roberts, Robertson, Rockwall, Runnels, Rusk,Sabine,San Augustine, San Jacinto, San Patricio,San Saba, Schleicher, Scurry, Shackelford, Shelby, Sherman, Smith, Somervell, Starr,Stephens, Sterling, Stonewall,Sutton, Swisher, Tarrant, Taylor, Terrell, Terry, Throckmorton, Titus, Tom Green, Travis, Trinity, Tyler, Upshur, Upton, Uvalde,Val Verde, Van Zandt, Victoria, Walker, Waller, Ward, Washington, Webb, Wharton, Wheeler, Wichita, Wilbarger, Willacy, Williamson, Wilson, Winkler, Wise, Wood, Yoakum, Young, Zapata, Zavala	254

COG #	Permit Number	Counties Served	Total Counties Served
4	2069A	Baylor,Bowie,Burleson,Childress,Cooke,Dallas,Denton,Eastland,Ellis,Erath,Fannin,Grayson,Harris,Haskell,Henderson,Live Oak,Llano,Mclennan,Montague,Nacogdoches,Navarro,Palo Pinto,Parker,Rockwall,Rusk,Sabine,San Saba,Sherman,Tarrant,Terrell,Travis,Trinity,Van Zandt,Wharton,Wichita,Wise,Wood	37
4	40080	Dallas,Hill,Hood,Johnson,Parker,Tarrant	6
4	40168	Johnson	1
4	40181	Bosque,Erath,Hood,Johnson,Somervell	5
4	2275	Collin,Dallas,Hill,Parker,Tarrant	5
4	2306	Tarrant	1
4	2379	Collin,Dallas,Denton,Tarrant	4
4	40052	Bexar,Dallas,Denton,Ellis,Johnson,Parker,Tarrant	7
4	40186	Hood,Parker,Tarrant	3
4	1225D	Anderson,Bastrop,Bell,Bexar,Bosque,Bowie,Burleson,Burnet,Caldwell,Cameron,Camp,Cherokee,Childress,Coleman,Collin,Comanche,Cooke,Coryell,Dallas,Denton,Eastland,Ellis,Erath,Falls,Fannin,Floyd,Franklin,Grayson,Hall,Hardin,Haskell,Hemphill,Henderson,Hood,Hopkins,Hunt,Hutchinson,Jack,Jackson,Jasper,Johnson,Kaufman,Kendall,Knox,Lamar,Lampasas,Liberty,Limestone,Llano,Lubbock,Madison,Mason,Mclennan,Mcmullen,Midland,Montague,Montgomery,Nacogdoches,Navarro,Palo Pinto,Parker,Polk,Rains,Robertson,Rockwall,San Saba,Smith,Somervell,Stephens,Tarrant,Taylor,Terrell,Throckmorton,Tyler,Wise,Young	76
4	2256A	Anderson,Collin,Dallas,Denton,Ellis,Henderson,Hunt,Hutchinson,Johnson,Navarro,Parker,Tarrant,Taylor	13
4	40241	Angelina,Bexar,Bosque,Brazoria,Brazos,Burleson,Calhoun,Collin,Dallas,Denton,Fort Bend,Galveston,Gonzales,Harris,Kaufman,Mclennan,Nacogdoches,Orange,Rockwall,Sherman,Tarrant,Travis,Uvalde	23
4	2294	Collin,Dallas,Denton,Fannin,Grayson,Hunt	6
4	62	Collin,Cooke,Dallas,Ellis,Fannin,Grayson,Hunt,Kaufman,Rains,Tarrant,Van Zandt	11

COG #	Permit Number	Counties Served	Total Counties Served
4	1394B	Dallas	1
4	1895A	Collin,Dallas,Kaufman,Rockwall,Tarrant	5
4	996C	Dallas,Ellis,Johnson,Tarrant	4
4	1025B	Collin,Dallas,Denton,Grayson,Tarrant,Wise	6
4	1312B	Collin,Dallas,Denton,Tarrant	4
4	1590A	Cooke,Denton,Tarrant	3
4	1749B	Collin,Dallas,Denton	3
4	1209B	Harris	1
4	1745B	Dallas,Ellis,Henderson,Kaufman,Navarro,Smith,Van Zandt	7
4	42D	Dallas,Ellis,Kaufman,Rockwall,Tarrant	5
4	664	Comanche,Erath,Hamilton,Hood,Somervell	5
4	1195A	Collin,Delta,Fannin,Franklin,Grayson,Hopkins,Hunt,Lamar,Rains ,Red River,Rockwall,Van Zandt,Wood	13
4	534	Johnson	1
4	1417B	Dallas,Denton,Johnson,Kaufman,Tarrant,Wise	6
4	2190	Ellis,Henderson,Hill,Limestone,Navarro,Van Zandt	6
4	47A	Erath,Hood,Palo Pinto,Parker,Tarrant	5
4	1983C	Dallas,Denton,Johnson,Parker,Tarrant	5
4	218C	Dallas,Denton,Johnson,Parker,Tarrant	5
4	358B	Dallas,Denton,Johnson,Tarrant	4
4	48012		
4	48016		
4	48018		
4	48027		
4	48028		
4	48032		
4	48033		
4	48042		
4	1025B		
5	2382	Camp,Fannin,Franklin,Hopkins,Hunt,Kaufman,Lamar,Rains,Red River,Rockwall,Rusk,Smith,Tarrant,Titus,Tyler,Upshur,Van Zandt,Wood	18
5	576C	Bowie,Camp,Cass,Franklin,Gregg,Marion,Morris,Titus,Upshur	9

COG #	Permit Number	Counties Served	Total Counties Served
5	2358	Bowie,Camp,Cass,Collin,Delta,Fannin,Franklin,Grayson,Gregg,Harrison,Henderson,Hopkins,Hunt,Lamar,Marion,Morris,Rains,Red River,Rockwall,Smith,Titus,Upshur,Van Zandt,Wood	24
5	797B	Bosque,Cass,Franklin,Gregg,Harrison,Henderson,Hopkins,Lamar,Marion,Morris,Panola,Rains,Rusk,Smith,Titus,Upshur,Van	17
6	2389	Anderson,Cherokee,Freestone,Houston,Leon,Madison,Smith	7
6	40005	Anderson	1
6	40006	Anderson	1
6	40040	Anderson,Cherokee,Freestone,Houston,Leon,Madison,Smith	7
6	40174	Camp,Upshur,Wood	3
6	2365	Gregg,Harrison,Marion,Morris,Panola,Rusk,Smith,Titus,Upshur,Wood	10
6	40172	Panola	1

COG #	Permit Number	Counties Served	Total Counties Served
6	40267	Anderson,Andrews,Angelina,Aransas,Archer,Armstrong,Atascosa,Austin,Bailey,Bandera,Bastrop,Baylor,Bee,Bell,Bexar,Blanco,Borden,Bosque,Bowie,Brazoria,Brazos,Brewster,Briscoe,Brooks,Brown,Burleson,Burnet,Caldwell,Calhoun,Callahan,Cameron,Camp,Carson,Cass,Castro,Chambers,Cherokee,Childress,Clay,Cochran,Coke,Coleman,Collin,Collingsworth,Colorado,Comal,Comanche,Concho,Cooke,Coryell,Cottle,Crane,Crockett,Crosby,Culberson,Dallam,Dallas,Dawson,Deaf Smith,Delta,Denton,Dewitt, Dickens, Dimmit,Donley, Duval, Eastland,Ector,Edwards,El Paso,Ellis,Erath,Falls, Fannin, Fayette, Fisher, Floyd,Foard,Fort Bend,Franklin, Freestone, Frio, Gaines,Galveston,Garza, Gillespie, Glasscock,Goliad,Gonzales, Gray, Grayson,Gregg, Grimes, Guadalupe,Hale,Hall,Hamilton, Hansford, Hardeman, Hardin, Harris,Harrison,Hartley, Haskell, Hays, Hemphill, Henderson, Hidalgo, Hill, Hockley, Hood, Hopkins, Houston, Howard, Hudspeth, Hunt, Hutchinson, Irion, Jack, Jackson, Jasper, Jeff Davis, Jefferson, Jim Hogg, Jim Wells, Johnson, Jones, Karnes, Kaufman, Kendall, Kenedy, Kent, Kerr, Kimble, King, Kinney, Kleberg, Knox, La Salle, Lamar, Lamb, Lampasas, Lavaca, Lee, Leon, Liberty, Limestone, Lipscomb, Live Oak, Llano, Loving, Lubbock, Lynn, Madison, Marion, Martin, Mason, Matagorda, Maverick, Mcculloch, Mclennan, Mcmullen, Medina, Menard, Midland, Milam, Mills, Mitchell, Montague, Montgomery, Moore, Morris, Motley,Nacogdoches, Navarro, Newton, Nolan, Nueces, Ochiltree, Oldham, Orange,Palo Pinto, Panola,Parker, Parmer, Pecos, Polk, Potter, Presidio, Rains, Randall, Reagan, Real, Red River, Reeves, Refugio, Roberts, Robertson, Rockwall,Runnels, Rusk,Sabine, San Augustine, San Jacinto, San Patricio,San Saba, Schleicher, Scurry, Shackelford, Shelby, Sherman,Smith,Somervell, Starr, Stephens, Sterling, Stonewall, Sutton, Swisher, Tarrant, Taylor, Terrell, Terry, Throckmorton, Titus, Tom Green, Travis, Trinity, Tyler, Upshur, Upton, Uvalde, Val Verde,Van Zandt, Victoria, Walker, Waller, Ward, Washington, Webb, Wharton, Wheeler, Wichita, Wilbarger, Willacy, Williamson, Wilson, Winkler, Wise, Wood, Yoakum, Young, Zapata, Zavala	254

COG #	Permit Number	Counties Served	Total Counties Served
6	356	Cherokee,Smith,Van Zandt,Wood	4
6	40266	Hopkins,Hunt,Rains,Smith,Van Zandt,Wood	6
6	40102	Wood	1
6	1614A	Anderson,Cherokee,Henderson,Houston,Nacogdoches,Rusk,Smith,Van Zandt	8
6	1327B	Cherokee,Gregg,Harrison,Marion,Nacogdoches,Panola,Rusk,Shelby,Smith,Upshur	10
6	1249B	Anderson,Cherokee,Gregg,Harrison,Nacogdoches,Panola,Rusk,Shelby,Smith	9
6	1972A	Anderson,Cherokee,Gregg,Henderson,Kaufman,Rusk,Smith,Van Zandt,Wood	9
6	48026		
6	48041		
7	1562A	Brown,Callahan,Coleman,Comanche,Eastland,Mason,Mcculloch,Mills,San Saba	9
7	1302	Coleman	1
7	9009	Haskell	1
7	1604B	Haskell,Jones	2
7	2325	Callahan,Coke,Eastland,Ector,Fayette,Houston,Howard,Hutchinson,Johnson,Kent,King,Knox,Midland,Mitchell,Palo Pinto,Reeves,Runnels,Scurry,Shackelford,Stephens,Sterling,Stonewall,Taylor,Throckmorton,Tom Green,Wichita,Winkler,Young	28
7	1469A	Brown,Callahan,Coleman,Comanche,Eastland,Fisher,Haskell,Jones,Knox,Nolan,Runnels,Scurry,Shackelford,Stephens	14
7	9004	Jones	1
7	420A	Mitchell	1
7	50B	Coke,Fisher,Nolan	3
7	9013	Runnels	1
7	1463B	Borden,Fisher,Howard,Kent,Mitchell,Nolan,Scurry	7

COG #	Permit Number	Counties Served	Total Counties Served
7	9000A	Stephens	1
8	728	El Paso	1
8	2355	El Paso	1
8	40237	El Paso	1
8	40261	Brewster,El Paso,Hudspeth,Presidio	4
8	40262	El Paso	1
8	1276	Brewster	1
8	2197	Brewster,Culberson,Jeff Davis,Pecos,Presidio,Terrell	6
8	1422	El Paso	1
8	2284	El Paso	1
8	729B	El Paso	1
8	495	Hudspeth	1
8	957A	Hudspeth	1
8	1737A	Brewster,Presidio	2
9	2373	Andrews,Cochran,Crane,Crockett,Culberson,Dawson,Ector,Gaines,Howard,Irion,Loving,Martin,Midland,Pecos,Reagan,Reeves,Sterling,Upton,Ward,Winkler,Yoakum	21
9	43028	Pecos	1
9	171	Andrews	1
9	427	Crane	1
9	517A	Dawson	1
9	2158	Andrews,Brewster,Crane,Crockett,Ector,El Paso,Glasscock, Howard,Jeff Davis, Loving,Martin,Midland,Pecos,Reagan, Reeves,Sterling,Terrell,Tom Green,Upton,Ward,Winkler	21
9	39	Gaines	1
9	2154	Glasscock	1
9	288A	Howard	1
9	2189	Martin	1

COG #	Permit Number	Counties Served	Total Counties Served
9	1605B	Ector,Glasscock,Howard,Martin,Midland,Reagan	6
9	976	Pecos	1
9	2120	Reeves	1
9	673	Terrell	1
9	566	Upton	1
9	691	Upton	1
9	772	Crane,Culberson,Ector,Loving,Midland,Pecos,Reeves,Ward,Win kler	9
10	2357	Coke,Coleman,Concho,Crockett,Glasscock,Irion,Mcculloch,Men ard,Nolan,Reagan,Runnels,Schleicher,Sterling,Sutton,Tom Green	15
10	2359	Brown,Coke,Coleman,Concho,Mason,Mcculloch,Menard,Midlan d,Mitchell,Reagan,Runnels,Schleicher,Sterling,Sutton,Taylor,To m Green	16
10	42022	Tom Green	1
10	26B	Kimble	1
10	195	Mason	1
10	1732	Mcculloch	1
10	1404	Menard	1
10	86B	Reagan	1
10	349	Crockett,Edwards,Kimble,Menard,Real,Schleicher,Sutton	7
10	2264	Crockett,Edwards,Kimble,Menard,Real,Schleicher,Sutton	7
10	79	Coke,Concho,Crockett,Irion,Kimble,Reagan,Runnels,Sterling,Sut ton,Tom Green	10
11	241D	Bell,Bosque,Dallas,Denton,Ellis,Falls,Freestone,Hamilton,Harris, Hill,Hood,Johnson,Leon,Limestone,Mclennan,Navarro,Tom	17
11	1558A	Falls,Freestone,Hill,Leon,Limestone,Mclennan,Navarro,Robertso	8
11	1646A	Bell,Bosque,Coryell,Falls,Hamilton,Hill,Mclennan	7
11	948A	Bell,Bosque,Coryell,Falls,Hamilton,Hill,Lampasas,Limestone,Mc lennan,Milam,Robertson	11

COG #	Permit Number	Counties Served	Total Counties Served
11	48020		
12	2260A	Aransas,Atascosa,Bandera,Bastrop,Bell, Bexar, Blanco, Bosque, Bowie, Burnet, Caldwell, Calhoun, Cameron, Colorado, Jim Hogg, Jim Wells, Karnes, Kendall, Kerr, Kimble, Kleberg, La Salle, Lamar, Lampasas, Lavaca, Lee,Live Oak,Llano, Matagorda,Maverick, Mclennan, Medina, Milam, Nueces, Polk, Refugio, Robertson, San Patricio, Schleicher, Taylor, Travis, Uvalde, Val Verde, Victoria, Webb, Williamson, Wilson, Zavala	48
12	2300	Blanco,Burnet,Comal,Gillespie,Hays,Kendall,Lampasas,Llano,Travis,Williamson	10
12	40035	Burnet,Llano	2
12	1787	Comal,Hays,Travis	3
12	119	Burnet,Hays,Llano,Travis,Williamson	5
12	2250	Bastrop,Bell,Blanco,Brown,Caldwell,Coleman,Colorado,Coryell, Falls,Fayette,Hays,Llano,Mason,Mcculloch,Mclennan,San Saba,Tom Green,Travis,Williamson	19
12	2310	Bastrop,Burnet,Hays,Travis,Williamson	5
12	2384	Bastrop,Bell,Bexar,Blanco,Burnet,Caldwell,Comal,Fayette,Gillespie,Gonzales,Guadalupe,Hays,Lampasas,Lee,Llano,Milam,San Saba,Travis,Williamson	19
12	40212	Hays,Travis	2
12	40243	Bastrop,Hays,Travis,Williamson	4
12	42016	Bastrop,Bexar,Blanco,Burleson,Burnet,Caldwell,Comal,Fayette, Gillespie,Gonzales,Guadalupe,Hays,Kendall,Travis,Williamson	15
12	466A	Bell,Burnet,Milam,Travis,Williamson	5
12	2123	Anderson,Atascosa,Bandera,Bastrop,Bell,Bexar,Burnet,Caldwell, Colorado,Comal,Dewitt,Fayette,Frio,Garza,Gillespie,Goliad,Gonzales,Guadalupe,Kendall,Lavaca,Llano,Medina,Milam,Williamso	24
12	1841A	Bastrop,Blanco,Caldwell,Fayette,Gonzales,Guadalupe,Hays,Karnes,Travis,Williamson	10
12	249D	Bastrop,Burnet,Hays,Llano,Travis,Washington,Williamson	7
12	1405B	Bell,Burnet,Milam,Travis,Williamson	5

COG #	Permit Number	Counties Served	Total Counties Served
12	48019		
13	42003	Brazos,Grimes	2
13	43026	Brazos,Burleson,Grimes,Leon,Madison,Robertson,Washington	7
13	2381	Austin,Colorado,Grimes,Washington	4
13	40018	Austin,Fayette,Grimes,Harris,Montgomery,Waller,Washington	7
13	40173	Austin,Fayette,Washington	3
13	2292	Anderson,Austin,Bastrop,Bell,Brazos,Burleson,Fayette,Grimes,Harris,Jefferson,Lee,Madison,Milam,Montgomery,Robertson,Walker,Waller,Washington,Wharton	19
14	40033	Houston	1
14	40044	Jasper	1
14	43007	Angelina,Cherokee,Nacogdoches,Rusk,San Augustine,Shelby	6
14	40277	Hardin,Houston,Liberty,Montgomery,Polk,San Jacinto,Tyler,Walker	8
14	40054	Sabine	1
14	40024	Nacogdoches,Sabine,San Augustine,Shelby	4
14	40013	Tyler	1
14	40038	Tyler	1
14	2105A	Angelina,Cherokee,Houston,Jasper,Nacogdoches,Polk,Sabine,San Augustine,Shelby,Tyler	10
14	720	Nacogdoches	1
14	2242A	Chambers,Hardin,Jasper,Jefferson,Newton,Orange,Polk	7
14	1384A	Houston,Liberty,Polk,San Jacinto,Trinity,Tyler,Walker	7
15	40164	Chambers,Hardin,Jasper,Jefferson,Liberty,Newton,Orange,Tyler	8
15	40225	Chambers,Jefferson,Orange	3

COG #	Permit Number	Counties Served	Total Counties Served
15	40268	Anderson,Angelina,Archer,Atascosa,Bastrop,Baylor,Bexar,Bosque,Bowie,Brazoria,Brown,Burleson,Burnet,Caldwell,Cameron,Camp,Cass,Cherokee,Clay, Collin,Comal, Cooke,Dallas, Delta,Denton, Duval, Ellis, Erath, Fannin,Fort Bend, Franklin, Freestone, Galveston, Gonzales, Grayson,Gregg, Hardin,Harris, Harrison,Haskell, Hays, Hidalgo,Houston, Jasper, Jefferson,Jim Hogg,Jim Wells,Karnes, Kenedy, Kleberg, Lavaca, Leon, Liberty, Limestone,Madison, Matagorda, Mcculloch,Milam, Montague, Montgomery, Nacogdoches, Navarro,Newton, Nueces,Orange, Panola,Parker, Polk, Red River, Refugio, Robertson, Rockwall, Runnels, Rusk,San Augustine, San Jacinto, San Patricio,Shelby, Smith, Starr, Tarrant, Taylor, Titus,Tom Green ,Travis ,Tyler,Uvalde ,Van Zandt, Victoria, Waller, Wharton, Wichita,Wilbarger, Willacy, Williamson, Wise, Yoakum, Zapata	98
15	43000	Chambers,Hardin,Jasper,Jefferson,Liberty,Newton,Orange,Tyler	8
15	2214A	Hardin,Jasper,Jefferson,Liberty,Newton,Orange,Tyler	7
15	2027	Hardin,Jefferson,Shelby	3
15	1486B	Chambers,Hardin,Jefferson,Orange	4
15	1815A	Hardin,Jefferson,Orange	3
16	40191	Austin,Colorado,Fayette,Fort Bend,Grimes, Harris,Lee, Waller, Washington,Wharton	10
16	2235	Brazoria,Galveston	2
16	2239A	Brazoria,Chambers,Fort Bend,Galveston,Harris, Montgomery, Orange,Walker, Waller	9
16	40282	Austin,Colorado,Fayette,Gonzales,Lavaca,Lee,Wharton	7
16	40053	Austin,Brazoria,Fort Bend,Harris,Waller,Wharton	6
16	40264	Austin,Brazoria,Chambers,Colorado,Fort Bend,Galveston, Harris,Matagorda,Waller	9
16	164	Galveston	1
16	2232A	Brazoria,Fort Bend,Galveston,Harris,Jefferson,Montgomery,Orange	7
16	1471	Harris	1

COG #	Permit Number	Counties Served	Total Counties Served
16	1578	Brazoria,Fort Bend,Harris,Montgomery	4
16	1697	Harris	1
16	2298	Brazoria,Chambers,Fort Bend,Galveston,Harris,Liberty,Montgomery,Waller	8
16	2350	Brazoria,Chambers,Fort Bend,Galveston,Harris,Liberty,Montgomery,Walker	8
16	2370	Anderson,Bastrop,Brazoria,Colorado,Fort Bend,Harris,Liberty,Montgomery,Waller,Wharton	10
16	2386	Fort Bend,Galveston,Harris	3
16	40098	Fort Bend,Harris,Jefferson,Montgomery	4
16	40131	Harris	1
16	40132	Harris	1
16	40133	Harris	1
16	40189	Brazoria,Chambers,Galveston,Harris,Montgomery,Waller	6
16	40211	Harris,Montgomery	2
16	40217	Fort Bend,Harris,Montgomery	3
16	40236	Brazoria,Chambers,Fort Bend,Galveston,Harris,Montgomery,Waller	7
16	40249	Brazoria,Fort Bend,Galveston,Harris	4
16	40250	Bexar,Brazoria,Chambers,Dallas,Fort Bend,Galveston,Harris, Jefferson ,Liberty, Montgomery,Travis,Walker,Wharton	13

COG #	Permit Number	Counties Served	Total Counties Served
16	40273	Anderson,Angelina,Archer,Atascosa,Austin,Bastrop,Baylor,Bee, Bell,Bexar,Bosque,Bowie,Brazoria,Brazos,Brown,Burleson,Burnet,Calhoun,Cameron,Cass,Chambers,Cherokee,Collin,Colorado,Comal,Cooke,Crosby,Dallas,Denton,Dewitt,Ellis,Erath,Falls,Fannin,Fayette,Fort Bend,Franklin,Freestone,Galveston, Gillespie, Goliad, Gonzales, Grayson, Gregg, Grimes,Guadalupe,Hamilton, Hardin, Harris, Hays, Henderson, Hidalgo,Hood, Hopkins,Houston, Hunt,Jackson, Jasper, Jefferson, Jim Wells, Johnson, Karnes, Kaufman, Kendall, Kerr, Kleberg, Lamar, Lee,Leon,Liberty,Live Oak, Madison, Marion, Matagorda, Mclennan, Medina,Montague, Montgomery, Morris, Nacogdoches, Navarro,Nueces, Orange, Parker, Polk, Potter, Randall, Red River, Reeves, Robertson, Rockwall, Rusk, Sabine, San Augustine, San Jacinto, San Patricio, Shelby, Smith, Somervell, Starr, Tarrant, Titus, Travis, Upshur, Van Zandt, Victoria, Walker, Waller, Washington, Webb, Wharton, Wichita, Wilbarger, Willacy, Williamson, Wilson,Wise, Wood, Zapata	119
16	40275	Harris,Montgomery	2
16	40283	Bell,Bexar,Brazoria,Chambers,Collin,Dallas,Ellis,Fort Bend,Harris, Hays, Jefferson,Johnson, Lampasas, Montgomery,Tarrant,Travis, Waller,Williamson,Wilson	19
16	43034	Austin,Bexar,Brazoria,Chambers,Colorado,Dallas,Denton,Dewitt, Fayette,Fort Bend,Galveston,Hardin, Harris,Jasper,Jefferson,Lavaca, Liberty,Matagorda,Montgomery,	22
16	1355A	Brazoria,Fort Bend,Harris	3
16	1483A	Harris	1
16	2234D	Austin,Bexar,Brazoria,Chambers,Colorado,Dallas,Denton,Dewitt, Fayette,Fort Bend,Galveston, Hardin,Harris,Jasper, Jefferson, Lavaca, Liberty, Matagorda,Montgomery, Orange, Travis,	22
16	2241A	Austin,Brazoria,Chambers,Fort Bend, Galveston,Grimes, Harris, Liberty, Madison, Matagorda, Montgomery,Orange, San Jacinto,Wharton	14
16	40028	Matagorda	1

COG #	Permit Number	Counties Served	Total Counties Served
16	2222	Anderson,Andrews,Angelina,Aransas,Archer,Armstrong,Atascosa,Austin,Bailey,Bandera,Bastrop,Baylor,Bee,Bell,Bexar,Blanco,Borden,Bosque,Bowie,Brazoria,Brazos,Brewster,Briscoe,Brooks,Brown,Burleson,Burnet,Caldwell,Calhoun,Callahan,Cameron,Camp,Carson,Cass,Castro,Chambers,Cherokee,Childress,Clay,Cochran,Coke,Coleman,Collin,Collingsworth,Colorado,Comal,Comanche,Concho,Cooke,Coryell,Cottle, Crane,Crockett,Crosby, Culberson, Dallam, Dallas, Dawson, Deaf Smith, Delta, Denton, Dewitt,Dickens, Dimmit,Donley, Duval, Eastland, Ector, Edwards,El Paso,Ellis, Erath, Falls, Fannin, Fayette, Fisher, Floyd, Foard,Fort Bend, Franklin,Freestone, Frio, Gaines, Galveston,Garza, Gillespie, Glasscock, Goliad, Gonzales, Gray, Grayson, Gregg, Grimes, Guadalupe, Hale,Hall, Hamilton, Hansford, Hardeman, Hardin, Harris, Harrison, Hartley,Haskell, Hays, Hemphill, Henderson, Hidalgo, Hill, Hockley, Hood, Hopkins, Houston, Howard, Hudspeth, Hunt, Hutchinson, Irion, Jack,Jackson, Jasper, Jeff Davis, Jefferson,Jim Hogg, Jim Wells, Johnson, Jones, Karnes, Kaufman, Kendall, Kenedy, Kent,Kerr, Kimble, King, Kinney, Kleberg, Knox, La Salle, Lamar, Lamb, Lampasas, Lavaca, Lee, Leon, Liberty, Limestone, Lipscomb, Live Oak, Llano,Loving, Lubbock, Lynn,Madison, Marion, Martin, Mason, Matagorda, Maverick, Mcculloch, Mclennan, Mcmullen,Medina, Menard, Midland, Milam, Mills, Mitchell, Montague, Montgomery, Moore, Morris, Motley, Nacogdoches, Navarro, Newton, Nolan, Nueces, Ochiltree, Oldham, Orange, Palo Pinto, Panola,Parker, Parmer, Pecos, Polk, Potter, Presidio, Rains, Randall, Reagan, Real, Red River, Reeves, Refugio, Roberts, Robertson, Rockwall, Runnels, Rusk, Sabine, San Augustine, San Jacinto, San Patricio, San Saba, Schleicher, Scurry, Shackelford, Shelby, Sherman, Smith, Somervell, Starr, Stephens, Sterling, Stonewall, Sutton, Swisher, Tarrant, Taylor, Terrell, Terry, Throckmorton, Titus, Tom Green, Travis, Trinity, Tyler, Upshur, Upton, Uvalde, Val Verde, Van Zandt, Victoria, Walker, Waller, Ward, Washington, Webb, Wharton, Wheeler, Wichita, Wilbarger, Willacy, Williamson, Wilson	247

COG #	Permit Number	Counties Served	Total Counties Served
16	2309	Montgomery	1
16	42037	Grimes,Harris,Liberty,Montgomery,San Jacinto,Walker,Waller	7
16	2387	Walker	1
16	40014	Waller	1
16	2318	Austin,Brazoria,Calhoun,Colorado,Fort Bend,Jackson,Matagorda, Victoria,Wharton	9
16	1708	Brazoria,Galveston,Harris	3
16	1539A	Brazoria,Calhoun,Chambers,Colorado,Fort Bend,Galveston,Harris, Jefferson, Liberty, Matagorda,Montgomery,Nueces,San Saba,Victoria,Wharton	15
16	1502A	Chambers,Galveston,Harris,Jefferson,Liberty	5
16	1535B	Brazoria,Chambers,Fort Bend,Galveston,Harris,Liberty, Montgomery,Walker,Waller	9
16	203A	Austin,Bastrop,Colorado,Fayette,Gonzales,Lavaca,Washington,W harton	8
16	2270	Austin,Brazoria,Fort Bend,Harris,Matagorda,Wharton	6
16	1505A	Brazoria,Fort Bend,Galveston,Harris	4
16	1797A	Brazoria,Fort Bend,Harris,Waller	4
16	1149B	Brazoria,Fort Bend,Galveston,Harris	4
16	1721A	Brazoria,Chambers,Fort Bend,Galveston,Harris,Liberty, Montgomery,Walker,Waller	9
16	1849B	Galveston	1
16	1193	Brazoria,Fort Bend,Galveston,Harris,Montgomery	5
16	1301	Brazoria,Chambers,Fort Bend,Galveston,Harris,Liberty, Montgomery,Walker,Waller	9
16	1403	Brazoria,Fort Bend,Harris	3
16	2185	Brazoria,Chambers,Fort Bend,Galveston,Harris, Liberty,Montgomery,Walker,Waller	9
16	2304	Harris,Montgomery	2
16	2344	Brazoria,Fort Bend,Galveston,Harris,Montgomery	5
16	1307D	Brazoria,Chambers,Fort Bend,Galveston,Harris,Liberty, Montgomery,Walker,Waller	9

COG #	Permit Number	Counties Served	Total Counties Served
16	1540A	Brazoria,Chambers,Fort Bend,Galveston,Harris,Liberty, Montgomery,Walker,Waller	9
16	1565B	Harris	1
16	1586A	Brazoria,Galveston,Harris	3
16	1599A	Fort Bend,Harris,Waller	3
16	1921A	Brazoria,Chambers,Fort Bend,Galveston,Harris,Liberty, Montgomery, Walker,Waller	9
16	2240B	Galveston,Harris	2
16	261B	Brazoria,Fort Bend,Galveston,Harris,Montgomery	5
16	2324	Grimes,Harris,Liberty,Montgomery,San Jacinto,Walker	6
16	1752B	Brazoria,Chambers,Fort Bend,Galveston,Harris, Liberty, Montgomery,Walker,Waller	9
16	1777		
16	48006		
16	48008		
16	48009		
16	48025		
16	48034		
16	48035		
17	40017	Dewitt,Gonzales,Lavaca	3
17	2181	Jackson,Victoria	2
17	40011	Lavaca	1
17	2330	Calhoun,Colorado,Dewitt,Fayette,Goliad,Gonzales,Jackson,Karne s,Lavaca,Matagorda,Refugio,Victoria,Wharton	13
17	2366	Calhoun,Dewitt,Goliad,Gonzales,Jackson,Lavaca,Refugio,Victori	8
17	42034	Calhoun,Dewitt,Lavaca,Victoria	4
17	1522A	Calhoun,Dewitt,Goliad,Gonzales,Jackson,Lavaca,Victoria	7
17	48036		
18	1443	Atascosa,Bandera,Bell,Blanco,Caldwell,Comal,Frio,Gillespie,Gu adalupe,Kendall,Kerr,Medina,Wilson	13

COG #	Permit Number	Counties Served	Total Counties Served
18	2248	Aransas,Atascosa,Bandera,Bastrop,Bee,Bexar,Blanco,Calhoun,Comal,Dewitt,Dimmit,Frio,Gillespie,Gonzales,Guadalupe,Karnes,Kenedy,Kerr,La Salle,Live Oak,Maverick,Medina,Nueces,Refugio,San Patricio,Tom Green,Uvalde,Val Verde,Victoria,Webb,Wilson,Zavala	32
18	2317	Atascosa,Bastrop,Bell,Bexar,Comal,Gonzales,Guadalupe,Kerr,Lampasas,San Saba,Travis,Williamson	12
18	40085	Aransas,Atascosa,Bandera,Bastrop,Bee,Bexar,Blanco,Calhoun,Comal,Dewitt,Dimmit,Frio,Hays,Jackson,Karnes,Kendall,Kenedy,Kerr,La Salle,Live Oak,Maverick,Medina,Nueces,Refugio,San Patricio,Tom Green,Uvalde,Val Verde,Victoria,Webb,Wilson,Zavala	32
18	40157	Bandera,Bastrop,Bee,Bell,Bexar,Blanco,Brooks,Burnet,Caldwell, Calhoun, Cameron,Comal,Frio,Gillespie, Gonzales,Guadalupe, Hays, Hidalgo, Jim Wells,Karnes, Kenedy,Kerr, Kinney, Kleberg,La Salle, Mcmullen, Medina, Nueces,San Patricio, Starr,Travis, Uvalde,Val Verde,Victoria,Webb,Willacy,Williamson,Wilson	38
18	40280	Aransas,Atascosa,Bee,Bexar,Comal,Frio,Gonzales,Guadalupe,Jim Wells,Karnes,Kendall,Live Oak,Maverick,Medina,Polk,San Patricio,Webb,Wilson	18
18	42032	Bexar	1
18	40244	Atascosa,Austin,Bastrop,Baylor,Bexar,Burleson,Burnet,Chambers,Comal,Dallas,Denton,Galveston,Gillespie,Guadalupe,Harris,Hays,Hidalgo,Lampasas,Lubbock,Midland,Nacogdoches,Tarrant,Travis,Victoria,Wichita	25
18	40240	Kerr	1
18	42028	Kerr	1
18	43011	Bandera,Bastrop,Bee,Bell,Bexar,Blanco,Brooks,Burnet,Caldwell,Calhoun,Cameron,Comal,Frio,Gillespie,Gonzales,Guadalupe,Hays,Hidalgo,Jim Wells,Karnes,Kenedy,Kerr,Kinney,Kleberg,La Salle,Mcmullen,Medina,Nueces,San Patricio,Starr,Travis,Uvalde,Val Verde,Victoria,Webb,Willacy,Williamson,Wilson	38

COG #	Permit Number	Counties Served	Total Counties Served
18	1410C	Atascosa,Bandera,Bexar,Comal,Dewitt,Guadalupe,Kendall,Lavaca,San Patricio,Travis,Wilson	11
18	2093B	Atascosa,Bandera,Bexar,Guadalupe,Maverick,Medina,Wilson	7
18	66B	Bexar,Comal,Guadalupe,Travis	4
18	1995	Gillespie	1
18	1848	Bexar,Comal,Guadalupe	3
18	1506A	Kerr	1
18	571	Mcmullen	1
18	48005		
18	48015		
18	48029		
18	48039		
19	40103	Jim Hogg	1
19	40238	Starr	1
19	954	Starr	1
19	2286	Dimmit,Duval,Hidalgo,Jim Hogg,La Salle,Starr,Webb,Zapata	8
19	1693B	Jim Hogg,La Salle,Webb,Zapata	4
19	783A	Zapata	1
20	40027	Aransas,San Patricio	2
20	40002	Live Oak	1
20	40228	Aransas,Bee,Duval,Goliad,Jim Wells,Kleberg,Live Oak,Mcmullen,Nueces,Refugio,San Patricio	11
20	40270	Aransas,Bee,Brooks,Calhoun,Cameron,Dewitt,Duval,Houston,Jim Hogg,Jim Wells,Kenedy,Kleberg,Live Oak,Nueces,Refugio,San Patricio,Victoria,Webb,Willacy	19
20	2319	Aransas,Duval,Jim Wells,Kenedy,Kleberg,Nueces,San Patricio	7
20	379	Brooks	1
20	1481	Duval,Jim Wells	2
20	262C	Bee,Brooks,Duval,Jim Wells	4
20	235B	Brooks,Duval,Jim Wells,Kenedy,Kleberg,Nueces	6
20	2267	Aransas,Bee,Brooks,Duval,Jim Wells,Kleberg,Live Oak,Nueces,Refugio,San Patricio	10

COG #	Permit Number	Counties Served	Total Counties Served
20	2269	Aransas,Bee,Duval,Goliad,Jim Wells,Kleberg,Live Oak,Mcmullen,Nueces,Refugio,San Patricio	11
20	2349	Aransas,Bee,Calhoun,Dewitt,Duval,Goliad,Jim Wells,Karnes,Kenedy,Kleberg,Live Oak,Nueces,Refugio,San Patricio,Victoria,Willacy	16
21	2334	Aransas,Bee,Brooks,Cameron,Duval,Harris,Hidalgo,Jim Hogg,Jim Wells,Kleberg,Nueces,Refugio,San Patricio,Starr,Travis,Willacy,Zapata	17
21	2375	Cameron,Hidalgo	2
21	40248	Cameron,Willacy	2
21	42015	Cameron	1
21	748	Hidalgo	1
21	2343	Cameron,Hidalgo,Starr,Willacy	4
21	2346	Brooks,Cameron,Hidalgo,Jim Hogg,Kenedy,Kleberg,Nueces,Starr,Webb,Zapata	10
21	1273A	Cameron	1
21	2302	Brooks,Cameron,Hidalgo,Starr,Willacy	5
21	2348	Cameron,Hidalgo,Kenedy,Starr,Willacy	5
21	1727A	Hidalgo	1
21	956B	Brooks,Cameron,Hidalgo,Starr,Willacy	5
21	48038		
22	1030	Cooke	1
22	1136	Grayson	1
22	2290	Cooke,Grayson	2
22	523B	Collin,Denton,Fannin,Grayson,Hunt,Lamar	6
23	2368	Bell,Burnet,Coryell,Lampasas,Mclennan,Travis,Williamson	7
23	40209	Bell,Burnet,Coryell,Lampasas,Williamson	5
23	40234	Bell,Bosque,Coryell,Falls,Hamilton,Lampasas,Mclennan,Milam,Robertson,Williamson	10
23	42035	Bell,Williamson	2
23	40145	Bell,Coryell,Lampasas	3
23	42017	Bell,Coryell,Lampasas	3

COG #	Permit Number	Counties Served	Total Counties Served
23	42040	Bell,Coryell	2
23	40004	Bosque,Erath,Hamilton	3
23	40160	San Saba	1
23	692A	Bell,Coryell,Falls,Hamilton,Lampasas,Mclennan,Milam,Mills,San Saba	9
23	1866	Bell,Coryell	2
24	40057	Edwards,Kimble,Real	3
24	40170	Kinney	1
24	40178	Kinney	1
24	40251	La Salle	1
24	40034	Uvalde	1
24	2225	Dimmit	1
24	2354	Kinney	1
24	1918	Maverick	1
24	2316	Dimmit,Maverick	2
24	1725	Uvalde	1
24	207A	Val Verde	1
24	2303	Frio,Zavala	2
24	1308A	Zavala	1
Subtotal			**3,505**

		States Served		Solid Waste Treatment	
COG #	Permit Number	States Served	DV	Incineration Total	AutoClave Total
1	40271	New Mexico, Oklahoma	1184.3	0	0
1	40192		533	0	0
1	43030		0	0	0
1	40026		166	0	0
1	40015		1062.5	0	0
1	40031		0	0	0
1	40263	Arkansas, Colorado, Kansas, Louisiana, Missouri, New Mexico, Oklahoma	0	0	1548.6
1	76A		260	0	0
1	40109		127.5	0	0
1	414		0		
1	1164		116.6		
1	445A		273.2		
1	2263		285		
1	955		4.3		
1	1038A		1073.1		
1	215A		85		
1	570		0		
1	2238		3888.7		
1	589A		0		
1	2266		59.9		
1	2352		1042.8		
1	1943		0		
1	2279		0		
1	2285		2650		
1	876A		1708		
1	791		0		
1	73A		140		
1	1663B		0		
1	1009A		184.9		
1	2281		0		
2	40051		209.3	0	0
2	2231		0	0	0
2	40176		0	0	0
2	40279	New Mexico	0	0	0
2	564		252		
2	2291		36		
2	2268		22		
2	9017		0		
2	2207		40		

		States Served		Solid Waste Treatment	
COG #	Permit Number	States Served	DV	Incineration Total	AutoClave Total
2	2227		0		
2	2157		3746		
2	1733		0		
2	2369		674.7		
2	1298		279		
2	2274		116		
2	363A		0		
2	583A		0		
2	69		4387.6		
2	2252		14.4		
2	2323		10807.9		
2	2328A		57.5		
2	549A		17.8		
2	2170	New Mexico	484.1		
2	2293		0		
2	2217		35.7		
3	40144		100	0	0
3	2295	Oklahoma	0	0	0
3	1429		1272.4	0	0
3	2229A	New Mexico, Oklahoma	0	0	0
3	40059	Oklahoma	8	0	0
3	9001A		0		
3	1428A		18542.5		
3	1571A	Oklahoma	0		
4	1494		308.7	0	0
4	40284		37728.7	0	0
4	2045A		46035	0	0
4	53A		148.1	0	0
4	12		19802.7	0	0
4	60		7383.1	0	0
4	227		1624	0	0
4	1145		18742.6	0	0
4	1263		0	0	0
4	1421		619	0	0
4	1453		9311.1	0	0
4	40196		26982.7	0	0
4	40265	Arkansas, Louisiana, New Mexico, Oklahoma	0	0	12414.26
4	2069A	Louisiana, Oklahoma	0	0	0
4	40080		0	0	0
4	40168		2786.2	0	0
4	40181		3643.5	0	0

		States Served		Solid Waste Treatment	
COG #	Permit Number	States Served	DV	Incineration Total	AutoClave Total
4	2275		87830	0	0
4	2306		53.5	0	0
4	2379		0	0	0
4	40052		26467	0	0
4	40186		88	0	0
4	1225D		0	0	0
4	2256A		0	0	0
4	40241	Arkansas, Louisiana, Oklahoma	0	0	0
4	2294		3410.7		
4	62		1062.2		
4	1394B		9943		
4	1895A		107416.6		
4	996C		30898.3		
4	1025B		75		
4	1312B		2.8		
4	1590A		109369		
4	1749B		0		
4	1209B		0		
4	1745B		0		
4	42D		130		
4	664		233.4		
4	1195A		0		
4	534		0		
4	1417B		0		
4	2190		0		
4	47A		0		
4	1983C		0		
4	218C		40459.2		
4	358B		492962.5		
4	48012				
4	48016				
4	48018				
4	48027				
4	48028				
4	48032				
4	48033				
4	48042				
4	1025B				
5	2382		0	0	0
5	576C	Arkansas	24		
5	2358		0		

		States Served		Solid Waste Treatment	
COG #	Permit Number	States Served	DV	Incineration Total	AutoClave Total
5	797B		0		
6	2389		0	0	0
6	40005		0	0	0
6	40006		0	0	0
6	40040		0	0	0
6	40174		0	0	0
6	2365		0	0	0
6	40172		553.5	0	0
6	40267	Alabama, Alaska, Arizona, Arkansas, California, Colorado, Connecticut, Delaware, District of Columbia, Florida, Georgia, Guam, Hawaii, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, Nevada, New Hampshire, New Jersey, New Mexico, New York, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, Puerto Rico, Rhode Island, South Carolina, South Dakota, Tennessee, Utah, Vermont, Virgin Islands of The United States, Virginia, Washington, West Virginia, Wisconsin, Wyoming	0	169.24	911.68
6	356		0	0	0
6	40266		0	0	0
6	40102		0	0	0
6	1614A		0		

		States Served		Solid Waste Treatment	
COG #	Permit Number	States Served	DV	Incineration Total	AutoClave Total
6	1327B		1		
6	1249B	Louisiana	5		
6	1972A		0		
6	48026				
6	48041				
7	1562A		5145.3		
7	1302		0		
7	9009		0		
7	1604B		0		
7	2325		40.7		
7	1469A		1922		
7	9004		0		
7	420A		0		
7	50B		0		
7	9013		0		
7	1463B		35		
7	9000A		0		
8	728		0	0	0
8	2355		0	0	0
8	40237	New Mexico	6247.7	0	0
8	40261	New Mexico	0	0	0
8	40262	New Mexico	0	0	180.41
8	1276		61.5		
8	2197		614.9		
8	1422		0		
8	2284		1400.2		
8	729B		0		
8	495		0		
8	957A		0		
8	1737A		0		
9	2373	New Mexico	0	0	0
9	43028		0	0	0
9	171		3096.7		
9	427		320		
9	517A		14.5		
9	2158		0		
9	39		51		
9	2154		0		
9	288A		1551.5		
9	2189		33.5		
9	1605B		1332.4		
9	976		963.6		

		States Served		Solid Waste Treatment	
COG #	Permit Number	States Served	DV	Incineration Total	AutoClave Total
9	2120		0		
9	673		35		
9	566		0		
9	691		0		
9	772		265.6		
10	2357		0	0	0
10	2359		0	0	0
10	42022		0	0	0
10	26B		26.8		
10	195		0		
10	1732		0		
10	1404		22.1		
10	86B		34		
10	349		0		
10	2264		5.9		
10	79		9.6		
11	241D		0		
11	1558A		0		
11	1646A		0		
11	948A		14480		
11	48020				
12	2260A		0	0	6830
12	2300		0	0	0
12	40035		0	0	0
12	1787		295	0	0
12	119		1739.5	0	0
12	2250		0	0	0
12	2310		0	0	0
12	2384		0	0	0
12	40212		0	0	0
12	40243		28509.9	0	0
12	42016		0	0	0
12	466A		11361.4	0	0
12	2123		149942.7		
12	1841A		23549.4		
12	249D		0.4		
12	1405B		261.7		
12	48019				
13	42003		1330.8	0	0
13	43026		0	0	0
13	2381		0	0	0
13	40018		4680.2	0	0
13	40173		0	0	0

		States Served		Solid Waste Treatment	
COG #	Permit Number	States Served	DV	Incineration Total	AutoClave Total
13	2292		4581.5		
14	40033		0	0	0
14	40044		165	0	0
14	43007		0	0	0
14	40277		0	0	0
14	40054		20	0	0
14	40024		0	0	0
14	40013		50	0	0
14	40038		37.5	0	0
14	2105A		24.7		
14	720		5023		
14	2242A	Louisiana	0		
14	1384A		0		
15	40164		0	0	0
15	40225		6539.8	0	0
15	40268	Louisiana, Oklahoma	0	0	1997
15	43000	Louisiana	0	0	0
15	2214A		0		
15	2027		0		
15	1486B	Louisiana	3261		
15	1815A		0		
16	40191		0	0	0
16	2235		1247.3	0	0
16	2239A	California	0	48	0
16	40282		564.4	0	0
16	40053		0	0	0
16	40264		0	0	0
16	164		0	0	0
16	2232A		0	212	155
16	1471		0	0	0
16	1578		0	0	0
16	1697		0	0	0
16	2298		0	0	0
16	2350		0	0	0
16	2370		0	0	0
16	2386		11002.1	0	0
16	40098		48410	0	0
16	40131		0	0	0
16	40132		0	0	0
16	40133		0	0	0
16	40189		9192	0	0
16	40211		12896.9	0	0
16	40217		10011	0	0

		States Served		Solid Waste Treatment	
COG #	Permit Number	States Served	DV	Incineration Total	AutoClave Total
16	40236		5271.3	0	0
16	40249		0	0	0
16	40250		44	0	215
16	40273	Louisiana	0	0	2216
16	40275		0	0	0
16	40283		0	0	0
16	43034		0	0	0
16	1355A		0	0	0
16	1483A		0	0	0
16	2234D		2089	0	0
16	2241A		0	0	0
16	40028		0	0	0
16	2222	Arkansas, Louisiana, Oklahoma	0	0	9664.66
16	2309		0	0	0
16	42037		372577	0	0
16	2387		2134.5	0	0
16	40014		0	0	0
16	2318		0	0	0
16	1708		2087		
16	1539A		0		
16	1502A		234.5		
16	1535B		0		
16	203A		0		
16	2270		0		
16	1505A		0		
16	1797A		69931.7		
16	1149B		0		
16	1721A		2945		
16	1849B		0		
16	1193		0		
16	1301		0		
16	1403		0		
16	2185		0		
16	2304		0		
16	2344		11603		
16	1307D		0		
16	1540A		0		
16	1565B		0		
16	1586A		0		
16	1599A		5885		
16	1921A		0		
16	2240B		0		

		States Served		Solid Waste Treatment	
COG #	Permit Number	States Served	DV	Incineration Total	AutoClave Total
16	261B		0		
16	2324		135		
16	1752B		0		
16	1777				
16	48006				
16	48008				
16	48009				
16	48025				
16	48034				
16	48035				
17	40017		1458.1	0	0
17	2181		2080.8	0	0
17	40011		1432.8	0	0
17	2330		0	0	0
17	2366		0	0	0
17	42034		0	0	0
17	1522A		0		
17	48036				
18	1443		3867.8	0	0
18	2248		0	0	0
18	2317		0	0	0
18	40085		0	0	0
18	40157		0	0	0
18	40280		0	0	0
18	42032		16000	0	0
18	40244		0	0	3407
18	40240		0	0	0
18	42028		0	0	0
18	43011		0	0	0
18	1410C		0		
18	2093B		10.6		
18	66B		0		
18	1995		2655.9		
18	1848		6281.2		
18	1506A		115.9		
18	571		27.6		
18	48005				
18	48015				
18	48029				
18	48039				
19	40103		40	0	0
19	40238		25	1408	0
19	954		27		

		States Served		Solid Waste Treatment	
COG #	Permit Number	States Served	DV	Incineration Total	AutoClave Total
19	2286		3.8		
19	1693B		19694		
19	783A		0		
20	40027		3400.6	0	0
20	40002		0	0	0
20	40228		7898.5	0	0
20	40270		0	0	0
20	2319		0	0	0
20	379		205		
20	1481		0		
20	262C		441		
20	235B		3424.7		
20	2267		0		
20	2269		76.7		
20	2349		0		
21	2334		0	0	0
21	2375		0	0	0
21	40248		0	0	0
21	42015		0	0	0
21	748		0	0	0
21	2343		0	0	0
21	2346		0	0	0
21	1273A		24298		
21	2302		0		
21	2348		0		
21	1727A		0		
21	956B		805		
21	48038				
22	1030		908.9	0	0
22	1136		4415	0	0
22	2290		111.6		
22	523B	Oklahoma	0		
23	2368		180.1	0	0
23	40209		6059	0	0
23	40234		0	0	0
23	42035		0	0	0
23	40145		2768.4	0	0
23	42017		1284	0	0
23	42040		0	0	0
23	40004		14.6	0	0
23	40160		110.8	0	0
23	692A		0		
23	1866		1084.5		

		States Served		Solid Waste Treatment	
COG #	Permit Number	States Served	DV	Incineration Total	AutoClave Total
24	40057		69.828	0	0
24	40170		34.8	0	0
24	40178		0	0	0
24	40251		0	0	0
24	40034		0	0	0
24	2225		4.5		
24	2354		0		
24	1918		657.9		
24	2316		0		
24	1725		173.5		
24	207A		7355.2		
24	2303		215		
24	1308A		0		
Subtotal			**2,109,109**	**1,837**	**39,540**

		Solid Waste Treatment		
COG #	Permit Number	Composting Total	Chemical Disinfection Total	Chipping/Grinding Total
1	40271	0	0	0
1	40192	0	0	0
1	43030	0	0	0
1	40026	0	0	0
1	40015	0	0	0
1	40031	0	0	0
1	40263	0	0	0
1	76A	0	0	0
1	40109	0	0	0
1	414	0		0
1	1164	0		0
1	445A	0		0
1	2263	0		0
1	955	0		0
1	1038A	0		0
1	215A	0		0
1	570	0		0
1	2238	0		0
1	589A	0		0
1	2266	0		0
1	2352	0		0
1	1943	0		0
1	2279	0		0
1	2285	0		0
1	876A	0		0
1	791	0		0
1	73A	0		0
1	1663B	0		0
1	1009A	0		0
1	2281	0		0
2	40051	0	0	0
2	2231	0	0	0
2	40176	0	0	0
2	40279	0	0	0
2	564	0		0
2	2291	0		0
2	2268	0		0
2	9017	0		0
2	2207	0		0
2	2227	0		0
2	2157	0		0
2	1733	0		0
2	2369	0		0

		Solid Waste Treatment		
COG #	Permit Number	Composting Total	Chemical Disinfection Total	Chipping/Grinding Total
2	1298	0		0
2	2274	0		0
2	363A	0		0
2	583A	0		0
2	69	0		0
2	2252	0		0
2	2323	0		0
2	2328A	0		0
2	549A	0		0
2	2170	0		0
2	2293	0		0
2	2217	0		0
3	40144	0	0	0
3	2295	0	0	0
3	1429	0	0	0
3	2229A	0	0	0
3	40059	0	0	0
3	9001A	0		0
3	1428A	18231.58		0
3	1571A	0		0
4	1494	0	0	0
4	40284	0	0	0
4	2045A	0	0	0
4	53A	0	0	0
4	12	0	0	0
4	60	0	0	0
4	227	0	0	0
4	1145	0	0	0
4	1263	0	0	0
4	1421	0	0	0
4	1453	0	0	0
4	40196	0	0	0
4	40265	0	0	0
4	2069A	0	0	0
4	40080	0	0	0
4	40168	0	0	2573.63
4	40181	0	0	0
4	2275	0	0	0
4	2306	0	0	0
4	2379	0	0	0
4	40052	0	0	0
4	40186	0	0	0
4	1225D	0	0	0

		Solid Waste Treatment		
COG #	Permit Number	Composting Total	Chemical Disinfection Total	Chipping/Grinding Total
4	2256A	0	0	0
4	40241	0	1376.2	0
4	2294	46023.48		0
4	62	0		0
4	1394B	0		0
4	1895A	0		6874.81
4	996C	0		0
4	1025B	0		0
4	1312B	0		0
4	1590A	16154		0
4	1749B	0		0
4	1209B	0		0
4	1745B	0		0
4	42D	0		0
4	664	0		233
4	1195A	0		0
4	534	0		0
4	1417B	0		0
4	2190	0		0
4	47A	0		0
4	1983C	0		0
4	218C	0		39993.35
4	358B	0		35900.43
4	48012			
4	48016			
4	48018			
4	48027			
4	48028			
4	48032			
4	48033			
4	48042			
4	1025B			
5	2382	8730.85	0	0
5	576C	0		0
5	2358	0		0
5	797B	0		0
6	2389	0	0	0
6	40005	0	0	0
6	40006	0	0	0
6	40040	0	0	0
6	40174	0	0	0
6	2365	0	0	0
6	40172	0	0	0

		Solid Waste Treatment		
COG #	Permit Number	Composting Total	Chemical Disinfection Total	Chipping/Grinding Total
6	40267	0	0	0
6	356	2196	0	0
6	40266	0	0	0
6	40102	0	0	0
6	1614A	0		0
6	1327B	0		0
6	1249B	0		0
6	1972A	0		0
6	48026			
6	48041			
7	1562A	281.24		4755.63
7	1302	0		0
7	9009	0		0
7	1604B	0		0
7	2325	0		0
7	1469A	0		0
7	9004	0		0
7	420A	0		0
7	50B	0		0
7	9013	0		0
7	1463B	0		648
7	9000A	0		0
8	728	0	0	0
8	2355	0	0	0
8	40237	0	0	1540.75
8	40261	0	0	0
8	40262	0	0	0
8	1276	0		0
8	2197	0		0
8	1422	0		0
8	2284	0		0
8	729B	0		0
8	495	0		0
8	957A	0		0
8	1737A	0		0
9	2373	0	0	0
9	43028	0	0	0
9	171	0		0
9	427	0		0
9	517A	0		0
9	2158	0		0
9	39	0		0
9	2154	0		0

		Solid Waste Treatment		
COG #	Permit Number	Composting Total	Chemical Disinfection Total	Chipping/Grinding Total
9	288A	0		0
9	2189	0		0
9	1605B	0		0
9	976	0		0
9	2120	0		0
9	673	0		0
9	566	0		0
9	691	0		0
9	772	0		0
10	2357	347.9	0	0
10	2359	713	0	0
10	42022	1689	0	0
10	26B	0		0
10	195	0		0
10	1732	0		0
10	1404	0		0
10	86B	0		0
10	349	0		
10	2264	0		
10	79	0		0
11	241D	0		0
11	1558A	0		0
11	1646A	0		0
11	948A	0		0
11	48020			
12	2260A	0	0	0
12	2300	0	0	0
12	40035	0		
12	1787	0	0	0
12	119	0	0	0
12	2250	0	0	0
12	2310	183784	0	0
12	2384	0	0	0
12	40212	0	0	0
12	40243	0	0	427.39
12	42016	8660.32	0	0
12	466A	0	0	702
12	2123	44887.32		0
12	1841A	0		0
12	249D	0		0
12	1405B	0		4680.79
12	48019			
13	42003	9511.33	0	1330.82

		Solid Waste Treatment		
COG #	Permit Number	Composting Total	Chemical Disinfection Total	Chipping/Grinding Total
13	43026	0		
13	2381	0	0	0
13	40018	0	0	4463.84
13	40173	0	0	0
13	2292	0		6186.85
14	40033	0	0	0
14	40044	0	0	0
14	43007	0	0	0
14	40277	0	0	0
14	40054	0	0	0
14	40024	0	0	0
14	40013	0	0	0
14	40038	0	0	0
14	2105A	0		0
14	720	0		0
14	2242A	0		0
14	1384A	0		0
15	40164	0	0	0
15	40225	0	0	0
15	40268	0	0	0
15	43000	0	0	0
15	2214A	0		0
15	2027	0		0
15	1486B	0		0
15	1815A	0		0
16	40191	0	0	0
16	2235	0	0	0
16	2239A	0	0	0
16	40282	0	0	0
16	40053	0	0	0
16	40264	0	0	0
16	164	0	0	0
16	2232A	0		
16	1471	0	0	0
16	1578	0	0	0
16	1697	0	0	0
16	2298	0	0	0
16	2350	0	0	0
16	2370	0	0	0
16	2386	0	0	0
16	40098	0	0	0
16	40131	0	0	0
16	40132	0	0	0

		Solid Waste Treatment		
COG #	Permit Number	Composting Total	Chemical Disinfection Total	Chipping/Grinding Total
16	40133	0	0	0
16	40189	0	0	0
16	40211	0	0	0
16	40217	0	0	0
16	40236	0	0	0
16	40249	0	0	0
16	40250	0	0	0
16	40273	0	0	0
16	40275	0	0	0
16	40283	0	0	0
16	43034	0	0	0
16	1355A	0	0	0
16	1483A	0	0	0
16	2234D	0	0	0
16	2241A	0	0	0
16	40028	0	0	0
16	2222	0	0	0
16	2309	0	0	0
16	42037	32407	0	360129
16	2387	0	0	0
16	40014	0	0	0
16	2318	3204	0	0
16	1708	0		2087
16	1539A	0		0
16	1502A	0		0
16	1535B	0		0
16	203A	0		0
16	2270	0		0
16	1505A	0		0
16	1797A	1120		
16	1149B	0		0
16	1721A	2945		0
16	1849B	0		0
16	1193	0		0
16	1301	0		0
16	1403	0		0
16	2185	0		0
16	2304	0		0
16	2344	500		4500
16	1307D	0		0
16	1540A	0		0
16	1565B	0		0
16	1586A	0		0

		Solid Waste Treatment		
COG #	Permit Number	Composting Total	Chemical Disinfection Total	Chipping/Grinding Total
16	1599A	0		0
16	1921A	0		0
16	2240B	0		0
16	261B	0		0
16	2324	0		0
16	1752B	0		0
16	1777			
16	48006			
16	48008			
16	48009			
16	48025			
16	48034			
16	48035			
17	40017	0	0	0
17	2181	0	0	2830.5
17	40011	0	0	0
17	2330	0	0	0
17	2366	0	0	0
17	42034	20486.16	0	0
17	1522A	0		0
17	48036			
18	1443	0	0	0
18	2248	0	0	0
18	2317	59371	0	0
18	40085	0	0	0
18	40157	0	0	0
18	40280	0	0	0
18	42032	97031	0	16000
18	40244	0	0	0
18	40240	0		
18	42028	8849.76	0	0
18	43011	0	0	0
18	1410C	0		
18	2093B	0		0
18	66B	0		0
18	1995	0		0
18	1848	0		0
18	1506A	8849.76		
18	571	0		0
18	48005			
18	48015			
18	48029			
18	48039			

		Solid Waste Treatment		
COG #	Permit Number	Composting Total	Chemical Disinfection Total	Chipping/Grinding Total
19	40103	0	0	0
19	40238	0	0	0
19	954	0		0
19	2286	0		0
19	1693B	0		10829
19	783A	0		0
20	40027	0	0	2958
20	40002	0	0	0
20	40228	0	0	0
20	40270	0	115.9	0
20	2319	1443	0	0
20	379	0		0
20	1481	0		0
20	262C	0		0
20	235B	0		0
20	2267	0		
20	2269	0		0
20	2349	0		0
21	2334	0	0	0
21	2375	0		
21	40248	0	0	0
21	42015	24209.06	0	0
21	748	0	0	0
21	2343	0	0	0
21	2346	0	0	0
21	1273A	0		0
21	2302	0		0
21	2348	0		
21	1727A	0		0
21	956B	0		0
21	48038			
22	1030	0	0	0
22	1136	0	0	0
22	2290	0		0
22	523B	0		0
23	2368	0	0	0
23	40209	0	0	0
23	40234	0	0	0
23	42035	6798	0	0
23	40145	0	0	0
23	42017	0	0	475
23	42040	0	0	0
23	40004	0	0	0

		Solid Waste Treatment		
COG #	Permit Number	Composting Total	Chemical Disinfection Total	Chipping/Grinding Total
23	40160	0	0	0
23	692A	0		0
23	1866	3091.91		0
24	40057	0	0	0
24	40170	0	0	0
24	40178	0	0	0
24	40251	0	0	0
24	40034	0	0	0
24	2225	0		
24	2354	0		0
24	1918	0		0
24	2316	0		0
24	1725	0		0
24	207A	0		0
24	2303	0		0
24	1308A	0		0
Subtotal		**611,516**	**1,492**	**510,120**

		LWT	Solid Waste Transfer		
COG #	**Permit Number**	**LWT Total Tons**	**Municipal In State**	**Municipal Out State**	**Municipal Total**
1	40271	0	9720.91	1946.76	11667.67
1	40192	0	1623.8	0	1623.8
1	43030	637	0	0	0
1	40026	0	4351.77	0	4351.77
1	40015	0	12127.79	0	12127.79
1	40031	0	1766	0	1766
1	40263	0	0	0	0
1	76A	0	154964	0	154964
1	40109	0	2179	0	2179
1	414				
1	1164				
1	445A				
1	2263				
1	955				
1	1038A				
1	215A				
1	570				
1	2238				
1	589A				
1	2266				
1	2352				
1	1943				
1	2279				
1	2285				
1	876A				
1	791				
1	73A				
1	1663B				
1	1009A				
1	2281				
2	40051	0	0	0	0
2	2231	9599	0	0	0
2	40176	0	424.44	0	424.44
2	40279	0	0	0	0
2	564				
2	2291				
2	2268				
2	9017				
2	2207				
2	2227				
2	2157				
2	1733				
2	2369				

		LWT	Solid Waste Transfer		
COG #	Permit Number	LWT Total Tons	Municipal In State	Municipal Out State	Municipal Total
2	1298				
2	2274				
2	363A				
2	583A				
2	69				
2	2252				
2	2323				
2	2328A				
2	549A				
2	2170				
2	2293				
2	2217				
3	40144	0	398.98	0	398.98
3	2295	0	52274.21	328.79	52603
3	1429	0	63280.68	0	63280.68
3	2229A	20627	0	0	0
3	40059	0	13595.9	919.83	14515.73
3	9001A				
3	1428A				
3	1571A				
4	1494	0	128041.59	0	128041.59
4	40284	0	0	0	0
4	2045A	0	303502.84	0	303502.84
4	53A	0	152687.46	0	152687.46
4	12	0	118534.33	0	118534.33
4	60	0	69908.87	0	69908.87
4	227	0	12751	0	12751
4	1145	0	152781.5	0	152781.5
4	1263	0	55107.01	0	55107.01
4	1421	45620	0	0	0
4	1453	0	62911	0	62911
4	40196	0	64822.95	0	64822.95
4	40265	0	0	0	0
4	2069A	137273	0	0	0
4	40080	0	0	0	0
4	40168	0	63389.03	0	63389.03
4	40181	0	1778.99	0	1778.99
4	2275	0	0	0	0
4	2306	0	142795.36	0	142795.36
4	2379	47413	0	0	0
4	40052	0	0	0	0
4	40186	0	148033	0	148033
4	1225D	63048	0	0	0

		LWT	Solid Waste Transfer		
COG #	Permit Number	LWT Total Tons	Municipal In State	Municipal Out State	Municipal Total
4	2256A	97781	0	0	0
4	40241	0	0	0	0
4	2294				
4	62				
4	1394B				
4	1895A				
4	996C				
4	1025B				
4	1312B				
4	1590A				
4	1749B				
4	1209B				
4	1745B				
4	42D				
4	664				
4	1195A				
4	534				
4	1417B				
4	2190				
4	47A				
4	1983C				
4	218C				
4	358B				
4	48012				
4	48016				
4	48018				
4	48027				
4	48028				
4	48032				
4	48033				
4	48042				
4	1025B				
5	2382	0	0	0	0
5	576C				
5	2358				
5	797B				
6	2389	0	10672	0	10672
6	40005	0	851.24	0	851.24
6	40006	0	1129.97	0	1129.97
6	40040	0	41321.99	0	41321.99
6	40174	0	30294	0	30294
6	2365	5790	0	0	0
6	40172	0	11914.01	0	11914.01

		LWT	Solid Waste Transfer		
COG #	Permit Number	LWT Total Tons	Municipal In State	Municipal Out State	Municipal Total
6	40267	0	0	0	0
6	356	0	0	0	0
6	40266	0	23247.81	0	23247.81
6	40102	0	0	0	0
6	1614A				
6	1327B				
6	1249B				
6	1972A				
6	48026				
6	48041				
7	1562A				
7	1302				
7	9009				
7	1604B				
7	2325				
7	1469A				
7	9004				
7	420A				
7	50B				
7	9013				
7	1463B				
7	9000A				
8	728	0	1605.38	0	1605.38
8	2355	17772	0	0	0
8	40237	0	0	0	0
8	40261	0	0	0	0
8	40262	0	0	0	0
8	1276				
8	2197				
8	1422				
8	2284				
8	729B				
8	495				
8	957A				
8	1737A				
9	2373	167484	0	0	0
9	43028	2336	0	0	0
9	171				
9	427				
9	517A				
9	2158				
9	39				
9	2154				

		LWT	Solid Waste Transfer		
COG #	Permit Number	LWT Total Tons	Municipal In State	Municipal Out State	Municipal Total
9	288A				
9	2189				
9	1605B				
9	976				
9	2120				
9	673				
9	566				
9	691				
9	772				
10	2357	0	0	0	0
10	2359	0	0	0	0
10	42022	0	0	0	0
10	26B				
10	195				
10	1732				
10	1404				
10	86B				
10	349				
10	2264				
10	79				
11	241D				
11	1558A				
11	1646A				
11	948A				
11	48020				
12	2260A	0	0	0	0
12	2300	0	18608	0	18608
12	40035	0	30267.4	0	30267.4
12	1787	0	555.65	0	555.65
12	119	0	7314.94	0	7314.94
12	2250	53646	0	0	0
12	2310	0	0	0	0
12	2384	87063	0	0	0
12	40212	147	0	0	0
12	40243	0	0	0	0
12	42016	0	0	0	0
12	466A	0	59960.15	0	59960.15
12	2123				
12	1841A				
12	249D				
12	1405B				
12	48019				
13	42003	0	0	0	0

		LWT	Solid Waste Transfer		
COG #	Permit Number	LWT Total Tons	Municipal In State	Municipal Out State	Municipal Total
13	43026	7405	0	0	0
13	2381	5292	0	0	0
13	40018	0	26086.28	0	26086.28
13	40173	0	34688	0	34688
13	2292				
14	40033	0	645	0	645
14	40044	0	20000	0	20000
14	43007	2246	0	0	0
14	40277	0	153.9	0	153.9
14	40054	0	2734.88	0	2734.88
14	40024	0	2368	0	2368
14	40013	0	3130	0	3130
14	40038	0	1689.39	0	1689.39
14	2105A				
14	720				
14	2242A				
14	1384A				
15	40164	250	0	0	0
15	40225	0	18667.6	0	18667.6
15	40268	0	0	0	0
15	43000	4443	0	0	0
15	2214A				
15	2027				
15	1486B				
15	1815A				
16	40191	0	6451	0	6451
16	2235	0	0	0	0
16	2239A	0	0	0	0
16	40282	0	33298.96	0	33298.96
16	40053	0	0	0	0
16	40264	0	0	0	0
16	164	0	97560.7	0	97560.7
16	2232A	0	0	0	0
16	1471	0	179600	0	179600
16	1578	0	444048	0	444048
16	1697	0	15510	0	15510
16	2298	27909	0	0	0
16	2350	52009	0	0	0
16	2370	89396	0	0	0
16	2386	0	0	0	0
16	40098	0	0	0	0
16	40131	0	182307.69	0	182307.69
16	40132	0	221695.65	0	221695.65

		LWT	Solid Waste Transfer		
COG #	**Permit Number**	**LWT Total Tons**	**Municipal In State**	**Municipal Out State**	**Municipal Total**
16	40133	0	181788.63	0	181788.63
16	40189	0	0	0	0
16	40211	0	0	0	0
16	40217	0	0	0	0
16	40236	0	0	0	0
16	40249	0	284473.09	0	284473.09
16	40250	0	0	0	0
16	40273	0	0	0	0
16	40275	0	4011.12	0	4011.12
16	40283	0	0	0	0
16	43034	13480	0	0	0
16	1355A	0	387079	0	387079
16	1483A	0	123166	0	123166
16	2234D	244648	0	0	0
16	2241A	131931	0	0	0
16	40028	0	6704.29	0	6704.29
16	2222	0	0	0	0
16	2309	0	16411.55	0	16411.55
16	42037	0	0	0	0
16	2387	0	42569.53	0	42569.53
16	40014	0	0	0	0
16	2318	0	0	0	0
16	1708				
16	1539A				
16	1502A				
16	1535B				
16	203A				
16	2270				
16	1505A				
16	1797A				
16	1149B				
16	1721A				
16	1849B				
16	1193				
16	1301				
16	1403				
16	2185				
16	2304				
16	2344				
16	1307D				
16	1540A				
16	1565B				
16	1586A				

		LWT	Solid Waste Transfer		
COG #	Permit Number	LWT Total Tons	Municipal In State	Municipal Out State	Municipal Total
16	1599A				
16	1921A				
16	2240B				
16	261B				
16	2324				
16	1752B				
16	1777				
16	48006				
16	48008				
16	48009				
16	48025				
16	48034				
16	48035				
17	40017	0	27119.84	0	27119.84
17	2181	0	1424.34	0	1424.34
17	40011	0	71.41	0	71.41
17	2330	25635	0	0	0
17	2366	737	0	0	0
17	42034	0	0	0	0
17	1522A				
17	48036				
18	1443	0	133446.82	0	133446.82
18	2248	35777	0	0	0
18	2317	0	0	0	0
18	40085	0	0	0	0
18	40157	0	0	0	0
18	40280	0	0	0	0
18	42032	0	0	0	0
18	40244	0	0	0	0
18	40240	0	74387.86	0	74387.86
18	42028	0	0	0	0
18	43011	66303	0	0	0
18	1410C				
18	2093B				
18	66B				
18	1995				
18	1848				
18	1506A				
18	571				
18	48005				
18	48015				
18	48029				
18	48039				

		LWT	Solid Waste Transfer		
COG #	Permit Number	LWT Total Tons	Municipal In State	Municipal Out State	Municipal Total
19	40103	0	8000	0	8000
19	40238	0	29825	0	29825
19	954				
19	2286				
19	1693B				
19	783A				
20	40027	0	3972	0	3972
20	40002	0	1290	0	1290
20	40228	0	59594.28	0	59594.28
20	40270	0	0	0	0
20	2319	12974	0	0	0
20	379				
20	1481				
20	262C				
20	235B				
20	2267				
20	2269				
20	2349				
21	2334	0	0	0	0
21	2375	0	155444.5	0	155444.5
21	40248	0	52702.45	0	52702.45
21	42015	0	0	0	0
21	748	0	42808	0	42808
21	2343	15810	0	0	0
21	2346	17231	0	0	0
21	1273A				
21	2302				
21	2348				
21	1727A				
21	956B				
21	48038				
22	1030	0	30613.09	0	30613.09
22	1136	0	11446	0	11446
22	2290				
22	523B				
23	2368	4213	0	0	0
23	40209	0	99870.42	0	99870.42
23	40234	0	0	0	0
23	42035	0	0	0	0
23	40145	0	28209	0	28209
23	42017	0	0	0	0
23	42040	0	0	0	0
23	40004	0	105.49	0	105.49

		LWT	Solid Waste Transfer		
COG #	Permit Number	LWT Total Tons	Municipal In State	Municipal Out State	Municipal Total
23	40160	0	3681.1	0	3681.1
23	692A				
23	1866				
24	40057	0	858.18	0	858.18
24	40170	0	818	0	818
24	40178	0	175.57	0	175.57
24	40251	0	16	0	16
24	40034	0	924.98	0	924.98
24	2225				
24	2354				
24	1918				
24	2316				
24	1725				
24	207A				
24	2303				
24	1308A				
Subtotal		**1,513,925**	**5,135,138**	**3,195**	**5,138,333**

		Solid Waste Transfer			
COG #	Permit Number	Industrial Total	Brush Total	Construction Demo Total	Tons Total
1	40271	0	0	0	11668
1	40192	0	0	682.7	2307
1	43030	0	0	0	0
1	40026	0	0	0	4352
1	40015	0	0	5302.06	17430
1	40031	0	28	367	2161
1	40263	0	0	0	0
1	76A	0	0	0	154964
1	40109	0	0	528.56	2708
1	414				
1	1164				
1	445A				
1	2263				
1	955				
1	1038A				
1	215A				
1	570				
1	2238				
1	589A				
1	2266				
1	2352				
1	1943				
1	2279				
1	2285				
1	876A				
1	791				
1	73A				
1	1663B				
1	1009A				
1	2281				
2	40051	0	0	45.78	46
2	2231	0	0	0	0
2	40176	0	0	0	424
2	40279	0	0	0	1512
2	564				
2	2291				
2	2268				
2	9017				
2	2207				
2	2227				
2	2157				
2	1733				
2	2369				

		Solid Waste Transfer			
COG #	**Permit Number**	**Industrial Total**	**Brush Total**	**Construction Demo Total**	**Tons Total**
2	1298				
2	2274				
2	363A				
2	583A				
2	69				
2	2252				
2	2323				
2	2328A				
2	549A				
2	2170				
2	2293				
2	2217				
3	40144	0	0	360.98	760
3	2295	0	0	0	52603
3	1429	0	0	0	63281
3	2229A	0	0	0	0
3	40059	0	0	3228.94	17745
3	9001A				
3	1428A				
3	1571A				
4	1494	0	7.37	0	128049
4	40284	0	0	45251.2	45251
4	2045A	0	0	0	303503
4	53A	0	5366.43	0	158054
4	12	0	0	0	118534
4	60	0	0	0	69909
4	227	0	0	0	12751
4	1145	0	0	0	152782
4	1263	0	0	0	55107
4	1421	0	0	0	17411
4	1453	0	0	0	62911
4	40196	0	0	0	64823
4	40265	0	0	0	12414
4	2069A	0	0	0	0
4	40080	0	0	0	0
4	40168	0	0	0	63389
4	40181	0	0	0	1779
4	2275	0	0	0	0
4	2306	0	0	0	142795
4	2379	0	0	0	0
4	40052	9520	0	0	9520
4	40186	11588	0	24193	183814
4	1225D	0	0	0	0

		Solid Waste Transfer			
COG #	Permit Number	Industrial Total	Brush Total	Construction Demo Total	Tons Total
4	2256A	0	0	0	0
4	40241	0	0	0	0
4	2294				
4	62				
4	1394B				
4	1895A				
4	996C				
4	1025B				
4	1312B				
4	1590A				
4	1749B				
4	1209B				
4	1745B				
4	42D				
4	664				
4	1195A				
4	534				
4	1417B				
4	2190				
4	47A				
4	1983C				
4	218C				
4	358B				
4	48012				
4	48016				
4	48018				
4	48027				
4	48028				
4	48032				
4	48033				
4	48042				
4	1025B				
5	2382	0	0	0	0
5	576C				
5	2358				
5	797B				
6	2389	0	0	0	10672
6	40005	0	0	0	851
6	40006	0	0	0	1130
6	40040	0	0	0	41322
6	40174	0	0	0	30294
6	2365	0	0	0	0
6	40172	0	0	0	11914

		Solid Waste Transfer			
COG #	Permit Number	Industrial Total	Brush Total	Construction Demo Total	Tons Total
6	40267	0	0	0	0
6	356	0	0	0	0
6	40266	0	0	0	23248
6	40102	0	0	0	11624
6	1614A				
6	1327B				
6	1249B				
6	1972A				
6	48026				
6	48041				
7	1562A				
7	1302				
7	9009				
7	1604B				
7	2325				
7	1469A				
7	9004				
7	420A				
7	50B				
7	9013				
7	1463B				
7	9000A				
8	728	0	0	0	1605
8	2355	0	0	0	0
8	40237	0	0	1394.99	1395
8	40261	0	0	0	1522
8	40262	0	0	0	0
8	1276				
8	2197				
8	1422				
8	2284				
8	729B				
8	495				
8	957A				
8	1737A				
9	2373	0	0	0	0
9	43028	0	0	0	0
9	171				
9	427				
9	517A				
9	2158				
9	39				
9	2154				

		Solid Waste Transfer			
COG #	Permit Number	Industrial Total	Brush Total	Construction Demo Total	Tons Total
9	288A				
9	2189				
9	1605B				
9	976				
9	2120				
9	673				
9	566				
9	691				
9	772				
10	2357	0	0	0	0
10	2359	0	0	0	0
10	42022	0	0	0	0
10	26B				
10	195				
10	1732				
10	1404				
10	86B				
10	349				
10	2264				
10	79				
11	241D				
11	1558A				
11	1646A				
11	948A				
11	48020				
12	2260A	0	0	0	1390
12	2300	0	0	185	18793
12	40035	0	0	52	30319
12	1787	0	0	1232.01	1788
12	119	0	0	167	7482
12	2250	0	0	0	0
12	2310	0	0	0	0
12	2384	0	0	0	0
12	40212	0	0	0	0
12	40243	0	0	5741.41	5741
12	42016	0	0	0	0
12	466A	0	0	13386.84	73347
12	2123				
12	1841A				
12	249D				
12	1405B				
12	48019				
13	42003	0	0	0	0

		Solid Waste Transfer			
COG #	Permit Number	Industrial Total	Brush Total	Construction Demo Total	Tons Total
13	43026	0	0	0	0
13	2381	0	0	0	0
13	40018	0	0	0	26086
13	40173	0	0	0	34688
13	2292				
14	40033	0	0	0	645
14	40044	0	0	0	20000
14	43007	0	0	0	0
14	40277	0	0	1297	1451
14	40054	344.25	0	374	3453
14	40024	0	0	0	2368
14	40013	0	0	172	3302
14	40038	0	0	0	1689
14	2105A				
14	720				
14	2242A				
14	1384A				
15	40164	0	0	0	0
15	40225	0	0	0	18668
15	40268	0	0	0	0
15	43000	0	0	0	0
15	2214A				
15	2027				
15	1486B				
15	1815A				
16	40191	0	0	0	6451
16	2235	0	0	0	0
16	2239A	0	0	0	0
16	40282	0	0	3699.89	36999
16	40053	0	0	0	0
16	40264	0	0	0	3863
16	164	0	0	0	97561
16	2232A	0	0	0	186
16	1471	0	0	0	179600
16	1578	0	0	0	444048
16	1697	0	0	2031	17541
16	2298	0	0	0	0
16	2350	0	0	0	1450
16	2370	0	0	0	12690
16	2386	0	0	156	156
16	40098	0	0	0	0
16	40131	0	0	59325.24	241633
16	40132	0	0	22518.73	244214

		Solid Waste Transfer			
COG #	Permit Number	Industrial Total	Brush Total	Construction Demo Total	Tons Total
16	40133	0	0	35369.89	217159
16	40189	0	0	65010	65010
16	40211	0	0	19473.94	19474
16	40217	0	0	60499	60499
16	40236	0	0	12110.21	12110
16	40249	0	0	0	284473
16	40250	0	0	0	0
16	40273	0	0	0	0
16	40275	0	0	587.88	4599
16	40283	0	0	0	348
16	43034	0	0	0	11895
16	1355A	0	1471	776.2	389326
16	1483A	0	0	0	123166
16	2234D	0	0	0	19723
16	2241A	0	0	0	0
16	40028	0	0	0	6704
16	2222	0	0	0	1918
16	2309	0	0	0	16412
16	42037	0	0	0	0
16	2387	0	0	0	42570
16	40014	0	0	0	89
16	2318	0	0	0	0
16	1708				
16	1539A				
16	1502A				
16	1535B				
16	203A				
16	2270				
16	1505A				
16	1797A				
16	1149B				
16	1721A				
16	1849B				
16	1193				
16	1301				
16	1403				
16	2185				
16	2304				
16	2344				
16	1307D				
16	1540A				
16	1565B				
16	1586A				

		Solid Waste Transfer			
COG #	Permit Number	Industrial Total	Brush Total	Construction Demo Total	Tons Total
16	1599A				
16	1921A				
16	2240B				
16	261B				
16	2324				
16	1752B				
16	1777				
16	48006				
16	48008				
16	48009				
16	48025				
16	48034				
16	48035				
17	40017	0	0	0	27120
17	2181	0	0	0	1424
17	40011	0	0	106.18	178
17	2330	0	0	0	0
17	2366	0	0	0	0
17	42034	0	0	0	0
17	1522A				
17	48036				
18	1443	0	0	10187.77	143635
18	2248	0	0	0	0
18	2317	0	0	0	0
18	40085	0	0	0	0
18	40157	0	0	0	0
18	40280	0	0	0	3702
18	42032	0	0	0	0
18	40244	0	0	0	0
18	40240	0	0	0	74388
18	42028	0	0	0	8850
18	43011	0	0	0	0
18	1410C				
18	2093B				
18	66B				
18	1995				
18	1848				
18	1506A				
18	571				
18	48005				
18	48015				
18	48029				
18	48039				

		Solid Waste Transfer			
COG #	**Permit Number**	**Industrial Total**	**Brush Total**	**Construction Demo Total**	**Tons Total**
19	40103	0	550	0	8550
19	40238	0	0	340	30418
19	954				
19	2286				
19	1693B				
19	783A				
20	40027	0	0	0	3972
20	40002	0	0	0	1290
20	40228	0	17.76	26765.84	86378
20	40270	0	0	0	0
20	2319	0	0	0	0
20	379				
20	1481				
20	262C				
20	235B				
20	2267				
20	2269				
20	2349				
21	2334	0	0	0	212
21	2375	0	0	0	155445
21	40248	0	0	11246.3	66178
21	42015	0	0	0	0
21	748	0	9550	0	52358
21	2343	0	0	0	764
21	2346	0	0	0	0
21	1273A				
21	2302				
21	2348				
21	1727A				
21	956B				
21	48038				
22	1030	0	0	0	30613
22	1136	0	0	0	11447
22	2290				
22	523B				
23	2368	0	0	0	175
23	40209	0	0	6976.11	106897
23	40234	0	0	0	441
23	42035	0	0	0	0
23	40145	0	0	0	28209
23	42017	0	0	0	0
23	42040	0	0	0	317
23	40004	0	0	0	105

		Solid Waste Transfer			
COG #	**Permit Number**	**Industrial Total**	**Brush Total**	**Construction Demo Total**	**Tons Total**
23	40160	0	0	0	3681
23	692A				
23	1866				
24	40057	0	0	0	867
24	40170	0	0	0	818
24	40178	0	0	0	176
24	40251	0	0	10	26
24	40034	0	0	0	925
24	2225				
24	2354				
24	1918				
24	2316				
24	1725				
24	207A				
24	2303				
24	1308A				
Subtotal		**21,452**	**16,991**	**441,153**	**5,732,970**

		Liquid Waste Transfer				
COG #	Permit Number	Sludge Total	Grease Total	Grit Total	Septage Total	Tons Total
1	40271	-	-	-	-	-
1	40192	-	-	-	-	-
1	43030	-	-	-	-	-
1	40026	-	-	-	-	-
1	40015	-	-	-	-	-
1	40031	-	-	-	-	-
1	40263	-	-	-	-	-
1	76A	-	-	-	-	-
1	40109	-	-	-	-	-
1	414					
1	1164					
1	445A					
1	2263					
1	955					
1	1038A					
1	215A					
1	570					
1	2238					
1	589A					
1	2266					
1	2352					
1	1943					
1	2279					
1	2285					
1	876A					
1	791					
1	73A					
1	1663B					
1	1009A					
1	2281					
2	40051	-	-	-	-	-
2	2231	-	-	-	-	-
2	40176	-	-	-	-	-
2	40279	-	-	-	-	-
2	564					
2	2291					
2	2268					
2	9017					
2	2207					
2	2227					
2	2157					
2	1733					
2	2369					

		Liquid Waste Transfer				
COG #	Permit Number	Sludge Total	Grease Total	Grit Total	Septage Total	Tons Total
2	1298					
2	2274					
2	363A					
2	583A					
2	69					
2	2252					
2	2323					
2	2328A					
2	549A					
2	2170					
2	2293					
2	2217					
3	40144	-	-	-	-	-
3	2295	-	-	-	-	-
3	1429	-	-	-	-	-
3	2229A	-	-	-	-	-
3	40059	-	-	-	-	-
3	9001A					
3	1428A					
3	1571A					
4	1494	-	-	-	-	-
4	40284	-	-	-	-	-
4	2045A	-	-	-	-	-
4	53A	-	-	-	-	-
4	12	-	-	-	-	-
4	60	-	-	-	-	-
4	227	-	-	-	-	-
4	1145	-	-	-	-	-
4	1263	-	-	-	-	-
4	1421	-	-	-	-	-
4	1453	-	-	-	-	-
4	40196	-	-	-	-	-
4	40265	-	-	-	-	-
4	2069A	-	-	-	-	-
4	40080	-	5,500	900	-	6,400
4	40168	-	-	-	-	-
4	40181	-	-	-	-	-
4	2275	-	-	-	-	-
4	2306	-	-	-	-	-
4	2379	-	-	-	-	-
4	40052	-	-	-	-	-
4	40186	-	-	-	-	-
4	1225D	-	-	-	-	-

		Liquid Waste Transfer				
COG #	Permit Number	Sludge Total	Grease Total	Grit Total	Septage Total	Tons Total
4	2256A	-	-	-	-	-
4	40241	-	-	-	-	-
4	2294					
4	62					
4	1394B					
4	1895A					
4	996C					
4	1025B					
4	1312B					
4	1590A					
4	1749B					
4	1209B					
4	1745B					
4	42D					
4	664					
4	1195A					
4	534					
4	1417B					
4	2190					
4	47A					
4	1983C					
4	218C					
4	358B					
4	48012					
4	48016					
4	48018					
4	48027					
4	48028					
4	48032					
4	48033					
4	48042					
4	1025B					
5	2382	-	-	-	-	-
5	576C					
5	2358					
5	797B					
6	2389	-	-	-	-	-
6	40005	-	-	-	-	-
6	40006	-	-	-	-	-
6	40040	-	-	-	-	-
6	40174	-	-	-	-	-
6	2365	-	-	-	-	-
6	40172	-	-	-	-	-

		Liquid Waste Transfer				
COG #	Permit Number	Sludge Total	Grease Total	Grit Total	Septage Total	Tons Total
6	40267	-	-	-	-	-
6	356	-	-	-	-	-
6	40266	-	-	-	-	-
6	40102	-	-	-	-	-
6	1614A					
6	1327B					
6	1249B					
6	1972A					
6	48026					
6	48041					
7	1562A					
7	1302					
7	9009					
7	1604B					
7	2325					
7	1469A					
7	9004					
7	420A					
7	50B					
7	9013					
7	1463B					
7	9000A					
8	728	-	-	-	-	-
8	2355	-	-	-	-	-
8	40237	-	-	-	-	-
8	40261	-	-	-	-	-
8	40262	-	-	-	-	-
8	1276					
8	2197					
8	1422					
8	2284					
8	729B					
8	495					
8	957A					
8	1737A					
9	2373	-	-	-	-	-
9	43028	-	-	-	-	-
9	171					
9	427					
9	517A					
9	2158					
9	39					
9	2154					

		Liquid Waste Transfer				
COG #	**Permit Number**	**Sludge Total**	**Grease Total**	**Grit Total**	**Septage Total**	**Tons Total**
9	288A					
9	2189					
9	1605B					
9	976					
9	2120					
9	673					
9	566					
9	691					
9	772					
10	2357	-	-	-	-	-
10	2359	-	-	-	-	-
10	42022	-	-	-	-	-
10	26B					
10	195					
10	1732					
10	1404					
10	86B					
10	349					
10	2264					
10	79					
11	241D					
11	1558A					
11	1646A					
11	948A					
11	48020					
12	2260A	-	-	-	-	-
12	2300	-	-	-	-	-
12	40035	-	-	-	-	-
12	1787	-	-	-	-	-
12	119	-	-	-	-	-
12	2250	-	237	-	-	11,241
12	2310	-	-	-	-	-
12	2384	-	-	-	-	-
12	40212	-	-	-	147	147
12	40243	-	-	-	-	-
12	42016	-	-	-	-	-
12	466A	-	-	-	-	-
12	2123					
12	1841A					
12	249D					
12	1405B					
12	48019					
13	42003	-	-	-	-	-

		Liquid Waste Transfer				
COG #	Permit Number	Sludge Total	Grease Total	Grit Total	Septage Total	Tons Total
13	43026	-	-	-	-	-
13	2381	-	-	-	-	-
13	40018	-	-	-	-	-
13	40173	-	-	-	-	-
13	2292					
14	40033	-	-	-	-	-
14	40044	-	-	-	-	-
14	43007	-	-	-	-	-
14	40277	-	-	-	-	-
14	40054	6	-	-	-	6
14	40024	-	-	-	-	-
14	40013	-	-	-	-	-
14	40038	-	-	-	-	-
14	2105A					
14	720					
14	2242A					
14	1384A					
15	40164	-	-	-	-	-
15	40225	-	-	-	-	-
15	40268	-	-	-	-	-
15	43000	-	547	283	-	830
15	2214A					
15	2027					
15	1486B					
15	1815A					
16	40191	-	-	-	-	-
16	2235	-	-	-	-	-
16	2239A	-	-	-	-	-
16	40282	-	-	-	-	-
16	40053	-	-	-	1,577	1,577
16	40264	-	-	-	-	-
16	164	-	-	-	-	-
16	2232A	-	-	-	-	-
16	1471	-	-	-	-	-
16	1578	-	-	-	-	-
16	1697	-	-	-	-	-
16	2298	-	-	-	-	-
16	2350	-	-	-	-	-
16	2370	-	-	-	-	-
16	2386	-	-	-	-	-
16	40098	-	-	-	-	-
16	40131	-	-	-	-	-
16	40132	-	-	-	-	-

		Liquid Waste Transfer				
COG #	Permit Number	Sludge Total	Grease Total	Grit Total	Septage Total	Tons Total
16	40133	-	-	-	-	-
16	40189	-	-	-	-	-
16	40211	-	-	-	-	-
16	40217	-	-	-	-	-
16	40236	-	-	-	-	-
16	40249	-	-	-	-	-
16	40250	-	-	-	-	-
16	40273	-	-	-	-	-
16	40275	-	-	-	-	-
16	40283	-	-	-	-	-
16	43034	-	-	-	-	-
16	1355A	-	-	-	-	-
16	1483A	-	-	-	-	-
16	2234D	-	-	-	-	18,166
16	2241A	-	-	-	-	-
16	40028	-	-	-	-	-
16	2222	-	-	-	-	-
16	2309	-	-	-	-	-
16	42037	-	-	-	-	-
16	2387	-	-	-	-	-
16	40014	-	-	-	-	-
16	2318	-	-	-	-	-
16	1708					
16	1539A					
16	1502A					
16	1535B					
16	203A					
16	2270					
16	1505A					
16	1797A					
16	1149B					
16	1721A					
16	1849B					
16	1193					
16	1301					
16	1403					
16	2185					
16	2304					
16	2344					
16	1307D					
16	1540A					
16	1565B					
16	1586A					

		Liquid Waste Transfer				
COG #	Permit Number	Sludge Total	Grease Total	Grit Total	Septage Total	Tons Total
16	1599A					
16	1921A					
16	2240B					
16	261B					
16	2324					
16	1752B					
16	1777					
16	48006					
16	48008					
16	48009					
16	48025					
16	48034					
16	48035					
17	40017	-	-	-	-	-
17	2181	-	-	-	-	-
17	40011	-	-	-	-	-
17	2330	-	-	-	-	-
17	2366	-	-	-	-	-
17	42034	-	-	-	-	-
17	1522A					
17	48036					
18	1443	-	-	-	-	-
18	2248	-	-	-	-	-
18	2317	-	-	-	-	-
18	40085	-	-	-	-	4,463
18	40157	-	592	-	-	592
18	40280	-	-	-	-	-
18	42032	-	-	-	-	-
18	40244	-	-	-	-	-
18	40240	-	-	-	-	-
18	42028	-	-	-	-	-
18	43011	-	-	-	-	-
18	1410C					
18	2093B					
18	66B					
18	1995					
18	1848					
18	1506A					
18	571					
18	48005					
18	48015					
18	48029					
18	48039					

		Liquid Waste Transfer				
COG #	Permit Number	Sludge Total	Grease Total	Grit Total	Septage Total	Tons Total
19	40103	-	-	-	-	-
19	40238	-	-	-	-	-
19	954					
19	2286					
19	1693B					
19	783A					
20	40027	-	-	-	-	-
20	40002	-	-	-	-	-
20	40228	-	-	-	-	-
20	40270	-	-	-	-	-
20	2319	-	-	-	-	-
20	379					
20	1481					
20	262C					
20	235B					
20	2267					
20	2269					
20	2349					
21	2334	-	-	-	-	-
21	2375	-	-	-	-	-
21	40248	-	-	-	-	-
21	42015	-	-	-	-	-
21	748	-	-	-	-	-
21	2343	-	-	-	-	-
21	2346	-	-	-	-	-
21	1273A					
21	2302					
21	2348					
21	1727A					
21	956B					
21	48038					
22	1030	-	-	-	-	-
22	1136	-	-	-	-	-
22	2290					
22	523B					
23	2368	-	-	-	-	-
23	40209	-	-	-	-	-
23	40234	-	-	-	-	-
23	42035	-	-	-	-	-
23	40145	-	-	-	-	-
23	42017	-	-	-	-	-
23	42040	-	-	-	-	-
23	40004	-	-	-	-	-

		Liquid Waste Transfer				
COG #	**Permit Number**	**Sludge Total**	**Grease Total**	**Grit Total**	**Septage Total**	**Tons Total**
23	40160	-	-	-	-	-
23	692A					
23	1866					
24	40057	-	-	-	-	-
24	40170	-	-	-	-	-
24	40178	-	-	-	-	-
24	40251	-	-	-	-	-
24	40034	-	-	-	-	-
24	2225					
24	2354					
24	1918					
24	2316					
24	1725					
24	207A					
24	2303					
24	1308A					
Subtotal		**6**	**6,876**	**1,183**	**1,724**	**43,422**

		Landfill Specific Data				
COG #	**Permit Number**	**Muncipal Total**	**Brush Total**	**Construction Demo Total**	**Medical Waste Total**	**Sludge Total**
1	40271	N/A	N/A	N/A	N/A	N/A
1	40192	N/A	N/A	N/A	N/A	N/A
1	43030	N/A	N/A	N/A	N/A	N/A
1	40026	N/A	N/A	N/A	N/A	N/A
1	40015	N/A	N/A	N/A	N/A	N/A
1	40031	N/A	N/A	N/A	N/A	N/A
1	40263	N/A	N/A	N/A	N/A	N/A
1	76A	N/A	N/A	N/A	N/A	N/A
1	40109	N/A	N/A	N/A	N/A	N/A
1	414	1,503	645	-	-	-
1	1164	2,555	-	-	-	-
1	445A	4,787	-	293	-	-
1	2263	2,480	-	317	-	-
1	955	3,231	223	246	-	-
1	1038A	7,511	3,710	-	-	595
1	215A	3,051	237	102	-	-
1	570	799	35	15	-	-
1	2238	50,851	-	-	-	2,290
1	589A	-	-	1,496	-	-
1	2266	7,088	-	-	-	-
1	2352	4,574	-	-	-	10
1	1943	1,584	-	-	-	23
1	2279	13,138	1,116	-	2	764
1	2285	2,082	-	4,635	-	-
1	876A	6,907	-	-	-	-
1	791	-	-	500	-	-
1	73A	238,360	-	-	-	-
1	1663B	68,399	-	25,556	817	327
1	1009A	5,742	179	-	-	-
1	2281	1,997	-	-	-	-
2	40051	N/A	N/A	N/A	N/A	N/A
2	2231	N/A	N/A	N/A	N/A	N/A
2	40176	N/A	N/A	N/A	N/A	N/A
2	40279	N/A	N/A	N/A	N/A	N/A
2	564	-	-	2,637	-	-
2	2291	7,267	-	-	-	-
2	2268	22	-	67	-	-
2	9017	-	-	267	-	-
2	2207	4,348	-	2,111	-	-
2	2227	3,206	22	1,332	-	-
2	2157	17,775	-	7,224	-	3,326
2	1733	-	-	153	-	-
2	2369	7,314	-	3,468	-	-

		Landfill Specific Data				
COG #	**Permit Number**	**Muncipal Total**	**Brush Total**	**Construction Demo Total**	**Medical Waste Total**	**Sludge Total**
2	1298	-	-	353	-	-
2	2274	5,822	-	1,294	-	-
2	363A	71	-	-	-	-
2	583A	5,500	-	1,832	-	-
2	69	-	2,080	19,218	-	-
2	2252	270,193	639	1,727	-	14,119
2	2323	-	-	110,282	-	-
2	2328A	7,300	-	2,962	-	-
2	549A	2,591	-	-	-	-
2	2170	9,055	-	4,736	-	-
2	2293	7,298	-	4,104	-	-
2	2217	6,436	183	2,899	-	-
3	40144	N/A	N/A	N/A	N/A	N/A
3	2295	N/A	N/A	N/A	N/A	N/A
3	1429	N/A	N/A	N/A	N/A	N/A
3	2229A	N/A	N/A	N/A	N/A	N/A
3	40059	N/A	N/A	N/A	N/A	N/A
3	9001A	-	-	400	-	-
3	1428A	136,911	-	-	-	-
3	1571A	106,206	-	33,910	-	3,575
4	1494	N/A	N/A	N/A	N/A	N/A
4	40284	N/A	N/A	N/A	N/A	N/A
4	2045A	N/A	N/A	N/A	N/A	N/A
4	53A	N/A	N/A	N/A	N/A	N/A
4	12	N/A	N/A	N/A	N/A	N/A
4	60	N/A	N/A	N/A	N/A	N/A
4	227	N/A	N/A	N/A	N/A	N/A
4	1145	N/A	N/A	N/A	N/A	N/A
4	1263	N/A	N/A	N/A	N/A	N/A
4	1421	N/A	N/A	N/A	N/A	N/A
4	1453	N/A	N/A	N/A	N/A	N/A
4	40196	N/A	N/A	N/A	N/A	N/A
4	40265	N/A	N/A	N/A	N/A	N/A
4	2069A	N/A	N/A	N/A	N/A	N/A
4	40080	N/A	N/A	N/A	N/A	N/A
4	40168	N/A	N/A	N/A	N/A	N/A
4	40181	N/A	N/A	N/A	N/A	N/A
4	2275	N/A	N/A	N/A	N/A	N/A
4	2306	N/A	N/A	N/A	N/A	N/A
4	2379	N/A	N/A	N/A	N/A	N/A
4	40052	N/A	N/A	N/A	N/A	N/A
4	40186	N/A	N/A	N/A	N/A	N/A
4	1225D	N/A	N/A	N/A	N/A	N/A

		Landfill Specific Data				
COG #	**Permit Number**	**Muncipal Total**	**Brush Total**	**Construction Demo Total**	**Medical Waste Total**	**Sludge Total**
4	2256A	N/A	N/A	N/A	N/A	N/A
4	40241	N/A	N/A	N/A	N/A	N/A
4	2294	671,678	10,723	190,067	-	135,420
4	62	1,578,024	1,032	229,335	-	18,498
4	1394B	198,848	1,271	-	-	-
4	1895A	408,994	42,236	38,383	-	34,463
4	996C	220,204	-	2,307	-	-
4	1025B	1,017,571	-	422,781	-	31,186
4	1312B	144,023	-	52,326	416	32,670
4	1590A	218,994	-	30,864	-	16,196
4	1749B	-	-	270,958	-	-
4	1209B	-	-	-	-	-
4	1745B	78,557	28	10,585	7,596	2,731
4	42D	903,486	-	150,763	-	65,566
4	664	-	-	12,635	-	-
4	1195A	88,795	81	13,205	-	5,915
4	534	-	-	-	-	729
4	1417B	422,088	-	1,428	-	23,956
4	2190	100,923	48	374	-	276
4	47A	140,763	1,375	43,268	-	11,903
4	1983C	-	-	367,477	-	-
4	218C	379,556	-	70,710	575	2,753
4	358B	876,122	-	42,830	-	21,173
4	48012	N/A	N/A	N/A	N/A	N/A
4	48016	N/A	N/A	N/A	N/A	N/A
4	48018	N/A	N/A	N/A	N/A	N/A
4	48027	N/A	N/A	N/A	N/A	N/A
4	48028	N/A	N/A	N/A	N/A	N/A
4	48032	N/A	N/A	N/A	N/A	N/A
4	48033	N/A	N/A	N/A	N/A	N/A
4	48042	N/A	N/A	N/A	N/A	N/A
4	1025B	N/A	N/A	N/A	N/A	N/A
5	2382	N/A	N/A	N/A	N/A	N/A
5	576C	100,848	-	14,068	-	841
5	2358	164,626	314	19,765	-	1,616
5	797B	43,837	-	2,315	-	5,293
6	2389	N/A	N/A	N/A	N/A	N/A
6	40005	N/A	N/A	N/A	N/A	N/A
6	40006	N/A	N/A	N/A	N/A	N/A
6	40040	N/A	N/A	N/A	N/A	N/A
6	40174	N/A	N/A	N/A	N/A	N/A
6	2365	N/A	N/A	N/A	N/A	N/A
6	40172	N/A	N/A	N/A	N/A	N/A

		Landfill Specific Data				
COG #	Permit Number	Muncipal Total	Brush Total	Construction Demo Total	Medical Waste Total	Sludge Total
6	40267	N/A	N/A	N/A	N/A	N/A
6	356	N/A	N/A	N/A	N/A	N/A
6	40266	N/A	N/A	N/A	N/A	N/A
6	40102	N/A	N/A	N/A	N/A	N/A
6	1614A	78,612	-	2,887	11	2,543
6	1327B	123,678	-	14,462	723	4,271
6	1249B	134,423	762	-	-	6,641
6	1972A	134,233	2,270	58,363	-	15,283
6	48026	N/A	N/A	N/A	N/A	N/A
6	48041	N/A	N/A	N/A	N/A	N/A
7	1562A	59,109	-	25,370	-	3,678
7	1302	-	-	34	-	-
7	9009	-	-	18	-	-
7	1604B	5,543	2,143	2,376	-	869
7	2325	24,833	-	46,633	-	-
7	1469A	152,044	-	39,833	-	1,319
7	9004	-	-	1,220	-	-
7	420A	9,636	9	522	-	-
7	50B	-	1,746	2,529	-	-
7	9013	-	-	400	-	-
7	1463B	27,280	-	10,859	-	1,324
7	9000A	-	-	6,452	-	-
8	728	N/A	N/A	N/A	N/A	N/A
8	2355	N/A	N/A	N/A	N/A	N/A
8	40237	N/A	N/A	N/A	N/A	N/A
8	40261	N/A	N/A	N/A	N/A	N/A
8	40262	N/A	N/A	N/A	N/A	N/A
8	1276	444	-	-	-	5
8	2197	7,296	139	7,286	-	-
8	1422	0	0	-	-	-
8	2284	394,461	718	69,106	-	-
8	729B	2	-	-	-	-
8	495	1,005	-	220	-	-
8	957A	4,853	-	408	-	-
8	1737A	5,219	257	-	-	-
9	2373	N/A	N/A	N/A	N/A	N/A
9	43028	N/A	N/A	N/A	N/A	N/A
9	171	6,962	-	4,681	-	-
9	427	3,412	70	210	-	-
9	517A	9,372	-	4,865	-	-
9	2158	203,339	-	61,683	-	15,378
9	39	6,862	393	5,701	-	135
9	2154	770	-	-	-	-

		Landfill Specific Data				
COG #	**Permit Number**	**Muncipal Total**	**Brush Total**	**Construction Demo Total**	**Medical Waste Total**	**Sludge Total**
9	288A	37,132	-	-	-	3,102
9	2189	6,039	195	260	-	-
9	1605B	137,666	-	105,822	-	343
9	976	8,425	1,797	2,910	-	1,324
9	2120	8,462	1	4,285	-	-
9	673	-	-	143	-	-
9	566	-	937	323	-	10
9	691	-	-	180	-	-
9	772	7,188	231	5,342	-	61
10	2357	N/A	N/A	N/A	N/A	N/A
10	2359	N/A	N/A	N/A	N/A	N/A
10	42022	N/A	N/A	N/A	N/A	N/A
10	26B	-	-	1,200	-	-
10	195	2,318	-	-	-	-
10	1732	6,467	941	2,824	-	162
10	1404	-	-	37	-	-
10	86B	3,310	17	907	-	61
10	349	-	-	1,053	-	-
10	2264	3,579	-	-	-	-
10	79	139,808	2,723	27,999	-	549
11	241D	32,162	-	7,423	-	6,493
11	1558A	21,704	-	4,598	-	361
11	1646A	38,660	226	15,118	-	384
11	948A	229,944	-	46,958	-	-
11	48020	N/A	N/A	N/A	N/A	N/A
12	2260A	N/A	N/A	N/A	N/A	N/A
12	2300	N/A	N/A	N/A	N/A	N/A
12	40035	N/A	N/A	N/A	N/A	N/A
12	1787	N/A	N/A	N/A	N/A	N/A
12	119	N/A	N/A	N/A	N/A	N/A
12	2250	N/A	N/A	N/A	N/A	N/A
12	2310	N/A	N/A	N/A	N/A	N/A
12	2384	N/A	N/A	N/A	N/A	N/A
12	40212	N/A	N/A	N/A	N/A	N/A
12	40243	N/A	N/A	N/A	N/A	N/A
12	42016	N/A	N/A	N/A	N/A	N/A
12	466A	N/A	N/A	N/A	N/A	N/A
12	2123	846,060	-	15	-	458
12	1841A	-	-	190,435	-	-
12	249D	715,248	-	250,625	-	2,069
12	1405B	280,974	4,681	121,122	-	7,919
12	48019	N/A	N/A	N/A	N/A	N/A
13	42003	N/A	N/A	N/A	N/A	N/A

		Landfill Specific Data				
COG #	Permit Number	Muncipal Total	Brush Total	Construction Demo Total	Medical Waste Total	Sludge Total
13	43026	N/A	N/A	N/A	N/A	N/A
13	2381	N/A	N/A	N/A	N/A	N/A
13	40018	N/A	N/A	N/A	N/A	N/A
13	40173	N/A	N/A	N/A	N/A	N/A
13	2292	337,629	12,625	25,625	-	13,119
14	40033	N/A	N/A	N/A	N/A	N/A
14	40044	N/A	N/A	N/A	N/A	N/A
14	43007	N/A	N/A	N/A	N/A	N/A
14	40277	N/A	N/A	N/A	N/A	N/A
14	40054	N/A	N/A	N/A	N/A	N/A
14	40024	N/A	N/A	N/A	N/A	N/A
14	40013	N/A	N/A	N/A	N/A	N/A
14	40038	N/A	N/A	N/A	N/A	N/A
14	2105A	86,077	283	10,932	-	1,776
14	720	69,378	-	-	-	3,379
14	2242A	142,770	-	950	-	21,700
14	1384A	107,508	-	16,085	-	2,719
15	40164	N/A	N/A	N/A	N/A	N/A
15	40225	N/A	N/A	N/A	N/A	N/A
15	40268	N/A	N/A	N/A	N/A	N/A
15	43000	N/A	N/A	N/A	N/A	N/A
15	2214A	50,716	-	1,200	-	-
15	2027	107,476	-	4,459	-	48,812
15	1486B	160,634	-	66,843	-	6,732
15	1815A	91,992	2,082	8,659	2,303	5,696
16	40191	N/A	N/A	N/A	N/A	N/A
16	2235	N/A	N/A	N/A	N/A	N/A
16	2239A	N/A	N/A	N/A	N/A	N/A
16	40282	N/A	N/A	N/A	N/A	N/A
16	40053	N/A	N/A	N/A	N/A	N/A
16	40264	N/A	N/A	N/A	N/A	N/A
16	164	N/A	N/A	N/A	N/A	N/A
16	2232A	N/A	N/A	N/A	N/A	N/A
16	1471	N/A	N/A	N/A	N/A	N/A
16	1578	N/A	N/A	N/A	N/A	N/A
16	1697	N/A	N/A	N/A	N/A	N/A
16	2298	N/A	N/A	N/A	N/A	N/A
16	2350	N/A	N/A	N/A	N/A	N/A
16	2370	N/A	N/A	N/A	N/A	N/A
16	2386	N/A	N/A	N/A	N/A	N/A
16	40098	N/A	N/A	N/A	N/A	N/A
16	40131	N/A	N/A	N/A	N/A	N/A
16	40132	N/A	N/A	N/A	N/A	N/A

		Landfill Specific Data				
COG #	Permit Number	Muncipal Total	Brush Total	Construction Demo Total	Medical Waste Total	Sludge Total
16	40133	N/A	N/A	N/A	N/A	N/A
16	40189	N/A	N/A	N/A	N/A	N/A
16	40211	N/A	N/A	N/A	N/A	N/A
16	40217	N/A	N/A	N/A	N/A	N/A
16	40236	N/A	N/A	N/A	N/A	N/A
16	40249	N/A	N/A	N/A	N/A	N/A
16	40250	N/A	N/A	N/A	N/A	N/A
16	40273	N/A	N/A	N/A	N/A	N/A
16	40275	N/A	N/A	N/A	N/A	N/A
16	40283	N/A	N/A	N/A	N/A	N/A
16	43034	N/A	N/A	N/A	N/A	N/A
16	1355A	N/A	N/A	N/A	N/A	N/A
16	1483A	N/A	N/A	N/A	N/A	N/A
16	2234D	N/A	N/A	N/A	N/A	N/A
16	2241A	N/A	N/A	N/A	N/A	N/A
16	40028	N/A	N/A	N/A	N/A	N/A
16	2222	N/A	N/A	N/A	N/A	N/A
16	2309	N/A	N/A	N/A	N/A	N/A
16	42037	N/A	N/A	N/A	N/A	N/A
16	2387	N/A	N/A	N/A	N/A	N/A
16	40014	N/A	N/A	N/A	N/A	N/A
16	2318	N/A	N/A	N/A	N/A	N/A
16	1708	-	-	48,519	-	-
16	1539A	585,252	-	14,020	-	-
16	1502A	12,327	1,048	11,092	-	1,620
16	1535B	202,990	-	3,490	-	19,810
16	203A	39,149	-	4,471	-	4,916
16	2270	997,983	131	3,316	-	36,168
16	1505A	949,043	-	53,630	519	105,819
16	1797A	-	-	307,236	-	-
16	1149B	329,331	-	45,157	144	5,874
16	1721A	333,035	-	5,280	-	35,400
16	1849B	-	-	20	-	-
16	1193	-	-	24	-	-
16	1301	-	-	56,929	-	-
16	1403	-	4,857	92,290	-	-
16	2185	-	-	16	-	-
16	2304	-	-	343,464	-	-
16	2344	-	4,931	298,555	-	-
16	1307D	1,015,850	-	70,920	-	42,550
16	1540A	-	-	101,900	-	-
16	1565B	-	-	176,600	-	-
16	1586A	-	-	151,362	-	-

		Landfill Specific Data				
COG #	Permit Number	Muncipal Total	Brush Total	Construction Demo Total	Medical Waste Total	Sludge Total
16	1599A	-	-	124,622	-	-
16	1921A	-	-	16	-	-
16	2240B	-	-	106,970	-	-
16	261B	600,736	9,724	140,197	9,613	204,440
16	2324	-	-	8,857	-	-
16	1752B	227,720	-	128,200	-	460
16	1777	N/A	N/A	N/A	N/A	N/A
16	48006	N/A	N/A	N/A	N/A	N/A
16	48008	N/A	N/A	N/A	N/A	N/A
16	48009	N/A	N/A	N/A	N/A	N/A
16	48025	N/A	N/A	N/A	N/A	N/A
16	48034	N/A	N/A	N/A	N/A	N/A
16	48035	N/A	N/A	N/A	N/A	N/A
17	40017	N/A	N/A	N/A	N/A	N/A
17	2181	N/A	N/A	N/A	N/A	N/A
17	40011	N/A	N/A	N/A	N/A	N/A
17	2330	N/A	N/A	N/A	N/A	N/A
17	2366	N/A	N/A	N/A	N/A	N/A
17	42034	N/A	N/A	N/A	N/A	N/A
17	1522A	124,740	-	64	-	751
17	48036	N/A	N/A	N/A	N/A	N/A
18	1443	N/A	N/A	N/A	N/A	N/A
18	2248	N/A	N/A	N/A	N/A	N/A
18	2317	N/A	N/A	N/A	N/A	N/A
18	40085	N/A	N/A	N/A	N/A	N/A
18	40157	N/A	N/A	N/A	N/A	N/A
18	40280	N/A	N/A	N/A	N/A	N/A
18	42032	N/A	N/A	N/A	N/A	N/A
18	40244	N/A	N/A	N/A	N/A	N/A
18	40240	N/A	N/A	N/A	N/A	N/A
18	42028	N/A	N/A	N/A	N/A	N/A
18	43011	N/A	N/A	N/A	N/A	N/A
18	1410C	567,386	18,880	50,168	6,165	11,695
18	2093B	707,847	3,689	215,110	-	3,904
18	66B	212,348	-	82,384	-	14,006
18	1995	32,357	-	-	-	1,780
18	1848	-	-	395,123	-	-
18	1506A	5	3,303	-	-	4,492
18	571	500	-	-	-	-
18	48005	N/A	N/A	N/A	N/A	N/A
18	48015	N/A	N/A	N/A	N/A	N/A
18	48029	N/A	N/A	N/A	N/A	N/A
18	48039	N/A	N/A	N/A	N/A	N/A

		Landfill Specific Data				
COG #	Permit Number	Muncipal Total	Brush Total	Construction Demo Total	Medical Waste Total	Sludge Total
19	40103	N/A	N/A	N/A	N/A	N/A
19	40238	N/A	N/A	N/A	N/A	N/A
19	954	3,411	-	-	-	189
19	2286	29,983	160	257	-	5,572
19	1693B	277,042	3,038	58,488	-	31,162
19	783A	2,161	-	-	-	-
20	40027	N/A	N/A	N/A	N/A	N/A
20	40002	N/A	N/A	N/A	N/A	N/A
20	40228	N/A	N/A	N/A	N/A	N/A
20	40270	N/A	N/A	N/A	N/A	N/A
20	2319	N/A	N/A	N/A	N/A	N/A
20	379	-	-	336	-	-
20	1481	-	3,666	294	-	-
20	262C	22,185	2,066	1,575	-	-
20	235B	24,048	-	6,374	-	708
20	2267	61,202	3,014	8,311	-	5,639
20	2269	338,720	10,121	93,034	-	34,458
20	2349	-	17,464	45,630	-	-
21	2334	N/A	N/A	N/A	N/A	N/A
21	2375	N/A	N/A	N/A	N/A	N/A
21	40248	N/A	N/A	N/A	N/A	N/A
21	42015	N/A	N/A	N/A	N/A	N/A
21	748	N/A	N/A	N/A	N/A	N/A
21	2343	N/A	N/A	N/A	N/A	N/A
21	2346	N/A	N/A	N/A	N/A	N/A
21	1273A	238,456	33,215	18,792	1,015	10,047
21	2302	-	53,195	69,933	-	-
21	2348	226,603	18,783	3,967	1,787	5,175
21	1727A	3,258	100	4,571	-	-
21	956B	476,632	4,633	4,121	-	7,429
21	48038	N/A	N/A	N/A	N/A	N/A
22	1030	N/A	N/A	N/A	N/A	N/A
22	1136	N/A	N/A	N/A	N/A	N/A
22	2290	150,372	-	-	-	1,137
22	523B	36,896	4,030	17,294	-	1,347
23	2368	N/A	N/A	N/A	N/A	N/A
23	40209	N/A	N/A	N/A	N/A	N/A
23	40234	N/A	N/A	N/A	N/A	N/A
23	42035	N/A	N/A	N/A	N/A	N/A
23	40145	N/A	N/A	N/A	N/A	N/A
23	42017	N/A	N/A	N/A	N/A	N/A
23	42040	N/A	N/A	N/A	N/A	N/A
23	40004	N/A	N/A	N/A	N/A	N/A

		Landfill Specific Data				
COG #	Permit Number	Muncipal Total	Brush Total	Construction Demo Total	Medical Waste Total	Sludge Total
23	40160	N/A	N/A	N/A	N/A	N/A
23	692A	284,113	-	81,556	1,791	12,476
23	1866	17,786	-	32	-	-
24	40057	N/A	N/A	N/A	N/A	N/A
24	40170	N/A	N/A	N/A	N/A	N/A
24	40178	N/A	N/A	N/A	N/A	N/A
24	40251	N/A	N/A	N/A	N/A	N/A
24	40034	N/A	N/A	N/A	N/A	N/A
24	2225	4,463	1,037	1,555	-	12
24	2354	394	-	-	-	-
24	1918	-	312	4,148	-	-
24	2316	46,335	-	-	-	-
24	1725	19,340	57	-	-	2,170
24	207A	37,891	-	11,356	-	249
24	2303	3,337	215	-	-	-
24	1308A	3,903	-	-	-	-
Subtotal		**23,101,736**	**303,093**	**6,982,658**	**33,477**	**1,226,348**

		Landfill Specific Data				
COG #	Permit Number	Grease Trap Total	Septag Total	Incinerator Ash Total	Tons Total	Tons Disposed Total
1	40271	N/A	N/A	N/A	N/A	N/A
1	40192	N/A	N/A	N/A	N/A	N/A
1	43030	N/A	N/A	N/A	N/A	N/A
1	40026	N/A	N/A	N/A	N/A	N/A
1	40015	N/A	N/A	N/A	N/A	N/A
1	40031	N/A	N/A	N/A	N/A	N/A
1	40263	N/A	N/A	N/A	N/A	N/A
1	76A	N/A	N/A	N/A	N/A	N/A
1	40109	N/A	N/A	N/A	N/A	N/A
1	414	-	-	-	2,148	2,148
1	1164	-	-	-	2,555	2,555
1	445A	-	-	-	5,079	5,079
1	2263	-	-	-	2,805	2,805
1	955	-	-	-	3,707	3,707
1	1038A	-	-	-	11,816	11,816
1	215A	-	-	-	3,390	3,390
1	570	-	-	-	849	849
1	2238	-	-	-	53,166	53,166
1	589A	-	-	-	1,496	1,496
1	2266	-	-	-	7,088	7,088
1	2352	-	-	-	4,585	4,585
1	1943	-	-	-	1,607	1,607
1	2279	-	-	-	15,022	15,022
1	2285	-	-	-	6,717	6,717
1	876A	-	-	-	6,907	6,907
1	791	-	-	-	500	500
1	73A	-	-	-	238,360	238,360
1	1663B	-	-	-	166,044	173,954
1	1009A	-	-	-	5,921	5,921
1	2281	-	-	-	3,728	3,728
2	40051	N/A	N/A	N/A	N/A	N/A
2	2231	N/A	N/A	N/A	N/A	N/A
2	40176	N/A	N/A	N/A	N/A	N/A
2	40279	N/A	N/A	N/A	N/A	N/A
2	564	-	-	-	2,637	2,637
2	2291	-	-	-	7,267	7,267
2	2268	-	-	-	89	89
2	9017	-	-	-	267	267
2	2207	-	-	-	6,459	6,459
2	2227	-	-	-	4,560	4,560
2	2157	-	-	-	28,451	28,451
2	1733	-	-	-	153	153
2	2369	-	-	-	10,781	10,781

		Landfill Specific Data				
COG #	Permit Number	Grease Trap Total	Septag Total	Incinerator Ash Total	Tons Total	Tons Disposed Total
2	1298	-	-	-	353	353
2	2274	-	-	-	7,117	7,117
2	363A	-	-	-	71	71
2	583A	-	-	-	7,332	7,332
2	69	-	-	-	21,418	21,418
2	2252	-	-	-	291,127	291,127
2	2323	-	-	-	110,324	110,324
2	2328A	-	-	-	10,262	10,262
2	549A	-	-	-	2,591	2,591
2	2170	-	-	-	13,797	13,797
2	2293	-	-	-	11,402	11,402
2	2217	-	-	-	9,518	9,518
3	40144	N/A	N/A	N/A	N/A	N/A
3	2295	N/A	N/A	N/A	N/A	N/A
3	1429	N/A	N/A	N/A	N/A	N/A
3	2229A	N/A	N/A	N/A	N/A	N/A
3	40059	N/A	N/A	N/A	N/A	N/A
3	9001A	-	-	-	400	400
3	1428A	-	-	-	136,911	136,911
3	1571A	-	-	-	172,109	172,109
4	1494	N/A	N/A	N/A	N/A	N/A
4	40284	N/A	N/A	N/A	N/A	N/A
4	2045A	N/A	N/A	N/A	N/A	N/A
4	53A	N/A	N/A	N/A	N/A	N/A
4	12	N/A	N/A	N/A	N/A	N/A
4	60	N/A	N/A	N/A	N/A	N/A
4	227	N/A	N/A	N/A	N/A	N/A
4	1145	N/A	N/A	N/A	N/A	N/A
4	1263	N/A	N/A	N/A	N/A	N/A
4	1421	N/A	N/A	N/A	N/A	N/A
4	1453	N/A	N/A	N/A	N/A	N/A
4	40196	N/A	N/A	N/A	N/A	N/A
4	40265	N/A	N/A	N/A	N/A	N/A
4	2069A	N/A	N/A	N/A	N/A	N/A
4	40080	N/A	N/A	N/A	N/A	N/A
4	40168	N/A	N/A	N/A	N/A	N/A
4	40181	N/A	N/A	N/A	N/A	N/A
4	2275	N/A	N/A	N/A	N/A	N/A
4	2306	N/A	N/A	N/A	N/A	N/A
4	2379	N/A	N/A	N/A	N/A	N/A
4	40052	N/A	N/A	N/A	N/A	N/A
4	40186	N/A	N/A	N/A	N/A	N/A
4	1225D	N/A	N/A	N/A	N/A	N/A

		Landfill Specific Data				
COG #	**Permit Number**	**Grease Trap Total**	**Septag Total**	**Incinerator Ash Total**	**Tons Total**	**Tons Disposed Total**
4	2256A	N/A	N/A	N/A	N/A	N/A
4	40241	N/A	N/A	N/A	N/A	N/A
4	2294	-	-	-	1,008,033	1,008,033
4	62	-	-	-	1,887,251	1,887,251
4	1394B	-	-	-	200,119	200,119
4	1895A	-	-	-	524,195	524,195
4	996C	-	-	-	222,822	222,822
4	1025B	-	-	-	1,580,060	1,580,118
4	1312B	-	-	-	354,845	354,845
4	1590A	-	-	-	268,000	268,000
4	1749B	-	-	-	270,958	270,958
4	1209B	-	-	-	25	25
4	1745B	-	-	-	177,334	177,334
4	42D	-	-	-	1,234,791	1,234,826
4	664	-	-	-	12,635	12,635
4	1195A	-	-	-	127,320	127,320
4	534	-	-	-	729	729
4	1417B	-	-	-	591,211	601,692
4	2190	-	-	-	102,860	102,860
4	47A	-	-	-	198,594	198,594
4	1983C	-	-	-	367,477	367,477
4	218C	-	-	-	557,081	557,081
4	358B	-	-	-	997,520	997,520
4	48012	N/A	N/A	N/A	N/A	N/A
4	48016	N/A	N/A	N/A	N/A	N/A
4	48018	N/A	N/A	N/A	N/A	N/A
4	48027	N/A	N/A	N/A	N/A	N/A
4	48028	N/A	N/A	N/A	N/A	N/A
4	48032	N/A	N/A	N/A	N/A	N/A
4	48033	N/A	N/A	N/A	N/A	N/A
4	48042	N/A	N/A	N/A	N/A	N/A
4	1025B	N/A	N/A	N/A	N/A	N/A
5	2382	N/A	N/A	N/A	N/A	N/A
5	576C	-	-	-	134,476	134,476
5	2358	-	-	-	214,681	214,681
5	797B	-	-	-	71,141	94,043
6	2389	N/A	N/A	N/A	N/A	N/A
6	40005	N/A	N/A	N/A	N/A	N/A
6	40006	N/A	N/A	N/A	N/A	N/A
6	40040	N/A	N/A	N/A	N/A	N/A
6	40174	N/A	N/A	N/A	N/A	N/A
6	2365	N/A	N/A	N/A	N/A	N/A
6	40172	N/A	N/A	N/A	N/A	N/A

		Landfill Specific Data				
COG #	Permit Number	Grease Trap Total	Septag Total	Incinerator Ash Total	Tons Total	Tons Disposed Total
6	40267	N/A	N/A	N/A	N/A	N/A
6	356	N/A	N/A	N/A	N/A	N/A
6	40266	N/A	N/A	N/A	N/A	N/A
6	40102	N/A	N/A	N/A	N/A	N/A
6	1614A	-	-	3,491	87,688	87,688
6	1327B	-	-	-	196,941	196,941
6	1249B	-	-	-	154,812	154,812
6	1972A	-	-	-	214,095	214,095
6	48026	N/A	N/A	N/A	N/A	N/A
6	48041	N/A	N/A	N/A	N/A	N/A
7	1562A	-	-	-	98,290	98,290
7	1302	-	-	-	34	34
7	9009	-	-	-	18	18
7	1604B	-	-	-	11,009	11,009
7	2325	-	1,294	-	116,338	123,690
7	1469A	117	-	-	214,042	273,956
7	9004	-	-	-	1,220	1,220
7	420A	-	-	-	10,218	10,218
7	50B	-	-	-	4,275	4,275
7	9013	-	-	-	400	400
7	1463B	333	-	-	40,183	40,183
7	9000A	-	-	-	6,452	6,452
8	728	N/A	N/A	N/A	N/A	N/A
8	2355	N/A	N/A	N/A	N/A	N/A
8	40237	N/A	N/A	N/A	N/A	N/A
8	40261	N/A	N/A	N/A	N/A	N/A
8	40262	N/A	N/A	N/A	N/A	N/A
8	1276	-	-	-	449	449
8	2197	-	-	-	14,721	14,721
8	1422	-	-	-	1	1
8	2284	-	-	-	474,043	474,043
8	729B	-	-	-	2	2
8	495	-	-	-	1,225	1,225
8	957A	-	-	-	5,261	5,261
8	1737A	-	-	-	5,542	5,542
9	2373	N/A	N/A	N/A	N/A	N/A
9	43028	N/A	N/A	N/A	N/A	N/A
9	171	-	-	-	11,644	11,644
9	427	-	-	-	3,712	3,712
9	517A	-	-	-	14,238	14,238
9	2158	275	-	-	316,294	321,794
9	39	-	-	-	13,231	13,231
9	2154	-	-	-	770	770

		Landfill Specific Data				
COG #	Permit Number	Grease Trap Total	Septag Total	Incinerator Ash Total	Tons Total	Tons Disposed Total
9	288A	-	-	-	40,257	40,257
9	2189	-	-	-	6,494	6,494
9	1605B	247	-	-	244,158	244,158
9	976	383	628	-	15,482	15,482
9	2120	-	-	-	19,855	19,855
9	673	-	-	-	143	143
9	566	20	-	-	1,291	1,291
9	691	-	-	-	180	180
9	772	-	-	-	12,938	12,938
10	2357	N/A	N/A	N/A	N/A	N/A
10	2359	N/A	N/A	N/A	N/A	N/A
10	42022	N/A	N/A	N/A	N/A	N/A
10	26B	-	-	-	1,200	1,200
10	195	-	-	-	2,318	2,318
10	1732	-	-	-	10,395	10,395
10	1404	-	-	-	37	37
10	86B	-	-	-	4,296	4,296
10	349	-	-	-	1,053	1,053
10	2264	-	-	-	3,579	3,579
10	79	821	-	-	182,781	182,781
11	241D	-	-	14	222,383	275,703
11	1558A	-	-	-	31,581	31,581
11	1646A	-	-	-	85,876	85,876
11	948A	-	-	-	278,638	278,638
11	48020	N/A	N/A	N/A	N/A	N/A
12	2260A	N/A	N/A	N/A	N/A	N/A
12	2300	N/A	N/A	N/A	N/A	N/A
12	40035	N/A	N/A	N/A	N/A	N/A
12	1787	N/A	N/A	N/A	N/A	N/A
12	119	N/A	N/A	N/A	N/A	N/A
12	2250	N/A	N/A	N/A	N/A	N/A
12	2310	N/A	N/A	N/A	N/A	N/A
12	2384	N/A	N/A	N/A	N/A	N/A
12	40212	N/A	N/A	N/A	N/A	N/A
12	40243	N/A	N/A	N/A	N/A	N/A
12	42016	N/A	N/A	N/A	N/A	N/A
12	466A	N/A	N/A	N/A	N/A	N/A
12	2123	-	-	-	848,106	848,106
12	1841A	-	-	-	190,435	190,435
12	249D	-	-	-	999,836	999,836
12	1405B	-	-	-	418,944	418,944
12	48019	N/A	N/A	N/A	N/A	N/A
13	42003	N/A	N/A	N/A	N/A	N/A

		Landfill Specific Data				
COG #	Permit Number	Grease Trap Total	Septag Total	Incinerator Ash Total	Tons Total	Tons Disposed Total
13	43026	N/A	N/A	N/A	N/A	N/A
13	2381	N/A	N/A	N/A	N/A	N/A
13	40018	N/A	N/A	N/A	N/A	N/A
13	40173	N/A	N/A	N/A	N/A	N/A
13	2292	576	-	3	392,956	392,956
14	40033	N/A	N/A	N/A	N/A	N/A
14	40044	N/A	N/A	N/A	N/A	N/A
14	43007	N/A	N/A	N/A	N/A	N/A
14	40277	N/A	N/A	N/A	N/A	N/A
14	40054	N/A	N/A	N/A	N/A	N/A
14	40024	N/A	N/A	N/A	N/A	N/A
14	40013	N/A	N/A	N/A	N/A	N/A
14	40038	N/A	N/A	N/A	N/A	N/A
14	2105A	-	-	-	99,510	99,510
14	720	-	-	-	72,840	72,840
14	2242A	-	-	-	211,240	232,710
14	1384A	-	-	-	129,477	129,477
15	40164	N/A	N/A	N/A	N/A	N/A
15	40225	N/A	N/A	N/A	N/A	N/A
15	40268	N/A	N/A	N/A	N/A	N/A
15	43000	N/A	N/A	N/A	N/A	N/A
15	2214A	-	-	-	53,710	53,710
15	2027	-	-	-	217,729	255,622
15	1486B	-	-	-	256,143	256,143
15	1815A	-	-	-	129,225	129,225
16	40191	N/A	N/A	N/A	N/A	N/A
16	2235	N/A	N/A	N/A	N/A	N/A
16	2239A	N/A	N/A	N/A	N/A	N/A
16	40282	N/A	N/A	N/A	N/A	N/A
16	40053	N/A	N/A	N/A	N/A	N/A
16	40264	N/A	N/A	N/A	N/A	N/A
16	164	N/A	N/A	N/A	N/A	N/A
16	2232A	N/A	N/A	N/A	N/A	N/A
16	1471	N/A	N/A	N/A	N/A	N/A
16	1578	N/A	N/A	N/A	N/A	N/A
16	1697	N/A	N/A	N/A	N/A	N/A
16	2298	N/A	N/A	N/A	N/A	N/A
16	2350	N/A	N/A	N/A	N/A	N/A
16	2370	N/A	N/A	N/A	N/A	N/A
16	2386	N/A	N/A	N/A	N/A	N/A
16	40098	N/A	N/A	N/A	N/A	N/A
16	40131	N/A	N/A	N/A	N/A	N/A
16	40132	N/A	N/A	N/A	N/A	N/A

		Landfill Specific Data				
COG #	Permit Number	Grease Trap Total	Septag Total	Incinerator Ash Total	Tons Total	Tons Disposed Total
16	40133	N/A	N/A	N/A	N/A	N/A
16	40189	N/A	N/A	N/A	N/A	N/A
16	40211	N/A	N/A	N/A	N/A	N/A
16	40217	N/A	N/A	N/A	N/A	N/A
16	40236	N/A	N/A	N/A	N/A	N/A
16	40249	N/A	N/A	N/A	N/A	N/A
16	40250	N/A	N/A	N/A	N/A	N/A
16	40273	N/A	N/A	N/A	N/A	N/A
16	40275	N/A	N/A	N/A	N/A	N/A
16	40283	N/A	N/A	N/A	N/A	N/A
16	43034	N/A	N/A	N/A	N/A	N/A
16	1355A	N/A	N/A	N/A	N/A	N/A
16	1483A	N/A	N/A	N/A	N/A	N/A
16	2234D	N/A	N/A	N/A	N/A	N/A
16	2241A	N/A	N/A	N/A	N/A	N/A
16	40028	N/A	N/A	N/A	N/A	N/A
16	2222	N/A	N/A	N/A	N/A	N/A
16	2309	N/A	N/A	N/A	N/A	N/A
16	42037	N/A	N/A	N/A	N/A	N/A
16	2387	N/A	N/A	N/A	N/A	N/A
16	40014	N/A	N/A	N/A	N/A	N/A
16	2318	N/A	N/A	N/A	N/A	N/A
16	1708	-	-	-	48,519	48,519
16	1539A	-	-	-	620,588	686,618
16	1502A	-	-	-	26,091	26,091
16	1535B	-	-	-	315,000	315,000
16	203A	-	-	-	48,629	48,629
16	2270	-	-	-	1,072,674	1,080,773
16	1505A	-	-	-	1,128,204	1,244,016
16	1797A	-	-	-	307,236	307,236
16	1149B	-	-	-	393,882	393,882
16	1721A	-	-	-	424,845	521,025
16	1849B	-	-	-	20	20
16	1193	-	-	-	24	24
16	1301	-	-	-	56,929	56,929
16	1403	-	-	-	97,147	97,147
16	2185	-	-	-	16	16
16	2304	-	-	-	344,369	344,369
16	2344	-	-	-	303,486	303,486
16	1307D	-	-	-	1,209,440	1,209,440
16	1540A	-	-	-	101,900	101,900
16	1565B	-	-	-	176,600	176,600
16	1586A	-	-	-	155,381	155,381

		Landfill Specific Data				
COG #	**Permit Number**	**Grease Trap Total**	**Septag Total**	**Incinerator Ash Total**	**Tons Total**	**Tons Disposed Total**
16	1599A	-	-	-	124,622	124,622
16	1921A	-	-	-	16	16
16	2240B	-	-	-	127,157	127,157
16	261B	2,784	-	143	1,364,814	1,364,814
16	2324	-	-	-	8,857	8,857
16	1752B	-	-	-	364,400	364,400
16	1777	N/A	N/A	N/A	N/A	N/A
16	48006	N/A	N/A	N/A	N/A	N/A
16	48008	N/A	N/A	N/A	N/A	N/A
16	48009	N/A	N/A	N/A	N/A	N/A
16	48025	N/A	N/A	N/A	N/A	N/A
16	48034	N/A	N/A	N/A	N/A	N/A
16	48035	N/A	N/A	N/A	N/A	N/A
17	40017	N/A	N/A	N/A	N/A	N/A
17	2181	N/A	N/A	N/A	N/A	N/A
17	40011	N/A	N/A	N/A	N/A	N/A
17	2330	N/A	N/A	N/A	N/A	N/A
17	2366	N/A	N/A	N/A	N/A	N/A
17	42034	N/A	N/A	N/A	N/A	N/A
17	1522A	-	-	-	152,074	152,074
17	48036	N/A	N/A	N/A	N/A	N/A
18	1443	N/A	N/A	N/A	N/A	N/A
18	2248	N/A	N/A	N/A	N/A	N/A
18	2317	N/A	N/A	N/A	N/A	N/A
18	40085	N/A	N/A	N/A	N/A	N/A
18	40157	N/A	N/A	N/A	N/A	N/A
18	40280	N/A	N/A	N/A	N/A	N/A
18	42032	N/A	N/A	N/A	N/A	N/A
18	40244	N/A	N/A	N/A	N/A	N/A
18	40240	N/A	N/A	N/A	N/A	N/A
18	42028	N/A	N/A	N/A	N/A	N/A
18	43011	N/A	N/A	N/A	N/A	N/A
18	1410C	68	61,049	-	871,237	939,912
18	2093B	-	-	-	1,058,107	1,063,232
18	66B	-	-	-	452,245	452,245
18	1995	375	-	-	34,614	34,614
18	1848	-	-	-	395,123	395,123
18	1506A	-	-	-	9,078	9,078
18	571	-	-	-	500	500
18	48005	N/A	N/A	N/A	N/A	N/A
18	48015	N/A	N/A	N/A	N/A	N/A
18	48029	N/A	N/A	N/A	N/A	N/A
18	48039	N/A	N/A	N/A	N/A	N/A

		Landfill Specific Data				
COG #	Permit Number	Grease Trap Total	Septag Total	Incinerator Ash Total	Tons Total	Tons Disposed Total
19	40103	N/A	N/A	N/A	N/A	N/A
19	40238	N/A	N/A	N/A	N/A	N/A
19	954	-	-	-	3,600	3,600
19	2286	70	-	-	40,070	41,048
19	1693B	-	-	-	377,655	377,655
19	783A	-	-	-	2,161	2,161
20	40027	N/A	N/A	N/A	N/A	N/A
20	40002	N/A	N/A	N/A	N/A	N/A
20	40228	N/A	N/A	N/A	N/A	N/A
20	40270	N/A	N/A	N/A	N/A	N/A
20	2319	N/A	N/A	N/A	N/A	N/A
20	379	-	-	-	336	336
20	1481	-	-	-	3,960	3,960
20	262C	-	-	-	25,881	25,881
20	235B	-	-	269	31,444	31,444
20	2267	-	-	-	153,451	153,451
20	2269	-	-	-	476,850	476,850
20	2349	-	-	-	63,094	63,094
21	2334	N/A	N/A	N/A	N/A	N/A
21	2375	N/A	N/A	N/A	N/A	N/A
21	40248	N/A	N/A	N/A	N/A	N/A
21	42015	N/A	N/A	N/A	N/A	N/A
21	748	N/A	N/A	N/A	N/A	N/A
21	2343	N/A	N/A	N/A	N/A	N/A
21	2346	N/A	N/A	N/A	N/A	N/A
21	1273A	-	-	-	317,655	317,655
21	2302	-	-	-	123,136	123,136
21	2348	3,339	771	-	290,314	291,619
21	1727A	-	-	-	8,179	8,179
21	956B	-	-	1,143	494,515	494,515
21	48038	N/A	N/A	N/A	N/A	N/A
22	1030	N/A	N/A	N/A	N/A	N/A
22	1136	N/A	N/A	N/A	N/A	N/A
22	2290	-	-	-	151,683	151,683
22	523B	-	-	-	62,617	62,617
23	2368	N/A	N/A	N/A	N/A	N/A
23	40209	N/A	N/A	N/A	N/A	N/A
23	40234	N/A	N/A	N/A	N/A	N/A
23	42035	N/A	N/A	N/A	N/A	N/A
23	40145	N/A	N/A	N/A	N/A	N/A
23	42017	N/A	N/A	N/A	N/A	N/A
23	42040	N/A	N/A	N/A	N/A	N/A
23	40004	N/A	N/A	N/A	N/A	N/A

		Landfill Specific Data				
COG #	**Permit Number**	**Grease Trap Total**	**Septag Total**	**Incinerator Ash Total**	**Tons Total**	**Tons Disposed Total**
23	40160	N/A	N/A	N/A	N/A	N/A
23	692A	-	-	-	433,986	433,986
23	1866	16	-	-	19,501	19,501
24	40057	N/A	N/A	N/A	N/A	N/A
24	40170	N/A	N/A	N/A	N/A	N/A
24	40178	N/A	N/A	N/A	N/A	N/A
24	40251	N/A	N/A	N/A	N/A	N/A
24	40034	N/A	N/A	N/A	N/A	N/A
24	2225	-	-	-	7,067	7,067
24	2354	-	-	-	394	394
24	1918	-	-	-	4,460	4,460
24	2316	-	-	-	46,335	46,335
24	1725	-	-	-	21,605	21,605
24	207A	-	-	-	51,764	51,764
24	2303	-	-	-	3,552	3,552
24	1308A	-	-	-	3,903	3,903
Subtotal		**9,424**	**63,743**	**5,063**	**34,718,269**	**35,307,308**

		Landfill Specific Data			
COG #	**Permit Number**	**Estimated Compaction Rate (lbs/yd3)**	**Current FY's Remaining Capacity (yd3)**	**FY's Remaining Capacity (Tons)**	**Remaining Years at Current Performance (years)**
1	40271	N/A	N/A	N/A	N/A
1	40192	N/A	N/A	N/A	N/A
1	43030	N/A	N/A	N/A	N/A
1	40026	N/A	N/A	N/A	N/A
1	40015	N/A	N/A	N/A	N/A
1	40031	N/A	N/A	N/A	N/A
1	40263	N/A	N/A	N/A	N/A
1	76A	N/A	N/A	N/A	N/A
1	40109	N/A	N/A	N/A	N/A
1	414	500	206,237	51,559	23
1	1164	550	451,852	124,259	49
1	445A	750	1,136,908	426,341	84
1	2263	800	2,349,474	939,790	119
1	955	800	466,453	186,581	50
1	1038A	785	1,190,829	467,401	40
1	215A	850	265,199	112,710	33
1	570	800	541,697	216,679	12
1	2238	1,300	8,410,464	5,466,802	102
1	589A	1,000	443,624	221,812	148
1	2266	800	912,514	365,006	51
1	2352	1,000	798,194	399,097	2
1	1943	850	431,269	183,289	52
1	2279	1,000	8,125,276	4,062,638	113
1	2285	800	224,877	89,951	3
1	876A	890	1,313,343	584,438	86
1	791	400	121,200	24,240	44
1	73A	800	64,165,864	25,666,346	108
1	1663B	1,553	2,368,290	1,838,977	9
1	1009A	850	732,439	311,287	47
1	2281	800	265,275	106,110	28
2	40051	N/A	N/A	N/A	N/A
2	2231	N/A	N/A	N/A	N/A
2	40176	N/A	N/A	N/A	N/A
2	40279	N/A	N/A	N/A	N/A
2	564	800	146,571	58,628	10
2	2291	800	413,014	165,206	22
2	2268	400	803,903	160,781	97
2	9017	400	32,000	6,720	N/A
2	2207	830	806,251	334,594	62
2	2227	650	112,621	36,602	7
2	2157	964	9,865,334	4,755,091	167
2	1733	850	221,683	94,215	80
2	2369	588	4,766,600	1,401,380	130

		Landfill Specific Data			
COG #	Permit Number	Estimated Compaction Rate (lbs/yd3)	Current FY's Remaining Capacity (yd3)	FY's Remaining Capacity (Tons)	Remaining Years at Current Performance (years)
2	1298	1,400	279,446	195,612	10
2	2274	1,400	1,236,312	865,418	94
2	363A	400	49,648	9,930	140
2	583A	666	782,566	260,594	31
2	69	731	466,447	170,486	8
2	2252	1,370	105,205,861	72,066,015	248
2	2323	666	2,278,213	758,645	28
2	2328A	850	814,622	346,214	49
2	549A	968	470,749	227,843	88
2	2170	1,087	4,337,554	2,357,461	171
2	2293	800	1,038,187	415,275	22
2	2217	800	1,876,036	750,414	79
3	40144	N/A	N/A	N/A	N/A
3	2295	N/A	N/A	N/A	N/A
3	1429	N/A	N/A	N/A	N/A
3	2229A	N/A	N/A	N/A	N/A
3	40059	N/A	N/A	N/A	N/A
3	9001A	400	7,957	1,671	N/A
3	1428A	1,040	68,275,169	35,503,088	260
3	1571A	1,200	26,992,460	16,195,476	90
4	1494	N/A	N/A	N/A	N/A
4	40284	N/A	N/A	N/A	N/A
4	2045A	N/A	N/A	N/A	N/A
4	53A	N/A	N/A	N/A	N/A
4	12	N/A	N/A	N/A	N/A
4	60	N/A	N/A	N/A	N/A
4	227	N/A	N/A	N/A	N/A
4	1145	N/A	N/A	N/A	N/A
4	1263	N/A	N/A	N/A	N/A
4	1421	N/A	N/A	N/A	N/A
4	1453	N/A	N/A	N/A	N/A
4	40196	N/A	N/A	N/A	N/A
4	40265	N/A	N/A	N/A	N/A
4	2069A	N/A	N/A	N/A	N/A
4	40080	N/A	N/A	N/A	N/A
4	40168	N/A	N/A	N/A	N/A
4	40181	N/A	N/A	N/A	N/A
4	2275	N/A	N/A	N/A	N/A
4	2306	N/A	N/A	N/A	N/A
4	2379	N/A	N/A	N/A	N/A
4	40052	N/A	N/A	N/A	N/A
4	40186	N/A	N/A	N/A	N/A
4	1225D	N/A	N/A	N/A	N/A

		Landfill Specific Data			
COG #	Permit Number	Estimated Compaction Rate (lbs/yd3)	Current FY's Remaining Capacity (yd3)	FY's Remaining Capacity (Tons)	Remaining Years at Current Performance (years)
4	2256A	N/A	N/A	N/A	N/A
4	40241	N/A	N/A	N/A	N/A
4	2294	1,572	118,151,738	92,867,266	92
4	62	1,600	80,696,563	64,557,250	32
4	1394B	1,413	13,098,243	9,253,909	46
4	1895A	1,441	30,888,671	22,255,287	45
4	996C	1,040	11,174,696	5,810,842	26
4	1025B	1,740	7,334,679	6,381,171	4
4	1312B	1,366	35,153,198	24,009,634	68
4	1590A	1,099	9,332,996	5,128,481	18
4	1749B	1,698	20,416,139	17,333,302	60
4	1209B	1,110	30,963,997	17,185,018	100
4	1745B	1,931	39,263,961	37,909,354	171
4	42D	1,440	44,781,880	32,242,954	28
4	664	1,200	821,606	492,964	64
4	1195A	1,258	5,298,819	3,332,957	23
4	534	1,000	17,839	8,920	12
4	1417B	1,457	6,930,739	5,049,043	9
4	2190	1,139	22,931,244	13,059,343	133
4	47A	1,310	830,321	543,860	3
4	1983C	984	8,101,265	3,985,822	11
4	218C	1,417	23,266,971	16,484,649	30
4	358B	1,524	49,384,553	37,631,029	33
4	48012	N/A	N/A	N/A	N/A
4	48016	N/A	N/A	N/A	N/A
4	48018	N/A	N/A	N/A	N/A
4	48027	N/A	N/A	N/A	N/A
4	48028	N/A	N/A	N/A	N/A
4	48032	N/A	N/A	N/A	N/A
4	48033	N/A	N/A	N/A	N/A
4	48042	N/A	N/A	N/A	N/A
4	1025B	N/A	N/A	N/A	N/A
5	2382	N/A	N/A	N/A	N/A
5	576C	1,180	10,717,156	6,323,122	47
5	2358	1,097	75,354,221	41,331,790	193
5	797B	1,903	19,558,208	18,609,635	168
6	2389	N/A	N/A	N/A	N/A
6	40005	N/A	N/A	N/A	N/A
6	40006	N/A	N/A	N/A	N/A
6	40040	N/A	N/A	N/A	N/A
6	40174	N/A	N/A	N/A	N/A
6	2365	N/A	N/A	N/A	N/A
6	40172	N/A	N/A	N/A	N/A

		Landfill Specific Data			
COG #	Permit Number	Estimated Compaction Rate (lbs/yd3)	Current FY's Remaining Capacity (yd3)	FY's Remaining Capacity (Tons)	Remaining Years at Current Performance (years)
6	40267	N/A	N/A	N/A	N/A
6	356	N/A	N/A	N/A	N/A
6	40266	N/A	N/A	N/A	N/A
6	40102	N/A	N/A	N/A	N/A
6	1614A	1,814	2,184,382	1,981,234	25
6	1327B	1,972	16,266,964	16,039,227	75
6	1249B	1,200	9,206,780	5,524,068	38
6	1972A	1,624	105,022,427	85,278,211	338
6	48026	N/A	N/A	N/A	N/A
6	48041	N/A	N/A	N/A	N/A
7	1562A	1,100	17,345,030	9,539,767	97
7	1302	500	12,851	3,213	32
7	9009	400	103,155	21,663	-
7	1604B	700	710,586	248,705	8
7	2325	1,600	18,424,602	14,739,682	68
7	1469A	1,399	88,346,821	61,798,601	226
7	9004	400	354,185	74,379	N/A
7	420A	700	191,692	67,092	5
7	50B	400	113,841	22,768	1
7	9013	400	44,065	9,254	N/A
7	1463B	1,000	10,134,544	5,067,272	126
7	9000A	400	177,933	37,366	N/A
8	728	N/A	N/A	N/A	N/A
8	2355	N/A	N/A	N/A	N/A
8	40237	N/A	N/A	N/A	N/A
8	40261	N/A	N/A	N/A	N/A
8	40262	N/A	N/A	N/A	N/A
8	1276	750	95,285	35,732	7
8	2197	329	2,971,358	488,788	39
8	1422	80	59,252	2,370	39
8	2284	1,200	17,632,437	10,579,462	20
8	729B	1,300	63,469,313	41,255,053	39
8	495	850	190,857	81,114	18
8	957A	850	1,258,799	534,990	60
8	1737A	400	586,762	117,352	20
9	2373	N/A	N/A	N/A	N/A
9	43028	N/A	N/A	N/A	N/A
9	171	855	874,934	374,034	32
9	427	700	324,039	113,414	31
9	517A	847	1,405,106	595,062	42
9	2158	1,194	30,950,803	18,477,629	57
9	39	700	1,532,499	536,375	49
9	2154	250	35,389	4,424	6

		Landfill Specific Data			
COG #	Permit Number	Estimated Compaction Rate (lbs/yd3)	Current FY's Remaining Capacity (yd3)	FY's Remaining Capacity (Tons)	Remaining Years at Current Performance (years)
9	288A	1,190	278,242	165,554	4
9	2189	1,000	515,487	257,743	40
9	1605B	989	32,286,490	15,965,669	65
9	976	800	148,130	59,252	5
9	2120	850	679,406	288,747	23
9	673	300	17,747	2,662	37
9	566	750	1,213,875	455,203	5
9	691	400	57,983	11,597	28
9	772	850	914,832	388,803	30
10	2357	N/A	N/A	N/A	N/A
10	2359	N/A	N/A	N/A	N/A
10	42022	N/A	N/A	N/A	N/A
10	26B	1,000	594,308	297,154	200
10	195	1,000	62,068	31,034	2
10	1732	900	2,130,690	958,811	39
10	1404	381	11,692	2,227	37
10	86B	795	109	43	82
10	349	1,500	548,821	411,616	195
10	2264	1,500	1,321,355	991,016	76
10	79	1,311	3,524,460	2,310,284	13
11	241D	1,378	47,636,242	32,821,371	101
11	1558A	1,040	7,618,747	3,961,748	107
11	1646A	1,400	874,598	612,219	7
11	948A	963	4,003,805	1,927,832	7
11	48020	N/A	N/A	N/A	N/A
12	2260A	N/A	N/A	N/A	N/A
12	2300	N/A	N/A	N/A	N/A
12	40035	N/A	N/A	N/A	N/A
12	1787	N/A	N/A	N/A	N/A
12	119	N/A	N/A	N/A	N/A
12	2250	N/A	N/A	N/A	N/A
12	2310	N/A	N/A	N/A	N/A
12	2384	N/A	N/A	N/A	N/A
12	40212	N/A	N/A	N/A	N/A
12	40243	N/A	N/A	N/A	N/A
12	42016	N/A	N/A	N/A	N/A
12	466A	N/A	N/A	N/A	N/A
12	2123	1,360	20,365,129	13,848,288	16
12	1841A	1,200	2,042,605	1,225,563	6
12	249D	1,500	10,297,663	7,723,247	11
12	1405B	1,450	59,405,152	43,068,735	113
12	48019	N/A	N/A	N/A	N/A
13	42003	N/A	N/A	N/A	N/A

		Landfill Specific Data			
COG #	Permit Number	Estimated Compaction Rate (lbs/yd3)	Current FY's Remaining Capacity (yd3)	FY's Remaining Capacity (Tons)	Remaining Years at Current Performance (years)
13	43026	N/A	N/A	N/A	N/A
13	2381	N/A	N/A	N/A	N/A
13	40018	N/A	N/A	N/A	N/A
13	40173	N/A	N/A	N/A	N/A
13	2292	1,473	34,145,935	25,148,481	64
14	40033	N/A	N/A	N/A	N/A
14	40044	N/A	N/A	N/A	N/A
14	43007	N/A	N/A	N/A	N/A
14	40277	N/A	N/A	N/A	N/A
14	40054	N/A	N/A	N/A	N/A
14	40024	N/A	N/A	N/A	N/A
14	40013	N/A	N/A	N/A	N/A
14	40038	N/A	N/A	N/A	N/A
14	2105A	1,200	3,387,530	2,032,518	20
14	720	1,238	2,834,064	1,754,286	33
14	2242A	1,260	41,871,118	26,378,804	143
14	1384A	1,408	7,819,099	5,504,646	39
15	40164	N/A	N/A	N/A	N/A
15	40225	N/A	N/A	N/A	N/A
15	40268	N/A	N/A	N/A	N/A
15	43000	N/A	N/A	N/A	N/A
15	2214A	1,700	790,902	672,267	11
15	2027	1,600	7,362,522	5,890,018	25
15	1486B	1,384	17,821,748	12,332,650	48
15	1815A	1,489	15,202,649	11,318,372	88
16	40191	N/A	N/A	N/A	N/A
16	2235	N/A	N/A	N/A	N/A
16	2239A	N/A	N/A	N/A	N/A
16	40282	N/A	N/A	N/A	N/A
16	40053	N/A	N/A	N/A	N/A
16	40264	N/A	N/A	N/A	N/A
16	164	N/A	N/A	N/A	N/A
16	2232A	N/A	N/A	N/A	N/A
16	1471	N/A	N/A	N/A	N/A
16	1578	N/A	N/A	N/A	N/A
16	1697	N/A	N/A	N/A	N/A
16	2298	N/A	N/A	N/A	N/A
16	2350	N/A	N/A	N/A	N/A
16	2370	N/A	N/A	N/A	N/A
16	2386	N/A	N/A	N/A	N/A
16	40098	N/A	N/A	N/A	N/A
16	40131	N/A	N/A	N/A	N/A
16	40132	N/A	N/A	N/A	N/A

		Landfill Specific Data			
COG #	Permit Number	Estimated Compaction Rate (lbs/yd3)	Current FY's Remaining Capacity (yd3)	FY's Remaining Capacity (Tons)	Remaining Years at Current Performance (years)
16	40133	N/A	N/A	N/A	N/A
16	40189	N/A	N/A	N/A	N/A
16	40211	N/A	N/A	N/A	N/A
16	40217	N/A	N/A	N/A	N/A
16	40236	N/A	N/A	N/A	N/A
16	40249	N/A	N/A	N/A	N/A
16	40250	N/A	N/A	N/A	N/A
16	40273	N/A	N/A	N/A	N/A
16	40275	N/A	N/A	N/A	N/A
16	40283	N/A	N/A	N/A	N/A
16	43034	N/A	N/A	N/A	N/A
16	1355A	N/A	N/A	N/A	N/A
16	1483A	N/A	N/A	N/A	N/A
16	2234D	N/A	N/A	N/A	N/A
16	2241A	N/A	N/A	N/A	N/A
16	40028	N/A	N/A	N/A	N/A
16	2222	N/A	N/A	N/A	N/A
16	2309	N/A	N/A	N/A	N/A
16	42037	N/A	N/A	N/A	N/A
16	2387	N/A	N/A	N/A	N/A
16	40014	N/A	N/A	N/A	N/A
16	2318	N/A	N/A	N/A	N/A
16	1708	880	1,858,100	817,564	17
16	1539A	1,750	21,334,654	18,667,822	28
16	1502A	1,200	17,469,329	10,481,597	402
16	1535B	1,580	8,958,079	7,076,882	23
16	203A	1,200	368,471	221,083	5
16	2270	1,750	35,973,138	31,476,496	29
16	1505A	1,226	142,373,978	87,275,249	88
16	1797A	1,044	13,904,680	7,258,243	24
16	1149B	1,500	37,084,042	27,813,032	53
16	1721A	1,900	12,062,148	11,459,041	22
16	1849B	1,314	3,689,381	2,423,923	50
16	1193	2,000	10,902,299	10,902,299	10
16	1301	1,260	75,608	47,633	1
16	1403	900	1,220,007	549,003	6
16	2185	1,540	43,880	33,788	4
16	2304	1,500	1,758,447	1,318,835	3
16	2344	1,000	10,958,517	5,479,259	16
16	1307D	1,520	38,458,529	29,228,482	24
16	1540A	1,680	2,549,795	2,141,828	19
16	1565B	1,480	17,606,869	13,029,083	37
16	1586A	1,500	2,954,017	2,215,513	12

		Landfill Specific Data			
COG #	Permit Number	Estimated Compaction Rate (lbs/yd3)	Current FY's Remaining Capacity (yd3)	FY's Remaining Capacity (Tons)	Remaining Years at Current Performance (years)
16	1599A	1,500	5,484,837	4,113,628	21
16	1921A	1,400	63,027	44,119	4
16	2240B	1,500	1,456,546	1,092,410	4
16	261B	2,212	21,472,319	23,748,385	16
16	2324	1,000	40,585,362	20,292,681	50
16	1752B	1,480	12,635,661	9,350,389	24
16	1777	N/A	N/A	N/A	N/A
16	48006	N/A	N/A	N/A	N/A
16	48008	N/A	N/A	N/A	N/A
16	48009	N/A	N/A	N/A	N/A
16	48025	N/A	N/A	N/A	N/A
16	48034	N/A	N/A	N/A	N/A
16	48035	N/A	N/A	N/A	N/A
17	40017	N/A	N/A	N/A	N/A
17	2181	N/A	N/A	N/A	N/A
17	40011	N/A	N/A	N/A	N/A
17	2330	N/A	N/A	N/A	N/A
17	2366	N/A	N/A	N/A	N/A
17	42034	N/A	N/A	N/A	N/A
17	1522A	1,678	7,122,229	5,975,550	28
17	48036	N/A	N/A	N/A	N/A
18	1443	N/A	N/A	N/A	N/A
18	2248	N/A	N/A	N/A	N/A
18	2317	N/A	N/A	N/A	N/A
18	40085	N/A	N/A	N/A	N/A
18	40157	N/A	N/A	N/A	N/A
18	40280	N/A	N/A	N/A	N/A
18	42032	N/A	N/A	N/A	N/A
18	40244	N/A	N/A	N/A	N/A
18	40240	N/A	N/A	N/A	N/A
18	42028	N/A	N/A	N/A	N/A
18	43011	N/A	N/A	N/A	N/A
18	1410C	1,639	70,456,792	57,739,341	45
18	2093B	1,750	103,403,670	90,478,211	77
18	66B	1,750	10,929,112	9,562,973	17
18	1995	1,180	1,560,737	920,835	22
18	1848	1,300	4,301,661	2,796,080	14
18	1506A	1,009	675,827	340,955	13
18	571	750	7,336	2,751	6
18	48005	N/A	N/A	N/A	N/A
18	48015	N/A	N/A	N/A	N/A
18	48029	N/A	N/A	N/A	N/A
18	48039	N/A	N/A	N/A	N/A

		Landfill Specific Data			
COG #	Permit Number	Estimated Compaction Rate (lbs/yd3)	Current FY's Remaining Capacity (yd3)	FY's Remaining Capacity (Tons)	Remaining Years at Current Performance (years)
19	40103	N/A	N/A	N/A	N/A
19	40238	N/A	N/A	N/A	N/A
19	954	850	17,774	7,554	1
19	2286	1,060	87,938,053	46,607,168	99
19	1693B	1,296	6,981,036	4,523,711	12
19	783A	1,000	273,849	136,925	33
20	40027	N/A	N/A	N/A	N/A
20	40002	N/A	N/A	N/A	N/A
20	40228	N/A	N/A	N/A	N/A
20	40270	N/A	N/A	N/A	N/A
20	2319	N/A	N/A	N/A	N/A
20	379	400	291,917	58,383	27
20	1481	800	10,218	4,087	6
20	262C	1,200	689,843	413,906	16
20	235B	827	3,043,714	1,258,576	43
20	2267	1,924	14,449,609	13,900,524	70
20	2269	1,074	123,169,630	66,142,091	139
20	2349	750	10,988,381	4,120,643	57
21	2334	N/A	N/A	N/A	N/A
21	2375	N/A	N/A	N/A	N/A
21	40248	N/A	N/A	N/A	N/A
21	42015	N/A	N/A	N/A	N/A
21	748	N/A	N/A	N/A	N/A
21	2343	N/A	N/A	N/A	N/A
21	2346	N/A	N/A	N/A	N/A
21	1273A	1,508	27,641,110	20,841,397	49
21	2302	1,094	10,309,433	5,639,260	32
21	2348	1,480	109,129,915	80,756,137	214
21	1727A	1,000	20,500	10,250	1
21	956B	1,293	5,179,505	3,348,550	6
21	48038	N/A	N/A	N/A	N/A
22	1030	N/A	N/A	N/A	N/A
22	1136	N/A	N/A	N/A	N/A
22	2290	900	22,494,065	10,122,329	75
22	523B	920	11,229,803	5,165,709	72
23	2368	N/A	N/A	N/A	N/A
23	40209	N/A	N/A	N/A	N/A
23	40234	N/A	N/A	N/A	N/A
23	42035	N/A	N/A	N/A	N/A
23	40145	N/A	N/A	N/A	N/A
23	42017	N/A	N/A	N/A	N/A
23	42040	N/A	N/A	N/A	N/A
23	40004	N/A	N/A	N/A	N/A

		Landfill Specific Data			
COG #	**Permit Number**	**Estimated Compaction Rate (lbs/yd3)**	**Current FY's Remaining Capacity (yd3)**	**FY's Remaining Capacity (Tons)**	**Remaining Years at Current Performance (years)**
23	40160	N/A	N/A	N/A	N/A
23	692A	1,400	6,608,681	4,626,077	10
23	1866	1,100	2,654,556	1,460,006	29
24	40057	N/A	N/A	N/A	N/A
24	40170	N/A	N/A	N/A	N/A
24	40178	N/A	N/A	N/A	N/A
24	40251	N/A	N/A	N/A	N/A
24	40034	N/A	N/A	N/A	N/A
24	2225	600	1,554,316	466,295	58
24	2354	800	462,689	185,076	147
24	1918	750	1,119,282	419,731	18
24	2316	811	14,625,394	5,930,597	120
24	1725	1,000	198,527	99,264	8
24	207A	700	1,097,655	384,179	7
24	2303	550	120,329	33,090	20
24	1308A	850	1,410,215	599,341	30
Subtotal		**213,139**	**2,833,951,162**	**1,926,872,853**	**10,340**

		LGR Facility Information				
COG #	Permit Number	LF Authori-zation No. where facility is located	Estimated Annual Gas Processed (ft3)	Estimated Annual Gas Distributed Off-Site (ft3)	Power Generated and Sold this FY (kWh)	Power Generated and Used on Site (kWh)
1	40271	N/A	N/A	N/A	N/A	N/A
1	40192	N/A	N/A	N/A	N/A	N/A
1	43030	N/A	N/A	N/A	N/A	N/A
1	40026	N/A	N/A	N/A	N/A	N/A
1	40015	N/A	N/A	N/A	N/A	N/A
1	40031	N/A	N/A	N/A	N/A	N/A
1	40263	N/A	N/A	N/A	N/A	N/A
1	76A	N/A	N/A	N/A	N/A	N/A
1	40109	N/A	N/A	N/A	N/A	N/A
1	414	N/A	N/A	N/A	N/A	N/A
1	1164	N/A	N/A	N/A	N/A	N/A
1	445A	N/A	N/A	N/A	N/A	N/A
1	2263	N/A	N/A	N/A	N/A	N/A
1	955	N/A	N/A	N/A	N/A	N/A
1	1038A	N/A	N/A	N/A	N/A	N/A
1	215A	N/A	N/A	N/A	N/A	N/A
1	570	N/A	N/A	N/A	N/A	N/A
1	2238	N/A	N/A	N/A	N/A	N/A
1	589A	N/A	N/A	N/A	N/A	N/A
1	2266	N/A	N/A	N/A	N/A	N/A
1	2352	N/A	N/A	N/A	N/A	N/A
1	1943	N/A	N/A	N/A	N/A	N/A
1	2279	N/A	N/A	N/A	N/A	N/A
1	2285	N/A	N/A	N/A	N/A	N/A
1	876A	N/A	N/A	N/A	N/A	N/A
1	791	N/A	N/A	N/A	N/A	N/A
1	73A	N/A	N/A	N/A	N/A	N/A
1	1663B	N/A	N/A	N/A	N/A	N/A
1	1009A	N/A	N/A	N/A	N/A	N/A
1	2281	N/A	N/A	N/A	N/A	N/A
2	40051	N/A	N/A	N/A	N/A	N/A
2	2231	N/A	N/A	N/A	N/A	N/A
2	40176	N/A	N/A	N/A	N/A	N/A
2	40279	N/A	N/A	N/A	N/A	N/A
2	564	N/A	N/A	N/A	N/A	N/A
2	2291	N/A	N/A	N/A	N/A	N/A
2	2268	N/A	N/A	N/A	N/A	N/A
2	9017	N/A	N/A	N/A	N/A	N/A
2	2207	N/A	N/A	N/A	N/A	N/A

		LGR Facility Information				
COG #	Permit Number	LF Authori-zation No. where facility is located	Estimated Annual Gas Processed (ft3)	Estimated Annual Gas Distributed Off-Site (ft3)	Power Generated and Sold this FY (kWh)	Power Generated and Used on Site (kWh)
2	2227	N/A	N/A	N/A	N/A	N/A
2	2157	N/A	N/A	N/A	N/A	N/A
2	1733	N/A	N/A	N/A	N/A	N/A
2	2369	N/A	N/A	N/A	N/A	N/A
2	1298	N/A	N/A	N/A	N/A	N/A
2	2274	N/A	N/A	N/A	N/A	N/A
2	363A	N/A	N/A	N/A	N/A	N/A
2	583A	N/A	N/A	N/A	N/A	N/A
2	69	N/A	N/A	N/A	N/A	N/A
2	2252	N/A	N/A	N/A	N/A	N/A
2	2323	N/A	N/A	N/A	N/A	N/A
2	2328A	N/A	N/A	N/A	N/A	N/A
2	549A	N/A	N/A	N/A	N/A	N/A
2	2170	N/A	N/A	N/A	N/A	N/A
2	2293	N/A	N/A	N/A	N/A	N/A
2	2217	N/A	N/A	N/A	N/A	N/A
3	40144	N/A	N/A	N/A	N/A	N/A
3	2295	N/A	N/A	N/A	N/A	N/A
3	1429	N/A	N/A	N/A	N/A	N/A
3	2229A	N/A	N/A	N/A	N/A	N/A
3	40059	N/A	N/A	N/A	N/A	N/A
3	9001A	N/A	N/A	N/A	N/A	N/A
3	1428A	N/A	N/A	N/A	N/A	N/A
3	1571A	N/A	N/A	N/A	N/A	N/A
4	1494	N/A	N/A	N/A	N/A	N/A
4	40284	N/A	N/A	N/A	N/A	N/A
4	2045A	N/A	N/A	N/A	N/A	N/A
4	53A	N/A	N/A	N/A	N/A	N/A
4	12	N/A	N/A	N/A	N/A	N/A
4	60	N/A	N/A	N/A	N/A	N/A
4	227	N/A	N/A	N/A	N/A	N/A
4	1145	N/A	N/A	N/A	N/A	N/A
4	1263	N/A	N/A	N/A	N/A	N/A
4	1421	N/A	N/A	N/A	N/A	N/A
4	1453	N/A	N/A	N/A	N/A	N/A
4	40196	N/A	N/A	N/A	N/A	N/A
4	40265	N/A	N/A	N/A	N/A	N/A
4	2069A	N/A	N/A	N/A	N/A	N/A
4	40080	N/A	N/A	N/A	N/A	N/A

		LGR Facility Information				
COG #	Permit Number	LF Authori-zation No. where facility is located	Estimated Annual Gas Processed (ft3)	Estimated Annual Gas Distributed Off-Site (ft3)	Power Generated and Sold this FY (kWh)	Power Generated and Used on Site (kWh)
4	40168	N/A	N/A	N/A	N/A	N/A
4	40181	N/A	N/A	N/A	N/A	N/A
4	2275	N/A	N/A	N/A	N/A	N/A
4	2306	N/A	N/A	N/A	N/A	N/A
4	2379	N/A	N/A	N/A	N/A	N/A
4	40052	N/A	N/A	N/A	N/A	N/A
4	40186	N/A	N/A	N/A	N/A	N/A
4	1225D	N/A	N/A	N/A	N/A	N/A
4	2256A	N/A	N/A	N/A	N/A	N/A
4	40241	N/A	N/A	N/A	N/A	N/A
4	2294	N/A	N/A	N/A	N/A	N/A
4	62	N/A	N/A	N/A	N/A	N/A
4	1394B	N/A	N/A	N/A	N/A	N/A
4	1895A	N/A	N/A	N/A	N/A	N/A
4	996C	N/A	N/A	N/A	N/A	N/A
4	1025B	N/A	N/A	N/A	N/A	N/A
4	1312B	N/A	N/A	N/A	N/A	N/A
4	1590A	N/A	N/A	N/A	N/A	N/A
4	1749B	N/A	N/A	N/A	N/A	N/A
4	1209B	N/A	N/A	N/A	N/A	N/A
4	1745B	N/A	N/A	N/A	N/A	N/A
4	42D	N/A	N/A	N/A	N/A	N/A
4	664	N/A	N/A	N/A	N/A	N/A
4	1195A	N/A	N/A	N/A	N/A	N/A
4	534	N/A	N/A	N/A	N/A	N/A
4	1417B	N/A	N/A	N/A	N/A	N/A
4	2190	N/A	N/A	N/A	N/A	N/A
4	47A	N/A	N/A	N/A	N/A	N/A
4	1983C	N/A	N/A	N/A	N/A	N/A
4	218C	N/A	N/A	N/A	N/A	N/A
4	358B	N/A	N/A	N/A	N/A	N/A
4	48012	358B	615,873,000	615,873,000	-	-
4	48016	1590A	358,659,682	-	11,828,021	10,856
4	48018	42D	1,008,766,000	-	47,292,196	1,621,804
4	48027	1019A	772,077,000	-	35,330,906	1,681,213
4	48028	1312A	-	-	25,681,100	799,289
4	48032	1417B	51,049,000	92,816,363	-	-
4	48033	62	4,071,698,000	1,979,729,000	-	-
4	48042	2294	47,108,000	23,554,000	-	-

		LGR Facility Information				
COG #	Permit Number	LF Authori-zation No. where facility is located	Estimated Annual Gas Processed (ft3)	Estimated Annual Gas Distributed Off-Site (ft3)	Power Generated and Sold this FY (kWh)	Power Generated and Used on Site (kWh)
4	1025B	1025B	2,307,530,000	-	93,580,158	2,539,741
5	2382	N/A	N/A	N/A	N/A	N/A
5	576C	N/A	N/A	N/A	N/A	N/A
5	2358	N/A	N/A	N/A	N/A	N/A
5	797B	N/A	N/A	N/A	N/A	N/A
6	2389	N/A	N/A	N/A	N/A	N/A
6	40005	N/A	N/A	N/A	N/A	N/A
6	40006	N/A	N/A	N/A	N/A	N/A
6	40040	N/A	N/A	N/A	N/A	N/A
6	40174	N/A	N/A	N/A	N/A	N/A
6	2365	N/A	N/A	N/A	N/A	N/A
6	40172	N/A	N/A	N/A	N/A	N/A
6	40267	N/A	N/A	N/A	N/A	N/A
6	356	N/A	N/A	N/A	N/A	N/A
6	40266	N/A	N/A	N/A	N/A	N/A
6	40102	N/A	N/A	N/A	N/A	N/A
6	1614A	N/A	N/A	N/A	N/A	N/A
6	1327B	N/A	N/A	N/A	N/A	N/A
6	1249B	N/A	N/A	N/A	N/A	N/A
6	1972A	N/A	N/A	N/A	N/A	N/A
6	48026	1972A	325,734,000	592,243,636	-	-
6	48041	1327B	142,787,000	259,612,000	-	-
7	1562A	N/A	N/A	N/A	N/A	N/A
7	1302	N/A	N/A	N/A	N/A	N/A
7	9009	N/A	N/A	N/A	N/A	N/A
7	1604B	N/A	N/A	N/A	N/A	N/A
7	2325	N/A	N/A	N/A	N/A	N/A
7	1469A	N/A	N/A	N/A	N/A	N/A
7	9004	N/A	N/A	N/A	N/A	N/A
7	420A	N/A	N/A	N/A	N/A	N/A
7	50B	N/A	N/A	N/A	N/A	N/A
7	9013	N/A	N/A	N/A	N/A	N/A
7	1463B	N/A	N/A	N/A	N/A	N/A
7	9000A	N/A	N/A	N/A	N/A	N/A
8	728	N/A	N/A	N/A	N/A	N/A
8	2355	N/A	N/A	N/A	N/A	N/A
8	40237	N/A	N/A	N/A	N/A	N/A
8	40261	N/A	N/A	N/A	N/A	N/A
8	40262	N/A	N/A	N/A	N/A	N/A

		LGR Facility Information				
COG #	Permit Number	LF Authori-zation No. where facility is located	Estimated Annual Gas Processed (ft3)	Estimated Annual Gas Distributed Off-Site (ft3)	Power Generated and Sold this FY (kWh)	Power Generated and Used on Site (kWh)
8	1276	N/A	N/A	N/A	N/A	N/A
8	2197	N/A	N/A	N/A	N/A	N/A
8	1422	N/A	N/A	N/A	N/A	N/A
8	2284	N/A	N/A	N/A	N/A	N/A
8	729B	N/A	N/A	N/A	N/A	N/A
8	495	N/A	N/A	N/A	N/A	N/A
8	957A	N/A	N/A	N/A	N/A	N/A
8	1737A	N/A	N/A	N/A	N/A	N/A
9	2373	N/A	N/A	N/A	N/A	N/A
9	43028	N/A	N/A	N/A	N/A	N/A
9	171	N/A	N/A	N/A	N/A	N/A
9	427	N/A	N/A	N/A	N/A	N/A
9	517A	N/A	N/A	N/A	N/A	N/A
9	2158	N/A	N/A	N/A	N/A	N/A
9	39	N/A	N/A	N/A	N/A	N/A
9	2154	N/A	N/A	N/A	N/A	N/A
9	288A	N/A	N/A	N/A	N/A	N/A
9	2189	N/A	N/A	N/A	N/A	N/A
9	1605B	N/A	N/A	N/A	N/A	N/A
9	976	N/A	N/A	N/A	N/A	N/A
9	2120	N/A	N/A	N/A	N/A	N/A
9	673	N/A	N/A	N/A	N/A	N/A
9	566	N/A	N/A	N/A	N/A	N/A
9	691	N/A	N/A	N/A	N/A	N/A
9	772	N/A	N/A	N/A	N/A	N/A
10	2357	N/A	N/A	N/A	N/A	N/A
10	2359	N/A	N/A	N/A	N/A	N/A
10	42022	N/A	N/A	N/A	N/A	N/A
10	26B	N/A	N/A	N/A	N/A	N/A
10	195	N/A	N/A	N/A	N/A	N/A
10	1732	N/A	N/A	N/A	N/A	N/A
10	1404	N/A	N/A	N/A	N/A	N/A
10	86B	N/A	N/A	N/A	N/A	N/A
10	349	N/A	N/A	N/A	N/A	N/A
10	2264	N/A	N/A	N/A	N/A	N/A
10	79	N/A	N/A	N/A	N/A	N/A
11	241D	N/A	N/A	N/A	N/A	N/A
11	1558A	N/A	N/A	N/A	N/A	N/A
11	1646A	N/A	N/A	N/A	N/A	N/A

		LGR Facility Information				
COG #	Permit Number	LF Authorization No. where facility is located	Estimated Annual Gas Processed (ft3)	Estimated Annual Gas Distributed Off-Site (ft3)	Power Generated and Sold this FY (kWh)	Power Generated and Used on Site (kWh)
11	948A	N/A	N/A	N/A	N/A	N/A
11	48020	948A	176,830,510	-	-	-
12	2260A	N/A	N/A	N/A	N/A	N/A
12	2300	N/A	N/A	N/A	N/A	N/A
12	40035	N/A	N/A	N/A	N/A	N/A
12	1787	N/A	N/A	N/A	N/A	N/A
12	119	N/A	N/A	N/A	N/A	N/A
12	2250	N/A	N/A	N/A	N/A	N/A
12	2310	N/A	N/A	N/A	N/A	N/A
12	2384	N/A	N/A	N/A	N/A	N/A
12	40212	N/A	N/A	N/A	N/A	N/A
12	40243	N/A	N/A	N/A	N/A	N/A
12	42016	N/A	N/A	N/A	N/A	N/A
12	466A	N/A	N/A	N/A	N/A	N/A
12	2123	N/A	N/A	N/A	N/A	N/A
12	1841A	N/A	N/A	N/A	N/A	N/A
12	249D	N/A	N/A	N/A	N/A	N/A
12	1405B	N/A	N/A	N/A	N/A	N/A
12	48019	249D	1,399,677,000	-	42,300,149	2,185,851
13	42003	N/A	N/A	N/A	N/A	N/A
13	43026	N/A	N/A	N/A	N/A	N/A
13	2381	N/A	N/A	N/A	N/A	N/A
13	40018	N/A	N/A	N/A	N/A	N/A
13	40173	N/A	N/A	N/A	N/A	N/A
13	2292	N/A	N/A	N/A	N/A	N/A
14	40033	N/A	N/A	N/A	N/A	N/A
14	40044	N/A	N/A	N/A	N/A	N/A
14	43007	N/A	N/A	N/A	N/A	N/A
14	40277	N/A	N/A	N/A	N/A	N/A
14	40054	N/A	N/A	N/A	N/A	N/A
14	40024	N/A	N/A	N/A	N/A	N/A
14	40013	N/A	N/A	N/A	N/A	N/A
14	40038	N/A	N/A	N/A	N/A	N/A
14	2105A	N/A	N/A	N/A	N/A	N/A
14	720	N/A	N/A	N/A	N/A	N/A
14	2242A	N/A	N/A	N/A	N/A	N/A
14	1384A	N/A	N/A	N/A	N/A	N/A
15	40164	N/A	N/A	N/A	N/A	N/A
15	40225	N/A	N/A	N/A	N/A	N/A

		LGR Facility Information				
COG #	Permit Number	LF Authori-zation No. where facility is located	Estimated Annual Gas Processed (ft3)	Estimated Annual Gas Distributed Off-Site (ft3)	Power Generated and Sold this FY (kWh)	Power Generated and Used on Site (kWh)
15	40268	N/A	N/A	N/A	N/A	N/A
15	43000	N/A	N/A	N/A	N/A	N/A
15	2214A	N/A	N/A	N/A	N/A	N/A
15	2027	N/A	N/A	N/A	N/A	N/A
15	1486B	N/A	N/A	N/A	N/A	N/A
15	1815A	N/A	N/A	N/A	N/A	N/A
16	40191	N/A	N/A	N/A	N/A	N/A
16	2235	N/A	N/A	N/A	N/A	N/A
16	2239A	N/A	N/A	N/A	N/A	N/A
16	40282	N/A	N/A	N/A	N/A	N/A
16	40053	N/A	N/A	N/A	N/A	N/A
16	40264	N/A	N/A	N/A	N/A	N/A
16	164	N/A	N/A	N/A	N/A	N/A
16	2232A	N/A	N/A	N/A	N/A	N/A
16	1471	N/A	N/A	N/A	N/A	N/A
16	1578	N/A	N/A	N/A	N/A	N/A
16	1697	N/A	N/A	N/A	N/A	N/A
16	2298	N/A	N/A	N/A	N/A	N/A
16	2350	N/A	N/A	N/A	N/A	N/A
16	2370	N/A	N/A	N/A	N/A	N/A
16	2386	N/A	N/A	N/A	N/A	N/A
16	40098	N/A	N/A	N/A	N/A	N/A
16	40131	N/A	N/A	N/A	N/A	N/A
16	40132	N/A	N/A	N/A	N/A	N/A
16	40133	N/A	N/A	N/A	N/A	N/A
16	40189	N/A	N/A	N/A	N/A	N/A
16	40211	N/A	N/A	N/A	N/A	N/A
16	40217	N/A	N/A	N/A	N/A	N/A
16	40236	N/A	N/A	N/A	N/A	N/A
16	40249	N/A	N/A	N/A	N/A	N/A
16	40250	N/A	N/A	N/A	N/A	N/A
16	40273	N/A	N/A	N/A	N/A	N/A
16	40275	N/A	N/A	N/A	N/A	N/A
16	40283	N/A	N/A	N/A	N/A	N/A
16	43034	N/A	N/A	N/A	N/A	N/A
16	1355A	N/A	N/A	N/A	N/A	N/A
16	1483A	N/A	N/A	N/A	N/A	N/A
16	2234D	N/A	N/A	N/A	N/A	N/A
16	2241A	N/A	N/A	N/A	N/A	N/A

		LGR Facility Information				
COG #	Permit Number	LF Authori-zation No. where facility is located	Estimated Annual Gas Processed (ft3)	Estimated Annual Gas Distributed Off-Site (ft3)	Power Generated and Sold this FY (kWh)	Power Generated and Used on Site (kWh)
16	40028	N/A	N/A	N/A	N/A	N/A
16	2222	N/A	N/A	N/A	N/A	N/A
16	2309	N/A	N/A	N/A	N/A	N/A
16	42037	N/A	N/A	N/A	N/A	N/A
16	2387	N/A	N/A	N/A	N/A	N/A
16	40014	N/A	N/A	N/A	N/A	N/A
16	2318	N/A	N/A	N/A	N/A	N/A
16	1708	N/A	N/A	N/A	N/A	N/A
16	1539A	N/A	N/A	N/A	N/A	N/A
16	1502A	N/A	N/A	N/A	N/A	N/A
16	1535B	N/A	N/A	N/A	N/A	N/A
16	203A	N/A	N/A	N/A	N/A	N/A
16	2270	N/A	N/A	N/A	N/A	N/A
16	1505A	N/A	N/A	N/A	N/A	N/A
16	1797A	N/A	N/A	N/A	N/A	N/A
16	1149B	N/A	N/A	N/A	N/A	N/A
16	1721A	N/A	N/A	N/A	N/A	N/A
16	1849B	N/A	N/A	N/A	N/A	N/A
16	1193	N/A	N/A	N/A	N/A	N/A
16	1301	N/A	N/A	N/A	N/A	N/A
16	1403	N/A	N/A	N/A	N/A	N/A
16	2185	N/A	N/A	N/A	N/A	N/A
16	2304	N/A	N/A	N/A	N/A	N/A
16	2344	N/A	N/A	N/A	N/A	N/A
16	1307D	N/A	N/A	N/A	N/A	N/A
16	1540A	N/A	N/A	N/A	N/A	N/A
16	1565B	N/A	N/A	N/A	N/A	N/A
16	1586A	N/A	N/A	N/A	N/A	N/A
16	1599A	N/A	N/A	N/A	N/A	N/A
16	1921A	N/A	N/A	N/A	N/A	N/A
16	2240B	N/A	N/A	N/A	N/A	N/A
16	261B	N/A	N/A	N/A	N/A	N/A
16	2324	N/A	N/A	N/A	N/A	N/A
16	1752B	N/A	N/A	N/A	N/A	N/A
16	1777	261B	2,493,599,645	1,401,788,000	-	-
16	48006	1307D	-	-	48,309,403	49,704,800
16	48008	1752B	-	-	22,416,015	22,729,000
16	48009	1721A	-	-	25,086,768	26,771,500
16	48025	261B	1,045,319,110	1,045,319,110	-	-

		LGR Facility Information				
COG #	Permit Number	LF Authori-zation No. where facility is located	Estimated Annual Gas Processed (ft3)	Estimated Annual Gas Distributed Off-Site (ft3)	Power Generated and Sold this FY (kWh)	Power Generated and Used on Site (kWh)
16	48034	2270	410,628,825	225,845,900	-	-
16	48035	1505A	1,347,008,040	319,759,000	-	-
17	40017	N/A	N/A	N/A	N/A	N/A
17	2181	N/A	N/A	N/A	N/A	N/A
17	40011	N/A	N/A	N/A	N/A	N/A
17	2330	N/A	N/A	N/A	N/A	N/A
17	2366	N/A	N/A	N/A	N/A	N/A
17	42034	N/A	N/A	N/A	N/A	N/A
17	1522A	N/A	N/A	N/A	N/A	N/A
17	48036	1522A	301,200,016	301,200,016	-	-
18	1443	N/A	N/A	N/A	N/A	N/A
18	2248	N/A	N/A	N/A	N/A	N/A
18	2317	N/A	N/A	N/A	N/A	N/A
18	40085	N/A	N/A	N/A	N/A	N/A
18	40157	N/A	N/A	N/A	N/A	N/A
18	40280	N/A	N/A	N/A	N/A	N/A
18	42032	N/A	N/A	N/A	N/A	N/A
18	40244	N/A	N/A	N/A	N/A	N/A
18	40240	N/A	N/A	N/A	N/A	N/A
18	42028	N/A	N/A	N/A	N/A	N/A
18	43011	N/A	N/A	N/A	N/A	N/A
18	1410C	N/A	N/A	N/A	N/A	N/A
18	2093B	N/A	N/A	N/A	N/A	N/A
18	66B	N/A	N/A	N/A	N/A	N/A
18	1995	N/A	N/A	N/A	N/A	N/A
18	1848	N/A	N/A	N/A	N/A	N/A
18	1506A	N/A	N/A	N/A	N/A	N/A
18	571	N/A	N/A	N/A	N/A	N/A
18	48005	1410C	1,285,169,317	-	58,742,508	4,339,582
18	48015	2093B	1,561,475,418	-	59,072,437	4,181,593
18	48029	66B	2,353,480,900	-	23,367,114	661,558
18	48039	1237	610,687,000	-	19,247,891	15,574
19	40103	N/A	N/A	N/A	N/A	N/A
19	40238	N/A	N/A	N/A	N/A	N/A
19	954	N/A	N/A	N/A	N/A	N/A
19	2286	N/A	N/A	N/A	N/A	N/A
19	1693B	N/A	N/A	N/A	N/A	N/A
19	783A	N/A	N/A	N/A	N/A	N/A
20	40027	N/A	N/A	N/A	N/A	N/A

		LGR Facility Information				
COG #	Permit Number	LF Authorization No. where facility is located	Estimated Annual Gas Processed (ft3)	Estimated Annual Gas Distributed Off-Site (ft3)	Power Generated and Sold this FY (kWh)	Power Generated and Used on Site (kWh)
20	40002	N/A	N/A	N/A	N/A	N/A
20	40228	N/A	N/A	N/A	N/A	N/A
20	40270	N/A	N/A	N/A	N/A	N/A
20	2319	N/A	N/A	N/A	N/A	N/A
20	379	N/A	N/A	N/A	N/A	N/A
20	1481	N/A	N/A	N/A	N/A	N/A
20	262C	N/A	N/A	N/A	N/A	N/A
20	235B	N/A	N/A	N/A	N/A	N/A
20	2267	N/A	N/A	N/A	N/A	N/A
20	2269	N/A	N/A	N/A	N/A	N/A
20	2349	N/A	N/A	N/A	N/A	N/A
21	2334	N/A	N/A	N/A	N/A	N/A
21	2375	N/A	N/A	N/A	N/A	N/A
21	40248	N/A	N/A	N/A	N/A	N/A
21	42015	N/A	N/A	N/A	N/A	N/A
21	748	N/A	N/A	N/A	N/A	N/A
21	2343	N/A	N/A	N/A	N/A	N/A
21	2346	N/A	N/A	N/A	N/A	N/A
21	1273A	N/A	N/A	N/A	N/A	N/A
21	2302	N/A	N/A	N/A	N/A	N/A
21	2348	N/A	N/A	N/A	N/A	N/A
21	1727A	N/A	N/A	N/A	N/A	N/A
21	956B	N/A	N/A	N/A	N/A	N/A
21	48038	956B	459,646,000	835,720,000	-	-
22	1030	N/A	N/A	N/A	N/A	N/A
22	1136	N/A	N/A	N/A	N/A	N/A
22	2290	N/A	N/A	N/A	N/A	N/A
22	523B	N/A	N/A	N/A	N/A	N/A
23	2368	N/A	N/A	N/A	N/A	N/A
23	40209	N/A	N/A	N/A	N/A	N/A
23	40234	N/A	N/A	N/A	N/A	N/A
23	42035	N/A	N/A	N/A	N/A	N/A
23	40145	N/A	N/A	N/A	N/A	N/A
23	42017	N/A	N/A	N/A	N/A	N/A
23	42040	N/A	N/A	N/A	N/A	N/A
23	40004	N/A	N/A	N/A	N/A	N/A
23	40160	N/A	N/A	N/A	N/A	N/A
23	692A	N/A	N/A	N/A	N/A	N/A
23	1866	N/A	N/A	N/A	N/A	N/A

		LGR Facility Information				
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24	40057	N/A	N/A	N/A	N/A	N/A
24	40170	N/A	N/A	N/A	N/A	N/A
24	40178	N/A	N/A	N/A	N/A	N/A
24	40251	N/A	N/A	N/A	N/A	N/A
24	40034	N/A	N/A	N/A	N/A	N/A
24	2225	N/A	N/A	N/A	N/A	N/A
24	2354	N/A	N/A	N/A	N/A	N/A
24	1918	N/A	N/A	N/A	N/A	N/A
24	2316	N/A	N/A	N/A	N/A	N/A
24	1725	N/A	N/A	N/A	N/A	N/A
24	207A	N/A	N/A	N/A	N/A	N/A
24	2303	N/A	N/A	N/A	N/A	N/A
24	1308A	N/A	N/A	N/A	N/A	N/A
Subtotal		**5,863**	**23,146,003,463**	**7,693,460,025**	**512,254,666**	**117,242,361**