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Analysis of the Impact Upon State and Local Roads of Transporting Garbage to Centralized Solid Waste Disposal Sites

Study SD93-08
Final Report

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16. Abstract

This report describes methods to evaluate incremental damage on unsurfaced roads and flexible pavement roads due to additional solid waste vehicle hauls. Load equivalencies used to estimate damage are presented for nine solid waste vehicle types. Incremental damage due to solid waste vehicles is evaluated by estimating damage due to existing traffic and damage due to additional solid waste vehicles. Incremental damage costs are evaluated for several cases of additional solid waste vehicles on different roadway types. Incremental damage costs are estimated from cost data obtained from counties in South Dakota. A model is presented to estimate incremental damage and damage costs for solid waste vehicles and other heavy vehicles. The model is written in Microsoft Basic and runs on IBM PC-compatible computers with an 8088 or higher processor.

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EXECUTIVE SUMMARY

Numerous landfills in the state of South Dakota have closed as a result of enactment of Subtitle D of RCRA (Resource Conservation and Recovery Act). At the same time, regulations require that all solid waste now be disposed of at certified landfill disposal sites. Fewer landfills, more solid waste vehicles, and longer hauls will result in more road damage. Solid waste vehicles typically have heavily loaded and sometimes overloaded axles depending on the location and type of lifting and compaction equipment on-board the vehicle. Increased damage to roads results in increased frequency of maintenance, resurfacing and rehabilitation or reconstruction of roads and therefore, cost.

The objectives of the study include (1) identifying solid waste vehicle types, and solid waste vehicle and axle loads, (2) estimating damage due to solid waste vehicles on city, county, and state roads, (3) generating cost estimates of road damage due to solid waste vehicles, (4) developing a model to evaluate the damage and damage costs due to solid waste vehicles for use by cities and counties, and (5) recommending strategies for reducing damage and damage costs due to solid waste vehicles.

Information on solid waste vehicle types and vehicle and axle loads were obtained by conducting site visits to the Rapid City and Watertown landfills. During the site visits, data were collected on vehicle model types, axle group configurations, gross weights, tare weights, and axle group weights. In addition, solid waste vehicle data from the months of January, May, August and October were obtained from each landfill and evaluated for the study.

We found that the vehicle types included single unit trucks, open container trucks, rear packer trucks and front loader trucks. All vehicle types had two axle groups. The front or steering axle consisted of a single axle and the rear axle consisted of a single, tandem, or tandem with tag axle. Load equivalencies were computed for a total of nine vehicle types using a fourth power load damage relationship. Load equivalencies for the solid waste vehicles ranged from 0.1 to 2.1. Of the nine vehicle types identified, one vehicle type had an overloaded steering axle and two vehicle types had overloaded rear axles.

Information on pavement types, pavement structures and existing traffic was obtained from databases available through SDDOT on county and state roads. Anecdotal information on city pavement structures and traffic was obtained from survey questionnaires and followup telephone interviews.

Three pavement types were identified for studying roadway damage due to solid waste vehicles, aggregate-surfaced pavements, surface-treated pavements, and flexible pavements. Damage equations for each pavement type were selected from the literature. The damage equation selected for aggregate-surfaced roads and surface-treated roads predicts the number of ESALs (equivalent single axle loads) for a rutting failure to occur. The user selects the appropriate rut depth to failure. The damage equation selected for flexible pavement roads predicts the number of ESALs to failure to reach the level of terminal serviceability specified by the user.

Damage due to solid waste vehicles was predicted by estimating the incremental damage due to existing traffic plus additional solid waste vehicles compared to the damage or time to failure of the road with existing traffic only. Additional solid waste traffic loading used for damage estimates consisted of 10, 50 and 100 percent of the total number of solid waste vehicles travelling to Rapid City and Watertown landfills.

The results of the damage evaluations indicate that damage to aggregate-surfaced roads is significant when the amount of additional solid waste vehicles using the road approaches 10 percent of the total solid waste vehicles to the landfills.

The incremental damage to low volume city and county surface-treated roads is moderate when the additional traffic is about 10 percent of the total traffic to the landfill and high when additional traffic is 50 percent or more or the traffic to the landfill. Damage to higher volume surface-treated roads on the state system is low for additional traffic equal to about 10 percent of the traffic to the landfill and moderate for additional traffic that is equal to 50 percent or more of the total traffic to the landfill.

Damage to low volume flexible pavements in cities and counties was found to be low to moderate for additional traffic up to about 50 percent of the total traffic to the landfill and moderate to high for additional solid waste traffic exceeding these amounts. Damage to high traffic volume flexible pavements on the state system and in cities was low for 10 percent of the traffic to the landfill and moderate for the 50 and 100 percent level.

Annualized damage costs were evaluated using unit cost data for typical maintenance, resurfacing, upgrading and reconstruction activities from the 1991 Local Roads Needs Study adjusted for inflation. The annualized incremental damage costs due to solid waste vehicles were found by estimating the cost of maintenance and resurfacing for the existing road and traffic and increasing the frequency, and therefore costs, of these activities in direct proportion to the reduction in pavement life due to additional solid waste vehicles. The additional solid waste traffic assumed for the analysis was 10 and 50 percent of the total number of solid waste vehicles to the Watertown landfill.

Increases in annualized damage costs ranged from 118 to 600 percent for aggregate-surfaced roads, 58 to 288 percent for surface-treated roads, 0 to 144 percent for low volume flexible pavements in cities and counties and 0 to 58 percent for higher volume flexible pavements in cities and on the state system for additional solid waste vehicles equal to 10 and 50 percent of the total solid waste traffic to the Watertown landfill.

A Heavy Vehicle Damage Cost Model was developed to estimate damage and damage costs due to additional solid waste vehicles on aggregate-surfaced, surface-treated, and flexible pavement roads. The cost of upgrading or reconstructing a road can also be evaluated using the model. The program is also capable of estimating damage and damage costs for any heavy vehicle defined by the user. The Heavy Vehicle Damage Cost Model is an interactive program written in Microsoft Basic PDS, Version 7.1, that runs on an IBM compatible-PC computer with an 8088 or higher processor.

The results from the Heavy Vehicle Damage Cost Model are sensitive to traffic loading, both existing traffic and additional heavy vehicle traffic. It is also sensitive to the frequency of maintenance and resurfacing activities which are defined by the user. Considerable engineering judgment and experience should be used in developing the inputs for the program and interpreting the results.

Several alternatives for mitigating damage due to solid waste vehicles are presented in the study. Alternatives for reducing damage to roads include implementing methods to reduce the volume of solid waste generated. These types of alternatives would most likely be implemented at the state level. Local and state agencies can elect to improve roads to accommodate the increased heavy vehicle loads due to solid waste vehicles. These agencies can commit to stricter enforcement of load limits, higher fines for load limit violations and/or user fees for heavy vehicles. Revenues from fines or fees could be used to fund MR&R activities on affected roads.

Transfer stations could be constructed in locations where large volumes of solid waste are generated or at locations where solid waste vehicle trips converge enroute to the landfill. This will reduce the number of miles travelled by solid waste vehicles with consistently overloaded vehicles.

Some additions or modifications to solid waste vehicles may result in reduced damage to roads. These additions and modifications include onboard scales and/or variable tire pressure equipment.

Further study of costs and benefits for all alternatives recommended is warranted prior to adoption.

CHAPTER 1

INTRODUCTION

Compliance with Subtitle D of RCRA (Resource Conservation and Recovery Act) has resulted in closure of numerous local landfills in South Dakota. At the same time, regulations require that all solid waste now be disposed of at certified landfill disposal sites. Fewer landfills and more solid waste vehicles on roads result in longer hauls to landfill disposal sites. Solid waste vehicles typically have heavily loaded and sometimes overloaded axles, depending on the location and type of lifting and compacting equipment on board the vehicle. Increases in the number of solid waste vehicles using roads will likely result in increased damage to roads, which in turn results in increased frequency of maintenance, resurfacing, and rehabilitation or reconstruction of roads and, therefore, increased cost.

The South Dakota Department of Transportation (SDDOT) identified the following objectives to evaluate impacts of solid waste vehicles on state and local roads:

1. Develop a representative model of solid waste disposal operations for South Dakota.
2. Quantify total loads and axle loads for solid waste vehicles.
3. Estimate the damage caused by solid waste vehicles on city, county, and state roads.
4. Generate cost estimates of road damage caused by solid waste vehicles.
5. Recommend strategies to reduce damage and cost associated with the damage caused by solid waste vehicles.

At the time that the request for the research proposal was developed, it was anticipated that there would be about 20 landfills in South Dakota. The locations for the landfills had been identified, and it was anticipated that cities and counties would have a designated landfill to which they would haul their solid waste. When the study began, we found that several proposed landfills would not be constructed because of lack of funding and/or difficulties in siting the landfill. In addition, we found that some of the landfills are competing for business by establishing low rates for solid waste disposal at their facility.

As a result of these changes in solid waste disposal practices, the ability to model the solid waste disposal operation in South Dakota was challenged. In addition, there was agreement by the Technical Panel that modeling solid waste flow was no longer needed or desirable. The Technical Panel indicated that it would be more beneficial to develop a model that could be used primarily by local agency representatives to evaluate the damage and cost of damage of solid waste hauls on road segments in their roadway system.

GeoEngineers identified the following tasks for the study in response to the research objectives outlined in the request for proposals and the changes in objectives identified early in the study:

1. Perform a literature review on several topics pertinent to the study, including damage models for different pavement structure types impacted by solid waste vehicles, evaluating costs from heavy vehicle damage, and alternatives for mitigating damage caused by heavy vehicles.
2. Gather information on solid waste vehicles including number and types of vehicles transporting solid waste to landfill sites, and axle loads and configurations.
3. Gather information on pavement structures and traffic loading on city, county, and state roadway facilities.
4. Estimate load equivalencies for solid waste vehicles operated in South Dakota.
5. Estimate incremental damage caused by solid waste vehicles to city, county, and state facilities with "typical" pavement structures and existing traffic loading conditions.
6. Obtain representative cost data for typical maintenance, resurfacing, rehabilitation, and reconstruction activities performed by cities and counties.
7. Develop a model to estimate damage caused by solid waste vehicles and evaluate costs of incremental damage from solid waste vehicles.
8. Identify alternatives for mitigating damage caused by solid waste vehicles.
9. Prepare a report and executive summary outlining the literature summary, research methods, results, conclusions and recommendations of the study.
10. Prepare a user's manual for the solid waste vehicle damage cost model.

Our report is organized as follows:

CHAPTER 2

LITERATURE SUMMARY

INTRODUCTION

The primary focus of the literature review for this study is identifying damage models for different pavement types. Failure mechanisms vary depending on the pavement type, pavement structure materials, the number of heavy loads sustained by a pavement, and prevailing climatic conditions. Numerous damage models or performance equations have been developed for different pavement types including aggregate-surfaced roads, surface-treated roads, flexible pavements and rigid pavements. Damage models found in the literature for aggregate-surfaced roads, surface-treated roads, and flexible pavements are summarized in this chapter. Rigid pavements were not considered to be significantly affected by the number of solid waste vehicles expected on South Dakota roads and therefore will not be examined for this study.

AGGREGATE-SURFACED ROADS

Aggregate-surfaced roads make up the majority of road mileage in the world. This pavement is the most economical type of road to construct and has been found to perform adequately in a range of climatic conditions where traffic volumes are low. Meyer, et al. [1] reviewed many factors affecting performance of low-volume aggregate-surfaced roads. They concluded that aggregate-surfaced roads constructed in hot-dry climates deteriorate as a result of significant surface wear, whereas aggregate-surfaced roads in cold-wet climates generally deteriorate as a result of high moisture content, which results in rutting, potholing and some aggregate loss at the surface.

The USFS (United States Forest Service) [2] developed a procedure that relates the number of ESALs (equivalent single axle loads) to two failure criteria. These failure criteria include terminal serviceability, as defined in the AASHO (American Association of State Highway Officials) design procedures and rut depth. The specified terminal serviceability, p_t, is 1.5 and the rut depth is 2 inches. The pavement structural number is calculated from the CBR (California Bearing Ratio) value for the aggregate-surfacing, the Group Index, GI, from the AASHTO (American Association of State Highway and Transportation Officials) Soil Classification procedure, and the thickness of the surfacing layer.

This USFS procedure for evaluating pavement performance and performing aggregate-surface pavement design was modified slightly and adopted by AASHTO (formerly AASHO) for use in the 1986 AASHTO Guide for the Design of Pavement Structures [3]. Resilient modulus properties of the roadbed and the aggregate surfacing are used in the AASHTO procedure in place of CBR and GI. In the AASHTO procedure, the user selects a value for rut depth and terminal serviceability.

A series of nomographs were developed by TRRL (Transport and Road Research Laboratory) [4] for relating number of load repetitions to failure to pavement condition for surface-treated pavements in tropical and subtropical climates. The researchers suggest that the nomographs are also applicable to aggregate-surfaced roads. This is accomplished by applying a factor of 0.78 to the surfacing thickness scale to estimate the number of load repetitions to failure for aggregate-surfaced roads. The required thickness is reduced for aggregate-surfaced roads because the authors suggest that this type of pavement can tolerate greater deformations at failure.

Barber et al. [5] performed a study cosponsored by the USFS and the USCOE (United States Army Corps of Engineers) Waterways Experiment Station in Vicksburg, Mississippi, in which they analyzed field performance data for aggregate-surfaced roads. A total of 254 data points was analyzed. An equation was developed to predict rut depth of aggregate-surfaced roads as follows:

$$RD = 0.1741 \frac{P_k^{0.4707}\ t_p^{0.5695}\ R^{0.2476}}{(\log t)^{2.002}\ C_1^{0.9335}\ C_2^{0.2848}} \qquad (1)$$

where RD = rut depth, in inches

P_k = equivalent single-wheel load, kips

t_p = tire pressure, in psi

R = the number of load repetitions

t = the thickness of the aggregate surfacing layer

C_1 = the CBR of the aggregate surfacing layer

C_2 = the CBR of the subgrade

It should be noted that most of the CBR values of the aggregate surfacing layers in the pavement structures analyzed for the study ranged from 8 to 17.

Luhr and McCullough [6] developed a method for estimating loads to failure based on AASHO Road Test data. Maximum compressive strain at the top of the subgrade is obtained using layered linear elastic analysis methods for the flexible pavement test sections in the road test. Using regression techniques, they developed an equation relating the number of load repetitions to failure to maximum subgrade compressive strain and serviceability. A comparison of the Luhr equation to the AASHO performance equation developed from the road test data indicates that the Luhr equation has a slightly better correlation to number of load repetitions to failure compared to structural number, SN, used in the AASHO performance equation. The equation is as follows:

$$\begin{aligned}\log W_{18} &= 2.15122 - 597.662(\epsilon_{sg}) - 1.32967\log(\epsilon_{sg}) \\ &+ \log\ \{[(4.2-p_t)\ /\ (4.2-1.5)]^{1/2}\}\end{aligned} \qquad (2)$$

where W_{18} = number of 18-kip equivalent single-axle loads

ϵ_{sg} = the maximum subgrade compressive strain

p_t = the terminal serviceability

Luhr and McCullough [6] recommend this equation for evaluating performance of aggregate-surfaced roads as well as surface-treated roads and flexible pavements. Other researchers such as Chou [7], who published an extensive literature review of design methods for aggregate-surfaced roads in 1989, caution against the use of this equation for aggregate-surfaced roads.

In a subsequent study published in 1983, Luhr et al. [8] recommend the use of the equation developed by Barber et al. [5], presented earlier, to predict performance of aggregate-surfaced roads.

Studies of aggregate-surfaced roads in Kenya were conducted by Hodges et al. [9] and Jones [10]. The aggregate surfacing in the roads studied included lateritic, quartzitic, volcanic, and sandstone gravels. Maintenance frequencies for these roads ranged from six months to over one year. The distress types studied included gravel loss, surface looseness, surface roughness, and rut depth. Performance equations were developed for each gravel type for each distress type. The authors found that gravel loss was the critical distress type for the roads studied.

Visser and Hudson [11] conducted studies on field performance of unpaved roads in Brazil. They developed performance equations for roughness, rut depth, and gravel loss for the unpaved roads studied. The independent variables used to predict performance for these distress types include vertical and horizontal alignment, liquid limit of the surfacing material, plasticity index of the surfacing material, percent of surfacing material passing the 0.42 and 0.074 mm sieves, ADT (average daily traffic), road width, season, and surfacing type descriptors.

Paige-Green [12] developed equations for roughness prediction and aggregate loss on aggregate-surfaced roads based on sampling and monitoring on 110 sections of unpaved roads in South Africa and Namibia over a period of three years. Roughness measurements were obtained using the LDI (Linear Displacement Integrator). Performance equations were developed for surface roughness and aggregate loss using time since blading, a plastic factor, season, climate factor, ADT, gradation data, and dust ratio.

An aggregate surfacing design guide was developed by Whitcomb, et al. [13] for the USFS in 1990. Although a literature review was not presented in the guide, the authors indicate that a thorough review of existing methods for performance prediction and design of aggregate-surfaced roads was performed. They selected the equation by Barber et al. [5] for use to design aggregate-surfaced roads. The authors note, however, that there is little evidence to suggest that the existing methods developed to predict performance of aggregate-surfaced roads, including the Barber method, have been field verified.

SURFACE-TREATED ROADS

Very few studies were found in the literature that specifically address performance of surface-treated roads. Those studies that were found were performed on roads in tropical and subtropical climates. The TRRL [4] Guide described in the previous section on aggregate-surfaced roads includes methods that were specifically developed to predict performance of surface-treated roads.

Jones [10] performed studies on road deterioration of paved roads in Kenya. The typical pavement consists of a surface-treated road with a cement stabilized base. Distress types studied for paved roads include surface roughness, rut depth, cracking and patching, and deflections. The author developed equations for the relationships between roughness and number of load repetitions to failure, and cracking and patching and the number of load repetitions to failure. Very little rutting was observed on the road section evaluated during the study period.

A study by Queiroz and Hudson [14] focused on the performance of surface-treated roads in Brazil. Deflection measurements were obtained on the roads studied using the Dynaflect and the Benkelman Beam. Roughness prediction models and crack initiation and propagation models were developed using structural number, Dynaflect deflection and Benkelman Beam deflections and combinations of these independent variables. Rutting was also studied as a significant distress type; however, it was found that rut depths were very small.

FLEXIBLE PAVEMENTS

Flexible pavement structures have been the most widely studied pavement type with respect to the accumulation of damage. Models have been developed to relate the accumulation of damage resulting from many different types of distress. These distresses can be because of environmental conditions, such as low-temperature cracking, or they can be the result of load-related distresses, such as fatigue cracking and rutting. Some models have been developed that relate the accumulation of damage or time to failure to the loss of serviceability, which represents the combined effect of all distresses on roadway deterioration. The models described in this section are limited to models that predict failure resulting from load-related distress and loss of serviceability of flexible pavements.

The two most widely recognized load-related distress types in flexible pavements are fatigue cracking and rutting. Generally, fatigue cracking is the critical or dominant load-related distress type for thick flexible pavements. Brown and Pell [15] developed an equation for fatigue failures in thick asphalt concrete pavements. The equation was obtained from the results of laboratory fatigue tests performed under conditions of controlled stress. A shift factor or field factor was applied to the results to make the equation more applicable to field conditions. The equation is as follows:

$$\epsilon_t = 3480\ N^{-0.347} \tag{3}$$

where ϵ_t = the maximum tensile strain in the asphalt concrete layer

N = the number of 18-kip single-axle load repetitions to failure

Santucci [16] developed a fatigue relationship for asphalt concrete pavements based on laboratory fatigue tests performed under conditions of controlled stress. The fatigue tests were performed on an asphalt concrete mix with an asphalt volume of 11 percent and an air void volume of 5 percent. Santucci recommended modifications to the equation for variations in asphalt cement and air void content and a shift factor of 3 to account for field conditions.

A fatigue equation that has been widely applied to estimate the number of load repetitions to failure for fatigue is the equation developed by Finn et al. [17], which is based on the results of laboratory fatigue tests performed under conditions of controlled stress with a shift factor applied that was developed from the AASHO Road Test data. The equation is as follows:

$$\log N_f = 15.947 - 3.291 \log(\epsilon_t /10^{-6}) - 0.854 \log(E/10^3) \tag{4}$$

where N_f = the number of 18-kip single-axle load repetitions to failure
ϵ_t = the maximum tensile strain in the asphalt concrete layer
E = the resilient modulus, in psi

In this method, failure is defined as fatigue cracking in 10 percent of the wheelpath area.

Elliott and Thompson [18] evaluated the results of laboratory-controlled stress fatigue tests and analyzed pavement response from the AASHO Road Test using ILLIPAVE, a finite element pavement analysis program. The fatigue equation obtained from this study is as follows:

$$\log N = 2.2340 - 3.16 \log \epsilon_t - 1.4 \log E \tag{5}$$

where N = number of 18-kip single-axle load repetitions to failure
ϵ_t = the maximum tensile strain in the asphalt concrete layer
E = the resilient modulus, in psi

The maximum subgrade compressive strain that occurs at the top of the subgrade layer is widely used as the primary response parameter to predict rutting or permanent deformation of a flexible pavement in the wheelpath. Santucci [16] proposed the following equation for predicting pavement rutting failures in flexible pavements. The equation is based on laboratory-repeated load tests in which resilient and permanent deformation of subgrade materials were measured and correlated with observations of 3/4-inch-deep ruts in the San Diego Road Test. The equation obtained is as follows:

$$\epsilon_v = 1.05 \times 10^2 N^{-0.233} \tag{6}$$

where ϵ_v = the maximum compressive strain at the top of the subgrade layer
N = the number of load repetitions to failure

Edwards and Valkering [19] developed the following equation for predicting rutting failure based on the performance of flexible pavements in the AASHO Road Test:

$$\epsilon_v = 2.8 \times 10^{-2} N^{-0.25} \tag{7}$$

Brown et al. [20] developed an equation to predict rutting failures based on analyses of a number of different pavement structures in Great Britain. The equation is as follows:

$$\epsilon_v = 2.16 \times 10^{-2} N^{-0.28} \tag{8}$$

Equation (2), developed by Luhr and McCullough [6] and presented in the section on aggregate-surfaced roads, which relates subgrade compressive strain and loss of serviceability to number of load repetitions to failure, is applicable to flexible pavements. As mentioned previously, this equation is based on performance data from test sections in the AASHO Road Test. Luhr et al. [8] subsequently developed an equation to estimate the subgrade compressive strain using the elastic moduli and layer thicknesses in the pavement structure. The equation is as follows:

$$\begin{aligned} \log \epsilon_{sg} = {} & 2.24002 - 2.91440 \times 10^{-5} E_{rbd} - 5.08514 \times 10^{-2} D_{ac} - \\ & 2.02947 \times 10^{-2} D_{bs} - 5.37288 \times 10^{-8} E_{ac} D_{ac} - \\ & 9.37888 \times 10^{-4} D_{bs} D_{sb} - 2.91066 \times 10^{-7} E_{bs} D_{bs} - \\ & 8.60253 \times 10^{-7} E_{sb} D_{sb} \end{aligned} \tag{9}$$

where

ϵ_{sg} = maximum compressive strain at the top of the subgrade layer due to an 18-kip single-axle load, in in/in
E_{rbd} = elastic modulus of the roadbed material, in psi
D_{ac} = the thickness of the asphalt layer, in inches
D_{bs} = the thickness of the base layer, in inches
E_{ac} = elastic modulus of the asphalt layer, in psi
D_{sb} = the thickness of the subbase layer, in inches
E_{bs} = elastic modulus of the base layer, in psi
E_{sb} = elastic modulus of the subbase layer, in psi

CHAPTER 3

SOLID WASTE VEHICLES

INTRODUCTION

In order to evaluate the damage that may result to roads from solid waste vehicles, information regarding configurations of solid waste vehicles used in South Dakota is required. The methods for collecting solid waste vehicle data are presented in this chapter along with a summary of the information obtained for characterizing the damaging effects of solid waste vehicles.

Two landfills were selected early in the study from which data on representative solid waste vehicles types would be collected. The landfills were selected using the following criteria:

1. One landfill should be located on the east side of the state and one on the west side of the state.
2. The landfill had to be in full operation during the summer of 1993.
3. Scales had to be present at the landfill to get gross vehicle weights, rear axle weights and tare weight.
4. Historical records of hauls to the landfill for at least one year were desirable to identify potential seasonal variations in frequency and size of solid waste hauls.

Using these criteria, two landfills were selected to gather solid waste vehicle information: (1) the Rapid City landfill, located south of Rapid City approximately 5 miles on State Route 79 and (2) the Watertown landfill, located on a county road approximately 1/2 mile south of Watertown between State Route 29 and State Route 81.

METHODS FOR GATHERING SOLID WASTE VEHICLE DATA

Records maintained by both of the landfills include information on gross and tare weights of all vehicles that come to the landfill to dispose of solid waste. All commercial vehicles have a vehicle identification designation that is assigned by the landfill operator. Private vehicles that come to the landfill to dispose of solid waste are identified by the vehicle type, such as van, pickup or passenger car. When commercial vehicles come to the landfill, the vehicles are weighed before and after their loads are dumped. This weight data are used to compute solid waste fees. The landfills studied maintained weight data by vehicle identification in their respective databases.

Damage resulting from heavy vehicles is estimated based on axle configuration (number of axles and axle group types) and loads on axle groups. In order to get detailed information on vehicle types, axle configuration, and axle loads, GeoEngineers visited each landfill site for one day. During the site visit, we collected the following information:

1. Date and time;
2. Vehicle identification (operator name and/or number);

3. Vehicle model type;
4. Substance hauled (when possible);
5. Axle group configuration;
6. Gross weight;
7. Tare weight;
8. Axle group weights.

During our site visit, our representative met with the landfill operator to obtain additional solid waste haul data for different times of the year to evaluate seasonal changes in solid waste haulage. We obtained one week of data on solid waste hauls for the months of January, May, August, and October from both landfills.

The data were reduced by using the vehicle identification and tare weight obtained from our site visits to identify and match vehicles in the remaining four weeks for which we had data. After the matches were obtained, front and rear axle weights were computed by assuming that the front or steering axle weight on the matched vehicle remained constant compared to the measured axle weight obtained during our site visit.

SOLID WASTE VEHICLES

We observed three different axle configurations on the solid waste vehicles at the Rapid City and Watertown landfills. These axle configurations are as follows:

1. A single steering axle with a tridem rear axle that consists of a tandem axle and a tag axle (1-3 axle configuration);
2. A single steering axle with a tandem rear axle (1-2 axle configuration);
3. A single steering axle with a single rear axle (1-1 axle configuration).

We observed a total of nine different solid waste vehicle types at the landfills. These vehicle types are as follows:

<u>1-3 Axle Configuration</u>

Front loader
Open container
Rear packer

<u>1-2 Axle Configuration</u>

Front loader
Open container
Rear packer
Single-unit truck

1-1 Axle Configuration
Rear packer
Single-unit truck

The number and type of solid waste vehicles observed at each landfill are presented in Table A1 and A2 for the Rapid City and Watertown landfills, respectively. The total number of vehicles using the Rapid City landfill is about 2-1/2 times the number of vehicles using the Watertown landfill. Total vehicles to the Rapid City landfill ranged from a low of 106 in January to 188 in May, compared to 35 vehicles in January and 87 vehicles in May at the Watertown landfill. The number of heavy vehicles, which includes the vehicle types summarized above, ranged from 76 to 92 at Rapid City and 24 to 62 at Watertown. The large variation in the number of vehicles at Watertown is mainly attributable to a large variation in the number of single-unit trucks with 1-1 axle configuration.

The number of rear packers with 1-3 and 1-2 axle configurations, open container trucks with 1-3 axle configurations and single unit trucks with 1-1 axle configurations observed at the Rapid City landfill was typically between 15 and 20 for all of these vehicle types. Additional heavy vehicles to the Rapid City landfill included approximately 10 single-unit trucks with 1-2 axle configurations, 8 front loaders with 1-3 axle configurations and 1 front loader with a 1-2 axle configuration.

The heavy solid waste vehicle stream to Watertown consisted of approximately 19 single-unit trucks and 14 rear packers both with 1-1 axle configurations, followed by 3 rear packers, 2 open container trucks and 1 single-unit truck, all with 1-2 axle configurations.

The total number of solid waste vehicles to both landfills was less in January than in the other months for which we had data. We did not observe any other seasonal variations in the solid waste traffic.

LOAD EQUIVALENCIES FOR SOLID WASTE VEHICLES

As mentioned previously, front and rear axle weights were obtained by assuming that the front or steering axle weight remained constant. Rear axle weights were obtained from the data by subtracting front axle weights from gross weights. The axle weights were used to obtain load equivalencies using a fourth power load-damage relationship as follows:

$$LEF = \sum_{i=1}^{n} \left(\frac{P_{s,i}}{18}\right)^4 + \left(\frac{P_t}{34}\right)^4 + \left(\frac{P_{tr}}{48}\right)^4 \tag{10}$$

where LEF = the load equivalency factor or equivalent number of 18-kip single-axle load repetitions

$P_{s,i}$ = the axle load for the ith single axle, in kips

P_t = the axle load for a tandem axle, in kips

P_{tr} = the axle load for a tridem axle, in kips

The denominator in each term in the equation represents the axle group load that is equivalent to an 18-kip single-axle load. The allowable load levels for tandem and tridem axle loads have been selected to represent an equivalent amount of damage as an 18-kip single-axle load when the axles are spaced at least 48 inches apart and the axle load is distributed evenly over the individual axles in the group. The load equivalencies for each vehicle type at the Rapid City and Watertown landfills are given in Tables A1 and A2, respectively, in Appendix A. Load equivalencies were calculated for each week of data for each vehicle type. Average load equivalency factors for all the data for each vehicle type are also presented in the tables.

Sufficient data were available to estimate load equivalencies for seven solid waste vehicle types that use the Rapid City landfill for solid waste disposal. The average load equivalencies for these vehicles range from a low of 0.07 for a single-unit truck with a 1-1 axle configuration to a high of 2.26 for a front loader with a 1-3 axle configuration. At the time of our site visit, we observed that all vehicles with 1-3 axle configurations entered the landfill with the tag axle in the up position. Therefore, the load equivalencies for all vehicles with 1-3 axle configurations given in Table A1 were calculated assuming the tag axle was in the up position.

We evaluated load equivalencies for three solid waste vehicle types at the Watertown landfill. The load equivalencies for these vehicles ranged from a low of 0.29 for a rear packer with a 1-2 axle configuration to a high of 1.74 for a rear packer with a 1-1 axle configuration.

Based on the vehicle summaries presented in Tables A1 and A2, we developed load equivalency factors for nine solid waste vehicle types for estimating damage which are presented in Table 1. Also shown in the table are the front or steering and rear axle loads for each vehicle type. The axle loads presented in this table indicate that front loaders with 1-3 axle configurations have overloaded steering axles (20 kips compared to an 18-kip allowable). Rear packers with 1-3 axle configurations have overloaded rear axles (36 kips compared to 34 kips) when the vehicle is operated with the tag axle in the up position. Rear packers with 1-1 axle configurations have overloaded rear axles (20 kips compared to 18 kips). We assumed that steering or front axle weights do not change appreciably when the vehicle is loaded or unloaded. Therefore, this suggests that front loaders with 1-3 axle configurations have front or steering axles that are overloaded in both a loaded and unloaded condition.

CHAPTER 4

PAVEMENT STRUCTURES AND TRAFFIC

INTRODUCTION

Traffic impacts on roads vary with the number, magnitude and configuration of the applied loads, prevailing environmental conditions, and the geometry and material types in a pavement structure. In order to evaluate impacts of the solid waste vehicles characterized in Chapter 3, it is necessary to identify the pavement structures on which these vehicles travel, as well as the preexisting traffic conditions.

The methods used to characterize pavement structures and traffic in order to evaluate damage caused by solid waste vehicles are outlined in the first part of this chapter. The remaining portion of the chapter includes a description of the pavement structures and existing traffic conditions selected for evaluating damage caused by solid waste vehicles.

Early in the study, we attempted to obtain information on the types of roads and pavement structures specifically used by solid waste vehicles. We sent questionnaires to road managers in 15 cities and all counties in South Dakota. We requested information specifically on roads used for solid waste haulage. The information requested included route designation and name, length of road segment, number of travel lanes, pavement structure information including pavement layer material types and layer thicknesses, drainage information, surface condition, and load restriction practices. In addition, we requested information on average daily traffic, percent trucks and number of solid waste hauls.

We received a total of nine responses. Four cities responded including Aberdeen, Rapid City, Sioux Falls, and Watertown. Five counties responded including Beadle, Deuel, Gregory, Spink, and Walworth. We conducted follow-up telephone interviews with representatives of the cities of Aberdeen, Mitchell, Pierre, Rapid City, and Watertown to obtain additional information on pavement structures, existing traffic, and solid waste traffic. The information from the questionnaires and the telephone interviews is summarized in Appendix B.

In general, the cities and counties that responded to the questionnaire indicated that they perceived that there was little impact to city or county roads resulting from solid waste haulage. The respondents indicated that, in general, most of the solid waste haul traffic and most of the increases in solid waste hauls occur on the state route system.

Since it was difficult to obtain information on pavement types, pavement structures and specific routes used for solid waste hauls, we decided to consider alternative methods for identifying pavement structures and solid waste traffic for the purpose of estimating damage caused by solid waste vehicles. A number of databases have been developed by or for SDDOT containing detailed information on roads and traffic on city-, county- and state-operated roads. These databases were made available to GeoEngineers for use for this study. This information was used to identify pavement types used by various agencies and to develop typical pavement structure profiles for each pavement type. The typical pavement structures were utilized along with typical traffic information also contained in the databases to estimate damage.

PAVEMENT STRUCTURE DATA

A database was developed for the 1991 Local Roads Needs Study [21], which contains information on approximately 15,600 centerline miles of county roads. There was a general belief on the part of SDDOT personnel involved in this study as well as the research team from GeoEngineers that county roads were likely to receive the greatest impacts from solid waste vehicles because of generally light pavement structures, low traffic volumes and locations of landfills. Therefore, considerable emphasis was placed on identifying pavement types and structures from this database.

Five pavement types were identified in the data including concrete, asphalt mix, surface seal, gravel and other. Two percent of the road mileage characterized in the database was classified as other and 0.6 percent of the road miles was classified as concrete. A total of approximately 14,100 centerline miles of roads was classified as gravel, surface seal, or asphalt mix. Sufficient information existed in the database for these pavement types to identify pavement structures.

We selected three categories of pavement types for this study. The categories were selected based on the available pavement structure data in the database and also by considering the equations or models available for use to evaluate roadway damage. The pavement type categories selected are as follows:

1. aggregate-surfaced roads,
2. surface-treated roads, which include all roads with some type of surface treatment that is less than 2 inches thick;
3. flexible pavement roads, which include all roads with an asphaltic surfacing layer that is 2 inches or greater in thickness.

For these pavement types, we found that 60 percent of the county road mileage consists of aggregate-surfaced roads, 20 percent of the mileage consists of surface-treated roads, and the remaining 20 percent of the road mileage consists of flexible pavements.

We developed frequency distributions for surfacing thickness for all three pavement types and for base thickness for surface-treated and flexible pavements in order to obtain "typical" pavement structures for each pavement type. The data indicate that the surfacing thicknesses of aggregate-surfaced roads varied from 1/2 inch to 8 inches. Typical aggregate surfacing thicknesses ranged from 2 to 5 inches. Surface-treated roads had surfacing thicknesses ranging from almost zero for dust treatments to 1½ inches. Most of the surface-treated roads had surfacing thicknesses of 1/2 inch to 1 inch. The base layers for surface-treated roads ranged from 0 to 8 inches. The typical base layer thickness was 6 inches. Flexible pavement roads had surfacing thicknesses ranging from 2 to 6 inches, with the majority of flexible pavements having thicknesses of 2 to 3 inches. Base layer thicknesses for flexible pavements ranged from 0 to 12 inches, with a typical base thickness of 6 inches.

Pavement structure information for state-operated roads was obtained from the 1993 Highway Needs Analysis [22]. We reviewed the pavement structure information for all state routes within a 50-mile radius of the Rapid City and Watertown landfills to obtain pavement structure information. No state-managed aggregate-surfaced roads were found in these areas. Surfacing thicknesses for surface-treated roads ranged from 0 to 1¾ inches, with a typical thickness of 1½ inches. Base layers for the surface-treated pavements varied from 3.5 to 7 inches thick, with a typical thickness of 6 inches. Most of state roads in these areas were classified as flexible pavements for this study. The surface layers consisted of 2 to 10.5 inches of asphalt concrete surfacing. The typical thickness was from 3 to 4 inches. Base layers in the flexible pavement structures varied from 0 to 18 inches in thickness, with typical thicknesses of 6 and 12 inches.

Very little data were available on city roads from the questionnaires or follow-up telephone interviews. A local roads needs study is currently in progress for cities in South Dakota; however, the data from this study are not currently available. Based on information from the telephone interviews and discussions with SDDOT personnel involved in the local roads study, we believe the majority of city street pavement structures are similar to the pavement structures constructed by the counties. In some instances, heavier pavement sections are used on arterials in cities. We believe that these pavement structures would be similar to pavement structures constructed by SDDOT for similar traffic volumes.

MATERIAL PROPERTIES

In order to evaluate damage for aggregate-surfaced, surface-treated and flexible pavement type roads, some material properties information is required. Specific material properties information did not accompany the pavement structure information in the county or state databases. We used information published in two studies by SDDOT to select representative material properties.

We reviewed a study conducted by SDDOT [23] that includes detailed information on subgrade soils at 34 project sites throughout the state. A total of 104 soil samples were tested for this study. The tests performed included sieve analyses, moisture content, Atterberg limits, density tests, field and laboratory CBR tests, and plate load tests.

Most of the soils were classified as A-7 soils according to the AASHTO Soil Classification System and as low plasticity clay soils (CL) according to the Unified Soil Classification System. Other soil types included high plasticity clays, low and high plasticity silt, and silty clayey sand. We evaluated the results of the field and laboratory CBR tests conducted on these soils for further use in this study. We found that field CBRs conducted at natural moisture contents varied from 2 to 36. The most typical values for field CBRs for the soils from these project sites ranged from 10 to 15. The laboratory CBR tests were conducted after the samples had soaked for 7 days.

Laboratory CBR values ranged from 1 to 13, with typical soaked CBR values ranging from 4 to 6. The CBR values for each project were plotted on a map. No trends for field or laboratory CBR values were observed based on geographic location.

Material properties for base and surfacing materials were obtained from a subsequent study conducted by SDDOT [24] to evaluate layer coefficients for surfacing, base, and subbase materials for design of pavements. The layer coefficients obtained in the study are analogous to the layer coefficients used in the AASHO (now AASHTO) pavement design procedures. We used these layer coefficients to evaluate suitable material properties for base and surfacing materials.

The study suggests that layer coefficients range from 0.36 to 0.42 for high stability plant-mixed asphalt concrete and 0.18 to 0.24 for low stability plant-mixed asphalt concrete. Using representative values of 0.40 and 0.20 for high and low stability plant-mixed asphalt concrete, respectively, and the relationship for layer coefficient for asphalt concrete versus elastic modulus at 68°F included in the 1993 AASHTO Guide for the Design of Pavement Structures, we selected the following values for elastic modulus for these materials:

Surfacing Material	Modulus (psi)
High stability plant mix	360,000
Low stability plant mix	100,000

We also selected a value of 0.20 for road-mixed asphalt or bituminous surfacing materials, which results in an elastic modulus of 100,000 psi for these surfacing materials at a reference temperature of 68°F.

We did not encounter any stabilized base materials in the pavement structure data from the county and state pavement data reviewed. Layer coefficients for unstabilized base materials in the study are divided into two categories: crushed rock and soil aggregate base. The recommended layer coefficients in the study are 0.14 for crushed rock and 0.10 for soil aggregate base. Using charts developed for the AASHTO Guide for correlations between layer coefficients and elastic modulus, we selected the following elastic modulus and CBR values for these two base types:

Base Material Type	CBR Value	Modulus (psi)
Crushed rock	55	30,000
Soil aggregate	30	20,000

PAVEMENT STRUCTURE CASE SELECTION

Based on our review of the SDDOT study on subgrade strength properties [23], we selected two subgrade CBR values, 10 and 15, for evaluating damage for all pavement types. These values represent CBR values when subgrades are not saturated. For saturated subgrade conditions that are likely to occur during spring thawing periods and prolonged periods of rain, which we understand typically occurs in the fall, CBR values of 4 and 6 should be used.

We selected the following pavement structures for each pavement type to evaluate damage resulting from solid waste vehicle traffic:

Aggregate-Surfaced Roads

Surfacing Type	CBR	Surfacing Thickness (inches)
Crushed rock	30	4
Soil aggregate	20	4

Surface-Treated Roads

Surfacing Type	Modulus (psi)	Surfacing Thickness (inches)
Low stability plant mix and road mix	100,000	1/2,1,1-1/2

Base Type	Modulus (psi)	Base Thickness (inches)
Crushed rock	30,000	6
Soil aggregate	20,000	6

Flexible Pavement Roads

Surfacing Type	Modulus (psi)	Surfacing Thickness (inches)
High stability plant mix	360,000	2,3,4,8
Low stability plant mix and road mix	100,000	2,3,4,8

Base Type	Modulus (psi)	Base Thickness (inches)
Crushed rock	30,000	6,12
Soil aggregate	20,000	6,12

TRAFFIC DATA

Information on existing traffic, including ADT (average daily traffic) and percent trucks, is contained in the 1991 Local Roads Needs Study [21] for county roads and in the 1993 Highway Needs Analysis [22] for state roads. We developed frequency distributions, as described in the previous section on Pavement Structure Data, to identify typical traffic loading conditions for aggregate-surfaced roads, surface-treated roads and flexible pavements. The following traffic loading cases were obtained from these analyses:

Aggregate-Surfaced Roads

ADT	Percent Trucks
50	10

Surface-Treated Roads

ADT	Percent Trucks
100	10,20
150	10,20
500	8

Flexible Pavement Roads

ADT	Percent Trucks
100	10,20
200	10,20
500	10
2,000	10

CONCLUSIONS

The pavement structure cases and traffic loading cases selected represent typical structures and traffic on city, county and state roads. These pavement structures will be used to evaluate the accumulation of damage or time to failure caused by existing traffic loading and existing traffic plus additional solid waste vehicles. Using this approach, the incremental damage and impacts on pavement life caused by solid waste vehicles can be examined for some typical pavements and traffic loading conditions found in South Dakota.

CHAPTER 5

DAMAGE EVALUATION

INTRODUCTION

The literature review conducted for this study provided several alternative methods for estimating damage on aggregate-surfaced, surface-treated, and flexible pavement roads. Methods selected to obtain damage estimates for this study had to satisfy two criteria. First, the methods had to provide reasonable results for pavement life or time to failure for South Dakota roads. Second, the information required to characterize pavement structures for the damage equations had to consist of information readily available from local or state agency personnel or from the county and state databases since there was no opportunity for additional data collection efforts for study. Using these criteria, we selected the most appropriate damage equation for each pavement type. The damage equations selected will be presented in this chapter along with the damage estimates for a number of different cases of solid waste vehicle traffic on typical pavement structures for aggregate-surfaced, surface-treated and flexible pavements.

DAMAGE EQUATIONS

Aggregate-Surfaced Roads

The damage equation selected for aggregate-surfaced roads is Equation 2, developed by Barber et al. [5]. The equation used for this study has been rearranged to obtain the number of 18-kip ESALs to failure as follows:

$$N = [0.1404 \times RD \times \log (t)^{2.002} \times C_1^{.9335} \times C_2^{.2848}]^{4.0388} \qquad (11)$$

where N = the number of 18-kip single-axle loads to failure

RD = the rut depth, in inches

t = the thickness of the aggregate surfacing layer, in inches

C_1 = the CBR of the aggregate surfacing layer

C_2 = the CBR of the subgrade

The original equation includes tire pressure as a variable. We used a tire pressure of 110 psi based on information provided by the Technical Panel for typical tire pressures currently found in South Dakota.

Surface-Treated Roads

The damage equations found in the literature for surface-treated roads were developed for roads in tropical and subtropical climates and, therefore, are not very applicable to conditions in South Dakota. Surface treatments less than 2 inches in thickness do not provide a significant amount of additional stiffness to the pavement structure. The primary functions of surface treatments are dust control, waterproofing and improved wearing surfaces. Resilient and permanent deformations that can be tolerated by surface-treated roads are greater than deformations that can be tolerated by flexible pavements. Based on these observations, we concluded that the best method available for estimating damage on surface-treated roads is the equation for aggregate-surfaced roads by Barber et al. [5]. When the equation is used for surface-treated roads, the tolerable rut depth is reduced compared to that for aggregate-surfaced roads. The equation uses the CBR of the surfacing layer to calculate the number of load repetitions to failure. In order to account for the presence of the surface treatment, we calculated an adjusted CBR value for the combined surface treatment and aggregate base as follows:

$$E_1 = \frac{E_{st}\, t_{st} + E_b\, t_b}{t_{st} + t_b} \tag{12}$$

where E_1 = the adjusted elastic modulus of the surface treatment and base

E_{st} = the elastic modulus of the surface treatment

t_{st} = the thickness of the surface treatment

E_b = the elastic modulus of the base

t_b = the thickness of the base

A commonly used relationship to estimate the elastic modulus of the base from CBR is as follows:

$$E = 1{,}800\ CBR^{0.7} \tag{13}$$

This leads to the following equation to predict the number of load repetitions to failure for surface-treated roads:

$$N = [0.1404 \times RD \times \log(t)^{2.002} \times (E_1/1{,}800)^{1.3336} \times C_2^{.2848}]^{4.0388} \tag{14}$$

where N = the number of 18-kip single-axle loads to failure

RD = the rut depth, in inches

t = the combined thickness of the surface treatment and the base layer, in inches

E_1 = the adjusted elastic modulus of the surface treatment and base

C_2 = the CBR of the subgrade

Flexible Pavement Roads

The damage equation selected for flexible pavements is the equation developed by Luhr and McCullough [6] from AASHO Road Test data that relates maximum subgrade compressive strain and loss of serviceability to the number of load repetitions to failure. The equation is as follows:

$$\log W_{18} = 2.15122 - 597.662\ (\epsilon_{sg}) - 1.32967 \log\ (\epsilon_{sg}) + \log\ \{[(4.2 - p_t)\ /\ (4.2 - 1.5)]^{1/2}\} \quad (2)$$

where W_{18} = number of 18-kip equivalent single-axle loads

ϵ_{sg} = the maximum subgrade compressive strain

p_t = the terminal serviceability

The maximum subgrade compressive strain is obtained using the following equation developed by Luhr et al. [8]:

$$\log \epsilon_{sg} = 2.24002 - 2.91440 \times 10^{-5} E_{rbd} - 5.08514 \times 10^{-2} D_{ac} - 2.02947 \times 10^{-2} D_{bs} - 5.37288 \times 10^{-8} E_{ac} D_{ac} - 2.91066 \times 10^{-7} E_{bs} D_{bs} \quad (5)$$

where ϵ_{sb} = maximum compressive strain at the top of the subgrade layer due to an 18-kip single-axle load, in in/in

E_{ac} = elastic modulus of the asphalt layer, in psi

E_{bs} = elastic modulus of the base layer, in psi

E_{rbd} = elastic modulus of the roadbed material, in psi

D_{ac} = the thickness of the asphalt layer, in inches

D_{bs} = the thickness of the base layer, in inches

DAMAGE EVALUATION

Introduction

In order to evaluate the damage caused by solid waste vehicles, it is first necessary to obtain the time to failure for existing traffic loading conditions. With this information, the reduction in pavement life can be evaluated. Using the typical pavement structure and traffic loading cases presented in Chapter 4, we evaluated the pavement life using the damage equations presented in the previous section. Equivalent single-axle loads for existing ADT and truck traffic were calculated using an average heavy truck factor of 1.088, obtained from a compilation of truck load factors by state that was prepared for the FHWA (Federal Highway Administration) [25].

Six solid waste traffic loading cases were selected to estimate damage or the reduction in pavement life resulting from solid waste vehicles. The cases selected for the analysis include 10, 50 and 100 percent of the total daily solid waste traffic volume to the Rapid City and Watertown landfills, respectively. The 10 percent case was selected to represent a road in a city or county where solid waste traffic is channeled as it leaves that jurisdiction. The 50 percent case was selected to represent a state or county road approaching the landfill. The 100 percent case represents the road on which the landfill is located.

The reduction in life resulting from solid waste vehicles was obtained by estimating the time to failure for the existing road under existing traffic loading conditions, and the time to failure for the existing road with existing traffic loading plus the solid waste vehicle traffic. The reduction in life was calculated as follows:

$$RL = \frac{T_{sw} - T_e}{T_e} \times 100\% \tag{16}$$

where RL = the reduction in life, in percent

T_{sw} = the time to failure for the existing road with existing traffic loading plus solid waste traffic

T_e = the time to failure for the existing road with existing traffic

In order to account for the changes in subgrade stiffness resulting from variations in moisture content throughout the year, we assumed that saturated or near-saturated moisture conditions prevailed for 3 months out of the year, and for the remaining 9 months the near-surface subgrade soils had moisture contents well below saturation. The expected life was calculated for both subgrade conditions. The expected life or number of load repetitions to failure used to compare existing traffic loading with and without solid waste vehicles is calculated as follows:

$$N = .75\ N_{dry} + .25\ N_{wet} \tag{17}$$

where N = the number of 18-kip single-axle load repetitions to failure for year-round conditions

N_{dry} = the number of 18-kip single-axle load repetitions to failure for relatively dry subgrade conditions

N_{wet} = the number of 18-kip single-axle load repetitions to failure for saturated subgrade conditions

A summary of the results obtained and the failure criteria used for each pavement type are presented in the following sections.

Aggregate-Surfaced Roads

Damage estimates were obtained for aggregate-surfaced roads with 4 inches of surfacing and existing traffic loading consisting of ADTs of 50 with 10 percent trucks. The failure criterion used for the aggregate-surfaced roads was a rut depth of 2 inches. The time to failure for the existing traffic loading was 0.1 to 0.2 years for an aggregate surface CBR of 20, and 0.4 to 0.7 years for an aggregate surface CBR of 30. The results for all cases analyzed are presented in Tables C1 and C2 in Appendix C. A summary of the reduction in life for the aggregate-surfaced roads with varying levels of solid waste traffic from the Rapid City and Watertown landfills is given in the following tables.

Rapid City Landfill

Solid Waste Traffic (percent of total solid waste traffic)	Reduction in Pavement Life (percent)
10	66
50	92

Watertown Landfill

Solid Waste Traffic (percent of total solid waste traffic)	Reduction in Pavement Life (percent)
50	86-89

The results suggest that the impacts of solid waste vehicle traffic may be significant on aggregate-surfaced roads with pavement structures comparable to those analyzed depending on the number and type of solid waste vehicles. In general, we anticipate that the number of solid waste vehicles on these types of roads is less than or comparable to 10 percent of the solid waste traffic. However, there may be some aggregate-surfaced roads in the vicinity of landfills that carry greater numbers of solid waste vehicles.

Surface-Treated Roads

Damage estimates were obtained for surface-treated roads with 1/2- and 1-inch-thick surface treatments and 6-inch-thick base layers. The existing traffic loading cases for low-volume city and county surface-treated roads include ADTs of 100 and 150 with 10 and 20 percent trucks. We also evaluated damage for a 1½-inch-thick surface-treated pavement with an ADT of 500 and 8 percent trucks to represent existing traffic on a more heavily traveled state road. The failure criterion used for surface-treated roads was a rut depth of 1 inch.

The results of all of the damage estimates for the surface-treated road cases analyzed are given in Tables C3 through C22 in Appendix C. The time to failure for the existing traffic loading ranged from 0.2 to 16 years for the pavements analyzed. The pavements with higher quality base material had significantly longer pavement lives. The reductions in life for the surface-treated roads with varying levels of solid waste traffic from the Rapid City and Watertown landfills are summarized in the following tables.

Existing Traffic Loading: ADT = 100, 150; Percent Trucks = 10, 20

Rapid City Landfill

Solid Waste Traffic (percent of total solid waste traffic)	Reduction in Pavement Life (percent)
10	25-58
50	64-85
100	79-93

Watertown Landfill

Solid Waste Traffic (percent of total solid waste traffic)	Reduction in Pavement Life (percent)
10	11-42
50	44-75
100	64-86

Existing Traffic Loading: ADT = 500; Percent Trucks = 8

Rapid City Landfill

Solid Waste Traffic (percent of total solid waste traffic)	Reduction in Pavement Life (percent)
10	11-13
50	42
100	58-60

Watertown Landfill

Solid Waste Traffic (percent of total solid waste traffic)	Reduction in Pavement Life (percent)
10	5-7
50	26
100	42

The results suggest that the impacts of solid waste vehicle traffic may be significant on light surface-treated roads depending on solid waste vehicle loading. The impacts of solid waste vehicles is much lower on surface-treated roads with thicker surface treatments and higher existing traffic loading.

Flexible Pavement Roads

We estimated damage to flexible pavement structures with surface layer thicknesses of 2, 3, 4 and 8 inches and base thicknesses of 6 and 12 inches for low and high stability asphalt concrete mixes and average and high quality base materials. Two- and three-inch-thick pavements were analyzed for existing traffic loading cases, which included ADTs of 100 and 200 with 10 and 20 percent trucks to represent low-volume city and county flexible pavement roads. We also evaluated damage for 3-, 4-, and 8-inch-thick flexible pavements with ADTs of 500 and 2,000 and 10 percent trucks to represent existing traffic conditions on state roads. The failure criterion used for the flexible pavements was a terminal serviceability of 2.0.

The results of all of the analyses on flexible pavement structures are given in Tables C23 through C56. The time to failure for existing traffic loads ranged from 6 to 111 years for the 2- and 3-inch-thick pavements with a maximum ADT of 200. The time to failure for the 3-, 4- and 8-inch-thick pavements with ADTs of 500 and 2,000 ranged from 1 to 35 years. Extremely long pavement lives resulted from a combination of rather substantial pavement structures compared to very low traffic loading conditions. For these combinations of pavement structures and loading conditions, we anticipate that moisture and aging effects will have a greater relative effect on pavement deterioration and that the pavement life will be controlled by these factors. For these reasons, we established an upper limit of 20 years for the pavement life for flexible pavements. The tables show the remaining life obtained from the flexible pavement damage equation and the associated reduction in life for solid waste traffic. In addition, an adjusted reduction in life has been calculated and is also shown in the tables using a maximum pavement life of 20 years. The reductions in life for flexible pavement roads with varying levels of solid waste traffic from the Rapid City and Watertown landfills are summarized in the following tables. The summary tables reflect reductions in life using a maximum pavement life of 20 years.

Existing Traffic Loading: ADT = 100, 200; Percent Trucks = 10, 20

Rapid City Landfill

Solid Waste Traffic (percent of total solid waste traffic)	Reduction in Pavement Life (percent)
10	0-40
50	20-80
100	55-90

Watertown Landfill

Solid Waste Traffic (percent of total solid waste traffic)	Reduction in Pavement Life (percent)
10	0-38
50	0-65
100	20-80

Existing Traffic Loading: ADT = 500, 2,000; Percent Trucks = 10

Rapid City Landfill

Solid Waste Traffic (percent of total solid waste traffic)	Reduction in Pavement Life (percent)
10	0-21
50	0-55
100	0-71

Watertown Landfill

Solid Waste Traffic (percent of total solid waste traffic)	Reduction in Pavement Life (percent)
10	0-15
50	0-38
100	0-54

Impacts of solid waste vehicle traffic may be significant for traffic loadings in the 50 to 100 percent range for lighter pavements. The impacts of solid waste vehicles on state roads or higher type pavements in cities may not be very significant depending on the specific pavement structure and existing traffic.

CHAPTER 6

COST EVALUATION

INTRODUCTION

One of the primary objectives of the study is to identify the cost of the damage that occurs as a result of additional solid waste vehicle traffic. In the preceding chapter we presented the method for evaluating damage caused by solid waste vehicles. The damage evaluation was performed by comparing the damage as a result of the preexisting traffic loading conditions to the damage caused by the existing traffic plus solid waste vehicles. We selected a similar approach for evaluating the cost of damage caused by solid waste vehicles. This approach is described in this chapter along with damage costs for selected pavement structures, and existing and additional solid waste traffic loading conditions.

METHODS FOR EVALUATING COST

In order to evaluate the cost of damage to roads for this study, information on the types of MR&R (maintenance, resurfacing, and reconstruction) activities typically undertaken for aggregate-surfaced roads, surface-treated roads, and flexible pavements is required. The 1991 Local Roads Needs Study [21] provides a summary of typical maintenance, resurfacing and reconstruction activities for county roads as well as unit costs for each of these activities. The MR&R activities applicable for this study are presented in Table 2 along with square-foot costs and costs per 1-foot-width per mile of road. The costs shown in the table are the costs from the 1991 Needs Study adjusted for inflation since 1991 using the nationwide Consumer Price Index. Specific MR&R activities and costs applicable to city streets are being developed for the 1994 Local Roads Needs Study. A summary of these activities and the associated costs were not available at the time the report for this study was being prepared.

As mentioned previously, the approach selected for evaluating damage cost impacts of additional solid waste vehicle traffic is an incremental cost approach similar to the method used to estimate damage. First, the annualized cost of MR&R activities that are routinely performed on a road for existing traffic loading conditions is obtained. The annualized cost is estimated using the unit costs in Table 2 and the time between successive MR&R activities. The annualized cost of MR&R activities for the road with existing traffic and additional solid waste traffic is obtained assuming that the same MR&R activities will be performed. However, the time between successive activities will be increased in proportion to the reduction in life caused by the additional solid waste traffic. The incremental annualized damage cost resulting from the additional solid waste traffic is the difference between these costs. The annualized costs are calculated assuming zero inflation and no discounting. A detailed example of the method used to evaluate damage costs resulting from solid waste vehicles is presented in Appendix D.

COST EVALUATION

Introduction

In order to gain some insight into the damage cost impacts that may occur as a result of additional solid waste vehicle traffic, we estimated damage costs for a number of typical pavement structures and existing traffic loading conditions. For the purposes of this evaluation, we assumed that the additional solid waste traffic loading was equal to 10 and 50 percent of the total solid waste traffic from the Watertown landfill. One-mile-long road segments were used to estimate costs. Assumptions regarding MR&R activities and a summary of the results are presented for each road type separately. The results of all of the analyses are presented in Appendix E.

Aggregate-Surfaced Roads

The aggregate-surfaced roads evaluated consisted of a two-lane road with 10-foot-wide travel lanes and 2-foot-wide shoulders. The travel lanes and shoulders were surfaced with 4 inches of aggregate. Complete descriptions of the pavement structure cases are included in Table E1 in Appendix E. The existing traffic consisted of an ADT of 50 with 10 percent trucks.

Maintenance consisted of blading the road four times per year or more if the pavement life obtained from the damage analysis was less than 3 months. Where the pavement life was less than 3 months, the time between bladings equaled the pavement life. It should be noted that the failure criterion used to obtain pavement life was a 2-inch rut depth. When the damage model indicates that a pavement failure has occurred, this means that a 2-inch rut has developed which can be corrected by blading. We assumed that resurfacing activities consisted of adding 4 inches of aggregate every three years when the pavement life was greater than or equal to 3 months. The time between resurfacings was decreased to two years when the pavement life obtained from the damage analysis was less than 3 months.

The results of the damage cost analyses for aggregate-surfaced roads are presented in Table E1 in Appendix E. The annualized cost of maintenance and resurfacing activities for the existing pavements with existing traffic ranged from $7,220 to $10,970 for the pavement structures and traffic loading conditions analyzed. Annualized incremental damage costs for additional solid waste traffic equal to 10 percent of the total traffic from the Watertown landfill ranged from $8,530 to $12,950, which represents an increase of 218 percent in annualized costs for maintenance and resurfacing. The annualized incremental costs of additional solid waste traffic equal to 50 percent of the Watertown landfill traffic were six times the cost of existing maintenance and resurfacing activities for existing traffic conditions.

Surface-Treated Roads

Damage costs were obtained for surface-treated roads with two 10-foot-wide travel lanes and two 3-foot-wide shoulders. Both the travel lanes and shoulders were surface-treated. Surface-treated roads consisted of 1/2- and 1-inch-thick surface treatments and a 6-inch-thick base. An ADT of 100 and 150 were assumed with 10 and 20 percent trucks, respectively. Complete descriptions of the pavement structures used for the analyses of surface-treated roads are presented in Tables E2 and E3 in Appendix E.

Times of 15 to 20 years were assumed as minimum and maximum times between resurfacings, respectively. A time of 15 years between resurfacings, which consist of adding 6 inches of crushed base and a prime coat and chip seal, was used when the pavement life computed by the program was 15 years or less. When the pavement life computed from the damage model was between 15 and 20 years, the pavement life was used as the time between resurfacings. When the pavement life exceeded 20 years, the time between resurfacings was assumed to be 20 years. We assumed that the time between maintenance activities, which consist of crack and chip sealing, were related to the pavement life as follows:

Pavement Life (years)	Time Between Crack Sealing (years)	Time Between Chip Sealing (years)
15 - 20	3	5
10 - 15	2	4
Less than 10	1	3

The damage costs for the surface-treated roads are presented in Tables E2 and E3 in Appendix E. We found that the annualized cost of the maintenance and resurfacing activities for the existing pavements with existing traffic ranged from $4,840 to $15,200 for the pavement structures and traffic loading conditions analyzed. The annualized incremental damage costs for additional solid waste traffic equal to 10 percent of the total traffic from the Watertown landfill ranged from $1,590 to $8,740. These incremental costs represent a 19 to 58 percent increase in costs of maintenance and resurfacing for these pavements.

The annualized incremental costs of additional solid waste traffic equal to 50 percent of the Watertown landfill traffic ranged from $7,940 to $43,780, or a 96 to 288 percent annual increase in maintenance costs for these roads. Some of these incremental costs are probably unrealistically high since the time between maintenance activities used to calculate costs for some of the cases was less than 1 year, which probably does not accurately reflect actual practice.

Flexible Pavement Roads

The typical flexible pavement roads for the damage cost evaluation consisted of two 11-foot-wide travel lanes with 4-foot-wide shoulders on both sides of the road. The shoulder and travel lanes were paved with asphalt concrete. Flexible pavements with 2 and 3 inches of asphalt concrete and 6-inch-thick base layers with ADTs of 200 and 10 and 20 percent trucks were evaluated to represent low-volume flexible pavement roads in cities and counties. In addition, flexible pavements with 3 inches of asphalt concrete surfacing, 6- and 12-inch thick bases and ADTs of 500 and 10 percent trucks were evaluated to represent higher traffic volume roads in cities and on the state system.

The pavement life obtained from the damage analysis for existing traffic was used for the time between resurfacings with a maximum time of 20 years. Maintenance activities consisted of crack sealing and chip sealing. The time between crack sealing was related to pavement life as follows:

Pavement Life (years)	Time Between Crack Sealing (years)
15 - 20	3
Less than 15	2

The time between chip sealing was assumed to be 4 years for ADTs of 500 and 5 years for ADTs of 200.

The results of these analyses are presented in Tables E4 through E6 in Appendix E. The annualized costs of maintenance and resurfacing for low volume flexible pavements with ADTs of 200 ranged from $7,500 to $14,050. The annualized incremental damage cost resulting from solid waste traffic that is the equivalent of 10 percent of the traffic to the Watertown landfill ranged from $0 to $2,450. This represents an increase in annual MR (maintenance and rehabilitation) costs of 0 to 29 percent. When the additional solid waste traffic was increased to the equivalent of 50 percent of the total solid waste traffic to the Watertown landfill, the incremental damage cost ranged from $0 to $12,230, or an increase of 0 to 144 percent.

Annualized costs of MR activities on flexible pavements with an ADT of 500 ranged from $8,100 to $11,920. When additional solid waste traffic equal to 10 percent of the traffic to Watertown was added to the existing traffic, the annualized incremental costs varied from $0 to $1,380, which represents an increase in annualized costs of 0 to 12 percent. The incremental costs varied from $0 to $6,870 for additional solid waste traffic equal to 50 percent of the traffic to Watertown, which represents an increase in MR costs of 0 to 58 percent.

CHAPTER 7

HEAVY VEHICLE DAMAGE COST MODEL

INTRODUCTION

We presented estimates of damage in Chapter 5 for 10, 50 and 100 percent of the solid waste traffic to the Rapid City and Watertown landfills on a variety of pavement structures with a range of existing traffic. The results indicate which types of pavement structures are likely to be impacted by these levels of additional solid waste vehicle traffic. The Technical Panel from SDDOT and the research team from GeoEngineers decided that it would be useful for local agencies to be able to evaluate damage and damage costs on specific roads within their jurisdictions for actual numbers and types of additional solid waste vehicles using the roads. We developed the Heavy Vehicle Damage Cost Model for this purpose. A description of the model and hardware and software requirements are presented in this chapter.

MODEL DESCRIPTION

The Heavy Vehicle Damage Cost Model is an interactive program in which the user defines an existing road segment, pavement structure, existing traffic loading conditions, additional solid waste or other heavy vehicle traffic loading, and typical maintenance and resurfacing activities. This information is used to estimate damage resulting from existing traffic, damage caused by existing traffic plus solid waste or other heavy vehicle traffic, the cost of MR&R activities for existing road and traffic conditions and the cost of MR&R activities for the additional traffic. In addition to evaluating the cost of increased maintenance and resurfacing activities, the user may evaluate the cost of upgrading or reconstructing a road subjected to additional heavy vehicle traffic. The model is divided into three parts: project description, damage evaluation and cost evaluation. A description of each part of the model is given in this chapter. A summary of the model is presented in Figure 1. A detailed flow chart for the model is included in Appendix F. A user's manual for the program has been prepared and accompanies this report.

Project Description

In the first part of the program, the user enters the necessary information to characterize the roadway segment to be analyzed. The following information is required:

1. Roadway segment designation;
2. Length of segment;
3. Number of lanes;
4. Lane and shoulder width;
5. Road type;
6. Surfacing material, thickness and material properties;
7. Shoulder surfacing material;

8. Base material, thickness and material properties;

9. Subgrade material type and material properties.

The material property required to characterize the surfacing material for surface-treated and flexible pavement roads is the elastic modulus at a reference temperature of 68°F. Aggregate surfacing, base and subgrade material properties may be given as CBR values or elastic modulus values. Default values are included in the program for surfacing, base and subgrade materials. These default values are as follows:

Layer	Material Type	Elastic Modulus (ksi)	CBR
Surface	High stability asphalt plant mix	360	--
	Low stability asphalt or bituminous plant or road mix	100	--
	Crushed rock	20	30
	Sand and gravel	15	20
Base	Crushed rock	30	55
	Sand and gravel	20	30
Subgrade	CL, moist	9-12	10-15
	CL, saturated	5-6	4-6

Damage Evaluation

Using the roadway description information entered in the first part of the program and traffic loading information entered in this part of the program, damage estimates are obtained for the existing road and traffic loading conditions, and existing traffic plus additional solid waste vehicles or other heavy vehicles. The damage equations presented in Chapter 4 for aggregate-surfaced, surface-treated, and flexible pavement roads are used to estimate damage.

Existing traffic loading is defined by entering the existing ADT and percent heavy trucks. Additional solid waste traffic loading is defined by entering the number and type of solid waste vehicles using the roadway segment. Nine solid waste vehicle types are defined and included in the model. These vehicle types and axle configurations are given in Table 1. A semi-tractor trailer is defined as the tenth vehicle type. The eleventh vehicle type is an arbitrary vehicle. Using this vehicle type, the user can define the number of axles, type of axles and axle loads for any heavy vehicle. This allows local agency personnel using this program to evaluate damage resulting from other vehicle types if desirable. The user has the option to edit axle loads for any vehicle type. Once the additional solid waste or other heavy vehicle traffic loading is defined, the program estimates damage or time to failure for the existing traffic and existing traffic plus additional solid waste or other heavy traffic and displays the time to failure in years for both traffic loading cases. The reduction in life is also calculated and displayed. The reduction in life is calculated as follows:

$$RL = \frac{T_{sw} - T_e}{T_e} \times 100\% \tag{16}$$

where RL = the reduction in life, in percent

T_{sw} = the time to failure for the existing road with existing traffic loading plus solid waste traffic

T_e = the time to failure for the existing road with existing traffic

Cost Evaluation

Damage costs are calculated in the program using the methods presented in Chapter 6. In order to calculate damage costs using this method, some information regarding the frequency of MR&R activities is required. For each road type, maintenance and resurfacing activities are specified. They are as follows:

Road Type	Maintenance Activities	Resurfacing Activities
Aggregate-surfaced	Blading	Adding 4 inches of aggregate
Surface-treated	Crack seal, chip seal	Adding 6 inches of base, prime coat and chip seal
Flexible	Crack seal, chip seal	Adding 2½ inches of asphalt surfacing

The user enters information on the frequency of performing MR&R activities on the existing road. The program calculates the increased frequency of MR&R activities and the associated increased annualized cost of MR&R activities using the percent reduction in life as follows:

$$T_{mrr,sw} = T_{mrr,e} \ (1 - RL) \tag{18}$$

where $T_{mrr,sw}$ = the time between MR&R activities with existing traffic plus additional solid waste vehicle traffic

$T_{mrr,e}$ = the time between MR&R activities with existing traffic

RL = the reduction in life resulting from solid waste vehicle traffic calculated in the damage evaluation

$$C_{ann,sw} = \left[\sum_{i=1}^{n} C_{mi}/t_{mi} + C_r / t_r \right] (1 - RL) \qquad (19)$$

where $C_{ann,sw}$ = the annualized damage cost of existing traffic plus additional solid waste vehicle traffic

C_{mi} = the cost of the *i*th maintenance activity for that road type

C_r = the cost of the resurfacing activity for that road type

t_{mi} = the time between the *i*th maintenance activity specified by the user

t_r = the time between resurfacing activities specified by the user

RL = the reduction in life due to additional solid waste traffic

After estimating the incremental damage costs, the program displays the results to the user. The user has the option to evaluate the costs for upgrading or accomplishing a full reconstruction of the road. Specific upgrades are defined in the program. They are as follows:

Road Type	Upgrade Alternatives
Aggregate-surfaced	Surface-treated road consisting of 6 inches of base and a prime coat and chip seal. Flexible pavement consisting of 2½ inches of asphalt concrete.
Surface-treated	Flexible pavement consisting of 2½ inches of asphalt concrete.

After the upgrade alternative is selected, damage estimates are obtained for the upgraded pavement with existing plus additional solid waste vehicle traffic. The user enters information on frequency of MR&R activities for the upgraded road and the program calculates damage costs. The damage cost for the upgraded road with existing plus additional solid waste or other heavy vehicle traffic is compared to the damage cost of the original pavement structure with existing traffic to obtain the incremental damage costs for upgrading the road.

The same approach is used to evaluate the incremental damage costs for a full reconstruction. The only reconstruction option available is full reconstruction starting with regrading the subgrade for a 2½-inch-thick asphalt concrete pavement. The analysis approach for this option is the same as the approach outlined in the previous paragraph for an upgraded road.

When the analysis of a road segment is complete, the results are saved to a file. The user can continue to evaluate the same road segment for different traffic loading conditions or proceed with other road segment analyses.

USE OF THE HEAVY VEHICLE DAMAGE COST MODEL

Users of the Heavy Vehicle Damage Cost Model should be aware of the variables that significantly affect the results obtained for pavement life, reduction in life, and damage costs. We did not perform a comprehensive sensitivity analysis on the variables used in the model. However, we were able to identify significant variables as a result of using the model to predict damage and damage costs for a variety of pavement structures for aggregate-surfaced, surface-treated and flexible pavement roads.

The time to failure or pavement life predicted by the damage equations is sensitive to pavement structure data, including material properties and layer thicknesses as well as the value of the failure criterion selected for the analysis. The damage equations calculate time to failure in ESALs (equivalent single-axle loads). ESALs to failure are converted to time in years using the daily traffic and percent trucks. Therefore, the actual time to failure is sensitive to the definition of existing daily traffic loading. The time to failure is displayed to the user during the analysis and should generally represent actual times to failure for the pavement structure and traffic loading conditions analyzed. When the time to failure obtained from the model is significantly different than judgment and experience indicate for the pavement structure being analyzed, we recommend that the user review pavement structure and traffic loading information and revise this information as appropriate to obtain better predictions of existing pavement life. It is important to note, however, that the pavement life is not used directly in obtaining estimates of reduction in life or incremental costs.

Estimates of the reduction in pavement life for existing traffic plus additional solid waste traffic are directly dependent on the number of ESALs for the existing daily traffic and the number of ESALs for the additional solid waste traffic. It is very important to define these traffic loading conditions as accurately as possible since the annualized incremental cost is estimated directly from the reduction in life.

Annualized costs for existing pavement and traffic loading conditions are sensitive to the type and frequency of maintenance and resurfacing activities typically performed on the road, and the cost of these activities. The user should be as accurate as possible in entering time between maintenance and resurfacing activities. Users should also review the unit costs in Table 2 and revise these costs as appropriate when using the model.

We recommend that considerable care and engineering judgment be exercised when using the model. The results should be interpreted as representative of the expected reduction in pavement life and incremental costs, provided that accurate information is used in defining pavement structure information, traffic loading conditions and costs. The results obtained from the model should not be interpreted as exact costs of incremental damage.

HARDWARE AND SOFTWARE REQUIREMENTS

The Heavy Vehicle Damage Cost Model program is an interactive program written in Microsoft Basic PDS (Professional Development System), Version 7.1. It has been developed to run on IBM PC-compatible computers with an 8088 or higher processor. A minimum of 640K of RAM and a monochrome monitor with a CGA adaptor board are required to run the program.

CHAPTER 8

ALTERNATIVES FOR MITIGATING DAMAGE CAUSED BY SOLID WASTE VEHICLES

INTRODUCTION

The damage cost evaluations presented in Chapter 6 and the damage cost model described in Chapter 7 allow local agencies to identify the cost of damage resulting from additional solid waste vehicles on selected roads in their jurisdiction. This is the first step toward identifying the impacts to their roadway system and the associated costs. Once the extent of damage is known, local agencies can determine what actions are appropriate to mitigate the damage.

The research team from GeoEngineers identified many alternatives possible for mitigating damage to solid waste vehicles on local roads. The alternatives presented in this chapter were obtained from a number of different sources, including conversations and interviews with local agency personnel, discussions with members of the Technical Panel, discussions with representatives from the solid waste industry, and literature on heavy vehicle impacts. The alternatives included in this chapter represent all of the alternatives that we were able to identify. We have not done detailed cost-benefit analyses on the alternatives, nor have we examined the regulatory philosophies of local or state agencies in South Dakota. The list of alternatives should be considered a starting point for selecting appropriate alternatives for mitigating damage resulting from solid waste vehicle traffic. Alternatives that may be appropriate for use should be examined more thoroughly, with local agency resources, local conditions, solid waste operations, cost effectiveness and other considerations taken as appropriate.

MITIGATING DAMAGE BY REDUCING SOLID WASTE

Reducing the volume of the solid waste stream will reduce the number of solid waste hauls required. The effect of this alternative can be examined using the damage cost model. While it may be possible to reduce solid waste volume through voluntary efforts, measurable results are more likely to be realized through regulation and/or incentive programs.

One form of regulation that could be adopted is a tax on all disposable products where the amount of the tax reflects the cost of handling all solid waste generated as a result of the manufacture and disposal of the product. This type of regulation is likely to result in reducing the use of disposable products where comparable products are available as well as reducing the amount of unnecessary packaging on products. An alternative form of regulation to taxation is to prohibit the sale and/or use of certain disposable products.

Alternatively, an agency could elect to offer incentives to individuals, businesses and industry to reduce the amount of solid waste produced. Incentives can be offered in the form of a variable rate structure for disposal of solid waste, with higher rates charged for increasing volumes of solid waste. Incentives can also be offered in the form of tax credits for instituting methods for reducing solid waste generation in one's business.

MITIGATING DAMAGE BY LOCAL AGENCY ACTIONS

Local agencies have numerous alternatives for mitigating damage depending on the extent of the system affected, their jurisdiction over solid waste operations in their locality, and the ability and interest in instituting various types of regulatory reforms to mitigate damage resulting from solid waste vehicles.

The simplest approach is the do nothing alternative. Using this approach, the agencies will either increase maintenance and resurfacing budgets to cover increased damage costs resulting from additional solid waste vehicles, or allow roads to take on more damage between the times when MR&R activities are performed. We anticipate that it may be difficult to obtain additional funding for increased damage using only existing funding mechanisms.

It may be possible to obtain funds to upgrade or reconstruct some road segments to accommodate the solid waste vehicle traffic using funding sources other than MR&R budgets. The damage cost model should be used to identify which roads are most appropriate for upgrading or reconstruction.

The results of the damage evaluations performed on various pavement structures indicate that the greatest amount of relative or incremental damage occurs on low-volume roads. It may be beneficial to limit solid waste vehicle traffic on low-volume roads such as alleys, residential streets and collectors to those vehicles that are collecting solid waste on these roads and designate haul routes for all heavy traffic including solid waste vehicle traffic. The haul routes should be designed to adequately carry all heavy vehicle traffic. The drawback to this approach is enforcement. It will be difficult to enforce since some solid waste vehicles will be permitted on low-volume roads for collection.

Enforcement of existing regulations for gross vehicle and axle loads is another alternative. Enforcement of existing load limits will result in imposing fines on some types of solid waste vehicles whenever they operate since some of the vehicle axle loads are greater than allowable without any payload. This could result in eventual replacement of these vehicles in the solid waste vehicle stream since it may not be cost-effective to routinely incur fines.

One method for monitoring the vehicle and axle loads of solid waste vehicles on a regular basis is to require that all landfills and transfer stations be equipped with scales. Local agencies could require that all vehicle and axle weights be recorded on every trip to the transfer station or landfill. These records could be reviewed by local or state agencies to determine if vehicles are operating within legal axle load limits. Further incentive to operate vehicles with legal axle loads could be provided by imposing more severe fines for noncompliance with axle load regulations.

We found that many of the larger solid waste vehicles are equipped with tag axles in the rear of the vehicle. Our data suggest that when these vehicles enter the landfill fully loaded, the rear axle is typically overloaded with the tag axle in the up position. Local agencies could require that all vehicles with tag axles keep these axles in the down position to share the rear axle load.

An alternative to routinely levying fines on solid waste vehicles with consistently overloaded axles is to develop a road user fee structure that accounts for the road damage that occurs from these vehicles. The damage cost model could be used to estimate incremental cost of overloaded axles by comparing damage from similar vehicles with legally loaded axles and overloaded axles.

We anticipate that any methods undertaken by a local or state agency to restrict solid waste vehicles to specific haul routes, monitor and enforce legal load limits, and/or change fines or fee structures for overloaded vehicles would likely have to be applied to all heavy vehicles that use the roads.

Representatives from the solid waste industry on the Technical Panel indicated that payload weights are significantly increased when solid waste is saturated. We were not able to verify the extent of overloading of axles that may result from solid waste being exposed to moisture and becoming saturated. It would be possible to identify the increase in payload weights resulting from rain by reviewing historical weather data and weight data from the landfills. If overloaded axles result from wet payloads, local agencies can require that all solid waste be stored in covered containers. One method for achieving this is to supply users with standardized containers.

In some localities, several solid waste operators compete for customers throughout the city or county. In addition, solid waste is collected two times per week by some operators. These practices result in increasing the frequency of solid waste vehicles on low-volume roads by four to six times. Where several operators currently provide service to a city or county, the local agency could negotiate contracts with these operators to provide a specified level of service in specific areas without overlapping. This will reduce solid waste traffic impacts to low-volume roads.

One of the greatest impacts of the changes in regulations for landfills is the increased travel distances to landfills to dispose of solid waste. We anticipate that there has been little change in solid waste vehicle traffic in cities provided that city roads are not used as through routes for solid waste traffic traveling to the landfill. However, we anticipate that there have been considerable increases in solid waste vehicle miles on some county and state roads.

A considerable percentage of the total weight of a loaded solid waste vehicle is the tare load of the vehicle from the heavy lifting and compacting equipment included in the vehicle. The mileage traveled by these vehicles can be reduced by establishing transfer stations at suitable locations where significant volumes of solid waste are generated or at locations within a county road system where solid waste traffic converges enroute to the landfill. Solid waste would be off-loaded from the solid waste vehicles at these locations and transferred to tractor-trailer trucks that do not include lifting or compaction equipment. This approach would reduce total vehicle miles on county roads resulting from solid waste vehicles as well as damage caused by overloaded axles.

If it is found that damage caused by additional solid waste vehicles is significant in many counties because of increased vehicle miles, it may be advisable to perform cost-benefit analyses to compare the cost of constructing additional landfills to the benefit of reducing road damage resulting from decreases in vehicle miles. The damage cost model could be used to evaluate the benefits of reduced vehicle miles.

MITIGATING DAMAGE BY CHANGES IN SOLID WASTE VEHICLES

Some additions or modifications to existing solid waste vehicles or changes in solid waste vehicle configurations could result in reductions in road damage. Changes in solid waste vehicles could be accomplished voluntarily by solid waste operators or could be required by local or state agencies. Prior to making or requiring changes in solid waste vehicles, more thorough cost-benefit analyses of these alternatives should be performed.

Modifications or additions to solid waste vehicles could include installing scales on the vehicles to measure loads to alert the operator when the vehicle and/or axles have reached the maximum allowable load. Scales may reduce some of the damage to roads caused by overloads; however, as mentioned previously, a portion of the damage that results from vehicles with overloaded axles is because of the vehicle design and heavy on-board lifting and compacting equipment.

Several studies [26] have shown that damage to roads can be reduced by reducing tire pressure. The effect of increased tire pressure on roadway damage increases with decreasing pavement structure stiffness. Therefore, lowering tire pressures would have the greatest impact on aggregate-surfaced and surface-treated roads. Variable tire pressure equipment has been developed that allows the vehicle operator to change the tire pressure while traveling. The use of this type of equipment could help reduce damage to low-volume roads. The USCOE and USFS have conducted studies that demonstrated substantial reduction in road damage from the use of vehicles with reduced tire pressures. The cost of equipping vehicles with on-board tire pressure inflation systems could be offset by the reductions in damage costs.

CHAPTER 9

CONCLUSIONS AND RECOMMENDATIONS

HEAVY WEIGHT VEHICLE IMPACTS STUDY

The following conclusions are based on the research, analysis and results from this study:

1. The solid waste vehicle data collected at the Rapid City and Watertown landfills suggest that front loader solid waste vehicles with tandem plus tag rear axles typically have overloaded steering axles. Rear packer solid waste vehicles typically have overloaded rear axles when the vehicle is loaded and the rear tag axle is in the up position. Rear packer solid waste vehicles with single rear axles typically have overloaded rear axles when loaded.
2. The total number of solid waste vehicles traveling to the landfill was lower in January than in May, August and October at both the Rapid City and Watertown landfills. The variation in the number of solid waste vehicles at different times of the year was considerably greater at Watertown compared to Rapid City.
3. Damage to typical aggregate-surfaced roads appears to be significant when the amount of additional solid waste vehicles using the road approaches 10 percent or more of the number of total solid waste vehicles to the Watertown or Rapid City landfill. This is equivalent to approximately three ESALs per day additional load on the aggregate-surfaced roads.
4. Damage to typical low-volume surface-treated roads in cities and counties appears to be moderate for additional solid waste traffic equal to 10 percent of the total solid waste traffic to the Rapid City or Watertown landfill, and high for additional solid waste traffic that is 50 percent or more of the total traffic to the landfill.
5. Damage to typical higher volume surface-treated roads on the state system appears to be low for additional solid waste traffic equal to 10 percent of the total solid waste traffic to the Rapid City or Watertown landfill, and moderate for additional solid waste traffic that is 50 percent or more of the total traffic to the landfill.
6. Damage to low-volume flexible pavements in cities and counties appears to be low to moderate for additional solid waste traffic equal to 10 percent of the total solid waste traffic to the Rapid City or Watertown landfill, low to high for additional solid waste traffic that is 50 percent of the total traffic to the landfill, and moderate to high for additional solid waste traffic equal to 100 percent of the total traffic to the landfill.
7. Damage to higher volume flexible pavements on the state system and in cities appears to be low for additional solid waste traffic equal to 10 percent of the total solid waste traffic to the Rapid City or Watertown landfill, and low to moderate for additional solid waste traffic that is 50 percent to 100 percent of the total traffic to the landfill.

8. Increases in annualized damage costs for typical aggregate-surfaced roads with additional solid waste traffic equal to 10 and 50 percent of the total solid waste traffic to the Watertown landfill ranged from 118 to 600 percent compared to annualized costs of maintaining roads with existing traffic conditions.
9. Increases in annualized damage costs for typical low-volume surface-treated roads in cities and counties with additional traffic equal to 10 and 50 percent of the total traffic to the Watertown landfill ranged from 58 to 288 percent compared to annualized costs of maintaining roads with existing traffic loading conditions.
10. Increases in annualized damage costs for typical low-volume flexible pavement roads in cities and counties with additional traffic equal to 10 and 50 percent of the total traffic to the Watertown landfill ranged from 0 to 144 percent compared to annualized costs of maintaining roads with existing traffic conditions.
11. Annualized damage costs for typical higher volume flexible pavement roads on the state system and in cities with additional traffic equal to 10 and 50 percent of the total traffic to the Watertown landfill ranged from 0 to 58 percent, with the majority of cases have little to no impacts.
12. The Heavy Vehicle Damage Cost Model has been developed to estimate damage and the associated costs of increased maintenance and resurfacing resulting from additional solid waste and other heavy vehicles. The program runs on an IBM PC-compatible computer with an 8088 or higher processor.
13. Alternatives for reducing or mitigating damage to roads caused by additional solid waste vehicles include implementing methods to reduce the volume of solid waste generated. These types of alternatives would most likely be implemented at the state level.
14. Local and state agencies can elect to improve roads to accommodate the increased heavy vehicle loads resulting from solid waste vehicles. The cost-effectiveness of these alternatives can be examined using the Heavy Vehicle Damage Cost Model.
15. Alternatives available to state and local agencies to mitigate damage caused by solid waste vehicles include stricter enforcement of load limits, higher fines for load limit violations and/or user fees for vehicles with over-legal loads. Revenues from fines or fees could be used to fund MR&R activities on affected roads.
16. Transfer stations could be constructed in locations where large volumes of solid waste are generated or at locations where solid waste vehicle trips converge enroute to the landfill. This will reduce the number of miles traveled by solid waste vehicles with consistently overloaded axles as a result of heavy on-board lifting and compacting equipment.
17. Some additions to solid waste vehicles may result in reduced damage to roads. These additions include on-board scales and/or variable tire pressure equipment. The impacts of these devices have not been explored in detail in this study. We recommend that further study of the impacts of these devices be undertaken prior to making any vehicle modifications.

The following recommendations are based on the research, analysis and results from this study:

1. Load equivalency factors for the solid waste vehicle types encountered at the Rapid City and Watertown landfills ranged from 0.1 ESALs (equivalent single axle loads) for a single unit truck to 2.1 ESALs for a front loader. We recommend that load equivalencies in this range be used to evaluate damage due to solid waste vehicles provided the vehicle types are similar to those encountered in the study.
2. The Heavy Vehicle Damage Cost Model can be used to evaluate the cost associated with upgrading or reconstructing a road damaged as a result of additional heavy traffic.
3. The results from the Heavy Vehicle Damage Cost Model are sensitive to pavement structure input values, traffic loading and information on MR&R activities, particularly the frequency of these activities. The user should make every effort to obtain the best available information to perform the analyses. Considerable engineering judgment is required to use and interpret the results from this program.
4. The Heavy Vehicle Damage Cost Model can be useful to local agencies for evaluating the damage and damage costs to roads impacted by additional solid waste vehicles or other heavy vehicles. We recommend that the program be demonstrated to interested local agency personnel to instruct them on the applicability of the program and its operation.

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TABLE 1
SOLID WASTE VEHICLE LOAD EQUIVALENCIES FOR ESTIMATING DAMAGE

Vehicle Type	Steering Axle Load (kips)	Rear Axle Load (kips)	Load Equivalency Factor
Tandem Plus Tag Rear Axle			
Front loader	20	30	2.1 (1.8)[1]
Rear packer	12	36	1.4 (0.7)
Open container	12	28	0.7 (0.4)
Tandem Rear Axle			
Front loader	18	30	1.6
Open container	12	26	0.5
Rear packer	12	24	0.4
Single unit truck	10	20	0.2
Single Rear Axle			
Rear packer	12	20	1.7
Single unit truck	8	10	0.1

Note:
[1]Load equivalency factors in parentheses are for tandem plus tag rear axle with the tag axle in the down position.
Other load equivalency factors are computed with the tag axle in the up position.

TABLE 2
COST DATA[1]

Improvement	$/1-Foot-Width/Mile	$/Square Foot
Maintenance		
Blading	1.20	.000227
Crack Sealing	110	.021019
Chip Sealing	400	.075668
Resurfacing		
Gravel[2]	900	.168150
Surface Treatment[3]	1,100	.210187
Asphalt[4]	2,700	.504451
Upgrade		
Gravel to Surface Treatment[3]	2,700	.210187
Gravel to Asphalt[4]	2,700	.504451
Surface Treatment to Asphalt[4]	2,700	.504451
Reconstruction[5]		
Asphalt	8,200	1.555390

Notes:

[1]Improvement costs from Local Roads Needs Study [21], adjusted for inflation.

[2]Includes 4 inches of gravel surfacing.

[3]Includes 6 inches of gravel, prime, chip seal.

[4]Includes 2.5 inches of asphalt.

[5]Reconstruction includes regrading of roadbed, new base and surfacing.

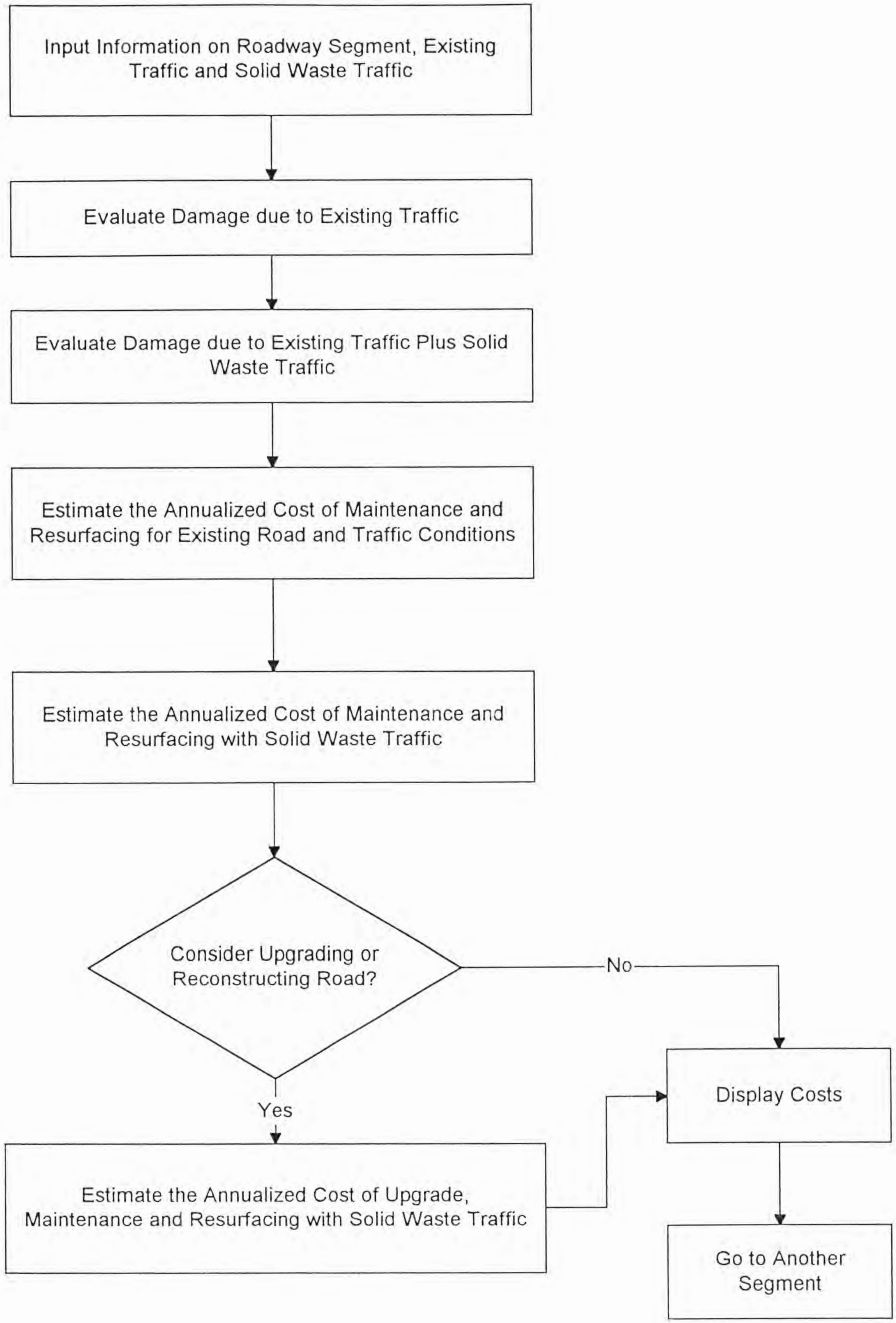


Figure 1. Heavy Vehicle Damage Cost Model Summary

TABLE A1
RAPID CITY LANDFILL
SOLID WASTE VEHICLE SUMMARY

	Vehicles Per Day				
	January	May	August	October	Average
Total Number of Vehicles	106	188	170	170	158
Total Number of Heavy Vehicles[1]	76	92	92	89	88
1-3 Axle Configuration					
Rear Packer	11	16	15	12	14
Open Container	15	15	19	12	15
Front Loader	7	8	10	9	8
1-2 Axle Configuration					
Rear Packer	17	20	19	22	20
Single Unit Truck	11	10	9	10	10
Front Loader	0	0	0	2	1
1-1 Axle Configuration					
Single Unit Truck	15	23	20	22	20
Other Vehicles					
Pickups/Vans/Cars	30	96	78	91	70
	Load Equivalency Factors				
1-3 Axle Configuration					
Rear Packer	1.16	1.37	1.46	1.29	1.32
Open Container	0.54	0.49	0.44	0.48	0.49
Front Loader	2.24	2.48	2.24	2.07	2.26
1-2 Axle Configuration					
Rear Packer	0.28	0.62	0.45	0.40	0.44
Single Unit Truck	0.16	0.17	0.16	0.10	0.15
Front Loader	--	--	--	1.55	1.55
1-1 Axle Configuration					
Single Unit Truck	--	--	0.06	0.07	0.07

[1]Heavy vehicles include all vehicles larger than pickups, vans or passenger cars.

TABLE A2
WATERTOWN LANDFILL
SOLID WASTE VEHICLE SUMMARY

	Vehicles Per Day				
	January	May	August	October	Average
Total Number of Vehicles	35	87	70	56	62
Total Number of Heavy Vehicles[1]	24	62	39	31	39
1-2 Axle Configuration					
Rear Packer	3	3	4	2	3
Single Unit Truck	1	1	1	1	1
Open Container	1	3	1	1	2
1-1 Axle Configuration					
Rear Packer	10	17	16	15	14
Single Unit Truck	9	38	17	12	19
Other Vehicles					
Pickups/Vans/Cars	11	25	31	25	23
	Load Equivalency Factors				
1-2 Axle Configuration					
Rear Packer	0.21	0.33	0.32	0.30	0.29
Open Container	0.69	0.56	0.41	0.38	0.51
1-1 Axle Configuration					
Rear Packer	1.35	2.27	1.81	1.52	1.74

[1]Heavy vehicles include all vehicles larger than pickups, vans or passenger cars.

APPENDIX B

QUESTIONNAIRES

Responder	Response
Clarence J. Fjeldheim City of Aberdeen 123 South Lincoln P.O. Box 1420 Aberdeen, SD 57402-1420	The city does not operate the landfill in this area. Brown County operates regional landfill. No changes to haul routes.
Michael Rye City of Watertown P.O. Box 910 Watertown, SD 57201-0910	All Watertown's landfill refuse will be coming into Watertown's landfill by state of South Dakota highways.
Thomas B. Darrell Jurrens Office of City Engineer 224 West 9th Street Sioux Falls, SD 57102	ADT 5,000 to 20,000 on 41st Street arterial. No other information available.
Jerry Wright City of Rapid City 300 6th Street Rapid City, SD 57704	ADT map for city attached. Average truck count to landfill - 100 trucks per day on SD79/US16.
Dennis Hintz Deuel County 400 5th Street West P.O. Box 616 Clear Lake, SD 57226	Information for county routes; ADTs 50 to 150, percent trucks 2 to 10, surface thickness, 1 to 4 inches, base thickness, 6 inches, no drainage problems, pavement surface condition good.
County Highway Superintendent Beadle County P.O. Box 165 Huron, SD 57350	County routes to landfill ADT 50 to 300, 50 percent trucks.

Tom Leinen Spink County Redfield, SD 57469	Spink County does not have any county roads used as solid waste haul routes.
Raymond K. Roggow Gregory County P.O. Box 425 Burke, SD 57523	No significant impact on county road system, all extra hauling on SR18.
Bill Dahlquist Walworth County Selby, SD 57472	County routes - aggregate-surfaced roads - surface thickness, 4 inches; base thickness, 6 inches; ADT 50, percent trucks 12 to 14. Other routes surface-treated or flexible pavements. ADT 20 to 230, percent trucks 4 to 28. All route surfaces adequate with normal maintenance.

TELEPHONE CONTACTS

Contact	Response
Larry Costeninski City Engineering Department Rapid City Pennington Co., SD (605) 394-4154	Aggregate alleys have 4 inches of aggregate and are bladed once a year with an approximate ADT of 35. No distinction between surface treated and asphalt concrete surfaced roads - all of these are being reconstructed as necessary to AASHTO pavement design specifications for ADTs and CBRs. ADTs on these roads similar to county road cases described.
David Padgett City of Pierre Hughes Co., SD (605) 224-5921	Aggregate alleys have 6 inches of aggregate. The alleys are bladed twice in the spring and once in the summer. Most of the problems are in the spring when the top few inches thaw and the remaining subgrade is still frozen. ADTs are 10 to 20. Flexible pavement roads have a typical section of 2 inches of asphalt and 6 inches of gravel base. There are no surface treated roads.
Clarence Fjeldheim City of Aberdeen Brown Co., SD (605) 622-7010	Aggregate alleys have 4 to 6 inches of aggregate and are bladed 6 to 8 times a year, mostly in spring and fall. ADTs range from 25 to 50. Surface-treated roads, called dustproof, are 1/2 to 3/4 inches for each treatment with a 12-inch-thick base. Flexible pavement sections have a maximum of 7 inches of asphalt concrete buildup over years. No ADT information is available.

Ron Olson City of Mitchell Davison Co., SD (605) 487-7390	Aggregate alleys have 3 inches of aggregate and are bladed 2 to 3 times a year. Ron does not perceive any damage from the solid waste trucks. Typical flexible pavement sections are 2 inches of asphalt and 6 inches of base. Very few blotter or surface-treated roads. ADTs similar to county road cases described.
Michael Rye City of Watertown Codington Co., SD (605) 886-8449	Aggregate alleys have 6 inches of gravel and are bladed 6 or more times a year. ADT is approximately 50. Typical paving sections constructed up to 1980 consist of 2 inches of asphalt and 6 inches of gravel base. Newer construction consists of 3 inches of asphalt and 9 inches of gravel base. Garbage trucks travel on state highways to the city of Watertown landfill.

TABLE C1
SOLID WASTE VEHICLE TRAFFIC IMPACTS
RAPID CITY LANDFILL

Aggregate-Surfaced Roads: 4-inch Surfacing
ADT = 50; Percent Trucks = 10
Failure Criterion: 2-inch Rut Depth

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)
Surfacing : CBR = 20	Existing Traffic	0.09	0
Subgrade : CBR = 10	10% Solid Waste Vehicles	0.03	66
	50% Solid Waste Vehicles	0.01	92
Surfacing : CBR = 20	Existing Traffic	0.15	0
Subgrade : CBR = 15	10% Solid Waste Vehicles	0.05	66
	50% Solid Waste Vehicles	0.01	92
Surfacing : CBR = 30	Existing Traffic	0.43	0
Subgrade : CBR = 10	10% Solid Waste Vehicles	0.13	70
	50% Solid Waste Vehicles	0.03	93
Surfacing : CBR = 30	Existing Traffic	0.69	0
Subgrade : CBR = 15	10% Solid Waste Vehicles	0.21	70
	50% Solid Waste Vehicles	0.05	93

TABLE C2
SOLID WASTE VEHICLE TRAFFIC IMPACTS
WATERTOWN LANDFILL

Aggregate-Surfaced Roads: 4-inch Surfacing
ADT = 50; Percent Trucks = 10
Failure Criterion: 2-inch Rut Depth

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)
Surfacing : CBR = 20	Existing Traffic	0.09	0
Subgrade : CBR = 10	10% Solid Waste Vehicles	0.04	56
	50% Solid Waste Vehicles	0.01	89
Surfacing : CBR = 20	Existing Traffic	0.15	0
Subgrade : CBR = 15	10% Solid Waste Vehicles	0.07	53
	50% Solid Waste Vehicles	0.02	87
Surfacing : CBR = 30	Existing Traffic	0.43	0
Subgrade : CBR = 10	10% Solid Waste Vehicles	0.20	53
	50% Solid Waste Vehicles	0.06	86
Surfacing : CBR = 30	Existing Traffic	0.69	0
Subgrade : CBR = 15	10% Solid Waste Vehicles	0.32	54
	50% Solid Waste Vehicles	0.10	86

TABLE C3
SOLID WASTE VEHICLE TRAFFIC IMPACTS
RAPID CITY LANDFILL

Surface-Treated Roads: 1/2-inch Surfacing; 6-inch Base
ADT = 100; Percent Trucks = 10
Failure Criterion: 1-inch Rut Depth

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)
Surfacing : E = 100 ksi	Existing Traffic	0.7	0
Base : E = 20 ksi	10% Solid Waste Vehicles	0.3	57
Subgrade : CBR = 10	50% Solid Waste Vehicles	0.1	84
	100% Solid Waste Vehicles	0.1	91
Surfacing : E = 100 ksi	Existing Traffic	1.2	0
Base : E = 20 ksi	10% Solid Waste Vehicles	0.5	58
Subgrade : CBR = 15	50% Solid Waste Vehicles	0.2	83
	100% Solid Waste Vehicles	0.1	92
Surfacing : E = 100 ksi	Existing Traffic	3.7	0
Base : E = 30 ksi	10% Solid Waste Vehicles	1.7	54
Subgrade : CBR = 10	50% Solid Waste Vehicles	0.6	84
	100% Solid Waste Vehicles	0.3	92
Surfacing : E = 100 ksi	Existing Traffic	6.0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	2.8	53
Subgrade : CBR = 15	50% Solid Waste Vehicles	0.9	85
	100% Solid Waste Vehicles	0.5	92

TABLE C4
SOLID WASTE VEHICLE TRAFFIC IMPACTS
RAPID CITY LANDFILL

Surface-Treated Roads: 1-inch Surfacing; 6-inch Base
ADT = 100; Percent Trucks = 10
Failure Criterion: 1-inch Rut Depth

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)
Surfacing : E = 100 ksi	Existing Traffic	2.7	0
Base : E = 20 ksi	10% Solid Waste Vehicles	1.3	52
Subgrade : CBR = 10	50% Solid Waste Vehicles	0.4	85
	100% Solid Waste Vehicles	0.2	93
Surfacing : E = 100 ksi	Existing Traffic	4.3	0
Base : E = 20 ksi	10% Solid Waste Vehicles	2.0	53
Subgrade : CBR = 15	50% Solid Waste Vehicles	0.6	86
	100% Solid Waste Vehicles	0.3	93
Surfacing : E = 100 ksi	Existing Traffic	9.9	0
Base : E = 30 ksi	10% Solid Waste Vehicles	4.6	54
Subgrade : CBR = 10	50% Solid Waste Vehicles	1.5	85
	100% Solid Waste Vehicles	0.8	92
Surfacing : E = 100 ksi	Existing Traffic	15.8	0
Base : E = 30 ksi	10% Solid Waste Vehicles	7.3	54
Subgrade : CBR = 15	50% Solid Waste Vehicles	2.3	85
	100% Solid Waste Vehicles	1.3	92

TABLE C5
SOLID WASTE VEHICLE TRAFFIC IMPACTS
RAPID CITY LANDFILL

Surface-Treated Roads: 1/2-inch Surfacing; 6-inch Base
ADT = 100; Percent Trucks = 20
Failure Criterion: 1-inch Rut Depth

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)
Surfacing : E = 100 ksi	Existing Traffic	0.4	0
Base : E = 20 ksi	10% Solid Waste Vehicles	0.2	50
Subgrade : CBR = 10	50% Solid Waste Vehicles	0.1	78
	100% Solid Waste Vehicles	0.1	88
Surfacing : E = 100 ksi	Existing Traffic	0.6	0
Base : E = 20 ksi	10% Solid Waste Vehicles	0.4	33
Subgrade : CBR = 15	50% Solid Waste Vehicles	0.2	67
	100% Solid Waste Vehicles	0.1	83
Surfacing : E = 100 ksi	Existing Traffic	1.9	0
Base : E = 30 ksi	10% Solid Waste Vehicles	1.2	37
Subgrade : CBR = 10	50% Solid Waste Vehicles	0.5	74
	100% Solid Waste Vehicles	0.3	84
Surfacing : E = 100 ksi	Existing Traffic	3.0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	1.9	37
Subgrade : CBR = 15	50% Solid Waste Vehicles	0.8	73
	100% Solid Waste Vehicles	0.4	87

TABLE C6
SOLID WASTE VEHICLE TRAFFIC IMPACTS
RAPID CITY LANDFILL

Surface-Treated Roads: 1-inch Surfacing; 6-inch Base
ADT = 100; Percent Trucks = 20
Failure Criterion: 1-inch Rut Depth

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)
Surfacing : E = 100 ksi	Existing Traffic	1.4	0
Base : E = 20 ksi	10% Solid Waste Vehicles	0.9	36
Subgrade : CBR = 10	50% Solid Waste Vehicles	0.3	79
	100% Solid Waste Vehicles	0.2	86
Surfacing : E = 100 ksi	Existing Traffic	2.2	0
Base : E = 20 ksi	10% Solid Waste Vehicles	1.4	36
Subgrade : CBR = 15	50% Solid Waste Vehicles	0.6	73
	100% Solid Waste Vehicles	0.3	86
Surfacing : E = 100 ksi	Existing Traffic	4.9	0
Base : E = 30 ksi	10% Solid Waste Vehicles	3.1	37
Subgrade : CBR = 10	50% Solid Waste Vehicles	1.3	73
	100% Solid Waste Vehicles	0.7	86
Surfacing : E = 100 ksi	Existing Traffic	7.9	0
Base : E = 30 ksi	10% Solid Waste Vehicles	5.0	37
Subgrade : CBR = 15	50% Solid Waste Vehicles	2.0	75
	100% Solid Waste Vehicles	1.2	85

TABLE C7
SOLID WASTE VEHICLE TRAFFIC IMPACTS
RAPID CITY LANDFILL

Surface-Treated Roads: 1/2-inch Surfacing; 6-inch Base
ADT = 150; Percent Trucks = 10
Failure Criterion: 1-inch Rut Depth

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)
Surfacing : E = 100 ksi	Existing Traffic	0.5	0
Base : E = 20 ksi	10% Solid Waste Vehicles	0.3	40
Subgrade : CBR = 10	50% Solid Waste Vehicles	0.1	80
	100% Solid Waste Vehicles	0.1	88
Surfacing : E = 100 ksi	Existing Traffic	0.8	0
Base : E = 20 ksi	10% Solid Waste Vehicles	0.4	50
Subgrade : CBR = 15	50% Solid Waste Vehicles	0.2	75
	100% Solid Waste Vehicles	0.1	88
Surfacing : E = 100 ksi	Existing Traffic	2.5	0
Base : E = 30 ksi	10% Solid Waste Vehicles	1.4	44
Subgrade : CBR = 10	50% Solid Waste Vehicles	0.5	80
	100% Solid Waste Vehicles	0.3	88
Surfacing : E = 100 ksi	Existing Traffic	4.0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	2.2	45
Subgrade : CBR = 15	50% Solid Waste Vehicles	0.8	80
	100% Solid Waste Vehicles	0.5	88

TABLE C8
SOLID WASTE VEHICLE TRAFFIC IMPACTS
RAPID CITY LANDFILL

Surface-Treated Roads: 1-inch Surfacing; 6-inch Base
ADT = 150; Percent Trucks = 10
Failure Criterion: 1-inch Rut Depth

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)
Surfacing : E = 100 ksi	Existing Traffic	1.8	0
Base : E = 20 ksi	10% Solid Waste Vehicles	1.0	44
Subgrade : CBR = 10	50% Solid Waste Vehicles	0.4	78
	100% Solid Waste Vehicles	0.2	89
Surfacing : E = 100 ksi	Existing Traffic	2.9	0
Base : E = 20 ksi	10% Solid Waste Vehicles	1.6	45
Subgrade : CBR = 15	50% Solid Waste Vehicles	0.6	79
	100% Solid Waste Vehicles	0.3	90
Surfacing : E = 100 ksi	Existing Traffic	6.6	0
Base : E = 30 ksi	10% Solid Waste Vehicles	3.7	44
Subgrade : CBR = 10	50% Solid Waste Vehicles	1.4	79
	100% Solid Waste Vehicles	0.8	88
Surfacing : E = 100 ksi	Existing Traffic	10.5	0
Base : E = 30 ksi	10% Solid Waste Vehicles	5.9	44
Subgrade : CBR = 15	50% Solid Waste Vehicles	2.2	79
	100% Solid Waste Vehicles	1.2	89

TABLE C9
SOLID WASTE VEHICLE TRAFFIC IMPACTS
RAPID CITY LANDFILL

Surface-Treated Roads: 1/2-inch Surfacing; 6-inch Base
ADT = 150; Percent Trucks = 20
Failure Criterion: 1-inch Rut Depth

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)
Surfacing : E = 100 ksi	Existing Traffic	0.2	0
Base : E = 20 ksi	10% Solid Waste Vehicles	0.2	25
Subgrade : CBR = 10	50% Solid Waste Vehicles	0.1	67
	100% Solid Waste Vehicles	0.1	79
Surfacing : E = 100 ksi	Existing Traffic	0.4	0
Base : E = 20 ksi	10% Solid Waste Vehicles	0.3	25
Subgrade : CBR = 15	50% Solid Waste Vehicles	0.1	68
	100% Solid Waste Vehicles	0.1	80
Surfacing : E = 100 ksi	Existing Traffic	1.2	0
Base : E = 30 ksi	10% Solid Waste Vehicles	0.9	25
Subgrade : CBR = 10	50% Solid Waste Vehicles	0.4	67
	100% Solid Waste Vehicles	0.3	75
Surfacing : E = 100 ksi	Existing Traffic	2.0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	1.4	30
Subgrade : CBR = 15	50% Solid Waste Vehicles	0.7	65
	100% Solid Waste Vehicles	0.4	80

TABLE C10
SOLID WASTE VEHICLE TRAFFIC IMPACTS
RAPID CITY LANDFILL

Surface-Treated Roads: 1-inch Surfacing; 6-inch Base
ADT = 150; Percent Trucks = 20
Failure Criterion: 1-inch Rut Depth

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)
Surfacing : E = 100 ksi	Existing Traffic	0.9	0
Base : E = 20 ksi	10% Solid Waste Vehicles	0.6	33
Subgrade : CBR = 10	50% Solid Waste Vehicles	0.3	67
	100% Solid Waste Vehicles	0.2	78
Surfacing : E = 100 ksi	Existing Traffic	1.4	0
Base : E = 20 ksi	10% Solid Waste Vehicles	1.0	29
Subgrade : CBR = 15	50% Solid Waste Vehicles	0.5	64
	100% Solid Waste Vehicles	0.3	79
Surfacing : E = 100 ksi	Existing Traffic	3.3	0
Base : E = 30 ksi	10% Solid Waste Vehicles	2.4	27
Subgrade : CBR = 10	50% Solid Waste Vehicles	1.1	67
	100% Solid Waste Vehicles	0.7	79
Surfacing : E = 100 ksi	Existing Traffic	5.3	0
Base : E = 30 ksi	10% Solid Waste Vehicles	3.8	28
Subgrade : CBR = 15	50% Solid Waste Vehicles	1.8	66
	100% Solid Waste Vehicles	1.1	79

TABLE C11
SOLID WASTE VEHICLE TRAFFIC IMPACTS
RAPID CITY LANDFILL

Surface-Treated Roads: 1-1/2-inch Surfacing; 6-inch Base
ADT = 500; Percent Trucks = 8
Failure Criterion: 1-inch Rut Depth

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)
Surfacing : E = 100 ksi	Existing Traffic	1.9	0
Base : E = 20 ksi	10% Solid Waste Vehicles	1.4	26
Subgrade : CBR = 10	50% Solid Waste Vehicles	0.8	58
	100% Solid Waste Vehicles	0.5	74
Surfacing : E = 100 ksi	Existing Traffic	3.0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	2.3	23
Subgrade : CBR = 15	50% Solid Waste Vehicles	1.2	60
	100% Solid Waste Vehicles	0.8	73
Surfacing : E = 100 ksi	Existing Traffic	5.5	0
Base : E = 30 ksi	10% Solid Waste Vehicles	4.2	24
Subgrade : CBR = 10	50% Solid Waste Vehicles	2.2	60
	100% Solid Waste Vehicles	1.4	74
Surfacing : E = 100 ksi	Existing Traffic	8.7	0
Base : E = 30 ksi	10% Solid Waste Vehicles	6.8	22
Subgrade : CBR = 15	50% Solid Waste Vehicles	3.6	59
	100% Solid Waste Vehicles	2.2	75

TABLE C12
SOLID WASTE VEHICLE TRAFFIC IMPACTS
WATERTOWN LANDFILL

Surface-Treated Roads: 1/2-inch Surfacing; 6-inch Base
ADT = 100; Percent Trucks = 10
Failure Criterion: 1-inch Rut Depth

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)
Surfacing : E = 100 ksi	Existing Traffic	0.7	0
Base : E = 20 ksi	10% Solid Waste Vehicles	0.5	29
Subgrade : CBR = 10	50% Solid Waste Vehicles	0.2	71
	100% Solid Waste Vehicles	0.1	86
Surfacing : E = 100 ksi	Existing Traffic	1.2	0
Base : E = 20 ksi	10% Solid Waste Vehicles	0.7	42
Subgrade : CBR = 15	50% Solid Waste Vehicles	0.3	75
	100% Solid Waste Vehicles	0.2	83
Surfacing : E = 100 ksi	Existing Traffic	3.7	0
Base : E = 30 ksi	10% Solid Waste Vehicles	2.4	35
Subgrade : CBR = 10	50% Solid Waste Vehicles	1.0	73
	100% Solid Waste Vehicles	0.6	84
Surfacing : E = 100 ksi	Existing Traffic	6.0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	3.8	37
Subgrade : CBR = 15	50% Solid Waste Vehicles	1.5	75
	100% Solid Waste Vehicles	0.9	85

TABLE C13
SOLID WASTE VEHICLE TRAFFIC IMPACTS
WATERTOWN LANDFILL

Surface-Treated Roads: 1-inch Surfacing; 6-inch Base
ADT = 100; Percent Trucks = 10
Failure Criterion: 1-inch Rut Depth

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)
Surfacing : E = 100 ksi	Existing Traffic	2.7	0
Base : E = 20 ksi	10% Solid Waste Vehicles	1.7	37
Subgrade : CBR = 10	50% Solid Waste Vehicles	0.7	74
	100% Solid Waste Vehicles	0.4	85
Surfacing : E = 100 ksi	Existing Traffic	4.3	0
Base : E = 20 ksi	10% Solid Waste Vehicles	2.7	37
Subgrade : CBR = 15	50% Solid Waste Vehicles	1.1	74
	100% Solid Waste Vehicles	0.6	86
Surfacing : E = 100 ksi	Existing Traffic	9.9	0
Base : E = 30 ksi	10% Solid Waste Vehicles	6.3	36
Subgrade : CBR = 10	50% Solid Waste Vehicles	2.6	74
	100% Solid Waste Vehicles	1.5	85
Surfacing : E = 100 ksi	Existing Traffic	15.8	0
Base : E = 30 ksi	10% Solid Waste Vehicles	10.0	37
Subgrade : CBR = 15	50% Solid Waste Vehicles	4.1	74
	100% Solid Waste Vehicles	2.3	85

TABLE C14
SOLID WASTE VEHICLE TRAFFIC IMPACTS
WATERTOWN LANDFILL

Surface-Treated Roads: 1/2-inch Surfacing; 6-inch Base
ADT = 100; Percent Trucks = 20
Failure Criterion: 1-inch Rut Depth

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)
Surfacing : E = 100 ksi	Existing Traffic	0.4	0
Base : E = 20 ksi	10% Solid Waste Vehicles	0.3	25
Subgrade : CBR = 10	50% Solid Waste Vehicles	0.2	63
	100% Solid Waste Vehicles	0.1	75
Surfacing : E = 100 ksi	Existing Traffic	0.6	0
Base : E = 20 ksi	10% Solid Waste Vehicles	0.5	17
Subgrade : CBR = 15	50% Solid Waste Vehicles	0.2	60
	100% Solid Waste Vehicles	0.2	75
Surfacing : E = 100 ksi	Existing Traffic	1.9	0
Base : E = 30 ksi	10% Solid Waste Vehicles	1.5	21
Subgrade : CBR = 10	50% Solid Waste Vehicles	0.8	58
	100% Solid Waste Vehicles	0.5	74
Surfacing : E = 100 ksi	Existing Traffic	3.0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	2.3	23
Subgrade : CBR = 15	50% Solid Waste Vehicles	1.2	60
	100% Solid Waste Vehicles	0.8	73

TABLE C15
SOLID WASTE VEHICLE TRAFFIC IMPACTS
WATERTOWN LANDFILL

Surface-Treated Roads: 1-inch Surfacing; 6-inch Base
ADT = 100; Percent Trucks = 20
Failure Criterion: 1-inch Rut Depth

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)
Surfacing : E = 100 ksi	Existing Traffic	1.4	0
Base : E = 20 ksi	10% Solid Waste Vehicles	1.0	29
Subgrade : CBR = 10	50% Solid Waste Vehicles	0.6	57
	100% Solid Waste Vehicles	0.3	78
Surfacing : E = 100 ksi	Existing Traffic	2.2	0
Base : E = 20 ksi	10% Solid Waste Vehicles	1.7	23
Subgrade : CBR = 15	50% Solid Waste Vehicles	0.9	59
	100% Solid Waste Vehicles	0.6	73
Surfacing : E = 100 ksi	Existing Traffic	4.9	0
Base : E = 30 ksi	10% Solid Waste Vehicles	3.8	23
Subgrade : CBR = 10	50% Solid Waste Vehicles	2.0	59
	100% Solid Waste Vehicles	1.3	73
Surfacing : E = 100 ksi	Existing Traffic	7.9	0
Base : E = 30 ksi	10% Solid Waste Vehicles	6.1	23
Subgrade : CBR = 15	50% Solid Waste Vehicles	3.2	59
	100% Solid Waste Vehicles	2.0	75

TABLE C16
SOLID WASTE VEHICLE TRAFFIC IMPACTS
WATERTOWN LANDFILL

Surface-Treated Roads: 1/2-inch Surfacing; 6-inch Base
ADT = 150; Percent Trucks = 10
Failure Criterion: 1-inch Rut Depth

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)
Surfacing : E = 100 ksi	Existing Traffic	0.5	0
Base : E = 20 ksi	10% Solid Waste Vehicles	0.4	20
Subgrade : CBR = 10	50% Solid Waste Vehicles	0.2	60
	100% Solid Waste Vehicles	0.1	80
Surfacing : E = 100 ksi	Existing Traffic	0.8	0
Base : E = 20 ksi	10% Solid Waste Vehicles	0.6	25
Subgrade : CBR = 15	50% Solid Waste Vehicles	0.3	63
	100% Solid Waste Vehicles	0.2	75
Surfacing : E = 100 ksi	Existing Traffic	2.5	0
Base : E = 30 ksi	10% Solid Waste Vehicles	1.8	28
Subgrade : CBR = 10	50% Solid Waste Vehicles	0.9	64
	100% Solid Waste Vehicles	0.5	80
Surfacing : E = 100 ksi	Existing Traffic	4.0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	2.9	28
Subgrade : CBR = 15	50% Solid Waste Vehicles	1.4	65
	100% Solid Waste Vehicles	0.8	80

TABLE C17
SOLID WASTE VEHICLE TRAFFIC IMPACTS
WATERTOWN LANDFILL

Surface-Treated Roads: 1-inch Surfacing; 6-inch Base
ADT = 150; Percent Trucks = 10
Failure Criterion: 1-inch Rut Depth

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)
Surfacing : E = 100 ksi	Existing Traffic	1.8	0
Base : E = 20 ksi	10% Solid Waste Vehicles	1.3	28
Subgrade : CBR = 10	50% Solid Waste Vehicles	0.6	67
	100% Solid Waste Vehicles	0.4	78
Surfacing : E = 100 ksi	Existing Traffic	2.9	0
Base : E = 20 ksi	10% Solid Waste Vehicles	2.1	28
Subgrade : CBR = 15	50% Solid Waste Vehicles	1.0	66
	100% Solid Waste Vehicles	0.6	79
Surfacing : E = 100 ksi	Existing Traffic	6.6	0
Base : E = 30 ksi	10% Solid Waste Vehicles	4.8	27
Subgrade : CBR = 10	50% Solid Waste Vehicles	2.3	65
	100% Solid Waste Vehicles	1.4	79
Surfacing : E = 100 ksi	Existing Traffic	10.5	0
Base : E = 30 ksi	10% Solid Waste Vehicles	7.6	28
Subgrade : CBR = 15	50% Solid Waste Vehicles	3.6	66
	100% Solid Waste Vehicles	2.2	79

TABLE C18
SOLID WASTE VEHICLE TRAFFIC IMPACTS
WATERTOWN LANDFILL

Surface-Treated Roads: 1/2-inch Surfacing; 6-inch Base
ADT = 150; Percent Trucks = 20
Failure Criterion: 1-inch Rut Depth

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)
Surfacing : E = 100 ksi	Existing Traffic	0.2	0
Base : E = 20 ksi	10% Solid Waste Vehicles	0.2	13
Subgrade : CBR = 10	50% Solid Waste Vehicles	0.1	50
	100% Solid Waste Vehicles	0.1	67
Surfacing : E = 100 ksi	Existing Traffic	0.4	0
Base : E = 20 ksi	10% Solid Waste Vehicles	0.3	25
Subgrade : CBR = 15	50% Solid Waste Vehicles	0.2	50
	100% Solid Waste Vehicles	0.1	75
Surfacing : E = 100 ksi	Existing Traffic	1.2	0
Base : E = 30 ksi	10% Solid Waste Vehicles	1.0	17
Subgrade : CBR = 10	50% Solid Waste Vehicles	0.6	50
	100% Solid Waste Vehicles	0.4	67
Surfacing : E = 100 ksi	Existing Traffic	2.0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	1.7	15
Subgrade : CBR = 15	50% Solid Waste Vehicles	1.0	50
	100% Solid Waste Vehicles	0.7	65

TABLE C19
SOLID WASTE VEHICLE TRAFFIC IMPACTS
WATERTOWN LANDFILL

Surface-Treated Roads: 1-inch Surfacing; 6-inch Base
ADT = 150; Percent Trucks = 20
Failure Criterion: 1-inch Rut Depth

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)
Surfacing : E = 100 ksi	Existing Traffic	0.9	0
Base : E = 20 ksi	10% Solid Waste Vehicles	0.8	11
Subgrade : CBR = 10	50% Solid Waste Vehicles	0.5	44
	100% Solid Waste Vehicles	0.3	67
Surfacing : E = 100 ksi	Existing Traffic	1.4	0
Base : E = 20 ksi	10% Solid Waste Vehicles	1.2	14
Subgrade : CBR = 15	50% Solid Waste Vehicles	0.7	50
	100% Solid Waste Vehicles	0.5	64
Surfacing : E = 100 ksi	Existing Traffic	3.3	0
Base : E = 30 ksi	10% Solid Waste Vehicles	2.8	15
Subgrade : CBR = 10	50% Solid Waste Vehicles	1.7	48
	100% Solid Waste Vehicles	1.1	67
Surfacing : E = 100 ksi	Existing Traffic	5.3	0
Base : E = 30 ksi	10% Solid Waste Vehicles	4.4	17
Subgrade : CBR = 15	50% Solid Waste Vehicles	2.7	49
	100% Solid Waste Vehicles	1.8	66

TABLE C20
SOLID WASTE VEHICLE TRAFFIC IMPACTS
WATERTOWN LANDFILL

Surface-Treated Roads: 1-1/2-inch Surfacing; 6-inch Base
ADT = 500; Percent Trucks = 8
Failure Criterion: 1-inch Rut Depth

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)
Surfacing : E = 100 ksi	Existing Traffic	1.9	0
Base : E = 20 ksi	10% Solid Waste Vehicles	1.6	16
Subgrade : CBR = 10	50% Solid Waste Vehicles	1.1	42
	100% Solid Waste Vehicles	0.8	58
Surfacing : E = 100 ksi	Existing Traffic	3.0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	2.6	13
Subgrade : CBR = 15	50% Solid Waste Vehicles	1.7	43
	100% Solid Waste Vehicles	1.2	60
Surfacing : E = 100 ksi	Existing Traffic	5.5	0
Base : E = 30 ksi	10% Solid Waste Vehicles	4.8	13
Subgrade : CBR = 10	50% Solid Waste Vehicles	3.2	42
	100% Solid Waste Vehicles	2.2	60
Surfacing : E = 100 ksi	Existing Traffic	8.7	0
Base : E = 30 ksi	10% Solid Waste Vehicles	7.6	13
Subgrade : CBR = 15	50% Solid Waste Vehicles	5.1	41
	100% Solid Waste Vehicles	3.6	59

TABLE C21
SOLID WASTE VEHICLE TRAFFIC IMPACTS
RAPID CITY LANDFILL

Flexible Pavement Roads: 2-inch Surfacing; 6-inch Base
ADT = 100; Percent Trucks = 10
Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life t_{max}=20 years[1] (percent)
Surfacing : E = 100 ksi	Existing Traffic	25	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	12	54	40
Subgrade : CBR = 10	50% Solid Waste Vehicles	4	85	80
	100% Solid Waste Vehicles	2	92	90
Surfacing : E = 100 ksi	Existing Traffic	49	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	23	53	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	7	86	65
	100% Solid Waste Vehicles	4	92	80
Surfacing : E = 100 ksi	Existing Traffic	29	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	14	54	30
Subgrade : CBR = 10	50% Solid Waste Vehicles	4	85	80
	100% Solid Waste Vehicles	2	92	90
Surfacing : E = 100 ksi	Existing Traffic	56	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	26	54	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	8	86	60
	100% Solid Waste Vehicles	4	93	80
Surfacing : E = 360 ksi	Existing Traffic	32	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	15	54	25
Subgrade : CBR = 10	50% Solid Waste Vehicles	5	85	75
	100% Solid Waste Vehicles	3	92	80
Surfacing : E = 360 ksi	Existing Traffic	60	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	28	53	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	9	85	55
	100% Solid Waste Vehicles	5	92	75
Surfacing : E = 360 ksi	Existing Traffic	37	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	17	54	15
Subgrade : CBR = 10	50% Solid Waste Vehicles	5	85	75
	100% Solid Waste Vehicles	3	92	85
Surfacing : E = 360 ksi	Existing Traffic	69	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	32	54	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	10	86	50
	100% Solid Waste Vehicles	5	93	75

Notes:

[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 years, the adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C22
SOLID WASTE VEHICLE TRAFFIC IMPACTS
RAPID CITY LANDFILL

Flexible Pavement Roads: 3-inch Surfacing; 6-inch Base
ADT = 100; Percent Trucks = 10
Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life t_{max}=20 years[1] (Percent)
Surfacing : E = 100 ksi	Existing Traffic	40	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	19	53	5
Subgrade : CBR = 10	50% Solid Waste Vehicles	6	85	70
	100% Solid Waste Vehicles	3	93	90
Surfacing : E = 100 ksi	Existing Traffic	74	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	34	54	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	11	85	45
	100% Solid Waste Vehicles	6	92	70
Surfacing : E = 100 ksi	Existing Traffic	46	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	21	54	0
Subgrade : CBR = 10	50% Solid Waste Vehicles	7	85	65
	100% Solid Waste Vehicles	4	91	80
Surfacing : E = 100 ksi	Existing Traffic	84	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	39	54	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	12	74	40
	100% Solid Waste Vehicles	7	92	65
Surfacing : E = 360 ksi	Existing Traffic	56	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	26	54	0
Subgrade : CBR = 10	50% Solid Waste Vehicles	8	86	60
	100% Solid Waste Vehicles	4	93	80
Surfacing : E = 360 ksi	Existing Traffic	99	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	46	54	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	15	85	25
	100% Solid Waste Vehicles	8	92	60
Surfacing : E = 360 ksi	Existing Traffic	63	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	29	54	0
Subgrade : CBR = 10	50% Solid Waste Vehicles	9	86	55
	100% Solid Waste Vehicles	5	92	75
Surfacing : E = 360 ksi	Existing Traffic	111	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	51	54	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	16	86	20
	100% Solid Waste Vehicles	9	92	55

Notes:
[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 years, the adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C23
SOLID WASTE VEHICLE TRAFFIC IMPACTS
RAPID CITY LANDFILL

Flexible Pavement Roads: 2-inch Surfacing; 6-inch Base
ADT = 100; Percent Trucks = 20
Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life t_{max}=20 years[1] (Percent)
Surfacing : E = 100 ksi	Existing Traffic	13	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	8	37	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	3	75	--
	100% Solid Waste Vehicles	2	85	--
Surfacing : E = 100 ksi	Existing Traffic	25	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	16	36	20
Subgrade : CBR = 15	50% Solid Waste Vehicles	6	76	60
	100% Solid Waste Vehicles	4	84	80
Surfacing : E = 100 ksi	Existing Traffic	15	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	9	37	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	4	74	--
	100% Solid Waste Vehicles	2	85	--
Surfacing : E = 100 ksi	Existing Traffic	28	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	18	36	10
Subgrade : CBR = 15	50% Solid Waste Vehicles	7	75	65
	100% Solid Waste Vehicles	4	86	80
Surfacing : E = 360 ksi	Existing Traffic	16	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	10	37	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	4	74	--
	100% Solid Waste Vehicles	2	85	--
Surfacing : E = 360 ksi	Existing Traffic	30	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	19	37	5
Subgrade : CBR = 15	50% Solid Waste Vehicles	8	73	60
	100% Solid Waste Vehicles	4	87	80
Surfacing : E = 360 ksi	Existing Traffic	18	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	12	36	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	5	74	--
	100% Solid Waste Vehicles	3	85	--
Surfacing : E = 360 ksi	Existing Traffic	34	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	22	35	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	9	74	55
	100% Solid Waste Vehicles	5	85	75

Notes:

[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 years, the adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C24
SOLID WASTE VEHICLE TRAFFIC IMPACTS
RAPID CITY LANDFILL

Flexible Pavement Roads: 3-inch Surfacing; 6-inch Base
ADT = 100; Percent Trucks = 20
Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life t_{max}=20 years[1] (Percent)
Surfacing : E = 100 ksi	Existing Traffic	20	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	13	35	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	5	75	--
	100% Solid Waste Vehicles	3	85	--
Surfacing : E = 100 ksi	Existing Traffic	37	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	23	38	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	10	73	50
	100% Solid Waste Vehicles	5	86	75
Surfacing : E = 100 ksi	Existing Traffic	23	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	15	35	25
Subgrade : CBR = 10	50% Solid Waste Vehicles	6	74	70
	100% Solid Waste Vehicles	3	87	85
Surfacing : E = 100 ksi	Existing Traffic	42	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	27	36	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	11	74	45
	100% Solid Waste Vehicles	6	86	70
Surfacing : E = 360 ksi	Existing Traffic	28	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	18	36	10
Subgrade : CBR = 10	50% Solid Waste Vehicles	7	75	65
	100% Solid Waste Vehicles	4	86	80
Surfacing : E = 360 ksi	Existing Traffic	49	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	31	37	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	13	73	35
	100% Solid Waste Vehicles	7	86	65
Surfacing : E = 360 ksi	Existing Traffic	32	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	20	40	0
Subgrade : CBR = 10	50% Solid Waste Vehicles	8	75	60
	100% Solid Waste Vehicles	5	84	75
Surfacing : E = 360 ksi	Existing Traffic	56	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	35	38	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	14	75	30
	100% Solid Waste Vehicles	8	86	60

Notes:

[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 years, the adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C25
SOLID WASTE VEHICLE TRAFFIC IMPACTS
RAPID CITY LANDFILL

Flexible Pavement Roads: 2-inch Surfacing; 6-inch Base
ADT = 200; Percent Trucks = 10
Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life t_{max}=20 years[1] (Percent)
Surfacing : E = 100 ksi	Existing Traffic	13	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	8	37	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	3	75	--
	100% Solid Waste Vehicles	2	85	--
Surfacing : E = 100 ksi	Existing Traffic	25	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	16	36	20
Subgrade : CBR = 15	50% Solid Waste Vehicles	6	76	70
	100% Solid Waste Vehicles	4	84	80
Surfacing : E = 100 ksi	Existing Traffic	15	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	9	37	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	4	74	--
	100% Solid Waste Vehicles	2	85	--
Surfacing : E = 100 ksi	Existing Traffic	28	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	18	36	10
Subgrade : CBR = 15	50% Solid Waste Vehicles	7	75	65
	100% Solid Waste Vehicles	4	86	80
Surfacing : E = 360 ksi	Existing Traffic	16	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	10	37	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	4	74	--
	100% Solid Waste Vehicles	2	85	--
Surfacing : E = 360 ksi	Existing Traffic	30	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	19	37	5
Subgrade : CBR = 15	50% Solid Waste Vehicles	8	73	60
	100% Solid Waste Vehicles	4	87	80
Surfacing : E = 360 ksi	Existing Traffic	18	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	12	36	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	5	74	--
	100% Solid Waste Vehicles	3	85	--
Surfacing : E = 360 ksi	Existing Traffic	34	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	22	35	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	9	74	55
	100% Solid Waste Vehicles	5	85	75

Notes:

[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 years, the adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C26
SOLID WASTE VEHICLE TRAFFIC IMPACTS
RAPID CITY LANDFILL

Flexible Pavement Roads: 3-inch Surfacing; 6-inch Base
ADT = 200; Percent Trucks = 10
Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life t_{nmax}=20 years[1] (Percent)
Surfacing : E = 100 ksi	Existing Traffic	20	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	13	35	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	5	75	--
	100% Solid Waste Vehicles	3	85	--
Surfacing : E = 100 ksi	Existing Traffic	37	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	23	38	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	10	73	50
	100% Solid Waste Vehicles	5	86	75
Surfacing : E = 100 ksi	Existing Traffic	23	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	15	35	25
Subgrade : CBR = 10	50% Solid Waste Vehicles	6	74	70
	100% Solid Waste Vehicles	3	87	85
Surfacing : E = 100 ksi	Existing Traffic	42	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	27	36	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	11	74	45
	100% Solid Waste Vehicles	6	86	70
Surfacing : E = 360 ksi	Existing Traffic	28	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	18	36	10
Subgrade : CBR = 10	50% Solid Waste Vehicles	7	75	65
	100% Solid Waste Vehicles	4	86	80
Surfacing : E = 360 ksi	Existing Traffic	49	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	31	37	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	13	73	35
	100% Solid Waste Vehicles	7	86	65
Surfacing : E = 360 ksi	Existing Traffic	32	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	20	40	0
Subgrade : CBR = 10	50% Solid Waste Vehicles	8	75	60
	100% Solid Waste Vehicles	5	84	75
Surfacing : E = 360 ksi	Existing Traffic	56	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	35	38	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	14	75	30
	100% Solid Waste Vehicles	8	86	60

Notes:

[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 years, the adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C27
SOLID WASTE VEHICLE TRAFFIC IMPACTS
RAPID CITY LANDFILL

Flexible Pavement Roads: 2-inch Surfacing; 6-inch Base
ADT = 200; Percent Trucks = 20
Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life t_{max}=20 years[1] (Percent)
Surfacing : E = 100 ksi	Existing Traffic	6	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	5	22	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	3	59	--
	100% Solid Waste Vehicles	2	75	--
Surfacing : E = 100 ksi	Existing Traffic	12	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	10	17	--
Subgrade : CBR = 15	50% Solid Waste Vehicles	5	58	--
	100% Solid Waste Vehicles	3	75	--
Surfacing : E = 100 ksi	Existing Traffic	7	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	6	22	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	3	55	--
	100% Solid Waste Vehicles	2	74	--
Surfacing : E = 100 ksi	Existing Traffic	14	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	11	21	--
Subgrade : CBR = 15	50% Solid Waste Vehicles	6	57	--
	100% Solid Waste Vehicles	4	71	--
Surfacing : E = 360 ksi	Existing Traffic	8	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	6	23	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	3	59	--
	100% Solid Waste Vehicles	2	74	--
Surfacing : E = 360 ksi	Existing Traffic	15	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	12	20	--
Subgrade : CBR = 15	50% Solid Waste Vehicles	6	60	--
	100% Solid Waste Vehicles	4	73	--
Surfacing : E = 360 ksi	Existing Traffic	9	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	7	22	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	4	59	--
	100% Solid Waste Vehicles	2	74	--
Surfacing : E = 360 ksi	Existing Traffic	17	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	13	24	--
Subgrade : CBR = 15	50% Solid Waste Vehicles	7	59	--
	100% Solid Waste Vehicles	4	76	--

Notes:

[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 years, the adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C28
SOLID WASTE VEHICLE TRAFFIC IMPACTS
RAPID CITY LANDFILL

Flexible Pavement Roads: 3-inch Surfacing; 6-inch Base
ADT = 200; Percent Trucks = 20
Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life t_{max}=20 years[1] (Percent)
Surfacing : E = 100 ksi	Existing Traffic	10	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	8	20	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	4	60	--
	100% Solid Waste Vehicles	3	70	--
Surfacing : E = 100 ksi	Existing Traffic	19	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	14	26	--
Subgrade : CBR = 15	50% Solid Waste Vehicles	8	58	--
	100% Solid Waste Vehicles	5	74	--
Surfacing : E = 100 ksi	Existing Traffic	12	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	9	25	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	5	58	--
	100% Solid Waste Vehicles	3	75	--
Surfacing : E = 100 ksi	Existing Traffic	21	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	16	24	20
Subgrade : CBR = 15	50% Solid Waste Vehicles	9	57	55
	100% Solid Waste Vehicles	5	76	75
Surfacing : E = 360 ksi	Existing Traffic	14	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	11	21	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	6	57	--
	100% Solid Waste Vehicles	4	71	--
Surfacing : E = 360 ksi	Existing Traffic	25	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	19	24	5
Subgrade : CBR = 15	50% Solid Waste Vehicles	10	60	50
	100% Solid Waste Vehicles	6	76	70
Surfacing : E = 360 ksi	Existing Traffic	16	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	12	25	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	6	63	--
	100% Solid Waste Vehicles	4	75	--
Surfacing : E = 360 ksi	Existing Traffic	28	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	22	21	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	11	61	45
	100% Solid Waste Vehicles	7	75	65

Notes:

[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 years, the adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C29
SOLID WASTE VEHICLE TRAFFIC IMPACTS
RAPID CITY LANDFILL

Flexible Pavement Roads: 3-inch Surfacing; 6-inch Base
ADT = 500; Percent Trucks = 10
Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life t_{max}=20 years[1] (Percent)
Surfacing : E = 360 ksi	Existing Traffic	11	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	9	18	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	5	55	--
	100% Solid Waste Vehicles	3	73	--
Surfacing : E = 360 ksi	Existing Traffic	20	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	18	10	--
Subgrade : CBR = 15	50% Solid Waste Vehicles	9	55	--
	100% Solid Waste Vehicles	6	70	--
Surfacing : E = 360 ksi	Existing Traffic	13	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	10	23	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	6	54	--
	100% Solid Waste Vehicles	4	69	--
Surfacing : E = 360 ksi	Existing Traffic	22	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	18	18	10
Subgrade : CBR = 15	50% Solid Waste Vehicles	10	55	50
	100% Solid Waste Vehicles	7	68	65

Notes:
[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 years, the adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C30
SOLID WASTE VEHICLE TRAFFIC IMPACTS
RAPID CITY LANDFILL

Flexible Pavement Roads: 4-inch Surfacing; 6-inch Base
ADT = 500; Percent Trucks = 10
Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life t_{max}=20 years[1] (Percent)
Surfacing : E = 360 ksi	Existing Traffic	18	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	15	17	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	9	50	--
	100% Solid Waste Vehicles	6	67	--
Surfacing : E = 360 ksi	Existing Traffic	31	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	25	19	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	14	55	30
	100% Solid Waste Vehicles	9	71	55
Surfacing : E = 360 ksi	Existing Traffic	21	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	17	19	15
Subgrade : CBR = 10	50% Solid Waste Vehicles	10	52	50
	100% Solid Waste Vehicles	6	71	70
Surfacing : E = 360 ksi	Existing Traffic	35	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	28	20	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	16	54	20
	100% Solid Waste Vehicles	10	71	50

Notes:

[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 years, the adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C31
SOLID WASTE VEHICLE TRAFFIC IMPACTS
RAPID CITY LANDFILL

Flexible Pavement Roads: 3-inch Surfacing; 12-inch Base

ADT = 500; Percent Trucks = 10

Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life t_{max}=20 years[1] (Percent)
Surfacing : E = 360 ksi	Existing Traffic	32	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	26	19	0
Subgrade : CBR = 10	50% Solid Waste Vehicles	15	54	25
	100% Solid Waste Vehicles	10	70	50
Surfacing : E = 360 ksi	Existing Traffic	52	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	42	19	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	24	54	0
	100% Solid Waste Vehicles	16	70	20
Surfacing : E = 360 ksi	Existing Traffic	40	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	32	19	0
Subgrade : CBR = 10	50% Solid Waste Vehicles	18	54	10
	100% Solid Waste Vehicles	12	70	40
Surfacing : E = 360 ksi	Existing Traffic	63	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	51	19	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	29	54	0
	100% Solid Waste Vehicles	19	70	5

Notes:

[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 years, the adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C32
SOLID WASTE VEHICLE TRAFFIC IMPACTS
RAPID CITY LANDFILL

Flexible Pavement Roads: 4-inch Surfacing; 12-inch Base

ADT = 500; Percent Trucks = 10

Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life $t_{max}=20$ years[1] (Percent)
Surfacing : E = 360 ksi	Existing Traffic	49	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	40	19	0
Subgrade : CBR = 10	50% Solid Waste Vehicles	23	54	0
	100% Solid Waste Vehicles	15	70	25
Surfacing : E = 360 ksi	Existing Traffic	76	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	62	19	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	35	54	0
	100% Solid Waste Vehicles	23	70	0
Surfacing : E = 360 ksi	Existing Traffic	59	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	48	19	0
Subgrade : CBR = 10	50% Solid Waste Vehicles	28	54	0
	100% Solid Waste Vehicles	18	70	10
Surfacing : E = 360 ksi	Existing Traffic	91	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	74	19	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	42	54	0
	100% Solid Waste Vehicles	27	70	0

Notes:

[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 years, the adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C33
SOLID WASTE VEHICLE TRAFFIC IMPACTS
RAPID CITY LANDFILL

Flexible Pavement Roads: 3-inch Surfacing; 6-inch Base
ADT = 2,000; Percent Trucks = 10
Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life $t_{max}=20$ years[1] (Percent)
Surfacing : E = 360 ksi	Existing Traffic	3	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	3	5	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	2	23	--
	100% Solid Waste Vehicles	2	37	--
Surfacing : E = 360 ksi	Existing Traffic	5	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	5	5	--
Subgrade : CBR = 15	50% Solid Waste Vehicles	4	22	--
	100% Solid Waste Vehicles	3	37	--
Surfacing : E = 360 ksi	Existing Traffic	3	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	3	5	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	2	23	--
	100% Solid Waste Vehicles	2	37	--
Surfacing : E = 360 ksi	Existing Traffic	6	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	5	5	--
Subgrade : CBR = 15	50% Solid Waste Vehicles	4	22	--
	100% Solid Waste Vehicles	4	37	--

Notes:
[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 years, the adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C34
SOLID WASTE VEHICLE TRAFFIC IMPACTS
RAPID CITY LANDFILL

Flexible Pavement Roads: 4-inch Surfacing; 6-inch Base
ADT = 2,000; Percent Trucks = 10
Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life t_{max}=20 years[1] (Percent)
Surfacing : E = 360 ksi	Existing Traffic	5	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	4	5	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	4	22	--
	100% Solid Waste Vehicles	3	37	--
Surfacing : E = 360 ksi	Existing Traffic	8	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	7	5	--
Subgrade : CBR = 15	50% Solid Waste Vehicles	6	22	--
	100% Solid Waste Vehicles	5	37	--
Surfacing : E = 360 ksi	Existing Traffic	5	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	5	5	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	4	22	--
	100% Solid Waste Vehicles	3	37	--
Surfacing : E = 360 ksi	Existing Traffic	9	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	8	5	--
Subgrade : CBR = 15	50% Solid Waste Vehicles	7	22	--
	100% Solid Waste Vehicles	5	37	--

Notes:

[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 years, the adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C35
SOLID WASTE VEHICLE TRAFFIC IMPACTS
RAPID CITY LANDFILL

Flexible Pavement Roads: 8-inch Surfacing; 6-inch Base
ADT = 2,000; Percent Trucks = 10
Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life t_{max}=20 years[1] (Percent)
Surfacing : E = 360 ksi	Existing Traffic	24	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	22	8	0
Subgrade : CBR = 10	50% Solid Waste Vehicles	18	25	10
	100% Solid Waste Vehicles	15	37	25
Surfacing : E = 360 ksi	Existing Traffic	35	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	33	6	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	27	23	0
	100% Solid Waste Vehicles	22	37	0
Surfacing : E = 360 ksi	Existing Traffic	26	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	25	4	0
Subgrade : CBR = 10	50% Solid Waste Vehicles	20	23	0
	100% Solid Waste Vehicles	16	38	20
Surfacing : E = 360 ksi	Existing Traffic	38	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	36	5	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	30	21	0
	100% Solid Waste Vehicles	24	32	0

Notes:
[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 years, the adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C36
SOLID WASTE VEHICLE TRAFFIC IMPACTS
RAPID CITY LANDFILL

Flexible Pavement Roads: 3-inch Surfacing; 12-inch Base
ADT = 2,000; Percent Trucks = 10
Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life t_{max}=20 years[1] (Percent)
Surfacing : E = 360 ksi	Existing Traffic	8	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	8	5	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	6	22	--
	100% Solid Waste Vehicles	5	37	--
Surfacing : E = 360 ksi	Existing Traffic	13	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	12	5	--
Subgrade : CBR = 15	50% Solid Waste Vehicles	10	22	--
	100% Solid Waste Vehicles	8	37	--
Surfacing : E = 360 ksi	Existing Traffic	10	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	9	5	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	8	22	--
	100% Solid Waste Vehicles	6	37	--
Surfacing : E = 360 ksi	Existing Traffic	16	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	15	5	--
Subgrade : CBR = 15	50% Solid Waste Vehicles	12	22	--
	100% Solid Waste Vehicles	10	37	--

Notes:

[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 years, the adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C37
SOLID WASTE VEHICLE TRAFFIC IMPACTS
RAPID CITY LANDFILL

Flexible Pavement Roads: 4-inch Surfacing; 12-inch Base
ADT = 2,000; Percent Trucks = 10
Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life t_{max}=20 years[1] (Percent)
Surfacing : E = 360 ksi	Existing Traffic	12	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	12	5	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	9	22	--
	100% Solid Waste Vehicles	8	37	--
Surfacing : E = 360 ksi	Existing Traffic	19	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	18	5	--
Subgrade : CBR = 15	50% Solid Waste Vehicles	15	22	--
	100% Solid Waste Vehicles	12	37	--
Surfacing : E = 360 ksi	Existing Traffic	15	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	14	5	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	12	22	--
	100% Solid Waste Vehicles	9	37	--
Surfacing : E = 360 ksi	Existing Traffic	23	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	21	5	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	18	22	10
	100% Solid Waste Vehicles	14	37	30

Notes:

[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 yeas, the adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C38
SOLID WASTE VEHICLE TRAFFIC IMPACTS
RAPID CITY LANDFILL

Flexible Pavement Roads: 8-inch Surfacing; 12-inch Base
ADT = 2,000; Percent Trucks = 10
Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life t_{max}=20 years[1] (Percent)
Surfacing : E = 360 ksi	Existing Traffic	50	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	47	5	0
Subgrade : CBR = 10	50% Solid Waste Vehicles	39	22	0
	100% Solid Waste Vehicles	32	37	0
Surfacing : E = 360 ksi	Existing Traffic	71	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	67	5	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	55	22	0
	100% Solid Waste Vehicles	45	37	0
Surfacing : E = 360 ksi	Existing Traffic	58	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	55	5	0
Subgrade : CBR = 10	50% Solid Waste Vehicles	45	22	0
	100% Solid Waste Vehicles	37	37	0
Surfacing : E = 360 ksi	Existing Traffic	82	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	77	5	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	63	22	0
	100% Solid Waste Vehicles	52	37	0

Notes:

[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 years, the adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C39
SOLID WASTE VEHICLE TRAFFIC IMPACTS
WATERTOWN LANDFILL

Flexible Pavement Roads: 2-inch Surfacing; 6-inch Base
ADT = 100; Percent Trucks = 10
Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life t_{max}=20 years[1] (Percent)
Surfacing : E = 100 ksi	Existing Traffic	25	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	16	37	20
Subgrade : CBR = 10	50% Solid Waste Vehicles	7	74	65
	100% Solid Waste Vehicles	4	85	80
Surfacing : E = 100 ksi	Existing Traffic	49	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	31	37	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	13	73	35
	100% Solid Waste Vehicles	7	86	65
Surfacing : E = 100 ksi	Existing Traffic	29	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	19	37	5
Subgrade : CBR = 10	50% Solid Waste Vehicles	8	74	60
	100% Solid Waste Vehicles	4	85	80
Surfacing : E = 100 ksi	Existing Traffic	56	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	36	36	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	14	75	30
	100% Solid Waste Vehicles	8	81	60
Surfacing : E = 360 ksi	Existing Traffic	32	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	20	37	0
Subgrade : CBR = 10	50% Solid Waste Vehicles	8	74	60
	100% Solid Waste Vehicles	5	85	75
Surfacing : E = 360 ksi	Existing Traffic	60	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	38	37	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	16	73	20
	100% Solid Waste Vehicles	9	85	55
Surfacing : E = 360 ksi	Existing Traffic	37	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	23	37	0
Subgrade : CBR = 10	50% Solid Waste Vehicles	10	74	50
	100% Solid Waste Vehicles	6	85	70
Surfacing : E = 360 ksi	Existing Traffic	69	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	44	36	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	18	74	10
	100% Solid Waste Vehicles	10	86	50

Notes:

[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 yeas, the adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C40
SOLID WASTE VEHICLE TRAFFIC IMPACTS
WATERTOWN LANDFILL

Flexible Pavement Roads: 3-inch Surfacing; 6-inch Base
ADT = 100; Percent Trucks = 10
Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life $t_{max}=20$ years (Percent)
Surfacing : E = 100 ksi	Existing Traffic	40	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	26	35	0
Subgrade : CBR = 10	50% Solid Waste Vehicles	10	75	50
	100% Solid Waste Vehicles	6	85	70
Surfacing : E = 100 ksi	Existing Traffic	74	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	47	36	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	19	74	5
	100% Solid Waste Vehicles	11	85	45
Surfacing : E = 100 ksi	Existing Traffic	46	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	29	37	0
Subgrade : CBR = 10	50% Solid Waste Vehicles	12	74	40
	100% Solid Waste Vehicles	7	85	65
Surfacing : E = 100 ksi	Existing Traffic	84	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	53	37	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	22	74	0
	100% Solid Waste Vehicles	12	86	40
Surfacing : E = 360 ksi	Existing Traffic	56	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	35	38	0
Subgrade : CBR = 10	50% Solid Waste Vehicles	14	75	30
	100% Solid Waste Vehicles	8	86	60
Surfacing : E = 360 ksi	Existing Traffic	99	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	63	36	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	25	75	0
	100% Solid Waste Vehicles	15	85	25
Surfacing : E = 360 ksi	Existing Traffic	63	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	40	37	0
Subgrade : CBR = 10	50% Solid Waste Vehicles	16	75	20
	100% Solid Waste Vehicles	9	86	65
Surfacing : E = 360 ksi	Existing Traffic	111	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	70	37	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	29	74	0
	100% Solid Waste Vehicles	16	86	20

Notes:

[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 years, the adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C41
SOLID WASTE VEHICLE TRAFFIC IMPACTS
WATERTOWN LANDFILL

Flexible Pavement Roads: 2-inch Surfacing; 6-inch Base
ADT = 100; Percent Trucks = 20
Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life t_{max}=20 years[1] (Percent)
Surfacing : E = 100 ksi	Existing Traffic	13	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	10	22	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	5	58	--
	100% Solid Waste Vehicles	3	74	--
Surfacing : E = 100 ksi	Existing Traffic	25	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	19	24	5
Subgrade : CBR = 15	50% Solid Waste Vehicles	10	60	50
	100% Solid Waste Vehicles	6	76	70
Surfacing : E = 100 ksi	Existing Traffic	15	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	11	22	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	6	59	--
	100% Solid Waste Vehicles	4	74	--
Surfacing : E = 100 ksi	Existing Traffic	28	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	22	21	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	11	61	45
	100% Solid Waste Vehicles	7	75	65
Surfacing : E = 360 ksi	Existing Traffic	16	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	12	23	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	7	59	--
	100% Solid Waste Vehicles	4	74	--
Surfacing : E = 360 ksi	Existing Traffic	30	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	23	23	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	12	60	40
	100% Solid Waste Vehicles	8	73	60
Surfacing : E = 360 ksi	Existing Traffic	18	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	14	22	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	8	59	--
	100% Solid Waste Vehicles	5	74	--
Surfacing : E = 360 ksi	Existing Traffic	34	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	27	21	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	14	59	30
	100% Solid Waste Vehicles	9	74	55

Notes:

[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 years, the adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C42
SOLID WASTE VEHICLE TRAFFIC IMPACTS
WATERTOWN LANDFILL

Flexible Pavement Roads: 3-inch Surfacing; 6-inch Base
ADT = 100; Percent Trucks = 20
Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life t_{max}=20 years (Percent)
Surfacing : E = 100 ksi	Existing Traffic	20	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	16	20	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	8	60	--
	100% Solid Waste Vehicles	5	75	--
Surfacing : E = 100 ksi	Existing Traffic	37	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	29	22	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	15	59	25
	100% Solid Waste Vehicles	10	73	50
Surfacing : E = 100 ksi	Existing Traffic	23	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	18	22	10
Subgrade : CBR = 10	50% Solid Waste Vehicles	9	61	55
	100% Solid Waste Vehicles	6	74	70
Surfacing : E = 100 ksi	Existing Traffic	42	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	33	21	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	17	60	15
	100% Solid Waste Vehicles	11	74	45
Surfacing : E = 360 ksi	Existing Traffic	28	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	22	21	0
Subgrade : CBR = 10	50% Solid Waste Vehicles	11	61	45
	100% Solid Waste Vehicles	7	75	65
Surfacing : E = 360 ksi	Existing Traffic	49	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	38	22	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	20	59	0
	100% Solid Waste Vehicles	13	73	35
Surfacing : E = 360 ksi	Existing Traffic	32	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	25	22	0
Subgrade : CBR = 10	50% Solid Waste Vehicles	13	59	35
	100% Solid Waste Vehicles	8	75	60
Surfacing : E = 360 ksi	Existing Traffic	56	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	43	23	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	23	59	0
	100% Solid Waste Vehicles	14	75	30

Notes:

[1]Where the time the failure calculated using the flexible pavement damage equation is greater than 20 years, the adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C43
SOLID WASTE VEHICLE TRAFFIC IMPACTS
WATERTOWN LANDFILL

Flexible Pavement Roads: 2-inch Surfacing; 6-inch Base
ADT = 200; Percent Trucks = 10
Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life t_{max}=20 years (Percent)
Surfacing : E = 100 ksi	Existing Traffic	13	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	10	22	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	5	58	--
	100% Solid Waste Vehicles	3	74	--
Surfacing : E = 100 ksi	Existing Traffic	25	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	19	24	5
Subgrade : CBR = 15	50% Solid Waste Vehicles	10	60	50
	100% Solid Waste Vehicles	6	76	70
Surfacing : E = 100 ksi	Existing Traffic	15	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	11	22	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	6	59	--
	100% Solid Waste Vehicles	4	74	--
Surfacing : E = 100 ksi	Existing Traffic	28	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	22	21	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	11	61	45
	100% Solid Waste Vehicles	7	75	65
Surfacing : E = 360 ksi	Existing Traffic	16	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	12	23	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	7	59	--
	100% Solid Waste Vehicles	4	74	--
Surfacing : E = 360 ksi	Existing Traffic	30	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	23	23	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	12	60	40
	100% Solid Waste Vehicles	8	73	60
Surfacing : E = 360 ksi	Existing Traffic	18	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	14	22	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	8	59	--
	100% Solid Waste Vehicles	5	74	--
Surfacing : E = 360 ksi	Existing Traffic	34	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	27	21	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	14	59	30
	100% Solid Waste Vehicles	9	74	55

Notes:

[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 years, the adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C44
SOLID WASTE VEHICLE TRAFFIC IMPACTS
WATERTOWN LANDFILL

Flexible Pavement Roads: 3-inch Surfacing; 6-inch Base
ADT = 200; Percent Trucks = 10
Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life t_{max}=20 years[1] (Percent)
Surfacing : E = 100 ksi	Existing Traffic	20	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	16	20	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	8	60	--
	100% Solid Waste Vehicles	5	75	--
Surfacing : E = 100 ksi	Existing Traffic	37	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	29	22	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	15	59	25
	100% Solid Waste Vehicles	10	73	50
Surfacing : E = 100 ksi	Existing Traffic	23	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	18	22	10
Subgrade : CBR = 10	50% Solid Waste Vehicles	9	61	55
	100% Solid Waste Vehicles	6	74	70
Surfacing : E = 100 ksi	Existing Traffic	42	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	33	21	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	17	60	15
	100% Solid Waste Vehicles	11	74	45
Surfacing : E = 360 ksi	Existing Traffic	28	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	22	21	0
Subgrade : CBR = 10	50% Solid Waste Vehicles	11	61	45
	100% Solid Waste Vehicles	7	75	65
Surfacing : E = 360 ksi	Existing Traffic	49	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	38	22	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	20	59	0
	100% Solid Waste Vehicles	13	73	35
Surfacing : E = 360 ksi	Existing Traffic	32	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	25	22	0
Subgrade : CBR = 10	50% Solid Waste Vehicles	13	59	35
	100% Solid Waste Vehicles	8	75	60
Surfacing : E = 360 ksi	Existing Traffic	56	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	43	23	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	23	59	0
	100% Solid Waste Vehicles	14	75	30

Notes:

[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 years, the adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C45
SOLID WASTE VEHICLE TRAFFIC IMPACTS
WATERTOWN LANDFILL

Flexible Pavement Roads: 2-inch Surfacing; 6-inch Base

ADT = 200; Percent Trucks = 20

Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life $t_{max}=20$ years[1] (Percent)
Surfacing : E = 100 ksi	Existing Traffic	6	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	5	13	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	4	41	--
	100% Solid Waste Vehicles	3	59	--
Surfacing : E = 100 ksi	Existing Traffic	12	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	11	8	--
Subgrade : CBR = 15	50% Solid Waste Vehicles	7	42	--
	100% Solid Waste Vehicles	5	58	--
Surfacing : E = 100 ksi	Existing Traffic	7	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	6	12	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	4	41	--
	100% Solid Waste Vehicles	3	59	--
Surfacing : E = 100 ksi	Existing Traffic	14	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	12	14	--
Subgrade : CBR = 15	50% Solid Waste Vehicles	8	43	--
	100% Solid Waste Vehicles	6	57	--
Surfacing : E = 360 ksi	Existing Traffic	8	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	6	31	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	5	43	--
	100% Solid Waste Vehicles	3	59	--
Surfacing : E = 360 ksi	Existing Traffic	15	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	11	27	--
Subgrade : CBR = 15	50% Solid Waste Vehicles	9	40	--
	100% Solid Waste Vehicles	6	60	--
Surfacing : E = 360 ksi	Existing Traffic	9	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	6	30	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	5	41	--
	100% Solid Waste Vehicles	4	59	--
Surfacing : E = 360 ksi	Existing Traffic	17	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	12	29	--
Subgrade : CBR = 15	50% Solid Waste Vehicles	10	41	--
	100% Solid Waste Vehicles	7	59	--

Notes:

[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 years, the adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C46
SOLID WASTE VEHICLE TRAFFIC IMPACTS
WATERTOWN LANDFILL

Flexible Pavement Roads: 3-inch Surfacing; 6-inch Base
ADT = 200; Percent Trucks = 20
Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life t_{max}=20 years[1] (Percent)
Surfacing : E = 100 ksi	Existing Traffic	10	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	9	10	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	6	40	--
	100% Solid Waste Vehicles	4	60	--
Surfacing : E = 100 ksi	Existing Traffic	19	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	16	16	--
Subgrade : CBR = 15	50% Solid Waste Vehicles	11	42	--
	100% Solid Waste Vehicles	8	59	--
Surfacing : E = 100 ksi	Existing Traffic	12	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	10	17	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	7	42	--
	100% Solid Waste Vehicles	5	58	--
Surfacing : E = 100 ksi	Existing Traffic	21	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	18	14	10
Subgrade : CBR = 15	50% Solid Waste Vehicles	12	43	40
	100% Solid Waste Vehicles	9	57	55
Surfacing : E = 360 ksi	Existing Traffic	14	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	9	36	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	8	43	--
	100% Solid Waste Vehicles	6	57	--
Surfacing : E = 360 ksi	Existing Traffic	25	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	16	36	20
Subgrade : CBR = 15	50% Solid Waste Vehicles	14	44	30
	100% Solid Waste Vehicles	10	60	50
Surfacing : E = 360 ksi	Existing Traffic	16	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	10	38	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	9	44	--
	100% Solid Waste Vehicles	6	63	--
Surfacing : E = 360 ksi	Existing Traffic	28	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	18	36	10
Subgrade : CBR = 15	50% Solid Waste Vehicles	16	43	20
	100% Solid Waste Vehicles	11	57	45

Notes:

[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 years, the adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C47
SOLID WASTE VEHICLE TRAFFIC IMPACTS
WATERTOWN LANDFILL

Flexible Pavement Roads: 3-inch Surfacing; 6-inch Base
ADT = 500; Percent Trucks = 10
Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life t_{max}=20 years[1] (Percent)
Surfacing : E = 360 ksi	Existing Traffic	11	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	10	9	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	7	36	--
	100% Solid Waste Vehicles	5	54	--
Surfacing : E = 360 ksi	Existing Traffic	20	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	18	10	--
Subgrade : CBR = 15	50% Solid Waste Vehicles	13	35	--
	100% Solid Waste Vehicles	9	55	--
Surfacing : E = 360 ksi	Existing Traffic	13	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	11	15	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	8	38	--
	100% Solid Waste Vehicles	6	54	--
Surfacing : E = 360 ksi	Existing Traffic	22	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	20	9	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	14	36	30
	100% Solid Waste Vehicles	10	55	50

Notes:

[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 years, the adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C48
SOLID WASTE VEHICLE TRAFFIC IMPACTS
WATERTOWN LANDFILL

Flexible Pavement Roads: 4-inch Surfacing; 6-inch Base
ADT = 500; Percent Trucks = 10
Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life t_{max}=20 years[1] (Percent)
Surfacing : E = 360 ksi	Existing Traffic	18	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	16	11	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	12	33	--
	100% Solid Waste Vehicles	9	50	--
Surfacing : E = 360 ksi	Existing Traffic	31	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	28	10	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	20	35	0
	100% Solid Waste Vehicles	14	55	30
Surfacing : E = 360 ksi	Existing Traffic	21	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	19	10	5
Subgrade : CBR = 10	50% Solid Waste Vehicles	13	38	35
	100% Solid Waste Vehicles	10	52	50
Surfacing : E = 360 ksi	Existing Traffic	35	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	31	11	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	22	37	0
	100% Solid Waste Vehicles	16	54	20

Notes:

[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 years, the adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C49
SOLID WASTE VEHICLE TRAFFIC IMPACTS
WATERTOWN LANDFILL

Flexible Pavement Roads: 3-inch Surfacing; 12-inch Base

ADT = 500; Percent Trucks = 10

Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life $t_{max}=20$ years[1] (Percent)
Surfacing : E = 360 ksi	Existing Traffic	32	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	29	10	0
Subgrade : CBR = 10	50% Solid Waste Vehicles	21	36	0
	100% Solid Waste Vehicles	15	54	25
Surfacing : E = 360 ksi	Existing Traffic	52	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	46	10	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	33	36	0
	100% Solid Waste Vehicles	24	54	0
Surfacing : E = 360 ksi	Existing Traffic	40	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	36	10	0
Subgrade : CBR = 10	50% Solid Waste Vehicles	25	36	0
	100% Solid Waste Vehicles	19	54	5
Surfacing : E = 360 ksi	Existing Traffic	63	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	56	10	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	40	36	0
	100% Solid Waste Vehicles	29	54	0

Notes:

[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 years, adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C50
SOLID WASTE VEHICLE TRAFFIC IMPACTS
WATERTOWN LANDFILL

Flexible Pavement Roads: 4-inch Surfacing; 12-inch Base

ADT = 500; Percent Trucks = 10

Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life t_{max}=20 years[1] (Percent)
Surfacing : E = 360 ksi	Existing Traffic	49	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	44	10	0
Subgrade : CBR = 10	50% Solid Waste Vehicles	31	36	0
	100% Solid Waste Vehicles	23	54	0
Surfacing : E = 360 ksi	Existing Traffic	76	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	68	10	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	48	36	0
	100% Solid Waste Vehicles	35	54	0
Surfacing : E = 360 ksi	Existing Traffic	59	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	53	10	0
Subgrade : CBR = 10	50% Solid Waste Vehicles	38	36	0
	100% Solid Waste Vehicles	29	54	0
Surfacing : E = 360 ksi	Existing Traffic	91	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	81	10	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	58	36	0
	100% Solid Waste Vehicles	42	54	0

Notes:

[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 years, adjusted reductior in life is calculated by seeting the time to failure equal to 20 years.

TABLE C51
SOLID WASTE VEHICLE TRAFFIC IMPACTS
WATERTOWN LANDFILL

Flexible Pavement Roads: 3-inch Surfacing; 6-inch Base
ADT = 2,000; Percent Trucks = 10
Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life t_{max}=20 years[1] (Percent)
Surfacing : E = 360 ksi	Existing Traffic	3	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	3	3	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	2	13	--
	100% Solid Waste Vehicles	2	22	--
Surfacing : E = 360 ksi	Existing Traffic	5	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	5	3	--
Subgrade : CBR = 15	50% Solid Waste Vehicles	4	13	--
	100% Solid Waste Vehicles	4	22	--
Surfacing : E = 360 ksi	Existing Traffic	3	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	3	3	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	3	13	--
	100% Solid Waste Vehicles	2	22	--
Surfacing : E = 360 ksi	Existing Traffic	6	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	5	3	--
Subgrade : CBR = 15	50% Solid Waste Vehicles	5	13	--
	100% Solid Waste Vehicles	4	22	--

Notes:

[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 years, the adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C52
SOLID WASTE VEHICLE TRAFFIC IMPACTS
WATERTOWN LANDFILL

Flexible Pavement Roads: 4-inch Surfacing; 6-inch Base
ADT = 2,000; Percent Trucks = 10
Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life t_{max}=20 years[1] (Percent)
Surfacing : E = 360 ksi	Existing Traffic	5	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	4	3	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	4	13	--
	100% Solid Waste Vehicles	4	22	--
Surfacing : E = 360 ksi	Existing Traffic	8	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	8	3	--
Subgrade : CBR = 15	50% Solid Waste Vehicles	7	13	--
	100% Solid Waste Vehicles	6	22	--
Surfacing : E = 360 ksi	Existing Traffic	5	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	5	3	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	5	13	--
	100% Solid Waste Vehicles	4	22	--
Surfacing : E = 360 ksi	Existing Traffic	9	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	8	3	--
Subgrade : CBR = 15	50% Solid Waste Vehicles	8	13	--
	100% Solid Waste Vehicles	7	22	--

Notes:

[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 years, adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C53
SOLID WASTE VEHICLE TRAFFIC IMPACTS
WATERTOWN LANDFILL

Flexible Pavement Roads: 8-inch Surfacing; 6-inch Base

ADT = 2,000; Percent Trucks = 10

Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life t_{max}=20 years[1] (Percent)
Surfacing : E = 360 ksi	Existing Traffic	24	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	23	4	0
Subgrade : CBR = 10	50% Solid Waste Vehicles	21	12	0
	100% Solid Waste Vehicles	18	25	10
Surfacing : E = 360 ksi	Existing Traffic	35	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	34	3	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	31	11	0
	100% Solid Waste Vehicles	27	23	0
Surfacing : E = 360 ksi	Existing Traffic	26	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	25	4	0
Subgrade : CBR = 10	50% Solid Waste Vehicles	23	11	0
	100% Solid Waste Vehicles	20	23	0
Surfacing : E = 360 ksi	Existing Traffic	38	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	37	3	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	33	13	0
	100% Solid Waste Vehicles	30	21	0

Notes:

[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 years, the adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C54
SOLID WASTE VEHICLE TRAFFIC IMPACTS
WATERTOWN LANDFILL

Flexible Pavement Roads: 3-inch Surfacing; 12-inch Base
ADT = 2,000; Percent Trucks = 10
Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life t_{max}=20 years[1] (Percent)
Surfacing : E = 360 ksi	Existing Traffic	8	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	8	3	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	7	13	--
	100% Solid Waste Vehicles	6	22	--
Surfacing : E = 360 ksi	Existing Traffic	13	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	13	3	--
Subgrade : CBR = 15	50% Solid Waste Vehicles	11	13	--
	100% Solid Waste Vehicles	10	22	--
Surfacing : E = 360 ksi	Existing Traffic	10	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	10	3	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	9	13	--
	100% Solid Waste Vehicles	8	22	--
Surfacing : E = 360 ksi	Existing Traffic	16	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	15	3	--
Subgrade : CBR = 15	50% Solid Waste Vehicles	14	13	--
	100% Solid Waste Vehicles	12	22	--

Notes:

[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 years, the adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C55
SOLID WASTE VEHICLE TRAFFIC IMPACTS
WATERTOWN LANDFILL

Flexible Pavement Roads: 4-inch Surfacing; 12-inch Base
ADT = 2,000; Percent Trucks = 10
Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life t_{max}=20 years[1] (Percent)
Surfacing : E = 360 ksi	Existing Traffic	12	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	12	3	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	11	13	--
	100% Solid Waste Vehicles	10	22	--
Surfacing : E = 360 ksi	Existing Traffic	19	0	--
Base : E = 20 ksi	10% Solid Waste Vehicles	19	3	--
Subgrade : CBR = 15	50% Solid Waste Vehicles	17	13	--
	100% Solid Waste Vehicles	15	22	--
Surfacing : E = 360 ksi	Existing Traffic	15	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	14	3	--
Subgrade : CBR = 10	50% Solid Waste Vehicles	13	13	--
	100% Solid Waste Vehicles	12	22	--
Surfacing : E = 360 ksi	Existing Traffic	23	0	--
Base : E = 30 ksi	10% Solid Waste Vehicles	22	3	--
Subgrade : CBR = 15	50% Solid Waste Vehicles	20	13	--
	100% Solid Waste Vehicles	18	22	--

Notes:

[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 years, the adjusted reduction in life is calculated by setting the time to failure equal to 20 years.

TABLE C56
SOLID WASTE VEHICLE TRAFFIC IMPACTS
WATERTOWN LANDFILL

Flexible Pavement Roads: 8-inch Surfacing; 12-inch Base
ADT = 2,000; Percent Trucks = 10
Failure Criterion: $p_t = 2.0$

Layer / Material Properties	Traffic Loading	Time to Failure (Years)	Reduction in Life (Percent)	Adjusted Reduction in Life t_{max}=20 years[1] (Percent)
Surfacing : E = 360 ksi	Existing Traffic	50	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	49	3	0
Subgrade : CBR = 10	50% Solid Waste Vehicles	44	13	0
	100% Solid Waste Vehicles	39	22	0
Surfacing : E = 360 ksi	Existing Traffic	71	0	0
Base : E = 20 ksi	10% Solid Waste Vehicles	69	3	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	62	13	0
	100% Solid Waste Vehicles	55	22	0
Surfacing : E = 360 ksi	Existing Traffic	58	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	57	3	0
Subgrade : CBR = 10	50% Solid Waste Vehicles	51	13	0
	100% Solid Waste Vehicles	45	22	0
Surfacing : E = 360 ksi	Existing Traffic	82	0	0
Base : E = 30 ksi	10% Solid Waste Vehicles	79	3	0
Subgrade : CBR = 15	50% Solid Waste Vehicles	71	13	0
	100% Solid Waste Vehicles	63	22	0

Notes:

[1]Where the time to failure calculated using the flexible pavement damage equation is greater than 20 years, adjusted reductior in life is calculated by setting the time to failure equal to 20 years.

APPENDIX D

EXAMPLE OF ESTIMATING DAMAGE COSTS

Road Segment Information

Black Hills Drive
Two-lane road
3.4-mile-long segment
11-foot-wide lanes
4-foot-wide paved shoulders

Pavement Structure Information

2 inches of hot-mix asphalt concrete,	E = 360 ksi
6 inches of crushed rock base,	E = 30 ksi
Silty sand subgrade,	E = 15 ksi, dry weather conditions
	E = 6 ksi, wet, thaw conditions

Existing Traffic Information

ADT = 250
% Trucks = 10

Additional Solid Waste Vehicles

5 rear packers
1-2 axle configuration

Failure Criteria

p_t = 2.0

Solution

1. Estimate the time to failure for the existing traffic using Equation 2:

$Nf,_{dry}$	=	87,746	
$N_{f,wet}$	=	29,903	
N_f	=	$.75\ Nf,_{dry} + .25\ Nf,_{wet}$	
N_f	=		**73,285 ESALs**
ESALs/day	=	1.088 × (250/2) × (.10)	
	=		**13.6 ESALs**
T_e	=	N_f/*ESALs/day*	
	=		**14.76 years**

2. Estimate the time to failure for the existing traffic plus the additional solid waste traffic:

Rear packer LEF	=	.446	
ESALs/day	=	5 × .446	
	=		**2.23 ESALs**
Total ESALs/day	=	2.23 + 13.6	
	=		**15.83 ESALs**
T_{sw}	=	N_f/*ESALs/day* × 1 year/365 days	
	=	73,285 / 15.83 × 1 / 365	
	=		**12.68 years**

3. Estimate the reduction in life

$$RL = \frac{T_e - T_{sw}}{T_e} \times 100\%$$

$$RL = [(14.76 - 12.68) / 14.76] \times 100\%$$

= **14.08%**

4. Identify the time between maintenance and resurfacing activities:

Crack sealing	-	2 years
Chip sealing	-	5 years
Overlay	-	15 years

5. Calculate the reduction in time between maintenance and resurfacing activities:

Crack sealing = (2 years) × (1 - RL)
= 2 × (1 - .1408)
= **1.72 years**

Chip sealing = (5 years) × (1 - .1408)
= **4.30 years**

Overlay = (10 years) × (1 -.1408)
= **8.59 years**

6. Estimate the annualized cost for MR&R activities for the existing traffic:

Cost of crack sealing:

C_{cr} = [($.021019) × (2 × 11 ft + 2 × 4 ft) × (3.4 mi × 5,280 ft/mi)]/2
= **$5,660**

Cost of chip sealing:

C_{ch} = [($.075668) × (2 × 11 ft + 2 × 4 ft) × (3.4 mi × 5,280 ft/mi)]/5
= **$8,150**

Cost of overlay:

C_{ov} = [($.504451) × (2 × 11 ft + 2 × 4 ft) × (3.4 mi × 5,280 ft/mi)]/10
= **$27,170**

Total cost of maintenance and resurfacing:

C_e = $5,660 + $8,150 + $27,170
= **$40,980**

7. Estimate the annualized cost for MR&R activities for existing plus solid waste traffic:

C_{sw} = \$40,980 / (1 - RL)
= **<u>\$47,700</u>**

8. The annualized incremental damage cost due to solid waste vehicles is:

Cinc = C_{sw} - C_e
= \$47,700 - \$40,980
= **<u>\$ 6,720</u>**

TABLE E1
SOLID WASTE VEHICLE DAMAGE COST ESTIMATES

Aggregate-Surfaced Roads
ADT = 50; Percent Trucks = 10

Pavement Structure Layer/Thickness/ Material Property	Estimated Annual Maintenance and Resurfacing Cost for Existing Traffic	Estimated Annual Maintenance and Resurfacing Cost for Existing Plus Solid Waste Traffic	Estimated Solid Waste Vehicle Damage Cost
Additional Vehicles: 10% of Solid Waste Vehicles from Watertown Landfill			
Surfacing: 4 inch, CBR = 20 Subgrade: CBR = 10	$10,970	$23,920	$12,950
Surfacing: 4 inch, CBR = 30 Subgrade: CBR = 15	$ 7,220	$15,750	$ 8,530
Additional Vehicles: 50% of Solid Waste Vehicles from Watertown Landfill			
Surfacing: 4 inch, CBR = 20 Subgrade: CBR = 10	$10,970	$75,840	$64,870
Surfacing: 4 inch, CBR = 30 Subgrade: CBR = 15	$ 7,220	$50,450	$43,230

TABLE E2
SOLID WASTE VEHICLE DAMAGE COST ESTIMATES

Surface-Treated Roads

ADT = 100; Percent Trucks = 10

Pavement Structure Layer/Thickness/ Material Property	Estimated Annual Maintenance and Resurfacing Cost for Existing Traffic	Estimated Annual Maintenance and Resurfacing Cost for Existing Traffic Plus Solid Waste Traffic	Estimated Solid Waste Vehicle Damage Cost
Additional Vehicles: 10% of Solid Waste Vehicles from Watertown Landfill			
Surfacing: 1/2 inch, E = 100 ksi Base: 6 inch; E = 20 ksi Subgrade: CBR = 10	$15,200	$23,940	$ 8,740
Surfacing: 1/2 inch, E = 100 ksi Base: 6 inch; E = 30 ksi Subgrade: CBR = 15	$ 8,270	$13,030	$ 4,760
Surfacing: 1 inch; E = 100 ksi Base: 6 inch; E = 20 ksi Subgrade: CBR = 10	$ 8,270	$13,030	$ 4,760
Surfacing: 1 inch; E = 100 ksi Base: 6 inch; E = 30 ksi Subgrade: CBR = 15	$ 4,840	$ 7,630	$ 2,790
Additional Vehicles: 50% of Solid Waste Vehicles from Watertown Landfill			
Surfacing: 1/2 inch, E = 100 ksi Base: 6 inch; E = 20 ksi Subgrade: CBR = 10	$15,200	$58,930	$43,730
Surfacing: 1/2 inch, E = 100 ksi Base: 6 inch; E = 30 ksi Subgrade: CBR = 15	$ 8,270	$32,080	$23,810
Surfacing: 1 inch; E = 100 ksi Base: 6 inch; E = 20 ksi Subgrade: CBR = 10	$ 8,270	$32,080	$23,810
Surfacing: 1 inch; E = 100 ksi Base: 6 inch; E = 30 ksi Subgrade: CBR = 15	$ 4,840	$18,780	$13,940

TABLE E3
SOLID WASTE VEHICLE DAMAGE COST ESTIMATES

Surface-Treated Roads

ADT = 150; Percent Trucks = 20

Pavement Structure Layer/Thickness/ Material Property	Estimated Annual Maintenance and Resurfacing Cost for Existing Traffic	Estimated Annual Maintenance and Resurfacing Cost for Existing Traffic Plus Solid Waste Traffic	Estimated Solid Waste Vehicle Damage Cost
Additional Vehicles: 10% of Solid Waste Vehicles from Watertown Landfill			
Surfacing: 1 inch, E = 100 ksi Base: 6 inch; E = 20 ksi Subgrade: CBR = 10	$15,200	$18,110	$ 2,910
Surfacing: 1 inch, E = 100 ksi Base: 6 inch; E = 30 ksi Subgrade: CBR = 15	$ 8,270	$ 9,860	$ 1,590
Additional Vehicles: 50% of Solid Waste Vehicles from Watertown Landfill			
Surfacing: 1 inch, E = 100 ksi Base: 6 inch; E = 20 ksi Subgrade: CBR = 10	$15,200	$29,770	$14,570
Surfacing: 1 inch, E = 100 ksi Base: 6 inch; E = 30 ksi Subgrade: CBR = 15	$ 8,270	16,210	$ 7,940

TABLE E4
SOLID WASTE VEHICLE DAMAGE COST ESTIMATES

Flexible Pavement Roads

ADT = 200; Percent Trucks = 10

Pavement Structure Layer/Thickness/ Material Property	Estimated Annual Maintenance and Resurfacing Cost for Existing Traffic	Estimated Annual Maintenance and Resurfacing Cost for Existing Traffic Plus Solid Waste Traffic	Estimated Solid Waste Vehicle Damage Cost
Additional Vehicles: 10% of Solid Waste Vehicles from Watertown Landfill			
Surfacing: 2 inch, E = 360 ksi Base: 6 inch; E = 20 ksi Subgrade: CBR = 10	$ 8,500	$10,950	$ 2,450
Surfacing: 2 inch, E = 360 ksi Base: 6 inch; E = 30 ksi Subgrade: CBR = 15	$ 7,500	$ 7,500	$ 0
Surfacing: 3 inch; E = 360 ksi Base: 6 inch; E = 20 ksi Subgrade: CBR = 10	$ 7,500	$ 7,500	$ 0
Surfacing: 3 inch; E = 360 ksi Base: 6 inch; E = 30 ksi Subgrade: CBR = 15	$ 7,500	$ 7,500	$ 0
Additional Vehicles: 50% of Solid Waste Vehicles from Watertown Landfill			
Surfacing: 2 inch, E = 360 ksi Base: 6 inch; E = 20 ksi Subgrade: CBR = 10	$ 8,500	$20,730	$12,230
Surfacing: 2 inch, E = 360 ksi Base: 6 inch; E = 30 ksi Subgrade: CBR = 15	$ 7,500	$10,720	$ 3,220
Surfacing: 3 inch; E = 360 ksi Base: 6 inch; E = 20 ksi Subgrade: CBR = 10	$ 7,500	$13,640	$ 6,140
Surfacing: 3 inch; E = 360 ksi Base: 6 inch; E = 30 ksi Subgrade: CBR = 15	$ 7,500	$ 7,500	$ 0

TABLE E5
SOLID WASTE VEHICLE DAMAGE COST ESTIMATES

Flexible Pavement Roads
ADT = 200; Percent Trucks = 20

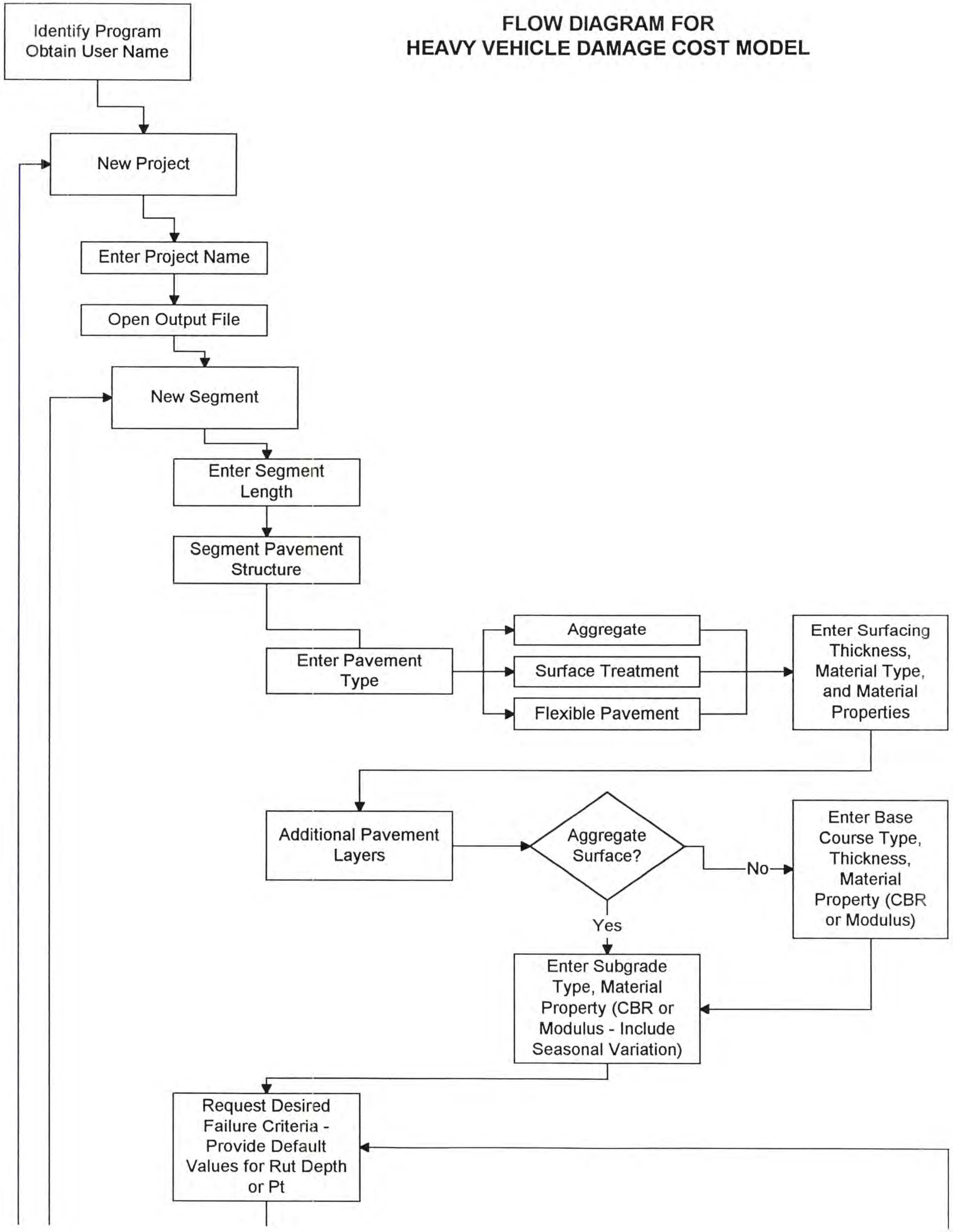
Pavement Structure Layer/Thickness/ Material Property	Estimated Annual Maintenance and Resurfacing Cost for Existing Traffic	Estimated Annual Maintenance and Resurfacing Cost for Existing Traffic Plus Solid Waste Traffic	Estimated Solid Waste Vehicle Damage Cost
Additional Vehicles: 10% of Solid Waste Vehicles from Watertown Landfill			
Surfacing: 2 inch, E = 360 ksi Base: 6 inch; E = 20 ksi Subgrade: CBR = 10	$14,050	$16,070	$ 2,020
Surfacing: 2 inch, E = 360 ksi Base: 6 inch; E = 30 ksi Subgrade: CBR = 15	$ 8,210	$ 9,390	$ 1,180
Surfacing: 3 inch; E = 360 ksi Base: 6 inch; E = 20 ksi Subgrade: CBR = 10	$ 9,770	$11,170	$ 1,400
Surfacing: 3 inch; E = 360 ksi Base: 6 inch; E = 30 ksi Subgrade: CBR = 15	$ 7,500	$ 7,500	$ 0
Additional Vehicles: 50% of Solid Waste Vehicles from Watertown Landfill			
Surfacing: 2 inch, E = 360 ksi Base: 6 inch; E = 20 ksi Subgrade: CBR = 10	$14,050	$24,160	$10,110
Surfacing: 2 inch, E = 360 ksi Base: 6 inch; E = 30 ksi Subgrade: CBR = 15	$ 8,210	$14,110	$ 5,900
Surfacing: 3 inch; E = 360 ksi Base: 6 inch; E = 20 ksi Subgrade: CBR = 10	$ 9,770	$16,800	$ 7,030
Surfacing: 3 inch; E = 360 ksi Base: 6 inch; E = 30 ksi Subgrade: CBR = 15	$ 7,500	$ 9,380	$ 1,880

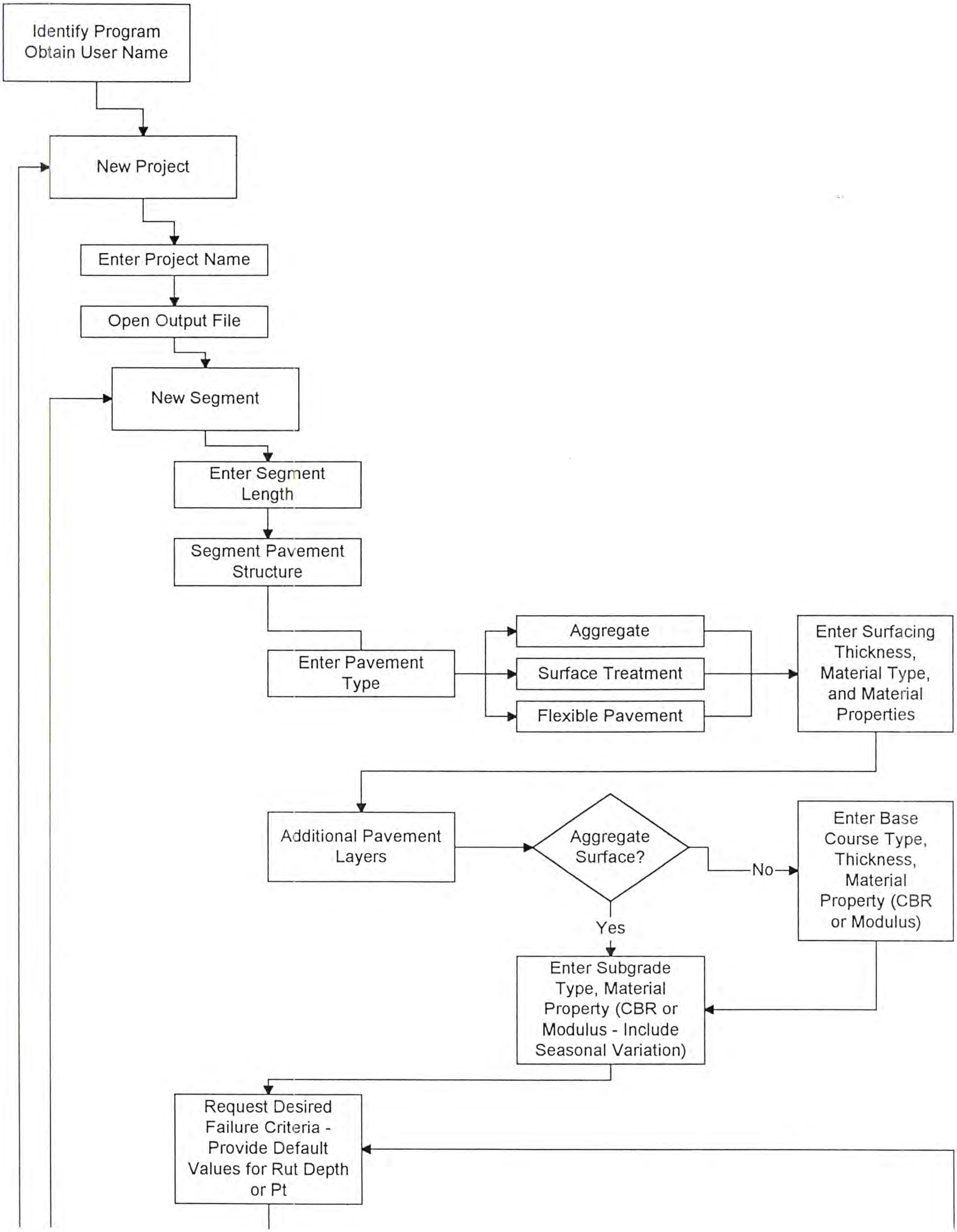
TABLE E6
SOLID WASTE VEHICLE DAMAGE COST ESTIMATES

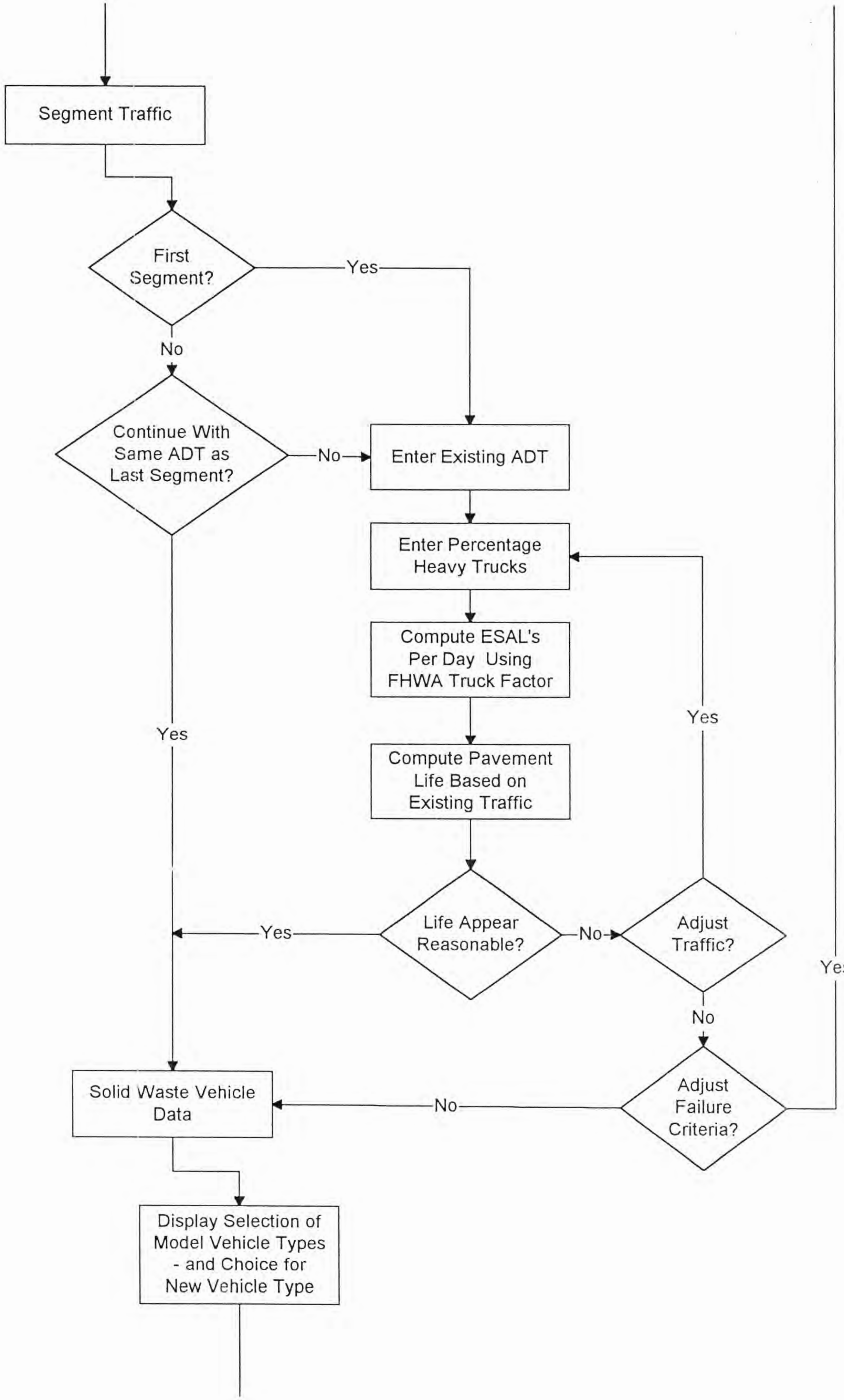
Flexible Pavement Roads
ADT = 500; Percent Trucks = 10

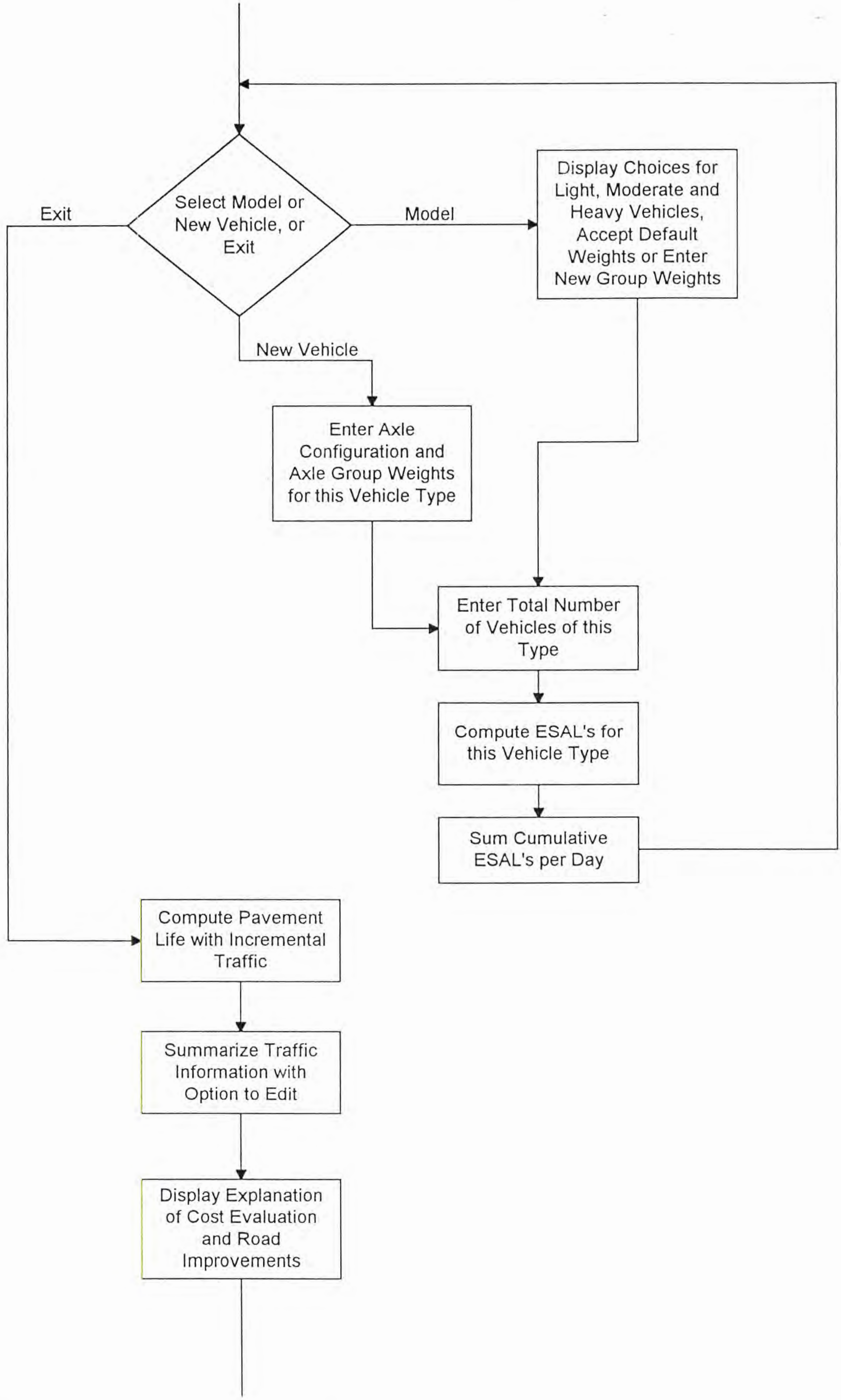
Pavement Structure Layer/Thickness/ Material Property	Estimated Annual Maintenance and Resurfacing Cost for Existing Traffic	Estimated Annual Maintenance and Resurfacing Cost for Existing Traffic Plus Solid Waste Traffic	Estimated Solid Waste Vehicle Damage Cost
Additional Vehicles: 10% of Solid Waste Vehicles from Watertown Landfill			
Surfacing: 3 inch, E = 360 ksi Base: 6 inch; E = 20 ksi Subgrade: CBR = 10	$11,920	$13,300	$ 1,380
Surfacing: 3 inch, E = 360 ksi Base: 6 inch; E = 30 ksi Subgrade: CBR = 15	$ 8,100	$ 8,100	$ 0
Surfacing: 3 inch; E = 360 ksi Base: 12 inch; E = 20 ksi Subgrade: CBR = 10	$ 8,100	$ 8,100	$ 0
Surfacing: 3 inch; E = 360 ksi Base: 12 inch; E = 30 ksi Subgrade: CBR = 15	$ 8,100	$ 8,100	$ 0
Additional Vehicles: 50% of Solid Waste Vehicles from Watertown Landfill			
Surfacing: 3 inch, E = 360 ksi Base: 6 inch; E = 20 ksi Subgrade: CBR = 10	$11,920	$18,740	$ 6,820
Surfacing: 3 inch, E = 360 ksi Base: 6 inch; E = 30 ksi Subgrade: CBR = 15	$ 8,100	$11,570	$ 3,470
Surfacing: 3 inch; E = 360 ksi Base: 12 inch; E = 20 ksi Subgrade: CBR = 10	$ 8,100	$ 8,100	$ 0
Surfacing: 3 inch; E = 360 ksi Base: 12 inch; E = 30 ksi Subgrade: CBR = 15	$ 8,100	$ 8,100	$ 0

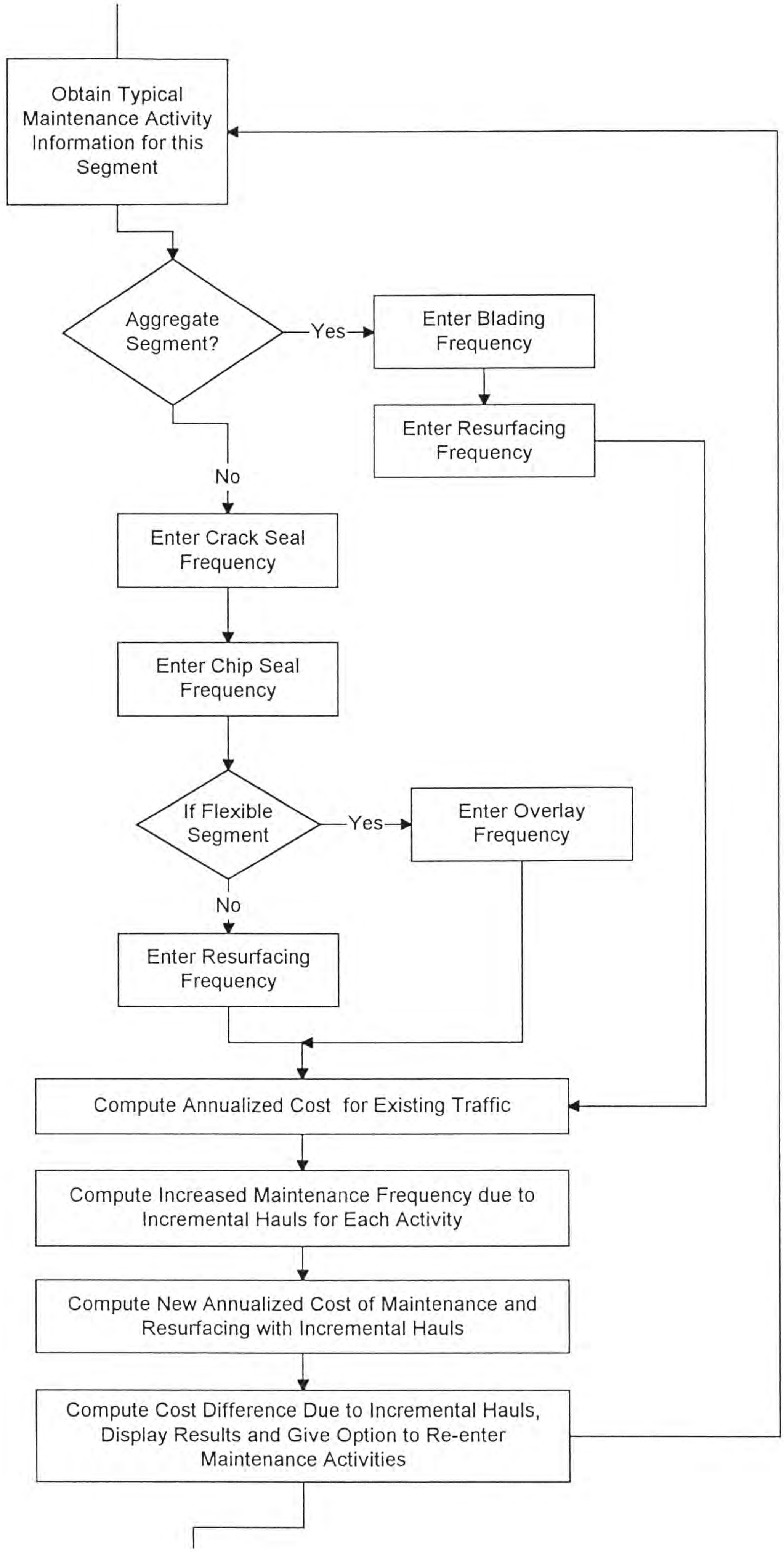
FLOW DIAGRAM FOR HEAVY VEHICLE DAMAGE COST MODEL

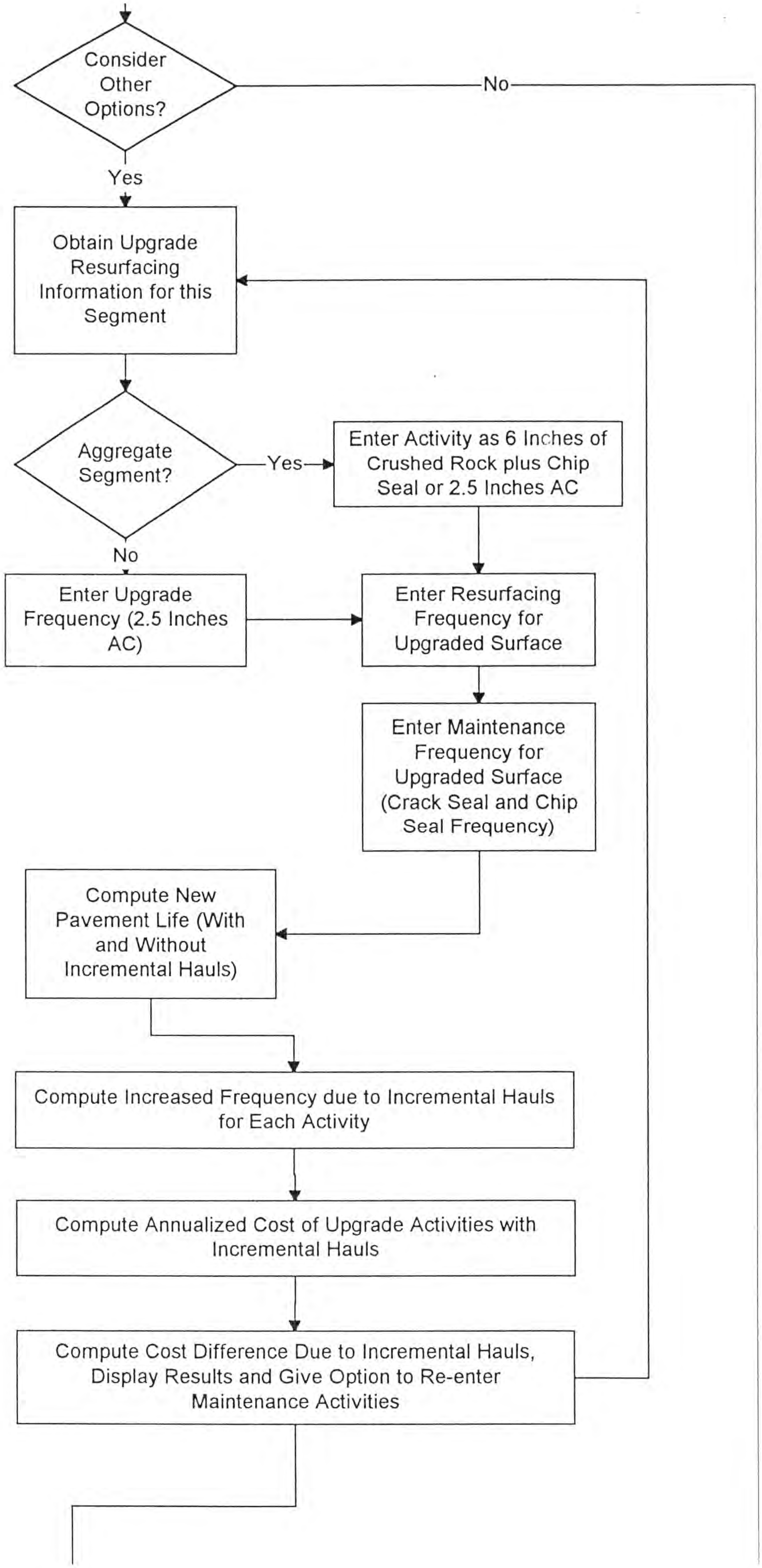


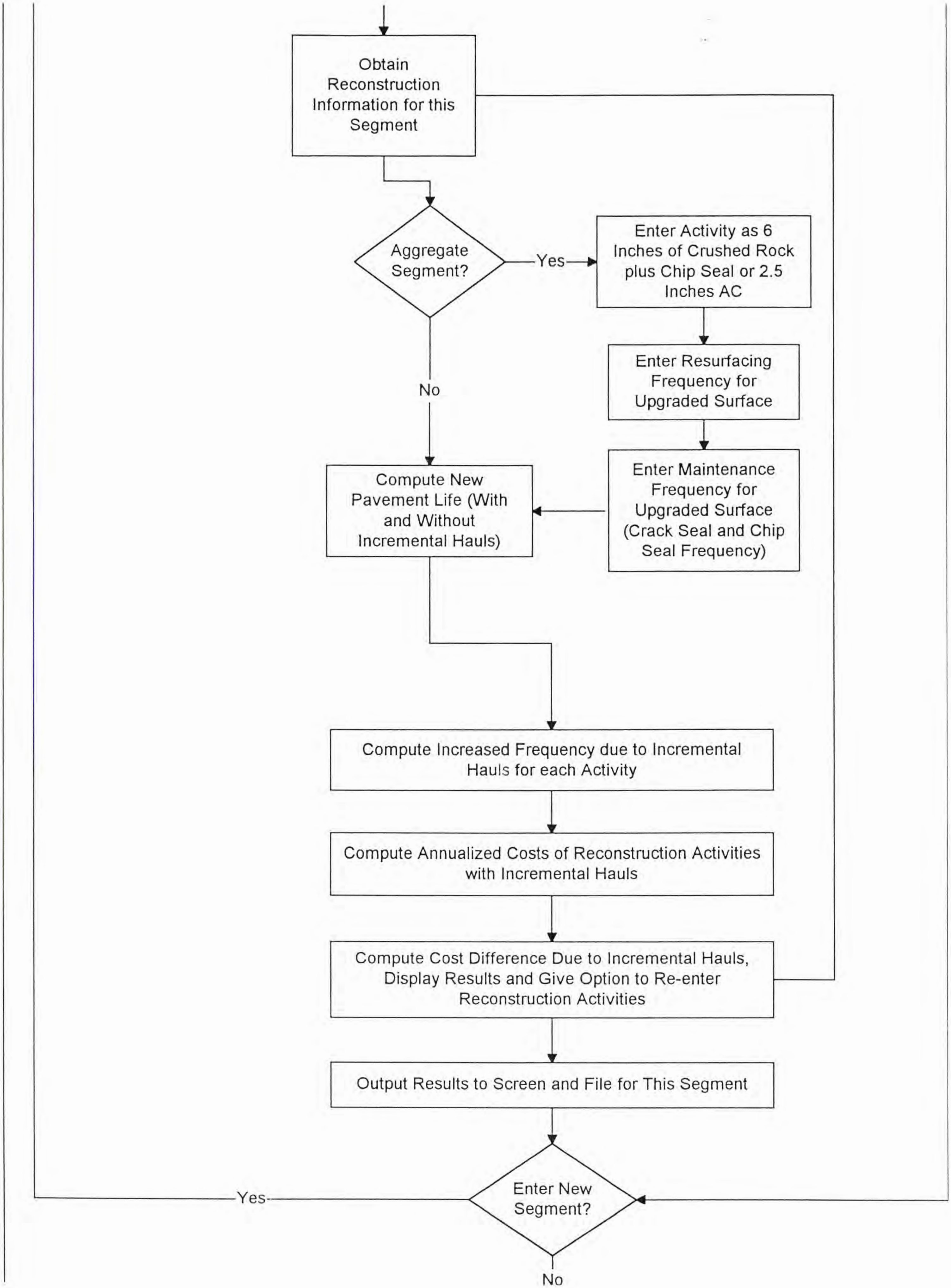

Identify Program
Obtain User Name
New Project
Enter Project Name
Open Output File
New Segment
Enter Segment Length
Segment Pavement Structure
Enter Pavement Type
Aggregate
Surface Treatment
Flexible Pavement
Enter Surfacing Thickness, Material Type, and Material Properties
Additional Pavement Layers
Aggregate Surface?
No
Yes
Enter Base Course Type, Thickness, Material Property (CBR or Modulus)
Enter Subgrade Type, Material Property (CBR or Modulus - Include Seasonal Variation)
Request Desired Failure Criteria - Provide Default Values for Rut Depth or Pt


Segment Traffic
First Segment?
Yes
No
Continue With Same ADT as Last Segment?
No
Enter Existing ADT
Enter Percentage Heavy Trucks
Compute ESAL's Per Day Using FHWA Truck Factor
Compute Pavement Life Based on Existing Traffic
Yes
Yes
Life Appear Reasonable?
Yes
No
Adjust Traffic?
Yes
No
Adjust Failure Criteria?
No
Solid Waste Vehicle Data
Display Selection of Model Vehicle Types - and Choice for New Vehicle Type

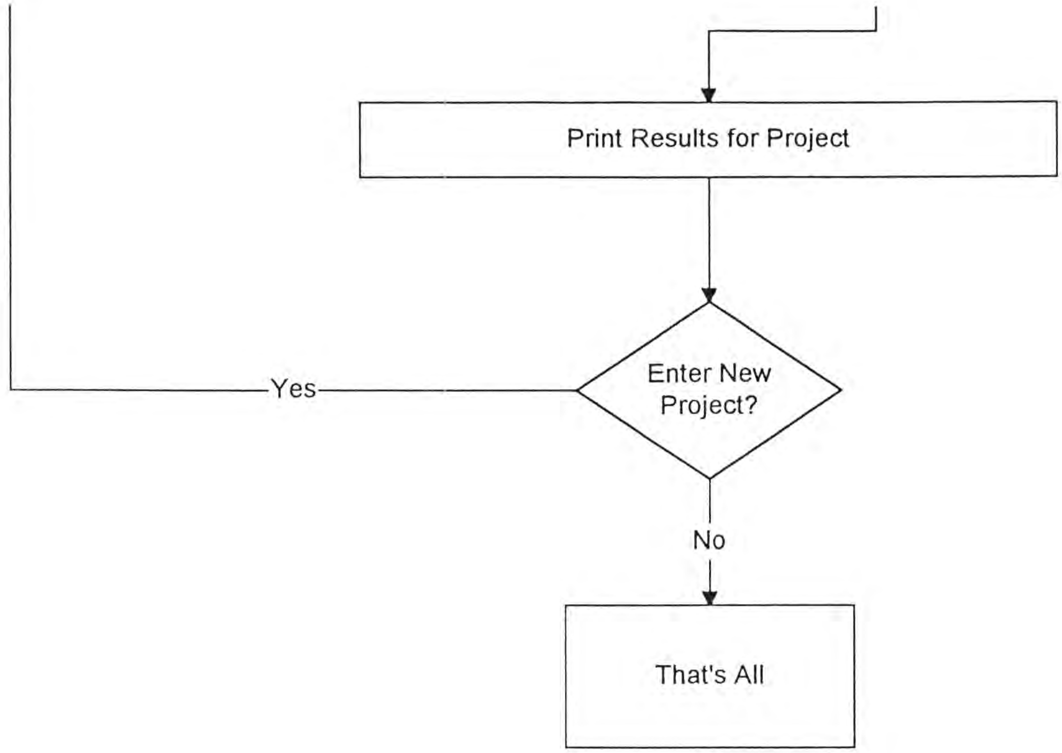

Select Model or New Vehicle, or Exit
Exit
Model
New Vehicle
Display Choices for Light, Moderate and Heavy Vehicles, Accept Default Weights or Enter New Group Weights
Enter Axle Configuration and Axle Group Weights for this Vehicle Type
Enter Total Number of Vehicles of this Type
Compute ESAL's for this Vehicle Type
Sum Cumulative ESAL's per Day
Compute Pavement Life with Incremental Traffic
Summarize Traffic Information with Option to Edit
Display Explanation of Cost Evaluation and Road Improvements


Obtain Typical Maintenance Activity Information for this Segment
Aggregate Segment?
Yes
Enter Blading Frequency
Enter Resurfacing Frequency
No
Enter Crack Seal Frequency
Enter Chip Seal Frequency
If Flexible Segment
Yes
Enter Overlay Frequency
No
Enter Resurfacing Frequency
Compute Annualized Cost for Existing Traffic
Compute Increased Maintenance Frequency due to Incremental Hauls for Each Activity
Compute New Annualized Cost of Maintenance and Resurfacing with Incremental Hauls
Compute Cost Difference Due to Incremental Hauls, Display Results and Give Option to Re-enter Maintenance Activities


Consider Other Options?
No
Yes
Obtain Upgrade Resurfacing Information for this Segment
Aggregate Segment?
Yes
Enter Activity as 6 Inches of Crushed Rock plus Chip Seal or 2.5 Inches AC
No
Enter Upgrade Frequency (2.5 Inches AC)
Enter Resurfacing Frequency for Upgraded Surface
Enter Maintenance Frequency for Upgraded Surface (Crack Seal and Chip Seal Frequency)
Compute New Pavement Life (With and Without Incremental Hauls)
Compute Increased Frequency due to Incremental Hauls for Each Activity
Compute Annualized Cost of Upgrade Activities with Incremental Hauls
Compute Cost Difference Due to Incremental Hauls, Display Results and Give Option to Re-enter Maintenance Activities



Obtain Reconstruction Information for this Segment
Aggregate Segment?
Yes
Enter Activity as 6 Inches of Crushed Rock plus Chip Seal or 2.5 Inches AC
Enter Resurfacing Frequency for Upgraded Surface
No
Enter Maintenance Frequency for Upgraded Surface (Crack Seal and Chip Seal Frequency)
Compute New Pavement Life (With and Without Incremental Hauls)
Compute Increased Frequency due to Incremental Hauls for each Activity
Compute Annualized Costs of Reconstruction Activities with Incremental Hauls
Compute Cost Difference Due to Incremental Hauls, Display Results and Give Option to Re-enter Reconstruction Activities
Output Results to Screen and File for This Segment
Yes
Enter New Segment?
No


Print Results for Project
Enter New Project?
Yes
No
That's All