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EXCOMP: An Exposure Comparison Methodology

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June 1986

**Prepared for the U.S. Department of Energy
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**Pacific Northwest Laboratory
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SUMMARY

EXCOMP is a computerized model that was developed to project occupational exposures based on conceptual designs for the Monitored Retrievable Storage (MRS) Facility. EXCOMP was developed to identify locations and operations in the facility that have a potential for significant occupational exposure rates. Unlike the computerized models that are currently used, EXCOMP is fast and provides the analyst more analysis flexibility.

The analyst has the option of evaluating the occupational exposures for an entire facility, specific work locations, personnel profiles based on employees' job descriptions, or the exposure potential of specific identified sources. Comparative analyses can be performed rapidly by initially analyzing the occupational exposures for a facility or a personnel profile and then modifying the database for selected specific work or source locations.

EXCOMP was developed to provide the analyst a tool that can be used to perform integrated facility evaluations of occupational and public exposures. EXCOMP provides estimates of exposure rates for the purpose of identifying areas with high exposure potential. These areas can be further evaluated using existing detailed exposure modeling computer codes or by performing "hands on" monitoring.

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1.0 INTRODUCTION

When designing new facilities or modifying existing facilities for handling or processing radioactive material, the radiological exposure of facility personnel and the general public must be carefully considered. The concept developed to control and monitor this exposure is called ALARA (as low as reasonably achievable). The objective of ALARA is to reduce the exposures to personnel and the general public to the lowest levels commensurate with sound economic and operating practices. Therefore, designers and licensing agencies need a method to determine if the ALARA concept has been applied when modifying facilities and when designing new facilities.

Computerized models are the principal method of applying the ALARA concept to a new design. The computerized models that are currently used for exposure evaluations are capable of evaluating only one relationship at a time, i.e., the effects of one source, its strength and location, on one work location. These relationships are user defined and are selected based on the user's judgment. When evaluating a work location that is affected by many sources, the use of current methods can be time consuming and costly. Furthermore, designers or licensees may not have the background to identify locations that should be evaluated or have at their disposal, the information or expertise necessary to perform an appropriate evaluation. Therefore, a need exists for better methods to identify areas and processes within a facility where the potential for significant exposures exist. The results of using this methodology provide a preliminary indication of the impact on occupational exposure from any proposed design work.

A methodology to evaluate exposures (EXCOMP, EXposure COMParison), sponsored by the Monitored Retrievable Storage (MRS) Program Office at Pacific Northwest Laboratory (PNL), was developed to meet these needs. This methodology, which is capable of evaluating each identified work location in a facility with respect to each identified source affecting it, was developed to provide a preliminary and comparative indication of the impacts of various facility designs on occupational exposures. The detail of the facility analyzed is limited by the detail and storage requirements of the database created by the user to characterize the facility. Creation of these databases requires

a knowledge of the facility layout and operations. The algorithms to calculate the exposure rates, based on distance and shielding are programmed into EXCOMP; therefore, the user will not be required to have a complete understanding of the effects of shielding and/or distance on the exposure received at each work location. EXCOMP simplifies exposure analysis procedures, reduces analysis time and costs, and makes analysis capabilities available to a wider range of potential users. EXCOMP is capable of performing an analysis based on a specific work location or on the complete facility, i.e., a floor by floor analysis, and is primarily intended to be used to perform comparative analyses. A comparative analysis requires an initial evaluation of the facility as currently designed or constructed and operated, followed by an analysis using a modified database to reflect each potential modification to the facility or to the radioactive material. The results from these analyses can be compared to determine if facility or material modifications will significantly reduce the exposures to personnel and the general public.

EXCOMP can perform analyses of exposures to personnel based on a user defined job description or personnel profile, as well as on individual target areas. The personnel profile analysis will project the total daily and quarterly exposure for a particular employee. The analyses performed in these operations are based on the same information used to evaluate the facility from the work or source location perspectives. By projecting employee exposures, EXCOMP provides a tool for management to analyze any opportunities to reduce exposure. Furthermore, decisions to restrict employee movements throughout the facility, or to increase staffing in operations with significant exposure potentials can be made on a more informed basis.

EXCOMP can be used effectively by the operator or the designer of any facility for the handling and storage of radioactive materials. EXCOMP does not require the user to have programming skills, but presently the user will need some knowledge of dBaseIII. In later versions of EXCOMP this requirement will be eliminated. The designer can use the results of the comparative analysis to specify facility modifications, i.e., increasing or decreasing shielding thickness, hence reducing or increasing construction costs. Licensees can use EXCOMP to identify areas where ALARA considerations should be well

documented. Facility management can use the personnel profile projections to aid in projecting staff requirements.

1.1 FUTURE APPLICATIONS

EXCOMP was designed to project occupational exposures at the Monitored Retrievable Storage (MRS) Facility. However, with some minor modifications to the program and new source descriptions, EXCOMP can be used to analyze other facilities and other radioactive or non-radioactive hazardous materials. The information necessary to modify the databases will be determined by the properties of the source and the hazards it represents. In the case of the MRS the hazard is radiological exposure or mrem/hr. For other hazardous materials the controlling factor(s) may be airborne limits or ppm or other limiting conditions of operation.

The essential structure of the methodology used to characterize the facility will remain unchanged. When evaluating different facilities, the new barriers may be filters, walls or containers constructed of different materials. Therefore, the user will be required to identify the new barriers based on their properties with respect to the new sources.

The majority of the changes required will be in the source characterization database. This database identifies the source location, characterizes the source strength, i.e. energy levels, parts per million and the quantity of material at the source location. Therefore, before creating the source database, for any analysis, the user will be required to identify the properties of the source. For airborne hazards this involves determining the various particle sizes and for liquid hazards this involves determining the composition of the solution.

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2.0 METHODOLOGY

The primary objective in creating EXCOMP was to provide the user a reasonable approximation of the exposure to be received by facility personnel and the general public due to the handling and storage of radioactive materials. By developing information for personnel profiles, work locations and the time spent at those locations, long and short term exposure rates can be projected for a typical employee. These anticipated or projected exposure rates can then be used to perform comparative analyses of the facility design.

EXCOMP has three components (see Figure 2.1). These consist of an interpreter, facility description and source description. The facility description database is used to identify the target locations and the source locations. The source locations identify locations where radioactive materials can be found. This includes hot cells, decon stations, waste processing areas, and lag or field storage locations. The target locations are the locations that are normally occupied by facility personnel. These locations may not necessarily contain sources of radioactive materials. Also identified in this database is the distance in feet and the sum of the thicknesses of the barriers or walls separating the source from the target location.

The source description database is used to identify the source locations, the source type, and to characterize the source with respect to the barriers. The source location is the same source location used in the facility description database. The source type is used for two purposes, the first is to verify that the proper type of source is used for each location, and the second is to establish the quantity of material found at that location. The source strength is characterized and identified as an adjusted MeV. This value is based on the energy levels of each source type and is adjusted by the attenuation value of the barriers present in the facility.

The interpreter prompts the user for the type of analysis to be performed. As an example, if the user is evaluating the total facility or specific work locations the interpreter module reads the facility database and identifies the first or specified target location. For each target location a number of source locations may be considered. When the first source location is identified for that target location, the interpreter module searches the source

FIGURE 2.1. Structure of EXCOMP

database for that source location. Then using the information in the facility database, i.e. distance to the source, and the thickness of shielding encountered, a radiological exposure is calculated based on the adjusted MeV with respect to the shielding encountered and the distance the target location is from the source. This process is repeated until each target-to-source relationship has been evaluated.

3.0 OUTPUT OPTIONS

There are four output options: total facility, specific work locations, specific source locations, and personnel profile. The total facility option is selected when performing the initial evaluation of the facility. The results of this evaluation are the basis of the comparative analysis and are also used to identify locations requiring further investigation or those locations with unacceptable exposure rates. The output from this evaluation (see Figure 3.1) identifies the target location (e.g. the room number), the source location, the distance to the target, the total shielding thickness, the personnel exposure rate, and the type or form of the radioactive material.

The specific work location option is used to examine the exposure potential of one work location. If this option is selected and no modifications have been made to the databases, the results will be identical to the results of the facility wide evaluation (see Figure 3.2). Therefore, this option should be selected when investigating a specific location to establish a base case for the comparative analysis or after modifying the facility database with respect to one or more work locations.

The specific source location is used when the investigator wants to adjust the quantity of material at a particular source location. This option does not alter the source database and is useful after performing a comparative analysis indicating that an increase in shielding or distance will not produce satisfactory exposure reductions. The user has the option to reduce or change the type or quantity of material found at that source location. The user also, has the option to increase the weight or type of material found at that source location (see Figure 3.3).

The personnel profile option is used when the user wants to investigate the exposure received by a specific employee type, i.e., manipulator operator, office staff, etc. This analysis provides projected exposure rates for the daily and quarterly exposures received at each of the employee's work locations (see Figure 3.4). These projected results are totaled to indicate the exposure rate an employee of a particular personnel profile will receive due to his/her movements throughout the facility.

Total Facility Analysis: Sample Facility

USER: USER1 RUN ID:001
 FSAMPLE.DBF SSAMPLE.DBF
 THIS EVALUATES THE DOSE FACILITY WIDE

<u>SOURCE LOCATION</u>	<u>DIST. TO TARGET (FT.)</u>	<u>SHIELDING THICKNESS (FT.)</u>	<u>CONTRIBUTION TO EXPOSURE (MREM/HR)</u>	<u>WASTE TYPE *</u>	<u>TOTAL</u>
ROOM 1000					
1100	25	5	1.047462E-04	LWR	
1102	60	12.5	1.256736E-10	PWR	
1103	70	14.4	5.890321E-14	HLW	1.047464E-04 MREM/HR
ROOM 1001					
1100	30	6.4	5.406448E-07	LWR	
1102	62	13.1	2.874943E-11	PWR	
1103	65	23.2	3.082993E-22	HLW	5.406735E-07 MREM/HR
ROOM 1002					
1002	43	14.8	6.358628E-17	LWR	
1102	70	18.9	5.503419E-17	PWR	
1103	65	12.5	5.570963E-12	HLW	5.571082E-12 MREM/HR
ROOM 1003					
1100	50	15.8	6.038932E-18	LWR	
1102	78	24.7	2.345117E-22	PWR	
1103	65	12.5	5.570963E-12	HLW	5.570969E-12 MREM/HR
ROOM 1004					
1100	38	10.7	1.414696E-12	LWR	
1102	15	5	1.689005	PWR	
1103	20	5	6.137475E-02	HLW	1.75038 MREM/HR
ROOM 10051					
1100	10	2.5	2.752627	LWR	
1102	25	5	1.216084	PWR	
1103	40	13	2.29251E-12	HLW	3.968711 MREM/HR
ROOM 10052					
1100	33	9.399999	4.628471E-11	LWR	
1102	40	13.1	3.799585E-11	PWR	
1103	28	5	4.801426E-02	HLW	4.801426E-02 MREM/HR

*

ARC--RECEIVED CASK
 BWR--ONE ASSEMBLY
 HLW--HIGH LEVEL WASTE

TRU--RECEIVED TRU
 CHE--CONTACT HANDLED
 LRW--LIQUID RAD WASTE
 EXPOSURE RATES <1E-35 ARE SHOWN AS 0.0

PWR--ONE ASSEMBLY
 RHE--REMOTE HANDLED
 SRW--SOLID RAD WASTE

FIGURE 3.1. Sample Facility Wide Evaluation

Location Specific Analysis: Sample Facility

USER: USER1 RUN ID:002
 FSAMPLE.DBF SSAMPLE.DBF
 THIS CALCULATES THE EXPOSURE AT WORK LOCATION(S) (2)

SOURCE LOCATION	DIST. TO TARGET (FT.)	SHIELDING THICKNESS (FT.)	CONTRIBUTION TO EXPOSURE (MREM/HR)	WASTE TYPE *	TOTAL
ROOM 1000					
1100	25	5	1.047462E-04	LWR	
1102	60	12.5	1.256736E-10	PWR	
1103	70	14.4	5.890321E-14	HLW	1.047464E-04 MREM/HR
ROOM 10052					
1100	33	9.399999	4.628471E-11	LRW	
1102	40	13.1	3.799585E-11	PWR	
1103	28	5	4.801426E-02	HLW	4.801426E-02 MREM/HR

*
 ARC--RECEIVED CASK TRU--RECEIVED TRU PWR--ONE ASSEMBLY
 BWR--ONE ASSEMBLY CHE--CONTACT HANDLED RHE--REMOTE HANDLED
 HLW--HIGH LEVEL WASTE LRW--LIQUID RAD WASTE SRW--SOLID RAD WASTE
 EXPOSURE RATES <1E-35 ARE SHOWN AS 0.0

FIGURE 3.2. Sample Specific Work Location

Specific Source Location Analysis: Sample Facility (Quantity of Material in 1102 Increased 2X)

USER: USER1 RUN ID:004
 FSAMPLE.DBF SSAMPLE.DBF
 THIS CALCULATES THE EXPOSURE DUE TO A SOURCE LOCATED IN 1102
 TYPE OF MATERIAL: PWR NEW WEIGHT: 924 KG.

TARGET LOCATION	DIST. TO TARGET (FT.)	SHIELDING THICKNESS (FT.)	CONTRIBUTION TO EXPOSURE (MREM/HR)	WASTE TYPE *
1000	60	12.5	2.513471E-10	PWR
1001	62	13.1	5.749886E-11	PWR
1002	70	18.9	1.100684E-16	PWR
1003	78	24.7	4.690235E-22	PWR
1004	15	5	3.378011	PWR
10051	25	5	2.432168	PWR
10052	40	13.1	7.59917E-11	PWR

*
 ARC--RECEIVED CASK TRU--RECEIVED TRU PWR--ONE ASSEMBLY
 BWR--ONE ASSEMBLY CHE--CONTACT HANDLED RHE--REMOTE HANDLED
 HLW--HIGH LEVEL WASTE LRW--LIQUID RAD WASTE SRW--SOLID RAD WASTE
 EXPOSURE RATES <1E-35 ARE SHOWN AS 0.0

FIGURE 3.3. Sample Specific Source Location

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SSAMPLE.DBF

4.0 APPLICATIONS OF EXCOMP

When using EXCOMP as a design or licensing tool, an initial evaluation of the total facility should be performed. This evaluation may identify areas with exposure rates that may warrant a more detailed analysis. Only if the primary objective is the evaluation of the exposure to a particular personnel type, is the initial facility wide evaluation optional. The initial total facility evaluation creates a base case for the comparative analyses that are performed with each design change.

4.1 DESIGN APPLICATION

Following the creation of the facility and the source databases, an initial evaluation is made of the total facility (see Figure 4.1). The results of this evaluation are analyzed to determine if the exposure levels are acceptable, i.e., less than or equal to DOE requirements, at each work location. If the exposure rates are unacceptable in easily identified work locations the designer can perform the specific work location analysis, thereby reducing the length of computer processing time. However, if the exposure rates are high throughout the facility the designer should re-evaluate and/or modify the facility and perform a new analysis of the total facility.

Assuming that the facility has been designed to handle specific materials, the designer will need to determine where and what facility modifications are required. The designer, without adjusting the process operations, has two options available. The first option is to increase the shielding or distances at specific locations or throughout the facility. The second option is to use new construction materials. If the designer selects either of these options, the databases will need to be modified to reflect these changes. If the designer changes the shielding thickness the specific work location analysis can be used to evaluate the changes. If a different construction material is used the source database will need to be modified. If there will be isolated changes, i.e., a new material is used for the walls of each hot cell, the adjusted MeV value, for each source location, will need to be modified to reflect the new attenuation value. However, if a new material will be used throughout the facility, the source strength or adjusted MeV value will need

FIGURE 4.1. Design Applications of EXCOMP

to be modified for all source locations to reflect the new attenuation value. For isolated changes in shielding material, the specific work location analysis can be used, reducing analysis time. If, after evaluating these changes, the exposure rates are still unacceptable the designer can repeat this process. However, after evaluating these modifications, the designer may decide to redesign the facility layout, perform a personnel profile analysis, or request a more detailed analysis of the facility using other more detailed analysis tools.

4.2 LICENSING APPLICATION

The licensing criteria for any facility is not based entirely on the exposure rates to the facility personnel or the public. However, exposure is a major consideration in granting an application for a license for a facility that handles radioactive materials. Therefore EXCOMP can be used to evaluate the exposure rates from a licensing agent's perspective (see Figure 4.2). If the licensing agent is unfamiliar with the exposure potential of a facility design, a facility-wide analysis can be performed to identify areas that may be of interest. EXCOMP can be used to further evaluate the exposure potential of these locations.

If the licensing agent has evaluated the facility using EXCOMP or has drawn some conclusions based on prior knowledge about the facility three options are available. The first option is to end the analysis and make recommendations, the second is to analyze specific locations in the facility, and the third is to investigate the exposure received by specific facility personnel. The results from the specific work location analysis or from the personnel profile analysis can be included in recommendations made by the agent. The results from each of these analyses can indicate areas requiring further investigations that can be performed using EXCOMP or other more detailed analysis tools.

It is important to note that the licensing agent's interests are not like those of the designer. The designer may modify the facility design and/or make recommendations regarding the proposed facility construction. The licensing agent is concerned about the established criteria regarding the exposure rates to the facility personnel and the public.

FIGURE 4.2. Licensing Applications of EXCOMP

4.3 PERSONNEL APPLICATIONS

Management can use EXCOMP to determine personnel needs throughout the facility based on an employee's work location or the time an employee is at a specific work location. The personnel profile analysis requires the investigator to identify a personnel type and the average hours per day an employee will be at a specific work location (see Figure 4.3). The personnel profile analysis will project the daily and quarterly exposures received for each personnel type investigated. Using these projections, management can determine the personnel requirements and assignments to operate the facility within the required exposure limits. When evaluating the results derived from an EXCOMP analysis, management can identify specific work locations where high exposures are expected. With this information, management can perform a location specific analysis to confirm the results or request design changes to reduce personnel requirements.

Although each type of analysis will use the same database the results required by each are different. Designers can use EXCOMP to substantiate the proposed facility design or recommend or initiate design changes. Licensing agents can use EXCOMP to evaluate the exposures to facility personnel and the public to determine if the criteria regarding exposure limits have been satisfied. If the criteria have not been satisfied, design recommendations, based on EXCOMP results, can be forwarded to the designer. Management can use EXCOMP to predict exposures to specific personnel and can also provide the designer with the information necessary to initiate design changes to reduce the need for personnel.

4.4 COMPARATIVE ANALYSES

The design, licensing and personnel applications all can use EXCOMP to perform a comparative analysis. When performing a comparative analysis it is important that only those elements that the user wants to modify be changed. EXCOMP operates on this basic principle if the proposed change is a facility modification, the characteristics and assumptions used to describe the source are not changed.

FIGURE 4.3 Personnel Applications of EXCOMP

The comparative analysis can be used by the designer and management before changing the facility design or operation. As each investigator determines some change is appropriate a new EXCOMP analysis can be performed. The results from these analyses can be compared to the first or original analysis to determine the changes in exposure rates. When analyses are performed before facility construction, they can later reduce costs if the completed facility has to be modified or if new personnel are added to operate the facility.

5.0 PROGRAM DESCRIPTION

The interpreter in EXCOMP is a computer program that interfaces with two databases and extracts the information required to perform an exposure analysis (see Figure 2.1). Given a user specified work location, EXCOMP will search the source database until the source location(s) corresponding to the work location is found. The main program, referred to as the interpreter module, controls the database searches and calculates the exposure rates at various locations throughout the facility. The user sets the parameters controlling the search, based on the option selected. The options available are a total facility analysis, a specific work location analysis, a specific source location analysis, and a particular personnel profile analysis. The methods used to calculate the exposure rates for each of these options are basically the same. However, the total facility, specific work location and specific source location analyses predict the exposure rate per hour to facility personnel, and the personnel profile option projects the exposure per day and sums these values, based on work locations, to project a quarterly exposure rate.

When the source location has been found, the interpreter projects the exposure rate for that location. The calculations are based on the source's characteristics, the distance the source is from the work location and the amount of shielding separating the source from the work location. The source is characterized based on the type of material, energy levels, quantity, and the attenuation of the shielding. The distances are calculated in feet as are the shielding thicknesses. The databases used to characterize the work location and the sources will be described in the following section.

5.1 PROGRAM EXECUTION

EXCOMP will prompt the user for the type of analysis to be performed (see Figure 5.1). If the user selects the facility wide option no further inputs are required. If the user selects the option to evaluate the exposure at a specific work location, the user will be required to identify that location. If the user selects the personnel profile option the user will be required to enter the person's job title, the work location in question and the average length of time per day the employee is at that location.

FIGURE 5.1. Program Description

5.2 DATABASE STRUCTURE

This program is designed to evaluate the effects any changes may have on personnel exposures from radioactive materials with respect to ALARA. There are two database files external to the program, one file characterizes the facility and the other file characterizes the source. The facility database identifies the work locations. The selection of the work locations or targets should be performed using the facility layout drawings in conjunction with a facility process description.

The work or target locations for the MRS, are defined, as those locations frequented by the facility personnel that do not involve contact handling of radioactive materials or packages. This will include the management and support offices and the operating corridors. This will not include any decon room, storage room, or radwaste handling rooms. These rooms were not included for the following two reasons: The non-radioactive storage rooms are used intermittently by the facility personnel and are not normally occupied daily; and any room involving the handling of radioactive material will be closely monitored by the onsite health physicist. However, this does not preclude these rooms from further analyses.

The difficulty in selecting a work location is in determining where an employee's work station is located in any one room and upon closer inspection of the office wing it will be even more difficult to predict the movements of the office staff. Therefore, a central location in each room, or in the office wing was identified as the work station for that particular work location (see Figure 5.2).

The source locations are defined for the MRS, as those locations where radioactive materials are stored, handled, processed, received/transported, or where contaminated equipment is decontaminated or stored. The same difficulty encountered in selecting the work location is encountered when identifying a source's exact location in a room.

The example facility is assumed to operate continuously; therefore, only those areas identified on the facility layout drawings as lag storage areas, have clearly defined source locations. Therefore, like the work locations,

the source locations are assumed to be in the central region of each room (see Figure 5.2). This assumption will create some error in the exposure predictions; however, if the same assumption is used throughout all analyses any comparative analyses performed will be valid.

The following paragraphs refer to the sample facility drawing (see Figure 5.1) and describe each of the following six fields created in the facility characterization database. The database was created with six fields, they are: 1)TARGET; 2)SOURCE; 3)DIST_FT; 4)BARRIERA; 5)BARRIERB; and 6)BARRIERC. The structure of these databases are not rigid and can be changed to suit the users needs.

TARGET--This is the work location. The work locations or targets are identified in the example drawing with a "T". When characterizing this example, the center of an office and/or the mid-point of a corridor is selected as the target location. These target locations are selected based on probable employee work stations. If the work stations have been identified, these should be used as the target locations.

FIGURE 5.2. Example Facility Layout

SOURCE--This is the location of each source that contributes to the exposure received by an employee at the identified target location. These source locations are identified with an "S" on the example drawing. The source location in a continuous operation is unpredictable. Therefore, unless strong justifications can be shown otherwise, the center of each room should be selected as the source location.

DIST_FT--This is the straight line distance from the target location (T) to the source location (S).

BARRIERA--This is the sum of the shielding encountered in a straight line from the target to the source location. In this example, BarrierA refers to the sum of the perpendicular or slant thicknesses of the concrete walls (2.35 g/cc).

BARRIERB--This is the sum of the perpendicular or slant thicknesses of the steel walls encountered in a straight line from the target to the source location.

BARRIERC--This is used to if the user increases the thickness of the shielding or if the user wants to determine the effects on exposure rates if another shielding material is used. Currently, EXCOMP assumes that the shielding identified in BarrierC is concrete. If the user wants to use some other material, i.e. lead, plastic, aluminum, etc., it will be necessary to modify the existing code. This requires the user to enter the linear attenuation coefficients of the new material based on the source's energy levels.

The second database characterizes the sources. The sources in this facility are assumed to be radioactive and can occur in various forms. Each of the process and in-process-storage locations should be considered source locations. The following descriptions describe each of the six fields created in the source characterization database to characterize the sources in the example facility (see Figure 5.1). The database fields used to identify and characterize the sources and their locations are: 1)SOURC; 2)MU1; 3)MU2; 4)MU3; 5)MU4; 6)TYPE; and 7)QUANTITY.

SOURCE--This is the location of the source, and is identified in the example with an "S". As stated previously in the Target database the exact location of the source is difficult to predict; therefore, unless specified otherwise, the center of the room should be used as the source location. These sources are the same sources identified in the facility database.

MU1, MU2, MU3, and MU4--These data base fields should be used to describe the source based on the energy groupings described in Appendix B. Because this example facility handles radioactive materials, these data base fields would contain the energy levels based on the type of radioactive materials present in the facility.

TYPE--This refers to the types of materials handled at the source locations, i.e. PWR, BWR, etc., and is not used in the calculations. This only appears in the output for information purposes.

QUANTITY--This database field represents the quantity of material found at each location. The source strengths and the release rates are based on one metric ton initial heavy metal (MTIHM). Based on the material type and normal operating conditions different quantities of material can be handled or processed at each source location. Therefore, this value is used to adjust the release rates based on the quantity of material normally handled at the source location.

APPENDIX A

CHARACTERIZING THE FACILITY

APPENDIX A

CHARACTERIZING THE FACILITY

A.1 CALCULATING THE DISTANCE FROM THE WORK TO THE SOURCE LOCATION

If only a single level is to be analyzed, the distance is a straight line path from the work location to the source location (see Figure 5.2), this method will represent shortest distance. However, if the work location and the source location are not on the same floor and not in a direct path, above or below, the distance is the shortest calculated distance.

A.2 CHARACTERIZING THE BARRIERS

Characterizing the barriers or shielding involves calculating the perpendicular thickness of the shielding and identifying the shielding construction materials. This work can be performed concurrently with calculating the distance from the work location to the source location. Referring to Figure 5.2, the line used to calculate the distance intersects a number of walls that comprise the shielding. The energy emitted from the source will penetrate the shielding and a portion of this energy will be absorbed by the shielding. The amount of energy absorbed is dependent on the shielding construction, the material used and its thickness. The material used to construct the shield will determine the rate at which the energy is absorbed. This rate is the attenuation factor for the particular shielding material (for a further discussion see Appendix B).

As the shielding increases in thickness the amount of energy absorbed will increase; therefore, the horizontal and vertical thicknesses were summed and adjusted to reflect the slant thickness. The program used to calculate the shielding thickness is as follows:

```
10 PRINT "THIS CALCULATES THE THICKNESS OF THE SHIELDING"
20 FOR I=1 TO 200
30 INPUT "HORIZ SHIELD THICK";H
40 INPUT "VERT SHIELD THICK";V
50 INPUT "ANGLE";A
60 TH=H/SIN (A/180*3.1416)
70 TV=V/COS (A/180*3.1416)
80 TT=TH+TV
90 PRINT "SHIELD THICKNESS ";TT
100 PRINT
110 NEXT
```


APPENDIX B

CHARACTERIZING THE SOURCE

APPENDIX B

CHARACTERIZING THE SOURCE

In the MRS Facility the majority of the materials processed will fall into three categories: 1. PWR Spent Fuel; 2. BWR Spent Fuel; and 3. High-Level Wastes and/or TRU, and the processing operations will generate low-level and high-level wastes. Essentially, each of these waste forms are composed of the same material; however, the energy levels and the quantity of material present will differ.

In this facility the source geometry changes with each operation. To reduce the errors that may be encountered when selecting the proper geometry a constant geometry was used throughout the facility analysis. For this analysis the source was assumed to be a culminating beam and was evaluated similar to the point source, i.e. the resultant was divided by the distance squared (see Appendix C).

Identifying the source is performed concurrently with identifying the source locations. It is possible from the facility layout to determine what the source is at each location. The room identification, supplied by the designer, may indicate what the source is, i.e., Room #1053 Solid Radwaste, etc. It is also necessary to examine the available documents describing the facility operations to determine if some process paths are dedicated to a specific source type.

There is available, from previous unrelated evaluations, information regarding the composition of spent fuel. However, there is virtually no information regarding the other forms of waste to be processed. The difficulty arises when characterizing and determining the quantity of material of these other waste forms. Therefore, all materials to be processed in the facility will be characterized on the basis of the ORIGEN2 runs for PWR and BWR Spent Fuel.

B.1. ORIGEN2 ANALYSIS OF PWR SPENT FUEL

The results of the ORIGEN2 (Croff et al. 1978) analysis for PWR Spent Fuel was used as the basis for all PWR sources identified. The ORIGEN2 analysis was based on: 4.4-W/O Enrichment; 55-GWD/MT Burnup; and a 10-year period since discharge. The assumptions used in the analysis were based on the data presented in Table B.1.

TABLE B.1. Photon Spectrum for PWR Spent Fuel

<u>EMEAN (MeV)</u>	<u>Photon Spectrum</u>		
	<u>Activation Products (photons/sec)</u>	<u>Actinides + Daughters (photons/sec)</u>	<u>Fission Products (photons/sec)</u>
1.50E-2	8.85E+12	1.07E+14	2.94E+15
2.50E-2	5.87E+12	2.46E+12	6.36E+14
3.75E-2	1.95E+12	5.31E+11	8.11E+14
5.75E-2	9.33E+11	3.57E+13	5.69E+14
8.50E-2	3.69E+11	1.86E+12	3.61E+14
1.25E-1	1.70E+11	1.60E+12	3.68E+14
2.25E-1	4.47E+11	1.28E+12	2.95E+14
3.75E-1	2.40E+12	7.47E+10	1.37E+14
5.75E-1	3.07E+12	2.17E+09	5.46E+15 } (a)
8.50E-1	1.81E+11	3.21E+09	5.44E+14 }
1.25E+0	3.03E+14	1.34E+09	2.15E+14 }
1.75E+0	4.95E+07	4.12E+08	6.10E+12 } (a)
2.25E+0	1.61E+09	1.82E+08	7.93E+10 }
2.75E+0	4.97E+06	9.82E+08	5.66E+09 }
3.50E+0	1.11E+02	9.49E+07	7.35E+08 (a)
5.00E+0	5.17E-08	4.06E+07	9.67E-05 } (a)
7.00E+0	3.35E-09	4.68E+06	6.27E-06 }
1.10E+1	<u>2.12E-10</u>	<u>5.38E+05</u>	<u>3.97E-07</u> }
TOTAL	3.27E+14	1.51E+14	1.20E+16

(a) Only these sections were used in the analysis.

As noted, only selected areas of the photon spectrum were used to characterize a PWR source. The selections were based on the expected shielding thicknesses and on conversations with an expert in shielding calculations. The very low-and very high-energy level photons, i.e., MeV<1.0 and MeV>3.5, were,

in the opinion of the expert, of no consequence. The expert's opinion was based on previous results when examining exposures due to spent fuel shipping casks. In the opinion of the expert, any shielding in the MRS Facility would be sufficient to shield the large quantities of the very low-level photons. It was also the opinion of the expert that very high-level photons would not contribute significantly to the exposure rate.

A method for photon grouping was devised to reduce the size of the database and to include the very high - and low-level photons. This method was based on a weighted average system. An example follows using the activation products in the range of 1.25 to 1.75 MeV:

<u>MeV MeV</u>	<u>Photons/ second</u>	<u>Total Photons/ second</u>	<u>% of Total</u>	<u>Weighted Average MeV</u>
1.25	3.03E+14	3.03E+14	>99%	1.25
1.75	4.95E+07		<1%	(MeV=[.99x1.25]+ [.01x1.75])

The weighted average MeV was calculated for the Actinides + Daughters and the Fission Products in this manner. A summary table lists the weighted average MeV and the average MeV for each decay product. The average MeV, column five, is used in the analysis to characterize the PWR source and to determine the effects of concrete as a shielding material.

<u>MeV Range</u>	<u>Fission Products</u>	<u>Actinides+ Daughters</u>	<u>Activation Products</u>	<u>Average MeV</u>
0.575-1.25	0.62	0.84	1.24	0.9
1.75-2.75	1.76	2.43	2.24	2.1
3.5	3.5	3.5	3.5	3.5
5.00-11.0	5.16	5.26	5.12	5.2

B.2. ORIGEN2 ANALYSIS OF BWR SPENT FUEL

The results of the ORIGEN2 (Croff et al. 1978) analysis for BWR Spent Fuel was used as the basis for all BWR sources identified. The ORIGEN2 analysis was based on: 3.6 W-0 Enrichment; 48-GWD/MT Burnup; and a 10-year discharge. The assumptions used in the analysis were based on the data presented in Table B.2.

TABLE B.2. Photon Spectrum for BWR Spent Fuel

<u>MEAN (MeV)</u>	<u>Photon Spectrum</u>		
	<u>Activation Products (photons/sec)</u>	<u>Actinides + Daughters (photons/sec)</u>	<u>Fission Products (photons/sec)</u>
1.50E-2	4.04E+12	9.54E+13	2.46E+15
2.50E-2	5.61E+12	2.21E+12	5.27E+14
3.75E-2	1.63E+12	4.83E+11	6.82E+14
5.75E-2	4.09E+11	3.20E+13	4.75E+14
8.50E-2	1.64E+11	1.74E+12	3.00E+14
1.25E-1	9.39E+10	1.47E+12	3.08E+14
2.25E-1	4.72E+11	1.16E+12	2.46E+14
3.75E-1	2.70E+12	7.00E+10	1.12E+14
5.75E-1	3.46E+12	1.69E+09	4.59E+15 } (a)
8.50E-1	6.37E+10	2.92E+09	4.13E+14 }
1.25E+0	1.24E+14	1.31E+09	1.79E+14 }
1.75E+0	4.56E+07	3.43E+08	5.16E+12 } (a)
2.25E+0	6.58E+08	1.62E+08	5.31E+10 }
2.75E+0	2.04E+06	6.23E+08	4.05E+09 }
3.50E+0	2.83E-02	8.42E+07	5.26E+08 (a)
5.00E+0	5.19E-08	3.60E+07	8.52E-05 } (a)
7.00E+0	3.36E-09	4.16E+06	5.53E-06 }
1.10E+1	2.13E-10	4.77E+05	3.50E-07 }
TOTAL	1.43E+14	1.35E+14	1.03E+16

(a) Only these sections were used in the analysis.

The same approach, described earlier, was used when determining the photon groupings in the BWR analysis. The summary table for the decay product follows. The averages in column five are used for the BWR source characterizations.

<u>MeV Range</u>	<u>Fission Products</u>	<u>Actinides+ Daughters</u>	<u>Activation Products</u>	<u>Average MeV</u>
0.575-1.25	0.62	0.86	1.23	0.9
1.75-2.75	1.76	2.35	2.21	2.1
3.5	3.5	3.5	3.5	3.5
5.00-11.0	5.16	5.26	5.12	5.2

It is noteworthy, that the MeV averages for the BWR are similar to the PWR MeV averages. Therefore, it will be assumed that all spent fuel received, with the identical compositions and burnup rates as those used in the ORIGEN2 analyses, have similar energy levels. This implies that wastes generated in the facility have the same energy levels; although, the quantity to be analyzed will be smaller.

B.3 ANALYSIS OF OTHER SOURCES

It is assumed that the other radioactive material encountered in the MRS facility will be comprised of PWR and BWR products. Therefore, the same weighted average MeV values will be used for those sources identified as HLW (high-level waste), SRW (solid rad waste), LRW (liquid rad waste), TRU (trans-uranic waste), CHE (contact-handled waste or equipment), and RHE (remote-handled waste or equipment).

The weight or quantity of material present at each source location is reduced to reflect lower concentrations. These reductions are based on engineering judgment or actual data if it is available. These reductions are necessary to evaluate each of the source's exposure potential, i.e. the less material present the less exposure potential. The photon spectrum for these sources are determined by averaging the photon release rates for PWR and BWR spent fuel.

B.4 RESULTS OF THE ANALYSES

The results of the analyses described in Sections B.1, B.2 and B.3 are used to determine the linear attenuation coefficients for the shielding materials, the photon energy flux to biological dose-rate factors and the buildup factors. These values are then combined with the intensities and the quantity of material present to calculate the dose rate.

The linear attenuation coefficients used in EXCOMP are interpolated values based on the following table (Glasstone and Sesonske 1981). As stated in the database description EXCOMP initially includes the linear attenuation coefficients for concrete and steel.

Table B.3. Linear Attenuation Coefficients in M^{-1} Units^(a)

Energy MeV	Water	Concrete	Aluminum	Iron	Lead
0.5	9.66	20.0	22.7	65.1	164
1.0	7.06	14.9	16.6	46.8	77.6
1.5	5.75	12.1	13.5	38.1	58.1
2.0	4.93	10.5	11.7	33.3	51.8
3.0	3.96	8.53	9.53	28.4	47.7
4.0	3.39	7.45	8.37	25.9	47.6
5.0	3.01	6.74	7.61	24.6	48.3
8.0	2.40	5.71	6.51	23.2	52.0
10.0	2.19	5.38	6.18	23.1	55.4

(a) Prior to the adoption of SI units, linear attenuation coefficients were reported in cm^{-1} units; the latter values are 0.01 times those in Table B.3.

The buildup factors used in EXCOMP are based on the calculated μx value which is based on the shielding thickness and the linear attenuation coefficient for the shielding material. The value μx is calculated in EXCOMP and the buildup factor is interpolated based on interpolated values derived from table B.4.

Table B.4. Gamma-Ray Exposure Buildup Factors for a Point Isotropic Source

Material	Energy, MeV	μx							
		0.50	1.00	2.00	4.00	7.00	10.00	15.00	20.00
Water [7]	0.5	1.60	2.44	4.84	12.6	31.9	61.2	135	243
	1.0	1.47	2.08	3.60	7.63	15.6	25.8	47	73
	2.0	1.38	1.83	2.81	4.98	8.63	12.7	20	28
	5.0	1.29	1.57	2.10	3.12	4.64	6.15	8.6	11
	10.0	1.21	1.39	1.70	2.28	3.13	4.64	6.15	8.6
Concrete [7] (Density 2.53 Mg/m ³)	0.5	1.57	2.27	4.04	9.02	20.3	36.7	76.2	132
	1.0	1.45	1.98	3.25	6.45	12.8	20.8	37.3	57.1
	2.0	1.37	1.78	2.66	4.63	8.00	11.7	18.6	26.1
	4.0	1.30	1.60	2.19	3.37	5.25	7.21	10.6	14.1
	6.0	1.26	1.49	1.93	2.80	4.15	5.53	7.88	10.3
	10.0	1.20	1.36	1.65	2.22	3.12	4.04	5.65	7.32
Iron [8]	0.5	--	1.98	3.09	5.98	11.7	19.2	35.4	55.6
	1.0	--	1.87	2.89	5.59	10.2	16.2	28.3	42.7
	2.0	--	1.76	2.43	4.13	7.25	10.9	17.6	25.1
	3.0	--	1.55	2.15	3.51	5.85	8.51	13.5	19.1

Table B.4. (Contd)

Material	Energy, MeV	μx							
		0.50	1.00	2.00	4.00	7.00	10.00	15.00	20.00
	4.0	--	1.45	1.94	3.03	4.91	7.11	11.2	16.0
	6.0	--	1.34	1.72	2.58	4.14	6.02	9.89	14.7
	10.0	--	1.20	1.42	1.95	2.99	4.35	7.54	12.4
Lead [8]	0.5	--	1.24	1.42	1.69	2.00	2.27	2.67	2.73
	1.0	--	1.37	1.69	2.26	3.02	3.74	4.81	5.86
	2.0	--	1.39	1.76	2.51	3.66	4.84	6.87	9.00
	3.0	--	1.34	1.68	2.43	3.75	5.30	8.44	12.3
	4.0	--	1.27	1.56	2.25	3.61	5.44	9.80	16.3
	6.0	--	1.18	1.40	1.97	3.34	5.69	13.8	32.7
	10.0	--	1.11	1.23	1.58	2.52	4.34	12.5	39.2

The photon energy flux to biological dose rate conversion factor is based on Table B.5.

Tables B.6 and B.4.5 present the results of the analyses of each source type. Table B.6 includes the average MeV values, photon intensities based on the material type, linear attenuation coefficients, and the energy to dose rate conversion factors. Table B.7 includes the buildup factors for concrete and steel based on the average MeV values.

TABLE B.5. Photon Energy Flux to Biological
Dose Rate Conversion Factor^(a)

E MeV	$k_m(E)$ rem/hr per MeV/cm ² sec	MeV	$k_m(E)$ rem/hr per MeV/cm ² sec
0.5	2.33-06	5.0	1.16-06
0.6	2.26	5.2	1.15
0.7	2.18	5.4	1.13
0.8	2.10	5.6	1.12
0.9	2.04	5.8	1.10
1.0	1.98-05	6.0	1.09-06
1.2	1.89	6.2	1.08
1.4	1.79	6.4	1.07
1.6	1.72	6.6	1.07
1.8	1.66	6.8	1.06
2.0	1.60-06	7.0	1.05-06
2.2	1.55	7.2	1.04
2.4	1.51	7.4	1.03
2.6	1.47	7.6	1.03
2.8	1.43	7.8	1.02
3.0	1.40-06	8.0	1.01-06
3.2	1.37	8.2	1.00
3.4	1.34	8.4	0.99
3.6	1.32	8.6	0.99
3.8	1.29	8.8	0.98
4.0	1.26-06	9.0	0.97-06
4.2	1.24	9.2	0.97
4.4	1.22	9.4	0.96
4.6	1.20	9.6	0.96
4.8	1.18	9.8	0.95
5.0	1.16-06	10.0	0.96-06

(a) Interpolated from data in: H. C. Claiborne and D. K. Trubey. 1970. "Dose Rates in a Slab Phantom from Monoenergetic Gamma Rays," Nuc. Appl. Tech., 8:450.

TABLE B.6. Summary of the Information Required to Determine the Radiological Dose Rates Based on the Material Type

MeV	Energy to Dose Coefficients Conversion Factor	Photon Intensity Based on Material Type				Linear Attenuation	
		PWR	BWR	TRU(a)	Other(b)	Concrete (2.53g/cc)	Steel
0.9	2.04E-06	6.52E15	5.31E15	5.70E15	5.92E15	0.160	0.505
2.1	1.58E-06	6.19E12	5.27E12	5.70E12	5.73E12	0.103	0.328
3.5	1.33E-06	8.30E08	6.10E08	6.31E08	7.20E08	0.080	0.272
5.2	1.15E-06	4.58E07	4.06E07	9.73E-05	4.32E07	0.067	0.245

(a) Intensity based on PWR and BWR intensities. Assumed that these waste streams have equal amounts of PWR and BWR fission products.

(b) Intensity based on PWR and BWR intensities. Assumed that these waste streams have equal amounts of PWR and BWR wastes.

TABLE B.7. Gamma-Ray Exposure Buildup Factors Based on Material Type

Material	Energy, MeV	μx							
		0.50	1.00	2.00	4.00	7.00	10.00	15.00	20.00
Concrete (2.53g/cc)	0.9	1.47	2.04	3.41	6.96	14.3	24.0	45.1	72.1
	2.1	1.37	1.77	2.64	4.57	7.86	11.5	18.2	25.5
	3.5	1.32	1.65	2.31	3.69	5.94	8.33	12.6	17.1
	5.2	1.28	1.53	2.03	3.03	4.59	6.20	8.97	11.8
Steel	0.9	-	1.89	2.93	5.67	10.5	16.8	29.7	45.3
	2.1	-	1.74	2.40	4.07	7.11	10.7	17.2	24.5
	3.5	-	1.50	2.05	3.27	5.38	7.81	12.4	17.6
	5.2	-	1.38	1.81	2.76	4.45	6.46	10.4	15.2

APPENDIX B REFERENCES

Croff, A. G., M. A. Bjerke, G. W. Morrison, and L. M. Petrie. 1978. Revised Uranium-Plutonium Cycle PWR and BWR Models for the Origen Computer Code, ORNL/TM-6051, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

APPENDIX C

DOSE CALCULATIONS

APPENDIX C

DOSE CALCULATIONS

A simplifying assumption in EXCOMP was used when performing dose calculations. That is, a point source geometry is used for all types of materials in the facility. A point source was used to reduce any confusion that may exist when initially identifying source geometries in a facility. Also, in radioactive material processing facilities, it is difficult to predict the source geometry at each process location or in each waste stream. This also reduces the time required to perform an analysis. The calculated exposure rates are conservative, i.e., higher than expected, for distances less than two times the length of the source. However, as this distance increases, the source will tend to act as a point source.

The background information required to perform the necessary calculations are described in Appendices A and B. This information includes the distance the source is from the work location, the thickness and type of each barrier encountered, the energy levels (MeV) and the quality of material present at each location. Table C.1 summarizes additional information necessary for the calculations (Appendix D presents the distance and barrier thicknesses for the MRS).

The following discussion describes how the interpreter in EXCOMP uses the information in the facility and the source databases to calculate dose.

C.1 CALCULATIONAL PROCEDURE

EXCOMP locates the record of interest in the facility database, based on the target location (see Figure C.1). For information on the database structure see Section 6. The information describing the target location is read and then EXCOMP searches the source database for the source location identified in the target location description.

The information describing the source is read. EXCOMP then uses information read from the facility database describing the target location, information from the source database describing the source at a particular

source location, and information internal to EXCOMP to calculate an estimated exposure rate.

FIGURE C.1. Simplified Flow Chart of EXCOMP Dose Calculational Procedure

C.2 DOSE CALCULATIONS

EXCOMP estimates the exposure rate at a particular target location using a photon grouping method and equation 1 and 3 (Glasstone and Sesonske, 1981).

Equation 1 is repeated once for each photon grouping with the total exposure rate being the sum of the exposure rates for the four groupings. The total calculated exposure rate is in rem/hr per MTIHM. Equation 3 converts the exposure rate to mrem/hr based on the quantity of material found at the source location.

$$(1) \text{ rem/hr} = \text{BF} (\text{II}e^{-\mu x} * \text{MU})\text{KE}/(4 * \pi * \text{Dist}^2)$$

where:

BF is a buildup factor (interpolated from Table B.4.5),^(a)

II is the initial source intensity (assigned from Table B.4.4),^(b)

μx is a unitless factor relating barrier thickness to attenuation,^(a)

MU is the average MeV value,^(c)

KE is a factor converting energy flux to biological dose equivalent (assigned from Table B.4.4,^(a) and

Dist is the distance from target to source in centimeters.^(c)

$$(2) \mu x = \text{LAC} * \text{thickness}$$

where:

LAC is a linear attenuation coefficient (assigned from Table B.4.4)^(a) and,

Thickness is the barrier thickness in centimeters.^(c)

$$(3) \text{ mrem/hr} = \left(\sum_{1}^n \text{ rem/hr} \right) * 1000 \text{ mrem/rem} * \text{ wt kg/MTIHM}$$

where:

$\sum_{1}^n$ sum of the calculated doses for each energy grouping^(a) and

wt is the quantity of material at a particular source location^(c)

(a) Calculated from values internal to EXCOMP.

(b) Value is internal to EXCOMP.

(c) Value is read in from the database.

TABLE C.1. Summary of Information Required for Dose Calculations

<u>Material</u>	<u>Average Mev</u>	<u>Photon Release Rate</u>	<u>Quantity of Material (MTIHM)</u>
PWR	0.9	6.52E15	1.28
	2.1	6.19E12	
	3.5	8.30E08	
	5.2	4.58E07	
BWR	0.9	5.31E15	1.38
	2.1	5.27E12	
	3.5	6.10E08	
	5.2	4.06E07	
LWR	0.9	5.92E15(a)	1.5E-02
	2.1	5.73E12	
	3.5	7.20E08	
	5.2	4.32E07	
HLW	0.9	5.92E15(a)	1.00
	2.1	5.73E12	
	3.5	7.20E08	
	5.2	4.32E07	
SRW	0.9	5.92E15(a)	1.0E-02
	2.1	5.73E12	
	3.5	7.20E08	
	5.2	4.32E07	
RHE	0.9	5.92E15(a)	5.0E-03
	2.1	5.73E12	
	3.5	7.20E08	
	5.2	4.32E07	
CHE	0.9	5.92E15(a)	5.0E-05
	2.1	5.73E12	
	3.5	7.20E08	
	5.2	4.32E07	
TRU	0.9	5.70E15(b)	1.0E-03
	2.1	5.70E12	
	3.5	6.31E08	
	5.2	9.73E-05	

- (a) Intensity based on PWR and BWR intensities. Assumed that these waste streams have equal amounts of PWR and BWR wastes.
- (b) Intensity based on PWR and BWR intensities. Assumed that these waste streams have equal amounts on PWR and BWR fission products.

APPENDIX C REFERENCES

Glasstone, S. and Sesonske, A. 1967. Nuclear Reactor Engineering. D. Van Nostrand Company, Inc., Princeton, New Jersey.

APPENDIX D

MRS TARGET LOCATIONS

TABLE D.1. Database Used to Characterize the Integral MRS Facility

Work Location	Source Location	Distance from Work To Source Location	Thickness of Shielding Separating Work and Source Locations, (in feet).			
			Existing	Additional	Additional	Total
1004	1063	125	4.9	0.0	0.0	4.9
1004	1064	162	13.8	0.0	0.0	13.8
1004	1065	205	11.8	0.0	0.0	11.8
1004	1070	223	10.6	0.0	0.0	10.6
1004	1071	226	14.6	0.0	0.0	14.6
1004	1073	205	14.2	0.0	0.0	14.2
1004	1079	284	18.8	0.0	0.0	18.8
1004	1084	297	26.2	0.0	0.0	26.2
1004	1085	276	28.5	0.0	0.0	28.5
1004	1086	292	40.0	0.0	0.0	40.0
1004	1090	351	40.9	0.0	0.0	40.9
1004	1091	329	43.6	0.0	0.0	43.6
1004	1092	348	42.6	0.0	0.0	42.6
1004	1113	417	67.3	0.0	0.0	67.3
1004	1130	502	71.6	0.0	0.0	71.6
1004	1135	552	76.9	0.0	0.0	76.9
1004	1136	491	74.1	0.0	0.0	74.1
1004	1141	550	53.0	0.0	0.0	53.0
1004	1142	486	47.0	0.0	0.0	47.0
1004	1162	319	28.7	0.0	0.0	28.7
1004	1163	319	35.2	0.0	0.0	35.2
1004	1164	298	30.0	0.0	0.0	30.0
1004	1170	255	21.5	0.0	0.0	21.5
1004	1171	236	10.1	0.0	0.0	10.1
1004	1172	258	9.3	0.0	0.0	9.3
1004	1179	231	2.8	0.0	0.0	2.8
1020	1063	175	4.5	0.0	0.0	4.5
1020	1064	226	8.5	0.0	0.0	8.5
1020	1065	263	9.5	0.0	0.0	9.5
1020	1070	287	10.5	0.0	0.0	10.5
1020	1071	282	10.5	0.0	0.0	10.5
1020	1073	228	9.4	0.0	0.0	9.4
1020	1079	345	13.0	0.0	0.0	13.0
1020	1084	313	21.7	0.0	0.0	21.7
1020	1085	287	32.6	0.0	0.0	32.6
1020	1086	297	32.4	0.0	0.0	32.4
1020	1090	350	37.9	0.0	0.0	37.9
1020	1091	324	44.8	0.0	0.0	44.8
1020	1092	337	46.8	0.0	0.0	46.8
1020	1113	382	53.4	0.0	0.0	53.4
1020	1130	450	60.4	0.0	0.0	60.4
1020	1135	497	91.7	0.0	0.0	91.7
1020	1136	438	57.8	0.0	0.0	57.8
1020	1141	486	57.1	0.0	0.0	57.1
1020	1142	425	39.4	0.0	0.0	39.4
1020	1162	226	36.7	0.0	0.0	36.7
1020	1163	231	57.2	0.0	0.0	57.2
1020	1164	210	48.8	0.0	0.0	48.8
1020	1170	165	12.3	0.0	0.0	12.3

TABLE D.1. Continued

Work Location	Source Location	Distance from Work To Source Location	Thickness of Shielding Separating Work and Source Locations, (in feet).			
			Existing	Additional	Additional	Total
1020	1171	146	10.8	0.0	0.0	10.8
1020	1172	162	5.5	0.0	0.0	5.5
1020	1179	139	1.0	0.0	0.0	1.0
1028	1063	148	4.5	0.0	0.0	4.5
1028	1064	196	8.5	0.0	0.0	8.5
1028	1065	234	9.5	0.0	0.0	9.5
1028	1070	258	10.5	0.0	0.0	10.5
1028	1071	252	10.6	0.0	0.0	10.6
1028	1073	207	15.6	0.0	0.0	15.6
1028	1079	319	13.0	0.0	0.0	13.0
1028	1084	293	19.4	0.0	0.0	19.4
1028	1085	268	23.3	0.0	0.0	23.3
1028	1086	282	28.6	0.0	0.0	28.6
1028	1090	338	40.9	0.0	0.0	40.9
1028	1091	313	30.4	0.0	0.0	30.4
1028	1092	327	33.7	0.0	0.0	33.7
1028	1113	380	59.3	0.0	0.0	59.3
1028	1130	462	56.1	0.0	0.0	56.1
1028	1135	505	92.5	0.0	0.0	92.5
1028	1136	444	71.9	0.0	0.0	71.9
1028	1141	495	48.5	0.0	0.0	48.5
1028	1142	433	42.0	0.0	0.0	42.0
1028	1162	247	21.8	0.0	0.0	21.8
1028	1163	250	33.3	0.0	0.0	33.3
1028	1164	228	35.8	0.0	0.0	35.8
1028	1170	184	14.8	0.0	0.0	14.8
1028	1171	165	10.0	0.0	0.0	10.0
1028	1172	186	9.1	0.0	0.0	9.1
1028	1179	170	1.6	0.0	0.0	1.6
1038	1063	151	4.6	0.0	0.0	4.6
1038	1064	202	8.8	0.0	0.0	8.8
1038	1065	236	9.6	0.0	0.0	9.6
1038	1070	263	10.7	0.0	0.0	10.7
1038	1071	250	10.5	0.0	0.0	10.5
1038	1073	191	9.2	0.0	0.0	9.2
1038	1079	319	13.1	0.0	0.0	13.1
1038	1084	271	25.2	0.0	0.0	25.2
1038	1085	244	33.4	0.0	0.0	33.4
1038	1086	252	26.0	0.0	0.0	26.0
1038	1090	308	58.6	0.0	0.0	58.6
1038	1091	279	45.6	0.0	0.0	45.6
1038	1092	292	44.2	0.0	0.0	44.2
1038	1113	337	48.0	0.0	0.0	48.0
1038	1130	414	67.7	0.0	0.0	67.7
1038	1135	456	88.8	0.0	0.0	88.8
1038	1136	396	80.8	0.0	0.0	80.8
1038	1141	446	47.3	0.0	0.0	47.3
1038	1142	385	41.3	0.0	0.0	41.3
1038	1162	201	35.1	0.0	0.0	35.1

TABLE D.1. Continued

Work Location	Source Location	Distance from Work To Source Location	Thickness of Shielding Separating Work and Source Locations, (in feet).			
			Existing	Additional	Additional	Total
1038	1163	202	36.4	0.0	0.0	36.4
1038	1164	181	29.0	0.0	0.0	29.0
1038	1170	138	27.2	0.0	0.0	27.2
1038	1171	122	10.7	0.0	0.0	10.7
1038	1172	146	10.1	0.0	0.0	10.1
1038	1179	162	1.5	0.0	0.0	1.5
1068	1063	122	10.3	0.0	0.0	10.3
1068	1064	72	6.2	0.0	0.0	6.2
1068	1065	40	2.9	0.0	0.0	2.9
1068	1070	19	1.1	0.0	0.0	1.1
1068	1071	53	2.1	0.0	0.0	2.1
1068	1073	130	10.0	0.0	0.0	10.0
1068	1079	61	4.9	0.0	0.0	4.9
1068	1084	170	9.0	0.0	0.0	9.0
1068	1085	175	18.7	0.0	0.0	18.7
1068	1086	191	26.3	0.0	0.0	26.3
1068	1090	239	11.5	0.0	0.0	11.5
1068	1091	239	29.0	0.0	0.0	29.0
1068	1092	258	24.4	0.0	0.0	24.4
1068	1113	364	60.1	0.0	0.0	60.1
1068	1130	457	64.0	0.0	0.0	64.0
1068	1135	531	91.8	0.0	0.0	91.8
1068	1136	470	71.2	0.0	0.0	71.2
1068	1141	550	70.3	0.0	0.0	70.3
1068	1142	494	64.6	0.0	0.0	64.6
1068	1162	433	67.7	0.0	0.0	67.7
1068	1163	417	61.7	0.0	0.0	61.7
1068	1164	404	60.3	0.0	0.0	60.3
1068	1170	367	47.6	0.0	0.0	47.6
1068	1171	359	46.7	0.0	0.0	46.7
1068	1172	401	68.8	0.0	0.0	68.8
1068	1179	433	30.8	0.0	0.0	30.8
10951	1063	151	5.6	0.0	0.0	5.6
10951	1064	162	4.5	0.0	0.0	4.5
10951	1065	161	13.5	0.0	0.0	13.5
10951	1070	178	13.1	0.0	0.0	13.1
10951	1071	138	10.2	0.0	0.0	10.2
10951	1073	74	1.5	0.0	0.0	1.5
10951	1079	199	12.5	0.0	0.0	12.5
10951	1084	69	12.6	0.0	0.0	12.6
10951	1085	40	7.2	0.0	0.0	7.2
10951	1086	42	7.2	0.0	0.0	7.2
10951	1090	93	18.8	0.0	0.0	18.8
10951	1091	71	16.3	0.0	0.0	16.3
10951	1092	88	16.2	0.0	0.0	16.2
10951	1113	175	8.0	0.0	0.0	8.0
10951	1130	268	17.0	0.0	0.0	17.0
10951	1135	337	75.6	0.0	0.0	75.6
10951	1136	276	65.2	0.0	0.0	65.2

TABLE D.1. Continued

Work Location	Source Location	Distance from Work To Source Location	Thickness of Shielding Separating Work and Source Locations, (in feet).			
			Existing	Additional	Additional	Total
10951	1141	353	63.4	0.0	0.0	63.4
10951	1142	295	60.4	0.0	0.0	60.4
10951	1162	279	53.6	0.0	0.0	53.6
10951	1163	258	32.4	0.0	0.0	32.4
10951	1164	252	35.4	0.0	0.0	35.4
10951	1170	246	32.0	0.0	0.0	32.0
10951	1171	247	27.5	0.0	0.0	27.5
10951	1172	276	33.0	0.0	0.0	33.0
10951	1179	361	34.8	0.0	0.0	34.8
10952	1063	154	25.6	0.0	0.0	25.6
10952	1064	162	4.5	0.0	0.0	4.5
10952	1065	226	25.0	0.0	0.0	25.0
10952	1070	241	24.6	0.0	0.0	24.6
10952	1071	204	35.7	0.0	0.0	35.7
10952	1073	141	1.5	0.0	0.0	1.5
10952	1079	254	36.2	0.0	0.0	36.2
10952	1084	69	25.8	0.0	0.0	25.8
10952	1085	85	26.1	0.0	0.0	26.1
10952	1086	69	11.9	0.0	0.0	11.9
10952	1090	72	12.5	0.0	0.0	12.5
10952	1091	42	7.3	0.0	0.0	7.3
10952	1092	42	7.2	0.0	0.0	7.2
10952	1113	106	8.0	0.0	0.0	8.0
10952	1130	201	17.0	0.0	0.0	17.0
10952	1135	271	93.4	0.0	0.0	93.4
10952	1136	210	44.2	0.0	0.0	44.2
10952	1141	291	59.4	0.0	0.0	59.4
10952	1142	236	39.0	0.0	0.0	39.0
10952	1162	271	42.0	0.0	0.0	42.0
10952	1163	244	16.0	0.0	0.0	16.0
10952	1164	244	36.6	0.0	0.0	36.6
10952	1170	250	15.7	0.0	0.0	15.7
10952	1171	255	21.7	0.0	0.0	21.7
10952	1172	284	15.5	0.0	0.0	15.5
10952	1179	388	42.9	0.0	0.0	42.9
11061	1063	226	32.4	0.0	0.0	32.4
11061	1064	250	18.4	0.0	0.0	18.4
11061	1065	255	22.9	0.0	0.0	22.9
11061	1070	274	28.5	0.0	0.0	28.5
11061	1071	240	22.9	0.0	0.0	22.9
11061	1073	163	14.8	0.0	0.0	14.8
11061	1079	298	31.9	0.0	0.0	31.9
11061	1084	157	24.7	0.0	0.0	24.7
11061	1085	133	22.2	0.0	0.0	22.2
11061	1086	122	18.1	0.0	0.0	18.1
11061	1090	133	12.6	0.0	0.0	12.6
11061	1091	104	7.1	0.0	0.0	7.1
11061	1092	99	7.0	0.0	0.0	7.0
11061	1113	112	29.3	0.0	0.0	29.3

TABLE D.1. Continued

<u>Work Location</u>	<u>Source Location</u>	<u>Distance from Work To Source Location</u>	<u>Thickness of Shielding Separating Work and Source Locations, (in feet).</u>			
			<u>Existing</u>	<u>Additional</u>	<u>Additional</u>	<u>Total</u>
11061	1130	197	23.6	0.0	0.0	23.6
11061	1135	252	30.0	0.0	0.0	30.0
11061	1136	191	24.1	0.0	0.0	24.1
11061	1141	262	64.2	0.0	0.0	64.2
11061	1142	202	36.8	0.0	0.0	36.8
11061	1162	212	12.5	0.0	0.0	12.5
11061	1163	183	7.0	0.0	0.0	7.0
11061	1164	185	16.6	0.0	0.0	16.6
11061	1170	197	28.8	0.0	0.0	28.8
11061	1171	205	21.4	0.0	0.0	21.4
11061	1172	228	34.7	0.0	0.0	34.7
11061	1179	343	38.8	0.0	0.0	38.8
11062	1063	250	28.7	0.0	0.0	28.7
11062	1064	286	36.1	0.0	0.0	36.1
11062	1065	300	39.8	0.0	0.0	39.8
11062	1070	324	45.0	0.0	0.0	45.0
11062	1071	292	46.8	0.0	0.0	46.8
11062	1073	212	38.0	0.0	0.0	38.0
11062	1079	361	36.6	0.0	0.0	36.6
11062	1084	231	38.4	0.0	0.0	38.4
11062	1085	202	21.2	0.0	0.0	21.2
11062	1086	196	27.2	0.0	0.0	27.2
11062	1090	215	12.5	0.0	0.0	12.5
11062	1091	186	16.6	0.0	0.0	16.6
11062	1092	183	7.0	0.0	0.0	7.0
11062	1113	169	34.7	0.0	0.0	34.7
11062	1130	228	47.6	0.0	0.0	47.6
11062	1135	263	61.8	0.0	0.0	61.8
11062	1136	199	36.8	0.0	0.0	36.8
11062	1141	255	28.5	0.0	0.0	28.5
11062	1142	191	24.0	0.0	0.0	24.0
11062	1162	130	12.5	0.0	0.0	12.5
11062	1163	100	7.0	0.0	0.0	7.0
11062	1164	101	16.8	0.0	0.0	16.8
11062	1170	120	23.2	0.0	0.0	23.2
11062	1171	132	30.2	0.0	0.0	30.2
11062	1172	151	20.6	0.0	0.0	20.6
11062	1179	274	35.3	0.0	0.0	35.3
1115	1063	271	44.1	0.0	0.0	44.1
1115	1064	282	4.5	0.0	0.0	4.5
1115	1065	276	47.5	0.0	0.0	47.5
1115	1070	290	47.2	0.0	0.0	47.2
1115	1071	255	42.6	0.0	0.0	42.6
1115	1073	194	1.5	0.0	0.0	1.5
1115	1079	297	40.0	0.0	0.0	40.0
1115	1084	146	29.5	0.0	0.0	29.5
1115	1085	133	31.2	0.0	0.0	31.2
1115	1086	114	27.3	0.0	0.0	27.3
1115	1090	88	15.8	0.0	0.0	15.8

TABLE D.1. Continued

Work Location	Source Location	Distance from Work To Source Location	Thickness of Shielding Separating Work and Source Locations, (in feet).			
			Existing	Additional	Additional	Total
1115	1091	72	21.6	0.0	0.0	21.6
1115	1092	56	7.5	0.0	0.0	7.5
1115	1113	56	8.0	0.0	0.0	8.0
1115	1130	149	17.1	0.0	0.0	17.1
1115	1135	223	54.8	0.0	0.0	54.8
1115	1136	165	54.8	0.0	0.0	54.8
1115	1141	239	46.8	0.0	0.0	46.8
1115	1142	199	37.9	0.0	0.0	37.9
1115	1162	282	68.8	0.0	0.0	68.8
1115	1163	252	72.8	0.0	0.0	72.8
1115	1164	258	47.0	0.0	0.0	47.0
1115	1170	271	52.6	0.0	0.0	52.6
1115	1171	279	46.7	0.0	0.0	46.7
1115	1172	305	60.7	0.0	0.0	60.7
1115	1179	417	52.7	0.0	0.0	52.7
1159	1063	327	47.6	0.0	0.0	47.6
1159	1064	369	38.3	0.0	0.0	38.3
1159	1065	388	48.3	0.0	0.0	48.3
1159	1070	412	49.2	0.0	0.0	49.2
1159	1071	382	49.5	0.0	0.0	49.5
1159	1073	300	40.9	0.0	0.0	40.9
1159	1079	449	57.0	0.0	0.0	57.0
1159	1084	324	64.3	0.0	0.0	64.3
1159	1085	295	39.5	0.0	0.0	39.5
1159	1086	290	55.0	0.0	0.0	55.0
1159	1091	274	56.8	0.0	0.0	56.8
1159	1092	271	61.7	0.0	0.0	61.7
1159	1113	228	31.2	0.0	0.0	31.2
1159	1130	261	53.3	0.0	0.0	53.3
1159	1135	266	44.1	0.0	0.0	44.1
1159	1136	218	31.8	0.0	0.0	31.8
1159	1141	236	48.7	0.0	0.0	48.7
1159	1142	181	33.3	0.0	0.0	33.3
1159	1162	64	17.0	0.0	0.0	17.0
1159	1163	40	7.1	0.0	0.0	7.1
1159	1164	58	10.7	0.0	0.0	10.7
1159	1170	106	21.8	0.0	0.0	21.8
1159	1171	125	25.7	0.0	0.0	25.7
1159	1172	125	27.6	0.0	0.0	27.6
1159	1179	255	34.5	0.0	0.0	34.5
1159	1090	303	54.0	0.0	0.0	54.0
11661	1063	231	20.1	0.0	0.0	20.1
11661	1064	276	31.8	0.0	0.0	31.8
11661	1065	303	33.5	0.0	0.0	33.5
11661	1070	329	37.3	0.0	0.0	37.3
11661	1071	305	39.4	0.0	0.0	39.4
11661	1073	228	33.6	0.0	0.0	33.6
11661	1079	377	40.5	0.0	0.0	40.5
11661	1084	279	33.5	0.0	0.0	33.5

TABLE D.1. Continued

Work Location	Source Location	Distance from Work To Source Location	Thickness of Shielding Separating Work and Source Locations, (in feet).			
			Existing	Additional	Additional	Total
11661	1085	249	28.0	0.0	0.0	28.0
11661	1086	249	48.6	0.0	0.0	48.6
11661	1090	286	21.0	0.0	0.0	21.0
11661	1091	255	15.4	0.0	0.0	15.4
11661	1092	260	15.8	0.0	0.0	15.8
11661	1113	265	42.7	0.0	0.0	42.7
11661	1130	327	61.4	0.0	0.0	61.4
11661	1135	355	50.5	0.0	0.0	50.5
11661	1136	297	50.6	0.0	0.0	50.6
11661	1141	337	74.6	0.0	0.0	74.6
11661	1142	276	60.5	0.0	0.0	60.5
11661	1162	93	20.5	0.0	0.0	20.5
11661	1163	85	21.0	0.0	0.0	21.0
11661	1164	66	19.7	0.0	0.0	19.7
11661	1170	37	7.3	0.0	0.0	7.3
11661	1171	37	7.2	0.0	0.0	7.2
11661	1172	66	0.0	0.0	0.0	0.0
11661	1179	175	16.9	0.0	0.0	16.9
11662	1063	277	31.8	0.0	0.0	31.8
11662	1064	319	56.4	0.0	0.0	56.4
11662	1065	340	36.3	0.0	0.0	36.3
11662	1070	367	39.9	0.0	0.0	39.9
11662	1071	337	39.5	0.0	0.0	39.5
11662	1073	255	25.4	0.0	0.0	25.4
11662	1079	404	36.1	0.0	0.0	36.1
11662	1084	287	21.3	0.0	0.0	21.3
11662	1085	258	32.9	0.0	0.0	32.9
11662	1086	255	15.4	0.0	0.0	15.4
11662	1090	279	20.5	0.0	0.0	20.5
11662	1091	247	15.0	0.0	0.0	15.0
11662	1092	247	27.5	0.0	0.0	27.5
11662	1113	228	38.9	0.0	0.0	38.9
11662	1130	276	55.3	0.0	0.0	55.3
11662	1135	295	56.2	0.0	0.0	56.2
11662	1136	242	35.5	0.0	0.0	35.5
11662	1141	274	59.2	0.0	0.0	59.2
11662	1142	213	52.5	0.0	0.0	52.5
11662	1162	66	12.5	0.0	0.0	12.5
11662	1163	37	7.3	0.0	0.0	7.3
11662	1164	37	7.2	0.0	0.0	7.2
11662	1170	66	12.5	0.0	0.0	12.5
11662	1171	85	19.9	0.0	0.0	19.9
11662	1172	96	19.8	0.0	0.0	19.8
11662	1179	226	32.1	0.0	0.0	32.1
2004	2015	98	12.4	0.0	0.0	12.4
2004	2017	155	36.0	0.0	0.0	36.0
2004	2023	109	18.9	0.0	0.0	18.9
2004	2024	74	9.6	0.0	0.0	9.6
2004	2050	184	25.5	0.0	0.0	25.5

TABLE D.1. Continued

<u>Work Location</u>	<u>Source Location</u>	<u>Distance from Work To Source Location</u>	<u>Thickness of Shielding Separating Work and Source Locations, (in feet).</u>			
			<u>Existing</u>	<u>Additional</u>	<u>Additional</u>	<u>Total</u>
2004	2052	154	24.5	0.0	0.0	24.5
2006	2015	93	14.1	0.0	0.0	14.1
2006	2017	143	28.1	0.0	0.0	28.1
2006	2023	125	20.8	0.0	0.0	20.8
2006	2024	72	11.2	0.0	0.0	11.2
2006	2050	212	36.1	0.0	0.0	36.1
2006	2052	175	28.8	0.0	0.0	28.8
20111	2015	56	5.5	0.0	0.0	5.5
20111	2017	78	23.7	0.0	0.0	23.7
20111	2023	202	16.5	0.0	0.0	16.5
20111	2024	114	11.0	0.0	0.0	11.0
20111	2050	268	26.9	0.0	0.0	26.9
20111	2052	260	26.0	0.0	0.0	26.0
20181	2015	24	5.5	0.0	0.0	5.5
20181	2017	93	16.5	0.0	0.0	16.5
20181	2023	148	50.3	0.0	0.0	50.3
20181	2024	63	19.1	0.0	0.0	19.1
20181	2050	224	31.1	0.0	0.0	31.1
20181	2052	204	64.8	0.0	0.0	64.8
2019	2015	80	7.6	0.0	0.0	7.6
2019	2017	101	12.2	0.0	0.0	12.2
2019	2023	67	13.2	0.0	0.0	13.2
2019	2024	24	2.2	0.0	0.0	2.2
2019	2050	146	19.2	0.0	0.0	19.2
2019	2052	125	18.0	0.0	0.0	18.0
2022	2015	123	18.1	0.0	0.0	18.1
2022	2017	146	19.5	0.0	0.0	19.5
2022	2023	24	2.2	0.0	0.0	2.2
2022	2024	66	13.2	0.0	0.0	13.2
2022	2050	98	11.8	0.0	0.0	11.8
2022	2052	80	7.0	0.0	0.0	7.0
20251	2015	160	19.8	0.0	0.0	19.8
20251	2017	95	8.4	0.0	0.0	8.4
20251	2023	117	16.5	0.0	0.0	16.5
20251	2024	27	5.5	0.0	0.0	5.5
20251	2050	200	24.9	0.0	0.0	24.9
20251	2052	239	30.1	0.0	0.0	30.1
2027	2015	93	16.5	0.0	0.0	16.5
2027	2017	27	5.5	0.0	0.0	5.5
2027	2023	173	18.1	0.0	0.0	18.1
2027	2024	109	10.0	0.0	0.0	10.0
2027	2050	205	22.3	0.0	0.0	22.3
2027	2052	223	37.3	0.0	0.0	37.3
20341	2015	285	48.4	0.0	0.0	48.4
20341	2015	215	34.4	0.0	0.0	34.4
20341	2023	88	31.4	0.0	0.0	31.4
20341	2024	27	5.5	0.0	0.0	5.5
20341	2050	258	34.7	0.0	0.0	34.7
20341	2052	316	42.5	0.0	0.0	42.5

TABLE D.1. Continued

Work Location	Source Location	Distance from Work To Source Location	Thickness of Shielding Separating Work and Source Locations, (in feet).			
			Existing	Additional	Additional	Total
20401	2015	234	29.2	0.0	0.0	29.2
20401	2017	197	24.5	0.0	0.0	24.5
20401	2023	32	5.5	0.0	0.0	5.5
20401	2024	117	16.5	0.0	0.0	16.5
20401	2050	90	5.9	0.0	0.0	5.9
20401	2052	155	16.8	0.0	0.0	16.8
2041	2015	244	30.7	0.0	0.0	30.7
2041	2017	205	23.5	0.0	0.0	23.5
2041	2023	43	2.3	0.0	0.0	2.3
2041	2024	109	13.8	0.0	0.0	13.8
2041	2050	133	25.2	0.0	0.0	25.2
2041	2052	199	43.3	0.0	0.0	43.3
2045	2015	226	33.3	0.0	0.0	33.3
2045	2017	207	22.2	0.0	0.0	22.2
2045	2023	85	7.6	0.0	0.0	7.6
2045	2024	157	17.9	0.0	0.0	17.9
2045	2050	29	5.5	0.0	0.0	5.5
2045	2052	96	16.5	0.0	0.0	16.5
20461	2015	260	26.0	0.0	0.0	26.0
20461	2017	268	26.8	0.0	0.0	26.8
20461	2023	58	11.0	0.0	0.0	11.0
20461	2024	146	22.0	0.0	0.0	22.0
20461	2050	85	23.5	0.0	0.0	23.5
20461	2052	56	5.5	0.0	0.0	5.5
20112	2015	77	23.5	0.0	0.0	23.5
20112	2017	56	5.5	0.0	0.0	5.5
20112	2023	218	38.0	0.0	0.0	38.0
20112	2024	146	29.2	0.0	0.0	29.2
20112	2050	260	26.0	0.0	0.0	26.0
20112	2052	268	34.1	0.0	0.0	34.1
20182	2015	64	19.5	0.0	0.0	19.5
20182	2017	104	19.5	0.0	0.0	19.5
20182	2023	90	19.5	0.0	0.0	19.5
20182	2024	26	5.5	0.0	0.0	5.5
20182	2050	173	24.1	0.0	0.0	24.1
20182	2052	146	38.8	0.0	0.0	38.8
20183	2015	148	38.8	0.0	0.0	38.8
20183	2017	172	32.2	0.0	0.0	32.2
20183	2023	24	5.5	0.0	0.0	5.5
20183	2024	91	33.5	0.0	0.0	33.5
20183	2050	98	20.6	0.0	0.0	20.6
20183	2052	62	19.5	0.0	0.0	19.5
20184	2015	205	64.8	0.0	0.0	64.8
20184	2017	223	38.2	0.0	0.0	38.2
20184	2023	64	19.1	0.0	0.0	19.1
20184	2024	148	46.9	0.0	0.0	46.9
20184	2050	93	16.5	0.0	0.0	16.5
20184	2052	24	5.5	0.0	0.0	5.5
20252	2015	255	19.6	0.0	0.0	19.6

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