SITING WASTE DISPOSAL FACILITIES IN HOST COMMUNITIES: IMPACTS AND ACCEPTANCE

by

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ABSTRACT

SITING WASTE DISPOSAL FACILITIES IN HOST COMMUNITIES: IMPACTS and ACCEPTANCE

The siting of municipal solid waste disposal facilities is often unsuccessful or delayed because of host community opposition. Physical, economic, social and political impacts of a landfill and an incinerator site are identified, assessed and combined in a rational model to explain the cause of opposition.

Residents' beliefs about facility impacts correspond well with the assessed physical impacts at the landfill in identifying odor, birds, traffic, water emissions and explosion risks as negative impacts and convenient disposal as a benefit. At the incinerator, common resident beliefs comprise odors, noise, traffic and air emissions as negative impacts and energy recovery as a benefit. Underlying these obvious physical impacts, however, is a group of non-physical beliefs about the harm to community image, loss of control, unfairness, and property value losses in the host community. These non-physical impacts influence the attitude about the facility as strongly as the physical impacts.

Finally, exposure to obvious physical impacts is shown to negatively influence the beliefs about physical and non-physical (economic, social and political) impacts. Thus, by screening the host community from obvious physical impacts (nuisances), the beliefs about community image, control, fairness and property values can be enhanced.

Since negative attitude and opposition action are strongest

prior to facility construction, the siting efforts need to be focused on this period. After construction, the host community adapts to the new situation.

The facility impacts are combined into a model to define a criterion for acceptance. The net value of facility impacts and benefits must reach or exceed in value the narrow tolerance range at the original host community reference point to avoid significant host community opposition. Impact reduction rather than compensation is theoretically shown to be the more effective approach to fulfilling the acceptance criterion. This approach is empirically tested at typical waste facility sites.

Despite higher costs for prevention and emission control methods to reduce physical and non-physical impacts, these methods are shown to be superior to mitigation and compensation in gaining community acceptance.

Based on the conclusions, the policy statement on waste facility sitings recommends first, defining entitlements and rules for the siting process, establishing increasing waste reduction and separation in a waste management plan, and using participative community planning as long-term, preventive facility siting measures. Short term siting measures comprise, the negotiation of siting agreements, the use of best available technical emission controls and continued monitoring by an overview committee. The focused use of prevention and control measures to address host community concerns can substantially enhance community acceptance of municipal solid waste facilities.

TABLE OF CONTENTS

Page

Chapter 1 Introduction 1

1.1 Overview 1
1.1.1 Problem Statement, Thesis Goals and Hypotheses 1
1.1.2 Thesis Structure, Objectives and Methodology 4
1.1.3 Scope, Limitations and Study Area 10
1.1.4 Significance 13

1.2 Selection and Description of Typical Municipal Solid Waste Facility Sites 13
1.2.1 Facility Survey 14
1.2.2 Landfill Site Description 14
1.2.3 Tacoma Landfill Siting Process 28
1.2.4 Incinerator Site Description 30
1.2.5 Salem Incinerator Siting Process 35

Chapter 2 Municipal Waste Disposal Facility Emissions, Host Community Characteristics and Resulting Impacts 42

2.1 Physical Emissions of Waste Facilities 42
2.1.1 Municipal Solid Waste Stream 43
2.1.2 Municipal Solid Waste Landfilling 46
Landfill Nuisances 49
Landfill Decay Processes and Products ... 50
Landfill Gas 58
2.1.3 Municipal Solid Waste Incineration 60
Incinerator Nuisances 64
Incinerator Combustion Process and Air Emissions 65
Incinerator Water Use and Emissions 71

2.2 Contaminant Transport and the Impact Footprints 72
2.2.1 Emission Transport Mechanisms 72
Air 72
Pressure Waves Propogation 75
View Propogation 75
Water 76
2.2.2 Impact Footprints 78
2.3 Host Community Characteristics 79
2.3.1 Patterns of Waste Facility Location 81
2.3.2 Characteristics of Rural Communities 86
2.4 Waste Facilities and Host Community Interaction: Qualitative Impact Identification 89

Page

2.4.1 Physical Impacts 89
2.4.2 Non-Physical Impacts 90
Economic Impacts 92
Social Impacts 99
Political Impacts 101
2.4.3 Facility Benefits 110
2.4.4 Chapter Summary 111

Chapter 3 Acceptance Criterion and Approach for Siting Waste Facilities in Host Communities 113

3.1 Facility Impact Model and Acceptance Criterion 113
3.2 The Basic Acceptance Approach 122
3.2.1 Values for Losses and Gains 122
3.2.2 Change Values for Different Impact Dimensions 127
3.2.3 In-Kind Impact Reduction as a Priority for Facility Acceptance 128
3.3 Priorities for Facility Impact Reduction Methods 129
3.3.1 Framing the Siting Process for Acceptance 133
3.3.2 Managing the Change Adaptation Process 136

3.4 Compensation for Negative Impacts of Waste Disposal Facilities 140
3.4.1 Normative Goals and Principles 141
3.4.2 Entitlements and Their Effects on Efficiency and Fairness 142
3.4.3 Compensation Principles and Practice 145
3.4.4 Summary - Legal and Negotiated Compensation 157

3.5 Summary and Conclusions 159

Chapter 4 Waste Facility Impact Assessment 162

4.1 Nuisances 162
4.1.1 Visual Impacts 162
4.1.2 Noise Impacts 167
4.1.3 Odor Impacts 182
Landfill 185
Incinerator 195

4.2 Air Quality Impacts 203
4.2.1 Landfill or Emissions 203
4.2.2 Air Quality Impacts from Incinerators 220

Page

4.3 Water Quality Impacts From Waste Facilities 237
4.3.1 Landfill Groundwater & Surface Water Impacts in Tacoma 239
4.3.2 Incinerator Water Impacts 259
4.4 Summary of Waste Facilities Physical Impacts 259

Chapter 5 Beliefs, Attitude and Action in Typical Host Communities 266

5.1 Overview or Study Structure & Methodology ... 266
5.1.1 Goal and Objectives 266
5.1.2 Methodology and Structure 269

5.2 Survey of Residents' Beliefs and Attitudes in Host Control Community 272
5.2.1 Rationale 272
5.2.2 Survey Structure and Method 273
5.2.3 Survey Design 275

5.3 Results 281
5.3.1 Validation of Results 281
5.3.2 Impact Beliefs 305
5.3.3 Physical Impacts and Impact Beliefs 317
5.3.4 Attitude among Host and Control Residents .. 319
5.3.5 Newspaper Reports about Waste Facilities and Negative Impact Beliefs among Residents .. 321
5.3.6 Summary - Beliefs and Attitudes about Waste Facilities 330
5.3.7 Effects of Facility Impact Beliefs and Attitudes on Neighborhood Beliefs and Attitudes 336
5.3.8 Awareness, Attitude and Behavioral Response 344

5.4 The Effects of Facility Impacts on Residential Real Estate in the Host Communities 349
5.4.1 Significance 349
5.4.2 Data Collection and Analysis 350
5.4.3 Results 355
5.4.4 Property Value Impact - Summary 368

5.5 Chapter Summary - Beliefs, Attitudes, Opposition to Waste Facilities in Residential Neighborhoods 369
5.5.1 Physical Impacts, Newspaper coverage, and Residents' Beliefs 369
5.5.2 Residents' Beliefs and Attitudes about Waste Facilities and Beliefs & Attitudes about Neighborhoods 373

6.1 Facility Siting Measures to Enhance Acceptance: Design, Costs and Reduction Effects 378

Page

5.5.3 Attitude and Action 375

Chapter 6 Impact Reduction Measures and Priorities for Facility Acceptance 378

6.1.1 Waste Facility Impact Reduction Methods ... 379
6.1.2 Summary of Siting Measures 401

6.2 Preferred Siting Measures and Their Effects on Attitude and Acceptance 409
6.2.1 Introduction 409
6.2.2 Acceptance Measures - Results 416
6.2.3 Impact Ranking and Reduction Priorities ... 424
6.2.4 Preferences for Impact Reduction Methods 426
6.2.5 The Effects of Acceptance Measures on Acceptance 432
6.2.6 Summary and Conclusions 439

Chapter 7 Summary and Conclusions 446

7.1 Waste Disposal System and Siting Scenario ... 446

7.2 Thesis Goal, Objectives and Methods 448

7.3 Summary of Hypotheses and Results 450
7.3.1 Facility Impacts and Resulting Beliefs among Residents 450
7.3.2 Residents' Attitude and Opposition 457
7.3.3 Systematic Approach to Facility Acceptance 460

7.4 Conclusions for Waste Facility Siting 464
7.4.1 Overview 465
7.4.2 Facility Impacts and Host Community Beliefs 465
7.4.3 Attitude and Opposition Action 467
7.4.4 Acceptance Approach and Methods 467
7.4.5 Summary and Contribution 468

Chapter 8 - Towards a Policy for Waste Facility Siting - Issues, Recommendations and Future Research 471

8.1 Waste Facility Siting Policy Issues 471
8.1.1 Discrepancy Between Proponent and Host Community Costs and Benefits 471
8.1.2 Disparity of Values 473
8.1.3 Motives for Strategic Behavior in Siting Processes 474

Page

8.1.4 Efficient Levels of Impact Reduction for Waste Facility Siting 476

8.2 Recommendations for Siting Measures 482
8.2.1 Entitlement and Protection Rules 482
8.2.2 Waste Management Plan 487
8.2.3 Community Plans 488
8.2.4 Siting Process 489
8.2.5 Waste Disposal System Measures 490
8.2.6 Summary 493

8.3 Future Research 494
8.3.1 Setting of Entitlements for Waste Facility Siting 494
8.3.2 Generalizations of Impact Model 494
8.3.3 Predictive Acceptance Model 494
8.3.4 Implications for Site Selection 496

Page

Bibliography 498

Appendices 517

1.A-Landfill Survey - List of Responsible Waste Agencies and Landfill Sites 518
1.B-Landfill Survey - Survey Questionnaire 520

4.A-View Impact Screening 525
4.B-Noise Impact Measurement 526
4.C1-Landfill Gas Impacts 546
4.C2-Landfill Gas Emission Rate & Concentration 553
4.D-Air Quality Impact Modelling for Salem Incinerator .. 555
4.E-Water Quality Impacts - Groundwater Contaminant Transport Modelling . 563
4.F-Health Risk Assessment Methodology 568

5 - A - Community Opinion Survey #1 Beliefs, Attitudes, & Opposition Action in Response to Waste Disposal Facilities 569
B - Facility Impact Coding 578
C - Results - Detailed Statistics 579

6 - A - Prevention of Landfill Leachate Emissions Through Separation and Composting of Organic Fraction 589
- B - Landfill Nuisance Prevention 619
- C - Prevention of Incinerator Air Emissions Through Separation of Refuse Derived Fuel 624
- D - Incinerator View Reduction 641
- E - Image Control 652
- F - Community Opinion Survey 2 - Priorities & Preferences for Impact Reaction Methods to Enhance Host Community Acceptance of Waste Facilities 658
- G - Tacoma Landfill - Fairness of Property Value Guarantees and Beliefs about Facility Impacts 672

LIST OF TABLES

Page

Chapter 1

Table 1.1: Methodology of Thesis Research 7
Table 1.2: Results of Landfill Site Survey of 21 Landfills in 15 Jurisdictions 17

Chapter 2

Table 2.1: Composition of Municipal Waste Stream in British Columbia, 1977 44
Table 2.2: MSW Landfill Leachate Characteristics and Drinking Water Standards 55
Table 2.3: Leachate Toxicity to Fish 57
Table 2.4: Landfill Gas Composition 59
Table 2.5: Incinerator Emissions and Standards . 69
Table 2.6: Potential Health Impacts of Incinerator Emissions 70
Table 2.7: Waste Facility Emissions, Transport and Impacts 73
Table 2.8: Compilation of Poitical Impacts in this Study with Risk Perception Factors in Previous Studies 102
Table 2.9: Summary of Municipal Solid Waste Facility Impacts 111

Chapter 3

Table 3.1: Entitlement/Protection Rule Mastrix .. 143
Table 3.2: Summary of Negotiated Compensation Cases 156

Chapter 4

Table 4.1: View Rating List of Waste Facilities.. 163
Table 4.2: Landfill - Measured Sound Levels 171
Table 4.3: Landfill - Measured and Estimated Community Noise Levels 175
Table 4.4: Incinerator - Measured Sound Levels .. 177
Table 4.5: Incinerator - Measured and Estimated Community Noise Levels 180
Table 4.6: Landfill-Odor Assessment Conditions .. 189
Table 4.7: Landfill Odor Impacts 190
Table 4.8: Tacoma Landfill Odor Impact Limits .. 196
Table 4.9: Incinerator Odor Measurement, Weather Conditions 200
Table 4.10: Incinerator Odor Impact Measurements .. 202
Table 4.11: Gas Migration Route Influences 206

Page

Table 4.12: Landfill - Measured Gas Concentrations in Gas Probes outside the Landfill detected in the Order of Magnitude of TLV 206
Table 4.13: Landfill Leachate Contaminant Physical-Chemical Data 210
Table 4.14: Landfill - Gas Concentration 213
Table 4.15: Landfill - Exposure of Residents to Landfill Gas 214
Table 4.15b: Landfill - Exposure of Employees to Landfill Gas 215
Table 4.15c: Landfill Gas Health Risks to 4-56 Residents 100m East 216
Table 4.15d: Health Risks to Employees 100 m West due to Inhalation 217
Table 4.16: Incinerator - Emission Rates & Concentrations for Main Pollutants .. 223
Table 4.17: Incinertor Gaseous Emission Concentrations 227
Table 4.18a: Incinerator - Particulate Dispersion Concentrations and Deposition 229
Table 4.18b: Incinerator Particulate Emission Concentration and Deposition 231
Table 4.19: Incinerator - Gaseous Emission Exposure and Health Risks 232
Table 4.20: Incinerator - Particulate Emission Exposure and Health Risks by Inhalation & Ingestion 234
Table 4.21: Incinerator - Sensitivity Analysis for Health Risks 235
Table 4.22: Incinerator - Air Quality Impacts 238
Table 4.23: Volatile Organic Compounds Detected in Groundwater Samples 243
Table 4.24: Landfill - Contaminant Vertical Migration Times 248
Table 4.25a: Landfill - Water Quality Health Risks for Domestic Wells 500m SW of Landfill Boundary 255
Table 4.25b: Health Risks from Groundwater 256
Table 4.26: Incinerator - Discharge Water Characteristics 261
Table 4.27: Summary Matrix of Data Collection Methods for Physical Impacts 262
Table 4.28: Physical Impact Summary 265

Chapter 5

Table 5.1: Methodology of Beliefs, Attitude and Action Study 270

Page

Table 5.2: Community Belief-Attitude Survey Structure 274
Table 5.3a: Landfill Survey Sample and Neighborhood Demographics for Orchard Neighborhood 282
Table 5.3b: Landfill Survey Sample and Neighborhood Demographics for Fircrest Township . 283
Table 5.4: Tacoma Landfill - Calculation of Host Community Survey Sample from weighted Survey Samples 284
Table 5.4D: Tacoma Landfill - Host & Control Sample Comparison 284
Table 5.5: Tacoma Host Community - Demographics Variables and Significantly Associated Negative Impact Beliefs 287
Table 5.6a: Salem - Comparison of Host Survey Sample With Census 289
Table 5.6b: Salem Comparison of Control Sample with Census 290
Table 5.7: Salem Host Community: Demographic Variables and Significantly Associated Negative Impact Beliefs 291
Table 5.8a: Tacoma Landfill Host Community Sample Demographics vs. Physical Impacts . 294
Table 5.8b: Salem Incinerator Host Community Sample vs. Physical Impacts 295
Table 5.9a: Tacoma Landfill - Internal Validation of Negative Beliefs about Facility Impacts - Association of Salient and Specific Impact Beliefs Ratings in the Host Community 299
Table 5.9b: Tacoma Landfill - Internal Validation of Negative Beliefs about Facility Impacts - Association of Specific Impact Belief Ratings and Impact Belief Statements in the Host Community .. 300
Table 5.9c: Salem Incinerator - Internal Validation of Negative Beliefs about Facility Impacts - Association of Ratings in the Host Community 301
Table 5.9d: Salem Incinerator - Internal Validation of Negative Beliefs about Facility Impact - Belief Ratings and Impact Belief Statements in the Host Community 302
Table 5.10: Internal Validation Through Rank-Order Correlation of Attitude Ranking & Rating of Facilities 304
Table 5.11: Spontaneous Concerns & Benifits about Waste Facilities 306

Page

Table 5.12a: Tacoma Landfill - Impact Belief Ratings and Connection with Attitude and Annoyance about the Waste Facility . 308
Table 5.12b: Tacoma Landfill - Impact Belief Statements and Connections with Attitude and Annoyance about waste Facility 309
Table 5.12c: Salem Incinerator - Impact Belief Ratings and Connection to Annoyance about the Waste Facility 312
Table 5.12d: Salem Incinerator - Impact Belief Statements and Connection to Annoyance about the Waste Facility 313
Table 5.13: Familiarity and Attitude about Waste Facilities 315
a. Tacoma City Landfill
b. Salem Incinerator
Table 5.14: Rank Order Correlation of Familiarity With Facility and Attitude about the Facility 316
a. Tacoma Landfill
b. Salem Incinerator
Table 5.15: Exposure to Physical Impacts and Resulting Negative Impact Beliefs 318
a. Tacoma Landfill
b. Salem Incinerator
Table 5.16: Attitudes about Waste Facilities 320
a. Tacoma Landfill Site
b. Salem Incinertor Site
Table 5.17: Content Analysis - Waste Facility Impacts and Benefits
a. Newspaper Readership 517
b. News From Newspaper versus TV News. 518
c. Cross Tabulation of Frequent Paper Readers with Frequent Watchers in the Host Communities 519
Table 5.18: Content Analysis of Newspaper Articles
a. About Landfill Comparison of Media Frequency with Surveyed Frequency of Impact Beliefs 326
b. About Incinerator Comparison of Media Frequency with Surveyd Frequency .. 327
Table 5.19: Tacoma Landfill - Association of Facility Beliefs with Beliefs and Attitudes about Neighborhood 338
Table 5.20: Tacoma Landfill - Correlation of Beliefs about Neighborhoods with Attitudes about Neighborhood in Host & Control Communities 339

Page

Table 5.21: Salem Incinerator - Facility Beliefs with Beliefs and Attitudes about Neighborhood 340
Table 5.22: Salem Incinerator - Association of Facility Beliefs with Beliefs & Attitudes about Neighborhood 341
Table 5.23a: Attitudes about Neighborhood and - Correlation with Attitude about waste Facility 342
Table 5.23b: Attitudes about Neighborhood and - Correlation With Attitude about Waste Facility 343
Table 5.24: Awareness Annoyance and Benavioral Response in Host Communities 346
Table 5.25: Association of Annoyance, Awareness and Action in Host Communities 348
Table 5.26: Real Estate Analysis Methods 351
Table 5.27: Multiple Regression Analysis of Facility Impacts on Property Values in Host Communities 353
Table 5.28: Tacoma Landfill - Host Community Residential Real Estate Sales. 1983-1984 - Multiple Regression Analysis Results 356
Table 5.29: Salem Incinerator - Host Community Residential Real Estate Sales, 1983-1987 - Multiple Regression Analysis Results 362
Table 5.30: Salem Host Community - Residential Property Listings and Outcomes 367

Chapter 6

Table 6.1: Summary of Significant Beliefs about Facility Impacts in Host Community .. 380
Table 6.2a: Landfill - Set of Siting Methods and Impact Reduction Measures 383
Table 6.2b: Incinerator - Set of Siting Methods and Impact Reduction Measures 384
Table 6.3a: Set of Methods to Address Health Risks from Water Emissions 402
Table 6.3b: Set of Methods to Address Landfill - Nuisances 403
Table 6.3c: Set of Methods to Address Health Risks from Incinerator Air Emissions 404
Table 6.3d: Set of Methods to Address View 405
Table 6.3e: Set of Methods to Address Loss of Control 406

Page

Table 6.3f: Set of Methods to Address Image Impacts 407
Table 6.3g: Set of Methods to Addres Unfairness ... 408
Table 6.4a: Ranking of Health Risk Measures by Cost and Effectiveness 410
Table 6.4b: Ranking of Nuisance Measures by Cost... 411
Table 6.4c: Ranking of Community Image Measures by Cost 412
Table 6.5: Sample Sizes for Acceptance Measure Interviews 414
Table 6.6: Comparison of Acceptance Interview Sample with Community Impact Survey (Survey 1) Sample by Demographics ... 417
Table 6.7: Comparison of Familiarity with Waste Facilities among Interview Respondents and the Host Community 419
Table 6.8: Comparison of Beliefs about Waste Facilities among Interview Respondents and Survey Respondents 421
Table 6.9: Comparison of Attitude about the Waste Facility among Interview Respondents and the Host Community 422
Table 6.10: Impact Priorities of Actual Facility Sites 425
Table 6.11: Priorities for Impact Reduction for a New Facility 427
Table 6.12: Preferences for General Impact Reduction Methods 428
Table 6.13: Preferences for Specific Impact Reduction Measures
a. Health Risk Reduction Measures ... 430
b. Community Image Impact Reduction Measures 431
Table 6.14: Fairness of Property Value Guarantees 433
Table 6.15: Effects of Property Value Guarantees on Acceptance of Facility Impacts at a New Incinerator 435
Table 6.16: Effects of Reduction Measures on Facility Aceptance
a. Health Risks Reduction Measures .. 437
b. Community Image Reduction Measures 438
Table 6.17: Acceptance with Combined Acceptance Measures 440
a. Landfill
b. Incinerator

Page

Table 6.18: Effect of Combined Impact Reduction Measures on Acceptance 441
a. Landfill
b. Incinerator

Chapter 7

Table 7.1: Methodology of Thesis Research 449
Table 7.2: Waste Facility Impacts and Benefits 451
Table 7.3: Attitudes about Waste Facilities 458
Table 7.4: Preferences for General Impact Reduction Methods 462

Chapter 8

Table 8.1: Comparison of Consequences to Proponent and Host Community for Conventional and Alternative Siting Approaches ... 472

LIST OF FIGURES

Page

Chapter 1

Figure 1.1: Municipal Waste Facility Impacts and Resulting Level of Host Community Opposition 3
Figure 1.2: Overview of Thesis Research 6
Figure 1.3: Waste Disposal System for Large Metropolitan Areas 11
Figure 1.4: Tacoma City Landfill Site, Tacoma, Washington 16
Figure 1.5: Tacoma Landfill Surrounding Land Use 24
Figure 1.6: Salem Incinerator Site in Brooks, Oregon 32

Chapter 2

Figure 2.1a: Residential & Commercial Solid Waste Disposed - 1980 45
Figure 2.1b: Residential & Comercial Solid Waste Disposed 1990 45
Figure 2.2: MSW Landfill Operation Emissions ... 47
Figure 2.3: Landfill Decay Process Characteristics 52
Figure 2.4: Municipal Solid Waste Incinerator - Cross Section. Source: LMRP 1984 .. 62
Figure 2.5: Mass-Burning Grate Incinerator Emissions 63
Figure 2.6: Temperature - Time Distribution in a MBG Incinerator 66
Figure 2.7a: Landfill Emission Footprint 80
Figure 2.7b: MSW Incinerator Impact Footprint ... 80
Figure 2.8: Dates of Landfill Closures Relative to the Extent of Urban Development in the Greater Vancouver Area, 1961-1981 83
Figure 2.9: Development after Facility Siting in a Typical Host Community 85
Figure 2.10: Distribution of Costs and Benefits of Waste Disposal Facilities 106

Chapter 3

Figure 3.1: Acceptance Model and Net Facility Impact 114
Figure 3.2: Change Resistance 119
Figure 3.3a: Value Curve According to the Prospect Theory 123

Page

Figure 3.3b: The Value of a Loss Reduction Exceeds that of an Equal Gain 123
Figure 3.4: Waste Disposal System and Impact Reduction Methods 130

Chapter 4

Figure 4.1: Landfill View Impact Field 165
Figure 4.2: Incinerator View Impact Field 166
Figure 4.3: Waste Facility Noise Frequency Spectra 170
Figure 4.4: Landfill Noise Impact Field 172
Figure 4.5: Incinerator Noise Impact Field 178
Figure 4.6: Predicted Community Response to Waste Facility Noise Impacts 181
Figure 4.7: Landfill Odor Impact Field 193
Figure 4.8: Air Emission Dispersion from a line Source for a Groundlevel Receptor . 197
Figure 4.9: Incinerator Odor Impact Field 201
Figure 4.10: Landfill Air Emission Transport Paths 204
Figure 4.11: Landfill Locations with Methane Explosive Detected over Concentrations..... 208
Figure 4.12: Landfill Gas Dispersion Model 212
Figure 4.13: Groundlevel, Centerline Concentrations for an Elevated, Point Source 225
Figure 4.14: Landfill Leachate Emission Pathway 241
Figure 4.15: Landfill - Hydraulic Gradients and Flow Direction 242
Figure 4.16a: Groundwater Transport Distance for Three Representative Contaminants With Varying Organic Soil Content.. 251
Figure 4.16b: Groundwater Transport Range for Vinyl Chloride for Retardation Due to Organic Soil Content 252
Figure 4.16c: Groundwater Transport of Vinyl Chloride with Varying Transport Conditions... 253
Figure 4.17a: Landfill Physical Impact Footprint ... 263
Figure 4.17b: Incinerator Physical Impact Footprint 264

Chapter 5

Figure 5.1: Structure & Variables in Belief Attitude Study 268

Page

Figure 5.2: Tacoma Landfill-Summary of Impacts, Beleifs and Attitudes 331
Figure 5.3: Salem Incinerator - Summary of Impacts, Beliefs and Attitudes 332
Figure 5.4a: Tacoma - Area 5 "county" Residential Listings and Sales 358
Figure 5.4b: Tacoma Area 6 "Fircrest" - Residential Listings and Sales 359
Figure 5.4c: Tacoma Area 10 "Orchard" - Residential Listings and Sales 360
Figure 5.5: Comparison of Listings and Sales in Salem and Host Community 364
Figure 5.6: Incinerator - Host Community Quarterly Frequency of Residential Property Listings during Siting Process 1982-87..... 365
Figure 5.7: Incinerator - Salem Average Sales Prices of Residential Properties 366
Figure 5.8: Tacoma Landfill - Summary of Beliefs, Attitudes and Opposition Activities . 371
Figure 5.9: Salem Incinerator - Summary of Beliefs, Attitudes and Activities..... 372

Chapter 6

Figure 6.1: Impact Reduction Methods in the Waste Disposal System 381
Figure 6.2: Landfill Nuisance Control Measures ... 389
Figure 6.3: Priorities for Impact Reduction in the Waste Disposal System 443

Chapter 7

Figure 7.1: Waste Disposal System 447
Figure 7.3a: Landfill - Summary of Impacts, Beliefs and Attitudes 455
Figure 7.3b: Incinerator - Summary of Impacts, Beliefs and Attitudes 456
Figure 7.4: Preference for Impact Reduction as a Rule of Increase Acceptance 461

Chapter 8

Figure 8.1: Disparity b/w Values for Waste Agents and Affected Host Communities..... 475
Figure 8.2: Difference of Values and the Optimal Level of Impact Reduction for Waste Facilities 478

CHAPTER 1 - INTRODUCTION

1.1 Overview

1.1.1 Problem Statement, Thesis Goals and Hypotheses.

Many large urban centers in North America need new sites for waste disposal facilities to accommodate a growing volume of municipal solid waste. Although the proposed facilities are superior to the older, obsolete facilities, host community opposition at the proposed sites often delays or prevents the construction and operation of newer, superior waste disposal facilities. As a result, more waste is disposed of at older, environmentally inferior sites, or has to be hauled over long distances to very remote sites outside the jurisdiction of the responsible urban waste agency. Thus, host community opposition leads to environmentally or financially costly waste management solutions.

From the facility proponent's and the waste agency's perspective, the siting of new, modern waste disposal facilities are a necessity to provide a vital service to protect public health and aesthetics as well as to close down older, inferior facilities. Yet, despite the large social benefits, the advantages of closing older facilities, and the very low levels of physical impacts from new disposal facilities, host community opposition to waste facilities is often very strong. Although everyone realizes the need for waste facilities, no one wants them in their own community. This attitude is referred to as the NIMBY (not-in-my-backyard) syndrome (e.g., Armour, 1983).

In contrast, the focus of host community opposition is on the facility's impacts and the resulting changes in the community. The opposition results from the perception of the facility as a net loss to the host community. The loss caused by a waste facility in a host community consists of the physical impacts (noise, traffic, odor, water and air emissions, etc.) and an additional, possibly non-physical, impact element that causes the NIMBY syndrome. This additional element increases the magnitude of the net facility impact (total impacts less benefits), and hence, increases the resistance to the facility in the host community (See Figure 1.1).

Although many facility proponents and local government waste agencies carry out intensive physical site selections and address many technical aspects in the facility design and operation, disproportionally strong host community resistance often causes costly delays or altogether prevents the construction of the facility at high financial and environmental costs to society and to the facility proponent.

The goals and hypotheses of this thesis result from the foregoing problem statement. First, the thesis must identify the complete set of physical and non-physical (economic, social, political) impacts in order to test and explain the importance of and interaction among facility impacts that generate opposition. The underlying hypothesis states that host community opposition is caused by a complex combination of physical and non-physical changes that are interpreted as negative impacts on the host community. This statement implies that there is a rational set of

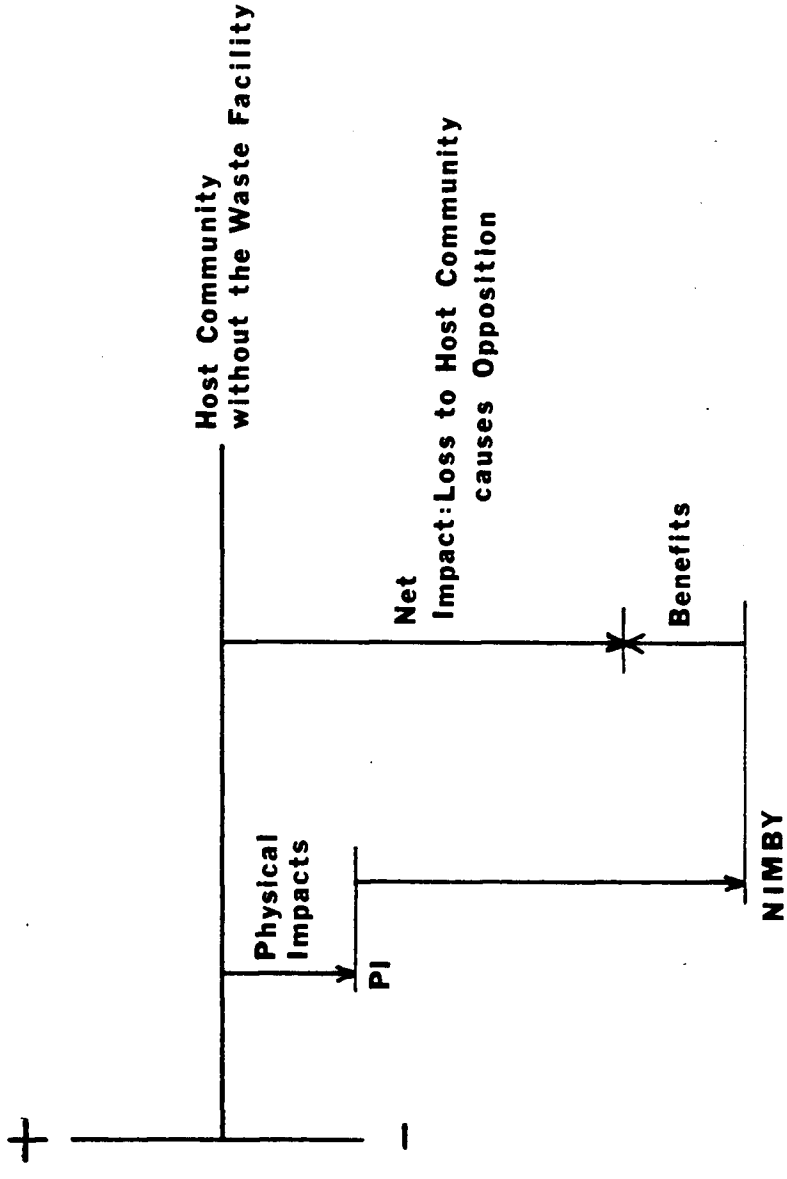


Figure 1.1: Municipal Waste Facility Impacts and Resulting Level of Host Community Opposition.

impacts, albeit possibly non-physical, that explains a negative attitude towards waste facilities in typical host communities.

The second goal is to derive and test an approach to gaining host community acceptance by testing different methods to address key facility impacts. This goal implicitly hypothesizes that there is a more effective way of achieving better host community acceptance than through a purely physical approach. Furthermore the hypothesis states that by understanding the interactions between impacts, perceptions, attitudes and action, a more effective and less costly facility siting approach can be developed.

1.1.2 Thesis Structure, Objectives and Methodology.

This thesis begins by explaining the complex interaction of municipal solid waste (MSW) disposal facilities and host communities. Then, the thesis derives and tests methods and priorities to obtain prior acceptance of waste disposal facilities in the host community. Finally, the conclusions outline a rational and more effective approach to facility siting.

The study is structured in three phases. Phase I forms the basis for the study through the selection and description of typical waste facilities in Chapter 1 and the determination of a set of typical facility impacts in Chapter 2. Chapter 3 describes a theoretical impact model, defines an acceptance criterion, and derives a principle for an effective approach to facility siting.

Phase II consists of the assessment of impacts, impact

perceptions and resulting action in typical host communities. Chapter 4 objectively assesses facility impacts, while Chapter 5 determines residents perceptions, attitudes and actions.

In Phase III, impact reduction measures are designed and tested in Chapter 6. Chapter 7 summarizes the findings, draws conclusions to select measures to gain facility acceptance, and lists the implications for future research.

In order to reach the thesis goals, the research achieves the following objectives by using literature reviews, qualitative and quantitative analyses (see Figure 1.2 and Table 1.1). In the second part of Chapter 1, a municipal solid waste (MSW) landfill and an MSW incinerator are selected as typical waste facilities. The sites and siting processes are described.

In Chapter 2, the typical waste disposal system is defined. The characteristics of landfills and incinerators are analysed to describe the physical emissions from these facilities. Typical host community characteristics are determined.

Through analysis of the interaction of the waste facility as the source of emissions and the host community as the receptor, a set of typical waste facility impacts is defined. The impacts and benefits in the set exhaustively and exclusively cover the effects a waste facility may have on a typical host community. This list of effects forms the dimensions with which the facilities' impacts are assessed in Chapter 4 and 5.

Chapter 3 explains how the impacts and benefits are combined into a rational model to define host community acceptance. This model follows economic and decision analysis theory to

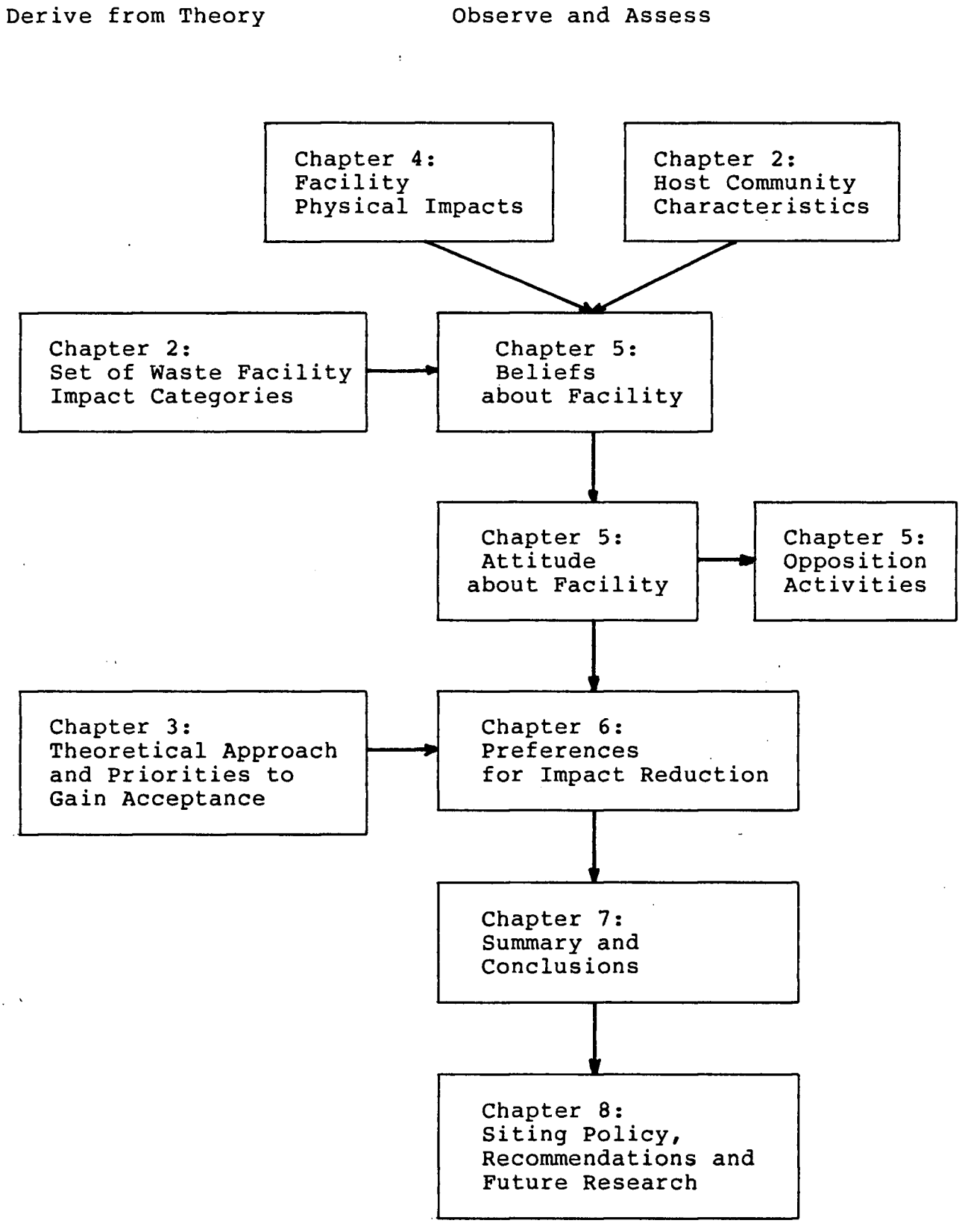


Figure 1.2 - Overview of Thesis Research

Table 1.1 - Methodology of Thesis Research

Phase I		
Chapter 1:	Study Site Selection and Description	Facility Survey
Chapter 2:	Set of Facility Impacts	Literature Review
Chapter 3:	Impact Model	Conceptual Analysis
	Acceptance Criterion	Conceptual Analysis
	Acceptance Approach	Conceptual Analysis
	Priorities for Acceptance Methods	Conceptual Analysis
Phase II		
Chapter 4:	Physical Impact Analysis	Physical Measurement and Validation
Chapter 5:	Beliefs, Attitudes and Action	Written Survey in Host and Control Communities
		Content Analysis of Newspapers
		Real Estate Analyses
Phase III		
Chapter 6:	Set of Practical Acceptance Measures	Technical Design of Prevention, Control, Mitigation and Compensation Measures
	Preferences for Acceptance Methods and Acceptance	Interviews with Host and Control Community Representatives
Chapter 7:	Summary and Conclusions	Deduction from Results in Previous Chapters
Chapter 8:	Siting Policy, Issues, Recommendations and Future Research	Deduction from Results in Previous Chapters

conceptually explain the combination of impacts and benefits and to define a criterion of acceptance. The criterion determines when a facility is considered acceptable by a host community. This criterion therefore defines the goal of a facility siting process.

Further in Chapter 3, the theoretically optimal approach to achieving acceptance is derived. The prospect theory (Kahnemann and Tversky, 1979) is applied to the set of facility impacts to determine the principle to be used to gain acceptance. Priorities are established for the use of specific measures in the typical waste disposal system. The conclusion of Chapter 3 presents a theoretically derived optimal approach to achieve facility acceptance in the host community.

The physical impacts of typical landfills and incinerators are measured and mapped in Chapter 4. The measured data are validated with impact decay models for noise, odor, view, air and water quality impacts. The results are presented as facility footprints to form the base for comparing physical impacts with perceptions among host community residents in Chapter 5.

The residents' beliefs, attitudes and behavior are summarized in Chapter 5. The analysis tests the connection between physical impacts measured in Chapter 4, perceived facility impacts and attitude about the facility. These connections show the chain of physical cause to effect in the perception and attitude about the facility. The media influence in this cause-effect pathway is tested. Then, the connection between beliefs about the facility and beliefs and attitude about the host community is determined.

Finally, the opposition activities are measured in three categories: exit, voice and adaptation. Property value losses and number of sales represent the exit response. Complaints, information gathering, and meeting attendance represent voice, while no opposition activity represents acceptance. Chapter 5 therefore describes residents' beliefs, and attitude and activities in response to the siting of typical waste facilities. The results indicate important impacts and their significance for the attitude about the facility.

In Chapter 6, acceptance measures are derived to fit the definitions of prevention, control, mitigation and compensation of facility impacts. Sets of specific measures are designed to address physical impacts of health risks and nuisances, and non-physical impacts on community control, image and fairness. These measures are tested to find priorities among facility impacts and preferences among the acceptance measures to render the facility acceptable. Finally, the effect of a combined set of measures on acceptance is tested. Chapter 6 establishes priorities and indicates the potential for facility acceptance with the theoretical approach as derived in Chapter 3.

The summary and conclusions in Chapter 7 outline an integrated approach to siting waste disposal facilities. The first section summarizes key results. The second section outlines a siting approach consisting of siting process and facility design measures. The last section derives the implications for the site screening process and for further research.

1.1.3 Scope, Limitations and Study Area

The study focuses on the two most common types of municipal waste disposal facility in North America, landfills and incinerators. Sanitary landfills provide over 90% of the total existing municipal solid waste (MSW) disposal capacity. However, incineration and resource recovery of MSW have already grown to 8% of the total waste stream in Canada and the U.S. and are projected to increase by a further 11% by 1990 (Waste Age, November, 1985).

Two systems are defined to delineate the scope of this thesis. The facility-host community impact system contains the facility and activities to the extent of significant impacts (dashed line in Figure 1.3). This system extends from the facility to include areas of physical and non-physical impacts. The larger waste generation-waste disposal system comprises the urban center as the main waste generator, transport systems to haul garbage to the facility, the facility, as the emitter emission transport in the environment, and the host community as the receptor of impacts (solid line in Figure 1.3). The waste agency is assumed to have control over the collection, transport, and facility elements, particularly in view of implementing methods to address facility impacts in the host community.

Since many non-physical impacts (e.g., the changes in the community image, loss of control and esteem, etc.) cannot be measured by objective methods, and, moreover, do not necessarily decay with distance from the facility, this definition of the waste disposal system and, specifically, of the facility-host community subsystem, implies an element of subjective judgment by

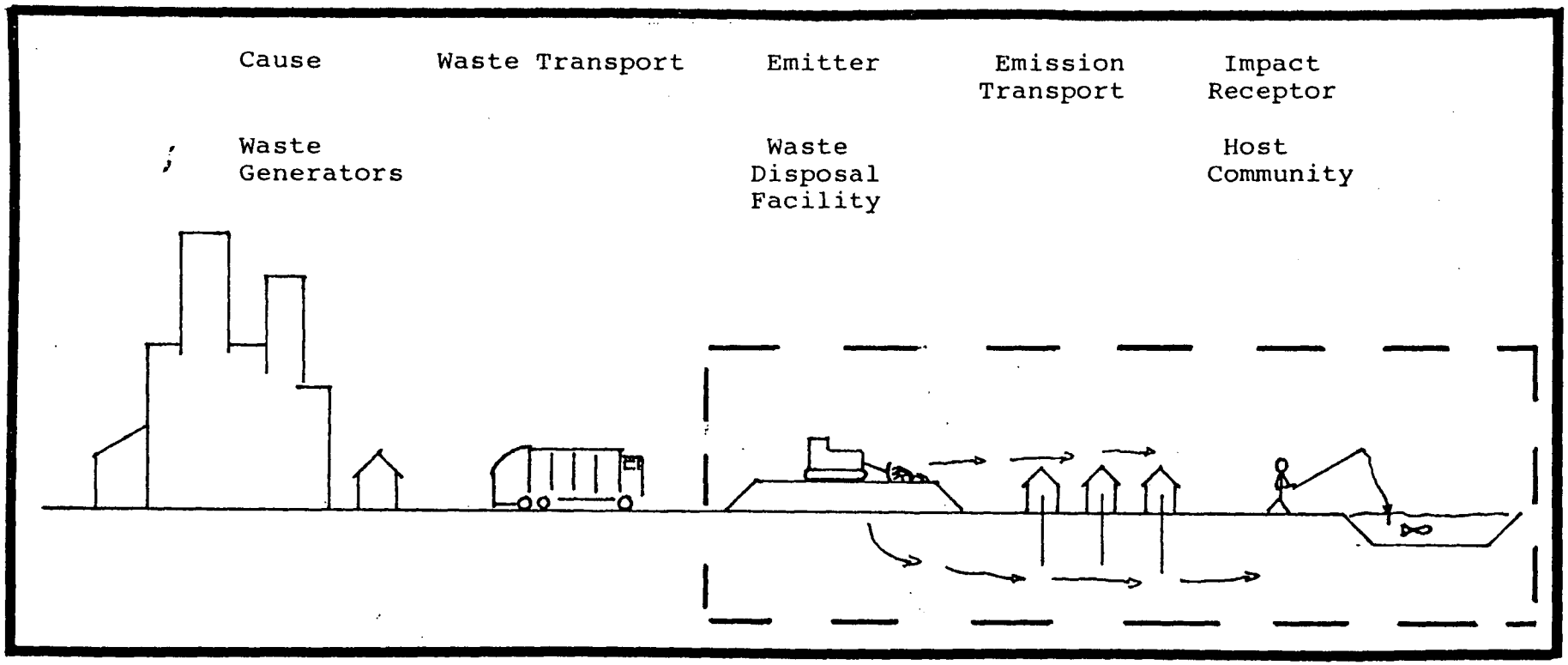


Figure 1.3 - Waste Disposal System for Large Metropolitan Areas

each potentially affected individual as to whether and how he or she is affected by the facility.

This assumption, though, is consistent with the assumption of the economic person, viz. that each individual is the best judge of his or her welfare and will behave rationally to maximize welfare. This assumption is accepted here to define the host community at the study sites to obtain opinions on beliefs and attitudes about the facility. Furthermore this rational behavior is assumed to underlie residents' choices of importance of impacts and of preferences for improvements to make facilities more acceptable.

This assumption does not ignore the possibility of strategic (intentional) or cognitive (unintentional) biases or action, but simply states that, within the limited waste disposal system, people will strive to achieve an optimal or at least a satisfactory position from their limited perspective. This is consistent with the concepts of Simon (1955, 1956) and March (1978) of bounded rationality and "satisficing" as they could be applied to the waste disposal system.

The research is limited to two specific case study sites because of time and money constraints. Thus, the validity of the research for general conclusions hinges on the representative character of the study sites. Although specific conditions may vary substantially, the generic applicability of the results is enhanced by (a) the selection of typical study sites from the set in the study area, and, (b) differentiation between generic and specific impacts and factors. The study area consists of the

provinces of Alberta, British Columbia, Manitoba and Saskatchewan in Canada, and Oregon and Washington in the United States.

1.1.4 Significance

Waste management agencies are attempting to replace obsolete and environmentally harmful disposal facilities with modern facilities. The opposition in host comunities, however, often delays or prevents an overall less harmful disposal facility because of low, but locally concentrated impacts. This problem of siting better waste disposal facilities is encountered throughout industrialized nations in Europe, Japan and North America. This thesis rationally explains the cause for, effects of and response to waste facility impacts. The research thus provides the basis for anticipating and predicting facility impacts. The research derives and tests basic guidelines for selecting effective acceptance measures for siting process and facility design. The results show priorities for impacts and methods to increase facility acceptance. As such, the results are used to outline a solution to a major concern of many waste agencies, local governments and facility proponents. The research therefore develops an approach to effectively achieving a more efficient and environmentally optimal condition for municipal waste disposal.

1.2 Selection and Description of Typical Municipal Solid Waste Facility Sites.

The purpose of this section is to identify and select typical MSW landfills and incinerators in the study area.

In order to carry out the assessment of a small number of sites, typical facility characteristics had to be identified. Two

study sites were then selected to best represent typical characteristics of landfills and incinerators.

1.2.1 Facility Survey

A set of 25 municipal waste landfills and 3 large incinerators that serve populations of over 100,000 residents in the study area were compiled. A written survey of information about the landfills was conducted through the responsible waste management agencies with the goal of finding typical site characteristics. Landfill surveys were sent out to 18 waste management agencies responsible for a total of 25 sites (see list in Appendix 1.A). The survey questions covered factual information about the facility characteristics, environmental controls, site characteristics, and host-community features (see survey form in Appendix 1.B). Completed responses on 21 landfills from 15 waste agencies were received for an 85% response rate. Potential landfill and incinerator study sites were then further evaluated by site visits and discussions with the local government officials and facility operators.

As a result, the Tacoma City Landfill in Washington was selected from the 25 landfills, because it best represents the evaluated set of landfills. The Marion County incinerator in Salem, Oregon was selected because it was the only large scale, mass-burning grate incinerator with modern filtration equipment operating in the study area in 1986.

1.2.2 Landfill Site Description

The Tacoma City landfill covers 200 acres on the western

boundary of Tacoma (see Figure 1.4). Since operations began in 1960, 3.2 million tonnes of household waste, sludges and some liquid wastes were deposited in cells of 6 to 20 metres depth. The landfill presently accepts about 170,000 tonnes per annum from 160,000 residents in the City proper and from 52,000 residents in surrounding, smaller municipalities. The expected remaining life is five to six years at current waste volumes (Black and Veatch, 1987).

The selected site differs only insignificantly from the average values for the survey sample (see Table 1.2a). In particular, the Tacoma landfill accurately represents the waste stream composition and source, and the number of lifts and fill depth.

Environmental Controls

Typical facility controls of physical emissions to water, air, and soil are summarized here.

Leachate

Most landfills (12 of 21) rely on a natural soil layer to contain leachate discharges; only five have a designed liner. The soil layers that underlie landfills range from sand and gravel, gravely loam, glacial till, shale, clay and bedrock with estimated hydraulic conductivities ranging from 10 cm/s for gravel to $1x10^{-10}$ cm/s for clay and shale. Clearly, landfills with sand and gravel layers are likely to cause substantial leachate discharges to soil and groundwater.

The Tacoma landfill is built on a 14 to 18 metre (50 to 60

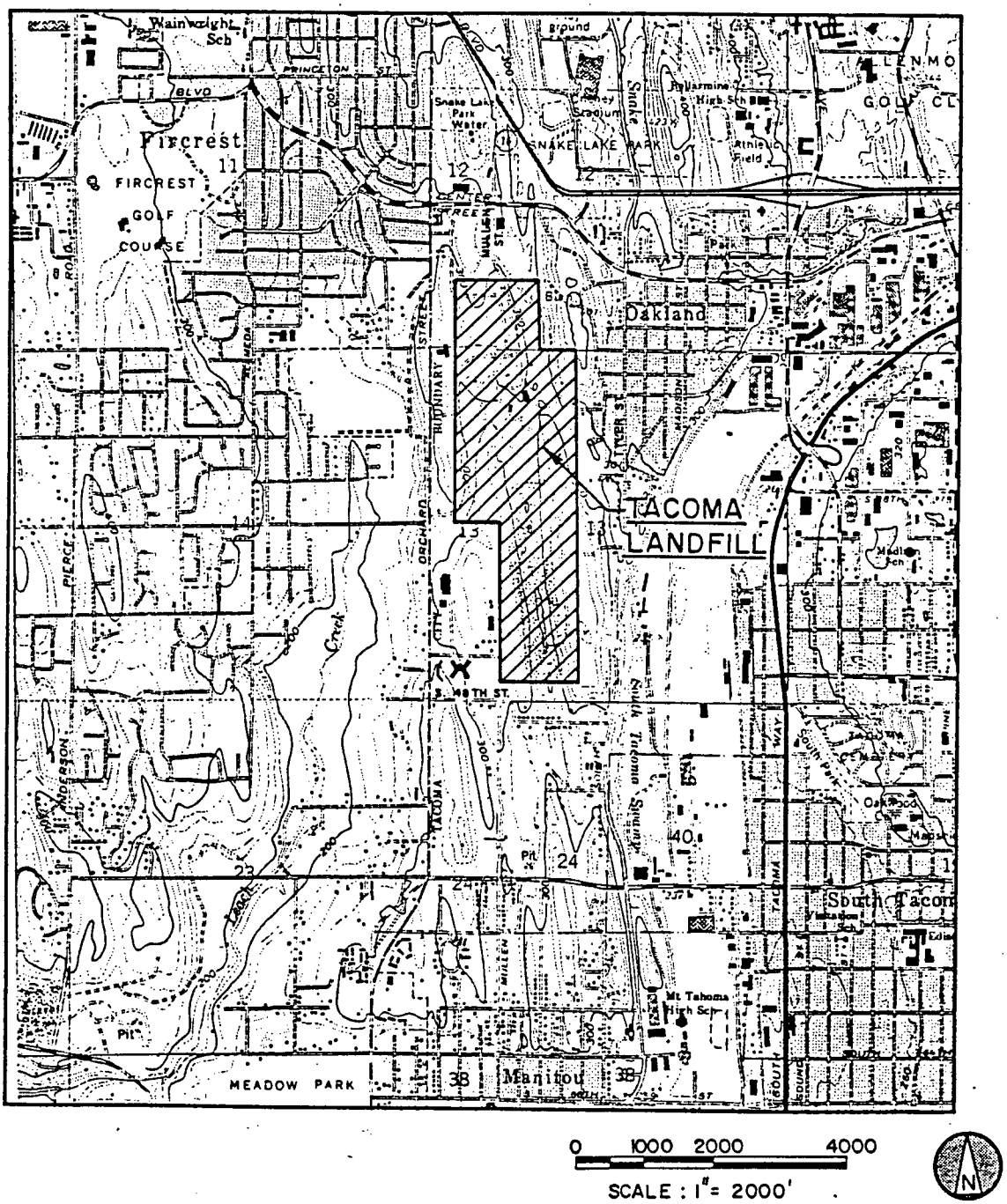


Figure 1.4 - Tacoma City Landfill Site, Tacoma, Washington
Source. Black and Veatch, 1987.

Table 1.2

Results of Landfill Site Survey of 21 Landfills in 15 Jurisdictions

a. Facility Characteristics

Attribute	Average or Frequency	Standard Deviation (for averages)	Study Site Tacoma City Landfill
Age	20.3 years	11.6 years	27 years
Capacity per year	256,500 tonnes	215,700 tonnes	170,000 tonnes
Remaining Life	14.8 years	17.5 years	6 years
Fill-Depth	26.1 m	13.3 m	6 - 20 m
Lifts	9	7	9
Waste Stream			
- MSW only	5		
- MSW and Sludge	7		MSW and Sludge and Other
- MSW and other	5		
Waste Source			
- own municipality	5		
- own and neighboring	7		own and neighboring communities
- own and large city	2		
- own, neighboring and large city	4		

feet) thick layer of glacial till with an estimated hydraulic conductivity of $1*10^{-7}$ cm/s. Although this layer was originally extended under the entire site, it has been removed for cover material or eroded away in the central part of the landfill (Black and Veatch, 1987). As a result, the glacial till layer may not be effective as a liner. The next lower layer consists of a glacial outwash with conductivities between $1*10^{-2}$ to $1*10^{-3}$ cm/s and a sand layer of 3 to $8*10^{-2}$ cm/s. Underneath this, a gravel layer of $1*10^{-1}$ cm/s conductivity, which, as a major regional aquifer, provides water to several large municipal and many domestic wells.

Most landfills, including Tacoma, have a partial leachate collection system in the form of a circumferential pipe system. Few sites have any special leachate treatment; most pump the leachate to their municipal sewage treatment plants, as Tacoma does (see Table 1.2.b).

Landfill Gas Collection

Only four of 21 sites have deep well gas collection systems, while ten have no system at all. At the time of the survey the City of Tacoma was installing a gas collection system to reduce gas migration in the soil adjoining properties and to reduce odor complaints.

View and Noise Screening

Nearly all the landfills have some natural screening with trees and shrubs as in Tacoma. Furthermore, the Tacoma site is screened on the east by a natural rise. Finally, the first row of buildings near the landfill site blocks view and noise from

Table 1.2

Results of Landfill Site Survey of 21 Landfills in 15 Jurisdictions

b. Environmental Controls

Attribute	Average or Frequency	Standard Deviation (for averages)	Study Site Tacoma City Landfill
Leachate Collection Systems			
- designed liner	5		
- natural soil layer	12		glacial till
- pipe collection system	11		partial pipe system
Leachate Treatment			
- on site	4		
- pumped to STP	5		some pumped to sewage treatment plants
- discharged without treatment	9		most not treated
Gas Collection			
- none	10		none at time of survey, but is to be installed
- surface flares	4		
- deep well system	2		
- deep well system with utilization	2		
Visual Screen			
- barriers	4		no
- trees	13		yes
-shrubs and grass	7		yes
Determined End Use			
- no	12		no
- yes	5		

further removed homes.

Site Characteristics

The basic physical features of the site (topography, water resources, and climate; see Table 1.2.c) determine the emission transport and attenuation capabilities and, hence, affect the resulting impacts.

Topography

Most landfills are on flat to slightly hilly terrain and are partially surrounded by trees and shrubs. Similar to most surveyed sites, the terrain in Tacoma slopes gently from the eastern ridge towards the west. Natural vegetation is still present on 50% of the landfill periphery.

Water Resources

Although the average distance to surface water (1,040 meters) and the depth from the fill bottom to the groundwater table (17 meters) are fairly high, their values range, respectively, from 0 meters to 8,000 m for distance, and 0 to 75 m for depth. Some landfills are built into surface water or sit in groundwater. In Tacoma, Leech Creek, a natural drainage channel and a partial groundwater discharge zone is located 1,000m west of the landfill boundary. The depth to the groundwater table ranges from 18 to 30 metres.

Climate

The weather conditions in Tacoma follow the sequence of frontal passages that begins with stable high pressure and

Table 1.2

Results of Landfill Site Survey of 21 Landfills in 15 Jurisdictions

c. Site Characteristics

Attribute	Average or Frequency	Standard Deviation (for averages)	Study Site Tacoma City Landfill
Topography			
- hilly	5		
- flat	12		flat with slight slope
- ravine	2		
Vegetation - % of circumference			
- woods	33%	37%	25%
- shrubs	16%	26%	25%
- grass	41%	42%	0%
Distance to Surface Water (average in m)			
	1040m	1890m	1000m
Groundwater Depth	17.7m	25.1m	18 to 30m
Precipitation	975mm	405mm	940mm
Evapotranspiration	-	-	300mm

northerly winds. As a front moves inland, it is preceded by rain and followed by dropping pressure and south winds for 6 to 18 hours. Usually, the low pressure zone passes within this time and a high gradually redevelops.

Typical pressures range between winter highs of 1030 mb to lows of 980 to 1002 mb. Prevailing winds during the winter, spring and fall are from the south to southwest at 3.9 to 4.5 m/s. In the summer (June to September), winds are from the north at 3.6 to 3.9 m/s, except after marine pushes, when south winds occur.

Ground inversions (at 250 to 400m height) usually develop during stable high pressure conditions and are indicated by ground fog (Nat. Weather Service, 1986 and pers. comm. John Januzzi, NOAA, Seattle, 1986). The annual precipitation in Tacoma of 940mm is close to the average of 975 mm for all landfills in the survey; 75% falls from October to March. Due to the heavy average precipitation and low evapo-transpiration in the Pacific Northwest, substantial amounts of leachate may be generated in landfills unless impermeable cover layers are applied. With the fairly impermeable cover material and the estimated evapo-transpiration in Tacoma, a 30% infiltration rate is probable (Black and Veatch, 1987).

Host Community Characteristics

Land uses and demographics near the site indicate the stability and maturity of the community in the development cycle (see Chapter 2, Zeiss and Atwater, 1986, Coote, 1985) and determines the potential level of impacts from facility emissions.

Land Use around Landfills

Typical land uses abutting the landfill boundary comprise about 33% agricultural, 24% residential, 24% undeveloped, and 19% industrial land. These figures coincide with a previous study's findings of 50% agricultural and undeveloped land, 25% residential and 25% industrial land surrounding landfills in Illinois (Stern, 1977). In contrast, 80% of the land adjacent to the Tacoma landfill is residential and 20% is industrial. There remains, however, a small pocket of original rural- residential land with 5 acre lots on the southwest corner of the landfill (see site zoning map, Figure 1.5).

Housing, Character and Income of Host Communities

On average, 750 residential units are located within 1.5 km of the landfills, whereas 3,500 are located within 1.5 km of the Tacoma landfill. Typically, 90% are single family dwellings, but only 70% of the dwellings are single family houses in Tacoma. Finally, at 60% of the surveyed sites, the host community has changed from rural-residential/agricultural to suburban/ industrial nature. The land use mix shifts have occurred or are occurring in Tacoma too, where 50% of the land is suburban or urban (apartments) residential, 35 to 40% is industrial, and 10 to 14% is still rural - residential.

Income levels are mainly lower middle to upper middle ranges, as in Tacoma. In summary, the Tacoma landfill site represents a mature form of the typical host community, but provides the entire range of land uses usually encountered around

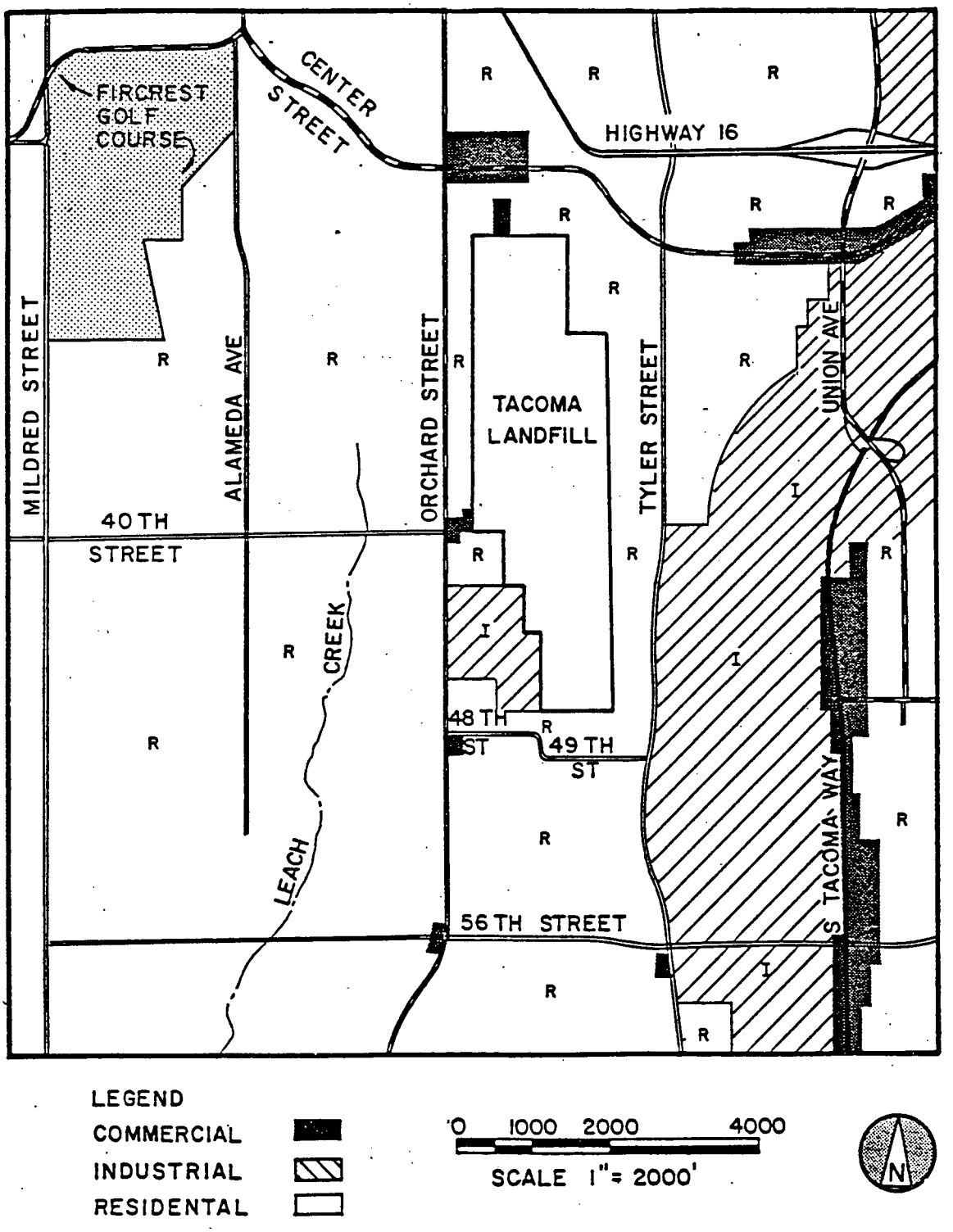


Figure 1.5 - Tacoma Landfill - Surrounding Land Uses;
Source: Black and Veatch, 1987.

Table 1.2

Results of Landfill Site Survey of 21 Landfills in 15 Jurisdictions

d. Host Community

Attribute	Average or Frequency	Standard Deviation (for averages)	Study Site Tacoma City Landfill
Land Use around Site (% of circumference)			
- residential	24%	29%	80%
- industrial	19%	28%	20%
- agricultural	33%	38%	-
- undeveloped	24%	30%	-
Number of Dwellings within 1.5 km			
	726	1,113	3,500
Type of Dwellings			
- single family	91%	19%	70%
- multiple family	6%	8%	30%
Value of Single Family Dwellings			
	$98,000	$35,000	$98,000

Table 1.2 - Continued -

Host Community Character

		Count Original	Present	Study Site Tacoma City Landfill
- agricultural/rural-residential		15	5	rural residential
- suburban/residential		2	12	rural/
- industrial		1	1	residential

Host Community Income

		Count	
- lower to lower middle		2	
- lower middle to middle		6	lower middle/
- middle to upper middle		8	middle to/middle
- upper middle to high		0	upper middle

Opposition

- active	yes	10	yes
	no	9	
- legal action	yes	6	no (at the time
	no	13	of the survey)

Complaints

- yes	14	yes
- no	5	

Reasons

- odor	3	odor and
- noise	3	water problems
- view	0	
- animals	2	
- traffic	1	
- water problems	0	
- air problems	0	
- fees	2	
- litter	10	

Public Participation in Siting Process of Landfills

- yes	3	
- no	16	no

landfills, with rural, suburban residential and industrial uses. The host community is experiencing rapid urban development with densification through four new apartment complexes and new single family developments right up to the landfill boundary. Although reported residential property values in Tacoma are essentially equal to the survey average value (US $90,000), the higher density in Tacoma suggests that the unit area property values may be higher. The host-community in Tacoma is apparently in a more mature phase of development (see Figure 2.9 in Chapter 2) than the other sites. Higher densities, more residential and industrial uses and more multiple family units support this finding.

Opposition to Landfills

About 50% of the sites encounter active opposition, as does Tacoma. At one third of the sites some legal action has occurred, with two-thirds having experienced complaints about a variety of impacts. The Tacoma landfill has had legal action taken and some complaints filed against it. Public participation was not made possible, nor was the end use for the site determined in the original siting process.

The Tacoma landfill was selected as the landfill study site because it matches the typical characteristics, environmental controls, site features and host community indicators of the sites in the study area. The few discrepancies however are limited to host community features that expand rather than bias the range of information available for the impact assessment. Moreover, a remedial investigation (Black and Veatch, 1987) of the landfill

impacts on groundwater and gas migration provides unique physical information that would not be available at many other sites.

1.2.3 Tacoma Landfill Siting Process

The landfill began operations in 1961 on a 47 acre plot on the northeast corner of the present site. Additional land to the total of 200 acres was purchased in 1965. No liner or leachate collection was installed at that stage. At the time, the area was still rural in character with large 5 acre lots. Orchard Street was a gravel road and the homes were supplied by well water. No official siting process took place, nor was any opposition apparent at the time.

By late 1968, a well at the Home Builders Association office building 70 m west of the landfill had elevated iron levels, discoloration, and slight odor. Berms and additional cover diverted the leachate and reduced infiltration enough to eliminate the problem. The affected well was later disconnected and replaced by connecting the building to the city water system.

Although the landfill officially never accepted hazardous wastes, informal records show some industrial liquids and sludges may have been disposed of during the 1960's and 1970's, including chlorinated organics, phenols, heavy metals, waste oils and paint sludges. The locations correspond with the active fill areas at the time, predominantly in the northern sections. No formal records were kept to show exact disposal locations (Black and Veatch, 1987).

In 1983, the USEPA detected organic and metal compounds in

leachate, groundwater, and sediments (USEPA-Region 10, 1983). The findings were corroborated by a university term project study in 1984 (Carter, 1985). During this period, residents 500 to 600 metres west of the landfill noticed their well water developing odor and turning orange with high iron concentrations. The Tacoma-Pierce County Health Department investigated their complaints and suggested they buy filtration systems to eliminate the iron in the water. Some homes had to have corroded pipes replaced. Shortly thereafter (1983), bottled water was supplied to the pocket of homes southwest of the landfill on order of the Washington State Department of Ecology (Hanson, 1985). Groundwater samples taken in 1985 and 1986 revealed chlorinated organics including vinyl chloride in four private wells. These homes were then connected to the city water supply. The site was then placed on the National Priorities list under Superfund regulations.

Throughout this phase, the City of Tacoma did not admit any responsibility. The Washington State Department of Ecology initiated and paid for bottled water and, ultimately, in 1986, the connection to the city water system for the homeowners with affected wells. The Tacoma-Pierce County Health Department was willing to take action at one point, but reversed its position (1986, Tacoma News Tribune). Finally, in 1985, some small methane flashes occurred on adjoining property. Tests confirmed the presence of explosive concentrations of methane gas (at 5 to 50%) under the surface in wells and entering into dwellings through cracks in foundations (pers. comm. R. Post, 1987). A gas

collection system was installed immediately in late 1985. Although gas concentrations have dropped in the meantime, landfill gas is still present in some pockets and increases during low pressure periods (Black and Veatch, 1987). Regular monitoring of adjacent buildings continues (pers. comm. R. Post. 1987).

In the last 25 years, the host community has developed more densely populated areas. The landfill impacts have provoked more concern and a stronger response from residents. Public meetings about groundwater and gas migration sparked a formal resolution from the Fircrest Town Council to have the landfill closed (1986, see typical events described in Chapter 2). Legal action has been taken by the adjacent pipe company based on the gas immigration and more recently by some residents (pers. comm. R. Post. 1988).

In addition to the reported characteristics of the landfill and the host community, the sequence of events in the siting process may influence the perception and interpretation of the facility for the host community. Although initially no opposition activity occurred, the recent appearance of groundwater and gas migration issues may be significant for the understanding of the meaning of the landfill for the community.

1.2.4 Incinerator Site Description

At the time of the site selection, the Resource Recovery Report (Waste Age, November, 1985) was screened for waste-to-energy facilities in the study area. European mass-burning grate incineration is the most frequently used burning technology for

large disposal facilities. The Salem, Oregon incinerator was chosen because it was the only large-scale, modern incinerator in operation within the period of the study (1985-1988).

The Marion County incinerator is located seven miles north of Salem, OR close to Interstate 5, in the village of Brooks (Figure 1.6). The incinerator was built between early 1985 and spring of 1986, when burning began. An increased waste stream of 170,000 tonnes per annum of municipal waste are presently burned, up from the original 130,000 tonnes. Originally, 70% of the waste stream volume was generated by the Salem-Oregon metropolitan area and 30% by the rest of Marion County. After the increase, 53% is generated in the Salem-Keizer metropolitan area, 23% from the rest of Marion County, and 24% is hauled in from Portland. The energy is used to generate electricity that is fed into the Pacific Gas and Electric grid.

Environmental Controls

The emission controls consist of a dry chemical scubber followed by baghouse filters and thus constitute the state-of-the-art (EPS, 1986). The exhaust exits through a 78 metre stack to the east of the plant. The combined bottom, fly and filter ash are disposed of in a special lined ash landfill about 16 kilometres to the north in Woodburn. As of February 1988, ferrous metal removal systems have just been installed to recover and sell the metals. The quench water is reused; only cooling and boiler blowdown water is discharged to the Willamette River 7 miles west. Domestic wastewater is discharged to a septic system. Some

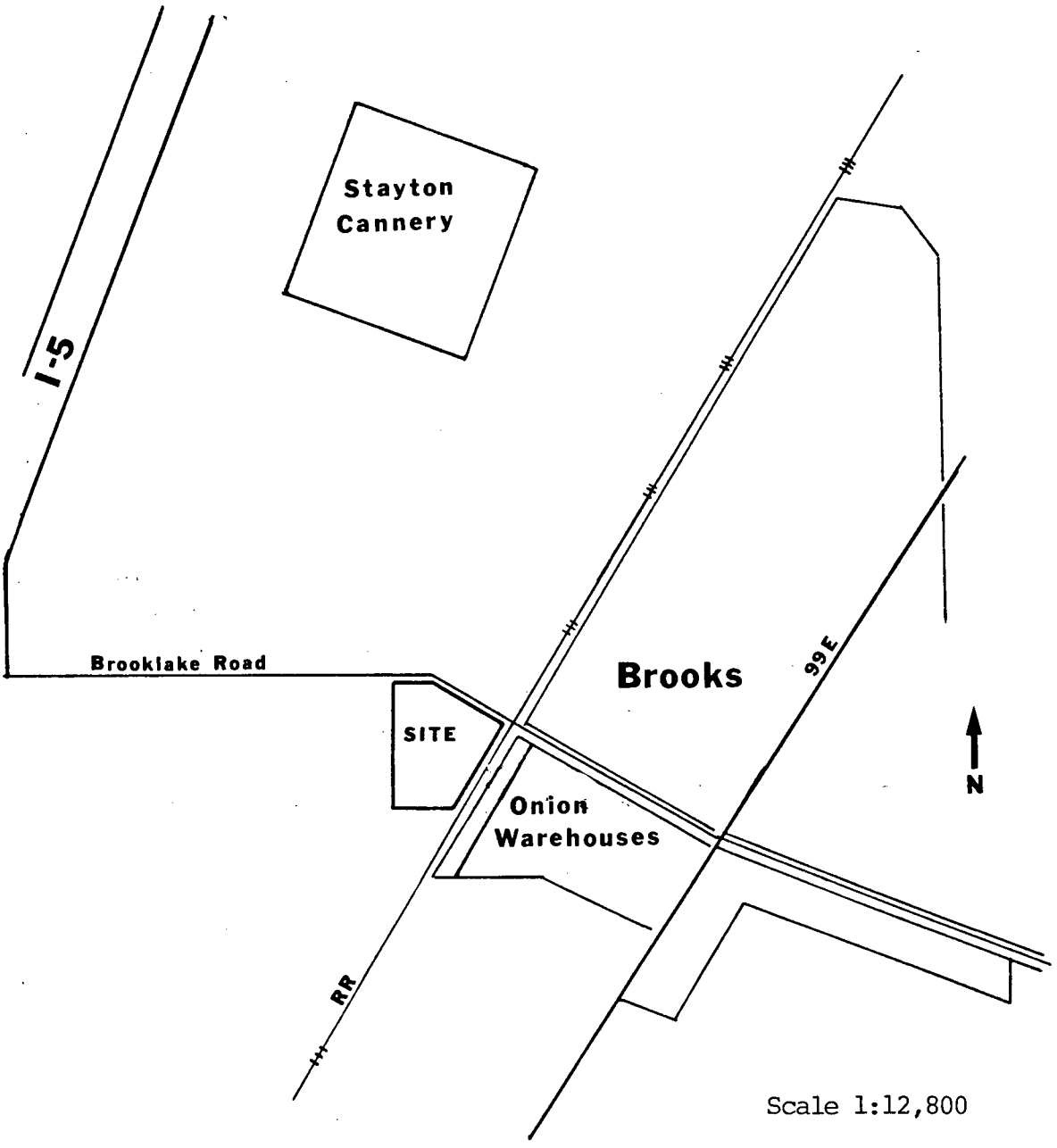


Figure 1.6 - Salem Incinerator Site in Brooks, Oregon

vegetation at the front is meant to beautify the site, but no major screening with vegetation or berms was considered necessary. No end-use of the site has been designated.

Site Characteristics

Topography

The site is in the middle of the wide, flat Willamette Valley. Some tall trees are located to the north and east of the site, but the vegetation consists mainly of low grass and shrubs. Buildings and elevated highway overpasses are the only other barriers to view. The distance to the closest surface water is about 10.4 km. The groundwater table is just below the ground surface. The plant draws its makeup water for steam production from a groundwater well at a rate of about 720,000 litres a day (pers. comm. F. Skrivin, Oregon DEQ, February, 1988). This rate is equivalent to one to two farm irrigation wells and, thus, constitutes a low withdrawal rate for the area.

Climate

The weather pattern in the Willamette Valley is characterized by a virtually permanent inversion condition. The inversion lid is lower in winter (often below 200 metres) in the mornings and under 600 metres during the day. Heavy morning fog during high pressure periods from October to January indicates the presence of ground inversions. Temperatures rise from 0 degrees C at the surface to 10 degrees at the inversion level. Inversion levels in the summer are higher, but even direct summer insolation breaks the inversion only on a few hot afternoons. The prevailing wind

direction is south to southwest at 3 to 4 m/s from September to June, and from the north at 3 m/s in July and August. The average precipitation is 1042 mm per year. Relative humidities are usually 80 to 90% at night, 60 to 90% in the fall, winter and spring days, but drop to 40% on hot summer days (Nat. Weather Service, 1986 and pers. comm. P. Peck, Nat. Weather Service, 1986).

Host Community Characteristics

In contrast to the Tacoma host community, Brooks represents a typical new host community. Brooks is a rural, unincorporated hamlet (with 300 residents) outside the Salem-Keizer urban growth boundary. It is located in the transport corridor of interstate, I-5, a major regional highway, and the main railway line through the valley.

The land use around the incinerator is about 75% agricultural, and 25% transport/industrial uses (truck stop, railway and onion warehouses). However, the nearest residential building is located within 200 metres of the plant; the village is entirely within 800 metres of the facility. Most of the houses in the village are old single family dwellings; some are owner occupied, while others are inhabited by agricultural workers and their families (see Figure 1.5). A trailer park and an old age retirement settlement with small single family dwellings are located to the north of the village. The value of these houses is difficult to estimate, but probably does not exceed U.S. $35,000. However, most residences outside the village are large, and sit

on large lots of one to five acres with values in the U.S. $60,000 to $80,000 range. The incomes are distributed proportionately, with low to lower middle incomes in the village and middle to upper middle incomes outside the town. Thus, Brooks fits the image of a typical agricultural/rural community (Chapter 2) that often is chosen as a host community.

There was substantial public information during the siting process. Formal public hearings were conducted as required to meet land use change regulations (Salem Statesman-Journal, 1983 to 1984). The active opposition throughout the siting process (see next section) initiated legal action and continues to file complaints about the incinerator impacts.

In summary, the Brooks site represents a modern incinerator facility in a typical new host community. Furthermore, the flat topography and consistent winds make this site suitable for representative impact assessment without interference through topography. Finally, the basic air emission and dispersion modelling information was made available through the permit application documents supplied by the owner/operator, Ogden-Martin systems (Seton, Johnson and Odell, 1984).

1.2.5 Salem Incinerator Siting Process

In early 1981, Marion County recognized the need for new garbage disposal capacity, because the existing Brown's Island landfill was suspected of causing water pollution problems in the Willamette River and, therefore, had to be closed by 1983. Within the year, waste-to-energy disposal was adopted as the future

disposal method for the County's 130,000 tonnes (145,000 tons) per annum. Salem-Keizer's garbage constituted 70% of this initial waste stream.

By early 1982, the Marion County board had picked Trans-Energy of Bellevue, WA to construct and operate an incinerator under an exclusive contract that guaranteed a minimum waste flow of 130,000 tonnes per year of municipal solid waste for 20 years. The site decision was based on the following criteria (R. Hansen, 1982):

- distance to the highway (I-5),
- distance to steam users and electrical transmission lines,
- maximum distance of 5 miles to the Salem-Keizer urban growth boundary,
- downwind location from population centres,
- the separation from congested and residential streets,
- road connection for outer county waste without traversing the city,
- out of flood plain,
- 20 acre minimum plot size.

These criteria are typical (see Chapter 2).

Initially, a site at the Chemawa Road intersection with I-5 was chosen from five possible locations that included the Brooks site. In contrast to Brooks, the first choice, Chemawa Road, was one highway intersection and three miles closer to Salem and within the urban growth boundary.

Immediately, opposition arose from residents in the northern

part of Salem and Keizer and from representatives of the Indian school nearby. The main reasons against the burner were cited as toxic air emissions of dioxins and heavy metals, unsuitable wind patterns in the Willamette Valley, visual impacts of the stack and garbage trucks, image impacts of the industrial facility at Salem's gateway, the continuing need for landfill capacity for the burner ash, traffic, odor, noise, questionable new technology, high disposal costs, property devaluation and the negative effect on incentive to recycle (Salem Statesman-Journal, 1982).

After the Salem and Keizer councils had publicly opposed the site, a formal appeal against the land use change decision virtually killed the first choice site by tying it up in court.

Shortly thereafter, the Brooks site was resurrected and first publicly mentioned in March, 1983 (Salem Statesman-Journal) as one of three alternatives sites outside Salem's growth boundary. At least two adequate pieces of land were being offered in Brooks. The Brooks site is within one mile of a highway (I-5), a major regional road (99E), a railroad and a transmission line.

Although resident opposition arose again, no official political body took a formal stance. As a result, the Marion County board again passed the necessary land use changes after public hearings. The courts then dismissed all opposing appeals and enabled the proponent, Trans-Energy, to obtain the garbage franchise by September, 1983 conditional on the air discharge permit that had to be obtained from the Oregon State Department of Environmental Quality (DEQ).

Before the permit could be issued, though, Marion County's

solid waste director, who had been an instrumental proponent of the waste-to-energy plant, was indicted for fraud and misrepresentation of his credentials. He was subsequently fired. However, the Marion County board defended the project as sound.

In December, 1983, the residents' opposition managed to collect enough signatures to have an item placed on the referendum ballot that would have virtually prohibited the garbage burner anywhere in the County by disallowing the construction of the facility within three miles of schools, hospitals, retirement homes, childcare centers, pools or athletic and convention centers. At the same time, however, the proponent obtained the air discharge permit after having conducted public hearings with the DEQ in Brooks. The permitted discharges were based on the DEQ's assessment of the best available air filtration technology that the proponent was able to provide.

In the following referendum campaign, the plant's benefits and impacts were discussed in depth. The benefits consisted of new jobs, business for locals, $40 million in tax base, low financial risks to the County, low air pollution because of the DEQ's tough new regulations, energy and ferrous metal recovery, and the replacement of inferior landfills with a better method. The impacts cited by the opposition included the same as listed above for the first site, plus the potential for excessive groundwater withdrawal and inefficient electricity production. These two additional impacts were due to the site change which required groundwater for cooling and make-up of the lost steam, and electricity production because no steam user could be found at

the new site.

In order to appease Brooks residents, a promise of a new sewer and water supply system for Brooks village was made by the proponent and some Marion County commissioners.

In the following referendum campaign the proponent outspent the opposition in the campaign by a ratio of 6 to 1 ($67,000 to $11,000). At the end of March, 1984, Marion County voters rejected the burner prohibition by a margin of 4,000 votes of 33,000 total cast votes. The nearest polls all voted for the prohibition, but all other rural communities voted against the measure (Marion County Election Board, 1987), possibly because they could have become potential candidates for a regional landfill had the incinerator prohibition been accepted.

Only three months after the vote, the proponent, Trans-Energy, was implicated for fraud of the Federal Government through its parent company. The charges held and forced Trans-Energy to sell its interest to Ogden Corporation, a large conglomerate. Through investment of its own capital, Ogden was able to obtain in September, 1984 the $48 million capital necessary to start construction of the incinerator.

A final legal appeal was launched in December, 1984 against the changes in the air discharge permit requested by Ogden to accommodate the new boiler and filter design. The appeal was dismissed for lack of grounds. The Marion County commissioners were questioned about the promised sewer system in February, 1985 and denied having made the promise. Instead, they stated that the former owner (Trans-Energy) was responsible, but that Ogden had

not accepted that responsibility with the purchase of the rights. Hence, the sewer was not built.

In the following 14 months, rising costs for garbage disposal were attributed to the plant. Furthermore, the continuing need for landfill capacity for the incinerator ash became apparent and was estimated to add substantial costs and risks to incinerator disposal. Local employment was, however, reported in the news as a benefit.

The incinerator formally opened and began burning garbage in April 1986. After startup, shakedown and some months of operation, the emissions were tested at burning rates of 130,000 and 170,000 metric tonnes per year. The emissions were under the permitted levels for all pollutants except nitrogen oxides (Zurlinden et al., 1986). By October, 1986, Marion County had negotiated a contract with Metro Portland to accept further 36,000 metric tonnes of waste at a tipping fee of $18.75 per tonne, $8 lower than the local tipping fees of $26.75 per tonne. The County commissioners indicated that without Portland's waste stream, the costs for local residents would be higher and that the additional waste was necessary to meet the contractually required amounts. The DEQ subsequently amended the air discharge permit to allow the burning of up to 170,000 tonnes of garbage.

Finally, the costs and impacts of the incinerator ash landfill began to generate opposition around the landfill in early 1987, because the existing landfill had to be extended by 70 acres and special liner systems had to be installed (Woodburn Independent, August 19, 1987).

Although the physical emissions from the incinerator were the main focus of the opposition in the siting process, issues of fairness, community image, control and confidence in the proponent and the local government may have been raised by the site selection process and the problems with the initial proponent and the responsible official in the waste agency.

The description of the siting process is important for the understanding of the perception and meaning of the facility for the host community. The facts about the siting processes and the facilities are used to design physical impact assessment methods and to analyse non-physical impacts in Chapter 4.

CHAPTER 2 - MUNICIPAL WASTE DISPOSAL FACILITY EMISSIONS, HOST COMMUNITY CHARACTERISTICS and RESULTING IMPACTS.

The objectives of this chapter are to derive common emissions from two types of municipal solid waste (MSW) facilities (landfills and incinerators), describe common host community characteristics, and determine a set of impacts caused by the interaction of the typical facility as the emitter and the host community as the receptor. The derived set of facility impacts forms the basis for testing facility impacts, residents' beliefs, attitudes, and actions in order to describe, explain and predict host community response to the siting of waste disposal facilities.

2.1 Physical Emissions of Waste Facilities

The first section identifies physical emissions and potential effects. The generation and characterization of emissions and transport paths and mechanisms are identified by describing the operational characteristics of the two predominant municipal solid waste disposal methods on the West Coast of North America: sanitary landfilling and incineration of municipal solid waste (MSW).

The MSW disposal facility-host community system comprises the facility with all access roads and services and the impact field to the maximum extent of the impacts. The impact field may be determined by physical impact boundaries and non-physical limits, such as cognitive or political boundaries of the host community. The mechanisms producing potentially negative effects are

reviewed, and the spatial and temporal dimensions of the impacts are derived qualitatively to show the typical impact footprint for each type of facility.

2.1.1 Municipal Solid Waste Stream

The Municipal Solid Waste Stream Composition

The composition of the municipal solid waste stream in Canada comprises large fractions of paper, putrescibles, glass, metals, yard wastes, lumber and other elements. Bird and Hale (1977) list the contents in Table 2.1 in % of the wet weight, in British Columbia. Similar contents are found in Alberta, Saskatchewan, and Manitoba. Franklin Associates (1982, Figure 2.1) indicate similar figures for the United States. The only significant difference lies in the higher paper content of the waste collected in Western Canada. In all estimates, the paper component is the largest and accounts for about 50% of the total heat value of the waste stream. The composition is projected to remain fairly constant through 1990, with small increases in the plastic and paper content (Franklin Associates, 1982).

In the short term, however, the waste stream quantity and composition vary according to season. In suburban areas, the yard and garden waste fraction increases the waste stream by 15 to 20% in April through June and September through November (GVRD, 1983). As a result, the organic content of the waste stream is likely to increase by approximately 60% to about 40% of the total weight. This is confirmed by Hocking (1975) with data from U.S. sources.

Heavy metals are a principle group of contaminants in the

Table 2.1 - Composition of Municipal Waste Stream in British Columbia;
Source: Bird and Hale, 1977

Component	As-received Wet Wt (%)	S.E.*	Moisture Content (%)
Paper	37.91	6.28	19.60
Kraft Paper	6.94	2.25	16.87
Newsprint	11.13	4.20	14.34
Fine Paper	3.22	1.89	10.98
Other Paper	16.63	5.42	25.94
Glass	7.78	1.21	0.82
Beer Containers	0.07	0.06	
Reuseable Soft Drink	0.31	0.29	
Non-reuseable Soft Drink	0.19	0.24	
Liquor and Wine	2.99	1.01	
Containers - Food	2.60	0.72	
Containers - Other	0.65	0.25	
Flat and Cullet	0.97	0.40	
Ferrous Metals	7.20	1.82	2.88
Beer Cans	0.00	0.01	
Soft Drink Cans	0.22	0.12	
Food Cans	3.13	1.07	
Other	3.85	2.70	
Non-Ferrous Metal	0.48	0.17	14.71
Aluminum	0.47	0.14	
Other	0.02	0.04	
Plastics	5.42	0.94	15.48
Containers	1.18	0.47	
Sheet Film Other	4.24	1.13	
Ceramics Rubble	3.28	3.71	3.24
Lumber	5.19	4.17	15.01
Putrescible	17.42	7.09	58.78
Textiles Leather Rubber	4.99	2.29	13.41
Yard Wastes Brush	7.28	3.96	45.12
Fines	2.80	2.88	14.86
Petroleum Chemical Mix	0.36	0.39	
TOTAL WEIGHTED MOISTURE CONTENT (%)			24.11

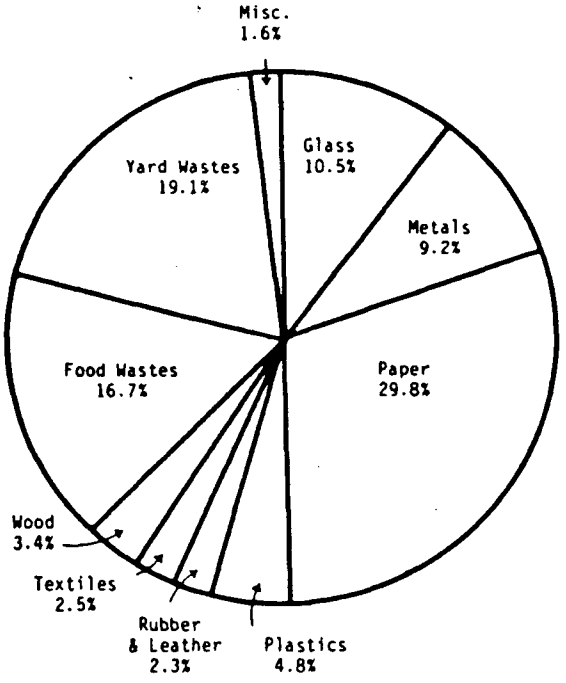


Figure 2.1a - Residential and Commercial Solid Waste Disposed, 1980; Source: Franklin Associates, 1982.

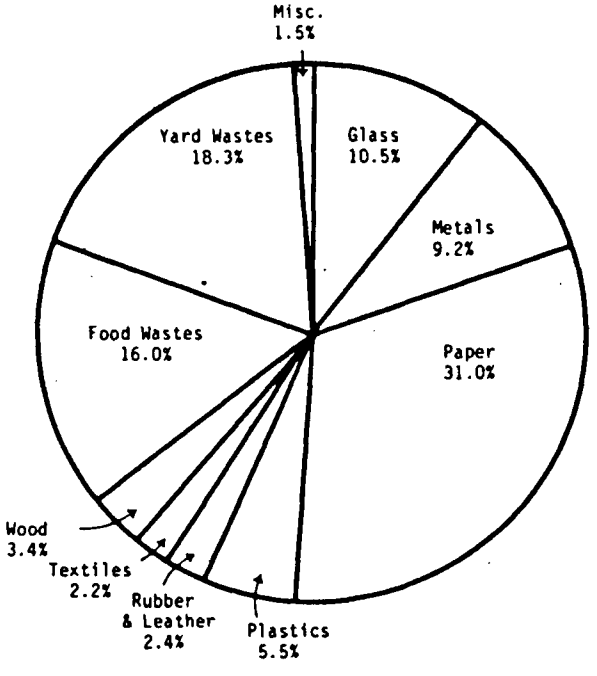


Figure 2.1b - Residential and Commercial Solid Waste Disposed, 1990; Source: Franklin Associates, 1982.

municipal waste stream. Krauss (1985) reports a seasonal variation in the lead, zinc and copper contents with minima in summer and maxima in winter. Discrete metal particles on one hand and color pigments on paper and plastic, respectively, are identified as contributors to the heavy metal concentrations.

2.1.2 Municipal Solid Waste Landfilling

Landfilling consists of tipping refuse from the collection vehicles onto the land, spreading and compacting the waste to minimize the volume, and covering the refuse layers with soil on a daily basis. The refuse is filled in cells, with a series of adjoining cells in the same layer making up a lift of 3 to 4 meters height. Landfills usually comprise two or more lifts; the top lift should be covered with a final soil layer of at least one meter depth (Tchobanoglous, 1977, USEPA, 1976). Daily and final soil covers distinguish a sanitary landfill from an open dump.

The consideration of the landfill operation subsystem through a mass-balance of materials and energy indicates the sources of potential external impacts (see Figure 2.2 below):

1. The waste stream enters the subsystem by being hauled and tipped at the landfill by collection or transfer vehicles, followed by the movement and compaction by special equipment. The waste stream constitutes a mass flow of varying quantity and composition into the subsystem for as long as the operation continues. The quantity and composition vary seasonally with superimposed random daily fluctuations. The side-

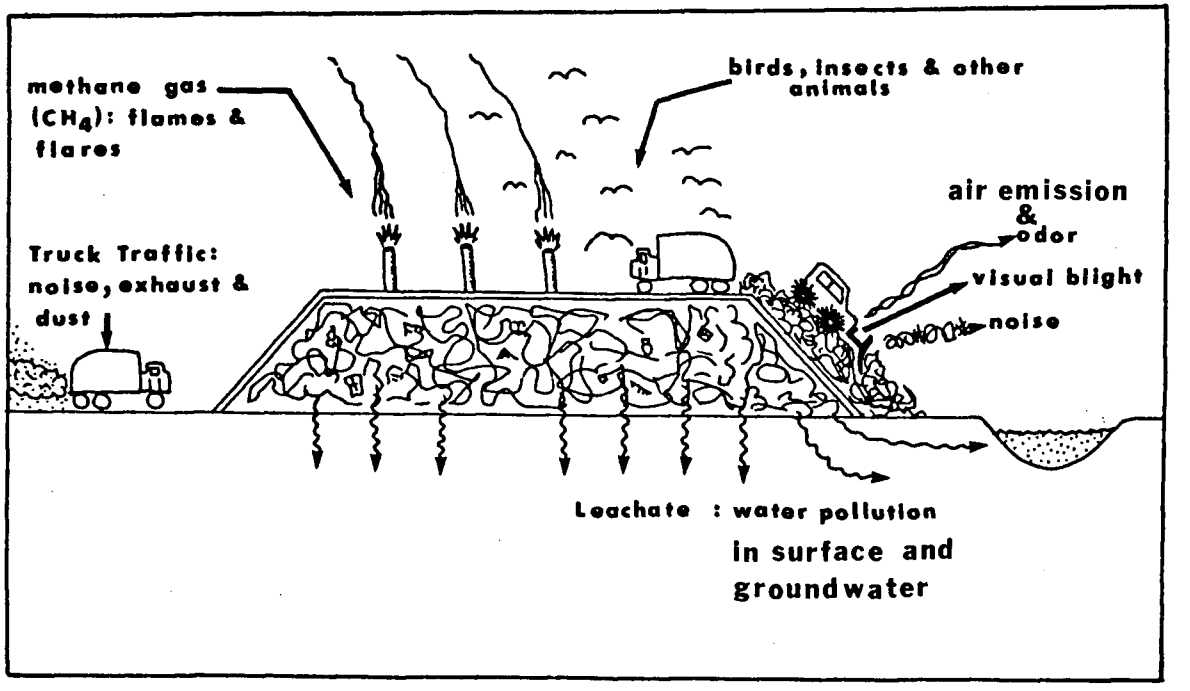


Figure 2.2 - MSW Landfill Operation Emissions

effects of this mass flow are the dispersion of garbage by wind, littering, and scavengers. Odors and visual impacts result from the presence of open garbage. The substantial input of energy to move, compact and cover the garbage results in noise, exhaust emissions, visual impacts and safety risks of heavy equipment operations.

2. The infiltration of rain or groundwater creates the conditions necessary for the characteristic biological decay of the decomposable organic matter and provides, as leachate, an important liquid flow to transport matter out of the fill. Suspended and dissolved particles, organic matter, inorganic salts, heavy metals, and refractory organic compounds are components transported as leachate. The resulting leachate is considered toxic (Koch and Cameron, 1980) if directly deposited in receiving surface or groundwater.
3. The anaerobic environment enhances bacterial activity and the generation of landfill gas, a mixture of methane, carbon dioxide and traces of hydrogen sulfide and other gases. This gas can migrate upwards and exit through the cover into the atmosphere, or can move laterally out of the site. Due to the methane content, landfill gas is explosive at concentrations between 10 and 30% with air. It can be odorous at low concentrations. Thus, the migration of landfill gas constitutes a hazard and a nuisance.

The external impacts from the landfill operations comprise

the direct effects of the operation (see item 1 above) and the emissions from the landfill decay process, i.e., leachate and landfill gas. The mechanisms and factors controlling the generation and transport of these impacts determine the distance and duration of their effects.

Nuisances

Equipment operations on medium to large landfills generate noise levels of 80 to 120 dBA (Schmalensee, 1975), presumably on or near the landfill site. Bird cries can also contribute to the sound of landfills, but vehicle operations are likely to dominate. The noise levels therefore depend directly on the number of vehicles and the operating times of the landfill.

Odors are generated by volatile substances and gases emitted by the landfill and depend on the composition of the waste in the landfill, especially in regard to sulphur and nitrogen compounds. Odor production is controlled by the mechanisms for landfill gas production described below. Although daily cover reduces the odor emissions, 10 to 25% of landfills in the U.S. require special odor control (Schmalensee, 1975). However, it is not proven that gas collection and flaring effectively reduces odors from landfills (Kaszynski et al. 1981).

Visual disamenities usually pertain to the open garbage at the working face, equipment, trucks, exhaust fumes, and bird-flocks. Topographical and vegetation screens can effectively reduce the impacts, but daily cover is the most effective method: 91% of all landfills without cover create sight nuisances, while

only 24% of landfills with daily cover are believed to cause unsightliness (Schmalensee, 1975).

Birds, flies, rats, bears, and stray dogs and cats are possible disease vectors and nuisances. Flies and rats in particular are known communicable disease carriers, but a linkage to landfills has never been established empirically. A 150 mm daily cover effectively reduces flies, but has not been proved to significantly affect birds and rats (Hanks, 1967).

In summary, most nuisances from landfill operations are usually very obvious in the immediate vicinity of the site and cannot be completely eliminated, but are simply controlled.

Landfill Decay Processes and Products

Leachate and landfill gas production are interconnected through the biological decay of the waste stream under anaerobic conditions. Recent research (Chian et al., 1985, Jasper et al., 1985, Ehrig, 1985) indicates three distinct phases in the typical landfill decay process (Figure 2.3):

1. After the placement and coverage of the waste, the trapped air is used by the aerobic bacteria in oxidizing conditions. In regions where rainfall exceeds evapotranspiration, and where the cover material is permeable, infiltrating water displaces the air in the void spaces and increases the moisture content of the material until field capacity is reached and eventually exceeded. As a result, the conditions in the fill turn anoxic, with nitrates and sulfates becoming the major

electron donors. Anaerobic conditions develop and permit the first step of the two-stage fermentation process to occur: the complex organic matter is decomposed into volatile fatty acids. This, in turn drives the pH down and results in the mobilization and complexation of the metal species. Nutrients are released from the complex organic compounds and contribute to the new biomass growth. In this phase, leachate organic strength is very high, while pH and ammonia content are low (5.5 and 150 mg/l, respectively).

2. Methane bacteria later establish themselves and utilise the volatile fatty acids (VFA's) as substrate to produce methane gas and carbon dioxide. The reduction in VFA's increases the pH, while the oxidation-reduction potentials decrease to their lowest values. Carbon digesting bacteria consume nitrogen and phosphorus and emit waste products as ammonia which increases to approximately 500 mg/l. Leachate organic strength decreases to 500 to 1,000 mg/l BOD_5. The methanogenic phase is the longest phase in the landfill process, but can be disrupted by unfavorable conditions (entry of air) or high infiltration (washing out of methane bacteria).
3. The final phase occurs when organic matter and nutrients are depleted, gas production drops off, and oxidizing conditions are restored.

The graph in Figure 2.3 is derived from Chian et al. (1985) and indicates the behavior of major characteristics and estimated

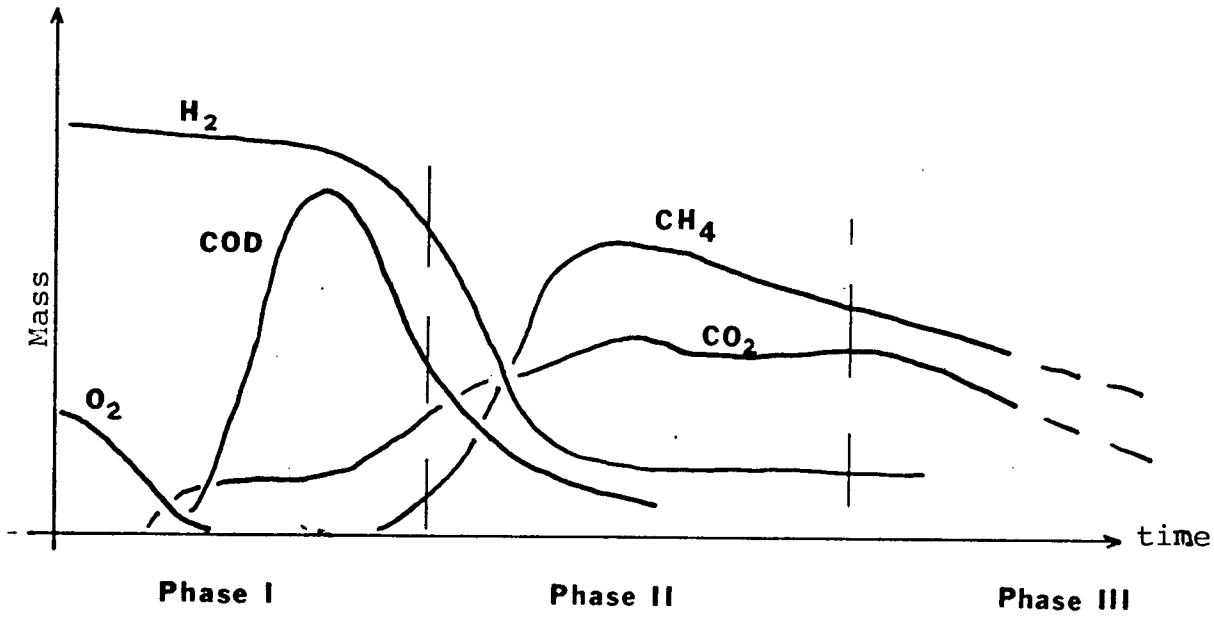


Figure 2.3 - Landfill Decay Process Characteristics

time periods for the three phases.

From the perspective of the engineering control of the process and of the resulting leachate and gas components, the following factors have been identified as the principal influences (Tchobanoglous, 1977, Jasper et al., 1985):

1. The waste stream composition, i.e., the content of bio-degradables, potential inhibitors (metals and toxic organics), and inert matter determine the rates of decay and, with the age of the landfill, determine the resulting concentration in the leachate. In general, a first order concentration decay with time has been found (Zison, 1978, Atwater, 1987) for typical leachate indicators (COD, total nitrogen, magnesium, etc.) in the early phases followed by an asymptotic decay thereafter (Atwater et al. 1982).
2. The moisture content and the infiltration rate determine how quickly the methane stage is reached. The organic loading of the leachate has also been shown to depend on the infiltration rate (Jasper et al., 1985), that determines the washing out of organic matter. The infiltration can be controlled by the choice of cover materials.
3. The residence time of the leachate in the fill is determined by the infiltration rate, the thickness and the compaction of the refuse layers and the under drainage and removal of leachate in the collection system. Residence time determines the degree of

decomposition and the resulting organic content of the leachate.

These factors, as well as uncontrollable environmental influences (pH, temperature) vary seasonally and between sites. It is therefore only possible to roughly predict leachate and gas quality or quantity without site-specific data.

Leachate Toxicity

Municipal landfill leachate as studied by numerous researchers contains a range of organic matter, nutrients, heavy metals and toxic trace organics. In general, a good correlation between cumulative leachate flows and constituent concentrations has been reported (Zison et al., 1978). Table 2.2 is compiled from numerous leachate studies. For comparison, the Canadian Drinking Water Guidelines are also listed.

Whereas ammonia, nitrates and nitrites do not generally exceed drinking water standards, iron, lead, manganese and mercury do. Moreover, volatile priority pollutants are also found in leachate (Black and Veatch, 1987, Atwater et al. forthcoming). Although the discharge of leachate to surface waters may be sufficient to dilute concentrations of metals and to volatilize organics down to below safe concentrations, leachate discharges to groundwater may remain at significant concentrations due to the persistence of organics (Atwater et al., forthcoming).

Several MSW leachate components can have serious effects on fish and other organisms in the aqueous environment:

- suspended and soluble organic mater (BOD and COD) oxidize in receiving surface waters and deplete the dissolved

Table 2.2 - MSW Landfill Leachate Characteristics and Drinking Water Standards;
Sources: Numerous Leachate Studies; Health and Welfare Canada, 1978).

Constituents	Leachate Concentrations Landfill Age New mg/l, except pH	Old	Range	Drinking Water Standards	Constituents of Concern
BOD^5	9,000	1,000	81-33,100	20 to 130 mg/l	x
Total Suspended Solids	1,000	500	460-10,440		
Ammonia	150	500	0.2-845		x
Total Phosphorus	10	10	0.8-49		
pH	5.5	6.5-7.0	5.2-8.5	6.5-8.5	
Metals	Average mg/l				
Arsenic	0.01		0.006-0.038	0.05	
Cadmium	0.005		0.001-0.22	0.005	
Chloride	376		96-4,101	250	x
Chromium	0.05		0.02-0.44	0.05	
Copper	0.3		.01-9.0	1.0	
Fluoride	0.13		0.1-0,27	1.5	
Iron	100-800		1.6-2.050	0.3	x
Lead	0.5		0.023-1.0	0.05	x
Manganese	5-15		0.6-70	0.05	x
Mercury	0.01		0.001-5.5	0.001	x
Zinc	10-20		0.01-135	5.0	x
Volatile Organic Compounds					
	Present at low Concentrations			0	x

oxygen necessary for fish and other organisms;

- dissolved solids reduce the saturation levels of oxygen in water;
- ammonia in the un-ionized form (NH_3) is extremely toxic to various fish and aquatic organisms at levels above 0.02 mg/L and possesses some sublethal effects on the growth and activity of fish, especially under conditions of low dissolved oxygen (Daoust and Ferguson, 1984, Thurston, 1984);
- heavy metals can be acutely toxic, but also exhibit sublethal effects on fish (Connell and Miller, 1984);
- organic materials in traces (e.g. solvents, antifreeze, dry cleaning chemicals, etc.) can further deteriorate the receiving waters, cause illness and accumulate in species in the food chain (Connell and Miller, 1984) and are potential carcinogens for humans;
- pathogenic bacteria have been shown to survive in leachates although conventional indicator organisms (coliforms) die off rapidly when mixed with leachate (Cameron and Macdonald, 1977).

Specific toxicity studies have shown leachate to be highly toxic to test animals (Cameron and Koch, 1980, Atwater et al., 1983). The results in Table 2.3 list the 96 hour LC50 for leachate as % of total volume.

Cameron and Koch (1980) identified ammonia, copper, tannin and pH to account for 94% of the observed variations in toxicity, while Atwater et al. (1983) postulated that zinc best explained

Table 2.3 - Leachate Toxicity to Fish;
Source: Cameron and Koch, 1980.

Leachate Characteristics:

Constituents	Concentrations all mg/L except pH
pH	6.3-7.8
BOD^5	120-2980
COD	730-4720
NH_3-N	0.3-427
Total P	0.8-4.7
Cl^-	125-2400
Fl^-	0.27
As	0.006-0.038
Cd	0.001-0.004
Cr	0.025-0.085
Ca	0.01-0.05
Fe	1.6-30.3
Pb	0.023-0.065
Mn	0.6-7.8
Ni	0.002-0.069
Zn	0.43-1.32

Constituents	Concentrations
Species	Leachate Toxicity (96 hour LC 50)
Rainbow Trout	4.9 - 7.0 % V/V
Sockeye Salmon	3.2 - 56 % V/V
Daphnia	3.8 - 86 % V/V

the toxic effects on Daphnia. In both studies pH effects were significant. Toxicity was found to decay over time and toxicity decreased with increasing precipitation and with recycling of the leachate. In summary, leachate is highly toxic and often remains so at the discharge point into receiving waters (Cameron and Koch, 1980).

Landfill Gas

Landfill gas is generated at rates of 5 to 30 L (at 50% methane concentration) per kg wet refuse per year over periods up to 100 years after the anaerobic process begins (Emcon Associates, 1980, Schumacher, 1983).

Under suitable conditions (pH between 6.4 and 7.4, absence of oxygen or inhibitors, adequate residence time, moisture and temperature), the total gas volume generated reaches approximately 180-500 L of landfill gas per kg of wet refuse in the lifetime of the fill (Schumacher, 1983). The composition of the landfill gas is initially mainly carbon dioxide, but the content of methane rises rapidly to about 50% within the first few years. Other components are also present in lower concentrations (see Table 2.4, Ham, 1979).

Gas migration can cause explosions if methane concentrations of between 5 and 15% (or landfill gas concentrations of between 10% and 30%) in air are reached (Tchobanoglous et.al., 1977). The dangers are insidious, because the migration can occur in the soil and transport the gas for up to ten times the full depth from the site (Rovers et.al., 1977). Landfill gas often acts as a carrier

Component	Component percent (dry volume basis)
Methane	47.5
Carbon dioxide	47.0
Nitrogen	3.7
Oxygen	0.8
Paraffin hydrocarbons	0.1
Aromatic & cyclic hydrocarbons	0.2
Hydrogen	0.1
Hydrogen sulfide	0.01
Carbon monoxide	0.1
Trace compounds[1]	0.5

1 Trace compounds include sulfur dioxide, benzene, toluene, methylene chloride, perchlorethylene, and carbonyl sulfide in concentrations up to 50 ppm.

Table 2.4: Landfill Gas Composition; Source: Ham, 1979

for volatile organics such as vinyl chloride (Baker and MacKay, 1985) as well. Therefore gas migration and emission to the ambient air can cause ambient concentrations of airborne priority pollutants. This has been found around combined municipal and hazardous waste landfills (Baker and MacKay, 1985). Odors are often present too at low concentrations of hydrogen sulfides, ammonia, organosulphurs and esters (methanethiol and ethyl butanoate) (Young and Parker, 1984).

Landfill gas recovery systems are often used to control gas migration. Often noxious gases emanate from the surface and the center of the landfill, while gas wells collect gas from the bottom and the periphery of the site. If withdrawal wells are not placed in gas production areas, then a gas collection system may not be completely successful in controlling gas migration, odors and air emissions (Kaszynski et al., 1981). Odors are particularly difficult to eliminate, because of the required high dilutions (up to 10,000 fold) to threshold for some odor components (Young and Parker, 1984).

2.1.3 Municipal Solid Waste Incineration

The concept of incineration, i.e., of simply burning garbage in an enclosed chamber, has been used since the late 1800's, but old facilities caused serious air pollution problems and were eliminated in North America after the Clean Air Act of 1970. The European mass-burning grate (MBG) incineration in conjunction with a waterwall boiler was developed in the late 1950's and put into operation throughout Europe and Japan in the 1960's and 1970's.

Since then, this technology is being more frequently applied in North America.

MBG incinerators possess several distinctive features which determine the physical impacts caused by the existence and operation of these facilities (Figure 2.4 and 2.5).

1. Waste is delivered and tipped by the collection vehicles into an enclosed bunker. The bunker doors are opened only during the tipping process and the garbage is never visible from outside the facility. The bunker area is kept under a slight vacuum by pulling additional combustion air from this area. Thus, odors, visual contact with garbage, and noise from the handling of the waste are eliminated. However, the traffic impacts along the access routes, i.e., noise, exhaust fumes, litter, visual and safety impacts are slightly increased over those of landfilling, because ash residue hauling increases the number of trips on access routes.
2. The waste stream is stored in the bunker and mixed by the crane to achieve a more homogeneous blend before being fed through the feed chutes onto the moving grates. the grate movement agitates and turns the waste while transporting it through the combustion zone. During the process, about 2/3 of the mass is burned and converted to flue gases, while 1/3 drops off the grates as siftings and residue into the quench water. Further, smaller quantities are collected as ash in the filtration devices.

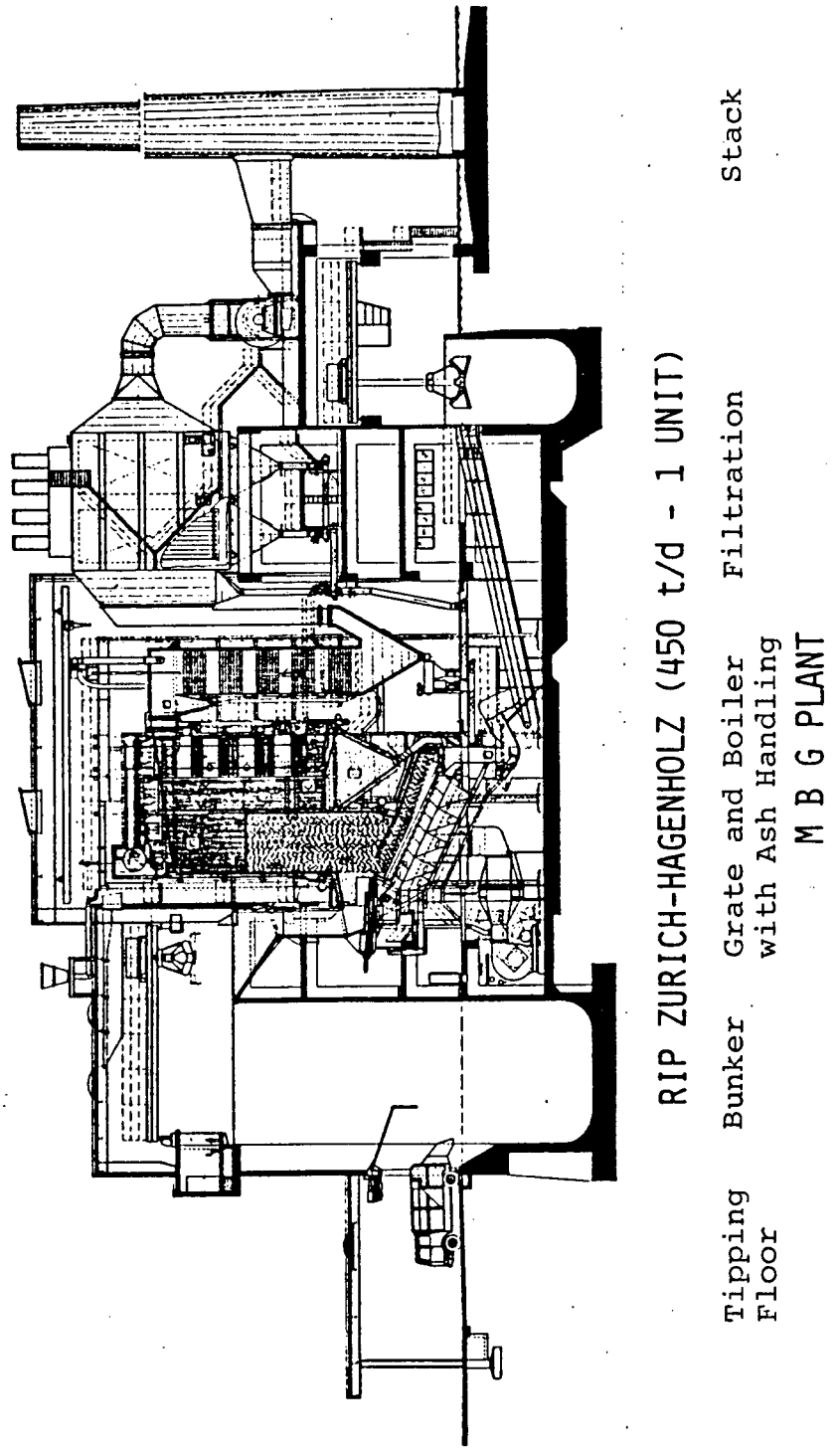


Figure 2.4: Municipal Solid Waste Incinerator - Cross Section; Source: LMRP, 1985

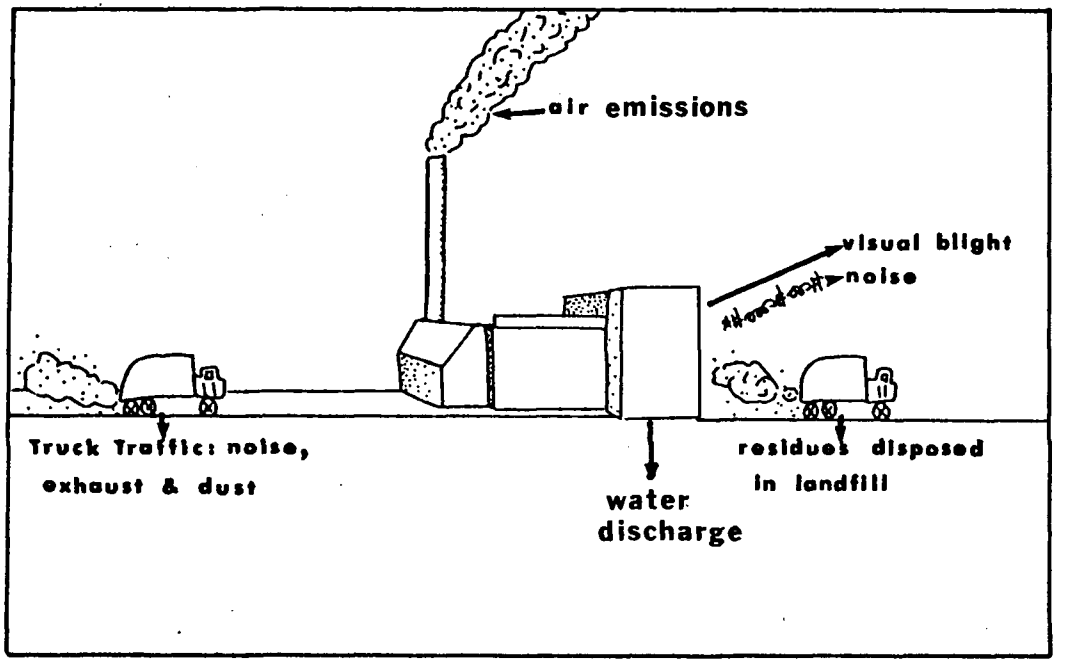


Figure 2.5: Mass Burning Grate Incinerator Emissions

The flue gases are combusted and heated further, passing through the furnace into the boiler. The heat is used to raise steam and the gases begin to cool down before entering an electrostatic precipitator (ESP) and the chemical gas scrubbing process. Alternately, chemical scrubber and following baghouse filter are used to filter exhaust gases before discharge from the stack. The combustion is influenced by three factors that determine the level of emissions (Brunner, 1984): (1) organic, inorganic and metallic contaminants in the waste stream; (2) crucial design features affecting the residence time, the turbulence and the temperature; and (3) the operational control of the air supply.

Incinerator Nuisances

The nuisance effects comprise traffic impacts and the noise, odor, and visual impact of the facility. The traffic impacts are similar to those described for a MSW landfill and will be limited to the areas immediately adjacent to the access route. Noise from the enclosed facility is low because the externally located exhaust fans are usually enclosed. Odors from the site will not occur, except during improper startup procedures (when the filtration devices have not reached operating temperature), or if the bunker doors are left open for lengthy periods on hot days. Both noise and odor will be limited to the immediate vicinity of the plant.

Visual impacts can arise from the visibility of the stack and

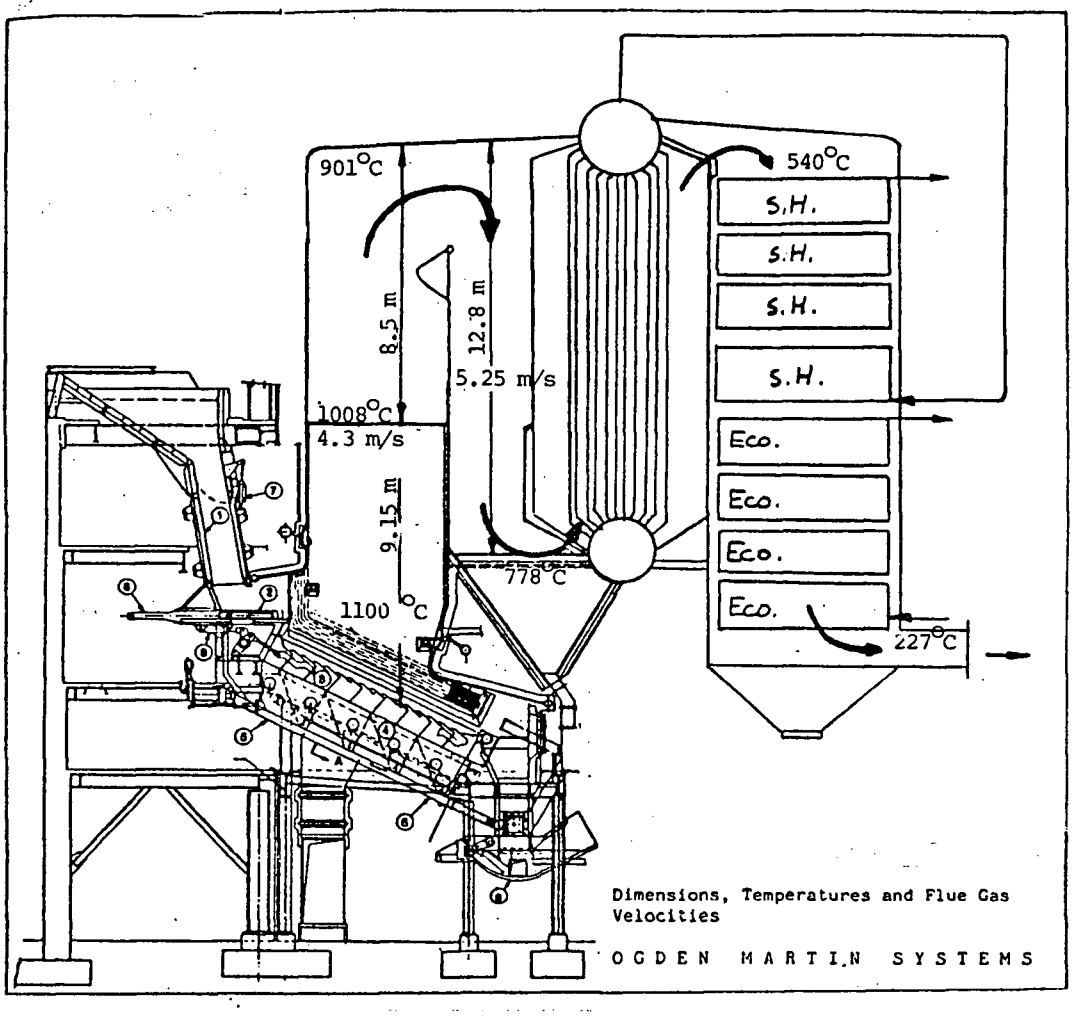
any exhaust plumes. These will be very noticeable in areas with no other similar facilities nearby. The visibility is limited to the line of sight and is therefore screened by vegetation or hilly topography.

Incinerator Combustion Process and Air Emissions

Apart from the large number of possible contaminants introduced into the combustion chamber in the waste stream, additional compounds can be readily formed during the combustion process. Although exact sources are not known, detected dioxins and furans are either present in the waste stream or are created from chemical precursors (e.g., pentachlorophenols in wood) at high temperatures (Connell and Miller, 1984). Neither the kinetics nor the sources of dioxin precursors have been established definitively, but their minimization through temperature, residence time and turbulence control is possible.

The geometry of the combustion chamber and the amount of air supplied to it determine the residence time, the turbulence and the temperature of the flame. Thus, the incinerator manufacturers have attempted to design into the system sufficient residence time and temperature to achieve high destruction efficiencies of the most stable constituent, usually dioxins, dichlorobenzene or PCB's (e.g., Zenon, 1985).

The only operational control factor available to the operator is the air supply. Careful control of the air supply is required to maintain adequate temperature, time, and turbulence to destroy toxic and odorous constituents. Favorable temperature-time



Temperature Range				Time
1100 °C	to	1008 °C		2.05 Seconds
1100 °C	to	901 °C		3.84 Seconds
1100 °C	to	778 °C		6.28 Seconds
1100 °C	to	540 °C		9.0 Seconds
1100 °C	to	227 °C		12.4 Seconds

Figure 2.6 - Temperature-Time Distribution in a MBG Incinerator; Source: Ogden-Martin, 1984

distribution throughout the incinerator is shown in the diagram below for a popular MBG incinerator design (Figure 2.6; source: Ogden-Martin, 1984).

Regulating the variations in combustion conditions in response to changing waste stream and environmental factors is difficult because of the following constraints (Brunner, 1984):

- the heat value of the waste stream fluctuates and requires the adjustment of the air quantity;
- the complete oxidation of the waste stream requires between 100 and 125% excess air; too little air increases the output of carbon monoxide, particulate and hydrocarbons; too much air decreases the flame temperature and the destruction efficiencies, while increasing NOx concentrations;
- the filtration devices are designed for certain exhaust gas volumes; additional air supply increases the gas velocity and decreases filtration efficiency.

The numerous emission standards cannot be met by simple air control, so most MBG incinerators are equipped with filtration devices:

- electro-static precipitators (ESP) remove particulate matter to dimensions above 0.01 microns;
- cloth filters remove particulate in the size range between 0 and 50 microns (Brunner, 1984).

The corollary effect of particulate removal is the removal of materials sorbed to the particles. Substantial amounts of sorbed heavy metals, and organics have been detected in flyash samples

taken from incinerator filters (Environment Canada, 1986).

Recently proposed incinerator emission standards in Europe (Germany and Switzerland) and the U.S. (Oregon) are based on the best available technology for the reduction of gaseous emissions, i.e., gas scrubbing, particularly for the removal of hydrogen chloride, other acidic components and metal vapors (Oregon DEQ, 1984). Gas scrubbers are able to provide between 90 to 98% filtration efficiency for the critical elements (Kisters, 1984, Environment Canada, 1986). Table 2.5 summarizes reported emissions from MBG incinerators with ESP filters only and combined ESP and gas scrubbers and compares them with the proposed emission standards.

The exact limits for toxicity of the resulting ambient concentrations of the critical elements are difficult to establish. Moreover, incinerators are seldom the only source of these contaminants in an air shed, because their emission compounds are common to many other stationary and mobile sources, e.g., SOx, NOx and CO from fossil fuel power plants and vehicles, Pb from vehicles, and HCL and HF from industrial processes. Thus, the contribution of the incinerator emissions to the ambient air quality often cannot be determined without significant airshed modeling effort. Moreover, the standards do not reflect any hard toxicological facts, but are based simply on the "best available technology" in filtration (Oregon State Department of Environmental Quality, 1984). There is no guarantee that emissions will not cause any long-term health effects. Some of the effects on human health, animals and plants are compiled in Table 2.6.

Table 2.5 - Incinerator Emissions and Standards;
Sources: Kebag, 1984, Tabarasan, 1984

	Emissions		Standards		
	ESP only (Kebag 1984)	ESP and Scrubbers (Tabarasan 1984)	FR Germany	Switzer-land	Sweden
	mg/Nm^3	mg/Nm^3	mg/Nm^3	mg/Nm^3	mg/Nm^3
Particulate	30 - 50	6 - 95	50 - 75	50	35
HCL	300 - 1500	41 - 75	30	100 (30)	200
HF	10 - 25	0.4 - 0.5	5	30	5
SO_2	200 - 400	18 - 25	200	500	-
Pb+Cu+Va	2 - 4	0.22	5		
Zn+As+Cr+ Co+Ni+Se	2 - 5	0.5 (Ni+Cr)		1	
Cd+Th	0.1 - 0.2	0.13		0.2	
Hg	0.4 - 1.4	0.05		0.1	

Table 2.6 - Potential Health Impacts of Incinerator Emissions

Particulate	- visibility decreases, respiratory disease and death rate among elderly increase at 100 - 150 micrograms/m3.
CO	- toxic to humans over 750 ppm, but is eliminated rapidly from the body; impaired visual acuity and psychomotor tests at 50 ppm; plants show virtually no effects below 100 ppm.
SOx	- at 0.19 ppm annual average with low particulate concentrations, increased mortality occurs, at 0.3 ppm, trees show injury; causes acid rain.
NOx	- is corrosive when converted to nitric acid, acts as an extreme irritant, increases bronchitis at <0.01 ppm, creates smog with hydrocarbons.
Hydrocarbons	- contain some carcinogens, e.g., polynuclear aromatic hydrocarbons, and contributes to smog formation.
VOC's	- some known and suspected carcinogens to humans
Metals - Hg	- affects the central nervous system and kidneys, accumulates in the body
Pb	- accumulates in the body, causes anemia, headaches, sterility
Ni	- changes lung structure, causes respiratory disease and lung cancer
Cd	- causes cardiovascular disease and hypertension.

Plants are harmed by SO_2, PAN, HF, HCl, Cl_2, H_2S, and NH_3.

The concern for the health effects of dioxin and furan emissions are results of the uncertainty about these materials. Although it has been established that all MBG incinerators emit low concentrations of various dioxin and furan isomers (ASME, 1981, Swiss Federal Office for Environmental Control, 1982, Nordrhein-Westfalen Institute for Air Pollution Control, 1982, numerous articles in Chemosphere, Vol.14, 1985), the controlling combustion variables have not been determined yet. The measured fluctuations and the resulting exposure of residents are variable and difficult to measure or estimate. To further complicate the matter, dioxin emissions from woodfires and other conventional combustion processes have been confirmed.

Moreover, the toxicological effects of dioxins and furans in humans are uncertain due to the problems involved with carrying out controlled dioxin experiments on humans. As a result, the effects of combined dioxins and furans have not been identified with "safe" daily uptake rates usually being extrapolated from animal tests.

As a result of the uncertainty, Sweden implemented and extended until the end of 1986 a moratorium on new incinerators (Swedish Department of Nature Conservation, 1985, pers. comm. Dr. Bilitewski, 1985), while Hamburg is engaging in a large study to test the connection between MBG incinerators and birth defects in the eastern part of the metropolitan area (Der Spiegel, 1984)

Water Use and Emissions.

Incinerator Ash Residue

Approximately 30 to 35% of the incoming solid waste stream by

weight and 15 to 20% by volume is discharged from the incinerator as residue and ash. This material has the potential of being considered a hazardous waste under the USEPA definition, but is usually exempted for practical reasons. This material must be hauled to a secure landfill. Although the leachate from such incinerator residue can contain heavy metals and organic matter, the impacts of the residual matter will be considered for this study as an integral part of the landfill where it is disposed of, and not of the incinerator. Thus, the only impact arising from the residual matter is the additional traffic from the incinerator site.

2.2 Contaminant Transport and the Impact Footprints

The transport of emissions from the source facility to the affected areas occurs by mass flux in air and water, or by pressure and view propagation in air. The matrix (Table 2.7) summarizes the emissions and transport mechanisms and resulting impacts for the two types of waste disposal facilities. These mechanisms will be discussed in view of making predictions about the contaminant transport.

2.2.1 Emission Transport Mechanisms

Air

Gas and Odor Transport

The atmospheric transport and dispersion process depends on the physical and chemical nature of the effluent, the location of the stack, the topographical characteristics and the meteorological conditions at the site. The eddy diffusion model

Table 2.7 - Waste Facility Emissions, Transport and Impacts

Emission	Transport Medium	Impacts MSW Landfill	MSW Incinerator
Mass flux of gaseous contaminants	Air Soil	Health risks Odors Air quality loss Explosion risks	Health risks Odors Air quality loss
Mass flux of contaminants to water as leachate	Soil Water	Health risks Water quality loss	Water quality loss
Pressure Energy as Noise	Air	Noise	Noise
Light	Air	Nuisance views of garbage, birds equipment	Nuisance view of plume, stack, building

and the assumption of normal density distribution around the centerline of the plume result in a commonly accepted and mathematically tractable model for predicting the concentration distribution for a continuous point source under steady-state conditions and constant wind-speed (Wark and Warner, 1981). By using the worst case scenarios the critical concentrations and their locations can be calculated (O'Connell, 1983, Oregon State Department of Environmental Quality, 1984, District of North Vancouver, 1985).

The dispersion of air emissions is subject to the temperature of the gases relative to the ambient air, the location of the emission relative to buildings and hills, the emission height, wind speed, stability of the weather conditions, terrain, and inversion height, if applicable. Under the most unfavorable conditions, usually with light but stable winds of between 1 to 2.5 metres per second, the critical short and long term maximum concentrations are found at distances between 700 metres to 30,000 metres from the site (O'Connell et.al., 1983, Seton, Odell & Johnson, 1984). Except for extreme downwash conditions, which are usually avoided through proper location of the stack, the maximum concentrations will not be found in the immediate vicinity of the plant. Thus, the critical potential impact area is delineated by two concentrical circles at approximately 700 to 30,000 m from the site. The resulting total exposure can be calculated from the wind direction frequency data and the concentrations.

This model is similarly applicable to ground-level line sources, e.g., a landfill, but fluctuating emission rates and transport conditions complicate the accuracy of predictions.

Pressure Waves

Noise Transport

Sound waves are transmitted through the air; they are affected by turbulence, temperature and wind gradients, and absorption and reflection by surfaces. The attenuation mechanisms are summarized in the list below (Mestre and Wooten, 1980):

- wave divergence reduces the noise level by about 6 dBA for every doubling of distance,
- absorption in the air, ground, or barriers,
- attenuation by precipitation and fog,
- wind and temperature gradients, turbulence,
- deflection off berms, terrain, trees, shrubs, etc.,
- attenuation due to temperature and barometric pressure gradients.

The numerous attenuation mechanisms are determined empirically and summarized in the noise control literature (see e.g., Kurze and Beranek, 1971). Although the prediction of sound pressure levels requires some experience and judgment, the actual measurement is straightforward. In general, noise levels are highest at the site boundary and decay rapidly with distance.

View Propagation

Visual Impacts

Vision is limited to the line of sight and therefore affects the immediate vicinity of the plant. However, the terrain can increase or decrease visibility on a flat plane. Moreover, vegetation and buildings can screen the facility from residents.

Vegetative screens may vary with seasons because of their loss of foliage in winter.

Although the range of visibility is easy to determine, the visual impact perception itself is not, because of attitudes involved in interpreting the sight. It has proven difficult to objectively judge the quality of physical views (Coughlin et al., 1973). However, apparent contrasts and landmarks affect the visual image of a location (Lynch, 1960).

Water

Surface

Contaminant transport in surface water is controlled by physical processes of advection and diffusion and biological-chemical processes of oxidation, biological decay and volatilization. The physical processes are modeled by the Fickian diffusion mass flux model, while the biological-chemical source-sink terms are usually based on first-order kinetic reactions.

Specifically, the physical transport in rivers relies on the expression of the turbulence energy as a shear velocity $u^* = f(\text{slope, depth of the channel})$ to estimate the average mixing coefficients in the transverse and longitudinal directions, while assuming a rapid and complete vertical mixing for most channels. Assuming Gaussian distribution, the two-dimensional eddy-diffusion model determines the downstream concentrations and the dimensions of the mixing zone. Although the results have been verified empirically, the accuracy in estimating the mixing coefficients is

very poor at plus-minus 50% (Fisher, 1979). Although the accuracy can be improved by on-site measurements, the data collection process is costly unless data are available from the literature (i.e., the velocity, slope, depth, width, geometry of the channel).

The biological processes require knowledge of the rate constants for various processes and substrates (oxidation, reaeration, settling, nitrification, etc.) and are usually dependent on temperature and pH. These data are also site specific, but can be measured with simple methods, or obtained from the literature for common circumstances. Once a homogeneous mix is established, only the biological-chemical processes are of importance.

Groundwater

In general, the contaminant transport in groundwater will be influenced by the contaminant characteristics (solubility, viscosity, density, diffusivity), the soil characteristics (hydraulic conductivity, porosity, attenuation) and the flow parameters (hydraulic gradient, flow velocity, dispersivity). The transport will be retarded by ion exchange, absorption, precipitation, and decay mechanisms in the soil.

The resulting contaminant plume movement is difficult to predict and will depend on the source release function, the amount present at the source, the nature of the material, and the specific conditions at the site. Although the resulting plumes vary substantially in their dimensions, extending from a few metres to thousands of metres from the site (MacFarlane et al.,

1983), Freeze's (1986) review of landfill leachate plumes reveals a surprising similarity in shapes and ratios of plume width to source width as well as similar directions in relation to the hydraulic gradient, similar conductivity values and depths of the plumes in unconsolidated strata.

If the underlying layer is permeable, then the resulting plume is long and thin, whereas the plume in impermeable strata is very short and stunted. Moreover, if a large amount of a compound is present in the source and is soluble in the groundwater, then a continuous plume can extend from the source and decrease in strength with distance until, at some finite distance, the background concentration is reached. Alternatively, a small volume of an immiscible or highly soluble contaminant will result in a slug release forming a "cloud" of a separate phase or of solute in the groundwater.

For a specific situation, the migration of a single contaminant can usually be modelled and predicted, if enough data are available, but complex situations with numerous and interacting contaminants are too complex for predictive efforts (Freeze and Cherry, 1979). However, the migration of multiple contaminants can be monitored by taking samples from downgradient wells.

2.2.2 Impact Footprints

Although the site-specific conditions prohibit the generalized calculation of the spatial limits of the impacts, the general considerations in the sections above indicate the qualitative patterns.

Municipal Waste Landfill

The substantial impact from MSW landfills is the leachate flow which is carried by surface and groundwater. These effects can carry for significant distances from the site due to the high toxicity of some constituents at low concentrations (below ppb levels). These water impacts are indicated by the extended plumes in receiving waters. Odor and noise effects are limited to the close proximity of the landfill site (see Figure 2.7a) but views may extend a few kilometres from the site.

Municipal Waste Incinerator

Air emissions are spatially the most significant impact beyond 500 to 600 metres distance. Thus, the air quality impact is confined to a segment in prevailing wind directions between 700m up to some kilometres from the site. View impacts extend from the site up to a few kilometres, but noise and traffic impacts are are likely to be concentrated locally (Figure 2.7b).

Typical physical effects of waste facilities are thus described and summarized in this section. In order to determine the impacts on the host community as the receptor, typical community's characteristics must be determined.

2.3 Host Community Characteristics

Typical host communities are described by their physical, and social characteristics in order to identify the possible impacts a waste facility may cause. In order to identify host community characteristics, it is first necessary to identify which communities typically host waste facilities. Then, specific

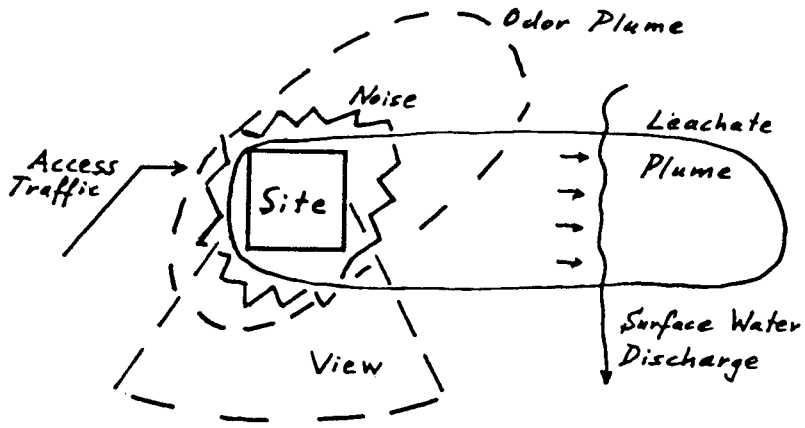


Figure 2.7a: MSW Landfill Footprint

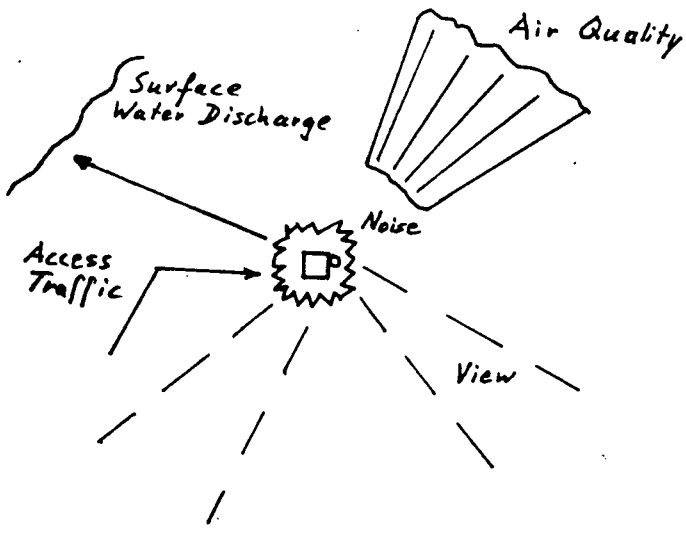


Figure 2.7b: MSW Incinerator Impact Footprint

characteristics and values are deduced. Finally, changes due to development in the host community are identified as a basis for identifying facility impacts in the next section.

2.3.1 Patterns of Waste Facility Location

Ideally, a number of factors are considered in the site selection, among them the availability and cost of land (particularly for landfills), accessibility and distance from the waste generating urban center, soil conditions, hydrogeology, climate, topography, and distance from dense residential areas (Tchobanoglous, et.al., 1977, Marion County, 1982). Intuitively, the criteria of availability and cost of land, and sufficient distance from dense residential areas conflict with the criteria for minimum distance to the waste generation centroid and accessibility. The site choices using the above criteria often result in locations outside the urban boundary, on marginal, cheap land, but close to major roads or highways.

Two studies (Stern 1977; Centaur Associates 1979) report that about 50% of, respectively, 30 solid waste and 21 hazardous waste disposal facilities are located in rural communities, about 25% in industrial areas, and 25% in areas with other land-uses.

Peripheral residential areas are also typically chosen for siting noxious facilities, because of the politics of externality control and land use changes (Ley, 1983). As a result, political channelling of spatial change (e.g., highways, noxious facilities) occurs through poorer, politically less sophisticated neighbourhoods (Ley, 1983, Jay in San Francisco Monitor, May,

1987). Negative land use changes tend to reinforce each other by destabilizing the community and making it more politically vulnerable, and, hence, susceptible to further change. Studies of attempts to site noxious facilities show high frequencies of land use conflicts at distances 16 to 20 kilometres from the central business district in Montreal (Ley, 1983), and predominantly in the transition zone and in peripheral residential areas (Janelle and Millward, 1976). Thus, waste facilities are often placed in rural host communities because of specific siting criteria (land costs, distance and low density) and because of political control.

Due to the proximity of the rural host community to the urban fringe, the urban growth boundary frequently catches up and overgrows the host community. For example, in the greater Vancouver (B.C.) metropolitan area, MSW disposal facilities fit this pattern and have played leap-frog with the urban growth boundary (see Figure 2.8). The location and opening and closing dates of municipal landfills, a new incinerator and a resource recovery facility are indicated on the map along with the location of major roads and distances from the downtown core. The trend shows increasing distances from the core and away from the urban growth boundaries that overgrow existing waste facilities which close shortly thereafter.

As a result of urban growth, open or agricultural land adjacent to the waste facility may be developed into commercial, industrial or residential land use. This phenomenon is mentioned in Schmalensee et al. (1975), and has been observed in Tacoma (see Chapter 4), at the BKK landfill site in West Covina, CA, near the

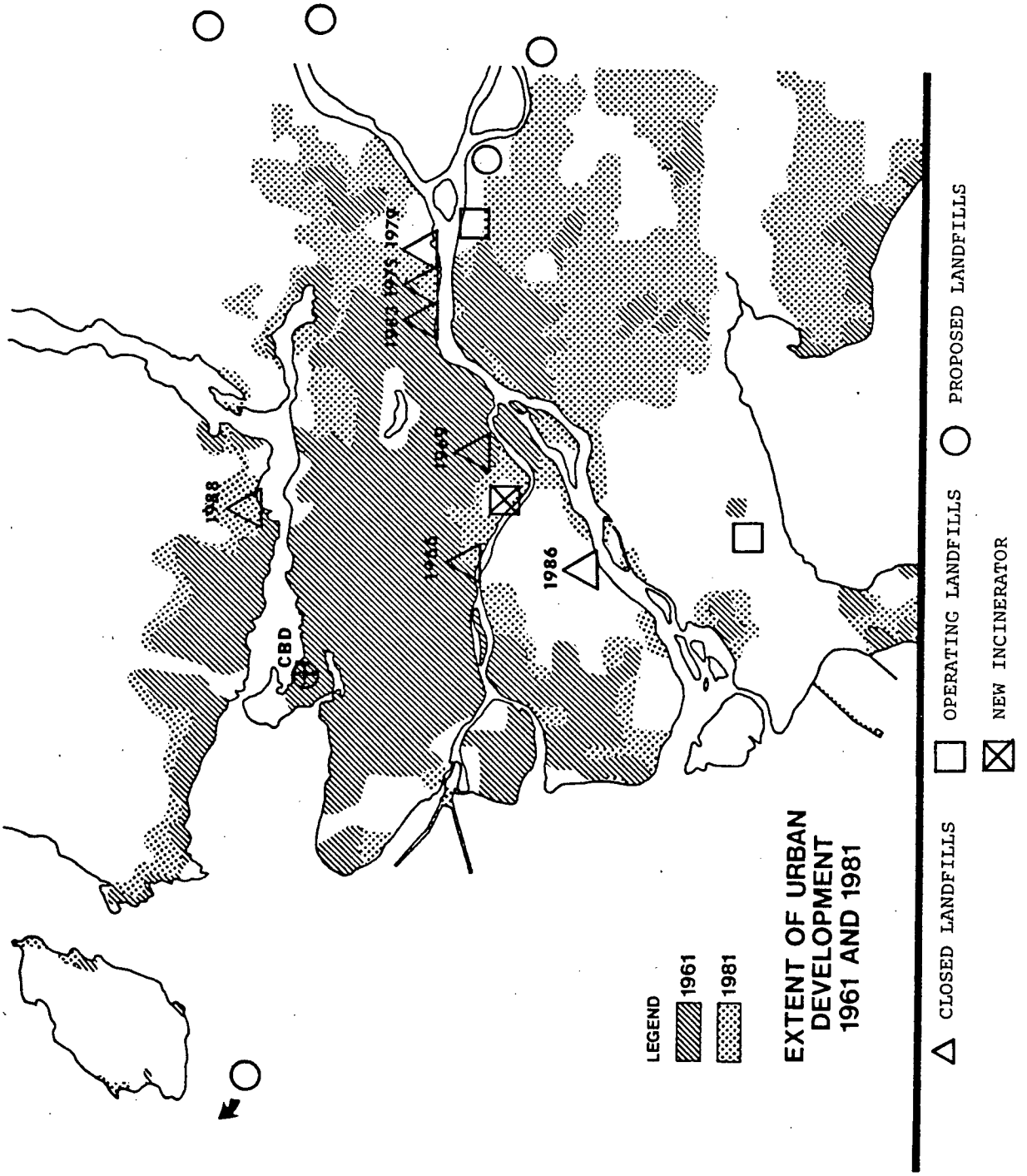


Figure 2.8 - Dates of Landfill Closures relative to Extent of Urban Development in the Greater Vancouver area, 1961-1981 based on GVRD, 1981.

Cedar Hills landfill in Seattle and others. Thus, the observed development around waste facilities in host communities fit a typical pattern of land use change in peripheral communities (Ley, 1983).

In the study area, a survey of 25 waste disposal facilities serving Metropolitan areas in Oregon, Washington, and provinces in Western Canada showed that 50% of the land uses around reported waste facility sites have changed from open or agricultural land uses to middle class suburban residential areas, while rapid development is reported near 65% of the waste disposal sites (see section on site selection in Chapter 1).

Thus, because of the strategic location of the host community close to and accessible from the urban center, development of initially inexpensive land leads to higher property prices and denser land uses. As a result, the character of the originally rural-agricultural community eventually shifts to a more suburban middle class community. These changes are graphically depicted in Figure 2.9. With the rise in unit property prices and increasing density, the effects of the waste facility on property values may be masked or overcome. Schmalensee et al. (1975) show property value increases near some California landfills. These value increases occur during the phase of new development and more than offset any facility impacts.

The denser, new development results in more people being exposed to the waste facilities effects. Concurrent to the development, the increase in waste volumes thus exposes more people to increasingly stronger facility emissions. In response,

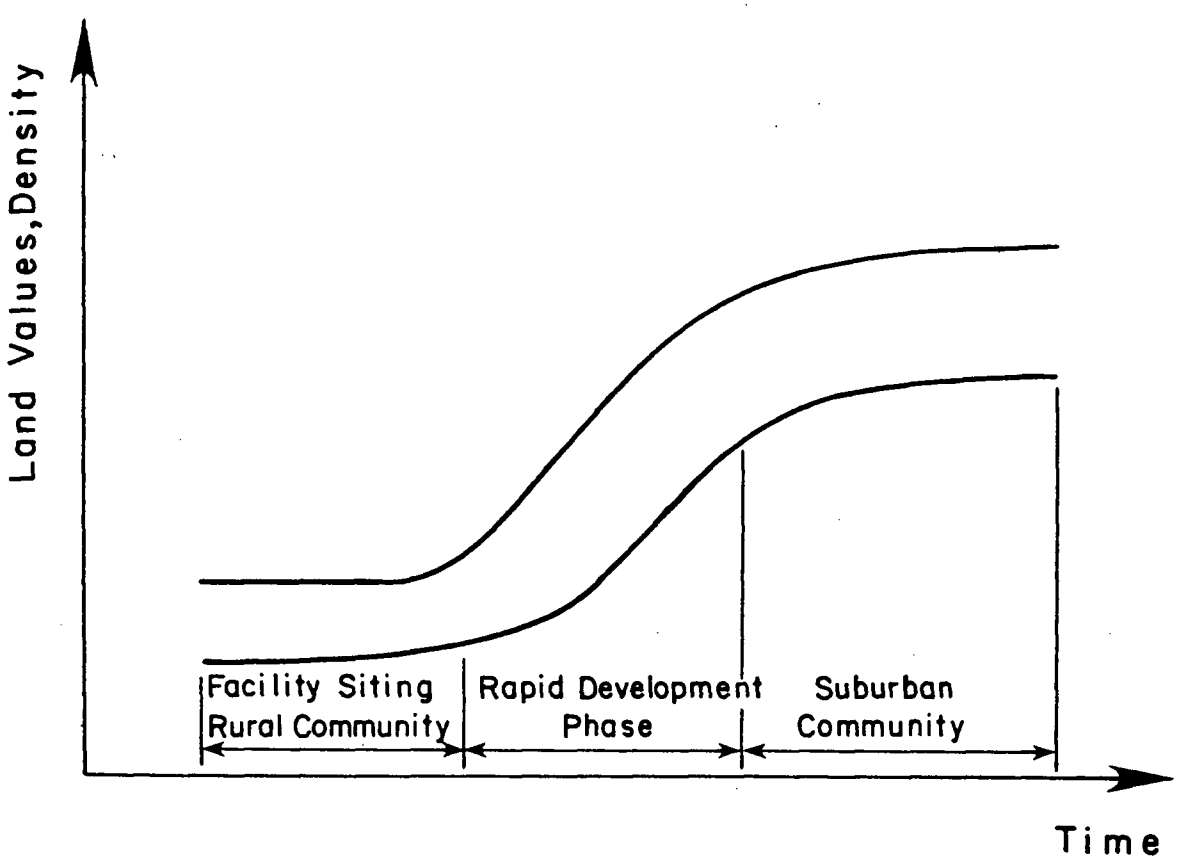


Figure 2.9 - Development after Facility Siting in a Typical Host Community

pressure is brought to bear on the facility owner to enhance emission controls or close the facility entirely (e.g., at the BKK site) in West Covina, CA (pers. comm. L. Goldmann, 1986), at Premier Street landfill in North Vancouver, at the Tacoma City landfill (Fircrest Town Council, 1986) and others. Thus, the concerns of the original rural host community may shift and intensify in the later suburban stages of the host community (Coughlin, 1973). These changes may require different responses to initially attain and then maintain host community acceptance throughout the life of the facility.

Typically, waste facilities are located in rural communities near the urban growth boundary close to transport routes. These communities typically experience rapid urban growth with subsequent higher densities and land values in areas surrounding the waste facilities. Thus, over the life of the facility, growth in the host community may increase the disposed waste volume and simultaneously expose more residents to the facility impacts.

2.3.2 Characteristics of Rural Communities

Common characteristics of towns and villages are identified as a basis for determining the effect and meaning of a waste facility to a typical rural host community.

Hodge and Quadeer (1983) identify five characteristics of land use patterns in small towns:

1. the area of the town is small
2. the density is low
3. the amount of vacant land is considerable

4. there is a single, dominant commercial area

5. there is a juxtaposition of different land uses.

The low density and the abundant vacant land were identified as the key criteria for the choice of rural areas for waste facility sites. The small total area, the single commercial area, and the juxtaposition of land uses contrast with the large single land use of a regional waste facility. Thus, the waste facility is likely to be highly conspicuous in the typical host community.

The demographic structure of small towns differs slightly from that of large cities in the household size (3.2 to 3.7 persons per household in villages versus 2.7 in large cities), more males than females (105 to 117 males per 100 females in villages versus 95 in large cities), and more children (63 to 69 under 20 years per 100 persons in villages versus 45 in large cities). Educational attainment is lower in villages than in large cities. The number of elderly, however, is virtually the same for villages and large cities (11 persons over 70 year age per 100 persons aged 20 to 69 years both in villages and in large cities).

While household characteristics, such as the presence of children, average age of household heads, and gender of the household head, tend to affect sensitivity to facility impacts, income and education levels show no consistent significant relationship with sensitivity (Madisso 1985). Hence, the demographical differences of rural and urban communities do not clearly indicate whether these communities are likely to oppose

waste facilities more or less than their urban counterparts.

Decision Making and Community Needs

The beliefs about small community life include notions of peacefulness, friendliness, lack of crime, community-minded orientation and a clean environment. Decision making is characterised by visibility of and familiarity with the decisions and the decision makers (Hodge and Qadeer, 1983). Thus, the smallness of the community is reflected in the decision making process. Preserving this smallness is a basic need in rural communities. The local siting of a large centralized waste facility through a complex decision making process is likely to violate the need for smallness. Multiple levels of government (provincial, regional, and metropolitan) consist of unfamiliar decision-makers. Thus, the lack of visibility and of familiarity of the decision process is foreign and adverse to basic rural beliefs, and does not appear to address community needs.

In contrast, community needs include recreation and entertainment (parks, arenas, and community centers), water, sewage and road services, health care facilities and employment (Hodge and Qadeer, 1983).

Typical host communities are characterized by small, low density land uses around a single core area. Decision making is through a visible and familiar process that preserves the need for smallness. The complex decision-making process and the large, distinct facility are likely to conflict with basic physical and social characteristics of typical rural communities.

2.4 Waste Facilities and Host Community Interaction: Qualitative Impact Identification

The location of a MSW facility in a rural host community can generate an array of effects as a result of the interaction of the facility as the emitter with the host community as the receptor. Both physical and non-physical interactions may occur and generate physical and non-physical changes in the host community. Physical and non-physical impacts and facility benefits are defined and possible interaction among impacts are described here from the perspective of the immediate host community.

2.4.1 Physical Impacts

The possible effects of physical emissions require definition and categorization in terms of their impacts on human activity. Here, three types of impact are defined:

1. Health effects comprise all possible emissions, events, risks and uncertainties that may affect human health. These may stem from water or air pollution or from sudden events such as fires or explosions. They include immediate and possible long-term risks. Although health regulations should prevent any direct, short-term health damage, the uncertain or unknown effects are difficult to regulate or monitor.
2. Nuisances include all impacts that infringe on the peaceful enjoyment of residential property without endangering human health. Although the distinction between nuisance and health effect is often not strictly defined, the difference may be very important from the

point of view of the host community. Although any type of physical emission (e.g., air emissions) can cause both health and nuisance effects, the severity of the impact determines whether it results in a health hazard or a nuisance impact. Some nuisances may further act as reminders of the negative social significance of the facility.

3. General environmental impacts generally do not directly effect human health or residential enjoyment, but may affect the environmental quality of fish and wildlife habitats, or may decrease the availability of limited resources (land, goods, materials, and energy).

The connection of emissions to impacts is then fairly intuitive. They can be related by the transport pathways between the facility and the host community (see Table 2.7).

The difference between health, nuisance and environmental change impacts of (say) water emissions consists of the concentration levels and the exposure patterns. Thus, in theory, one type of emission can cause all three impacts depending on the level of emissions and on the patterns of human use and enjoyment of the receiving environment. The classification of impact type is very significant for interpreting the meaning of the emission in terms of overall impact on human activity.

2.4.2 Non-Physical Impacts

Opposition to waste disposal facilities may be strongly rooted in the existential meaning of the facility to the host community. Because residents choose to live and associate

themselves with certain places, these places provide a summary of the people the residents see themselves to be (Ley, 1983). Thus, the physical reality of a community is interpreted in socio-economic terms. Because residents make sizable economic, social and symbolic investments in the community they choose to live in (Ley, 1983), they are therefore more concerned about local issues and changes than the facility proponent and the higher levels of government (e.g., regional district county, or provincial governments) above the local government in the host community.

The significance of the non-physical impacts is evident from the distribution of opposition activities, because, "the most active opposition often does not stem from the [physically] most strongly affected residents" [L. Goldmann, pers. comm., 1986, in Zeiss and Atwater, 1987). Residents frequently object to, "just knowing that it [the facility] is there" (Coughlin et al. 1973) and thereby indicate the non-physical meaning of the facility.

In the following, a set of non-physical impacts are compiled from siting case studies (O'Hare, et al, 1983, Centaur Associates, 1979, Zeiss et al., 1982, Zeiss, 1984) and risk perception studies (Slovic et al. 1984, Vlek and Stallen, 1981, Hohenemser et al. 1986, Earle and Lindell, 1981, Earle and Lindell, 1983).

Economic, social and political impact categories are postulated here to separate the non-physical impact elements into exhaustive and mutually exclusive categories. These three categories and their elements and indicators are discussed in the following section.

Economic Impacts

Facility Impacts on Property Values

Property value differentials are an indirect method of measuring externalities, because they evaluate the average response of the individuals in the marketplace to the entire package of residential enjoyment obtained by purchasing residential property (Freeman, 1979).

The value of residential property reflects the expected yields of peaceful enjoyment to the owner or tenant. The value of a residential parcel consists purely in the scarcity of the characteristics of the parcel, i.e., the advantage of the parcel in location, amenity, or any other attributes that are desired by prospective buyers.

Because the market price reflects the value of the expected future stream of benefits, i.e., of residential enjoyment of the property, it includes any expected changes to this stream in the future. Thus, if quiet homes are expected to become more noisy, then their value compared with presently noisy homes will decline (Mishan, 1982). The expected future yields are converted into the present worth with the applicable discount rate so that the market price reflects the sum of the properly discounted future yields (Knetsch, 1983).

From the statements above, it follows that any changes that affect the enjoyment of the property as perceived by the owner or occupant will diminish the capability of the property to produce the expected yields. However, the loss will only carry over to the next owner if he or she is equally or more sensitive to the

effects. The market price declines only if a significant number of people in the market perceive the effect to be undesirable.

The advantage of market price differentials is the summary measurement and weighting of all effects as perceived by those persons in the marketplace with the highest reservation value (Schmalensee, 1975). This postulate implies that only those impacts that are perceived by the prospective buyers are valued, whereas long-term and insidious effects that are not perceived do not enter the valuation (Freeman, 1979).

Psychological effects such as risk, uncertainty, and stigma will be reflected insofar as they are perceived by the prospective buyers. Thus, the property value differences between affected and unaffected parcels provide in theory a simple summary dollar measure of the external effects as they are perceived by the prospective buyers. In particular, no sentimental, or special value to the owner enters into the market price (Knetsch, 1983).

Property value losses are frequently mentioned as an impact of noxious, undesirable facilities (Zeiss, 1984a, Zeiss and Atwater, 1987). Numerous property value studies around noxious or risky facilities have been carried out. Some of the results of property value studies at solid waste disposal facilities are reviewed here:

- Havlicek, Richardson and Davies (1972), in Schmalensee, (1975) used distance and angle from the downwind direction from landfills as independent variables on the Multiple Listing Service sales prices to achieve a total explanation of variation of 79% at significant correlation.

- Goldberg (1972), in Schmalensee, (1975), tested distance and visibility as indicators to explain the percentage change (i.e., the rate of change) in property values over time near landfills. The results showed no significant effects. It is not clear why the rate of change in property values was chosen as the dependant variable, because the primary issue is whether there is a difference in property values, rather than in the rate of appreciation.
- Schmalensee et al. (1975) studied properties around four landfills in California and found only marginally significant correlation between distance and property sales prices. No significant effect on appreciation or residential development near the site was observed.
- Hockman et al. (1976) studied 55 landfills and 15 incinerator sites in the Chicago SMSA using distance and angle from the predominant downwind direction to estimate property sales prices. The results were significant and indicated impacts of landfills extending over three city blocks, equivalent to 6 to 7 cents per ton. Incinerator effects extended 20 city blocks and amounted to $1.70 per ton.
- Groth (1981) studied the effects of five landfills in California, Oregon and Washington on property values, appreciation rates, land-use patterns, and rents. Only a few and marginally significant effects were observed.
- Baker (1982) regressed market prices on linear, logarithmic

and square root transformations of distance to three landfills for domestic solid waste in New York State. The study methodology was appropriate although the underlying assumptions were not tested. The accuracy of distance as an indicator for the physical impacts was not checked; it may not be appropriate. The results show some significant effect of distance, particularly after 1978 (Love Canal) at the industrial and hazardous waste sites. The property value effects at the municipal waste landfills were insignificant. The results were not very firm, but tended to indicate some property value impacts from hazardous waste landfills.

- Zeiss (1984) regressed market prices on distance from the landfill and access road of the Premier Street Landfill in North Vancouver, B.C. and found a 20% increase in prices between 120 to 600 metres distance from the site among townhouses on the eastern side of the site, while among single family residences to the west, a marginally significant price difference of 7% over 1,500 metres distance was found. The study covered only 101 property sales over a two-year period, and included only floor space and number of bedrooms as property characteristics. In particular the influence of view and other amenities was not entered into the analysis for lack of data. These somewhat contradictory results were discussed in interviews with eleven real estate agents and appraisers. All contacts confirmed some effect of landfill view and odor on

price; estimates ranged from 15% to 25%, with an average of 20% property value difference at the landfill boundary.

- Gamble and Downing (1984) found significantly lower property values near landfills as compared with control areas, but the effects were not confirmed in a correctly specified hedonic price model, except for those parcels on the main access road, where a statistically significant effect was found. However, the expectations of residents that the landfill site will become a park were mentioned as an explanation for the lack of a significant effect. Furthermore, people may offset the lower property values by constructing more expensive homes.

Studies of similar, or supposedly more noxious facilities show ambiguous results.

- Blomquist (1974) found significant correlation of property value differentials within 11,500 feet (= 3 kms) of the Winnetka electrical utility power plant in Illinois. The differentials were best fitted by a linear function with a 0.9% decline for every 10% decrease in distance from the plant.
- Nelson (1981) studied the sales prices before and after the Three Mile Island accident and found no significant price or appreciation rate differences within a 20 mile radius of the plant. However, other possible explanations for the lack of effects were identified:
    - clean-up workers may have taken up the slack in the market;

- the observation period after the accident was only 9 months; this may have been too short for the price level to adjust;
- the expectation of federal and state assistance may have kept the property values at par with other areas;
- the lack of any damage from the accidental release and the prompt clean-up may have resulted in merely short-term costs of evacuation and anxiety to the residents.

- Gamble and Downing (1982) studied property sales around four nuclear power plants in the Northeastern U.S. Both linear and log-linear functions relating plant visibility and distance to the property values showed no significant correlation. Moreover, 583 single family dwelling sales in a 25 mile radius from the Three Mile Island site and 112 sales in a control area were analysed, but showed no significant effects. However, the analysts hypothesized that the plant closure during the study period may have delayed the effect on property values. This study attempted to assess the impact of clean-up workers moving into the area and found no effect.

The results of the empirical studies contradict the results of the risk perception studies about risky facilities (Slovic et. al. 1985) in that nuclear reactors and toxic wastes would be expected to cause significant impacts on perception of residential safety and, hence, would be reflected in the market price

differentials. Moreover, the results also contradict the stated perceptions of the residents and the frequent public opposition to the hazardous and noxious facilities. It is particularly curious that nuclear power plants show no effect on property values while a coal-burning electric plant does.

None of the studies verified the underlying assumptions of the hedonic equation for property values, nor did they measure the strength and distribution of the impacts (other than through distance and angle from downwind direction). Potentially offsetting benefits may have eliminated the effects of externalities on the sales prices. In the absence of apparent visual, aural or olfactory nuisances, the non-apparent impacts may not be perceived and, hence, may not be reflected in the price. As a result, the property value studies are unreliable as indicators for the impacts of noxious facilities, unless a variety of other variables are measured and included in the analysis.

It is, however, possible that facility impacts are reflected in the average time required to sell residential property rather than in the price. Sensitive vendors may be willing to wait until less sensitive buyers are found who are willing to pay full market price. Thus, the average number of days on the market until sale may be higher for impacted property.

Finally, sensitive owners may sell and move-out in response to a new facility. They may sell to uninformed buyers, who, on becoming aware of their predicament, may, in turn, resell. Thus, the percentage of property sales and moves may increase in impacted areas. Abelson (1977) reports an increased number of

household moves around the Sydney airport in proportion to the noise annoyance levels. Thus waste facility siting may affect residential real estate through property prices, length of time to sell property, or number of sales.

Further Economic Impacts

Property values effects are the most obvious impacts, but effects on future development, road maintenance infrastructure (waste, sewer) investments, police, fire and emergency response services and monitoring and inspection costs are important (Smith et al. 1985). Except for property value and future development impacts, these effects are reflected in local taxes to all residents in the political jurisdiction that includes the host community. Hence construction and operation of municipal waste facilities usually do not require major infrastructure costs, except for roads. These infrastructure costs may be explicitly or implicitly offset by the property taxes on the site. Finally, health impacts can result in loss of wages and health care costs. These are deemed remote and are not considered further.

In summary economic impacts including property values, retardation of future development and tax increases for additional services may affect the community.

Social Impacts

The social impact is defined here as the social significance of the waste facility to the community image and reputation. Because the meaning of space and social structure is to separate and stabilize the community's position (Ley, 1983), the mere

presence of a large waste disposal facility may affect the social image through the facility's connotations of urban waste and pollution (Bealer et al. 1982). For example, the names of the community opposition groups reflect the aversion to the stigma of having a waste facility in one's community: "Don't Dump on Delta, South Langley Against Garbage" (Zeiss, 1984b).

The social impact of waste and pollution lies in the implications of immoral behavior and harmful, contagious consequences. Waste in our society carries a strong negative meaning as expressed by Bealer, et al. (1982), "the subject of waste comes up a loser in a society strongly valuing the opposite." Pollution, seen as the harmful result of waste, carries a similar negative connotation. The apparent connection of the immoral (waste) with the harmful (pollution) through the visible signs of waste and pollution, emphasizes the underlying belief in a causal connection between the two. Since "pollution beliefs trace causal chains from immoral actions [to waste] to disasters" (Douglas and Wildavsky 1982), the combination of these two notions by the physical presence of a waste facility increases the social impact. The result is viewed as a stigma (a "mark of shame," Bealer, et al. 1982) on the reputation of the host community.

The result of the stigma is "to keep some categories of people apart so others can be together" (Douglas and Wildavsky 1982). Thus, implicitly, the location of the waste facilities separates the rural host community from the rest of society by associating the community with waste and pollution. In the

context of Ley's (1983) existential regions of a city (security-stress, stimulus-ennui, and status-stigma), siting a waste facility in a rural host community places a center of stigma, stimulus and stress in a location of rural security, ennui and status. The conspicuous presence and urban significance of the facility are bound to clash with the beliefs in the peaceful, small, friendly, clean environment of the rural community. As a result, the waste facility can represent a major social impact on the community's image.

Political Impacts

The decision-making process of establishing the waste management plan, facility location and the siting process generates a set of political impacts that affects the change resistance to a new technological facility in a host-community:

1. Loss of control over the magnitude and duration of the changes;
2. Lack of fairness of the distribution in time and space of the facility losses and gains;
3. Lack of familiarity with the facility technology, operation, impacts and with coping mechanisms and resources;
4. Loss of confidence in the technology, its proponents and the environmental regulation and enforcement agency.

The first three elements are derived from and include several risk perception factors of Slovic, Fischhoff and Lichtenstein (1984, 1985), Vlek and Stallen (1981), and Hohenemser et al. (1986).

Table 2.8: Compilation of Political Impacts in this Study with Risk Perception Factors in Previous Study (Slovic et al. 1985).

Political Impacts In this Study	Risk Perception Factors (Slovic et.al., 1985) and siting process factors subsumed under political impacts
Loss of Control	. involuntary . uncontrollable . not easily reduced . high risk to future generations . catastrophic
Unfairness	. affects one personally . not equitable
Lack of Familiarity	. unknown to those exposed . not observable . effects delayed . new risk . decision making process unfamiliar
Lack of Confidence	. risks unknown to science . proponent and decision makers unknown

Confidence is added specifically to include the participants who often provide and interpret information and act as agents for the host-community; the facility proponent, the local government, and the environmental agency. Confidence in the technology itself is important too. The confidence element is a complementary factor to the residents' personal familiarity. Both familiarity and confidence are contained in the Slovic et al. (1984) "knowledge" factor.

The elements of control and fairness were selected from the 11 "dread" risk elements in the study by Slovic et al. (1984) (see Table 2.8). The other elements in the "dread" dimension were dropped because they are not relevant to MSW facility impacts (e.g., global catastrophic, consequences fatal, high risk to future generations, and risk increasing). The unknown risk dimensions are subsumed under familiarity and confidence in decision makers.

The combination of multiple factors into the four elements here simplifies and clarifies the dimensions specifically for determining resistance to waste facilities in host-communities.

Loss of Host-Community Control

The host community's resistance to the facility frequently requires the waste agency to site the facility using political or legal power. The imposition of an undesirable facility, however, violates the host community's feeling of control over its environment. Furthermore, the political meaning of strategic siting decisions implies the existence of power of the

decision-makers over the host community. The facility proponent and the local government body may decide the site location and, hence, exercise externality control which amounts to a redistribution of income (Ley, 1983) for the host community. The location of a noxious facility is both attracted by the prior channelization of locally undesirable land uses (highways and transport corridors for access, and factories as steam users) and reinforce future location of additional undesirable facilities. Simultaneously, the noxious facility exemplifies the political power of the urban center over the rural periphery. The resulting feeling of helplessness consists of mental and psychological stress among host community residents as documented by Madisso (1985). Risk perception studies (Slovic et al., 1984; Starr 1969) have shown that involuntarily encountered risks are perceived to be worse and, hence, more dreaded than voluntarily accepted risks. The loss of control stemming from the presence of a waste facility demoralize the community and, hence, demands substantial adaptation effort from the residents to cope with the new situation. The feeling of lost control often occurs at the time of the change, i.e., during the siting process. However, if facility impacts continue or if uncertainties persist, and if complete adaptation is impossible, then the loss of control may extend throughout facility life and well beyond closure (e.g., for landfills). In both scenarios, the loss of control requires substantial coping effort and therefore increases the resistance to change. Thus, the demoralizing effect of the imposed facility on the host community increases the perceived significance of the

risks and impacts and, hence, increases the value of the losses to the host community (Michelman 1967).

Unfairness

Fairness in the context of facility siting is defined as a distribution of facility costs in proportion to its benefits among all beneficiaries, and by the absence of external impacts among non-beneficiaries.

For a typical waste facility, the financial costs are distributed equally among waste generators in the catchment area through unit disposal costs, while, in contrast, the external effects (facility impacts) are concentrated in the host-community and particularly in the immediate local area of the facility (see Figure 2.10) because the host community is defined by the impact field. Thus, the large number of waste generators benefit from the waste disposal service, while the small number of host-community residents suffer the losses. This distribution is unfair by the definition used here, because the benefits are widespread while costs (impacts) are concentrated on the host community alone.

The larger the number of contributing waste generators in relation to the host-comunity residents, the more unfair the arrangement will be. The unfairness will be exacerbated further if waste from other political jurisdictions is accepted at the facility. While residents seem to accept responsibility for their own waste, they are very sensitive to other people's waste, particularly if it comes from a large city. The results from a

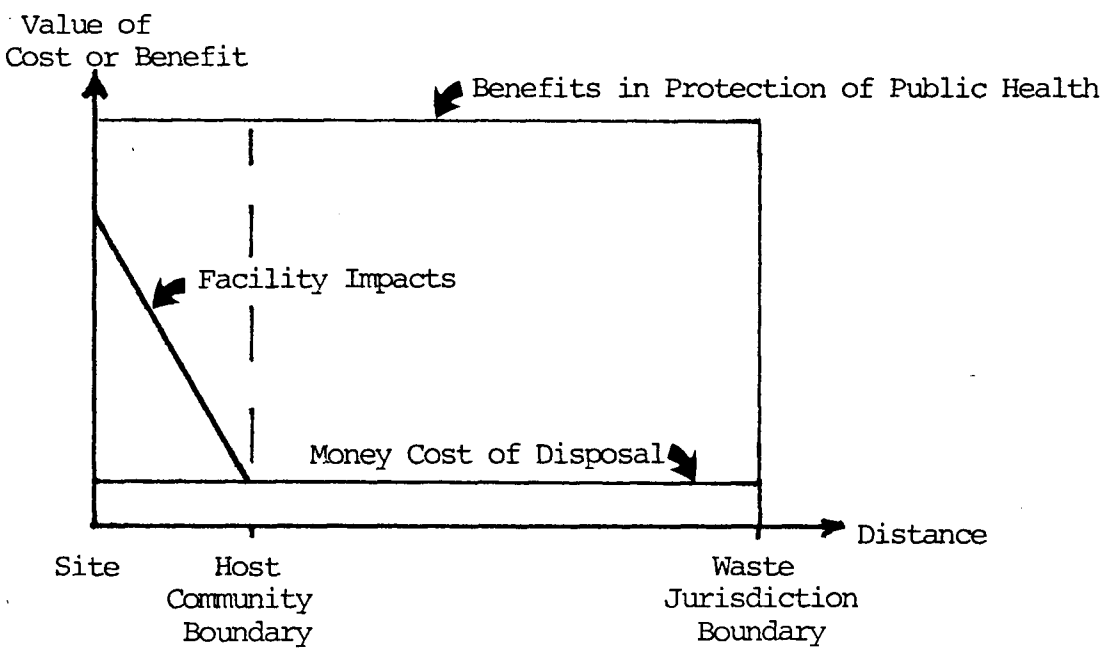


Figure 2.10: Distribution of Costs and Benefits of Waste Disposal Facilities; Source: Zeiss and Atwater, 1987.

small public workshop (Zeiss, 1984b) show that the acceptance of a waste facility drops if the facility serves other communities, and particularly if it serves a large city. Thus, the perception of unfairness is connected with social stigma, urban-rural conflict, and loss of control through the siting of a waste facility.

Community Familiarity with the Facility and Its Impacts

Although some people have seen or visited a small landfill (i.e., the garbage dump) at one time or another, large modern facilities such as incinerators, regional landfills, and hazardous waste facilities are practically unknown to many people. The residents are unfamiliar with many aspects of large modern waste facilities including the siting process, disposal technology, impacts, and coping and adaptation mechanisms, because the siting process is an infrequent event that occurs in very few communities. Thus, general knowledge about the process and the facility is scarce and limited. Uncertainty among waste management professionals about the siting process, facility technology, impacts and coping strategies may contribute to the perceived lack of familiarity, because the host-community relies on these professionals for its information about complex technology and impacts. Slovic et al. (1985) identify scientific knowledge as a necessary factor for explaining risk perception. Thus, personal familiarity and confidence in experts and decision-makers are complementary factors in risk perception. Earle and Lindell (1983) show that individuals who are

professionally or physically close to hazardous facilities, and thus more familiar with the facilities, tend to accept the facility more readily. Moreover, a given individual in a large city is less likely to be aware of a specific noxious industrial facility than would a resident of a smaller community in which a major industrial facility is located (Earle and Lindell 1983).

Since the familiarity with the impacts is low, but the awareness of the facility and its impacts are high, the resulting anxiety, uncertainty, and risk perception of the physical and social impacts are greater for unfamiliar facilities and impacts than for common facilities (LMRP 1985; Madisso 1985; Slovic et al. 1984). In response, many public participation programs focus many of their efforts on familiarizing residents with the facility and its operation (Connor and Svendson 1986) with the intent of lowering anxiety, and, hence opposition.

Confidence in the Proponent, Enforcement Agency, and Disposal Technology

The good image and honest intentions of the public or private proponent have long been recognized as essential to a successful siting process (Centaur Assoc. 1979; O'Hare, et al. 1983). Since Love Canal and its reverberations in the press, waste management companies and agencies have become very aware of the harm to new siting attempts caused by poor management of existing facilities. The proponent must be capable and honest, must provide a necessary service and possess a good environmental record, deal openly with the residents and avoid any strategic maneuvering. Many firms and waste agencies are making special efforts to maintain a good

public image to aid the siting of waste facilities (Redhead 1986). Confidence in the local government as an important decision maker and representative of the host community's interests is important, and especially if the local government is also the operator of the facility.

However, confidence in the regulating and enforcement agency is almost equally important, particularly where risks and uncertainty about the project are present. A government agency that has inadequate or no regulations in place to protect the host community will not gain the confidence of the residents. This is particularly important if the proponent is a private firm which is perceived to have a short-term profit motive and, hence, may have an incentive to violate regulations (Harford, 1978). Not surprisingly, Slovic, et al. (1984) found a correlation between risk perception and the perception of the need for more stringent regulation of risky activities and facilities.

Finally, the host community confidence in the disposal technology and emission controls will influence the host-community's perception of the facility. Confidence in the technology reduces concern and doubt about the facility impacts. Earl and Lindell (1983) show that groups which are either professionally or geographically closer to risky facilities, and presumably more familiar with the facilities, are more confident and less concerned about health effects and are more accepting of the activity. It follows that familiarity seems to generate more confidence and both correlate with better acceptance.

2.4.3 Facility Benefits

The needs of the host community usually consist of the waste disposal service for their own refuse, but may also include employment and property tax revenues. If the facility meets crucial host-community needs, then the facility is bound to be more desirable and more tolerable for the residents.

Although a solid waste facility fulfills one of the host-comunity's needs (disposal service), this need could easily be provided by a number of alternative methods other than hosting a regional waste facility. This is especially true for a rural community with low waste volumes and much open land. Thus, foregoing the disposal services provided by the facility is a small loss for the host community compared with the losses associated with hosting a large regional waste facility.

Both employment and tax revenues from waste facilities are relatively small, and are primarily used to offset additional infrastructure costs for roads, sewer, power, fire protection and emergency services. Furthermore, the value of reclaimed land from landfilling is low, because of its (originally) remote location and because of the difficulties of construction on a filled area. Some recreational uses are suitable (e.g., golf courses), but in a rural host community, the premium for open land for a golf course is probably small.

Overall, the benefits accruing specifically to the host community from the facility construction and operation are probably small and, judging from the frequency and strength of the opposition, the benefits do not offset the losses.

2.4.4 Chapter Summary

MSW landfills and incinerators generate emissions to air, water and soil. Typical locations for waste facilities are in rural host communities where small, diverse and low density land uses are characteristic, decision-making process are transparent and decision-makers are known. The siting of a large, regional waste facility generates physical emissions and results in a set of physical and non-physical impacts. Physical impacts comprise health risks, nuisances, and environmental changes. These impacts can in theory, be measured to establish facility footprints on the host community.

The set of non-physical impacts includes economic, social, and political effects of a waste facility on a rural host community. Although these impacts are not physically measurable, they may be associated with and triggered by exposure to physical impacts. Furthermore, these impacts may be interrelated with each other. Table 2.9 lists a generic summary of impacts at the MSW facilities.

Table 2.9 - Summary of Municipal Solid Waste Facility Impacts

Impacts	Landfill	Incinerator
Health risks		
Air	(x)	x
Water	x	
Explosion	x	
Nuisances		
Noise	x	x
Odor	x	
View	x	x
Environmental Change		
Air quality	(x)	x
Water quality	x	(x)
Wildlife	x	(x)
Economic		
Property Values	x	x
Future development	x	x
Infrastructure	x	x
Social		
Community Image	x	x
Political		
Loss of Control	x	x
Fairness	x	x
Familiarity	x	x
Confidence	x	x
Benefits		
Waste Disposal Service	x	x
Convenience	x	x
Energy		(x)
Employment	(x)	(x)
Tax Revenues	(x)	(x)

x = impact/benefit typically occurs
(x) = impact/benefit may occur

CHAPTER - 3 ACCEPTANCE CRITERION and APPROACH for SITING WASTE FACILITIES in HOST COMMUNITIES

The goal of this chapter is to determine theoretically the most effective approach to gaining facility acceptance in host communities. A criterion to define "acceptance" in the host community is derived from a conceptual model of facility impacts and benefits. Then, the most effective approach to reaching facility acceptance is derived theoretically from environmental economic theory. This basic approach is then translated into specific methods of addressing facility impacts. Finally, common legal and legislated compensation options for noxious facility impacts are reviewed to determine their effectiveness in gaining acceptance based on the theoretically determined approach. The conclusions summarize the findings as hypotheses for an optimal approach.

3.1 Facility Impact Model and Acceptance Criterion

The acceptance model conceptually treats facility impacts as losses and facility benefits as gains to the host community. These losses and gains are shown in Figure 3.1 as changes from the host community's reference level, that is, as changes to the original condition in the community. The original reference point in a stable community is simply the situation in the community before the change (the facility). If, however, some change has occurred prior to the proposed facility siting, then the reference point may be unclear. For typical, stable host communities as defined in Chapter 2, the reference point is likely to be the host

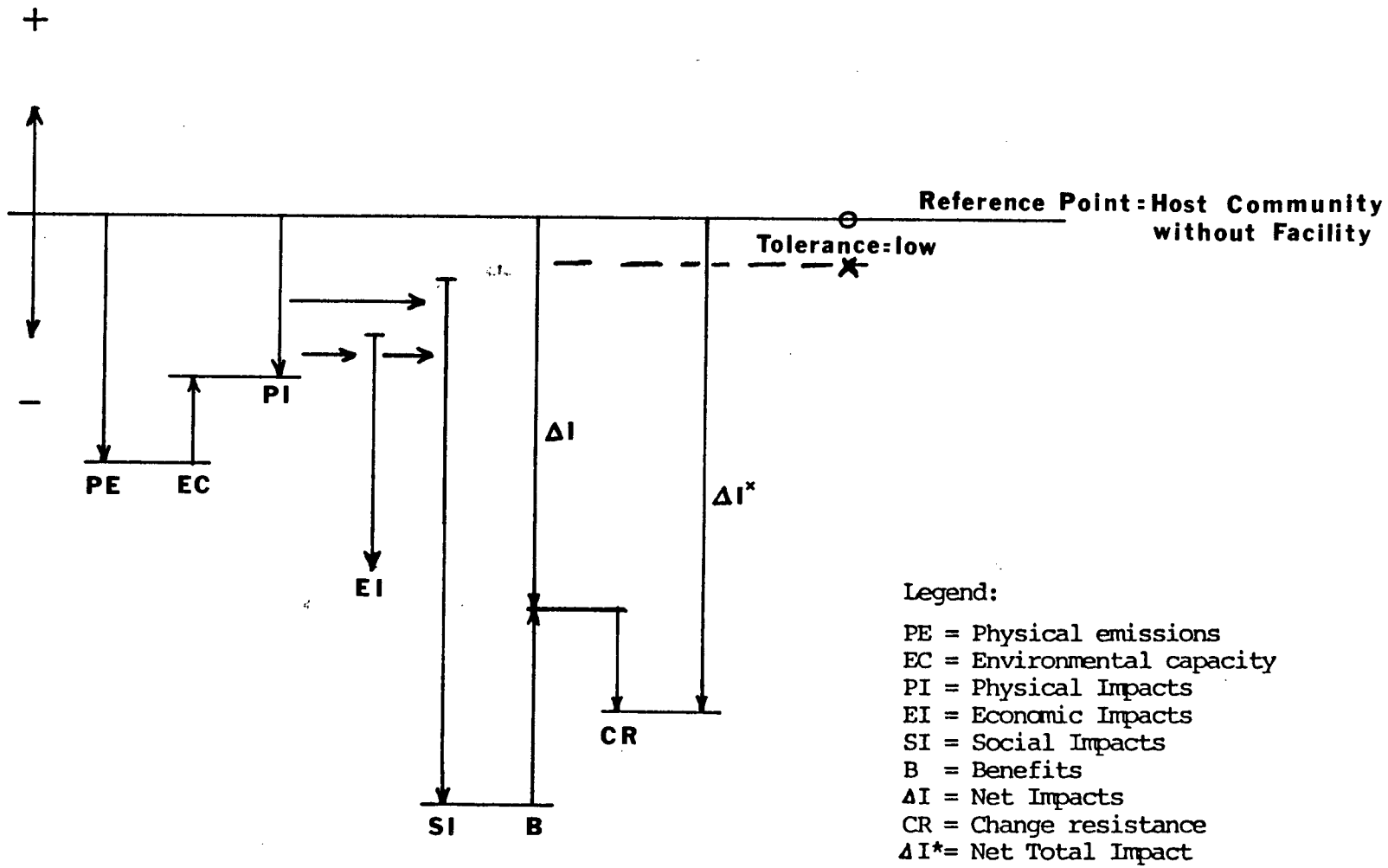


Figure 3.1: Acceptance Model and Net Facility Impact.

community without the facility.

Losses comprise three specific impact types:

- Physical emissions (PE) to air, water and soil are determined by the physical design. They are attenuated by the physical characteristics of the site to the extent of its environment capacity (EC). The physical impacts (PI) are the resulting net physical changes the facility causes to surrounding areas.
- Social impacts (SI) consist of the social meaning of the facility and of its association with the host-community. Social impacts may occur independently of physical emissions; the complaint of "just knowing the facility is there" is an indication of social impacts. However, obvious physical nuisances (odor, noise, view) may act as reminders, or triggers for social impacts.
- Economic impacts (EI) comprise possible property value depreciation and loss of future development. They are theoretically caused by physical or social impacts. Furthermore, if health impacts occur, loss of wages and health care costs can result. These are, however, disregarded here.

All impacts represent individual values based on personal judgment as perceived by residents. Each person determines if and to what degree he or she is affected by the facility. This is consistent with the basic economic principle that each individual is the best judge of his or her welfare.

For the purpose of facility siting, "acceptance" is defined

as the absence of significant, tangible opposition as exit or voice (Hirschmann, 1970) in response to facility siting. Thus, the definition is based on behavioral response rather than on attitude. The definition assumes a correlation between sensitivity to facility impacts, resulting negative attitude and opposition action (Fishbein and Ajzen, 1978) but relies on opposition activity as the indicator for degree of "acceptance".

Exit of significant numbers of households from the host community may lead to a weakening and destabilization, whereas opposition activities can cause serious delay to the facility, e.g., through law suits, referenda and major political pressure. Both forms of opposition lead to further losses as a result of facility siting.

Since a large number of host community residents are potentially involved, the aggregation of individual values among host community residents must be addressed in order to define an acceptance criterion. Rather than assuming rules for aggregating values, the acceptance criterion is defined for a single, marginal resident's opposition actions. Thus, the following model is defined for the instrumental resident who is most likely to, move away, take legal action, start a referendum, or initiate an opposition group if facility siting proceeds.

Thus, the critical (or marginal) individual or household is one that feels threatened or annoyed by the facility and is sufficiently connected in the host community to obtain support to generate a sustainable opposition. The individual who is "on the edge" of actively opposing the facility and is likely to incite

others to follow is the marginal resident on whom acceptance hinges. Therefore acceptance is achieved when this marginal resident refrains from active opposition. Obviously, it is difficult to predict a priori who the marginal resident will be. However, interviews with community leaders, long-term residents, and environmentally concerned individuals are commonly used in facility siting to indicate initial reactions and intentions (e.g., Connor and Svendson, 1985). Regardless of the measurement problems, the conceptual definition of acceptance is used here for the hypothetical marginal resident deciding whether to take significant opposition action in response to the waste facility.

From the discussion in Chapter 2, it is likely that physical impacts may cause and, hence, interact with economic and social impacts. Therefore, the impacts may not be independent, or, hence, additive in a decision model. These impacts are therefore shown as overlapping arrows in Figure 3.1 to indicate the interaction, which is equivalent to a multiplicative form of value aggregation (Von Winterfeldt and Edwards, 1986).

Negative values from the reference point are indicated by downward arrows; positive effects are shown by arrows pointed upward. The values of physical (PI), social (SI), and economic (EI) impacts combine to the gross facility impact (loss I), shown in this hypothetical case as the combined length of the individual impact values. Facility benefits (shown as an upward arrow) are usually small and do not nearly offset the impacts.

Any change comprises a set of gains (benefits) and losses (impacts). Change resistance is a concept used here to reflect

the effort and reluctance to deal with this set of losses and gains. The process of identifying the dimensions of change, evaluating the gains and losses, determining opposition, avoidance and coping behavior, and adapting to the change require mental and physical effort on the part of the affected residents. Moreover, even a small initial change may generate large change resistance because its subsequent ramifications may require further substantial change adaptation effort (Von Winterfeldt and Edwards, 1986). Thus, change resistance reflects the expected effort for dealing with initial change and its ramifications.

Political impacts were originally identified as non-physical in the host community. Although political impacts (loss of control, and confidence, unfairness, lack of familiarity) do not objectively affect the size of specific impacts, they are hypothesized to cause additional change resistance. Thus political impacts are combined into the change resistance loss arrow in Figure 3.2. Since lack of familiarity with the project and lack of confidence in the decision makers require from the residents more effort to evaluate the project in terms of the changes, as the loss of control and fairness require special attention so as to prevent intolerable changes, the combination of the four political impacts into change resistance is conceptually accurate.

The specific political impacts of familiarity (with the facility impacts) and confidence in the decision makers are interdependent as are control and confidence. These connections are shown in Figure 3.2. The direction of causation is shown by

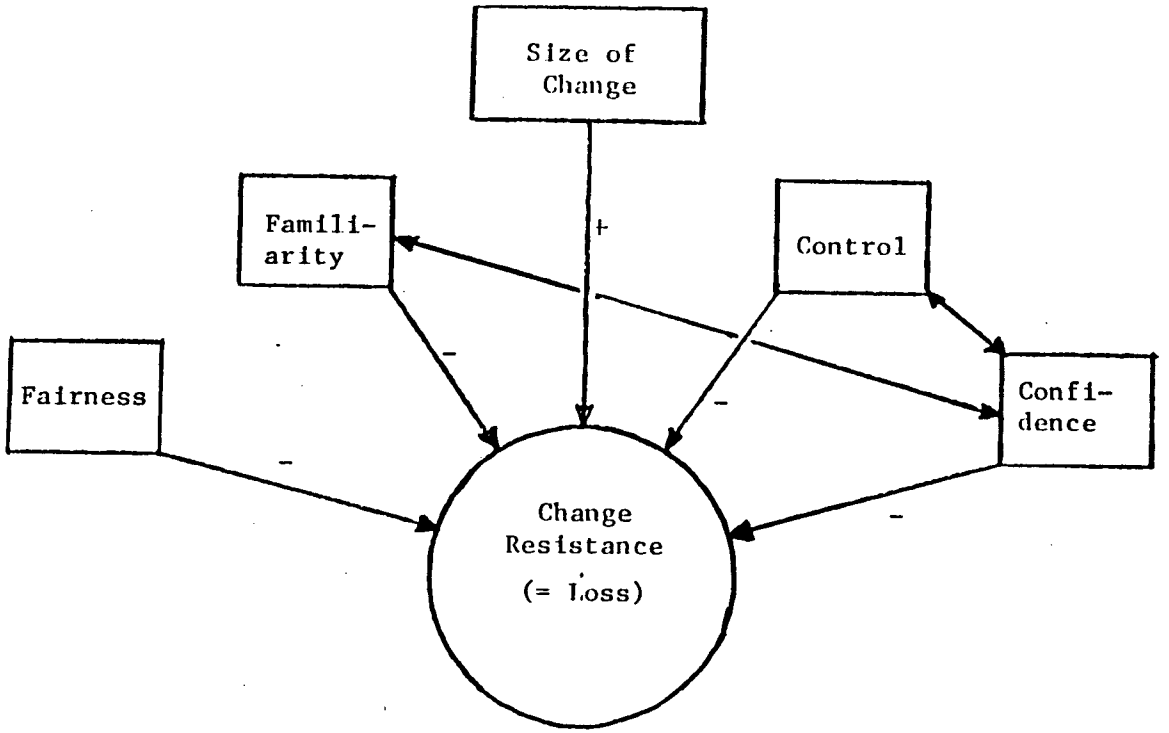


Figure 3.2: Change Resistance.

the arrows; the plus signs (+) indicate proportional, the minus signs (-) indicate inversely proportional relationships. The resulting change resistance is determined by these relationships with the four political impacts.

Resistance to change is a common issue in community planning (Lynch, 1981, Downs, 1981, Wolpert et al. 1972, Coote, 1985). Since change resistance is a common response to virtually any change, it constitutes a generic "friction" loss that increases the negative value of the change to the host community. The net resulting facility impact ΔI^* can therefore be stated as the negative value of combined physical, social and economic impacts offset by the positive value of benefits, increased by the negative value of the change resistance (CR in Figure 3.1).

The facility acceptance criterion requires that the net facility impact ΔI^* fall within the (very small) tolerance range of the host community, that is, essentially be equal to zero:

Acceptance Criterion
$\Delta I^* = \Delta I - CR \simeq 0$

This criterion states that the only outcome comparable to not having the facility is achieved when no net loss occurs. This condition is corroborated by demand of some host communities' to have zero net impact for acceptance of waste facilities (Centaur Associates, 1979, Fish and Romano, 1980). The condition of net zero impact, taking into account the change resistence, is furthermore rational and optimal from the perspective of the host

community, because negative impacts constitute income losses with no equivalent offsetting benefit. Thus, facility acceptance hinges on reducing below tolerance level the net loss to the community.

Implications of the Acceptance Criterion

The acceptance model shows that the condition of no net loss can be met either through reducing losses or by increasing benefits to the host community. More specifically, there are three approaches for the facility siting agency to achieve facility acceptance:

1. Reduce the facility's physical, social and economic impacts by e.g., screening of views, collecting and treating water and air emissions, preventing community association with the facility by choosing a different facility name, and by guaranteeing property values for property owners within a certain radius of the facility (see e.g., City of Seattle, 1986).
2. Reduce change resistance by enhancing fairness through redistributing a larger portion of facility costs to the waste generators outside the host-community, enhancing familiarity by providing facility tours and presentations, increasing host-community control through participation during the siting process and in liaison committees during the operation phase, and building confidence through selection of proven technology and reputable, locally known operators.
3. Increase benefits by compensating the community in

alternative benefits, e.g. a new sewer system, improvements, a new fire hall, etc.

The most effective approach is not intuitively evident. Moreover, operational methods to address pertinent impacts are not self-evident either.

3.2 The Basic Acceptance Approach

The choices for the siting agency to meet the acceptance criterion consist of either reducing negative facility impacts (losses), or increasing facility benefits (gains) to the host-community. If the absolute values of gains and losses to the host-community were equal, then the two approaches would have identical effects and could be used interchangeably. Fortunately, common choice behavior among people who are confronted with decisions about changes provides basic guidelines for choosing the most effective approach.

3.2.1 Values for Losses and Gains

The prospect theory (Kahnemann and Tversky, 1979, see Figure 3.3a) states that:

1. losses from a reference point are valued more negatively than equal gains are valued positively, or, the absolute value of losses exceeds the value of equal gains;
2. people evaluate changes as positive or negative differences from a reference point, rather than as comparisons of final wealth positions (see also Marshall et al., 1986).

The value disparity of willingness to pay (gain) value (WTP)

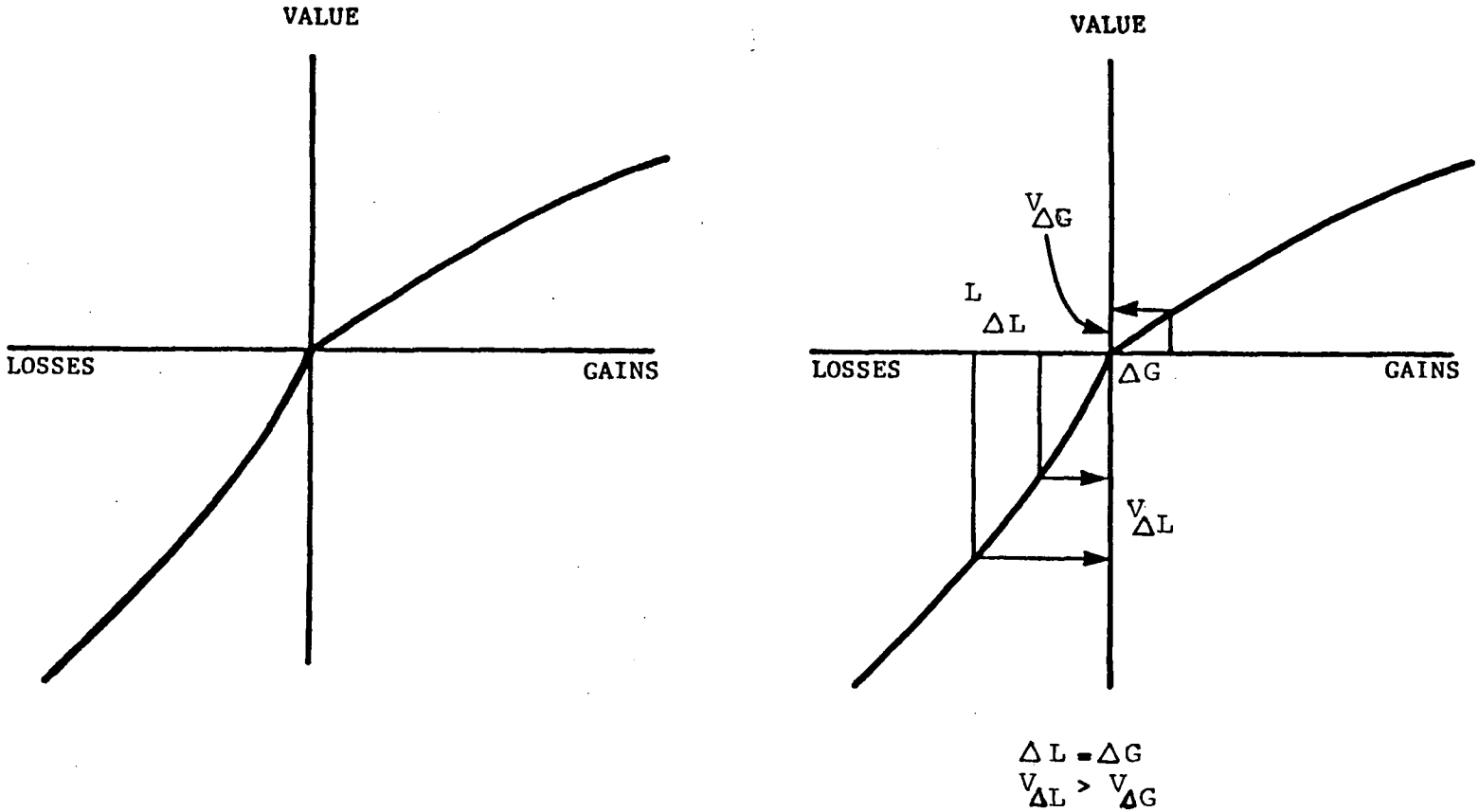


Figure 3.3: (a) Value Curve According to the Prospect Theory; Source: Kahneman and Tversky, 1979.
(b) The Value of a Loss Reduction Exceeds an Equal Gain.

and compensation demanded (loss) value (CD) has been theoretically and empirically validated for numerous goods, including environmental quality (Kahnemann and Tversky, 1979, Thaler, 1980, Gregory, 1982, Knetsch, 1983, Knetsch and Sinden, 1984, Brookshire et al. 1980). The results show compensation demanded value for a loss to equal 2 to 15 times the WTP value (Knetsch, 1983).

The prospect theory of Kahnemann and Tversky (1979) thus refutes the value symmetry of gains and losses and thereby provides a simple and empirically validated guideline for selecting the most effective acceptance approach. If we assume all facility impacts (losses) and benefits (gains) to be contained in the one dimension on the horizontal axis and, further, that the reference point is the condition in the host-community without the facility, then the following reasoning holds true as illustrated in Figure 3.3b.

If siting a waste facility imposes a loss of L on a typical host-community resident, then the reduction of that loss by L will result in the reduction of the value loss by $V_{\Delta L}$. Because of the flatter slope of the value curve on the gains side, an equal sized gain of $\Delta G = \Delta L$ will only result in a value increase of $|V_{\Delta G}| < |V_{\Delta L}|$. Hence, in general, it will be more effective to reduce the losses to the host-community than to offer alternative benefits.

The conclusion holds true for a smooth curve of generally concave shape for the gains and convex shape for the losses. However, two situations constrain the general conclusion:

a) Large losses (at the extreme left of the loss curve) may decline in marginal value to the point where the marginal

value of a small gain increment (from zero, the reference point) exceeds that of an equal marginal loss reduction, that is, the steepest slope of the gain curve near the reference point exceeds that of the loss-value curve (or $V_{\Delta G}/G > V_{\Delta L}/L$). To the left, beyond this (very) large loss, adding gains will be more effective, but only back to the point where $V_{\Delta L}/L = V_{\Delta G}/G$. To the right of this point the losses are still more effectively addressed by reduction.

b) Thresholds at critical points in the curve or lumpiness in the size of loss or gain increments may locally reverse the relation of curve slopes to produce convex regions in the gain regions and concave areas in the loss region (Kahneman and Tversky, 1979) to form "toes" and "shoulders" in the curve. For example, if the facility impact becomes intolerable and forces residents to give up their homes and move to an otherwise less desirable community, then the loss curve near the critical impact (giving up one's home) is likely to be very steep. Conversely, specific thresholds on the gain value curve can generate locally steep slopes, e.g., the value to a presently unemployed person of getting a job at the facility.

Applied to the choice of acceptance measures, the prospect theory indicates that a reduction of the losses caused by the facility is more effective in restoring the host-community residents to their original reference point than is an equal increase in gains through additional benefits.

Reference Point

The reference point for host-community residents is likely to be the condition of the host-community without the facility. Although the reference point on each impact dimension is conceptually easily defined by the state of the host-community without the facility, the reference condition may be very difficult to accurately describe or objectively measure (e.g., the image of a community). Moreover, the standing on different dimensions may differ. To avoid disconcerting effects, people tend to select from among many the most favorable dimension as the measure to compare themselves with peers at similar socio-economic status levels (Brickman and Campbell, 1971). For example, recent changes in the community, in the comparative condition of other communities in the area or the past experience of living in other neighborhoods, may influence residents' reference points. If recent (possibly unrelated) changes occurred in the host-community (new development, sudden unemployment due to plant closures), residents may not have adapted to the new situation. The reference point may therefore be the original condition before the changes. Other communities may appear better off. The host-community reference point may be pegged above the actual status quo or vice-versa. Finally, recent experience of living in other communities may influence newly arrived residents' reference point. The latter influence is likely to be small for those communities where most residents have lived there for over 5 years. Therefore, in most stable communities, the reference point is most likely to be the condition in the host-community without

the facility, but this condition must be verified for each host community.

Finally, the reference point for evaluating change is likely to be at a high initial level within a range of similar communities, i.e., other rural communities on the urban fringe. This reference point is an important condition, because people show a very strong desire to break even, i.e., return to the reference point after taking an initial loss. Thaler and Johnson (1986) document increased risk seeking behavior following a loss in order to regain the original reference point. This finding supports the derived acceptance rule (net impacts must equal zero) because it shows the importance of achieving zero net loss, that is, a break-even, by returning the host-community to its original reference point.

3.2.2 Change Values for Different Impact Dimensions

Waste facilities affect host-comunities on many dimensions. Yet evidence suggests that people categorize their gains and losses into accounts (Kahneman and Tversky, 1984; Thaler, 1985) and keep separate account balances (e.g., for "food", "car", or possibly "environmental quality"). This compartmentalized accounting system inhibits the exchange of gains and losses between accounts (dimensions). People exhibit this behavior even in cases where gains and losses in different accounts are measured on commensurate scales (such as dollars, see Thaler, 1985).

The measurement and valuation of many different and often intangible impacts is, however, difficult and expensive (if

possible at all) because of the numerous biases and problems with contingent valuation in money (Bishop and Heberlein, 1979, Schulze et al. 1981, Gregory, 1982, Freeman, 1979, Sinden and Worrell, 1979). The difficulties involving intangible costs of waste facilities are documented in Schmalensee et al. (1975) and Zeiss, (1984a). In addition to the complexities of physical emission and impact prediction and measurement, the analyst faces problems in establishing values for losses of intangible, non-market environment "goods", e.g. risk, odor, view, image impacts. In addition to exhibiting unintentional (cognitive) and strategic biases (Gregory, 1982), respondents are uncertain and reluctant to place dollar values on environmental quality. As a result, equivalent trades of gains on one dimension for losses on another are very difficult to identify or carry out. This lack of certainty in valuing impacts furthermore results in residents' reluctance to accept alternative benefits as compensation for losses.

3.2.3 In-Kind Impact Reduction as a Priority for Facility Acceptance

The reduction of each impact on its own dimension, that is "in kind", is the only inherently acceptable approach to meeting the acceptance criterion, because loss reductions increase the net value of a change more effectively than equal gains. In addition, in-kind reduction avoids awkward exchanges of intangibles between residents' intuitive accounts of different environmental quality indicators (say, e.g., noise vs. air emissions vs. community image). In-kind reduction is furthermore superior in fairness,

because it most effectively reduces impacts by shifting the costs of achieving impact reduction to the facility beneficiaries. In-kind reduction minimizes the change-resistance by minimizing effort for evaluating and coping with changes caused by facility impacts. Finally, the practical difficulties in establishing values for intangible facility impacts can be avoided through using market price values for impact reduction methods. Thus, impact reduction is a more predictable and more effective approach than compensation through alternative goods to meeting the acceptance criterion.

3.3 Priorities for Facility Impact Reduction Methods

In order to more finely differentiate operational methods of reducing impacts, four categories are defined in the context of the waste disposal system (see Figure 3.4):

- Prevention is defined as a measure that reduces the cause of impacts prior to the emission source, i.e., before the siting process begins or before the waste stream reaches the facility.
- Control measures focus on impact reduction within the subsystem boundary of the waste facility or during the siting process.
- Mitigation comprises all measures to reduce impacts downstream from the facility and after the facility is built. Basically this category includes measures outside the compliance boundary, i.e., those which reduce impacts at the receptor rather than at the source.
- Compensation measures are alternative benefits that are

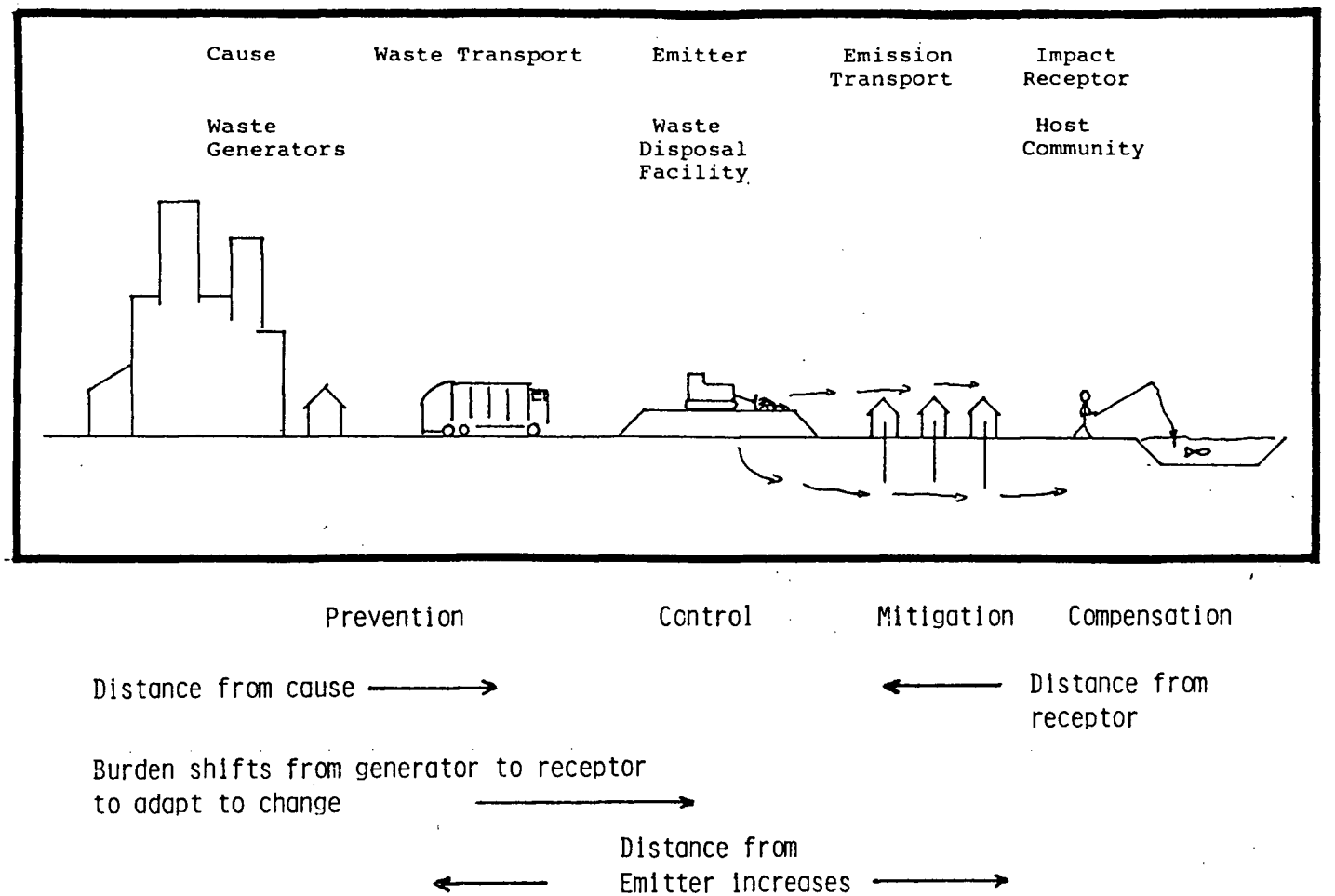


Figure 3.4 - Waste Disposal System and Impact Reduction Methods

offered instead of impact reduction. Compensation can be in-kind, e.g., as the provision of an alternate water source for contaminated ground-water, or as an alternate good, e.g., as a different intangible good or as money. The distinction between mitigation and in-kind compensation lies in the distinction between the reduction of the specific impact as opposed to the replacement of the lost good by another good, albeit of the same type.

Although these four concepts are intuitive, the definition of the underlying dimension, or axis, is not. Thus, the following explanation of the differences between the methods will result in a meaningful definition of the dimension as a priority for selecting impact reduction measures.

Intuitively, prevention is superior to control, because prevention reduces the cause outside the boundaries of the host community, whereas control and mitigation limit the effects in the host community. In the context of the waste disposal system, prevention affects the system closer to the cause, i.e. the waste generators, and prior to the arrival of the waste stream or prior to construction of the facility in the host community. From the host community's perspective, the "distance" from the cause to the impact reduction effect increases (inversely to the distance from the community) in the sequence of prevention, control, mitigation and compensation.

On a more abstract level, this sequence of measures follows a simple cause-effect sequence of the cause, "waste," being brought to the facility (that is into the community), where it generates

"contaminants" that then "pollute" the water, soil and air and result in "disease" in the community. This causative sequence follows the rationale for social impacts of waste facilities (see Chapter 2).

There is a further difference between the methods on the time dimension. Prevention implies that impacts are reduced by earlier intervention, control indicates immediate intervention, while mitigation occurs after damage has occurred.

Finally, with increasing distance and time lag between the cause and the efforts to reduce impacts, the gap increases between the waste generators as beneficiaries and the impacted residents as receptors of (intangible) costs. Thus, the distribution of benefits and costs becomes more unfair and the responsibility to deal with the problem moves further away from the source and closer to the receptor, the host community.

In summary, the sequence of prevention, control, mitigation and compensation methods reflects an increasing physical distance between cause and effect, increasing progression on the cause-effect chain, increasing time lag and increasing unfairness and shift of responsibility to the host community. Thus, the burden to the receiving host community of adapting to change increases in the sequence of prevention, control, mitigation, compensation. Thus, if the cause of and responsibility for waste facility impacts is seen to originate in the waste generating urban area, then it is predicted that facility acceptance will be enhanced according to this sequence of methods:

1. Prevention

2. Control

3. Mitigation

4. Compensation

In contrast, if concerns about impacts are focussed on the waste facility as the cause or source, then the following sequence would be most effective for acceptance:

1. Control

2./3. Prevention/Mitigation

4. Compensation

Finally, the objective impact reduction effects or the additional costs may determine the choice of methods.

In summary, the basic approach to facility acceptance is through impact reduction rather than compensation. This section defines prevention, control, mitigation and compensation as methods of reducing facility impacts. These methods differ in distance, time, gap between cause and effect, and degree of waste generator responsibility and effort for reducing facility impacts. These dimensions could center on the urban waste generating center or on the waste facility as the cause. Finally, objective impact reduction effectiveness and/or costs could determine the effectiveness of these methods to enhance facility acceptance.

3.3.1 Framing the Siting Process for Acceptance

This section deals with the process of introducing change in the host-community through the facility siting. The issues of whether to combine losses and gains, and how to schedule actions to address the losses are derived from theories on adapting to change (Helson, 1964) and on accepting losses (Kubler-Ross, 1969).

Dimensioning the Rate and Size of Change

Assuming that the waste facility causes a loss to the host community, the question arises of how to stage the change to permit adaptation rather than opposition. The Adaptation Level (AL) theory (Helson, 1964) offers three guidelines for planning change (Brickman and Campbell, 1971):

1. the subjective experience is a function of the difference between past and present levels, i.e., not of the end result;
2. the affective value of the change is reduced if the transition is gradual rather than sudden;
3. the subjective experience of change is reduced through habituation, i.e., through getting used to the changed situation.

The first rule is virtually synonymous with the prospect theory, because the latter was based on AL theory. But AL theory makes statements about the rate of change and its influence on affective value. Hence, both size and the rate of changes resulting from facility siting affect the residents' response. Given that the siting process and the construction of a waste facility are episodic events for a stable rural community, the size of the initial change increment is best minimized, as previously concluded. Furthermore, a gradual implementation of the facility will reduce the negative value. Change strategies in urban planning by Lynch (1972) suggest continuous change at an appropriate rate with clear, understandable but moderate increments to render change acceptable to the residents. Coote (1985) stipulates that, in order to maintain neighborhood

stability, changes must be within the range of residents' adaptation as determined by the extent of their psychological and physical capability to adjust. This is equivalent to the tolerance level in the impact model. Thus, the host community's tolerance for change determines what is acceptable and must not be exceeded (Coote, 1985, Lynch, 1972). As a result of this analysis, the losses and gains associated with the facility can conceivably either be separated into multiple smaller losses throughout the siting process, or integrated into a single siting package.

The prospect theory and empirical research (Thaler, 1985 and 1986) show, however, that single large losses are evaluated more favorably than in sum equal, but separate smaller ones. Although the combination of losses into one package may contradict the principle of gradual transition, it has been empirically shown to be an optimal approach for managing single event changes (Thaler and Johnson, 1986). The apparent contradiction requires further discussion.

The optimal treatment of gains is indeterminate unless the size of the loss and, hence, the slope of the value curve are known. It is assumed that waste facility impacts are closer to the reference point than the point where the slope of the loss curve is smaller than that of the gain curve because the benefits (gains) from the facility are relatively small and unimportant. Under these conditions, the optimal strategy consists of integrating gains with losses (Thaler and Johnson, 1986) on similar dimensions.

The overall strategy must attempt to reduce the net impact in kind below the tolerance level for change in a stable host-community. The facility impacts and gains are best combined to minimize the value of the loss. If possible, the resulting changes should be phased in small increments, without, however, causing them to be cognitively separated into multiple losses.

If the losses cannot be reduced to tolerable levels through impact reduction and advantageous framing of losses, then the siting process may be managed to allow easier acceptance.

3.3.2 Managing the Change Adaptation Process

If after reduction efforts, residual losses cannot be avoided, then the stress response can be anticipated and reduced through proper siting process management. Thus, stress management can be used as a siting measure to aid the acceptance process among residents. The stress response and coping mechanisms are reviewed here to derive guidelines for the siting process.

The announcement of a change sets off a process among affected persons of (1) appraising the change for its impact on the individual, and (2) evaluating the options for adapting and coping. If the available coping measures are inadequate to reduce the impacts below the tolerance level, stress results. Stress reflects the physiological, emotional, cognitive and behavioral effort required to reduce or minimize the impact and to cope with the change (Fleming, 1985). The physiological response to the stressor consists of arousal of the nervous system, with subsequent increase of the heart rate and blood pressure,

increased intensity, and decreased reaction time. These symptoms represent typical "fight or flight" reactions that lead to resistance or to avoidance of the waste facility as the stressor.

Following the resistance, a phase of coping and adaptation occurs, which, if prolonged, leads to exhaustion among the stresses (Fleming, 1985).

A similar and seminal description of the loss acceptance process is given by Kubler-Ross (1969). Her description consists of 5 steps for the acceptance of death as the ultimate loss:

1. Disbelief
2. Anger
3. Bargaining to avoid the loss
4. Depression
5. Acceptance.

These stages are applicable for coping with less serious losses (Beattie, 1987). Disbelief, anger and bargaining are readily expressed at public meetings on facility siting, whereas depression and acceptance are mentioned as latter stages in Fleming (1985) and Madisso (1985). However, the grieving process is a plausible route for residents who still experience a loss caused by the facility.

It is important to note that only the directly affected persons must make the emotional and physical effort to deal with the stress of loss acceptance. Decision makers in local government and environmental regulatory bodies, who may act as agents for the host-community with the community's best interests in mind, are, however, not required to deal with the same personal loss-acceptance effort. This difference in perspectives may be the cause for the smaller discrepancy in values for gains and

losses among decision makers acting as agents for others (Marshall et al. 1986). This causes agents, i.e., local government and environmental agency officials, to set different priorities for impact reduction and compensation, because losses to agents do not loom as strongly negative as they do for personally affected residents.

The facility siting process can theoretically enhance or expedite acceptance by either identifying coping mechanisms or by facilitating the loss acceptance process. Fleming (1985) tested the effectiveness of four types of support on coping with stress from exposure to toxic waste spills and facilities:

- Appraisal support provides information about the threat or impact. Appraisal is effective in reducing stress <u>only</u> if it reduces the perceived risk or provides positive information about effective coping mechanisms. Appraisal support is not effective if the stressor is socially unacceptable or stigmatised. As a result, appraisal support is not likely to be very effective in dealing with waste facility impacts because of the inherent stigma of "waste" and "pollution" (see Chapter 2).
- Emotional and esteem support enhance self-confidence and control over the environment. Social support from other similar people buffers psychological stress symptoms, but not physiological and somatic measures. Furthermore, acknowledgement of risks or impacts by environmental professionals is shown to alleviate resident stress. Thus, emotional and social support through enhancing the

feeling of control are effective only if the stressor can be changed as a function of the control. But emotional support can help the psychological coping process and, hence, may be effective where physical impacts are minor, but non-physical impacts are significant.

- Tangible support through extra services and materials (e.g., emergency response or health care services) may generate emotional support as well as reducing tangible impacts.

Through using appraisal support to reduce uncertainty and offer coping mechanisms and by providing readily apparent tangible support and control to change the stressor and to simultaneously generate emotional support, stress from coping can likely be reduced. The key factor in providing support consists of fitting the type of support to the concerns and needs of the stressee.

In summary, the facility siting agency can reduce stress by assisting residents in the acceptance process:

- The siting agency and its professional consultant must acknowledge and validate the concerns of the residents because such acknowledgment in itself has been shown to reduce stress levels in exposed residents.
- The siting process must be designed to allow time and possibility for residents to experience and express the concerns in the five steps of acceptance. Disbelief and anger are integral phases of the process and are best calmly acknowledged and accommodated by the siting agency. However, demonstrating honest sympathy and concern through

tangible support and coping methods are likely to ease the mood on to bargaining. The bargaining stage can be used advantageously for negotiation of siting and monitoring agreements, methods to address impacts, etc. and to simultaneously grant some control to the host community. Depression may be addressed by showing positive psychological coping methods and enhancing community control in order to reach the final stage of acceptance.

- The combination of control by the residents' with clear and visible tangible support to address residents concerns are key factors throughout the siting process and may have to be extended to the operational phase of the facility.

The acceptance of facility impacts as losses to a host community resembles a grieving process and is accompanied by physiological and psychological stress. Stress levels can be reduced by acknowledging and addressing residents' concerns through emotional, social, appraisal and tangible support combined with a degree of resident control.

3.4 Compensation For Negative Impacts of Waste Disposal Facilities

This section reviews the intent of compensation for negative externalities and the legal principles and limitations reflected in the judicial decision-making. The findings are compared with administrative and legislated compensation mechanisms.

The implicit assignment of entitlements to property rights is derived from this review and compared with the normative goals

of just compensation. The implications for waste facility siting are inferred from the comparison of the practice with the intended function of compensation.

3.4.1 Normative Goals and Principles

The goal of just compensation is to restore those persons affected by externalities to their original level of well-being. Thus, compensation can also be a remedy for inequities arising from the distribution of the benefits and losses from the project, if the "demoralization" caused by the unfairness is recognized as a loss (Michelman, 1967). Compensation therefore serves to ensure the project's efficiency in terms of its potential Pareto optimality, and its fairness in terms of distributing the costs and benefits proportionately to the gainers and losers. But Michelman (1967) points out that efficiency and fairness need not be opposing goals if the political impacts (change resistance), reflected as demoralization costs due to allocation of the project's costs and benefits, are considered as true social costs (see also O'Hare, 1983 and Williamson, 1970). In other words, if the losses are perceived as having been imposed systematically and strategically, then the overall costs to the losers will rise due to this fact. These additional demoralization costs will contribute to the total costs and thereby decrease the net benefits of the project. Conversely, if fairness were served, then the overall efficiency would increase proportionately. This is identical to the rationale for change resistance in the first section of this chapter.

The actual payment of compensation is noted as having an

exacting influence on the choice of "efficient" projects, because compensation provides an incentive for administering agencies to make more efficient decisions (Cordes and Weisbrod, 1979). Thus, compensation may be required as a vehicle to restore equity, but it can also contribute to the efficiency of decision-making (O'Hare, 1983).

3.4.2 Entitlements and Their Effects on Efficiency and Fairness

Legal entitlements constitute the criteria for judgments on who shall prevail in conflicts regarding property rights and torts (Calabresi and Melamed, 1972). Although Coase (1960) showed that the assignment of entitlements does not affect an efficient outcome when transaction costs are neglected, Kennedy (1981) argues that the original entitlements may pre-determine the outcome of cost-benefit studies when wealth effects and transaction costs are accounted for.

Calabresi and Melamed (1972) give a unified perspective on the achievable outcomes from different original entitlement positions and rules for protection. The efficiency issue focuses on assigning entitlements so that the outcome with the highest value will be favored, e.g., the more valuable land-use will prevail or the lowest pollution control costs will be incurred to achieve a reduction of external effects. The fairness aspect concerns the distribution of the costs to achieve the most beneficial solution.

In the case of a waste facility as an external impact generator, and a group of affected residents as the receptors, the entitlement could be set to allow the free generation of external

impacts, or, conversely, to grant the residents freedom from all side-effects. A partial or total exchange of these basic rights is allowed and the parties can bargain and negotiate for these rights. While the original entitlement determines which party can set the terms for an exchange, the protection of the entitlement can occur through three rules:

- the inalienability rule does not allow any exchange;
- the property rule absolutely guarantees the right to the owner unless he or she willingly sells it at a subjectively sufficient price;
- the liability rule allows the taking of the rights for a public utility with sufficient merit to avoid injunction but permits the taking only with proper compensation for the loss.

Although some side-effects may infringe upon inalienable rights, (e.g. carcinogenic emissions), it is assumed for this thesis that both facility proponent and affected residents are free to transfer their rights. Combining the possibilities for original assignments and property and liability protection rules, the following matrix is obtained (Calabresi and Melamed, 1972):

	Entitlement	
	to Facility Proponent	Residents
Property Rule - injunction	I	II
Liability Rule - compensation	IV	III

Table 3.1: Entitlement/Property Rule Matrix

I - the waste facility is entitled to pollute, and can be deterred only by full payment by the residents of the costs to stop;

II - Residents are entitled to freedom from pollution, and can be enticed by the waste facility to put up with pollution only at the full compensation demanded value;

III- Residents are entitled to limited freedom from pollution, but damages are to be paid by the waste facility;

IV - the waste facility is entitled to emit limited amounts of pollution, and the costs of further emission reduction are paid by the residents.

Efficiency requires that the more valuable use prevails, or the liability be placed on the party best able to avoid or mitigate the conflict at least cost. If this party cannot be identified, then the liability should be placed on the party best able to induce a change and achieve a correct assignment with the lowest transaction costs (Knetsch, 1983). However, multiple parties, such as the residents, create special problems for the transaction process, because strategic incentives make the determination of the true value to the entire group difficult. In this situation, the original entitlement is likely to be the final assignment (Knetsch, 1983), because high transaction costs may prevent the transactions necessary to reach the most efficient state.

Because of the difficulty in objectively determining the value of the environment to conflicting uses, no definite criterion exists to determine where the entitlement should be placed for an efficient and fair outcome. Moreover, leaving the

question of entitlement undetermined results in lower predictability for both facility proponent and host community. Lower predictability increases uncertainty, which is itself a cost. Without some specific measure to compare the value of land uses, the conflict cannot be decided by a consistent and rational rule. The disparity between the loss value (compensation demanded) and the gain value (willingness to pay) only exacerbates the problems of establishing values for the impacts and the resulting losses as siting criteria.

Unfortunately, recent articles do not provide a decision rule to determine the correct entitlement or protection rule to choose. Although it is reasoned that liability rules are superior to strict property rules because they allow some flexibility in allowing noxious uses where acceptable by requiring compensation, this rule will not provide the correct measure for siting and operating waste facilities, unless impact and impact reduction costs can be identified and compared. In conclusion, the choice of entitlement and protection rule is indeterminate without specific values.

3.4.3 Compensation Principles and Practice

Legal Principles, Defenses and Precedents

External impacts from waste disposal facilities fall under two basic categories of law, statutory and tort law, the latter being part of the unwritten common law. Statutory laws may be simply regulatory in that they are adopted to control those responsible for causing emissions, waste pollution and noise

levels; or they may expand private rights by widening the scope of tort law. Recently, regulatory statutes have been extended in the U.S. to cover contamination of soil and groundwater from waste disposal sites (CERCLA, 1980). Torts (civil wrongs other than breach of contract) cover the duties owed to persons in general. The three areas of tort law applied most often to the impacts of waste disposal facilities are negligence, nuisance (injurious affection) and strict liability. These are all unintentional interferences. An action in trespass (intentional interference) is seldom used (Congressional Research Service, 1980).

Since the following summary focuses on North American conditions, examples from Canada and the U.S. are used. Where important, differences in U.S. and Canadian law are identified.

Tort law addresses the allocation of losses caused by the clashes of incompatible human activities. Its goal is therefore to compensate for losses which have already occurred. Moreover, tort law does not provide perfect compensation for all losses, because the shifting of a loss is only considered justifiable when there is a special reason for the defendant to bear the loss rather than the plaintiff (Holmes, 1881, in Fleming, 1977). Thus, the protection against unintended harm is less complete than against intentional interference, because the defendant's freedom of action sometimes constitutes a valid interest which offsets the obligation to pay for the loss. Thus it is indicative of this consideration that the use of strict liability gave way to liability of negligence due to some provable fault in the 19th century and coincided with the industrial revolution to permit

free enterprise.

1. Strict Liability

Strict liability addresses the consequences of activities which are considered risky no matter how carefully they are carried out. Thus, the element of "fault" is not essential, but merely the harmful event itself. Strict liability allows beneficial, but dangerous activities to proceed if they can pay their way. Fleming (1977) cites nuclear power stations as examples of activities which may fall under strict liability.

The principle of strict liability is laid down in Rylands vs. Fletcher by Mr. Justice Blackburn (1866) as "a person who for his own purposes brings on his lands and collects and keeps there anything likely to do mischief if it escapes, must keep it at his own peril, and, if he does not do so, is prima facie answerable for all damage which is the natural consequence or its escape." More recently, however, the qualifier of the defendant as a "non-natural" user of the land must be proven by the plaintiff in order for strict liability to apply. Thus, the special nature of the land-use in the context of the community and its surroundings is considered too. The simple presence of a dangerous substance alone does not necessarily qualify; there also has to be a proven escape of the substance from the land under control of the defendant to a place outside his occupation. Finally, some U.S. states have restricted strict liability to the activities of land owners and have thereby excluded the waste generators, dischargers and transporters of wastes from strict liability.

The defences to strict liability are the following:

1. consent of the plaintiff
2. default of the plaintiff
3. Acts of God
4. acts of strangers which could not be anticipated
5. statutory authority

The statutory authority defence eliminates actions against government agencies, but only if the agency observes the strictest safety standards, proportioned to the highest degree of risk, with regard to the construction, management and possible improvement of the plant, and avails itself of all accessible scientific aid. The statutory authority must be specific to the task. In Gertsen vs. Metro Toronto (1973), strict liability action against a landfill was allowed by Canadian law, because the landfill operation was not covered by a specific bylaw and the landfill from which methane gas escaped was deemed a non-natural user in a residential area. Had Metro Toronto passed a specific bylaw, then the strict liability rule could have been avoided.

2. Negligence

Negligence is a common reason for seeking an award of damages for accidental losses. This concept is based on a standard of normal or acceptable conduct in a given community. The "fault" consists of a breach of this standard duty of care in the way the activity in question is carried out. Specifically, there are five elements in such a cause of action:

1. a duty to protect others against unreasonable risks;
2. a failure to conform to the duty of care;

3. a material damage to the interests of the plaintiff;
4. a reasonable proximate connection between the defendant's conduct and the injury;
5. the absence of contributory conduct by any injured party and of any voluntary assumption of risk.

Although the victims of injuries from hazardous substances are basically protected by the law of negligence (e.g., Gertsen vs. Metro Toronto), the burden of proof is on the plaintiff. If the waste discharger does not violate a specific statutory rule, the plaintiff must prove the following points:

1. an act of pollution has occurred, the likely route of transport, a detailed chain of circumstances, and the detection of the specific pollutant;
2. the act proximately caused an injury; this is especially difficult in cases of long latency periods, where the medical and scientific knowledge is incomplete (Jasonoff, 1983, Congressional Research Service, 1980); mental distress is more difficult to establish than physical harm, except when a person's presence in an area of physical risk has caused nervous shock (Fleming, 1977).

The burden of proof of a cause-effect linkage has proven very difficult to establish for many contaminants (Jasonoff, 1983). Claims have good chances if the following conditions apply:

- the damages are a result of discrete exposure to an identifiable hazard,
- the damages and routes of exposure are well documented,
- the incident is local in nature,

- the number of culpable parties is small.

The remoteness of damage rule limits the recognition of poorly understood transport mechanisms and contaminants. Thus, many risks and uncertainties are not protected by an entitlement to the residents.

With the advent of specific statutory legislation on the management of hazardous waste (RCRA, 1976, Superfund-CERCLA legislation, 1980) in the U.S. the States undertake the research and prosecution of dischargers. Once sentenced under these statutory laws, violators become liable under negligence to the victims. Moreover, the scientific evidence is available to the public.

3. Nuisance and Injurious Affection

Public nuisance is an unreasonable interference with a common right of the general public, while private nuisance affects the enjoyment or use of private interests in property. Both look to the harmful result of activities rather than the cause or fault.

The harm to private interest in land by the impacts of public services provided under statutory powers constitutes injurious affection if it meets four criteria (Todd, 1976):

1. the damage must result from activities rendered lawful by the statutory powers;
2. the damage must be actionable under common law;
3. the damage must be an injury to the land and not to business or trade;
4. the damage must stem from the construction of the project, not from its use.

Criteria 1,3, and 4 are only of passing interest here, because rule one is usually fulfilled; rule three is usually not of interest, but it makes the compensation smaller than possible damage by excluding damage to busines; rule four has been overturned by recent decisions to allow "injurious affection" to arise from the actual operation and not only from the construction of facilities (Todd, 1976).

The second rule, the actionable rule, is crucial because it subjects the claims against public works to the same rules used to judge nuisance from private sources. For private nuisances, the most important requirement is that the plaintiff's injury differ not only in degree, but in kind from that shared by the public at large (Fleming, 1977, Todd, 1976). Moreover, the particular or special loss must be shown to have been caused by the activity. The intent of this rule is to limit the claims to those which are proper and reasonable.

To be compensable, the damage must be unreasonable, i.e., the balance between the utility of the noxious activity and the gravity of harm imposed on others must be severely threatened in view of the duration and the severity of the nuisance. The effects can include physical discomfort and inconvenience, actual damage to property and health. The character of the neighborhood has a strong bearing on the standard of comfort the plaintiff is entitled to. Grossly dissimilar land-uses are more likely to cause actionable nuisances. But in general, even a great public benefit does not eliminate the proponent's responsibility to adjust the side-effects to the neighborhood. However, for a

nuisance to exist, there must be both a generator and a recipient.

Although Todd (1976) argues for a more extensive liability of the public works over private enterprise, because it is desirable that the public bear the full burden of public works, the actionable rule places on the same level the nuisances generated by publicly and privately owned sources.

The following examples distinguish the actionable nuisances from the "normally" acceptable side-effects (Fleming, 1977):

Actionable Nuisances	Tolerable Effects
noxious fumes from alkali works	occasional whiff of unpleasant smoke from a household incinerator or domestic chimney
noise from circular saws, a speedway track, or jet engines	sounds from a nursery, music room or a residence used by students in a proper manner

Examples of injurious affection include the changing of street grades, traffic flow direction, and the location of public works such as schools, hospitals, sewage lagoons, and airports (Todd, 1976). In the U.S. private nuisance action was successful against most common forms of air, water, solid waste, noise and sight pollution from powder mills, factories, or stables in residential areas. These same uses are perfectly permissible elsewhere (Hirsch, 1977). In Canadian law, impacts from waste disposal facilities are actionable under nuisance law (Gertsen vs. Metro Toronto, 1973, Plater vs. Collingwood Town, 1968, etc.).

Caveat to Injurious Affection: "Coming to the Nuisance"

In the context of the siting scenario for waste disposal

facilities, a limitation is placed on the judicial award of remedy for an established nuisance by the "coming to the nuisance" doctrine. This rule is intended to prevent those who willingly place themselves in a situation whereby they suffer injuries from recovering full damages from the nuisance generator (Hirsch, 1977). But in order to discourage inefficient "first come - first serve" land-uses, a party coming to the nuisance should and under circumstances can prevail (Spur vs. Webb, 1972), e.g., by having the nuisance removed, but at cost to the newly arrived land user. However, U.S. U.K. and Canadian practice differs on this issue, in that the U.S. allows most protection to the new owner, U.K. law allows none, and Canadian law allows some.

This doctrine applies to the newcomers who move into the affected area after the facility is operating. Although they are subject to the same physical effects, their claims may be mitigated by the fact that they knowingly and willingly moved to the nuisance. However, if the residential land use is more valuable, then they may be protected by a liability rule, but may be required to pay compensation for restrictions imposed on the noxious use (see e.g., Spur vs. Webb, in Knetsch, 1983).

Legal Valuation of Damages and Compensation

Traditionally, there is a bias toward compensating property losses only. Personal injuries are more difficult to recover, while economic losses are usually not compensable, especially if they are the only claim (Congressional Research Service, 1980). Many intangible losses are not compensable either (pollution of air, water, wildlife habitat, etc.). There must be a proven

physical cause-effect linkage (see above) even in the presence of acknowledged property value losses (Shuttleworth vs. Vancouver General Hospital, 1927).

Injurious affection damages are commonly measured in terms of the market value of the affected properties. The value may be established by an a priori assessment of the externalities (i.e., a direct measurement), or by market valuation before and after the imposition of the effects and thereby including any off-setting benefits from the project into the valuation (Todd, 1976). The latter method will be prone to some inaccuracies in trying to isolate the project's effects from general inflation and appreciation after the project implementation period (Knetsch, 1983). Both methods exclude any sentimental value, demoralization and moving costs. Therefore they tend to underestimate the true social losses.

In the more serious contamination liability cases, recent court decisions include compensation for "psychological distress" and "lifestyle impacts" due to groundwater contamination (Madisso, 1985). Thus, the judicial decisions seem to recognize the entitlement of the residential property owner to be free of nuisance and harm and recognize intangible losses and psychological distress.

Negotiated and Legislated Compensation

These forms of compensation are usually established prior to the operation of the waste facility. In contrast to the judicially determined monetary compensation, negotiated and administered compensation can take several forms (O'Hare, 1983,

Boyle, 1982):

1. Monetary compensation as property tax revenues, royalties, cost-plus tipping fees, gross receipts taxes, and special impact payments;
2. Mitigation measures, such as additional hazard protection e.g., in fire and police equipment and training;
3. Conditional guarantees, e.g., property value guarantees;
4. In-kind compensation, e.g., free disposal service, substitute land, parks etc.

These forms are usually tailored to meet specific, foreseeable impacts of construction and continued operation. They may also alleviate some of the general concerns.

Some of the examples of negotiated compensation are listed in Table 3.1. The resulting compensation agreements vary significantly. Because of the difficulty in finding a valid and acceptable formula for just compensation for hazardous waste sites, several U.S. states have legislated guidelines or mandatory formulas for the compensation for hosting a waste facility (McMahon, 1982, Carnes, 1982):

New Jersey- 5% of gross receipts to the facility to be used for hazard protection, roads inspection, monitoring, and extra insurance fees (NJ Hazardous Waste Siting Commission, 1983)

Connecticut- $0.05 per gallon of special waste plus 2.5% of gross receipts to the host-community for extra costs

Kentucky - 2% of gross receipts to the host-community

Table 3.2: Summary of Negotiated Compensation Cases

Facility	Cause	Compensation
Grayrocks Dam	loss of water for irrigation	-$7.5 million to replace water rights and establish new habitat
Skagit County Nuclear Power Plant	construction and environmental impacts	-public service costs -mitigation efforts -land use planning for transport impacts
Hartville, Tenn. Nuclear power plant	Health and medical services for more residents education overburden lack of housing	-resident employment -planning assistance -additional classrooms -financial assist. for sewer and water
Shopping Mall	property value losses environmental degradation	-5 year property value guarantee at pre-construction value -berms
MBG Incinerator	truck traffic noise air pollution (within legal limits) loss of quality of life change in community character stigma of being "region's dump site"	-$500,000 to $1 million in property taxes -$1/ton royalty

Here again the lack of a standard formula becomes apparent. Only the experience with the legislated compensation rules will show if the true costs are covered.

3.4.4 Summary - Legal and Negotiated Compensation

Legal practices recognize the right of the residents to a limited degree of freedom from noxious impacts. But even this right is not protected absolutely, i.e., through injunction, after a facility is operating. More frequently, affected residents are granted some compensation if their cause is found to be justified.

The legal process is unlikely to provide adequate compensation to the affected or potentially affected host-community residents because of the underlying intent of the tort laws and because of the legal process. As a result, compensation through legal channels may leave the residents with a net loss:

1. The harm or damage must occur first before any claim can be made. Thus, uncertainty and risks cannot be addressed. Residents are first required to adapt to changes that occur.
2. The burden of proof rests on the claimant. Since the transport paths and the effects of contaminants are not well known, the risks of losing the case are high and rest entirely with the harmed parties. This is particularly true where fault must be proven in addition to the cause of harm.
3. The financial costs for legal action are very high if expert witnesses must be called and extensive tests must

be done.

4. The legal principles of tort law incorporate some discounting of the claim by weighing the benefits to society with the losses to the host-community. These societal benefits may, however, not accrue to the host-community at all. Furthermore, nuisance law requires that plaintiffs suffer impacts that are "unreasonable" and "different in kind" from those suffered by others. This may further discount the measure of harm below a certain threshold determined by the court.
5. The method of valuation for damage used by the courts relies on property values, which may not reflect the true impacts at all in view of the inconsistent findings in property value impacts in Chapter 2. Business and intangible psychological stress losses are usually disregarded.
6. The compensation is awarded almost exclusively in money and does not replace the intangible losses commensurately (environmental quality, quality of life, etc.).

For these reasons court-decided compensation most likely does not adequately replace the value of total impacts of waste facilities. Therefore, the capability of court-decided compensation to achieve voluntary and a priori acceptance among host-community residents is inadequate.

Negotiated and legislated compensation are only partially based on rational formulas; often they result from negotiations

and political processes. The results may be satisfactory to address some specific foreseeable impacts, but they vary substantially and do not include other types of impacts.

Most negotiated solutions address the financial costs of additional infrastructure and services (emergency response and health monitoring). Thus, the losses are allowed to occur, but are reduced or minimized. Alternatively, monetary compensation is offered for the residual losses i.e., those which are below legal limits or cannot technically be reduced any farther, and for "social" losses.

The exception to this rule is the provision of in-kind substitutes, e.g., in the case of Gray Rocks dam (O'Hare, et al. 1983), by supplying money to establish alternative wildlife habitats and to replace water rights. Notably, the costs for this solution ($7.5 million) were half of the originally offered monetary compensation ($15 million).

The most significant conclusion is that both legal and negotiated compensation schemes do not adequately resolve the numerous losses to the host-community. In particular, many intangible losses are not compensated, because they cannot be valued commensurately by market pricing.

3.5 Summary and Conclusions

Facility acceptance in the host community is defined by the lack of significant opposition, in particular by the absence of major legal action and public opposition. The criterion for acceptance requires that the net impact of the facility not

exceed the community tolerance of change. In typical rural host communities, this tolerance is very low.

Since the negative value of losses exceeds the positive value of equal gains, impact reduction is predicted to be more effective than compensation in gaining acceptance. The most effective priority for impact reduction measures is expected to follow the sequence of prevention, control, mitigation, followed by compensation. This sequence follows the simple cause-effect connection. Hence prevention reduces losses closest to the perceived cause or source of the problem, viz, the urban center, while mitigation addresses the damage after it has occurred. Therefore it is predicted that prevention will be preferred despite better objective impact reduction through control. Finally, within the expected cost range (up to $25 per person per year), the costs are not likely to be considered a major factor.

The siting process optimally must integrate all losses and gains into one package, but gradually implement changes. Ideally, some gains (employment, taxes, park-buffer zone, etc.) should be in place before the impacts occur. The exact framing and timing of the gains and losses is important.

Unavoidable residual losses can be adapted to by the host community residents through a process involving denial, anger, bargaining and depression leading to acceptance. The stress of this process can be managed by providing support to the residents through control, tangible changes in response to concerns, successful coping strategies, etc. Thus, the loss adaptation can be better managed in the siting process.

The possibility of obtaining compensation through legal action is unlikely to have a significant positive effect on facility acceptance, because it addresses only damages, usually with money and can be obtained only when damages (losses) have occurred. The conditions for action, burden of proof and costs are often prohibitive for a successful action against waste facility impacts. Negotiated siting compensation usually addresses only safely quantifiable monetary costs of community infrustructure. Intangible impacts to individuals are usually not compensated.

CHAPTER 4 - WASTE FACILITY IMPACT ASSESSMENT

Typical waste disposal facility impacts are assessed to compare them with host community beliefs and attitudes in Chapter 5. The purpose of this chapter is to observe, measure and quantify the impacts of the two typical waste facilities on the surrounding communities. The chapter describes typical patterns and the spatial extent of the physical impacts. Physical impacts are presented by transport pathway and mechanism because one type of emission can cause more than one type of impact. View and noise impacts are described individually. Air emission impacts such as odors, health risks and air quality changes are covered in one section, while all water emission effects as health risks, water quality and wildlife habitat changes are contained in another. The last section summarizes the impacts in the description of waste facility footprints for landfill and incinerator individually.

4.1 Nuisances

4.1.1 Visual Impacts

Visual impact from a residence is defined here as any view that contains any object, activity, or emission associated with the waste facility.

Personal observation of views according to the scale in Table 4.1 follows Hatry's method (1977), previously used in Zeiss (1984a). The specific scales were developed to represent in ascending order increasing levels of view impact. The observer drove all main public roads within 3 km of the landfill and

Table 4.1 - View Rating List of Waste Facilities

Landfill

1 - View Impairment

2 - Birds, animals, dust

3 - Equipment and truck traffic

4 - Open garbage

5 - Leachate seeps, gas and fumes, gas burners

Incinerator

1 - Plume only

2 - Stack and Plume

3 - Building

4 - Trucks and Traffic

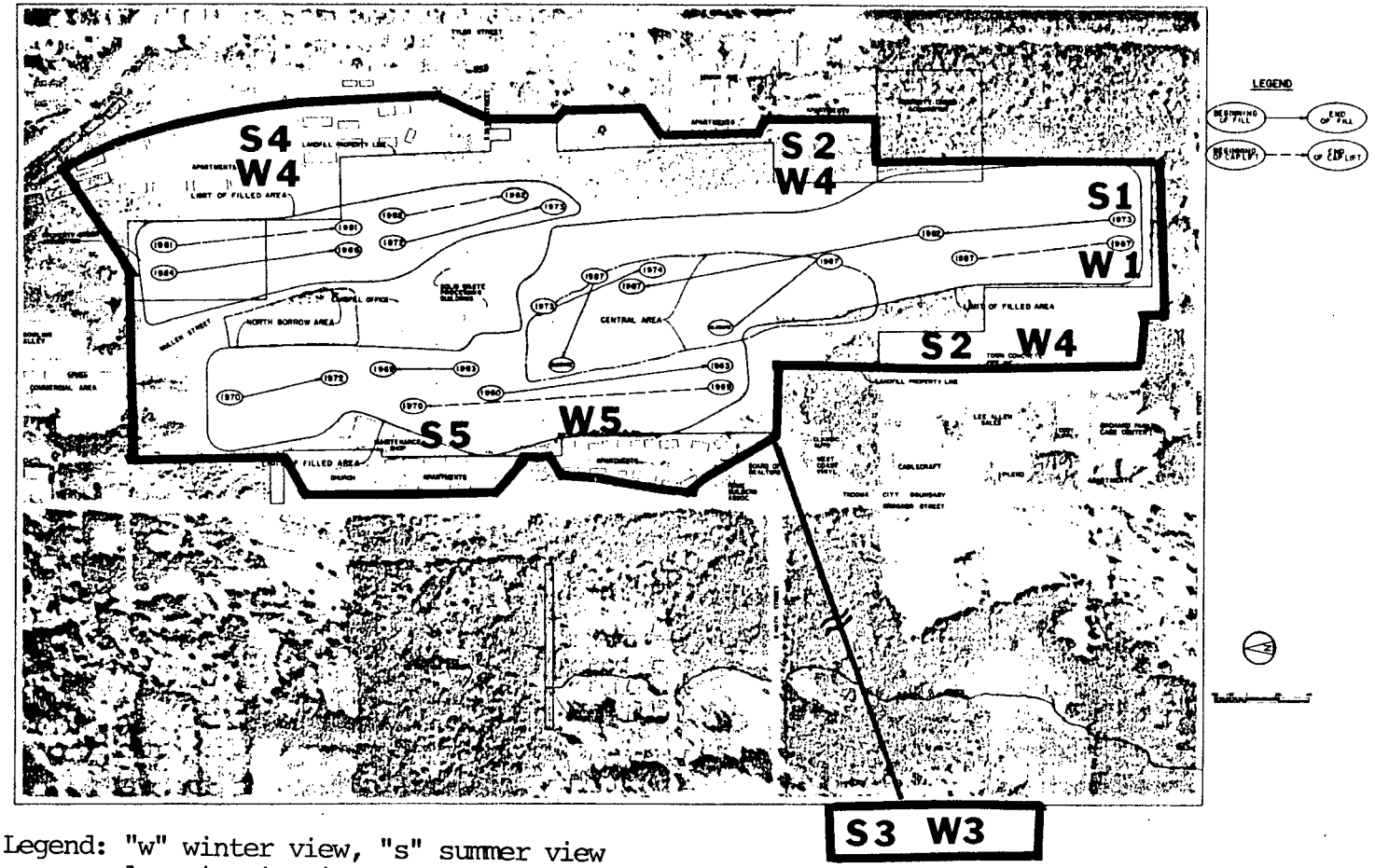
5 - Ash Handling/on site equipment

within 5 km of the incinerator and rated each vantage point by the scales (Table 4.1). Photographs were taken at most points to document the observations. The process was completed twice; the first time in the winter (January and February, 1987) for winter foliage and the second time in the summer (August, 1987) for summer foliage. Residences of attitude survey respondents and properties that were listed for sale between 1983 and 1987 were identified and rated individually.

The results are summarized in Figures 4.1 and 4.2 for the landfill and incinerator. Each observation point is marked with a rating; differences between summer and winter are indicated where necessary.

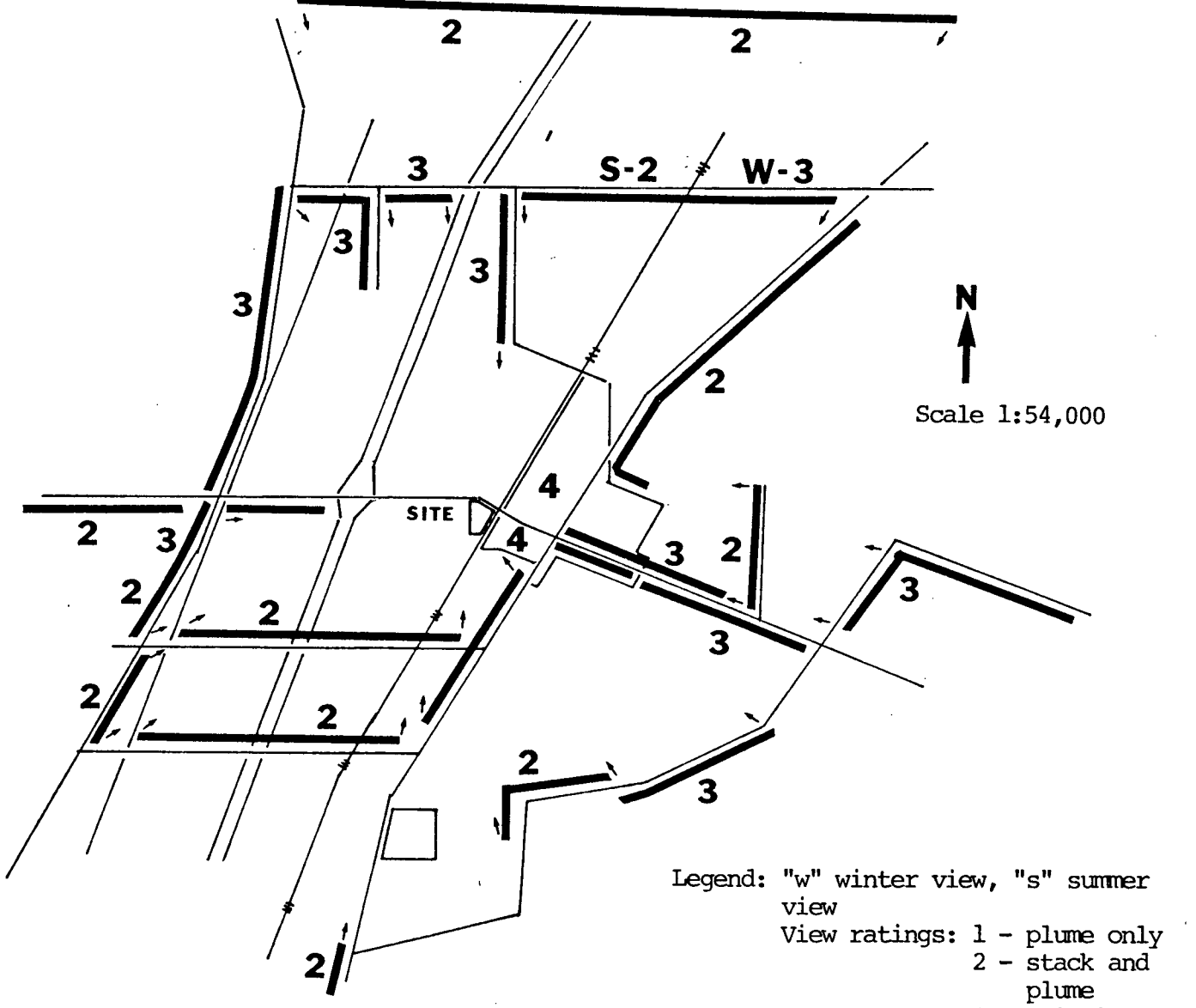
As intuitively expected, the view of the landfill is limited to a narrow strip of land next to the boundary, except for some elevated land on a ridge about 2 kms to the west. The landfill view is usually screened by trees, shrubs and the first row of buildings, except when the elevation of the filled area exceeds the screen height, e.g., for older landfills. Generally, the view includes objects that relate to "waste:" garbage trucks, birds, open garbage. Very few indicators of "pollution" could be seen, e.g., seeps of leachate were absent, but gas flares were apparent when the flames rose over the burner flashing, e.g., during low pressure periods.

At the garbage burner, the stack and plume are generally visible up to 5 kms from the site in all directions on the flat terrain. Within 3 kms, some trucks and the buildings are visible too (codes 3 and 4). Trees and houses cut the view of the



Legend: "w" winter view, "s" summer view
1 - view impairment, 2 - birds, dust, 3 - equipment and trucks, 4 - open garbage, 5 - leachate, gas fumes

Figure 4.1: Landfill View Impact Field



Legend: "w" winter view, "s" summer view
View ratings: 1 - plume only
2 - stack and plume
3 - building
4 - trucks and traffic
5 - ash handling on site

Figure 4.2: Incinerator View Impact Field

building for residents outside the immediate vicinity (about 300m), but the stack and plume remain visible over trees and buildings unless the viewer is very close to the screening objects. In particular, the incinerator view included large steam plumes from the stack (about 1 to 2 stacks lengths long) and from the cooling tower (about 1/2 to 1 stack length long) during low humidity and low temperature conditions, i.e., predominantly in winter and on cold mornings.

While landfill operations are screened by trees, berms or houses, the view of the incinerator stack and plume is only screened immediately behind objects (see Figure 4.A2 in Appendix). For a 10 m high tree, the tree must be under 200 m from the viewer at a distance of 2 km of the site to effectively screen the stack and plume (110m). Therefore any screening effect is very limited spatially at the incinerator. As a result, the stack and plume remain visible throughout the host-community except in small pockets of well screened houses. Moreover, residents who cannot see the incinerator from their own home may be able to see it when they drive through the neighborhood.

4.1.2 Noise Impacts

The goal of noise measurements at waste facilities is to describe typical noise footprints, to determine whether waste facility noise creates significant impact on the host community, and to relate the noise levels to the surveyed community beliefs and attitudes (see Chapter 5).

Two criteria were adopted to characterize the noise

contours:

1. the area where the equivalent sound pressure level (L_{eq}) is significantly over background, i.e., 3 dBA over the background noise level (see code 1 in Figure 4.4 and 4.5 below);
2. the area where the facility noise is above the recognition threshold, but not significantly (i.e., not more than 3 dBA) over the background level (see code 2 in Figures 4.4 and 4.5 below);

As a corollary, the normalized community noise equivalent level (CNEL) is calculated from the measured noise levels to predict levels of community response to compare with the community survey results (see Chapter 5).

Method

A hand held CEL noise meter mounted on a 1.5 m tripod was used to determine sound levels and equivalents. Location, weather conditions and time of day were selected to obtain representative results. Background noise was measured under similar conditions of exact measuring locations, conditions and times. They are recorded in Appendix 4.B. The basic measurement schedule is briefly explained here.

Based on a qualitative prediction of the noise field, three to four locations were selected close to but in different directions from the main noise source (the facility). Measurements were taken at four times of day to get nighttime, morning, midday and afternoon readings so that background levels

and fluctuations caused by operational routines could be measured. Weather conditions during measurements were always monitored to verify the similarity to typical conditions for each site. Wind speed and direction were fairly typical, but did not influence the noise levels as much as expected. However, high temperatures and humidity on hot summer afternoons substantially reduced ambient sound levels from facility and background sources at the incinerator, and, to a lesser extent, around the landfill. They did not, however, shift the noise footprint boundaries.

Landfill Noise Levels

Landfill noise sources comprise three elements: heavy compaction equipment on the working face, access traffic, and birds. Although all three elements fluctuate, they frequently reoccur during short periods (about 10 minutes). The frequency curve (see Figure 4.3) for the landfill shows a predominance of low frequencies (32 to 100 Hz) with some higher frequencies (500 to 1,000 Hz) at 90 to 100 m.

The noise measurements are summarized for three active site locations and four community locations in corresponding directions in Table 4.2 and in Figure 4.4. Ratings of 1 and 2 correspond with the noise criteria (above) and with the inner and outer noise contour in the map. The inner boundary contains areas with significant facility noise impacts (i.e., more than 3 dBA over background); the outer boundary is the facility noise recognition threshold. The highest noise levels at 60 to 70 dBA are right behind the active fill area (W2 and S2 locations), because the

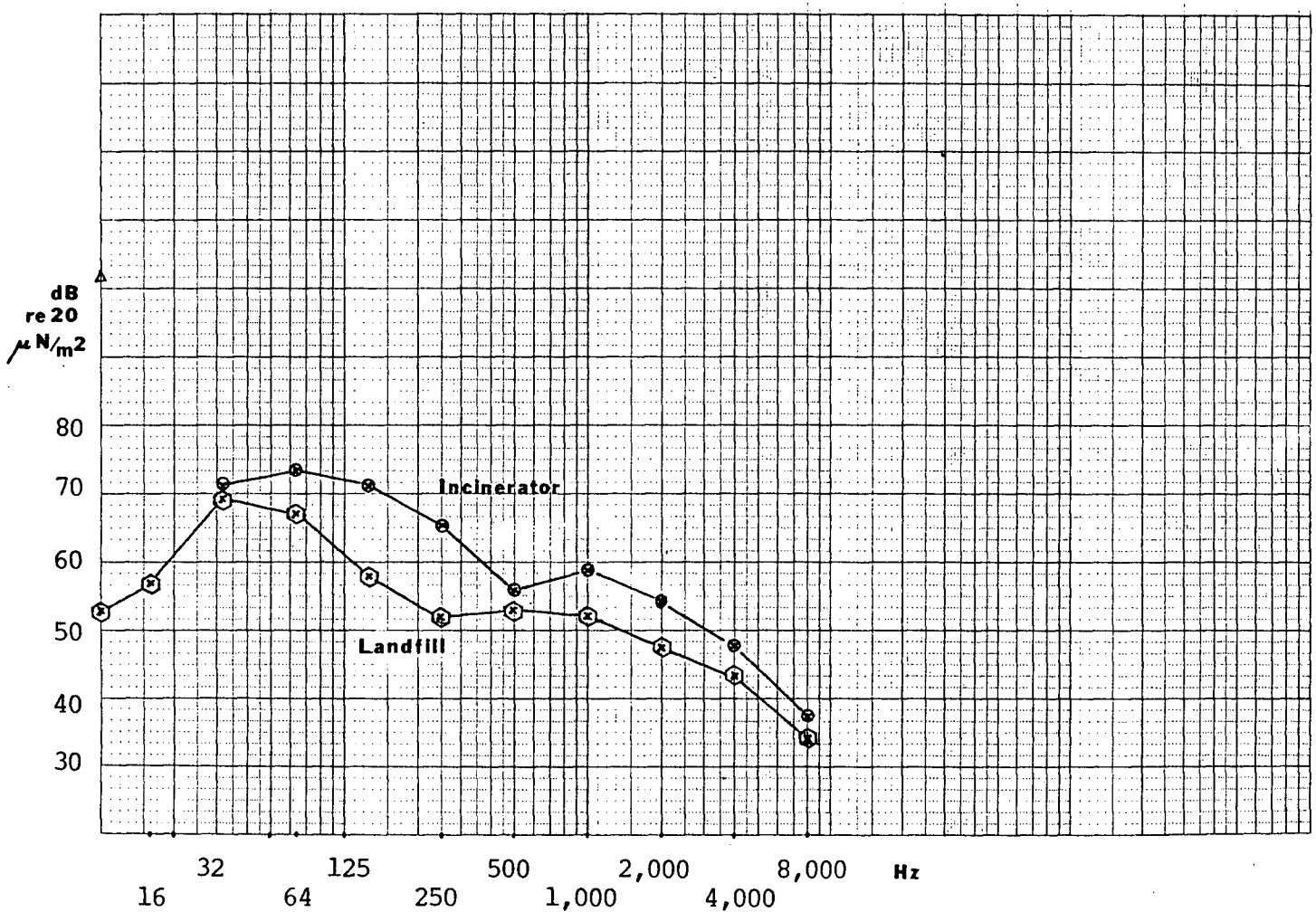


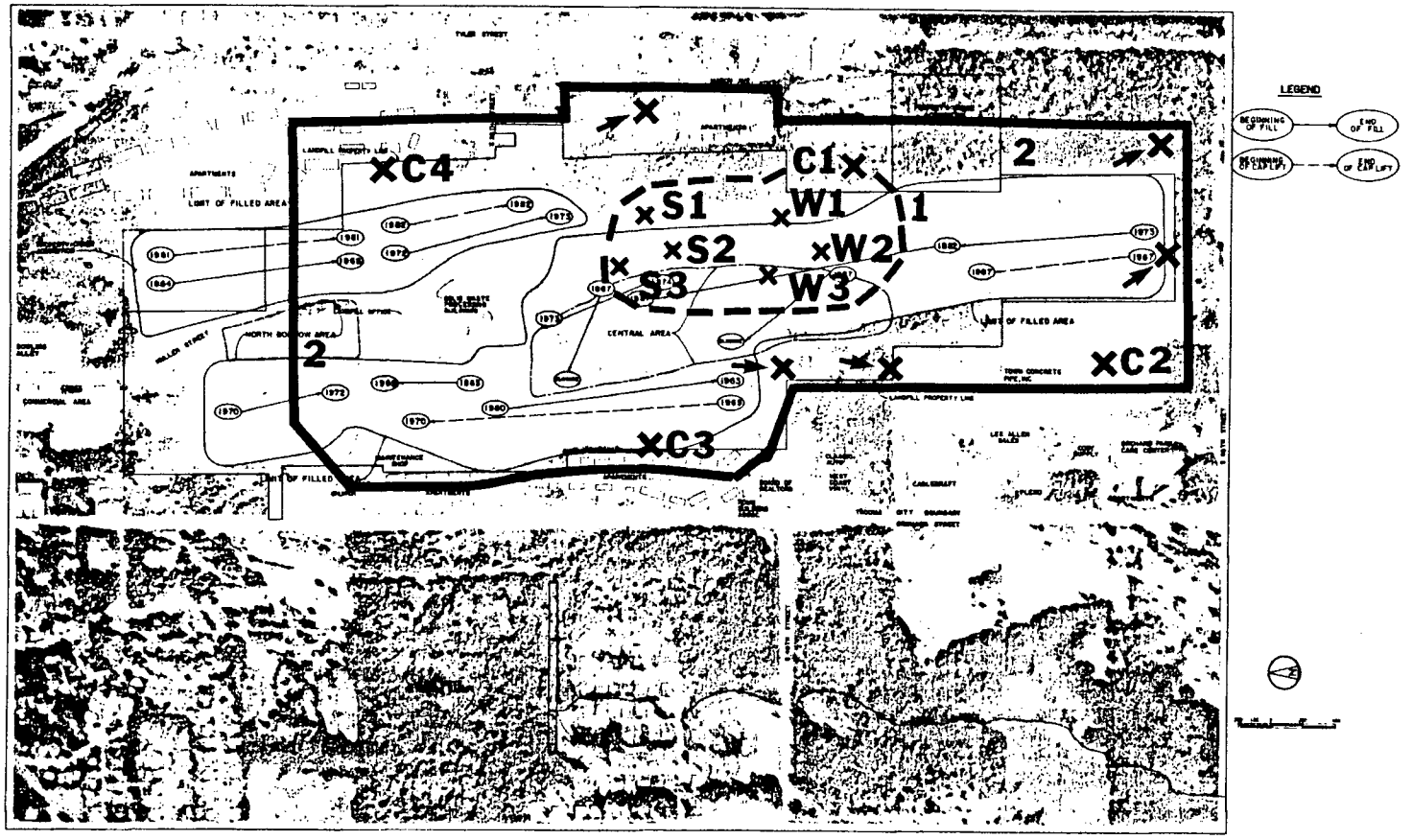
Figure 4.3: Waste Facility Noise Frequency Spectra for Landfill at 90 metres from active area, and Incinerator at 60 m distance

Table 4.2 - Landfill - Measured Sound Levels

Location/ Distance from source	Sound Level Busy Periods		Quiet Periods		Background Noise Level	
	L_{eq}	Range	L_{eq}	Range	Range	Source
	dBA	dBA	dBA	dBA	dBA	
Site						
W1/90-100m	58-64	54-71	54-57	48-60	47-48	traffic
W2/60m	60-70	43-73	56-58	48-60	47-48	traffic
W3/55m	56-66	50-70	51-53	48-56	47-48	traffic
Host Community						
C1/130-140m	55-63	-	49-54	-	38-39	traffic
C2/350m	53	-	<49	-	48-50	traffic
C3/400m	53-57	-	45-52	-	42-53	traffic
C4/340m	54-57	-	44-47	-	<39	traffic

Legend

Leq is the equivalent sound level averaged over 5 minute periods
Range values indicate the range of momentary sound levels



Legend: Locations - "w" winter active area, "s" summer active area,
"c" community noise measurement location
Solid line - recognition boundary, dashed line significant impact boundary

Figure 4.4: Landfill Noise Impact Field

compactors' exhaust outlets usually face this direction.

The measured community noise levels are verified by rough estimation of the noise levels from site noise levels (W2 to W3) and standard attenuation factors (Mestre and Wooten, 1980, and Beranek, 1971). The detailed attenuation estimates are contained in Appendix 4.B.4. The estimated levels correspond roughly to the measured levels (see Table 4.3).

The significant impact area extends about 700 to 800 m in all directions, depending on the background noise, topography, barriers and vegetation. Rows of buildings and hill slopes are very effective in cutting sound levels, while vegetation has a minor effect. The noticeable bulge in the noise threshold at mid length of the eastern landfill boundary corresponds with a cut in the ridge running along that side of the landfill.

The landfill usually generates three levels of sound corresponding to the levels of operation: a "busy" level at 55 to 70 dBA during peak times when one or both compactors are operating continuously, a "quiet" time at 50 to 55 dBA when only one compactor is operating intermittently in 20 minute cycles with 5 to 10 minutes of bird and access traffic noise only, and, finally, background noise of road traffic and plane overflights. The busy levels last 5 hours per weekday (9:30 am to 2:30 pm), the quiet levels occur 5 hours per weekday (8 am to 9:30 am, 2:30 pm to 6 pm) and 10 hours each on Saturday and Sunday. On weekdays there are also impact sounds from banging trucks and tailgates.

Simple attenuation estimates (Mestre and Wooten, 1980) are used to relate the sound levels at the site boundary to the

measured levels in the community (see Appendix 4.B for detailed calculations). The measured and estimated levels are simplified in Table 4.3. The estimated levels at location C2 and C3 are slightly lower than measured levels. This is probably because background noise levels contribute significantly at these locations, while location C1 is close to the source and less affected by traffic noise.

The estimates of distance to the recognition noise boundary using wave divergence only are entered into the observed noise contour (see squares in Figure 4.4). The estimated distances coincide well with the observed boundaries on flat terrain, that is except for the boundary east of the active area, where the ridge and drop of the topography reduce sound propagation.

Based on the landfill noise data, the Community Noise Equivalent Level (CNEL) is calculated by logarithmically adding the measured noise levels weighted by their relative duration by day (Wyle, 1971, see Table 4.3b). With the normalized CNEL sound level of 52.5 dBA, no community reaction would be predicted based on expected community response curve (Wyle, 1971, see Figure 4.6).

Incinerator Noise Levels

The incinerator noise sources consist of the constant plant noise from fans, conveyers and air rushing, and variable noise from access traffic, ash handling, and outside yard operations. The variable operations reoccur roughly on an hourly basis for ash handling, while access traffic consists of regularly spaced arrivals every 5 to 10 minutes. Traffic contributes very little

Table 4.3 - Landfill Measured and Estimated Community Noise Levels.

a. Sound Levels

Location	Sound Pressure Levels Measured dBA	Estimated dBA	Difference
C1	49 - 63	47 - 57	estimated levels slightly lower
C2	49 - 53	37 - 49	estimated levels slightly low
C3	45 - 57	35 - 49.5	estimated levels slightly low

b. Community Noise Equivalent Level (CNEL)

Landfill CNEL Estimate at Community Receptor 150-200m from active area:

Day	5 hours "busy"	55	dBA
	5 hours "quiet"	50	dBA
	5 hours "background"	45	dBA
Night	9 hours "background"	40	dBA
Measured CNEL		52.5	dBA

The correction factors are applied to adjust the measured level for community response (Wyle, 1982)

Correction Factors		
- year round operation	0.0	dBA
- community background noise level: noisy urban near roads and industrial area	-5.0	dBA
- some previous experience with source, but little effort to control noise	0.0	dBA
- impact sounds present	+5.0	dBA
Landfill Normalized CNEL	51.5	dBA

to the noise impact because of the low speeds and the proximity of the exit road to the plant.

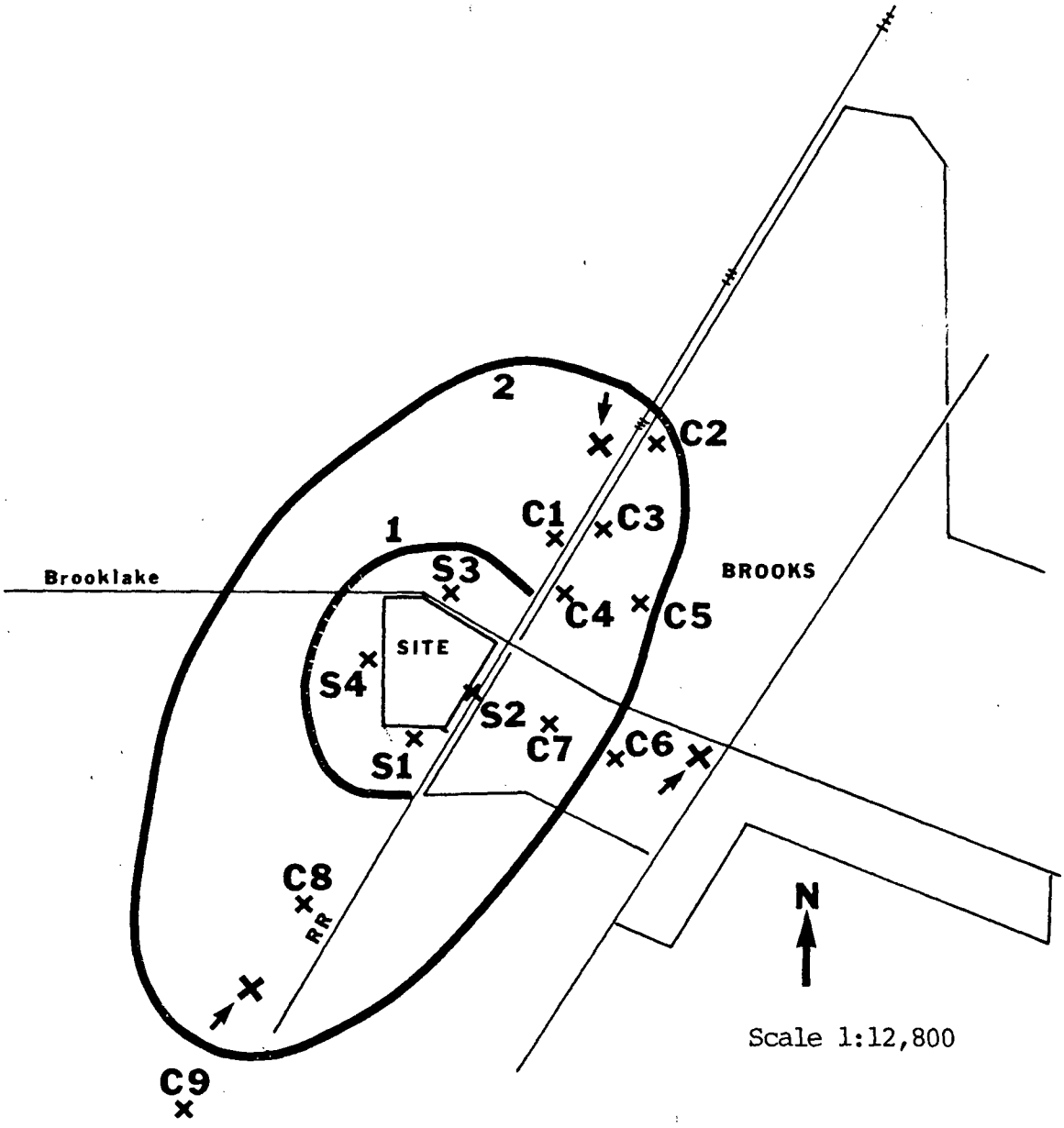
Table 4.4 and Figure 4.5 show the measurement locations and sound levels. Because of the high background noise levels from the highway (I-5 at 800 m to the west, 99E 500 m to the east) and the railroad (100 m to the east), because of the screening effect of the row of onion warehouses along the railroad tracks between the plant and the village and, finally, because of the prevailing wind directions from the southwest and northeast, the significance and recognition thresholds for the incinerator site are concentrical ovals. The significance area is confined virtually on-site, because of the enclosed tipping floor, ash handling and mechanical systems.

The recognition boundary extends far outside the site boundary, because the height of the source (10 to 20 m) and the presence of relatively low frequencies (see Figure 4.3 for the frequency distribution) allow the sound to propagate 250 to 800 m beyond the site boundaries in the flat terrain. Hence, even on hot, dry summer days, a low hum can be heard at some distance from the plant, while the higher pitches of plant and background noises are not audible. As a result, the recognition boundary position varies little, but the measured sound level drops about 10 to 12 dBA on hot, dry summer days. The sound level drop correlates with the typical temperature increase and humidity decrease on summer afternoons (Salem Meterological Data, National Weather Service, 1986). In winter and summer conditions, the measured community sound levels are barely over traffic background noise levels (see

Table 4.4: Incinerator - Measured Sound Levels

Location/ Distance	Seasons	Sound Level Night/Morning		Noon/Afternoon		Background	
		L_{eq} dBA	Range dBA	L_{eq} dBA	Range dBA	Range dBA	Source dBA
Site							
S1/80m	W	56	55-57	55-60	52-62	low	traffic
	S	56	55-58	43-47	42-53	low	traffic
S2/60m	W	64.5	-	61-63	60-65	low	traffic
	S	63.4	53-57	52-54	50-57	low	traffic
Host Community							
C1/200m	S	55	53-57	40-43	37-44	low	traffic
C2/550m	S		plant not audible				
C3/300m	W	52.5	49-56	56	53-62	38-40	traffic
C4/200m	W	54	51-55	-	-	low	traffic
	S	-	48-55	-	38-45	low	traffic
C5/300m	S	barely audible	44-46	barely audible	36-38	low	traffic
C6/300m	S	slight	<43dBA	-	-	40-45	traffic
C7/200m	S	barely audible	53-55	-	-	36-45	traffic
C8/350m	W	-	-	slight	46-50	44	traffic
C9/850m	W	-	-	not audible		43-45	traffic

Seasons: W = winter
S = summer



Legend: S designates site location, C designates community location, with numbers for locations
"1" line indicates significant noise impact boundary, i.e., over 3 dBA over background,
"2" line indicates recognition noise impact boundary
Arrows to "X's" indicate predicted noise boundaries

Figure 4.5: Incinerator Noise Impact Field

Table 4.4).

Some simple attenuation (see Appendix 4.B) estimates allow the systematic prediction of the measured sound levels in the community from site boundary noise levels (see Table 4.5). Furthermore, the distance to the pure background noise level as estimated from wave divergence only is within the observed recognition boundary, except towards the east, into Brooks. Here, additional attenuation of buildings, trees, etc. probably reduces the distance to the recognition boundary. The estimated noise levels in the community coincide with measured levels and support the estimated distances from the incinerator to the recognition threshold boundary.

The prediction of community response is accomplished with the time weighted calculation of measured noise equivalent levels and the correction for specific factors (after Wyle, 1971, see Table 4.5b). The night sound levels elevate the equivalent noise levels to over 60 dBA and may lead to widespread complaints based on the predicted response (see curve in Figure 4.6).

Although the measured sound levels do not constitute a significant increase in community noise levels, they can act as constant reminders of the presence of the facility up to 800 m from the site. The community response may be very negative due to the noise impacts, particularly due to the nighttime operations.

Noise Attenuation Estimates Between Site Boundaries and Community Locations

Community noise levels are estimated from site noise levels and noise attenuation for the specific conditions (see Appendix

Table 4.5 - Incinerator Measured and Estimated Community Noise Levels.

a. Sound Levels

Location	Sound Pressure Levels		
	Measured dBA	Estimated dBA	Difference
C1	40 - 55	41 - 55	not siginficant
C2	plant not audible	below background	not significant
C3	52 - 56	47 - 50.5	estimated level slightly low
C4	48 - 55	50.5 - 54	not significant
C5	plant hardly audible	below background	not significant
C6	plant hardly audible	below background	not significant
C7	53 - 55	42.5 - 53	estimated level low
C8	46 - 50	48 - 53	not significant
C9	plant not audible	below background	

The difference between measured and estimated levels is considered not significant if the upper or lower levels are within plus or minus 3dBA.

b. Community Noise Equivalent Levels

Incinerator Community Noise Equivalent Level (CNEL) at 200m distance:

Measured Levels	at site boundary	and	at 200m	
Day	15 hours at 60	dBA	54	dBA
Night	9 hours at 55	dBA	50	
Measured CNEL	62.8	dBA	57.5	dBA
Corrections				
- year round operation	0.0		0.0	
- community noise level: quiet, rural community with some trucks, near freeway	0.0		0.0	
- no prior exposure to noise source	+5.0		+5.0	
- no pure tone or impulsive noises	0.0		0.0	
Normalized CNEL	67.8	dBA	62.5	dBA

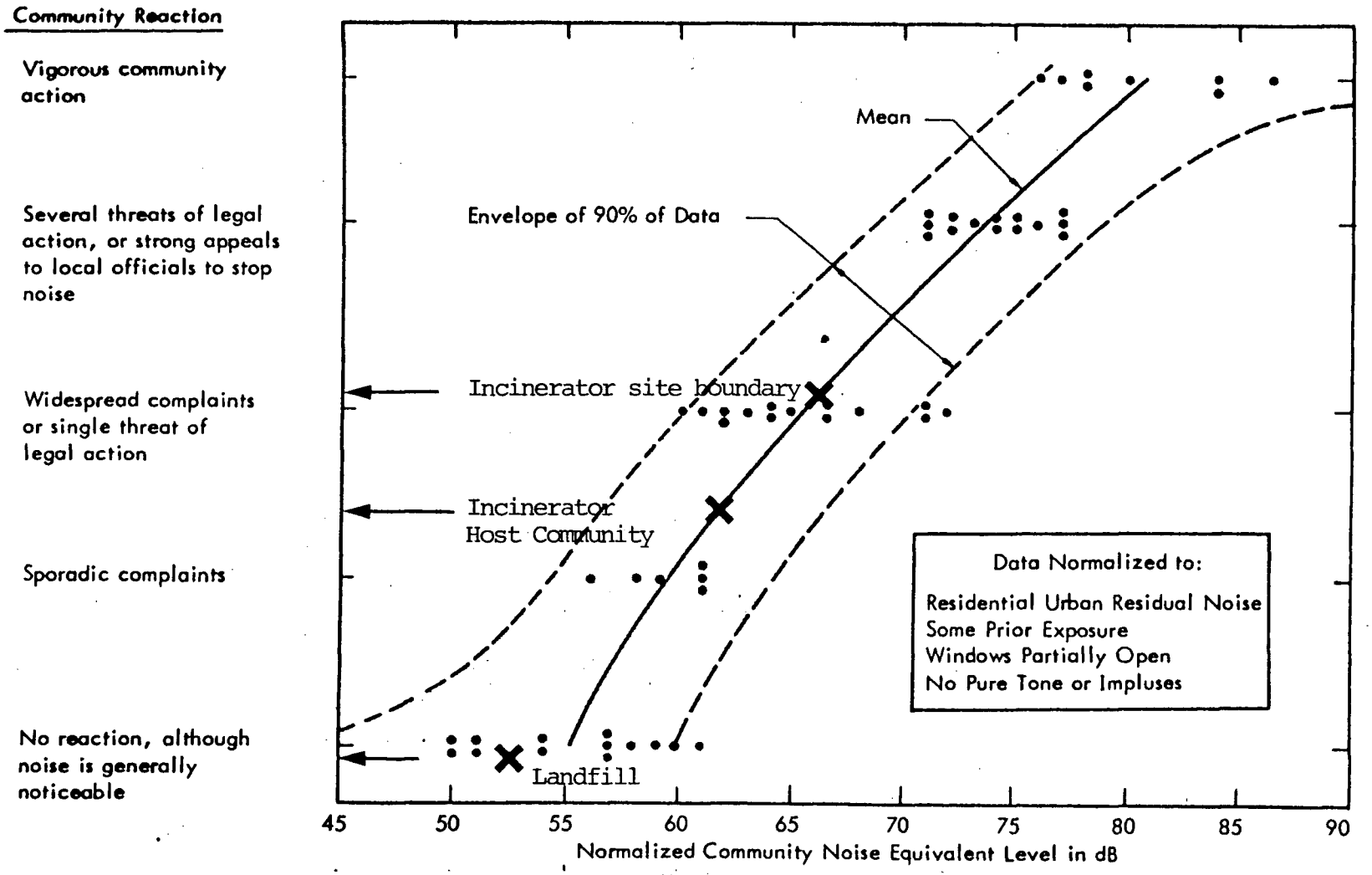


Figure 4.6: Predicted Community Response to Waste Facility Noise Impacts; after Wyle, 1971.

4.B).

The attenuation levels are subtracted from site boundary values to verify the measured values in the community (see Tables 4.3 and 4.5).

The minimum distance from the site boundary to the background noise threshold can be roughly and conservatively estimated from the relationship for sound pressure reduction due to wave divergence. The maximum distance to recognition threshold for a typical facility is not necessarily reduced by excess attenuation because specific conditions may vary. Therefore, the excess attenuation is disregarded. The formula without excess attenuation is used to estimate background noise level distances in three directions (Appendix 4.B.5.). The distances and directions are indicated in the site noise impact maps, Figures 4.4 and 4.5.

4.1.3 Odor Impacts

Odors are defined for this study as airborne substances that exceed the odor threshold. They are considered nuisances. Odor is treated separately here, but is in fact one element of air quality impacts.

Odor perception and response is complex because it depends on many physical and perceptional factors: (Turk et al. 1979):

- physical factors: composition, concentration, frequency and duration of exposure;
- perceptional factors: intensity, character, hedonic tone, and mixing characteristics.

In order to simplify the assessment, three typical landfill odors were characterized. Fortunately, the odor recognition and detection thresholds are known for some characteristic components of the typical odor elements (Young and Parker, 1984a and b).

Odor Impact Definition

The choice of an odor impact definition must take into account the method of odor intensity measurement, the frequency of the odor, and the method of connecting the odor with the source. Waste facility odors can be transient, variable, and can occur frequently or very seldom. The odor must be identifiable by personal observation and recognition because the very low recognition thresholds are difficult to reliably detect with reasonably simply analytical methods. An operational definition of odor impact can rely on resident observations and on verification by local authorities. Schroeder (1975) uses these principles to suggest a definition of odor impact:

1. If one or more odor complaints are initiated by residents of a community and are verified by local authorities, or
2. if 20 or more odor complaints are initiated without verification, or
3. if odors extend beyond the property limits of the source and occur more than once or last more than one day in any three months, and exceed an intensity of 7 dilutions to threshold as measured by the Barneby-Cheney Scentometer.

These criteria exceed many common odor bylaws, but they are adapted for this study to reflect the sensitive meaning of the odor source, i.e., the waste facility. The suggested criteria rely on personal observation. Specifically, criterion 3 adopts a simple personal sampling method to fit the definition of waste site odor impacts.

Odor Measurement

The definition calls for the use of a personal sampler, the "Scentometer," to measure the odor intensity or strength (Huey, 1960). The Scentometer allows odorous and carbon filtered air to be inhaled at different set ratios by opening different sized ports. The observer starts at the smallest opening (largest dilution) and opens one hole at a time until odor is detected. The first opening where odor is detected is the Scentometer reading and corresponds to the minimum dilution to threshold (Barneby-Cheney, 1959). Since the method relies on one observer's perception, it does not account for interpersonal variation of odor sensitivities of up to 1:50 (Wilby, 1969, Turk et al., 1979). Moreover, the odor perception varies with the substance. However, the olfactory variation of one person over time is negligible, with this method, because it varies less than the measurement intervals of the Scentometer (Huey et al., 1960). Therefore, the odor strengths as measured by the same observer will be accurate for relative comparisons but will not necessarily reflect the correct odor perception in the general population. More representative results could be achieved through odor panels.

The frequency, strength and spatial extent of odor impacts depend on three basic sets of conditions for the generation, transport, and reception of odors:

1. source odor generating conditions, e.g., incinerator burning rates, landfill biological activity, and factors that influence the emission rates.

2. transport and dispersion conditions, such as weather and wind conditions, and

3. receptor exposure factors, e.g., patterns of outdoor activities, time of day, season, etc.

The common worst-case conditions for odor impacts are identified for each stage of odor impact generation. Measurements are carried out during common worst-case conditions.

Landfill Odor Impacts

Source Conditions

Odor emissions at the landfill are produced by biological activity in the landfill, from volatilized emissions of open garbage at the working face, and from leachates. These three types of odors possess distinctly different characteristics as identified by the pre-testing of odor measurements:

- Landfill gases have slightly sour, buttery, penetrating odors that carry substantial distances (500 to 1,000m) from the source, due to the low odor thresholds of the principal odor substances identified by Parker and Young (1984) as butyric acids (ethyl butanoate, alkyl benzenes, methanethiol, limonene) and sulfur mercaptans. The dilution to threshold is estimated at 1,000 to 10,000 fold.

- Open garbage has a sweet, putrid, moldy smell that carries moderate distances to about 200 to 300 m. The odor substance is identified as ethanol (Parker and Young, 1984).

- Leachate has a heavy, sickening, fecal smell that usually

disperses within 100 to 200 m from the source. The odor substances are carboxylic acids, (e.g., butyric acid) and hydrogen sulfide (Parker and Young, 1984).

Worst-case source conditions enhance the generation or flux of odorous gases from any part of the landfill into the air. Thibodeaux et al. (1982) modeled the mass flux and determined the most important factors:

- Cell depth increases the gas flux because of the larger amount of biodegradable, gas producing material available per unit surface area.

- Cover thickness and porosity theoretically affect the emission rates, but are shown to be negligible when gas from biological decay is the predominant transport medium, as is the case in the Tacoma landfill.

- Rate of infiltration, water level, temperature in the fill and age affect gas production. However, the only factors that vary in the short term are the rate of infiltration and the water level. Precipitation may increase gas production by increasing the anaerobic zone. Precipitation does not seriously affect gas transport through the cover, although it may increase the moisture content of the landfill cover.

- Ambient barometric pressure drops can create pressure pumping and increase the gas emissions, while temperature gradients may drive gas to the surface. Inside the fill, the effects of surface temperature changes are likely very small, especially for depths, below 5 to 10 feet. However landfill pressure may build up as daytime temperatures rise and ambient air gets lighter (Schumacher, 1983).

- Volatilization of odorous substances from open garbage and leachate depend on concentrations and vapor pressures. Volatization increases with temperature and with decreasing pressure.

These conditions can be related to common weather conditions in Tacoma:

- Precipitation is higher and evapotranspiration is lower in winter, resulting in a higher net infiltration rate. Specific infiltration events usually occur in conjunction with frontal passages and are often followed by low pressure zones.

- High temperatures occur usually with high pressure and low precipitation in summer. Surface garbage and leachate odors are likely to increase; high temperatures heat ambient air to increase pressure gradients that increase gas emissions from inside the landfill.

Dispersion and Exposure Conditions

For ground level sources, such as the landfill, stable atmospheres characterised by increasing temperatures with height create maximum concentrations of air pollutants, and, hence, of odor (Samuelson, 1980). High stability consists of calm to low (up to 1 m/s), persistent winds towards populated areas, low and persistent mixing heights, and low insolation with cloud cover, resulting in a very high stability rating (E to F, see Appendix 4.G). Surface inversions occur under clear skies and light winds early in the morning and late in the evening when the earth surface has cooled off and the air above it is still warm. Tacoma experiences ground-level inversions frequently in the summer and in the winter (see site description in Chapter 1, section 2).

The maximum exposure occurs when prevailing winds are towards populated areas, and outdoor activities are frequent, particularly in the summer. In Tacoma, populated areas are downwind from the landfill in both the prevailing wind directions (north and south).

Odor Measurements

Odor observations were carried out under the identified worst-case conditions:

- maximum source emission conditions with low pressures, high temperatures during periods of high precipitation, probably under unstable conditions,

- minimum dispersion in inversion conditions with light winds, i.e., high ground level stability with E to F ratings.

The dates and weather conditions for odor assessment at the landfill are listed in Table 4.6. Both winter (February/March) and summer (August) conditions for ground level inversions are covered. Low pressure conditions during winter are included. While no low pressure zones were captured in the summer, warm summer afternoon conditions (August 26.) have a similar effect of inducing pressure buildup in the landfill (Schumacher, 1983).

The odor measurements are compiled in Table 4.7 for key locations on the landfill boundary and in the community. The results are then indicated geographically in Figure 4.7.

The area of intense odors (requiring 7 fold dilution to threshold) is usually less than 100 m outside the landfill boundary (dashed line in map), but transient odors are present above recognition threshold up to 200 to 300 m beyond the boundary (solid line in map).

Low pressure and afternoon measurements seem to consistently generate odor readings, while ground inversions are not always correlated with odors. Residences to the east and south are most affected, in part because of the shorter distances and the prevailing northerly winds during odor measurements (see Table 4.6). Low barometric pressures and high temperatures create the highest odor intensities, probably from the same pumping mechanism.

Notably, leachate odors are very intense at the landfill boundary but drop off rapidly so they are usually not detectable in the community. In contrast, the landfill gas and open garbage odors persist above threshold for up to 200 to 300 m outside the

Table 4.6 - Landfill - Odor Assessment Conditions

Date/ Time	Wind Vel.	Direction	Barom. Press./Rating	Temp Dewp.	Clouds	Weather Scenario
Feb.24 6am	5.1m/s	NNE	1015/mod.high mb	4 C	Clear	mod. high ground inversion at 800-1000 ft.
Feb.26 12pm	4.1m/s	SW	1020/av.high mb	9.5 C	10,000 broken	Average high
Mar. 6 12pm	3.1m/s	NNE	1006.5/av.low mb	11 C	6,000 scat. 35,000 scat	Average low
Mar. 8 7am	calm	calm	1001.6/low mb	0 C	8,000 scat.	Low
Aug.25 7am	calm	calm	1021.4/av.high mb	12 C	ground fog 5,000 scat. 20,000 scat.	Average high ground inversion
Aug.26 12pm	1.0m/s	N	1021.7/av.high mb	20 C	800 sc. 15,000 br.	Average high

Table 4.7 - Landfill Odor Impact

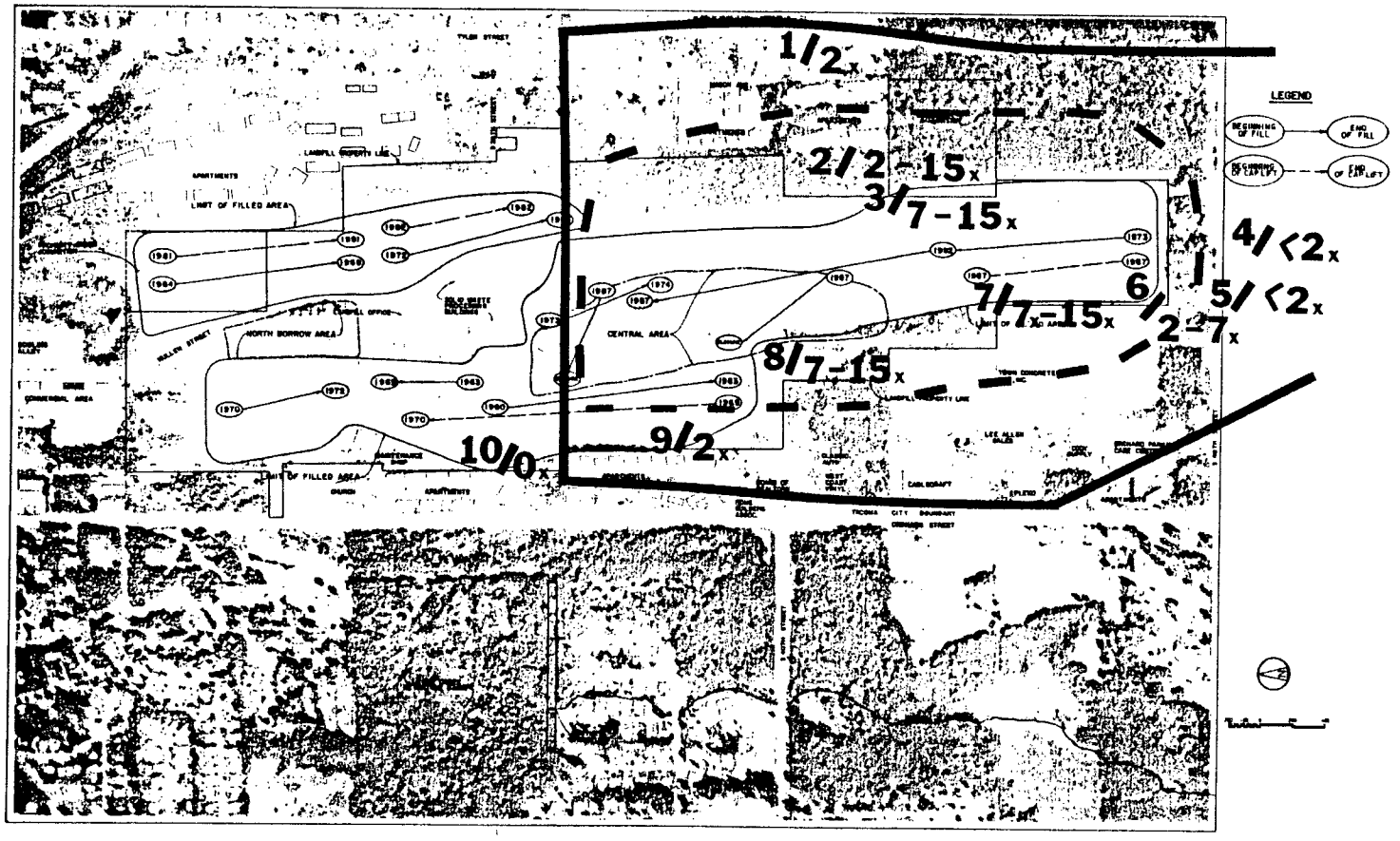
Location	Date/ time	Weather Conditions Barom. Pressure	Odor Dillutions to Dilution Thresholds	Odor Impact Rating
1-Tyler Deli	Mar. 6 12pm	Average low	1/2	1
	Feb.26 2pm	Average high	0	0
2-Forest Hills Apts.	Feb.26 2pm	Av. high winter	2/17	2
2-Forest Hills Apts.	March 6 12pm	Av. low winter	2 - 3/ sour/garbage	2
2-Forest Hills Apts.	Aug.25 7am	Av. high with ground inversion	1/2 musty	1
2-Forest Hills Apts.	Aug.26 12pm	Av. high	0	0
3-LF Boundary	Feb.24 7am	Mod.high w. ground inversion	0	0
	Feb.26 2pm	Av. high	2/7	2
	Mar.6 12pm	Av. low	3/15 sour/garbage	2
	Mar.8 7am	low	<1/2 garbage	1
	Aug.25 7am	Av.high w. ground inverstion	2/7 sour	2
	Aug.26 12pm	Av. high	2/7 leachate	2

Table 4.7 - Landfill Odor Impact

Location	Date/ time	Weather Conditions Barom. Pressure	Odor Rating/ Dilution	Odor Impact
4-S.49th Ave.	Mar.26 12pm	Av. high	<1/<2 musty	<1
	all other	Winter - high -low	0	0
5-48th Grove Street	Mar.6 12pm	Av. low	<1/<2 sour	<1
	all other	winter -high -low	<1/<2	<1
6-SW Corner	Feb.24 7am	mod high W. Surface inversion	<1/<2 sour/garbage	<1
	March 8 7am	Low	1-2/2 - 7 sour/rotten	1
	Aug.25 7am	av. high	0	0
7-SW Flank	Feb.24 7am	mod.high m.surface inversion	2/7 garbage	2
	Mar.8 7am	low	3/15 sour/garbage	2
	Aug.26 12pm	av. high	1-2/2 - 7 leachate	1
8-West Flank	Feb.24 7am	mod. high w. inverstion	1-2/2-7 sour/garbage	1
	Mar.8 7am	low	2-3/7-15 sour/rotting	2

Table 4.7 - Landfill Odor Impact

Location Distance/ div. from Active Fill	Date/ time	Weather Conditions Barom. Pressure	Odor Rating/ Dilution	Odor Impact
g-Grey Apts	Feb.24 7am	mod. high in. gr. inversion	<1/<2 sour/garbage	1
	Mar.9 7 am	low	1/2 sour	1
	Aug.25 7am	Av. high in. inversion	0	0
	Aug.26	av. high -low	0	0
10-Orchard View Apts	Feb.24 7am	mod. high w. inversion	0	0
	March 8 7am	Low	0	0
	Aug.25 7am	av. high inversion	0	0
	Aug.26 12 pm	av. high	0	0
11-Nob Hill Apts.	all	all	0	0



Legend: First number is location/ second number is odor reading as required dilutions to threshold
Solid line is odor impact boundary, dashed line is boundary for significant odor impacts

Figure 4.7: Landfill Odor Impact Field

boundary. As a result, odor impacts can either be worst during low pressure or high temperature conditions. Surface inversions did not create the highest odor impacts, probably because they occur with high pressures and low temperatures, that is, with conditions that are not conducive to high gas generation. Thus, odors seem to depend mainly on the gas generation and less on the dispersion conditions.

Comparison of Measured and Calculated Odors

The observed odor impacts are validated with a simple dispersion calculation using some basic assumptions (e.g., non-reactive pollutans, see detailed calculations in Appendix 4.C). The odorous gases are assumed to follow the ground-level, linear source Gaussian dispersion model (Wark and Warner, 1980). The assumption of a necessary minimum dilution of 1,000 to 10,000 fold required for the strongest odor substances and 100 fold dilution through the landfill cover (Parker and Young, 1984a) to the ground surface concentration results in a required surface dispersion dilution of 100 fold to reduce the odors below threshold.

Given the relative dilution from the source (on the right side of Figure 4.8), the remaining required dilution ratio to achieve the required 10,000 fold can be determined as a function of distance from the landfill boundary. The dispersion calculations indicate a required distance of about 500 to 600 m from the odor source to the recognition boundary at F stability (see Figure 4.8) to obtain 100 fold surface dilution. Table 4.8 below compares the estimated with the observed dilutions and

indicates the prediction of odor impacts based on dispersion estimates. Since both filled and active areas are potential sources of odors, distances to both are included in Table 4.8 to determine the distance from potential sources.

The estimated and observed odor impacts coincide fairly well because both provide dilution ratios in the same order of magnitude (compare estimated and observed dilution due to dispersion) and indicate similar predicted odor impacts. Thus, the measured odors are supported by the rudimentary estimates of odors and odor thresholds as a function of distance from the landfill active area.

Incinerator Odor Impacts

Potential odors from garbage burners stem from the stack gases, open garbage on the tipping floor and bunkers, and from ash residue storage and handling. Thus, the worst case conditions for both elevated sources and ground level sources need to be considered. These conditions were determined by qualitative evaluation of generation and transport conditions.

Source conditions are very steady due to a constant burning rate 24 hours per day, seven days a week. The seasonal variation from 85% to 115% of the annual average is the only variation apart from short downtime during maintenance periods for either burning unit.

Odor transport and dispersion conditions for both ground-level and elevated odor sources apply. The conditions for maximum ground-level odors are the same as the landfills with calm

Table 4.8 - Tacoma Landfill Odor Impact Limits

	Location	Distance to Landfill boundary/ active area	Estimated Dilution due to Dispersion	Total	Odor Impact Predicted	Observed Dilution due to Dispersion	Total
1 -	Tyler Deli	235/335m	42/57	4,200/ 5,700	yes	50	5,000
2 -	Forest Hills	50/150m	10/27	1,000/ 2,700	yes	7 - 50	700- 5,000
3 -	Landfill Boundary east	0/100m	2/27	200/ 2,000	yes	7 - 15	700- 1,500
4 -	S.49th Ave.	200/500m	40/83	4,000/ 8,300	yes	>50	>5,000
5 -	S.48th/Gove	100/400m	20/67	2,000/ 6,700	yes	50	5,000
6 -	SW Landfill Corner	50/350m	2/60	200/ 6,000	yes	15 - 50	1,500/ 5,000
7 -	SW Boundary	0/300m	2/59	200/ 5,900	yes	7 - 15	700/ 1,500
8 -	West Boundary	0/200m	2/37	200/ 3,700	yes	7 - 15	700/ 1,500
9 -	Grey Apts. West	20/400m	5/67	500/ 6,700	yes	50	5,000
10 -	Orchard Apts. West	20/550m	5/91	500/ 9,100	barely	>100	>10,000

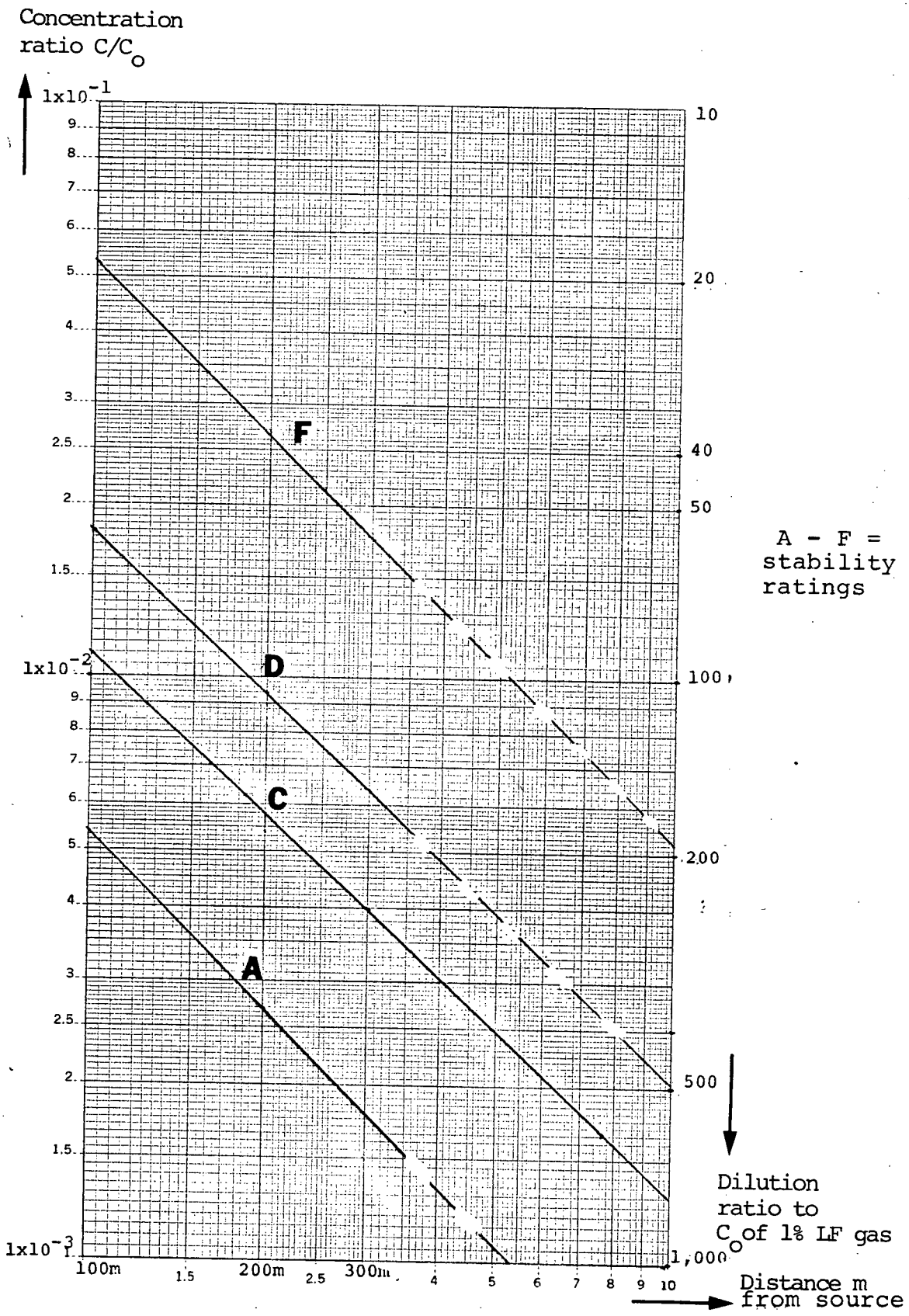


Figure 4.8: Air Emission Dispersion from a Line Source for a Groundlevel Receptor

winds through the bunker and storage bin, low persistent mixing heights, and high stability with low persistent inversion heights (see previous section).

Elevated sources create odors under conditions that limit the vertical plume rise, trap the pollutants below a moderate mixing height and provide mixing that transports the pollutants down to the ground. Stable conditions limit the vertical plume rise, but may also keep the pollutants concentrated above an elevated layer. Thus, some instability is required to bring the odors down to ground level. Hence, light to strong winds at 2 to 15 m/s persistently towards populated areas, moderately low, persistent mixing heights, and moderately low to low stability to generate mixing are usually the worst-case conditions.

Plume modeling with Gaussian plume shapes predict maximum near field impacts at 700 to 1,500 m from the source under low to moderate wind speeds and A to C stabilities (Seton, Johnson, & Odell, 1984; see Appendix 4.C and the next section "Air Quality Impacts"). A and B stability conditions occur very seldom in the Willamette Valley; hence C stability is the most probable realistic condition for maximum potential odors.

From the typical weather conditions in the Willamette Valley, two scenarios constitute the worst case conditions. The first is low ground level inversion on clear mornings and evenings with concurrent ground fog. Inversion heights are lower in winter (about 700 feet or 215 m) with average prevailing winds at about 12 to 14 km/hr (3 to 4 m/s) from the south to southwest. However, morning and evening winds are slower and coincide with

ground-level inversions. The second scenario requires instability and, hence, high insolation during the summer. Wind speeds, however, are lower at 10 to 11 km/h (2.8 to 3 m/s) from the north during July and August.

Odor Measurements

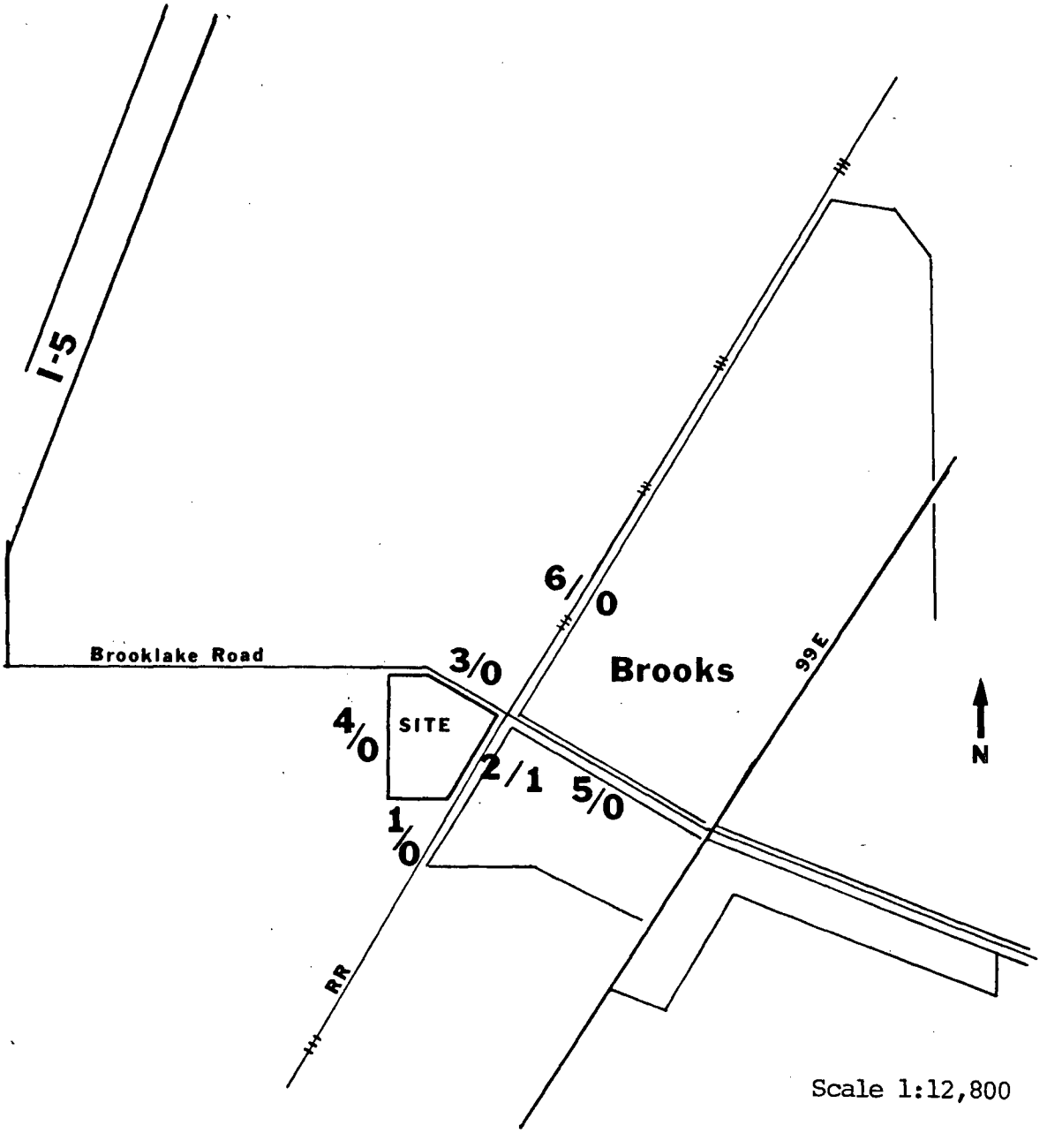
Odor observations are carried out under the weather conditions summarized in Table 4.9 below. Both worst-case odor scenarios are included in the measurement program. The odor measurements in Table 4.10 and Figure 4.9 show no significant impact nor are they correlated with either weather scenario.

Odors from the incinerator are practically nil under all conditions for both ground-level and elevated sources. This finding is also corroborated by dispersion calculations in the section on air quality.

Only very weak scents of metal salts from ash handling were occasionally detected downwind from the ash storage building, while weak garbage odors from their tippling floor were observed only once. Never were any odors from the stack emissions detected anywhere. As a result, odors from large incinerators are considered to be virtually nil and do not impact on any residents in the host community.

Table 4.9 - Incinerator Odor Measurement, Weather Conditions

Date/ Time	Wind Vel.	Dir.	Barom. Press./Rating	Temp Dewp.	Clouds	Weather Scenario
Jan.21 7:40am	1.5m/s	NNE	1025.3/high mb	$-3^{o}C$	fog	av.high with surface inversion
Jan.22 11:40am	calm	N	1018.2/av.high mb	2° C	7,000 overcast	weakening high
Feb. 8 23:00	1.5m/s	SSE	1012.8/av.high mb	$4^{o}C$/ 3° C	fog 25,000 thin over-cast	weak high w. surface inversion
Feb. 9 7:00am	3.1m/s	SSE	1012.8/av.high mb	2° C/ 1° C	13,000 scattered	weak high w. surface inversion
Aug.12 7am		NNW	1016/high mb	$22^{o}C$	scattered	warm summer



Legend: first number is location designation/
second number is odor rating, e.g. 1/0 designates a reading of zero at location 1.

Figure 4.9: Incinerator Odor Impact Field

Table 4.10 - Incinerator Odor Impact Measurements

Location	Date/ time	Weather Conditions Barom. Pressure	Odor Rating/ Dilution	Odor Impact
1-100m south of plant at fence	Aug.12 3pm	High	<1 dank, garbage	<1
	all other			
2-70m east of plant at fence	Jan.21/ Feb.9- 2am	av. high with surface inverstion	<1 metallic ash	<1
	Jan.22 11:40am	av. high	0	0
	Feb.8 23:00	low	0	0
	Aug.12 3pm	high-summer	<1 hot metal-salt	<1
3-N of site of brook-lake Road.	Aug.12 3pm	high-summer	background ripe vegetable smell in summer	0
4-West of site-50m from bunker door	Jan.21 7am	av. high with surface inversion	<<1 garbage	<1
	all other	all	0	0
5-Brooks post office	Feb.9 7am	Surface inversion	0	0
	Aug.12 3pm.	high-summer	0	0

4.2 Air Quality Impacts

4.2.1 Landfill Gas Emissions

Biological processes in landfills produce four bulk gas components. Carbon dioxide and methane each range between 25 and 50% of volume; nitrogen and hydrogen amount to 1 to 5% of volume (Schumacher, 1983). Numerous trace materials are present at low concentrations. Parker and Young (1984) list some 30 organic compounds including some known carcinogens (e.g., vinyl chloride). Since the trace compounds are often difficult to detect, methane is used as an indicator for the concentration of landfill gas components (Parker and Young, 1984).

The potential impacts of landfill gas migration consist of explosion risks due to methane concentrations between 5% and 15%, and of health risks due to hazardous pollutants above acceptable intake levels.

Landfill Gas Transport

The transport of gaseous pollutants from landfills can occur through four routes (see Figure 4.10, USEPA, 1987):

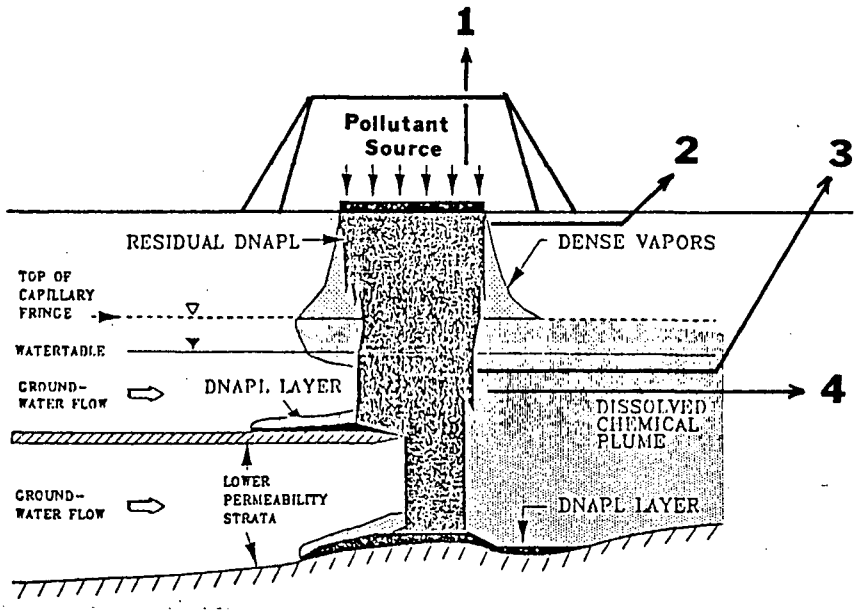
1. Direct upward migration through the cover followed by dilution and dispersion in the air;

2. gaseous migration in the unsaturated soil zone with subsequent transport through the ground into the atmosphere with subsequent dispersion;

3. aqueous migration in groundwater, followed by volatilization and upward migration through the unsaturated zone to the atmosphere with subsequent dispersion;

4. aqueous migration in groundwater or leachate with surface discharge, concurrent or subsequent volatilization to the air with subsequent dispersion.

Gaseous transport mechanisms are enhanced by maximal generation



Legend: DNAPL = Dense, non-aqueous phase pollutant Liquid

Figure 4.10: Landfill Air Emission Transport Paths; Source: USEPA, 1987

and minimal dilution and dispersion (see odor impacts section). Certain landfill features, however, determine whether vertical or horizontal migration is most likely. Thickness, porosity, moisture content ratios of the cap and adjacent soil layers influence the emission route as summarized in the matrix (Table 4.11) below. Migration through the soil potentially results in the emission of gas to the air far beyond the landfill boundary. The rule of thumb predicts that gas can migrate up to a distance of ten times the landfill thickness from the filled area (Rovers et.al., 1977).

Aqueous migration followed by volatilization of pollutants is favored by high water solubility, low sorption capacity in the soil, with high volatility and low molar weight to enhance buoyancy. Furthermore, shallow groundwater depths favor gaseous emissions to the air. Kerfoot (1987) shows that unsaturated soil gas concentrations above the groundwater table correlate well with the aqueous concentrations of volatile organics. Finally, surface discharge of leachate or groundwater result in aeration and volatilization of pollutants. Aeration, mixing and high temperatures will enhance emissions to air from the aqueous phase.

Tacoma Landfill Gas Emissions

For the evaluation of landfill gas emissions in Tacoma, methane flashes and monitoring results indicate the presence of landfill gas beyond the site boundaries. Methane at 40 to 50% levels and 21 volatile organic priority pollutants were detected at or above trace levels in gas probes (Black and Veatch, 1987).

Table 4.11 Gas Migration Route Influences

Features	Favored Route Through Cover	Through Soil
Cover		
Thickness	thin	thick
Porosity	high	low
Moisture	low	high
Soil		
Thickness	thin	thick
Porosity	low	high
Moisture	high	low

Table 4.12 - Landfill - Measured Gas Concentrations in Gas Probes outside the Landfill detected in the Order of Magnitude of TLV
Source: Black and Veatch, 1987

Compound	Sample No.	Highest Value microgr/m3	TLV microgr/m3
Benzene	GS 012	4800	30,000
1,1 Dichloro-ethene	GS 007	17,000	20,000
Trans-1,2-Dichloroethene	GS 012	120,000	790,000
Ethyl benzene	GS 011	77,000	435,000
Methylene Chloride	GS 007	73,000	350,000
Toluene	GS 010	860,000	375,000
Vinyl Chloride	GS 001	52,000	10,000
Total Xylenes	GS 011	170,000	435,000

Six pollutants were in the order of magnitude of the time-weighted average of the threshold limit values (for workers during 8 hours/day, see Table 4.12, Black and Veatch, 1987).

In order to estimate the health effects of landfill gas, the concentrations at exposure points in the host-community must be estimated through the transport paths and compared with the measured data. Both gaseous paths are considered. The aqueous paths are disregarded because leachate is partially collected and discharged to the sewer; further, the solubilities of all pollutants are low, and finally, convective and buoyancy forces are fairly small due to the lack of air exchange at 20 m depth and the high molecular weights of the pollutants. Finally, diffusion mass transport is likely small from depths of 20 m. Thus, gaseous transport through soil and air are considered to be the only two significant pathways.

By applying the gas migration range rule of 10 fold lateral migration (Rowes et.al. 1979) to the fill depths of 6 to 21 m in Tacoma, the migration in soil could range from 60 to 210 m outside the fill boundary. The gas monitoring results consist of two sets of methane gas measurements in June and July, 1986 showing pockets of virtually undiluted landfill gas (at 50% methane concentration) at up to 70 m outside the boundary (see Table 4.C2 in Appendix, Tacoma Pierce Country Health Dept., 1986). The results are presented in Figure 4.13 wherein the probe samples with concentration readings over 5% are indicated by "X". It is evident from the clusters of X's that gas migration in explosive concentrations is occurring outside the collection perimeter and

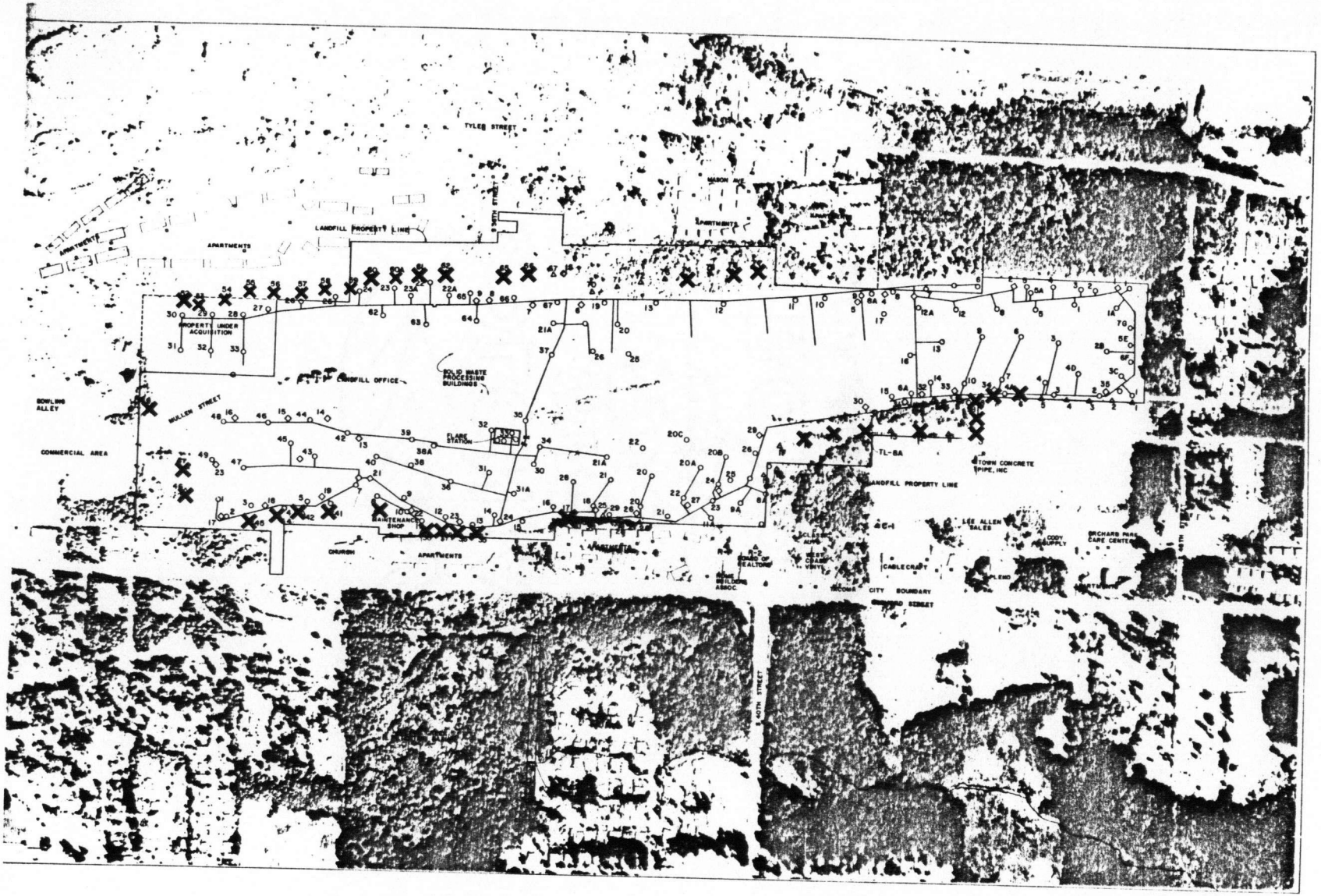


Figure 4.11: Landfill - Locations with Methane Detected over Explosive Concentrations

LEGEND

- ○ GAS WELL
- ▲ PROBE
- ◇ CONDENSATION DRAIN
- • OFFSITE MONITORING LOCATION

within 30 to 100 m of inhabited buildings. Moreover, low concentrations (3% methane), were found entering through cracks into basements (pers. comm. R. Post, 1987). Since there is no other source of methane in the area, and the measurements and minor gas flashes at the cement pipe plant are within the estimated range of migration (60 to 210 m), landfill gas migration is very probably the cause of explosion risks outside the perimeter of the landfill.

Health risks from inhalation of landfill gas are more difficult to determine because these pollutants are present in trace concentrations only and were only measured in one set of data in June, 1986 (Black and Veatch, 1987). But, if trace organics behave proportionately to methane, then both methane data sets can be used (see Table 4.C2 in Appendix 4.C). The comparison of concentration based on methane concentrations indicates that the same undiluted concentrations of trace organics are present outside the boundary too, if they behave similarly to methane. However, sorption to organic matter in the soil may disproportionately affect trace organic pollutants.

The comparison of the octonol-water partition coefficients provides some indication of the sorption of similar trace compounds relative to methane (see Table 4.13), e.g., methylene chloride.

The results show some difference between the various compounds and in particular the ones similar to methane (methylene chloride). Only benzene compounds (benzene, ethylbenzene and toluene) exhibit potentially significant sorption due to high

Table 4.13 - Landfill Leachate Contaminant Physical/Chemical Data; Source: Black and Veatch, 1987.

Waste Component	CAS #[a]	MW[b]	Water Solubility mg/L	Vapor Pressure mmHg	Henry's Law Constant atm-m^3/mo[1]	Koc[c] ml/g	Log Kow[d]	y/x[e]	Fish BCF[f]
Tetrachloroethene	127-18-4	166	1.50×10^{2}	1.78×10^{1}	2.59×10^{-2}	364	2.6	0.02	31.0
Trichloroethene	79-01-6	131	1.10×10^{3}	5.79×10^{1}	9.10×10^{-3}	126	2.4	0.08	10.6
1,1-Dichloroethene	75-35-4	97	2.25×10^{3}	6.00×10^{2}	3.40×10^{-2}	65	1.8	0.79	5.6
Trans-1,2-Dichloroethene	540-59-0	97	6.30×10^{3}	3.24×10^{2}	6.56×10^{-3}	59	0.5	0.43	1.6
Vinyl Chloride	75-01-4	63	2.67×10^{3}	2.66×10^{3}	8.19×10^{-2}	57	1.4	3.50	1.2
1,1,1-Trichloroethane	71-55-6	133	1.50×10^{3}	1.23×10^{2}	1.44×10^{-2}	152	2.5	0.16	5.6
1,1-Dichloroethane	75-34-3	99	5.50×10^{3}	1.82×10^{2}	4.31×10^{-3}	30	1.8	0.24	NA
1,2-Dichloroethane	107-60-2	99	8.52×10^{3}	6.40×10^{1}	9.78×10^{-4}	14	1.5	0.08	1.2
Chloroethane	75-00-3	65	5.74×10^{3}	1.00×10^{3}	NA	37	1.4	1.32	NA
Benzene	71-43-2	78	1.75×10^{3}	9.52×10^{1}	5.59×10^{-3}	83	2.1	0.13	5.2
Ethylbenzene	100-41-4	106	1.52×10^{2}	7.00×10^{0}	6.43×10^{-3}	1100	3.2	0.01	37.5
Chlorobenzene	108-90-7	113	4.66×10^{2}	1.17×10^{1}	3.72×10^{-3}	330	2.8	0.02	10.0
Toluene	108-88-3	92	5.35×10^{2}	2.81×10^{1}	6.37×10^{-3}	300	2.7	0.04	10.7
Xylene (mixed)	1330-20-7	106	1.98×10^{2}	1.00×10^{1}	7.04×10^{-3}	240	3.3	0.01	NA
Butanone	78-93-3	72	2.68×10^{5}	7.75×10^{1}	2.74×10^{-5}	4.5	0.3	0.10	0
Acetone	67-64-1	58	1.00×10^{6}	2.70×10^{2}	2.06×10^{-5}	2.2	-0.2	0.36	NA
1,2-Dichloropropane	78-87-5	113	2.70×10^{3}	4.20×10^{1}	2.31×10^{-3}	51	2.0	0.05	NA
Chloroform	67-66-3	119	8.20×10^{3}	1.51×10^{2}	2.87×10^{-3}	31	2.0	0.20	3.8
Methylene Chloride	75-09-2	85	2.00×10^{4}	3.62×10^{2}	2.03×10^{-3}	8.8	1.3	0.48	5.0
Chloromethane	74-87-3	50	6.50×10^{3}	4.31×10^{3}	4.40×10^{-2}	35	0.9		NA
Trans-1,3-Dichloropropene	542-75-6	111	2.80×10^{3}	2.50×10^{1}	1.30×10^{-3}	48	2.0		1.9

[1] Source: "Superfund Public Health Evaluation Manual", Reference 14.

NA = Not Available

[a] Chemical Abstracts Identification Umber

[b] Molecular Weight

[c] Organic Carbon Partition Coefficient

[d] Octanol-Water Partition Coefficient

[e] Gas liquid equilibrium constant (vapor/liquid)

[f] Fish Bioaccumulation Factor

partition coefficients, low vapor pressures and some empirical evidence of sorption to sedimentary organic material (USEPA, 1979). Furthermore, low soil organic contents of (say) 0.5 to 1% (USEPA, 1987) and the presence of direct gas emission pathways along conduits and roots are likely to minimize sorption capacity. Furthermore, oxidation and biological decay are unlikely for the pollutants (vinyl chloride, benzene, methylene chloride, toluene, etc., see Table 4.12) (USEPA, 1979). Therefore, the anticipated priority pollutant concentrations in the landfill and in surrounding soils are interpolated herein from measured methane concentrations and emissions rates (Black and Veatch, 1987).

Using Young and Parker's (1984) estimated dilution ratio of landfill gas in the fill to the surface of 100:1, the resulting surface air concentrations can be easily estimated from the gas well measurements (see Table 4.12).

The landfill is then assumed to act as a linear groundlevel emitter of 1% landfill gas. Using a Gaussian model to estimate dispersion (as done on the last section for odors) the order of magnitude of resulting downwind concentrations of methane and trace organics can be obtained by multiplying their source (surface) concentrations with the estimated dilution factors. The detailed derivation of assumptions and calculations are contained in Appendix 4.C. Figure 4.12 below shows the qualitative form of the dispersion model.

The Gaussian model results in the following centerline, groundlevel concentration from an emission concentration of 1 mg/m3 (see Figure 4.11). By prorating the source concentrations,

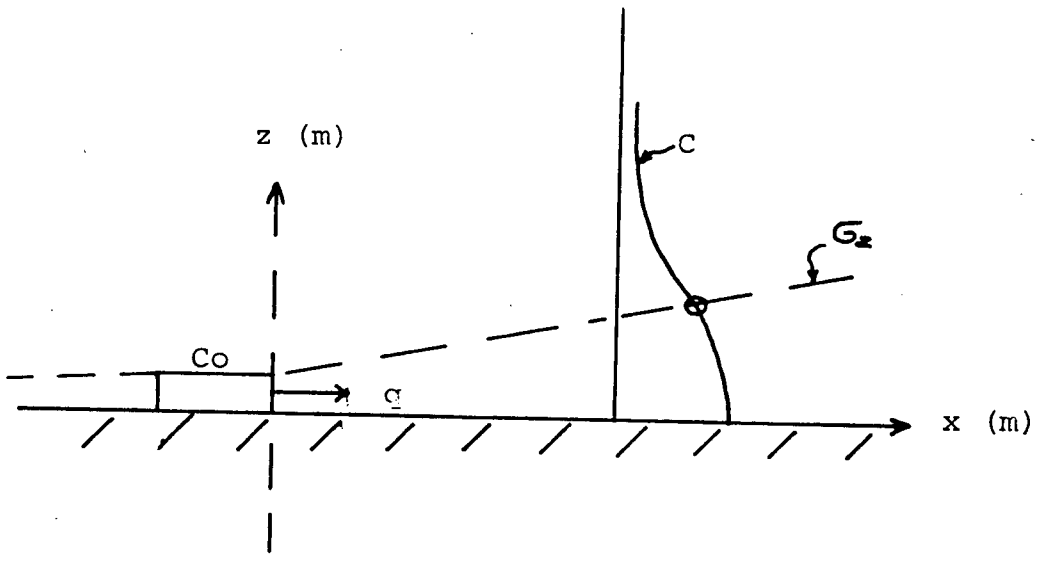


Figure 4.12: Landfill Gas Dispersion Model

Table 4.14 - Landfill Gas Concentration

Pollutant	Concentration in Landfill 1:1 (measured at flares)	Concentration at Surface 1:100	Estimated Concentrations in Air		
Distances			100m	200m	300m
Stability			C/F	C/F	C/F
Dilution ratio			97.5x/20x	215x/38x	325x/55x
			microg/m3	microg/m3	microg/m3
Methane	20-50% 326 g/m3	.2 - .5% 3.26 g/m3	167 / 815	76 / 429	65 / 296
	microgr/m3	microgr/m3			
Benzene	1,750	17.5	0.18/0.88	0.28/0.46	0.05/0.32
Ethyl benzene	18,500	185	1.9/9.3	0.86/4.9	0.57/3.4
Toluene	100,000	1,000	10.3/50.0	4.7/26.3	3.1/18.1
Methylene Chloride	40,000	400	4.1/20.0	1.9/10.5	1.2/7.3
Vinyl Chloride	12,000	120	1.2/6.0	0.6/3.2	0.4/2.2
1,1 Dichloro ethene	100	1	0.01/0.05	0.005/0.03	0.003/0.02
1,2 trans Dichloro ethene	19,500	195	2.0/9.8	0.9/5.1	0.6/3.5

Table 4.15a - Landfill - Exposure of Residents to Landfill Gas

Exposure at residences 100m to the east with 20 m3/day inhalation (or 0.29 m3/kg-bodyweight per day) and during 11 months per year (0.92) = 0.27 m3/kg-bw-day:

	Short-term maximum conc. (F-Stab.) microgr/m3	SDI microg/ kg-bw	Long-term maximum concentrat. C-stability microg/m3	CDI microgr/ kg-bw
Benzene	0.88	0.24	0.18	0.048
Ethylbenzene	9.3	2.5	1.9	0.51
Toluene	50.0	13.4	10.3	2.8
Methylene Chloride	20.0	5.3	4.1	1.1
Vinyl Chloride	6.0	1.6	1.2	0.32
1,1 Dichloro ethene	0.05	0.01	0.01	0.003
1,2 trans Dichloro ethene	9.8	2.6	2.0	0.53

Table 4.15b - Landfill - Exposure of Employees to Landfill Gas

Exposure of employees 100m to the west with 20 m3/day inhalation for 8 hours (or 0.095 m3/kg-bodyweight per day * 5/7 day/week = 0.068m3/Kg-bw/day):

	Short-term maximum conc. (1: 5) to surface conc. microgr/m3	SDI microg/ kg-bw	Long-term maximum conc. (1:10) microg/m3	CDI microgr/ kg-bw
Benzene	3.50	0.24	1.75	0.12
Ethylbenzene	37.0	2.53	18.5	1.26
Toluene	200	13.60	100	6.79
Methylene Chloride	80	5.44	40	2.71
Vinyl Chloride	24	1.63	12	0.81
1,1 Dichloro ethene	0.2	0.014	0.1	0.007
1,2 trans Dichloro ethene	39.0	2.65	19.5	1.3

Table 4.15c - Landfill Gas Health Risks to Residents 100 m East

Carcinogens

	CDI mg/kg-bw	Carcinogen Potency Factor kg/mg	Risk for Lifetime Exposure	Risk for 10 years Exposure
Benzene	$4.8*10^{-5}$	$2.6*10^{-2}$	$1.25*^{-6}$	$1.25*10^{-7}$
Methylene Chloride	$1.1*10^{-3}$	$6.3*10^{-4}$	$6.93*10^{-7}$	$6.93*10^{-8}$
Vinyl Chloride	$3.2*10^{-4}$	$2.5*10^{-2}$	$8.0*10^{-6}$	$8.0*10^{-7}$
1,1 Dichloro ethene	$3.0*10^{-6}$	$1.5*10^{-1}$	$4.5*10^{-7}$	$4.5*10^{-8}$
Total Health Risk for lifetime exposure			$1.04*10^{-5}$	$1.04*10^{-6}$
Excess risk over a lifetime			1 in 96,154	1 in 961,538

Table 4.15d - Health Risks to Employees 100m West due to Inhalation

Pollutant	CDI mg/m3	Exposure 10/70 years	Carcinogen Potency Factor kg/mg	Risk for Lifetime Exposure
Benzene	$1.2*10^{-4}$	0.143	$2.6*10^{-2}$	$4.46*10^{-7}$
Methylene Chloride	$2.71*10^{-3}$	0.143	$6.3*10^{-4}$	$2.44*10^{-7}$
Vinyl Chloride	$8.1*10^{-4}$	0.143	$2.5*10^{-2}$	$2.9*10^{-6}$
1,1 Dichloro ethene	$7*10^{-6}$	0.143	$1.5*10^{-1}$	$1.5*10^{-7}$
Total Health Risk for lifetime exposure				$3.74*10^{-6}$
Excess risk over a lifetime of				1 in 267,369

the resulting concentrations for methane and the principal priority pollutants in the landfill gas are given in Table 4.15 for two stabilities at 100, 200 and 300 m distance from emission line.

Health risks are then calculated for two exposure points, the residences 100 m east of the landfill, and the cement pipe plant immediately to the west of the landfill. The difference between these locations comprise the distances from the emission point, because the residences are 100 m to the east of outer gas probe, while the plant is immediately over a gas emission area. Furthermore, exposure at the plant is shorter at 8 hours per day than the potential worst case exposure duration of 24 hours for residences. The resulting health risks are estimated using the USEPA Superfund Health Risk Manual (USEPA, 1986). Tables 4.15a to d show the results.

The required dilution to prevent excessive health risks is calculated as follows:

Since vinyl chloride and benzene cause, respectively, about 79% and 12% of the risk, and both have similar potency factors (0.025 and 0.026), the allowable chronic daily intake can be calculated from the allowable sum of vinyl chloride and benzene caused risks:

Allowable risks from vinyl chloride and benzene:

91% of $1 * 10^{-6}$ equals $9.1 * 10^{-7}$ additional lifetime risk

Allowable Chronic Daily Intake (mg/kg-bw):

$9.1 * 10^{-7}$ 0.026 = $3.50 * 10^{-5}$ mg/kg-bw

Allowable long-term concentration:

split $3.52 * 10^{-05}$ mg/kg-bw into

vinyl chloride contribution (87%) = $3.04 * 10^{-5}$ mg/kg

and benzene contribution (13%) = $4.62 * 10^{-6}$ mg/kg

divide by 0.29 * 0.92 = 0.27 to attain allowable concentrations:

vinyl chloride = $1.14 * 10^{-4}$ mg/m^3 = 0.114 microg/m^3

benzene = $1.71 * 10^{-5}$ mg/m^3 = 0.017 microg/m^3

The division of the estimated surface concentrations through the determined allowable concentrations indicates required additional dilution:

	Estimated microg/m3	Allowable microg/m3	Additional Dilution Required
Vinyl chloride	1.2	0.114	10.53 *
Benzene	0.18	0.017	10.55 *

Therefore, an additional 11 fold dilution is required to stay under the allowable risk. Additional dilution to (97.5 fold existing times additional required 11 fold equals) 1070 fold can be determined from Figure 4.8 as 1,200m with C stability.

At both locations, potential health risks from inhalation of landfill gases can occur if the (USEPA 1986) limit of 1 in 1 million lifetime excess cancer risk is accepted as the criterion for health risks and all other assumptions hold. The calculation is conservatively high, particularly with the large uncertainties in the actual ambient air concentrations. Nonetheless, the landfill gas emissions seem to possibly cause explosion and inhalation health risks to residents within 100 to 200 m of the

outer gas exit point where the total dilution is below 10,000 to 100,000 fold necessary to reduce health risks to under 1 in 1 million excess cancer risk.

Coincidentally, dilutions of 1,000 to 10,000 fold are necessary to reduce landfill odors under the odor threshold. Hence, the area of potential health effects corresponds to the area where landfill gas odors were observed.

Odors therefore appear to be a good indicator for risks. The odor assesment supports the findings in this section in that it confirms that residents and employees may be exposed to high concentrations of landfill gas. Both odor and health impacts occur in the same limited distance of approximately 200 m from the landfill boundary.

4.2.2 Air Quality Impacts from Incinerators

Air emission impacts criteria are defined on two levels:

1. air quality deterioration through some contribution to ambient pollutant concentrations;
2. potential health impacts as defined by the USEPA (1986) criterion of an excess lifetime cancer risk of 1 in 1 million.

Dispersion modelling is used to determine concentration increases for incinerator emissions. Health risks are determined and compared with the stipulated additional health risk limit; air quality deterioration is assumed present if the increase in air pollutants is in the order of magnitude of background concentrations.

Gaseous Emission Dispersion and Groundlevel Concentrations

The two worst case scenarios for air emissions were derived under the odor impact section. They consist of groundlevel inversions in the winter and unstable days in summer. Under these conditions, the resulting groundlevel concentrations from stack gases can be estimated using trapping conditions at D to F (high) stabilities and low winds to reflect strong inversion scenarios, while unstable (A or B) conditions and moderate winds are assumed for summer conditions. However, the highest instability (A or B) levels seldom occur in the Willamette Valley so C level stability is assumed with average wind speeds of 3 m/s. The increased wind speed at stack height over the measured wind speed at 10 m height is neglected conservatively (see Appendix 4.D.).

The main incinerator emissions of concern comprise particulate matter (TSP), smog producing agents, such as nitrogen oxides (NOx), acid gases such as sulfur dioxides (SO2), hydrogen chlorides and fluorides (HCL and HF), an array of heavy metals, e.g., beryllium (Be), cadmium (Cd), copper(Cu), Chromium (Cr), lead (Pb), mercury (Hg), nickel (Ni) and zinc (Zn) (Tabarasan, 1984, LMRP, 1984), and carcinogenic organics, especially dioxins and furans (TCDD's and TCDF's). While volatile organic chemical (VOC's) emissions were measured at the Salem incinerator, there was some doubt whether they were artifacts of the sampling and analysis method (pers. comm. van dem Fange, 1988). However, other studies report significant concentrations of VOC's from burning municipal waste and refuse derived fuel in Swedish mass burning incinerators (Peterson, 1987), and from burning waste in an

incinerator and burning refuse derived fuel in a dedicated boiler (Ozvacic et al. 1985). These unproven, but probable VOC emissions at Salem will be tested in a sensitivity analysis of the emission dispersion model to long concentrations of chlorophenols, benzo (a) pyrene, and PCB's (Peterson, 1987, Ozvacic, et.al.,-1985).

The Salem incinerator emission rates are taken from the Air Quality Test Report (Zurlinden et al., 1986) and from Hahn et al. (1986) for all measured pollutants. Copper and zinc emission concentrations were prorated with the particulate emission ratio from typical incinerator emissions in Europe (Tabarasan, 1984). Maximum emission rates occur at full burning capacity of 152,000 tonnes p.a.; average emission rates correspond to a burning rate of 130,000 tonnes p.a. The emission concentrations and rates for major pollutants are listed in Table 4.16. The detailed calculations are carried out in the Appendix 4.D with data from Seton, Johnson and Odell (1984).

Emission Transport

The basic dispersion model consists of an elevated source (stack) with a virtual source at height H equal to the stack height h plus the heat rise h (see Appendix 4.D for the calculation of H). From this point (H), gaseous and particulate emissions disperse differently. While some compounds stay gaseous (hydrogen chlorides, fluorides, nitrogen oxides, hydrocarbons, carbon monoxide, sulfur oxides,) others may adsorb onto particulate (trace metals, dioxins and furans, EPS Canada, 1986). Therefore dispersion models are constructed here for both gaseous

Table 4.16: Incinerator - Emission Rates and Concentrations for Main Pollutants

Pollutant	Emission Rates		Emission Concentration at 33 Nm3/s average volume flow rate
	Average (at 91.5% capacity)	Maximum (at 100% capacity)	
	g/s	g/s	mg/Nm^3
NO_x	13.7	15.4	428
SO_2	2.6	3.9	108.3
CO	0.52	0.58	16.1
Particulate	0.57	0.74	20.6
HCL	0.42	0.45	0.0125
HF	0.012	0.018	$5*10^{-4}$
TCDD	$4.8*10^{-9}$	$5.7*10^{-9}$	$1.58*10^{-7}$
VOC's	0.038	0.05	$1.4*10^{-3}$
Beryllium*	$5.5*10^{-8}$	$6.8*10^{-8}$	$1.89*10^{-6}$
Cadmium*	$3.4*10^{-6}$	$4.5*10^{-6}$	$1.25*10^{-4}$
Copper	$1.42*10^{-3*}$	$1.78*10^{-3}$	$4.94*10^{-2}$
Chromium (Total)	$6.6*10^{-6}$	$8.25*10^{-6}$	$2.3*10^{-4}$
Chromium (hexavalent)	$6.6*10^{-7}$	$8.3*10^{-7}$	$2.3*10^{-5}$
Lead	$7.6*10^{-4}$	$1.0*10^{-3}$	$2.8*10^{-2}$
Mercury	$8.0*10^{-3}$	$9.0*10^{-3}$	0.25
Nickel*	$2.3*10^{-3*}$	$3.3*10^{-3}$	$9.17*10^{-2}$
Zinc	0.04	0.051	1.42

Legend: Star in first column indicates carcinogen

Star in second column indicates emission rates derived by prorating with particulate concentrations from values in Tabarasan, 1984.

and particulate behavior. Both models assume that all pollutants disperse identically and in proportion to a unit emission of 1 g/s from the stack. The results are compared to determine the worst case.

Gaseous Transport

Normal dispersion from an elevated source assumes normally distributed concentration profiles on horizontal and vertical axes with increasing standard deviations as a function of distance. When the lower plume boundary touches the ground, the model shows a reflection of the concentration by mirroring a virtual source at minus the effective stack height. The maximum groundlevel concentrations occur down wind from this initial impingement point.

In trapping conditions, an additional mirror surface is assumed at the trapping levels above the stack height so the plume concentrations are reflected both on the ground and at the trapping (inversion) levels. The concentrations per unit emission (g/sec) are calculated in Appendix 4.D for both dispersion conditions and for different stability classes. The results are shown in Figure 4.13. The results for both scenarios are compared to determine the worst case. From the graph it is apparent that normal dispersion at C stability and 3 m/s wind speed produce higher groundlevel concentrations than any likely trapping conditions. The curves in Figure 4.13 indicate the maximum to occur at 700 m (A stability) to 1,500 m (C stability) from the stack. Since highly unstable (A and B) weather conditions are not common in the Willamette Valley, C stability is considered the

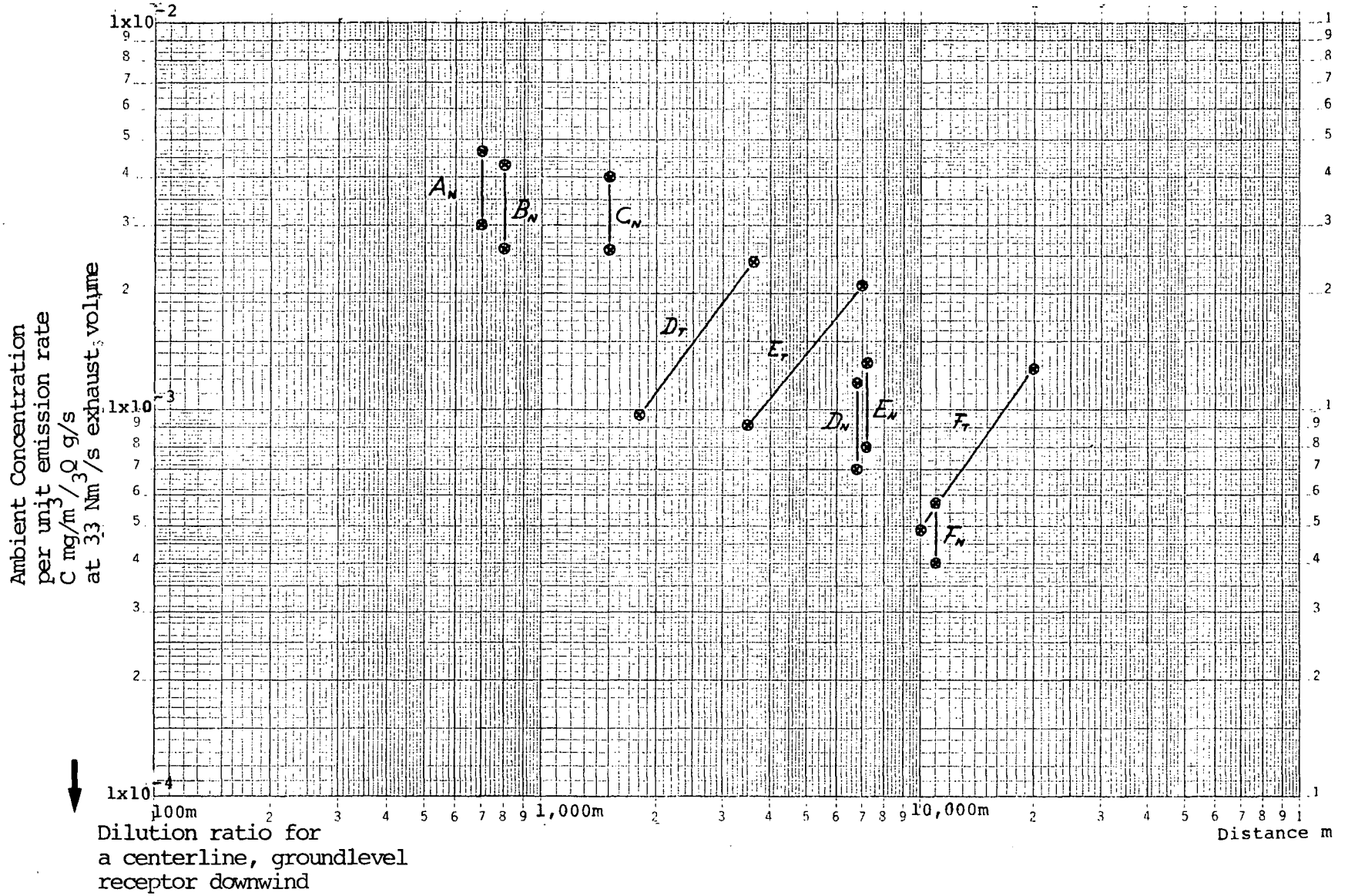


Figure 4.13: Groundlevel, Centerline Concentrations of Non-reactive Pollutants from an Elevated, Point Source

maximum common, worst-case condition. Therefore the maximum concentrations for gaseous transport are taken from this scenario. The minimum dilution ratio of 0.004 mg/m3/groundlevel concentration per unit emission g/s at C stability and 3 m/s wind speed occurs at 1,500 m distance. This figure is used to calculate the resulting ground level, centerline concentrations in Table 4.17.

Particulate Transport

Particulate dispersion is modelled with Gaussian distributions, but particles experience a general settling motion due to gravity. The ground reflection term is dropped because particles are deposited on the ground. The result is a downward sloping plume centerline. The Gaussian model applies here too, but must be modified to eliminate ground reflections and to include a downward vertical settling velocity. These changes reduce the distance of maximum concentrations. The results as particulate concentrations in the air are the data for the assessment of health impacts from inhalation.

Air pollutant health impacts from oral intake of particulate pollutants may also result from deposition of particulate-borne contaminants on edible plants. The deposition rate is simply the volume rate of deposition times concentration per area, or by simplification, equal to the settling velocity times concentration (Wark and Warner, 1980). Since settling velocities vary with particle size, the average settling velocity must be weighted by the mass fractions in particle size ranges. With the data on the

INCINERATOR EXHAUST GAS IMPACTS

Gaseous Emission Transport

Pollutants	Maximum emission rate	Average emission rate	Dilution Ratio at 3m/s	Groundlevel concentration at 3m/s wind speed maximum	average	Maximum Averages for Time Periods 3 hr max. = 0.9 x 1 hr max	8 hr max. = 0.75 x 1 hr max	24 hr max. = 0.4 x 1 hr max
	gram/sec	gram/sec	4.0000E-03	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3
NOx	1.5400E+01	1.3700E+01	NOx	6.1600E-02	5.4800E-02	5.5440E-02	4.6200E-02	2.4640E-02
SOx	3.8600E+00	2.6000E+00	SOx	1.5440E-02	1.0400E-02	1.3896E-02	1.1580E-02	6.1760E-03
HCl	4.5000E-01	4.2000E-01	HCl	1.8000E-03	1.6800E-03	1.6200E-03	1.3500E-03	7.2000E-04
TSP	7.5000E-01	5.7000E-01	TSP	3.0000E-03	2.2800E-03	2.7000E-03	2.2500E-03	1.2000E-03
TCDD	3.8300E-11	1.4500E-11	TCDD	1.5320E-13	5.8000E-14	1.3788E-13	1.1490E-13	6.1280E-14
Cl Phen	0	0		0	0	0	0	0
Benz(a)pyr	0	0		0	0	0	0	0
PCB	0	0		0	0	0	0	0
Be	6.8000E-08	5.5000E-08	Be	2.7200E-10	2.2000E-10	2.4480E-10	2.0400E-10	1.0880E-10
Cd	4.5000E-06	3.4000E-06	Cd	1.8000E-08	1.3600E-08	1.6200E-08	1.3500E-08	7.2000E-09
Cu	1.7800E-03	1.4200E-03	Cu	7.1200E-06	5.6800E-06	6.4080E-06	5.3400E-06	2.8480E-06
Cr tot	8.2500E-06	6.6000E-06	Cr tot	3.3000E-08	2.6400E-08	2.9700E-08	2.4750E-08	1.3200E-08
Cr6	8.3000E-08	6.6000E-07	Cr6	3.3200E-10	2.6400E-09	2.9880E-10	2.4900E-10	1.3280E-10
Pb	1.0000E-03	7.6000E-04	Pb	4.0000E-06	3.0400E-06	3.6000E-06	3.0000E-06	1.6000E-06
Hg	9.0000E-03	8.0000E-03	Hg	3.6000E-05	3.2000E-05	3.2400E-05	2.7000E-05	1.4400E-05
Ni	1.2700E-04	1.0600E-04	Ni	5.0800E-07	4.2400E-07	4.5720E-07	3.8100E-07	2.0320E-07
Zn	5.1100E-02	4.0000E-02	Zn	2.0440E-04	1.6000E-04	1.8396E-04	1.5330E-04	8.1760E-05

Table 4.17 - Incinerator Gaseous Emission Concentrations

particle size distributions at the Salem incinerator (Hahn et al., forthcoming) and settling velocity curves for particles (Wark and Warner, 1980) the weighted average settling velocity was determined (see Appendix 4.D) as 0.13 cm/s.

Using the Gaussian model for particulate transport, the maxima for groundlevel concentrations and deposition rates were calculated (see Table 4.18 below). The maxima occur at 1,200 m distance in wind direction at $1.87 \times 10^{(-6)}$ g/m3 particulate concentration (Cp) and 2.24×10^{-9} g/m2-s particulate deposition (Wp) for a unit particulate emission (1 g/s).

Concentrations of respirable particulate (under 5 microns) in air can be entered into the health risk assessment for inhalation uptake. Deposited particulates, however, undergo decay due to oxidation, washing out with rain, and, possibly, biodegradation. The decay effects are represented by the decay factor lambda, which is a function of the halflife in air. The maximum particulate pollutant density is reached at equilibrium, i.e., when removal (decay) reaches deposition rate. Thus, the relationship for the maximum surface concentration of deposited particulate concentration can be formulated as a first-order relationship:

$$\frac{dC}{dt} = - \lambda * C_s + w_p = 0 \qquad (1)$$

for equilibrium conditions, $\frac{dCs}{dt}$ equals zero, hence

$$\text{with} \quad \lambda = \frac{Ln\ 2}{t_{1/2}}, \quad t_{1/2} = \text{halflife} \qquad (2)$$

$$\text{surface concentration } C_s = \frac{w_p}{\lambda} = \frac{w_p \quad t_{1/2}}{0.692} \frac{g}{m2} \qquad (3)$$

Table 4.18a - Incinerator - Particulate Dispersion Concentrations and Deposition

Virtual Height = 110 m

Wind Speed = 3 m/s

Stability = C

Distance	Standard Deviations in m y	z	Particulate Concentrations in air Q_p * mg/m^3	Particulate Deposition on Ground Q_p * mg/m^2 -sec
300 m	35	21	$8.2 * 10^{-8}$	$1.07 * 10^{-10}$
500 m	55	34	$1.54 * 10^{-4}$	$2.0 * 10^{-7}$
700 m	75	46	$8.95 * 10^{-4}$	$1.16 * 10^{-6}$
1,000 m	110	64	$1.74 * 10^{-3}$	$2.26 * 10^{-6}$
1,200 m	130	75	$1.87 * 10^{-3}$	$2.44 * 10^{-6}$
1,500 m	150	85	$1.82 * 10^{-3}$	$2.36 * 10^{-6}$
2,000 m	220	130	$1.3 * 10^{-3}$	$1.7 * 10^{-6}$

Halflife values for absorbed contaminants range from 4.8 days (minimum, USEPA, 1986) for metals in air, to 14 days for dioxins and furans (Swiss Ministry of Environment, 1983). The maximum pollutant density on the ground surface (mg/m^2) is equal to 7 (for halflives of 4.8 days) to 20 (for halflives of 14 days) times the air concentrations (mg/m^3). The surface concentrations are listed in Table 4.18b below parallel to the concentrations in air.

Health Risks from Incinerator Emissions

Health risks may arise from inhalation of gaseous pollutants or the inhalation and oral consumption of particulate emissions. Identical health risk assessments were carried out for inhalation of gaseous and particulate concentrations in air. Particulate deposition on the ground, however, was evaluated as an oral uptake through edible plants. For both health risk scenarios, a significant health risk criterion is assumed to be an increase of equal to or over 1 in 1 million additional cancer risk for a lifetime (USEPA, 1986).

The risk assessment from gaseous emissions follows the standard procedure (USEPA, 1986, see Appendix 4.E) with the slight reduction of daily intakes by prorating the exposure by a factor of 0.83 for the prevailing wind direction during 10 of 12 months per year. The results for gaseous pollutants (Table 4.19) amount to total risks of approximately 1 in 5.86 million additional carcinogenic risk over lifetime and well under 1 in non-carcinogenic risk. This additional risk is below the stipulated health risks limit of 1 in 1 million.

Particulate Emission Transport

	Maximum emission rate g/s	Average emission rate g/s	Dilution Ratio at 3 m/s 1.8700E-03	Air Concentration maximum mg/m3	Air Concentration minimum mg/m3	Maximum Averages for Time Period 3 hr max. = 0.9 x one hr max mg/m3	8 hr max. = 0.7 x one hr max mg/m3	24 hr. max. = 0.4 x one hr max mg/m3
NOx	1.5400E+01	1.3700E+01		2.8798E-02	2.5619E-02	2.5918E-02	2.1598E-02	1.1519E-02
SOx	3.8600E+00	2.6000E+00		7.2182E-03	4.8620E-03	6.4963E-03	5.4136E-03	2.8872E-03
HCl	4.5000E-01	4.2000E-01		8.4150E-04	7.8540E-04	7.5735E-04	6.3112E-04	3.3660E-04
TSP	7.5000E-01	5.7000E-01		1.4025E-03	1.0659E-03	1.2622E-03	1.0518E-03	5.6100E-04
TCDD	3.8300E-11	1.4500E-11		7.1621E-14	2.7115E-14	6.4458E-14	5.3715E-14	2.8648E-14
Cl Phen	0	0		0	0	0	0	0
Benz(a)pyr	0	0		0	0	0	0	0
PCB	0	0		0	0	0	0	0
Be	6.8000E-08	5.5000E-08		1.2716E-10	1.0285E-10	1.1444E-10	9.5370E-11	5.0864E-11
Cd	4.5000E-06	3.4000E-06		8.4150E-09	6.3580E-09	7.5735E-09	6.3112E-09	3.3660E-09
Cu	1.7800E-03	1.4200E-03		3.3286E-06	2.6554E-06	2.9957E-06	2.4964E-06	1.3314E-06
Cr (tot)	8.2500E-06	6.6000E-06		1.5427E-08	1.2342E-08	1.3884E-08	1.1570E-08	6.1710E-09
Cr (hex)	8.3000E-08	6.6000E-07		1.5521E-10	1.2342E-09	1.3968E-10	1.1640E-10	6.2084E-11
Pb	1.0000E-03	7.6000E-04		1.8700E-06	1.4212E-06	1.6830E-06	1.4025E-06	7.4800E-07
Hg	9.0000E-03	8.0000E-03		1.6830E-05	1.4960E-05	1.5147E-05	1.2622E-05	6.7320E-06
Ni	1.2700E-04	1.0600E-04		2.3749E-07	1.9822E-07	2.1374E-07	1.7811E-07	9.4996E-08
Zn	5.1100E-02	4.0000E-02		9.5557E-05	7.4800E-05	8.6001E-05	7.1667E-05	3.8222E-05

Pollutant	Dilution Ratio Air conc. to surface density	Decay rate in air lambda	Surface Density maximum mg/m2	Surface Density minimum mg/m2	Maximum Averages for Time Periods 3 hr max. mg/m2	8 hr max. mg/m2	24 hr max. mg/m2
NOx							
SOx							
HCl							
TSP							
TCDD	2.1000E-01	5.0000E-02	1.6086E-10	6.0900E-11	1.4477E-10	1.2064E-10	6.4344E-11
Cl phens	2.1000E-01	1.4000E-01	0	0	0	0	0
Benz(a)pyr	2.1000E-01	1.4000E-01	0	0	0	0	0
PCBs	2.1000E-01	1.4000E-01	0	0	0	0	0
Be	2.1000E-01	1.4000E-01	1.0200E-07	8.2500E-08	9.1800E-08	7.6500E-08	4.0800E-08
Cd	2.1000E-01	1.4000E-01	6.7500E-06	5.1000E-06	6.0750E-06	5.0625E-06	2.7000E-06
Cu	2.1000E-01	1.4000E-01	2.6700E-03	2.1300E-03	2.4030E-03	2.0025E-03	1.0680E-03
Cr (tot)	2.1000E-01	1.4000E-01	1.2375E-05	9.9000E-06	1.1137E-05	9.2812E-06	4.9500E-06
Cr (hex)	2.1000E-01	1.4000E-01	1.2450E-07	9.9000E-07	1.1205E-07	9.3375E-08	4.9800E-08
Pb	2.1000E-01	1.4000E-01	1.5000E-03	1.1400E-03	1.3500E-03	1.1250E-03	6.0000E-04
Hg	2.1000E-01	1.4000E-01	1.3500E-02	1.2000E-02	1.2150E-02	1.0125E-02	5.4000E-03
Ni	2.1000E-01	1.4000E-01	1.9050E-04	1.5900E-04	1.7145E-04	1.4287E-04	7.6200E-05
Zn	2.1000E-01	1.4000E-01	7.6650E-02	6.0000E-02	6.8985E-02	5.7487E-02	3.0660E-02

Table 4.18b - Incinerator - Particulate Emission Concentration and Deposition

Gaseous Emission Transport

Pollutant	Daily Intake by inhalation of .29 m3/kg-bodyweight for 10 months of year SDI mg/kg	CDI mg/kg	Carcinogen Risk at Lifetime Exposure	Non-Carcinogen Ratio of Intake to allowable daily intake Sub-chron	Chronic
NOx	1.4886E-02	1.3243E-02		5.1333E-02	4.5666E-01
SOx	3.7313E-03	2.5133E-03		9.8974E-02	1.7333E-01
HCl	4.3500E-04	4.0600E-04		3.0000E-02	9.3333E-02
TSP	7.2500E-04	5.5100E-04		1.3157E-02	2.7142E-02
TCDD	3.7023E-14	1.4016E-14	2.1865E-09		
Cl Phen	0	0		0	0
Benz(a)pyr	0	0	0		
PCB	0	0			
Be	6.5733E-11	5.3166E-11	2.5838E-10		
Cd	4.3500E-09	3.2866E-09	2.0048E-08		
Cu	1.7206E-06	1.3726E-06			1.3726E-04
Cr (tot)	7.9750E-09	6.3800E-09			1.1258E-06
Cr (hex)	8.0233E-11	6.3800E-10	2.6158E-08		1.2509E-07
Pb	9.6666E-07	7.3466E-07			1.7085E-03
Hg	8.7000E-06	7.7333E-06		1.7058E-02	1.5163E-01
Ni	1.2276E-07	1.0246E-07	1.2193E-07	4.2333E-07	3.5333E-06
Zn	4.9396E-05	3.8666E-05		4.9396E-04	3.8666E-03
	Total Risks over life		1.7058E-07	1.7553E-02	1.5735E-01
	Additional Risk		5.8621E+06	<< 1	<< 1

Legend: SDI = Sub-chronic daily intake
CDI = Chronic daily intake

Table 4.19 - Incinerator Gaseous Emission Exposure and Health Risks

Health risks from particulate pollutants are estimated by standard procedure with the prorated reduction of airborne daily intake for the duration of prevailing winds. The oral intake is based on traditional crop growing densities (Lorenz and Maynard, 1980) and average consumption of leafy vegetables in Canada (Statistics Canada and Agriculture Canada, 1981, 1983 and 1984), in particular for lettuce and celery, because these plants are not washed before packing (pers. comm. M. Sweeney, B.C. Ministry of Agriculture and Fisheries, 1987).

The intake of contaminants was calculated from the net surface area of the plants times the surface concentrations (see Appendix 4.D). Exposure was assumed to occur during a 70 year lifetime for inhalation and oral intake. The results are presented in Table 4.20 below for carcinogens and non-carcinogenic pollutants. The total health risks of inhaled and orally consumed pollutants amount to one in 14.8 million, for a safety factor of 14.8.

Sensitivity Analysis

The health risks resulting from possible variations in some key factors are calculated and compared with the base case. Table 4.21 shows the resulting total additional health risks for higher wind speed, different time period averages, and for estimated volatile organic emissions. Total health risks in the first two cases remain under acceptable risks, but exceed the stipulated allowable health risk in the latter case. Very low concentrations of organic carcinogens (benzo(a)pyrene and PCB, Ozvacic et al.

Table 4.20 - Incinerator Particulate Emission Exposure and Health Risks by Inhalation and Ingestion

Particulate Emission Transport Pollutant	Daily Intake by Inhalation of .29 m3/kg for 10 months per year SDI mg/kg	CDI mg/kg	Carcingen Risks at lifetime Exposure	Non-carcinogen Risks Ration of allowable daily intake Sub-chronic	Chronic
NOx	6.9595E-03	6.1912E-03		2.3998E-02	2.1349E-01
SOx	1.7443E-03	1.1749E-03		4.6270E-02	8.1033E-02
HCl	2.0336E-04	1.8980E-04		1.4025E-02	4.3633E-02
TSP	3.3893E-04	2.5759E-04		6.1513E-03	1.2689E-02
TCDD	1.7308E-14	6.5527E-15	1.0222E-09		
	0	0		0	0
	0	0	0		
	0	0			
Be	3.0730E-11	2.4855E-11	1.2079E-10		
Cd	2.0336E-09	1.5365E-09	7.4674E-09		
Cu	8.0441E-07	6.4172E-07			6.4172E-05
Cr (tot)	3.7283E-09	2.9826E-09			5.2635E-07
Cr (hex)	3.7509E-11	2.9826E-10	1.4495E-09		5.8483E-08
Pb	4.5191E-07	3.4345E-07			7.9873E-04
Hg	4.0672E-06	3.6153E-06		7.9750E-03	7.0888E-02
Ni	5.7393E-08	4.7903E-08	5.7004E-08	1.9790E-07	1.6518E-06
Zn	2.3092E-05	1.8076E-05		2.3092E-04	1.8076E-03
	Total risk over life		6.7063E-08	8.2061E-03	7.3561E-02
	Additional risk		1.4911E+07	<< 1	<< 1

Pollutant	Daily Intake by Ingestion is surface density times 4.7000E-05 for 10 months/year times 8.3333E-01 mg/kg-d	mg/kg-d	Carcinogen Risk at lifetime exposure	Non-Carcinogen Risks Sub-chron	Chronic
TSP					
TCDD	6.3003E-15	2.3852E-15	3.7209E-10		
Cl phens	0	0		0	0
Benz(a)pyr	0	0	0		
PCBs	0	0	0		
Be	3.9950E-12	3.2312E-12		7.9900E-09	6.4625E-09
Cd	2.6437E-10	1.9975E-10		9.1163E-07	6.8879E-07
Cu	1.0457E-07	8.3425E-08		2.8263E-06	2.2547E-06
Cr (tot)	4.8468E-10	3.8775E-10		3.4272E-11	3.4897E-10
Cr (hex)	4.8762E-12	3.8775E-11		1.9505E-10	7.7550E-09
Pb	5.8750E-08	4.4650E-08		4.1964E-05	3.1892E-05
Hg	5.2875E-07	4.7000E-07		2.5178E-04	2.2380E-04
Ni	7.4612E-09	6.2275E-09		2.5728E-08	2.1474E-07
Zn	3.0021E-06	2.3500E-06		1.4295E-05	1.1190E-05
	Oral intake risk		3.7200E-10	3.1181E-04	2.7006E-04
	Additional risk		2.6881E+09		
Total additional risk			6.7435E-08	8.5179E-03	7.3831E-02
Additional risk probability			1.4829E+07		

Table 4.21 - Incinerator Sensitivity Analysis for Health Risks

	Carcinogenic Risks	Non-carcinogenic risks sub-chronic	chronic	
Base Case				
Gaseous	1 in 5.86 million	0.018	0.16	<1
Particulate	1 in 14.8 million	0.009	0.07	<1
Wind-seed 5 m/s				
Gaseous	1 in 7.32 million	0.014	0.126	<1
Particulate	1 in 22.9 million	0.0055	0.048	<1
Time period				
Gaseous				
3 h max	1 in 13.7 million	0.008	0.076	<1
8 h max	1 in 16.4 million	0.008	0.0623	<1
24 h max	1 in 30.8 million	0.008	0.033	<1
Volatile Organics present				
Gaseous	1 in 607,990	0.018	0.16	<1
Particulate	1 in 1,011,120	0.0085	0.075	<1

1985) can easily increase the carcinogenic risks. As little as $2.5 * 10^{-4}$ g/s emission rate, or 15 to 20 mg/Nm^3 concentration each of PCB and benzo(a)pyrene will increase the health risks to significant levels. The total additional cancer health risks with these low, possible concentrations of VOC carcinogens amount to 1 in 607,990 for gaseous dispersion and 1 in 1 million for particulate transport compared with 1 in 5.86 million and 1 in 15 million for the respective base emission cases (see Appendix 4.D). Ozvacic et al. (1985) report emission rates from Toronto incinerators and RDF burning plants for PCB's, chlorinated benzenes and chlorophenols between 16 and 92 micrograms per Nm^3. They also show trace concentrations of chlorinated organics in the incoming waste stream. Although there are no data to support the presence of chlorinated organics in the waste stream entering the Salem incinerator, it is possible that minimal amounts of PCB's, chlorinated benzenes and chlorophenols are contained in the waste stream (from electrical components, carbon paper, treated wood, etc.) and are emitted from the stack.

In conclusion, significant health risks are shown not to result from incinerator emissions. But small additional amounts of unproven carcinogenic pollutants can easily generate significant risks in the maximum emission concentration zones at 700 to 1,500 m in prevailing wind directions. Table 4.22 compares maximum estimated incinerator impacts on air quality with ambient air quality. Although the comparison shows some influence of the incinerator on NO_2 concentrations, the comparison is hampered by two factors: (a) the time interval basis is not identical for some

impact and background measurements, and (b) the background measurements are taken in Portland where substantially higher pollutant concentrations are expected.

Air quality impacts from the Salem incinerator consist of air quality deterioration based on the comparison in Table 4.22. Although no significant health risks occur, some quality deterioration does result for the prevailing wind directions in the host community. Within 700 m to 3,000 m downwind, the area north to northeast and south to southwest are estimated to experience slight air quality impacts. These are rated as a level of 1 for mere air quality deterioration.

4.3 Water Quality Impacts From Waste Facilities

Water quality impacts from waste facilities may stem from effluent discharges to ground and surface waters, while the consumptive needs of a landfill are usually very small, i.e., for watering of roadways and fill area to prevent dust, and can be disregarded. Conversely, the water discharges from an incinerator are usually innocuous, or small and consist of cooling water and sanitary sewer wastewater, provided the ash quench water is recycled as is the case of the Salem incinerator. Thus, the analysis concentrates on leachate discharges from landfills and consumptive uses for the incinerator.

Three types of water quality impacts are considered here: health risks to humans, water quality deterioration and degradation of wildlife habitat due to water quality loss.

Table 4.22 - Incinerator Air Quality Impacts

Pollutant	Time Interval	Maximum Incinerator Impact microgr/ m3	Present Ambient Background Level microgr/ m3	Incinerator Contribution %
Particulate	1 hour	3	130	2.3
SO2	3 hours	13.9	963	1.4
NO2	24 hours	24.6	52[a]	47.4*
Pb	24 hours	0.0016	0.46[a]	0.35*

a = annual average in Portland, OR.
* = note comparison of average values over different time intervals and at different locations.

4.3.1 Landfill Groundwater and Surface Water Impacts in Tacoma

The criteria for determining the presence and strength of an impact caused by landfill leachate discharges are based on causal connections between landfill leachate and observed changes in the receiving water. Specifically, the causal connection requires that a likely transport pathway be available and the necessary transport conditions be met. Furthermore, the pollutants in the receiving waters must be identical to those emitted by the landfill, while other sources of similar pollutants must be shown to be absent or unlikely to contribute significantly to the contaminant levels in the receiving waters. The following assessment considers these conditions based on the information derived from the Phase I Remedial Investigation Report - Tacoma Landfill (Black and Veatch, 1987).

Contaminant Transport Route

The likely transport route is identified in the remedial report through the characterization of the strata under the Tacoma landfill (Black and Veatch, 1987). Four continuous geologic units extend from the landfill to the downgradient wells and the discharge areas:

1. Vashon till, unsaturated, 0 to 50 feet (0 to 15 m) thick with estimated hydraulic conductivity of 10^{-6} to 10^{-7} cm/sec. This relatively impermeable, "hardpan" layer is missing in some patches under the landfill because of natural erosion or landfill excavation operations (Black and Veatch, 1987). However, this layer basically provides a natural impermeable barrier to downward leachate migration.

2. Vashon advance outwash, unsaturated, 20 to 50 feet thick (6 to 15 m) thick, slightly silty to silty, gravelly sand with an estimated hydraulic conductivity of 10^{-2} to 10^{-3} cm/sec.

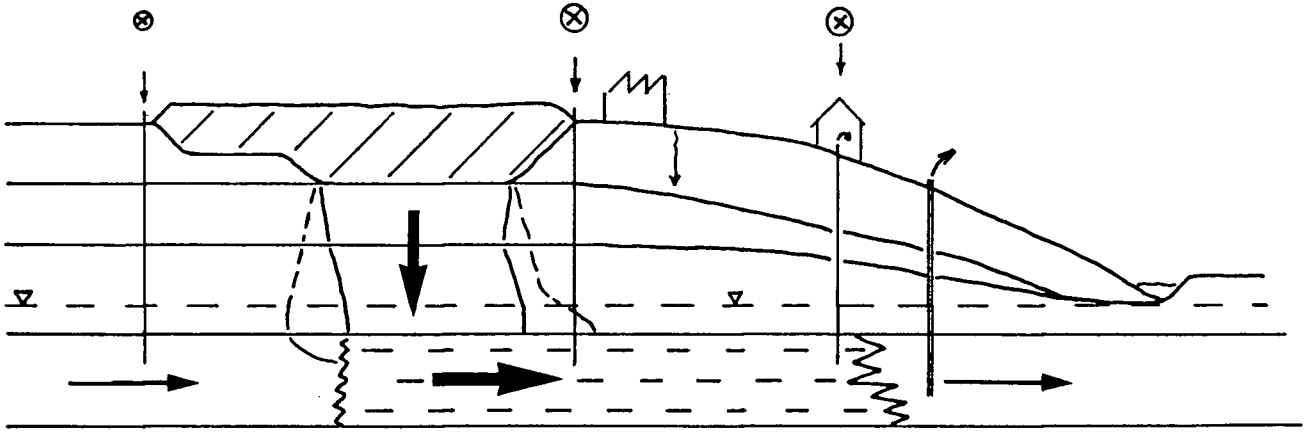
3. Colvos sand, partially saturated in the lower levels, about 70 feet (21 m) thick with an estimated hydraulic conductivity of $1*10^{-2}$ to $5*10^{-2}$ cm/s.

4. Older gravel, saturated, sandy gravel of 50 feet thickness (15 m) and 10^{-1} cm/s hydraulic conductivity. This layer is an important regional aquifer for many municipal and domestic wells. The top is about 120 feet (36.5 m) under the landfill surface while it is underlain by an old till layer.

The transport mechanism operates through an estimated infiltration of 270mm, or 30% of the 900mm (37 inches) annual precipitation, onto the filled waste. Where the till layers underlie the waste, the downward migration of leachate is slow and perched lenses may form with discharge towards the areas where this layer is interrupted (Black and Veatch, 1987). Without the Vashon till, the leachate flows through the Vashon outwash and the Colvos Sand to the older gravel aquifer. The tainted drinking water wells are located downgradient in the same older gravel layer, to the west of the landfill. This pathway is illustrated in Figure 4.14 (after Black and Veatch, 1987 and USEPA, 1987).

The downward, southwesterly direction of the flow is caused by decreasing head downward and to the southwest (Figure 4.20; Black and Veatch, 1987). The landfill is in a local recharge zone, while Leach Creek is a partial discharge zone. The average linear groundwater velocities range from 0.2m/day to 0.65 m/day in the Older Gravel. The direction of the natural groundwater flow is a plausible transport route for landfill contaminants towards contaminated wells down gradient. The arrow in the Figure 4.14 shows the possible pathway; "X"s mark wells with detected volatile organic contaminants above background levels.

The type and location of detected contaminants in the



Legend: "x" s indicate wells with detected contaminants

Figure 4.14: Landfill Leachate Emission Pathway

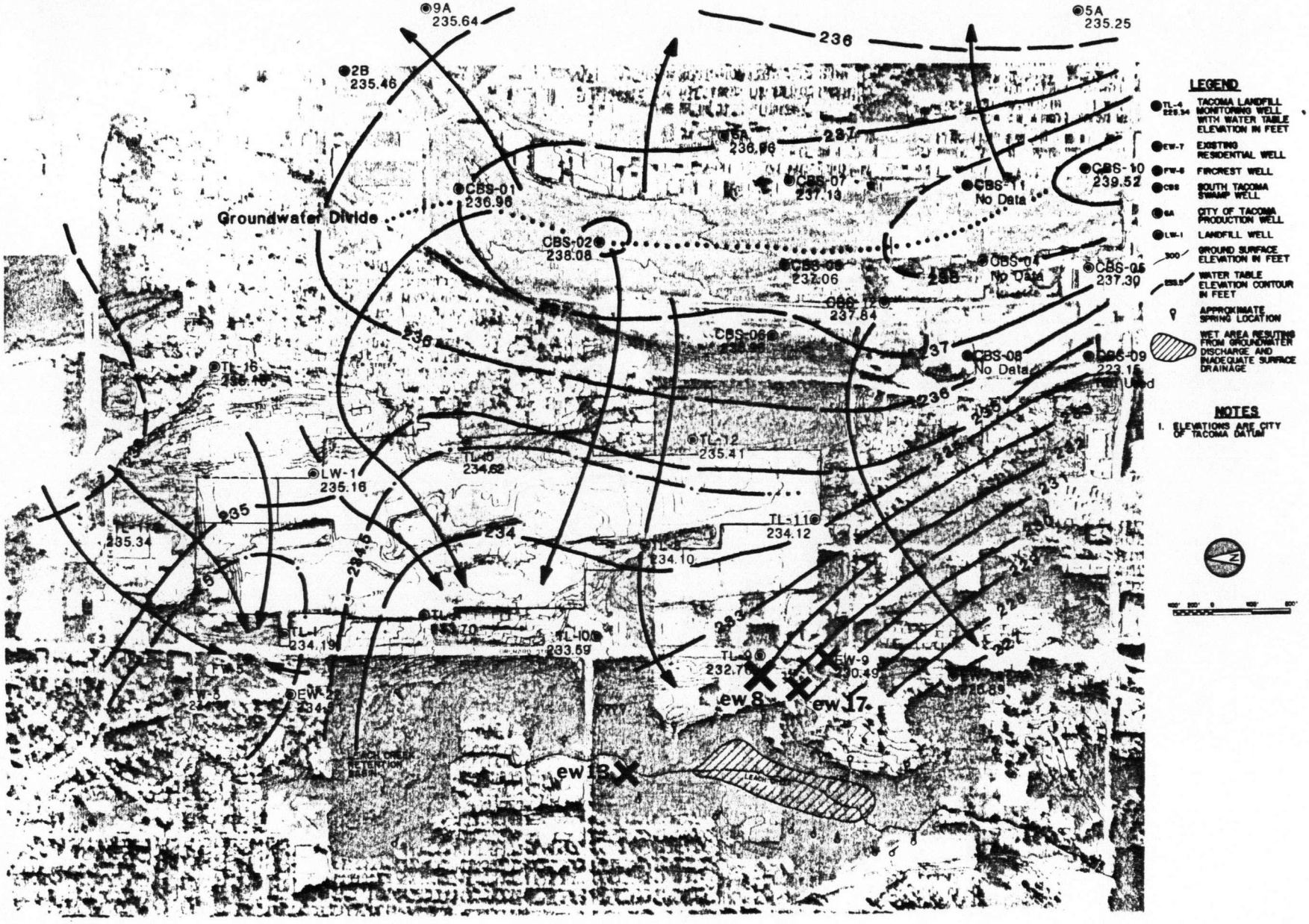


Figure 4.15: Landfill - Hydraulic Gradients and Flow Direction

Table 4.23
Summary of Volatile Organic Compounds
Detected in Ground Water Samples
Source: Black and Veatch, 1987
Concentrations in microgram/L

	Downgradient Domestic Wells						Landfill Boundary Wells									
							Well Number									
	EW-08		EW-09	EW-13	EW-17		TL-1c	TL-4	TL-8a	TL-8b	TL-9a	TL-9b	TL-11	TL-15a	TL-15b	TL-17a
Compound	08/86	12/86	08/86	12/86	10/86	12/86	10/86	11/86	10/86	10/86	10/86	10/86	10/86	10/86	10/86	10/86
Benzene	-	-	-	NA	-	NA	-	9	6	-	-	-	4	-	-	-
Chlorobenzene	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-
Ethylbenzene	-	-	-	-	-	-	-	9	-	-	-	-	2	-	-	-
Methylene Chloride	-	-	-	-	-	-	-	-	-	-	-	-	160B	36B	-	-
Toluene	-	-	-	NA	-	NA	-	34	2	-	-	-	18	-	-	-
Total Xylenes	-	-	-	NA	-	NA	-	28	6	-	-	-	2	-	-	-
Tetrachloroethene	-	-	-	-	-	-	-	-	-	-	-	-	8	-	-	-
Trichloroethene	-	-	-	-	-	-	-	1	8	-	-	-	11	-	-	-
1,1-Dichloroethene	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Trans-1,2-Dichloroethene	-	0.32	-	-	-	0.23	-	110	86	-	-	-	9	-	-	-
Vinyl Chloride	-	-	9-15	-	7	-	-	23	5	-	1	1	44	4	-	4
Chloroform	-	-	-	-	-	-	-	-	-	-	-	-	-	7	3	5
1,1,1-Trichloroethane	48	65	-	0.32	-	0.99	-	-	1	-	16	1	10	-	-	1
1,1-Dichloroethane	TR	2.5	TR	-	4	3.7	-	-	18	-	-	2	56	1	-	-
1,2-Dichloroethane	-	0.61	-	-	-	-	-	-	-	-	-	-	4	-	-	-
Chloroethane	TR	-	12-15	-	6	-	-	-	9	3	3	3	31	7	-	-
1,2-Dichloropropane	-	-	-	-	-	-	-	-	3	-	-	-	1	-	-	-
Acetone	-	-	-	NA	-	NA	-	100B	-	-	-	-	-	-	-	-
2-Butanone	-	-	-	NA	-	NA	-	280B	-	-	-	-	-	-	-	-
4-Methyl-2-pentanone	-	-	-	NA	-	NA	-	130	-	-	-	-	-	-	-	-
Dichlorofluoromethane*	-	-	-	-	-	-	3	-	140	60	7	80	1200	200	-	-
Trichlorofluoromethane*	-	-	268	-	-	-	-	-	10	-	-	7	-	-	-	-

Notes:

* Tentatively identified volatile organic compounds.
TR Found at trace levels below the detection limit.
B Indicates analyte was also found in the reagent blank.
NA Not Analyzed.
\- Not Detected below the detection limit.
Chloroform has been detected in several of the blanks and therefore may be due to laboratory contamination.

See Figure 4.19 for well locations

groundwater should correspond to the landfill contaminants to corroborate the cause-effect connections. The analytical evidence from groundwater samples shows low concentrations of volatile organics in upgradient wells (e.g., well TL-15a, with some vinyl chlorides, chloroform, chloroethanes), but higher concentrations of more contaminants in three downgradient wells (TL-4, TL-8a, and TL-11) on the landfill boundary and lower concentrations of fewer compounds in downgradient wells (EW-08, EW-09, EW-13, EW-17, see Figure 4.15 and Table 4.23) 200 m to 1,000 m west of the landfill boundary and on the same streamlines. The upgradient concentrations could stem from landfill gas diffusion, or from gradient reversal due to periodic well pumping of the Tacoma City wells to the east, but the upgradient concentrations are much lower than the downgradient levels. Hence, over the width of the landfill, substantial concentration increases occur in the underlying groundwater.

Furthermore, some inorganic elements that are typically found in leachate (iron and manganese) as well as color and total dissolved solids, were found to exceed secondary (that is aesthetic) drinking water standards in downgradient drinking water wells. Unfortunately, one important downgradient well that showed similar elevated inorganic components was contaminated by a lost bore auger, but other wells showed elevated iron and manganese levels too. Finally, although, high iron levels can occur naturally in the Puget Sound area, residents' statements indicate that strong water discoloration with an orange color occurred suddenly in their wells between 1982 and 1983. Prior to this incident,

there was no such indication (pers. comm. Donaldson, Higgins, and Miller, 1987). This evidence supports the suspicion of the leachate plume as the source of well contamination.

Over a dozen industries and commercial businesses between the landfill boundary and the contaminated wells are alternative or complementary potential sources of groundwater contaminants. These intercedant sources cannot be ruled out as contributing sources. Although some of these industries use and discharge to sewers an array of potential contaminants (solvents, degreasers and heavy metals), none of them has been in operation longer than 14 years (some 11 years less than the landfill). The first case of well contamination, however, occurred in 1969 at the Home Builders' Association right outside the western landfill boundary and was traced to the landfill.

Furthermore, the impermeable Vashon till layer that is punctured under the landfill is continuous and thicker under the industries' location (see cross section in Figure 4.14). This layer reduces the migration potential for spilled or wasted contaminants downward to the well screens in the older gravel. Although the volumes remaining in the soil as residual saturation would virtually stop all free flow for small amounts of non-aqueous phase pollutants, the downward flow of water could still dissolve and transport contaminants from the sites to the groundwater table. Thus, although the industries could be contributing to the groundwater contamination, all conditions are less favorable for contaminant transport from these sources. Numerical calculations of the transport potential are used to test

the contaminant transport from the landfill and the industries to the affected wells.

Contaminant Transport Model

The possible causal connection of landfill and well contamination is tested with a transport model to verify that groundwater transport could have carried contaminants to the wells within the 25 years since landfill operation began, and to test for contaminant concentrations from other sources.

From the large number of detected contaminants, vinyl chloride was selected as the indicator compound. The flow model is split into a vertical downward movement from the bottom of the landfill to the groundwater table, and the horizontal transport in the groundwater.

The initial vertical transport from the bottom of the landfill to the groundwater table covers a total thickness of 19.2 metres in three strata. The layers are unsaturated. The flow pattern is downward with a hydraulic head of unity. In order to estimate and compare the order of magnitude of transport times, the conductivity values for a hydraulically equivalent, homogeneous, anisotropic layer was calculated for composite stratas with and without the complete till layer (see Appendix 4.E) The vertical hydraulic conductivities range between $7.88 * 10^{-5}$ m/s without, to $5.33 * 10^{-8}$ m/s with the till layer. the resulting velocities are determined from the discharges and the estimates of porosity; they range between $1.33 * 10^{-7}$ m/s with the till layer to $3.94 * 10^{-4}$ m/s without.

Disregarding dispersion and diffusion, the transport times

for advective transport from the landfill bottom to the groundwater table are estimated in Table 4.24a. The large differences between maximum and minimum are caused by the lower conductivity of the Vashon till layer and to a lesser degree by the sorption retardation.

With a four-fold thicker Vashon till layer of 12.2 m under the industrial sites versus at best a 3m thick layer under the landfill, the minimum travel times to the groundwater table increase to 7.75 to 24 years (see Table 4.24b). At the minimum time required of 7.75 years, all firms but the pipe company are eliminated as potential sources, because the firms have been at this location for only 8 to 9 years. The pipe firm is essentially excluded too except if the most conducive vertical transport conditions are assumed.

The range of horizontal transport distances over 25 years was determined with a simple one-dimensional model of the boundary value problem. The basic model uses the one-dimensional analytical solution to the boundary value problem for the ratio of concentrations C/Co at distance x, time t, and velocity v (Freeze and Cherry, 1979, see Appendix 4.E). The underlying assumptions of a one dimensional flow field with parallel stream lines and a linear release across the flowfield seem to apply here because of the constant thickness of the aquifer and the behavior of dense non-aqueous phase pollutants (USEPA, 1987, see Figure 4.10). Furthermore, retardation of contaminant transport is assumed to occur due to sorption onto a range of 0,0.1% and 1% organic matter in the aquifer. Although volatilization could occur in shallow

Table 4.24a - Landfill Contaminant Vertical Migration Times

	Non-Retarded	Retarded
Maximum with till layer of 3m thickness	4.6 years	14.2 years
Minimum without till layer	13.5 hours	42 hours
		R = 3.1 with 1% soil organic content Koc = 30 n=0.3 rho=2.1 g/cm3

Table 4.24b - Industrial Site Vertical Migration Times

	Non-Retarded	Retarded
Maximum with till layer of 12.2m thickness	15.5 years	48.0 years
Minimum with till layer of 12.2m thicknes	7.7 years	24.0 years
		R = 3.1 with 1% soil organic content Koc = 30 n=0.3 rho= 2.1 g/cm3

depths, it is not considered a major factor in deep aquifers. Ion exchange, oxidation and biological decay are also not considered plausible retardation processes in this specific conservative estimate of contaminant transport (USEPA, 1979).

The basic flow parameters are derived from the Tacoma Remedial Investigation Report (Black and Veatch, 1987) and from Freeze and Cherry (1979). Both maximum and minimum values are given in a range for the aquifer:

Hydraulic conductivity	1×10^{-3} m/s
Porosity	0.2 - 0.4
Flow velocity	$2.18 - 7.06 \times 10^{-6}$ m/s
Dispersivity of strata:	$\alpha = 0.1 - 100$ m
Diffusivity $D^* = D * \omega$	D = Diffusion coefficient for substance in water (Lyman et al. 1982) [ω] = tortuousity factor 0.01-0.5

With these data, the model was set up to calculate the range of plausible contaminant transport distances for five year intervals for 50% and 1% breakthrough points (see Appendix 4.E). Standard initial and boundary conditions were assumed:

- initial condition: source concentration, Co=0 at x metres and time=0
- boundary conditions: the source concentration, C=Co at 0 metres and time=0, C=0 at infinite distance at any time.

Water Quality Impacts Results

The range of possible contaminant transport distances was obtained through three runs of varying sorption capacity, i.e., at

0, 0.1 and 1% average organic content in the aquifer. The results are contained in Figure 4.16a for 5 to 25 years for three contaminants with different sorption characteristics. The maximum and minimum distances present an envelope for possible contaminant migration of vinyl chloride shown in Figure 4.16b. All contaminated wells are within the maximum range of 1,000 metres for contaminant transport from the landfill centerline for the low to medium sorptive compounds. Although the variation in the resulting concentrations is large, the easily sorbed compounds (ethylbenzene, toluene) tend to be absent from the more distant wells (see Table 4.23).

In order to narrow the range of resulting distances, and to accommodate recent conclusions about the effect of dispersion on contaminant transport (USEPA, 1987), three versions of sorptive organic content were run with maximum advective and minimum dispersive transport of vinyl chloride. This configuration (in a one dimensional model) best approximates the heterogeneous character of the strata (USEPA, 1987). The results (Figure 4.16c) show that all wells with detected contaminants are within the transport distance for all three scenarios. The twenty-five year life of the landfill could therefore easily permit landfill contaminants to have been transported vertically down to the groundwater table and horizontally to the wells.

A rudimentary mass balance of vinyl chloride fluxes indicates the feasibility of the landfill as the source (see Appendix 4.E). Only 366g of vinyl chloride per meter width of the aquifer are required to generate the highest observed concentration in the

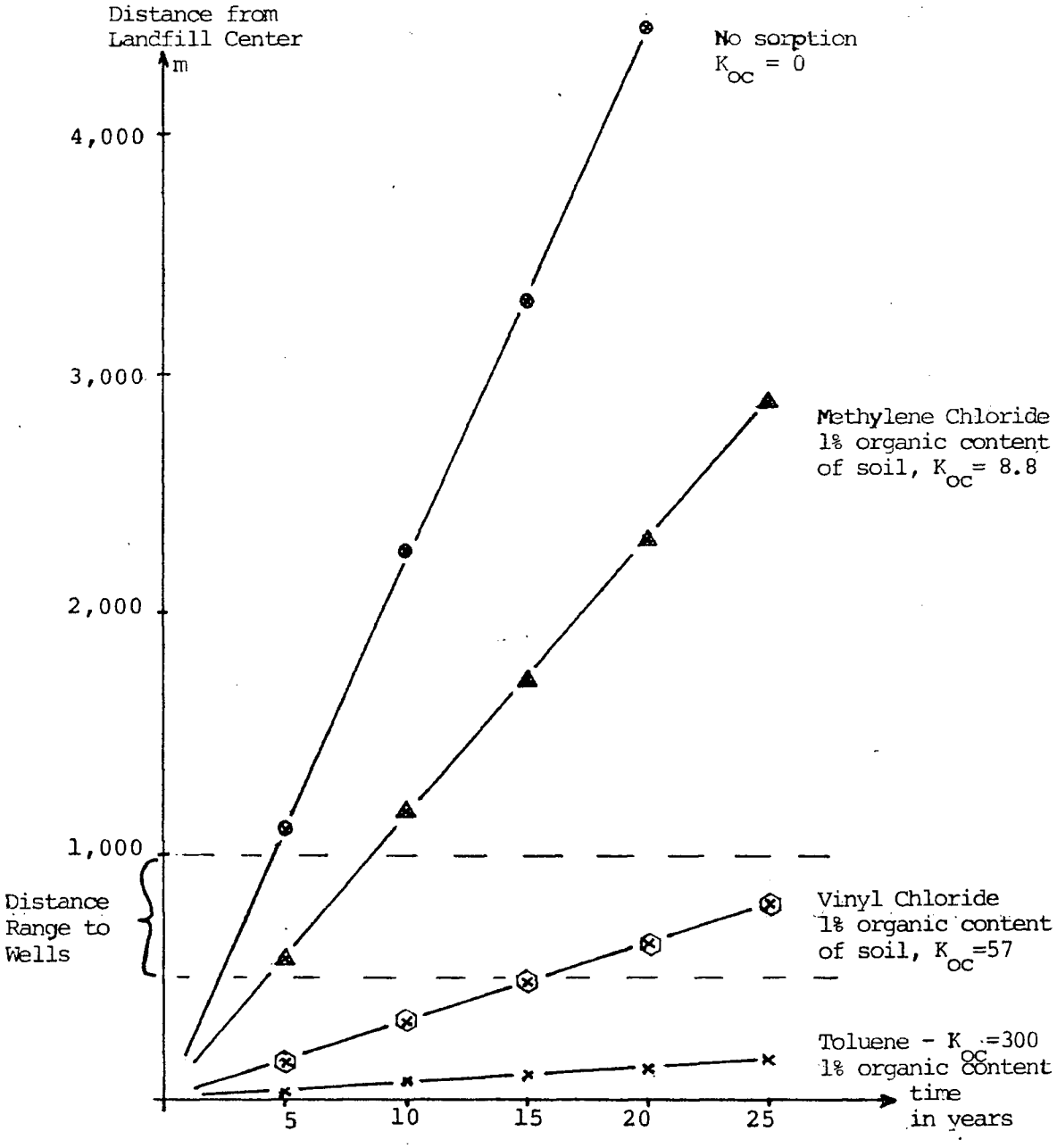


Figure 4.16a: Groundwater Transport Distance for Three Representative Contaminants with Varying Organic Soil Content

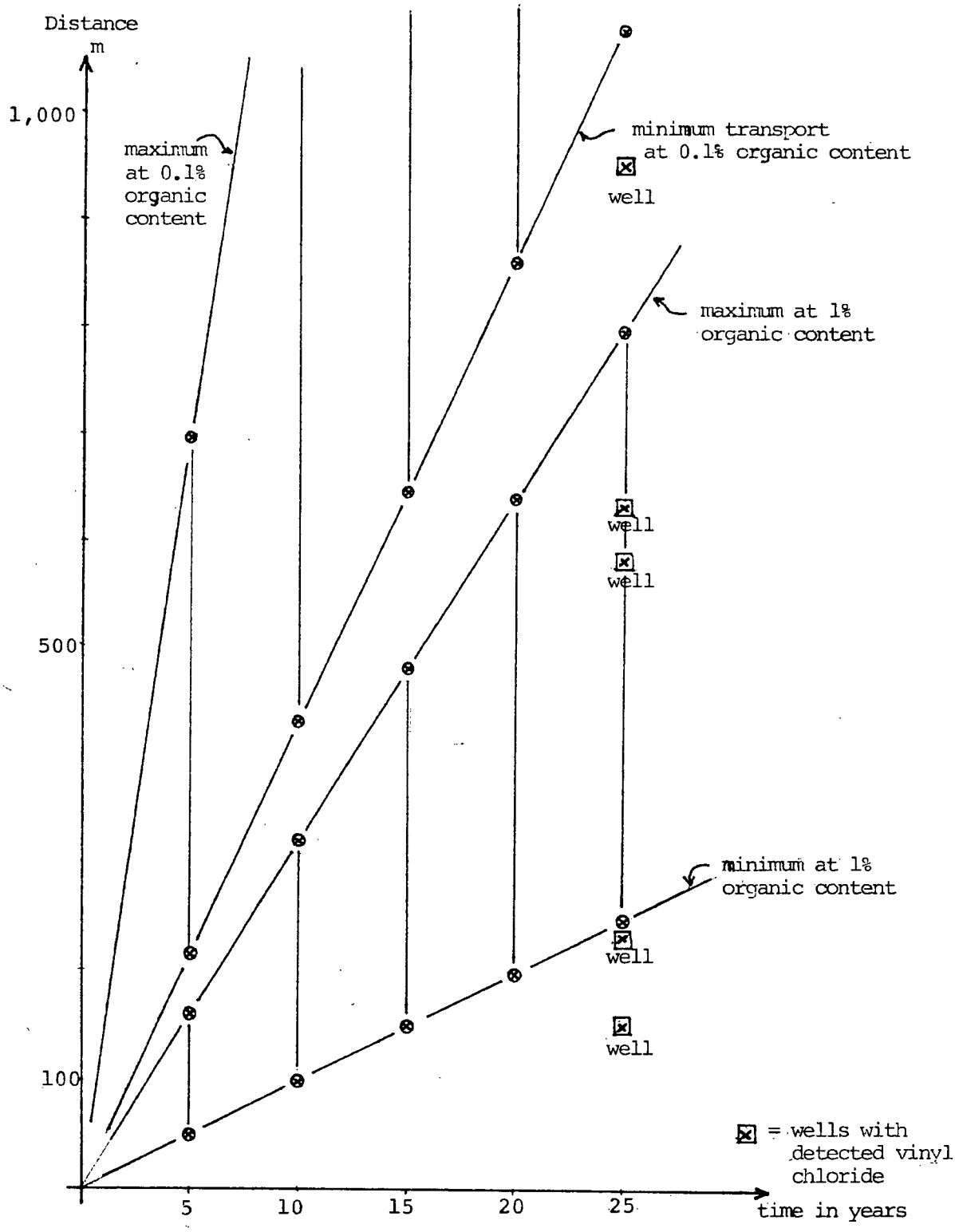


Figure 4.16b: Groundwater Transport Range for Vinyl Chloride for Retardation due to Organic Soil Content

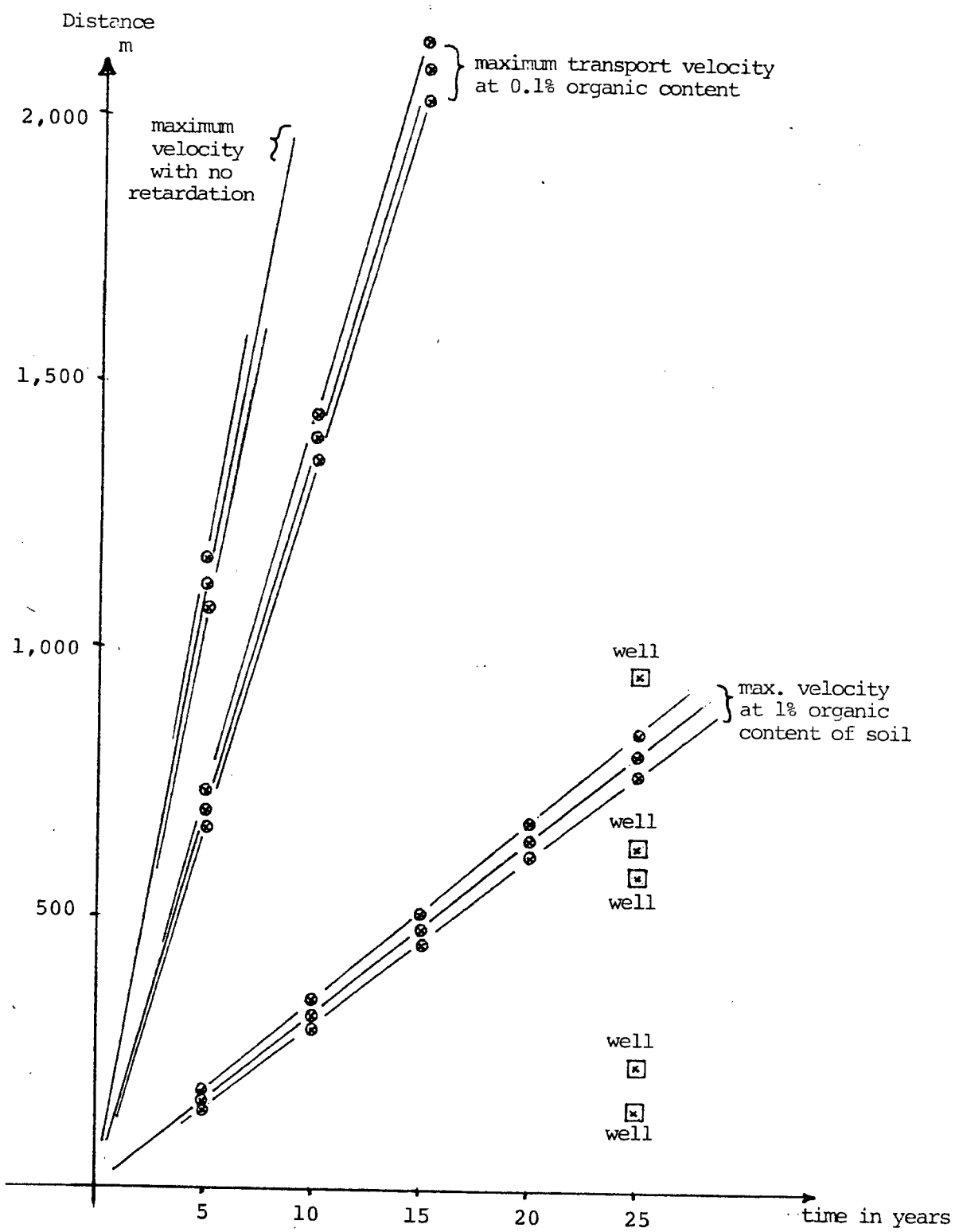


Figure 4.16c: Groundwater Transport of Vinyl Chloride with Varying Transport Conditions

groundwater (80 microg/L); the required mass flux across the landfill boundary is 223.1 mg/day at the highest groundwater discharge. Very small amounts of vinyl chloride are necessary to generate the observed concentration levels.

The evidence of identical materials being deposited in the landfill during the 1960's as are measured in the wells and the plausibility of the transport pathway support the connection of the landfill as the source of contamination of the receiving wells. Finally, other contributary sources are highly unlikely based on higher estimated vertical migration time estimates and contaminant concentrations in wells at the landfill boundary.

Drinking Water Health Impacts

Some of the volatile organic compounds were found in private drinking water wells about 850 metres downgradient from the landfill centerline to the west (see Table 4.23, Black and Veatch, 1987). In particular, three of 21 monitored wells contained significant levels (i.e., over zero concentration USEPA, 1986) of known carcinogens, e.g., vinyl chloride.

The public health risk evaluation procedure (USEPA, 1986) is applied to the detected concentrations of indicator pollutants. Since the affected residences were connected to the city water supply only three years after the first pollutants were detected, the exposure was prorated down by the ratio of 3 years/ 70 years to reflect the short exposure. The resulting estimates of health risks to the 21 residences with domestic wells to the southwest are contained in Table 4.25. The additional carcinogenic risks

Table 4.25a - Landfill Water Quality Health Risks for Domestic Wells 500 m Southwest of Landfill Boundary

Exposure Pathway through Consumption of Water only, no exposure through air or soil included

a. Average Daily Intake

Contaminant	Concentration found in wells microgram/L	Human Water Intake L/kg-day	Average Daily Intake microgram/kg-day
Vinyl Chloride	7 - 15	0.029	0.2 - 0.44
trans 1,2 Dichloroethane	0.23-0.32	0.029	0.0067 - 0.009
1,1,1 Trichloroethane	0.3 - 65	0.029	0.0087 - 1.89
1,1 Dichloroethane	2.5 - 4	0.029	0.073 - 0.12
1,2 Dichloroethane	0.61	0.029	0.018
Chloroethane	6 - 15	0.029	0.17 - 0.44

Table 4.25b - Health Risks from Groundwater

Carcinogens

Contaminant	Average Daily Intake mg/kg-day	Duration Ratio 3/70 years	Potency Factor kg-day/mg	Lifetime Risk
Vinyl Chloride	$0.2-0.44*10^{-3}$	0.043	2.3	$2.0-4.4*10^{-5}$
trans 1,2 Dichloroethane	$0.0067-0.009*10^{-3}$	0.043	$6.9*10^{-2}$	$1.99-2.65*10^{-8}$
	Total Carcinogenic Risks			$2.0-4.4*10^{-5}$
	Equivalent to a risk of 1 in 22,730 to 50,000			

Non-Carcinogens

	Daily Intake mg/kg-day	Acceptable Intake mg/kg-day	CDI/AIC
1,1,1 Trichloroethane	$0.0087 - 1.89 * 10^{-3}$	n.a.	-
1,1 Dichloroethane	$0.073 - 0.12 * 10^{-3}$	$5.4 * 10^{-1}$	$1.34-2.22 * 10^{-4}$
1,2 Dichloroethane	$0.018 * 10^{-3}$	$1.2 * 10^{-1}$	$1.5 * 10^{-4}$
Chloroethane	$0.17 - 0.44 * 10^{-3}$	n.a.	
	Total Ratio of Daily Intake to Acceptable Intake		$2.83 - 3.72 * 10^{-4}$ <<1

are about 1 in 33,500 at three years exposure and exceed the stipulated limit of 1 in 1 million excess risk.

Furthermore, six Fircrest town wells and four University Place wells are located west of the landfill boundary. Fircrest wells 2,4 and 5 are within 300 metres downgradient of the boundary; University Place wells are within 500 metres of the boundary. Although no contaminant concentrations have been detected yet (January, 1988), the wells are being monitored (pers. comm. D. Mascal, Town of Fircrest, 1988). There is a latent risk of water quality deterioration between monthly monitoring times. The risk extends to the entire area supplied by these wells, and comprises approximately 25% of Fircrest residences and all University Place water consumers.

Surface Water Impacts

Landfill runoff and on-site discharges to the sewer system may impact on the water quality of receiving waters. A deterioration in water quality may degrade the wildlife habitat for fish. The Remedial Study (Black and Veatch, 1987) addresses these impacts through a sampling and analysis program to identify organic and inorganic contaminants in sewer and drainage water and in sediments in drainage channels. Four catchment areas collect runoffs:

1. Surface runoff from the capped south area drains into the South Tacoma Channel drainage basin. This runoff does not contact deposited waste and is therefoe not contaminated.

2. Surface runoff from the western portion drains into Leach Creek through three drainage systems. A leachate

collection system also discharges into the sewer line that connects these systems to Leach Creek. Although no priority pollutant organic compounds were detected in the water samples from Leach Creek and its contributaries, sediment samples show some organics (methylene chloride, tetrachloroethene, toluene, acetone, 2-butanone, etc.). Although low concentrations of these organics are detected in sediments at the exit of landfill, they are also found in the contributing sewer outfall sediments that do not stem from the landfill. Therefore, the landfill is not the only possible source.

Except for iron and manganese all metals in the creek are below water quality standards, but no specific concentrations are reported (Black and Veatch, 1987).

3. The runoff from the north end drains into a sewer line which empties into the Leach Creek retention basin. The possible impacts of this area therefore are similar to those covered under the last section. However, a collection pond prior to the catch basin show elevated levels of toluene and several metals (cadmium, copper, lead, mercury, silver, sodium, and zinc) as were detected in the leachate. Although it is possible that leachate is leaching into this pond, drainage from elsewhere may also be a source.

4. The runoff from the working area of the fill is collected in a sewer line along with several leachate collection lines and is piped to Tacoma's No. 1 sewage treatment plant. This primary treatment plant discharges the treated runoff with sewage effluent into the Puyallup River.

This summary assessment indicates that nowhere is landfill leachate or runoff a proven significant cause of water quality loss. But the similarity of pollutants and measured concentrations indicate the landfill to be a possible contributor to pollutant concentrations. Hence, no conclusive evidence is present to show landfill impacts on the wildlife (Salmon) habitat in Leach Creek. Moreover, (street-runoff from general development in the area may be more significant than landfill discharges.

4.3.2 Incinerator Water Impacts

The steam production at the incinerator requires approximately 100,000 to 200,000 gallons of water per day or 250 to 500 liters per minute for steam makeup, cooling and boiler blowdown. This withdrawal ratio is equivalent to the rate of 2 to 3 farm irrigation wells in the same area and, to date, has not been shown to have any negative effects on groundwater table or water availability in private wells (pers. comm. F. Skrivin, Oregon OEQ, February 1988).

The water discharges from cooling and boiler blowdown normally amount to 50,000 to 60,000 gallons per day, or 125 to 150 L/minute. However, peak discharges of up to 220,000 gallons per day have been noted. The discharged water carries low amounts of BOD, ammonia and chlorine residual (see Table 4.26), but are not of concern to the receiving Willamette River (Skrivin, DEQ, 1988).

4.4 Summary of Waste Facilities' Physical Impacts

This chapter tests the presence of observable physical impacts around a typical landfill and a typical incinerator for municipal solid wastes. Whenever possible, direct measurement by personal observation was used; for all impacts except incinerator air emissions, actual monitoring results outside the site boundaries were used to assess the impacts. The results were then verified through theoretical order of magnitude estimates of the impact levels in the host community. The matrix in Table 4.27 summarizes the impact assessment methods.

The detected impacts are listed in Table 4.28 by facility and categorized by type of impact. The landfill creates

significant nuisances, as noise, odors and limited views, some health risks through landfill gas emissions and leachate discharges. Some wildlife habitat impacts are suspected, but cannot be proven. As shown in Figure 4.17a, the impacts are concentrated within 300 to 1,000 m of the landfill. Farther reaching impacts are caused by specific topography that allows more distant views and municipal wells that impact on a larger number of residences if polluted by landfill leachate. Generally, though, landfill impacts affect only immediate neighbours within 500 metres to 1 km of the site boundary.

In contrast, the incinerator (see Table 4.29 and Figure 417b) generates views of the stack and plume up to 3 to 4 kilometres from the facility, and air quality impacts from 700 to 3,000 metres from the stack. Except for minor noise effects, proven impacts are less severe, but spread over a longer distance from the site. The stack height inversely affects air concentrations but proportionately increases the view range. Hence, air quality effects and view impacts constitute tradeoff parameters for selecting stack height. There remains, however, some uncertainty about the long-term risks from incinerator emissions.

Overall, the landfill has generated more significant risks and causes typical apparent nuisances (odors, noise, view) while the incinerator has caused no proven risks and few nuisances (view, some noise).

The area of the landfill site is much larger and the impact areas are concentrated within 200 to 1,000 metres of the site boundary. The incinerator is smaller, but spreads impacts much farther.

Table 4.26 - Incinerator Discharge Water Characteristics

pH - 7 to 8.9, with peaks to 11.4 to 11.7

Temperature at plant	- 76 to 96°F, but after passage through 7 miles of buried pipe, likely about soil temperature
Ammonia as N	- 0.05 to 0.66 ug/l
TSP	- 3 to 5 ug/l
BOD	- 3 to 4.8 mg/l
COD	- non-detectable
Chlorine residuals	- 0.01 to 0.05 mg/l

Table 4.27 - Summary Matrix of Data Collection Methods for Physical Impacts

Emission	Verification Method	Impact Definition	Conditions
Noise	handheld noise meter	1. recognition threshold 2. 3 to 10 dBA over background	Typical wind dir. and speeds
Odor	personal sampling with Scentometer and dispersion estimates	1. odor recognition 2. > #2 port, 7-fold dilution to threshold	1. ground level inversion 2. hot afternoons LF-low pressure IN-instable with high winds
View	personal observation and photograph	1. minor 2. moderate 3. distinct 4. major	winter and summer vegetation conditions
Air Emissions	dispersion modelling	1. some increase over background 2. potentially health-significant increase over background	LF-max. emission rate conditions (see odors) IN-max. burning rate, worst dispersion conditions
Liquid Emissions	Groundwater monitoring and ground-water modelling	1. risk of increase of contaminants in drinking water 2. significant levels detected and LF plausible source	Transport plausible at max. advection with sorption retardation
Gas Migration	methane monitoring and air dispersion modelling	1. gas detected in soil at over 5% 2. gas at explosive levels in buildings in gas probes outside landfill boundary	detection during last 12 months, at worst case (low pressure) conditions
Wildlife Habitats	as above for wild-life areas	1. risk to habitats but no obvious impact 2. distinct destruction or interference	physical connect-ion between facil-ity and habitat must be established, and must be known to harm species

Legend: LF = Landfill
IN = Incinerator

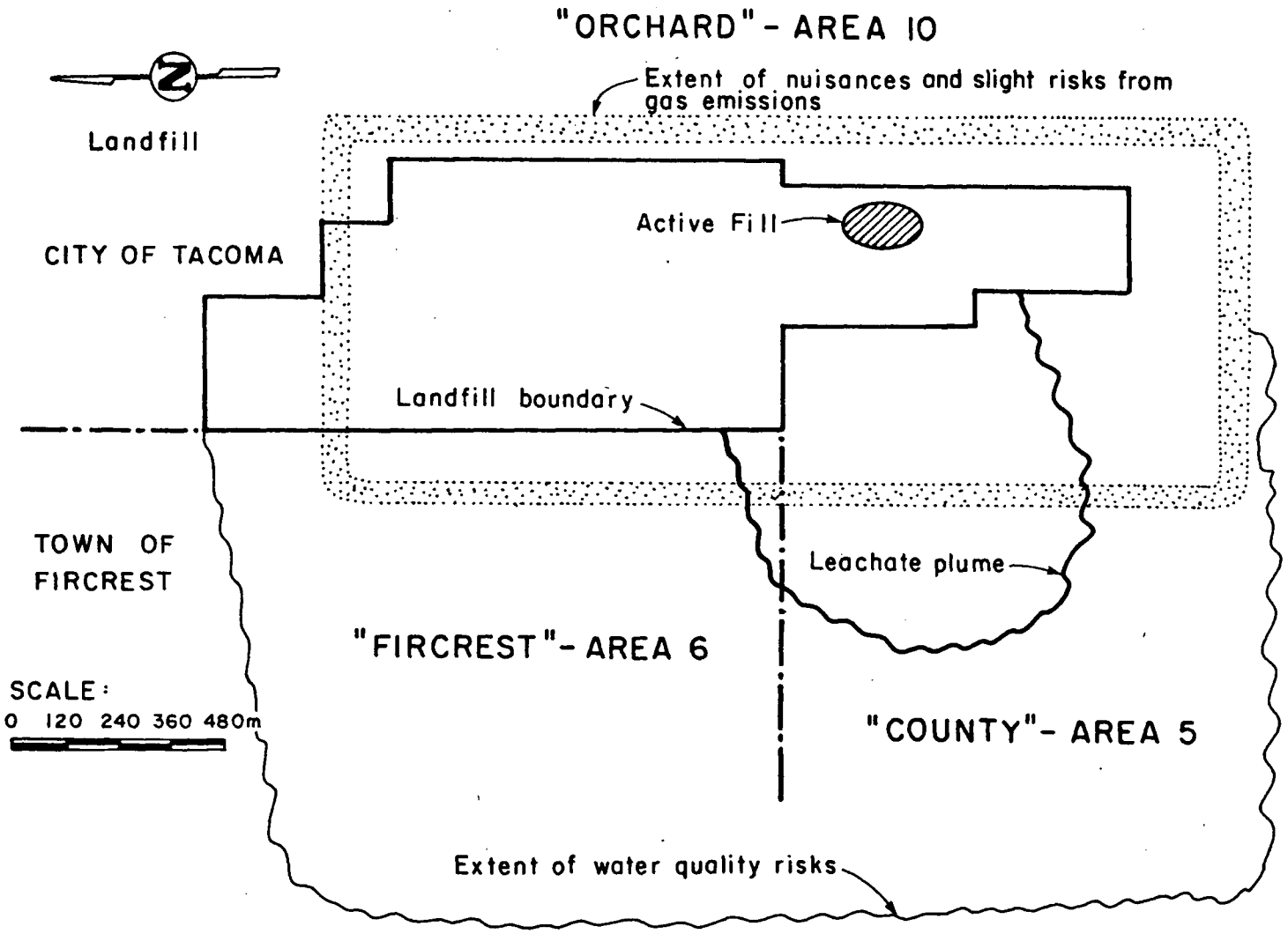


Figure 4.17a: Landfill Physical Impact Footprint

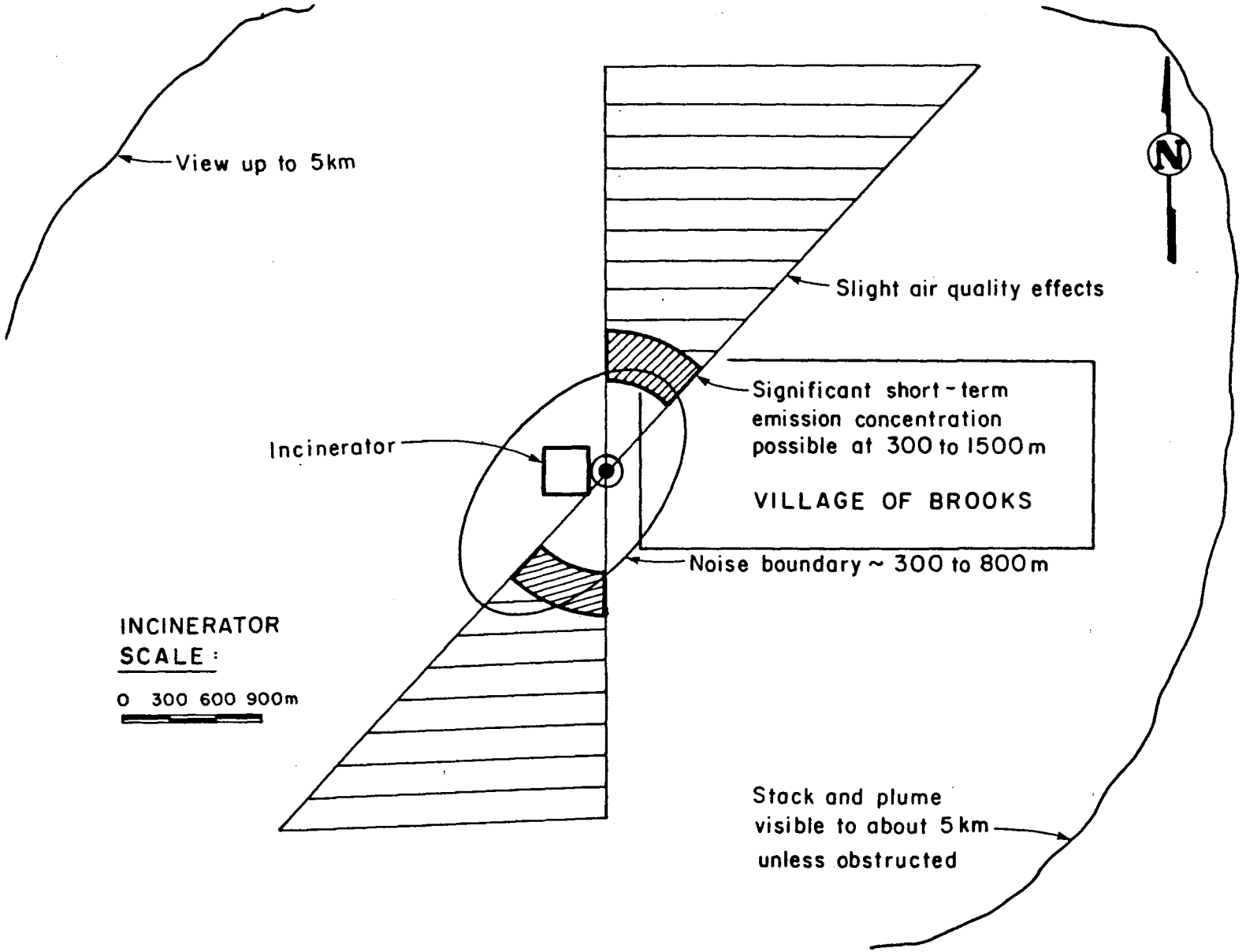


Figure 4.17b: Incinerator Physical Impact Footprint

Table 4.28 - Physical Impact Summary

	Landfill	Incinerator
Nuisances		
View	X	X
Noise	X	X
Odor	X	-
Health Risks		
Air emissions	X	-
Water emissions	X	-
Accident/ Explosion	X	-
Environmental Change		
Air quality	(X)	X
Water quality	X	-
Wildlife habitat	(X)	-

X - impact detected and verified

(X) - impact alleged

\- - no impact

CHAPTER 5 - BELIEFS, ATTITUDE and ACTION in TYPICAL HOST COMMUNITIES

5.1 Overview of Study Structure and Methodology

5.1.1 Goal and Objectives

The goal is to explain and predict the influence of waste facility impacts on beliefs, attitude and opposition activity among residents. "Beliefs" are pieces of factual information about specific aspects of the facility that individuals believe to be true, e.g., that incinerators generate air emissions. Beliefs are categorized as "spontaneous" (or salient) if they are readily available and relevant. Salient beliefs are the first five to seven points mentioned about a concept or facility (Fishbein and Ajzen, 1975). Salient beliefs can be elicited by open ended questions. In contrast, respondents require some thought to identify less available (specific) beliefs. "Attitude" is, in contrast, an overall evaluation judgment about the desirability of the facility.

The waste facility generates physical impacts. These impacts lead to beliefs about waste facilities among host community residents. The sum of the set of beliefs then determines attitude about the facility. Finally, attitude is assumed to cause various actions depending on required effort, probability of success and payoffs (Fishbein and Ajzen, 1975). This model is accepted here as an applicable structure to assess public beliefs and attitudes about technical facilities (Thomas et al. 1980).

In order to explain and predict the influence of waste facility impacts on host community opposition, actions, the

connection of the facility impacts (Chapter 4) must be traced through residents' specific beliefs to the resulting overall attitude about the facility (see Figure 5.1). Beliefs and attitude about the facility are related to beliefs and attitude about the community itself and, finally, with opposition activities.

The results indicate the cause-effect connection from waste facility impacts through to host community opposition. Once this framework is established, methods to enhance acceptance can be identified.

Four sets of questions are posed to test the hypothesis of a causal connection between facility impacts, residents beliefs and attitudes, and opposition behavior (see Figure 5.1):

1. Which facility impacts do residents consider significant? What is the resulting overall attitude about waste facilities? What level of opposition activity occurs? The objective is to determine levels of significant impact beliefs, attitude and types of action.
2. Are there significant associations between physical impacts, media reports, and spontaneous beliefs with specific beliefs about facility impacts? In other words, is there evidence to support a causal connection between the facility and the perceptions about it? Are beliefs about impacts correlated with the residents' attitude? Is the attitude associated with opposition behavior? The objective is to test for causal connections between facility impacts and resulting attitudes and behavior.

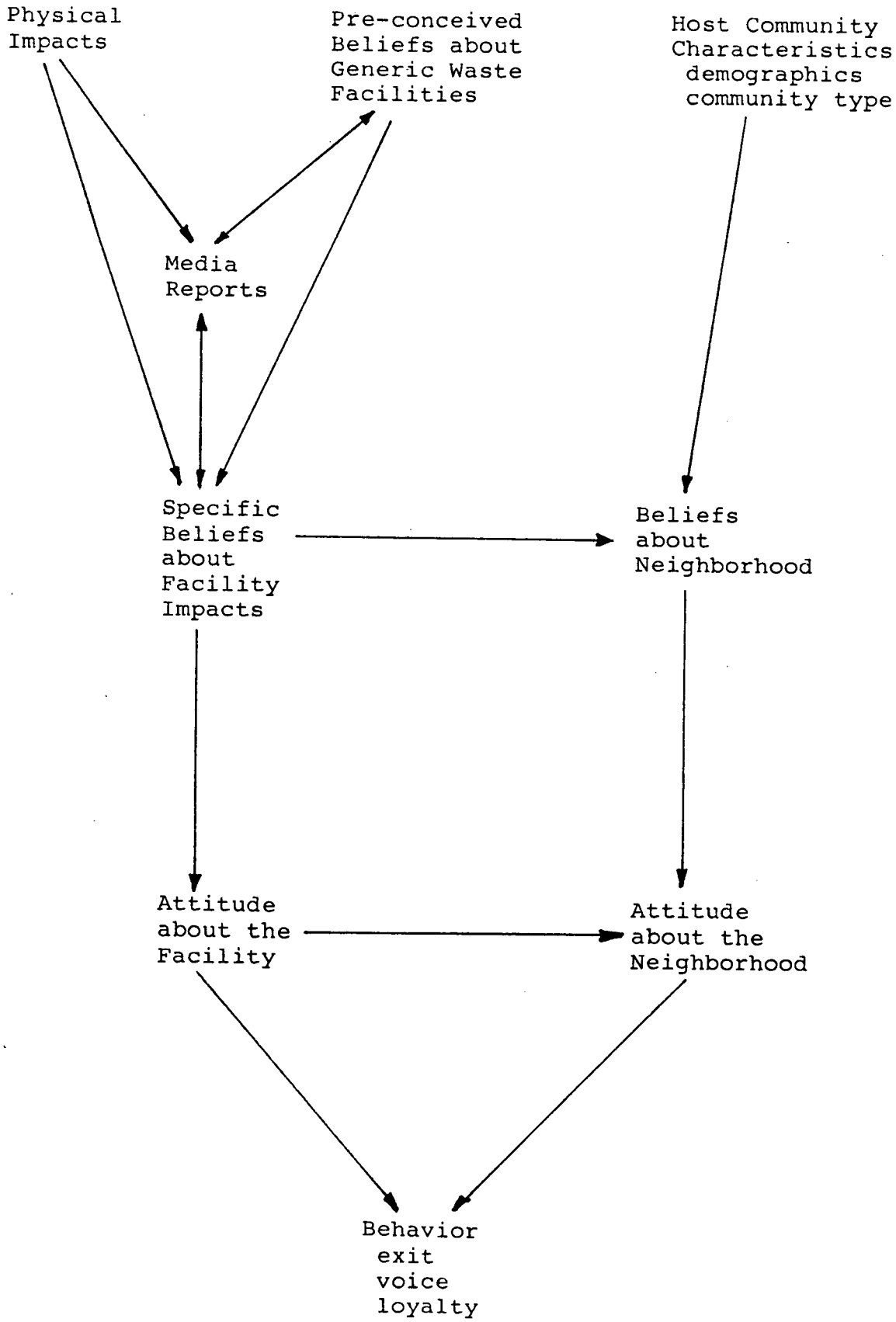


Figure 5.1 - Structure and Variables in Belief Attitude Study

3. Are specific beliefs about facility impacts associated with beliefs about the host community? Does attitude about the facility correlate with attitude about the community? Does attitude about the facility or community correlate with opposition behavior?
   These questions test the influence of facility beliefs on beliefs about the community and test the connection between attitudes and action.
4. What are the effects of waste facilities on community stability? Are property values affected? Do properties take longer to sell? Do more households move? These analyses test for significant avoiding action in the host community.

5.1.2 Methodology and Structure

Four methods are used to determine the elements in this section; they are listed in Table 5.1. The physical impact assessment results are presented in Chapter 4. A survey among host and control community residents was used to determine beliefs about waste facility impacts, attitudes about the facilities and opposition activities. A content analysis of newspaper articles during recent years describes media coverage of waste facilities and tests for the influence on resident beliefs. Finally, a real estate analysis of sales prices, time on the market until sale and number of sales tests for property value impacts and significant resident migration from host communities.

The study methods, analyses and results are presented in the following sequence:

Table 5.1 - Methodology of Beliefs, Attitude and Action Study

	Community		Method	Indicator
	Host	Control		
Neighborhood Beliefs and Attitudes	X	X	Survey	Belief and Attitude Scales
Media Reports	X	X	Content Analysis	Frequency of Mention of Impacts
Impact Beliefs				
Salient	X	X	Survey	Listings of issues
Specific	X	-	Survey	Belief Scales
Attitude about Facility	X	X	Survey	Attitude Ratings
Behavior				
Household Moves	X	-	Real Estate Analysis	Number of Sales
Property Values	X	-	Real Estate Analysis	Sales prices
Opposition	X	-	Survey	Stated Opposing Activities

1. The survey instrument and process are reviewed. Survey questions, pretests and sample selection are briefly reviewed to address important design features.
2. The survey sample is externally validated through comparison of sample demographics with census values and through cross-comparison of sample demographics with exposure to physical impacts. These tests indicate whether the surveyed respondents are representative of the community and whether they are randomly distributed over the physical impact field. The survey responses are internally validated by testing associations (with chi-square tests) between similar questions. The answers are expected to be consistent for them to be considered reliable.
3. The negative beliefs about specific impacts are tested by difference of proportions for significant frequencies and are rank correlated with attitude about the facility.
4. The connection of spontaneous (or pre-held) beliefs and specific negative beliefs, between exposure to physical impacts and negative beliefs, and between media coverage and negative beliefs are tested with chi-square tests.
5. The average attitudes about the facility are compared between groups by differences of means tests. A summary of beliefs and attitudes about the facility is given.
6. The association is tested by chi-square of negative beliefs about the facility with beliefs about the community. Similarly, the attitudes are rank-correlated

to test for connections.

7. Opposition behavior is tested for association with attitudes about facility and community by chi-square tests. A summary of beliefs about facility and community and their correlation with behavior is given.
8. The chapter results are summarized and conclusions are stated.

The statistical analysis comprises five common methods: difference of proportions, difference of means for comparing individual variables between samples, chi-square and Fisher exact tests for testing cross tabulated data from two variables in the same sample and Goodman-Kruskal rank-order correlation of ordinal (i.e., ranked) data on two variables in the same sample.

5.2 Survey of Residents' Beliefs and Attitudes in Host and Control Communities

5.2.1 Rationale

The objective of the survey is to obtain a representative set of opinions about the facility impacts on communities. The survey approach is a direct method to obtain personal beliefs and attitude ratings from a representatively selected cross section of the host and control communities. The alternative method consisted of personally interviewing community leaders, politicians, or opposition spokespersons. Because all representatives are prone to personal bias, their evaluation of the beliefs and attitudes among residents may be limited or one-sided. This is especially true in small communities, where the number of community representatives is very small. As a

result, a survey of randomly chosen respondents was selected, but in depth interviews with spokespersons were conducted parallel to the written surveys to allow feedback, to gain details and to explore the connections and motivation for beliefs.

5.2.2 Survey Structure and Method

In order to compare host and control community responses, two sets of respondents had to be chosen at each site. Furthermore, the information level of the control residents about specific facility characteristics was expected to be lower than among host community residents. Finally, the required number of valid responses was estimated by the number of entries necessary for chi-square and Fisher exact tests in 2 x 2 cross tables. A minimum of 20 to 25 per group and site are required in order to get significant variation and at least 4 to 5 entries in each cell.

The survey contents was structured in six sections. The questions progressed from general issues (beliefs and attitudes about the neighbourhood) to specific beliefs about facilities and the specific waste facility, to opposition activities. The last section tested the fairness of property value guarantees as a common approach to impact management. All respondents received the entire questionnaire containing 27 questions on 17 pages, but control group responses to the questions about specific facility impacts were omitted because of the lack of specific information. The overview of the belief-attitude survey and of the obtained responses is summarized in Table 5.2; the survey questionnaire is in Appendix 5.A.

Table 5.2 - Community Belief - Attitude Survey Structure

Section	Respondents' Community		Purpose
	Host	Control	
1. Beliefs and attitudes about neighborhood	X	X	introduction and general neighborhood evaluation
2. Household characteristics	X	X	demographic data for external validation and community comparison
3. Beliefs and attitudes about facilities in the neighborhood	X	X	basic beliefs and attitudes about various facilities
4. Specific impact beliefs and attitudes about waste facility	X	-	quantified impact beliefs and attitudes
5. Specific actions in response to the waste facilty	X	-	
6. Fairness of property value guarantees	X	X	test of compensation measure

A mailed written survey was chosen because of the length of the document, to allow consultation among persons in a household, and to minimize the researcher's time and effort in data collection.

5.2.3 Survey Design

The survey instrument proceeded from general beliefs and attitudes about the respondent's neighborhood to specific questions about undesirable facilities (see the survey instrument in Appendix 5.A). The purpose of the survey as described to the respondents was to obtain their opinions about their neighborhood and its municipal and industrial facilities. The questionnaire did not specifically identify the waste facility as the object of interest. Respondents were asked to consider any facility in their neighborhood that annoyed, bothered or concerned them. Thus, most host community respondents were expected to identify the specific waste facility. Other respondents were asked to consider the waste facility only if they did not identify another facility that bothered or concerned them.

Crucial questions about neighborhood and facility beliefs were asked in two or three different ways in order to avoid bias and enhance validity.

Salient beliefs about the neighborhood were elicited in open ended questions about the likes and dislikes about the neighborhood:

5a. What did you particularly like about this neighborhood that made you decide to move here?

_____

6a. When you moved in to your present neighborhood, what did you particularly dislike about the neighborhood you live in now?

_____

Respondents were asked to fill in their answers. The answers were coded (see Appendix 5.A). Then, the respondents were presented with specific dimensions to rate their neighborhood:

8. How do you rate your neighborhood in terms of the items in the list below?

	excellent			acceptable			intolerable
Nuisances							
noise	1	2	3	4	5	6	7
odors	1	2	3	4	5	6	7
etc.							

Similar questions asked salient concerns about and benefits from waste facilities in general:

17a. A Garbage Landfill

Please assume that a garbage landfill to serve the entire metropolitan area were to be built within 1 mile from where you live.

What would annoy, bother or concern you about the garbage landfill and how would you benefit by having the facility located in your neighborhood?

Concerns _____ Benefits _____

_____ _____

Then, the respondents were presented with a complete list of hypothesized dimensions, or impacts, which correspond to the list of impacts derived in Chapter 2 and include physical, economic, social and political impacts. Respondents were asked to rate their beliefs about facility impacts on seven point scales of "intolerable" to "excellent", with "acceptable" as the mid-point

(see question 19):

19. Please fill in the name of the facility you identified or were asked to consider in the last question (question 18):

_____

a. Does the facility cause nuisances in the neighborhood?

	No effect	intolerable			acceptable		excellent	
noise	0	1	2	3	4	5	6	7

Finally, specific facility impacts weRe verified by presenting a list of impact statements to which respondents marked their degree of agreement or disagreement (see question 20):

20. Please transfer the name of the one facility you identified or were asked to consider in question 18:

Landfill or Incinerator

Please consider the following statements about this one facility and indicate to what extent you disagree or agree with them:

a. The fact that the facility is located in the neighborhood is fair.

1	2	3	4	5
strongly disagree	disagree	not sure	agree	strongly agree

Thus, the crucial beliefs about facility impacts were obtained in three different ways with changing scales and scale directions to avoid identical ratings across all impacts. Questions that queried facts (distances, household characteristics) or factual evaluations (familiarity) were asked in a straightforward way. Responses were either filled in or rated on numbered scales. Factual questions were used to separate sections of beliefs and

attitudes; household characteristics were used to separate neighborhood and facility sections.

Survey Instrument Pre-Testing

The survey instrument was first informally pretested among interested colleagues, then twice formally pretested among randomly selected respondents around the Premier Street landfill in North Vancouver, with controls in other suburban - rural municipalities in the Greater Vancouver Regional District.

The pre-test survey was announced with an introductory letter, followed by the survey package including complimentary pen and return addressed and stamped envelope. One week thereafter, follow-up phone calls were made to those recipients who had not responded. The results were informally reviewed. The findings are listed here:

- Few respondents gave "across the board" ratings; most responses varied and seemed well considered.
- The survey was judged to be long by about 25% of respondents; 25% noted they enjoyed the survey, most indicated 20 to 30 minutes as the required time.
- Although most host-community residents indicated the waste facility as being the facility of concern, few respondents seemed to pick up on the waste facility as the central focus.
- Response rates were between 50 and 60%. The initial contact letter and follow-up phone calls likely enhanced the response.

Based on these results, the survey sequence for the study sites at Tacoma and Salem was determined as follows to reduce costs:

1. Initial contact letter introducing the survey, stating the purpose, and describing the process, indicating return date and giving names and phone numbers of the researchers.
2. Phone call to screen respondents for their correct address, understanding of English, and to ask their willingness to participate.
3. Survey packages sent with 10 days allowance for return.
4. Phone calls to non-respondents' as follow up.

With this procedure, response rates of 60% were obtained in Tacoma and 56% in Salem. In both cases, host community response rates were slightly higher at 60% to 65% than control community rates at 45 to 50%.

Sampling Procedures

Host community respondents were selected from a list of all households within 2 kilometres of the Tacoma Landfill, and within 3 kilometers of the Salem incinerator site boundaries. Street addresses were compiled from official street maps and the Page address directories (1986) for Tacoma and Salem. This process was adequate in Salem because the stability of neighborhoods is high; in Tacoma, however, 30 to 50% of the listings were invalid. As a result, a second set of potential respondents had to be selected in Tacoma to achieve a total of 30 respondents in the Orchard neighborhood east of the landfill. This second selection could

bias the sample by increasing the proportion of long-term residents, i.e., those whose street addresses had not changed. However, the second set was chosen from the new apartment addresses to ensure the percentage of new residents and reduce the increased probability of selecting long-term residents. The host community sample is tested for validity on this characteristic in the next section.

Two hundred control community residents each were randomly selected from current phone book listings in Tacoma and Salem metropolitan areas. All addresses within inner city or distinctly urban areas were eliminated in order to obtain a set of suburban and rural residents to match the characteristics of the host community. The shortened list comprised 100 to 120 addresses at each site. These respondents were contacted in the same way as the host community residents.

This selection process avoided the difficulty of, first, choosing similar communities by similar demographics and, then, selecting residents from these communities. The limited selection of neighborhoods and the number demographic variables made this latter approach unmanageable.

The chosen method probably provides a wider cross-section of opinions and a smaller risk of bias. The concern about lower response rates due to lack of interest proved to be unfounded; the profile of control respondents is shown in the following section to be comparable to that of the host communities on most dimensions.

5.3 Results

5.3.1 Validation of Results

External Validation

The purpose of this section is to verify the representativeness of the sample and to test for internal consistency of the responses. Host community respondent sample characteristics should compare with host community census demographics and with control respondent sample characteristics to establish the validity of the sampled responses.

Six demographic variables (time in community, type of home, home ownership, presence of children, education, income) were surveyed in section II of the questionnaire and were compared with the available 1980 U.S. Census data at each site to verify the external validity of the samples.

a. Tacoma Sample Validation

The host community of the landfill comprises two distinct sub-areas. The low to middle income Orchard neighborhood extends from the eastern and southern boundaries between the landfill and Madison Street, north to Center Street, south to 56th Street (see Figure 1.4 in Chapter 1). Fircrest is a separate middle class township on the western city limit of Tacoma. Due to the distinctly different characteristics and census tract boundaries, the samples from the two areas are validated separately and then combined into one host-community sample.

In Tables 5.3a and b, the two host neighborhoods are compared with the respective census tract figures; the control

Table 5.3a - Landfill - Survey Sample and Neighborhood Demographics for Orchard Neighborhood

Orchard Neighborhood

Characteristics	Sample N = 18 Proportions	Census Tract #628 Proportions	Difference of Proportions (sig. at 95% confidence)
Time in Community			
under 5 years	60%	69%	non-sig.
over 5 years	40%	31%	non-sig.
Type of home			
single family	53%	65%	non-sig.
multiple family	47%	35%	non-sig.
Rent/own			
own	32%	42%	non-sig.
rent	68%	53.5%	non-sig.
Children under 18 in household			
yes	20%	56%	sig.S<C*
no	80%	44%	sig.S>C*
Education			
high school	87%	68.2%	sig.S>C*
college degree	33%	9%	sig.S>C*
Income			
under $15,000	7%	32.7%	sig.S<C*
$15 to 30,000	53%	52.9%	non-sig.
over $30,000	33%	14.4%	sig.S>C*

Note: Tacoma census tract #628 population equals 6,470 in 1986
* S=sample proportion, C=census proportion
for example, S>C=sample proportion is significantly larger than census proportion

Table 5.3b - Landfill - Survey Sample and Neighborhood Demographics for Fircrest Township

Fircrest Township

Characteristics	Sample N = 16 Proportions	Census Tract Proportions	Difference of Proportions (sig. at 95% confidence)
Time in Community			
under 5 years	11%	35%	sig.S<C*
over 5 years	89%	64%	sig.S>C*
Type of home			
single family	88%	82%	non-sig.
multiple family	13%	18%	non-sig.
Rent/own			
own	87%	72%	non-sig.
rent	13%	21%	non-sig.
Children under 18 in household			
yes	12%	38%	sig.S<C*
no	88%	62%	sig.S>C*
Education			
high school	94%	89.5%	non-sig.
college degree	50%	32%	marg.-sig. S>C*
Income			
under $15,000	7%	14%	non-sig.
$15 to 30,000	29%	27%	non-sig.
over $30,000	64%	59%	non-sig.

Note: Fircrest population equals 5,400 in 1986
* S=sample proportion, C=census proportion
for example, S>C=sample proportion is significantly larger than census proportion

Table 5.4a - Tacoma Landfill - Calculation of Host Community Survey Sample from Weighted Survey Samples

	Number of Respondents	Population	
Orchard	18	6,470	
Fircrest	16	5,400	
Ratio	1.125	1.198	Difference is not significant at 95%

Table 5.4b - Tacoma Landfill - Host and Control Sample Comparison

	Host Sample Proportion N = 34	Control Sample Proportion N = 27	Difference of Proportions (significant at 95%)
Characteristics			
Time in Community			
under 5 years	36.4%	44.4%	non-sig.
over 5 years	63.6%	55.6%	non-sig.
Type of home			
single family	68.8%	81.5%	non-sig.
multiple family	31.3%	11.1%	sig.HC>CC*
trailer	0%	7.4%	
Rent/own			
own	58.1%	81.5%	sig CC>HC*
rent	41.9%	18.5%	sig HC>CC*
Children under 18 in household			
yes	15.6%	33.3%	
no	67.2%	66.7%	non-sig.
Education			
high school	65.5%	65.4%	non-sig.
college degree	34.5%	34.6%	non-sig.
Income			
under $15,000	10.3%	7.4%	non-sig.
$15 to 30,000	41.4%	33.3%	non-sig.
over $30,000	48.3%	59.3%	non-sig.

Note: HC = host community sample, CC = control community sample

group characteristics are then compared with the combined host sample in Table 5.4, whereby the characteristics of two host neighborhoods are weighted by the ratio of their relative populations to the total host community population.

Host Community Sample Evaluation

In the Orchard neighborhood, households with no children, higher education, and over (US) $30,000 per year incomes are over-represented in the sample.

In Fircrest, long-term residents, households without children and with higher education are over-representated. These findings indicate that these respondents were more interested in responding to the survey and, therefore, presents a slight sampling bias. This result was expected, though, because single family households with higher educations and incomes tend to be more concerned about their neighborhood, and tend to answer surveys more easily and willingly.

Orchard and Fircrest samples are then combined into a host community sample (Table 5.4a) and are compared with the control sample (Table 5.4b). Households in multiple family dwellings and rented units in the host sample exceed those in the control sample. Since most dwelling units at the landfill boundary are rental apartments, these differences are expected and accurately represent the conditions in the host community. The next test for external validity was performed to see if the differences in the demographic variables would influence the resulting responses on beliefs about negative impacts. The test for cross-association of

sample demographics with impact beliefs shows that single family home owners tend to be more negative about the wildlife impacts on the fish bearing Leach Creek, while low and medium income households are more negative than high income households about the impact on property values, image and for nuisances (see Table 5.5). But predominantly single family home owners are close to the wildlife bearing stream, while more apartment renters are exposed to nuisances (see previous section 5).

Although medium income households in the host community are more negative about property value and development effects than low or high income households, there is only one significant difference in the Orchard area between income in the survey sample and in census statistics. Moreover, actual shifts have occurred in the Orchard neighborhood since the 1980 census because new residential development has brought in more educated people (university students). These are better reflected in the sample. The population in Fircrest is stable and has therefore aged and increased the number of long-term residents (over 5 years) since the 1980 census was taken. Thus, the results reflect the actual situation. The response sample therefore represents the opinion of committed residents who are exposed to specific impacts.

Control Sample Evaluation

The control sample is compared with the host sample instead of with the census figures because the census figures are outdated. Further, combining the independently validated survey samples from Orchard and Fircrest communities was judged to be

Table 5.5 - Tacoma Host Community: Demographic Variables and Significantly Associated Negative Impact Beliefs

Community Demographics	Associated Negative Impact Beliefs
Time in Community	- no significant association with impact beliefs
Type of home	- single family dwellers mention wildlife habitat effects more frequently
Ownership	- no significant association with impact beliefs
Children in household	- no significant association with impact beliefs
Eduction	- no significant association with impact beliefs
Income	- low income households mention noise and odor impacts more frequently than medium or high income households
	- medium income households more frequently mention impacts on property values, community image, and nuisances in general

see Table 5.C5 in Appendix

more accurate than combining outdated census statistics for larger areas. The host sample is likely to represent the community cross-section. The comparison shows that the control sample coincides well with the host sample, except for a surplus of multiple family residents, and, as a result, a larger proportion of renters in the host sample. The excess of multiple family dwellings and renters accurately represents the host community.

Salem-Incinerator-Sample Validation

The host community sample in Salem consists of a group of 34 households compared with a control sample of 23. Because of a simple, well defined census tract (#25 in Salem Metropolitan Area) and relative stability of host and control areas the census tract data (see Table 5.6a and b below) are considered accurate; both samples are compared with these data. Census tract #25 is, however, substantially larger than the host community (Brooks). Within host and control samples, the same respondent self-selection bias towards higher education and income appear. Furthermore, the number of long-term residents is higher in the host sample. Finally, the proportion of respondents living in households without children is higher in the host sample.

Overall, the slight sample biases tend to favor more concerned, long-term residents, and, hence, a sample more likely to oppose an undesirable development (Madisso, 1985).

In order to control for possible biases due to sample self-selection in Salem, the dependence of beliefs and attitudes on sample demographics was tested (see Table 5.7). Income levels

Table 5.6a - Salem - Comparison of Host Survey Sample with Census

Characteristics	Sample Proportion N = 34	Census Proportion Tract 25	Difference of Proportions (significant at 95%)
Time in Community			
under 5 years	33%	52%	sig. C>S*
over 5 years	68%	48%	sig. S>C*
Type of home			
single family	85%	77%	non-sig.
multiple family	15%	20%	non-sig.
Rent/own			
own	85%	81.6%	non-sig.
rent	15%	18.4%	non-sig.
Children under 18 in household			
yes	27%	43%	sig.S<C*
no	73%	57%	sig.S>C*
Education			
high school	81.3%	67%	sig.S>C*
college degree	31.3%	29%	non-sig.
Income			
under $15,000	20%	36%	sig.S>C*
$15 to 30,000	37%	32%	non-sig.
over $30,000	43%	33%	non-sig.

Note: * S=sample proportion, C=census proportion
for example, S>C=sample proportion is significantly larger than census proportion

Table 5.6b - Salem - Comparison of Control Sample with Census

Characteristics	Sample Proportion N = 23	Census Proportion Tract 25	Difference of Proportions (significant at 95%)
Time in Community			
under 5 years	52%	52%	non-sig.
over 5 years	48%	48%	non-sig.
Type of home			
single family	86%	77%	non-sig.
multiple family	14%	20%	non-sig.
Rent/own			
own	86%	81.6%	non-sig.
rent	14%	18.4%	non-sig.
Children under 18 in household			
yes	36%	43%	non-sig.
no	64%	57%	non-sig.
Education			
high school	87%	67%	sig.S>C*
college degree	43%	29%	marg.sig.
Income			
under $15,000	26%	36%	non-sig.
$15 to 30,000	30%	32%	non-sig.
over $30,000	43%	33%	non-sig.

Note: * S=sample proportion, C=census proportion
for example, S>C=sample proportion is significantly larger than census proportion

Table 5.7 - Salem Host Community: Demographic Variables and Significantly Associated Negative Impact Beliefs

Community Demographics	Associated Negative Impact Beliefs
Time in Community	- no significant asociation with impact beliefs
Type of home	- single family dwellers more frequently mention air quality impacts and loss of community control
Ownership	- no significant association with impact beliefs
Children in household	- no significant association with impact beliefs
Eduction	- no significant association with impact beliefs
Income	- low income households more frequently mention view impact - medium income households more frequently mention impacts on property values, community image, and nuisances in general

See Table 5.C7 in Appendix

are associated with impact beliefs; lower income households mentioned view impacts more other groups, than medium income households mentioned property values, image and nuisances more. No other demographic variables with significant differences between the sample respondents and the census statistics (time in the community, households with children, high school education) are associated with any significant differences in impact beliefs or attitudes. Only a marginally significant association is noted between length of time in the neighborhood and the belief about impacts of air contamination, air quality, confidence in the environmental agency, and, the attitude about the garbage burner.

Sample Respondents and Physical Impacts

A further test of the external validity was to compare demographics with the distribution of respondents within physical impact fields. Table 5.8 contains a summary of results of cross-associations between variables and physically impacted respondents.

Some significant demographic differences appear in both locations. In Tacoma, short-term residents also rent apartments more often, and experience view, odor, noise and explosion risk impacts, while more long-term, single family home owners are subject to water quality impacts. Although these differences constitute biases in terms of the sample, closer scrutiny of the impacts and community patterns shows that these results are consistent with the expected demographic distribution around the landfill. Rental apartments are built close to the landfill

boundaries and therefore experience the physical impacts, while the water quality impacts affect the more stable, owner occupied single family homes in Fircrest (see site map in Chapter 4). It is assumed that the over-representation of affected apartment renters will, if anything, result in an understatement of negative beliefs and attitudes, while the excess of water quality impacted, long-term owners should over-emphasize this impact. These patterns were checked in the pattern of belief responses in the last section and showed no significant connection. Hence the sample demographics tend to accurately represent conditions in the host community and sample without biasing the results.

The Salem sample shows some discrepancies also, but these are less consistent. The explanations are derived from comparing physical impact footprints with demographic patterns:

- Time in the neighborhood

  The over-representation of long-term residents in view-impact areas may be caused by the better visibility beyond 0.5 to 0.8 km. Hence, short-term residents in the village may be less affected by views because screening by trees and buildings is more effective.

- Income:

  More high-income households live over 1.5 km away from the plant, while lower income households predominate under the 1.5 km distance. Furthermore lower income households are over-represented in the air quality impacted areas. This is, however, a reflection of the location of a mobile home park and a church retirement community about 500 to 1,000 m

Table 5.8a - Tacoma Landfill Host Community Sample Demographics versus Physical Impacts

Demographic Variables	Physical Impacts
Time in Community	- significantly more residents of less than five years are exposed to odor, noise, air quality impacts
Type of home	- significantly more apartment dwellers are exposed to odor, noise, air quality and water quality impacts - significantly more single family dwellers are exposed to wildlife habitat impacts
Ownership	- significantly more renters are exposed to odors, noise, air quality and water quality and wildlife habitat impacts
Children in household	- no significant association with physical impacts
Education	- no significant association with physical impacts
Income	- no significant association with physical impacts

See Table 5.C8a in Appendix

Table 5.8b - Salem Incinerator Host Community Sample Demographics Versus Physical Impacts

Demographic Variables	Physical Impacts
Time in Community	- significantly more residents of over five years are exposed to view impacts
Type of home	- no significant association with physical impacts
Ownership	- significantly more renters are exposed to air quality impacts
Children in household	- more childless households are exposed to air quality impacts
Education	- no significant association with physical impacts
Income	- more low income households are exposed to air quality impacts

See Table 5.C8b in Appendix

to the northeast of the plant. Since lower income households are likely to express less concern, this pattern has the conservative effect of de-emphasizing the air quality impact beliefs.

- Ownership

  The lower ratio of property owners in the air quality impact zone reflects the presence of the mobile home park and the retirement facility.

The discrepancies reflect actual patterns of impacts and host community demographics. However, only income associates significantly with impact beliefs (see previous section); but no connection of income with beliefs about air quality impacts is significant. All discrepancies except the view exposure of long-term residents are expected to diminish negative ratings, and, hence, exert a conservative effect on the results.

Internal Validation

The purpose of internal validation is to test the effectiveness of different questions in eliciting consistent responses, and to identify possible bias that results from misunderstood or leading questions.

The primary focus of the survey is on beliefs and attitudes about the waste facility. Limits to the length of the questionnaire restricted the frequent use of redundant questions about these most important and volatile issues. Hence, only very basic internal validation tests were possible.

Three questions are relevant for testing the internal

validity of the central issues:

- the open-ended listings of salient concerns and benefits of waste facilities
- the belief impact ratings of facility impacts
- the agreement-disagreement opinions to statements about facility impacts.

Two caveats apply to the following comparison. First, the salient concerns and benefits are not necessarily representative of the beliefs about the specific facility, because the question asks (question 17, see questionnaire in Appendix 5.A) about generic landfills and incinerators. Second, the specific impact beliefs ratings elicit to what degree the respondent believes the impact levels are above or below acceptable levels, while, in contrast, the impact statements simply elicit agreement or disagreement about the existence of the impacts. For example, a respondent may agree that the facility causes nuisances, but may consider the level of nuisance impacts acceptable. Hence, the response to the statement would indicate a negative belief about the impact, while the impact rating would be positive (i.e., better than acceptable). Nonetheless, some correspondence is expected between negative impact ratings (i.e., lower than "acceptable") and agreement with negative impact statements, because any negative change is more likely to be considered less than acceptable. Thus, the respondents are expected to give corresponding answers to these two questions about the same impacts.

Tables 5.9a and c list the salient concerns that were

mentioned and the impacts that were negative (less than acceptable) by a significant number of respondents (columns 1,and 2). Column 3 indicates whether a significant association between the salient concerns and the negative impact belief rating was found. For most nuisances, and for general environmental change, the salient concerns were associated with the belief ratings. These results indicate some consistency, although not for water and air health risks. Furthermore, in Tables 5.9b and d (columns 1 and 2) the results of chi-square tests of significant association between impact ratings and statements are indicated. Significant association between responses to two sets of questions is accepted at or above 95% significance level for chi-square and Fisher exact tests.

In both surveys, negative impact ratings are significantly associated with negative statements for most impacts (see column 3). Negative ratings are furthermore significantly associated with salient impact beliefs for 5 of 8 salient impacts in Tacoma, but show no significant association in the Salem host community. This difference probably occurs because the Tacoma landfill physically portrays typical landfill impacts, whereas the respondents in Salem may not have yet adapted their salient beliefs about generic waste facilities to their specific impact beliefs about the incinerator. As a result, the lack of association appears between general salient concerns and specific impact ratings.

The contrast of scarce mention on one hand of any economic, social, or political impacts among the salient beliefs and the

Table 5.9a - Tacoma Landfill - Internal Validation of Negative Beliefs about Facility Impacts: Association of Salient and Specific Impact Belief Ratings in the Host Community

1 Salient Impact Beliefs	2 Specific Impact Belief Ratings	3 Association of Salient Impact Beliefs with Specific Impact Beliefs about the Waste Facility
N=33	N=33	N=19-23
Nuisances	Nuisances	
(Noise)	Noise	significant
Odor	Odor	non-sig.
Traffic	traffic	significant
Birds	animals	significant
	(litter)	significant
	view	non-sig.
Health Risks	Health Risks	
	air pollution	non-sig.
water pollution	water pollution	non-sig.
accident risks		
Environmental Change	Environmental Change	significant
	air quality	non-sig.
	water quality	non-sig.
	wildlife	non-sig.
	Economic Impacts	
	property values	non-sig.
	Social Impacts	
	Community Image	non-sig.
	Political Impacts	
	Loss of Control	non-sig.
	Loss of confidence	non-sig.
	in local government	non-sig.
Benefits		
Convenience		non-sig.
Significance criteria:		
Significant if proportion >28% Marg. Significant (in brackets) if proportion >18%	Significant if proportion 38% Marg. Significant if (in brackets) if proportion >23%	Chi square and Fisher Exact tests significant if $p<0.05$

Table 5.9b - Tacoma Landfill - Internal Validation of Negative Beliefs about Facility Impacts: Association of Specific Impact Belief Ratings and Impact Belief Statements in the Host Community

1 Negative Impact Beliefs Ratings N=33	2 Negative Impact Belief Statements N=33	3 Association of Impact Belief Ratings with Impact Belief Statements N=13-20
Nuisances noise odor traffic animals (litter) view	Nuisances	significant
Health Risks air emissions water emissions	Health Risks	significant
Environmental Change air quality water quality wildlife habitat	Environmental Change	significant
Economic Impacts property values	Economic Impacts property values	significant
Social Impacts Community Image	Social Impacts Community Image	non-sig.
Political Impacts Loss of Control Loss of confidence in local gov't.	Political Impacts Loss of Control Loss of confidence in local Gov't. (unfairness) Lack of Information	significant
Significance criteria: Significant if proportion >38% Marg. Significant (in brackets) if proportion >23%		Chi square and Fisher Exact tests significant if $p<0.05$

Table 5.9c - Salem Incinerator - Internal Validation of Negative Beliefs about Facility Impacts: Association of Salient Impact Beliefs, Specific Impact Belief Ratings in the Host Community

1 Salient Impact Beliefs	2 Negative Impact Ratings	3 Association of Salient Impact Beliefs with Specific Impact Belief Ratings
N=34 Nuisances	N=34 Nuisances	N=13-22
noise	(noise)	non-sig.
odor	(odor)	non-sig.
view	(view)	non-sig.
traffic	(traffic)	non-sig.
Health Risks air emissions	Health Risks air emissions	non-sig.
Environmental Change air quality	Environmental Change air quality	non-sig.
Economic Impacts property values	Economic Impacts property values	non-sig.
	Social Impacts Community Image	non-sig.
	Political Impacts Loss of Control	non-sig.
	unfairness	non-sig.
	Loss of confidence in local Gov't.	non-sig.
	in owner/operator	non-sig.
	in environ. agen.	non-sig.
Benefits better disposal method		non-sig.
energy		non-sig.
Significance Significant if proportion >28% Marg. Significant (in brackets) if proportion >18%	Significance Significant if proportion >38% Marg. Significant (in brackets) if proportion >23%	Chi square and Fisher Exact tests significant if $p<0.05$

Table 5.9d - Salem Incinerator - Internal Validation of Negative Beliefs about Facility Impacts: Impact Belief Ratings and Impact Belief Statements in the Host Community

1 Negative Impact Ratings	2 Negative Impact Statements	3 Association of Impact Belief Ratings with Impact Belief Statements
N=34	N=34	N=20-34
Nuisances (noise) (odor) (view) (traffic)	Nuisances	significant
Health Risks air emissions	(Health risks) (Health risks)	significant significant
Environmental Change air quality	Environmental Change	significant
Economic Impacts property values	Economic Impacts property values	 significant
Social Impacts Community Image	Social Impacts Community Image	 significant
Political Impacts Loss of Control unfairness Loss of confidence in Local Gov't. in owner/operator	Political Impacts Loss of Control unfairness Loss of confidence (in local Gov't.)	 significant significant significant non-sig.
	Benefits	
	lack of need	non-sig.

Significance criteria:
Significant if proportion >38%
Marg. Significant (in brackets) if proportion) >23%

Chi square and Fisher Exact tests significant if proporiton <0.05

frequency and significance of association between impact ratings and statements of these impacts on the other, indicates a significant difference between the concerns about a generic waste facility and the impact beliefs about a specific facility. This difference will be further discussed in the next section.

The second validity check was performed on the responses to two questions about attitudes about the facility as a neighbor in the community. Respondents were asked first to rank the desirability of six facilities, then to rate (on a scale of -4 to +4) the desirability of each of six facilities as neighbors in their community. For internal consistency, there should appear some significant rank-order correlation as measured by the non-parametric Goodman - Kruskal gamma correlation factor (Roscoe, 1975).

This validity test of attitudes is somewhat hampered by the few complete responses to both the ranking question and to the attitude rating question (Tacoma N = 25 and 23, Salem N = 22 and 17). The rough validity test is furthermore hampered by the incompatibility of a rank order and a rating scale. Although both are measured on ordinal scales, the rating allows for ties and provides some indication of strength in the difference of ratings. Therefore, the Goodman - Kruskal gamma test was used. The results are summarized in Table 5.10 below for the combined samples in Tacoma and Salem by host, control and total samples.

The results show significant correlation in the combined samples. Thus, respondents appear to answer similarly the two independent questions about attitude towards facilities. The

Table 5.10 - Internal Validation through Rank-order Correlation between Attitude Ranking and Rating of Facilities

Correlation of Two Attitude Variables

	Host	Control	Host and Control
	N=37-43	26-32	66-75
Gravel Pit	non-sig.	significant	significant
Landfill	significant	non-sig.	significant
Electrical Power Plant	significant	marg.-sig.	significant
Garbage Burner	significant	significant	significant
Chemical Plant	non-sig.	significant	significant
Hazard. Waste Facility	marg.-sig.	significant	significant

Goodman Kruskal Gamma significant at 95%, marginally sign. at 90%

validation indicates that the sample well represents the typical host community but slightly over-emphasizes more educated, higher income households. These discrepancies are not associated with the physical impact footprints, and only slightly correlate with the results on perception of impacts. Two separate responses on attitude about waste facilities are consistent for the combined samples in Tacoma and Salem.

The analysis of the results proceeds in the following section based on these validation results.

5.3.2 Impact Beliefs

Spontaneous Beliefs

Spontaneous beliefs about waste facilities were coded and compiled into impact categories for host and control respondents at each site (see Appendix 5.B.1 for coding list). The concern or benefit is significant (at 95% confidence level) if at least 15% of the respondents list the impact at a sample size of 30 per community group.

Furthermore, the frequency ratios of host and control group salient beliefs were analysed for significant differences. The results are listed in Table 5.11 for the landfill and incinerator sites. Landfills generate spontaneous concerns about odors, traffic, birds, water contamination and explosion risks, with convenience of disposal as a benefit. Incinerators cause concerns about noise, odors, traffic, air emissions and quality with benefits of energy production and the advantage of being better than other disposal methods.

Table 5.11 - Spontaneous Concerns and Benefits about Waste Facilities

a. Tacoma Landfill
Proportion of respondents who mention these concerns and benefits

Concerns/ Benefits	Community Host	Control	Difference of Proportions
Nuisances	N=33	N=28	
odor	58%	82%	HC<CC sig.
noise	(<18%)	(21%)	marg.sig.
traffic	33%	43%	non-sig.
birds	(20%)	40%	HC<CC sig.
Health			
water emissions	27%	29%	non-sig.
explosion risk	24%	32%	non-sig.
Benefits			
convenient disposal	40%	(21%)	HC>CC sig.

b. Salem Incinerator
Proportion of respondents who mention these concerns and benefits

	Community Host	Control	Difference of Proportions
Nuisances	N=34	N=23	
noise	32%	(22%)	non-sig.
odor	35%	61%	HC<CC sig.
traffic	29%	35%	non-sig.
Health			
air emissions	(21%)	35%	non-sig.
General Environment			
air quality	32%	44%	non-sig.
Economic			
property values	-	(22%)	marg.sig.
Benefits			
energy	-	(22%)	HC<CC sig.
better method	(18%)	26%	non-sig.

Legend: HC=host comunity, CC=control comunity,
Impacts are significant if proportion is at least 23%,
marginally significant at or over 18% are in brackets ( )

Noticeably, non-physical impacts (economic, social and political factors) are not significantly mentioned at all. As predicted, the host-community mentions some typical impacts significantly less frequently than the control respondents. But, in general, the salient impact beliefs about waste facilities are similar among host and control respondents. Odors at incinerators were not detected, but are a salient belief among host and control residents.

Specific Beliefs

The specific impact beliefs are separately indicated by ratings and statements. For the proportion of negative beliefs to be statistically significant at the 95% confidence level and sample sizes of 25 to 34, at least 38% of respondents must rate their beliefs as negative. To achieve marginal significance, 23% of the respondents must consider the impact negative. This stringent criterion was applied here to reduce the potential bias of a small fraction of undifferentiated negative ratings throughout the list. The significant specific impact beliefs are summarized in Table 5.12.

At the landfill, nuisances (noise, odor, view, litter, traffic and animals), health risks (air and water emissions), environmental change (air and water quality, wildlife habitat), property values, community image and control are perceived to be affected by the facility.

At the incinerator, odor and view, air emissions and quality, property values, community image, control, fairness and confidence in government, facility owner and environmental agency are

Table 5.12a - Tacoma Landfill - Impact Belief Ratings and Connection with Attitude and Annoyance about the Waste Facility

1 Type of Impacts	2 Percentage of Respondents with Negative Beliefs % negative	3 Correlation of Impact Beliefs on Attitude (G-K Gamma)	4 Ranking of correlation Strength	5 Association of Impact Belief Ratings with Annoyance about Waste Facility
N=19-25		N=24		N=20-26
Nuisances		0.54	(2)	
noise	(24.2%)	0.56	(5)	non-sig.
odor	(30.3%)	non-sig.		significant
view	(24%)	non-sig.		non-sig.
litter	(24%)	non-sig.		high-sig.
traffic	(30%)	0.69	(2)	non-sig.
animals	42%	0.72	(1)	non-sig.
Health Risks				
air emissions	(33%)	non-sig.		significant
water emissions	52%	non-sig.		significant
Environmental Change				
air quality	(36%)	non-sig.		non-sig.
water quality	39%	non-sig.		marg.-sig.
wildlife habitat	(30%)	0.57	(3)	non-sig.
Economic Property Values	(30%)	0.57	(3)	non-sig.
Social				
Image	39%	non-sig.		non-sig.
Political				
Loss of Control	(27%)	non-sig.		non-sig.
Unfairness		non-sig.		marg.sig.
Significant if over 38% negative, Marg. significant (in brackets) if over 23%		Goodman-Kruskal Gamma significant at 95%		Chi-square significant at 95%

Table 5.12b - Tacoma Landfill - Impact Belief Statements and Connections with Attitude and Annoyance about Waste Facility

1 Type of Impacts	2 Percentage of Respondents with Negative Beliefs % negative	3 Correlation of Belief Statements on Attitude (G-K Gamma)	4 Ranking of Correlation Strength	5 Association of Impact Beliefs with Annoyance about Facility
N=28-29		N=24		N=16-27
Nuisances	66%	0.54	(2)	sig.
Health risks	45%	0.53	(3)	marg.sig.
Environmental Change	52%	0.49	(4)	non-sig.
Property Values	41%	0.47	(5)	significant
Image	41%	0.56	(1)	significant
Loss of Control	50%	non-sig.		significant
(Unfair)	(31%)	non-sig.		significant
Lack of Information	41%	non-sig.		non-sig.
Lack of benefits	59%	non-sig.		significant
Significant if over 38% negative, marginally significant (in brackets) at over 23%		Goodman-Kruskal Gamma significant at 95%		Chi-square significant at 95%

affected in residents' beliefs.

In contrast to the focus on physical impacts in the salient impact beliefs, the specific impact beliefs comprise elements in all physical and non-physical categories, including the economic impacts on property values, social impacts on community image, political impacts through loss of control and of confidence, and unfairness.

Specific Impact Beliefs and Attitude about the Facilities

The influence of the specific beliefs on the attitude about the waste facilities were tested by the Goodman - Kruskal rank - correlation analysis. Two sets of rank - correlation tests were used to accommodate the different foci and the different scales of the questions. Belief statement responses were used to test correlations of general physical impact categories (nuisances, health, environmental change) and of non-physical impacts with attitude, whereas specific belief ratings were used to correlate the effects of specific physical impacts (noise, odor, etc.) with attitude. This approach was taken because the specific belief rating results were less reliable. The results are listed in columns 2 of the Table 5.12 for the attitude ratings about each waste facility.

The strength of the rank-order correlation is indicative of the significance of individual beliefs for the resulting attitude. Thus, significant rank order coefficients are listed in columns 2 of Tables 5.12a to d with the rank of their magnitude (1 for the highest correlation, 2 for the next, etc.). At the landfill, image impacts rank highest, followed by nuisances, health risks,

environmental change and property values. At the incinerator, the loss of control ranks highest, followed by health risks, property value, image impacts, nuisances, unfairness, lack of need and environmental change. At both sites, non-physical (control and image) impacts rank highly in correlation with the attitude about the facility.

Finally, significant impact beliefs were tested for association with annoyance about the facility (on column 3 of Tables 5.12a to d). Many significant negative impact beliefs are associated with annoyance, but more so at the incinerator site.

Two criteria are considered important for testing a causal connection between impact beliefs and resulting attitude: a significant percentage of negative beliefs on at least one, but preferably on both opinion and rating responses, and a significant rank - correlation with attitude. These two criteria may conflict, because strongly negative belief ratings or attitudes may be clustered and may therefore not contain enough variation to generate a significant rank-correlation. This may be the reason why some of the beliefs with high negative proportions do not correlate with attitude. The scrutiny of the distribution of belief showed no extreme negative skewedness. Hence, the two criteria do not actually exclude each other in this case.

In Tacoma, both criteria are met for a variety of physical impacts (nuisances, health risks and environmental change), property values, and community image. Specific physical impacts, e.g., noise, traffic and animals, property value and community image impacts are very strong.

Table 5.12c - Salem Incinerator - Impact Belief Ratings and Connection to Annoyance about the Waste Facility

1 Type of Impacts	2 Percentage of Respondents with Negative Beliefs % negative	3 Rank-order Correlation of Belief on Attitude (G-K Gamma)	4 Ranking of Correlation Strength	5 Association of Impact Beliefs with Annoyance about Facility
N=23-25		N=18		N=20-30
Nuisances				
noise	(32%)	non-sig.	-	significant
odor	(33%)	non-sig.	-	significant
view	(40%)	non-sig.	-	significant
traffic	(35%)	non-sig.	-	significant
Health risks				
air emissions	56%	non-sig.	-	significant
Environmental Change				
air quality	39%	non-sig.	-	non-sig.
Economic Impacts				
Property Values	60%	non-sig.	-	significant
Community Image	56%	non-sig.	-	significant
Political Impacts				
Loss of Control	64%	non-sig.	-	non-sig.
Unfair	61%	non-sig.	-	significant
Lack of Confidence				
in local govt.	65%	non-sig.	-	non-sig.
in owner	50%	non-sig.	-	non-sig.
in environmental agency	58%	non-sig.	-	non-sig.
Significant if over 38% negative, marginally significant (in brackets) at over 23%		Goodman-Kruskal Gamma significant at 95%		Chi-square significant at 95%

Table 5.12d - Salem Incinerator - Impact Belief Statements and Connection to Annoyance about the Waste Facility

1 Type of Impacts	2 Percentage of Respondents with Negative Beliefs % Negative	3 Rank-order Correlation of Beliefs Statement on Attitude (G-K Gamma)	4 Ranking of Correlation Strength	5 Association of Impact Beliefs Statements with Annoyance about Facility
N=33-34		N=20		N=19-30
Nuisances	41%	0.69	(5)	high-sig.
Health risks	(38%)	0.8	(2)	high-sig.
Environmental Change	39%	0.52	(8)	high-sig.
Economic Impacts				
Property Values	38%	0.78	(3)	significant
Social Impacts				
Community Image	42%	0.76	(4)	significant
Political Impacts				
Loss of Control	42%	0.82	(1)	non-sig.
Unfair	44%	0.68	(6)	significant
Lack of need, benefits	56%	non-sig.		non-sig.
Significant if over 38% negative, marginally significant at over 23%		Goodman-Kruskal Gamma significant at 95%		Chi-square significant at 95%

In Salem, the findings are somewhat less convincing because many belief ratings do not correlate with attitude despite significant negative impact beliefs (see columns 1 and 2 in Table 5.12c and d). In contrast, most significant statement opinions correlate with the attitude about the garbage burner. Moreover, heavy intercorrelation between impact belief responses was found in Salem. The lack of clear differentiation among the belief responses may indicate a halo effect among residents; that is, a generally negative attitude causing a tendency to indicate negative impact beliefs throughout. The lack of significant correlation of specific impacts with the attitude supports this suspicion and diminishes the confidence in the results in Salem. However, the results of both belief questions are consistent and the rank-correlation of the more reliable belief statement set with attitude confirms some degree of correlation for political (control, unfairness, lack of confidence), social (image), economic (property values), and physical impacts.

Respondents' self-rated familiarity with the waste facilities was measured for their own and five other types of facilities. The mean and standard deviation values are contained in Table 5.13a. As expected, host community respondents' familiarity is higher, while the standard deviation is lower than among control respondents. The difference is more pronounced in Salem, likely because the technology and the facility are new. Among none of the host or control groups does familiarity significantly rank correlate (Table 5.14) with attitude about the facilities. Self-judged familiarity, therefore, is not a significant influence on host-community attitude.

Table 5.13 - Familiarity and Attitude about Waste Facilities

a. Tacoma City Landfill

	Community Host N=33	Community Control N=27	Difference of Means Confidence interval at 99%
Familiarity with Facility Scale from 1 (unfamiliar) to 7 (familiar)			
average (scale 1 to 7)	5.72	5.0	non-sig.
standard deviation	(1.5)	(2.1)	
Attitude Ranking on scale of 1 (best) to 6 (worst)			
average	3.48	3.7	non-sig.
standard deviation	(1.55)	(1.18)	
Rating on scale of -4 (very undesirable) to +4 (very desirable)			
average (-4 to +4)	-1.65	-2.57	sig.
standard deviation	(2.1)	(1.7)	HC>CC

b. Salem Incinerator N=34 N=23

Familiarity with Facility on scale from 1 (unfamiliar) to 7 (familiar)			
average (scale 1 to 7)	5.02	3.65	sig. HC>CC
standard deviation	(1.7)	(2.41)	
Attitude Ranking on scale of 1 (best) to 6 (worst)			
average	3.13	3.71	non-sig.
standard deviation	(1.25)	(1.45)	
Rating on scale of -4 (very undesirable) to +4 (very desirable)			
average	-0.53	-0.88	non-sig.
standard deviation	(2.46)	(2.15)	

Legend: HC = host community
CC = control community

Table 5.14 - Rank-order Correlation of Familiarity with Facility and Attitude about Facility

a. Tacoma

Familiarity	Community Host	Control	G-K Gamma significance at 95%
with	N=25	20	
Attitude	Rank-order correlation G-K Gammas		
Rank (1 to 6)	.164	.254	non-sig.
	N=26	21	
Rating (-4 to +4)	-.075	.161	non-sig.

b. Salem

Familiarity	Community Host	Control	G-K Gamma significance at 95%
with	N=22	16	
Attitude	Rank-order correlation G-K Gammas		
Rank (1 to 6)	.168	-.39	non-sig.
	N=30	16	
Rating (-4 to +4)	.07	.326	non-sig.

5.3.3 Physical Impacts and Impact Beliefs

The association of residents exposure to observed physical impacts (see Chapter 4) on the host community survey responses would verify causal linkages between physical impacts and beliefs, and would indicate connections ("triggers") between physical impacts and non-physical impact beliefs.

The physical impact levels were coded according to the observed physical impacts at the home locations of survey respondents (see Figures 4.22 a and b in Chapter 4). The coding was done liberally by recognizing a possible impact in doubtful cases. In particular, the view range of the incinerator was extended to driveways and access lanes to a residence.

The low variation in the physical impact codes preempted rank correlation analysis, so the simpler chi-square and Fisher exact test were used to test for significant associations between exposure to physical impacts and impact beliefs. Significant relationships are listed in Table 5.15 for the Tacoma and Salem sites. Note that the overlapping impact fields result in multiple exposure of certain residents. The resulting connections must be interpreted with care. For example, respondents who live within 1.6 kilometres from the site are more likely to perceive impacts from nuisances, image and loss of confidence.

The tabulation of results show two points:

1. There is an unexpected lack of consistent association between physical impacts and physical impact beliefs. The dependence of perceived view impacts on physical

Table 5.15 - Exposure to Physical Impacts and Resulting Negative Impact Beliefs

a. Tacoma Landfill

Exposure to Physical Impacts	Impacts that Exposed Residents are more likely to perceive as Negative			
	Physical	Economic	Social	Political
Distance under 1.6 km	(+nuisances)	o	+image	(+confidence in local gov't)
View	+view	+property values	o	+loss of fairness
Noise	+view	o	o	o
Odor	+view	o	o	(+loss of fairness)
Health Risk	+view	o	o	+loss of fairness

b. Salem Incinerator

Exposure to Physical Impacts	Associated Residents' Negative Beliefs about Facility Impacts			
Indicators	Physical	Economic	Social	Political
Distance under 1.6 km	(+nuisances) (+traffic)	o	o	(+loss of confidence in local gov't
View	+accident risks	o	+image	+loss of +confidence in owner/operator (+loss of control)
Air quality	o	o	o	+loss of control +loss of confidence in owner/operator +loss of fairness

Chi-square and Fisher Exact Tests
Legend: significantly associated beliefs if $p <$ or $= 0.05$ are marked with a "+"
marginally significantly associated beliefs if $0.05 < p < 0.1$ are indicated by (+)
beliefs with not significant association are indicated by "o"

view, noise, odor and health risks in Tacoma probably occurs because the physical impact boundaries for view, noise, odor and risk coincide (see impacts in Figure 4.22a).

2. There is a significant association between physical impacts and some non-physical impact beliefs, e.g., between view and property values, image, and fairness at Tacoma; in Salem, view and air quality impacts are associated with lack of confidence, loss of control and of fairness.

The results support the connection of physical impacts (triggers) with non-physical impact beliefs.

5.3.4 Attitudes among Host and Control Residents

The prediction derived from risk perception (see Chapter 2) states that host community residents will tend to adapt to the facility impacts and, hence, be more accepting of the facility than control respondents, or, than a host community of a different type of facility.

This may result from self-selection of less sensitive residents who remain in the host community, while more sensitive households move out. Alternatively, residents may shift their own belief-attitude set to minimize the negative impact by adapting to the facility (see Chapter 3). The attitude ratings and variances among host and control respondents are tabulated below (Tables 5.16a and b) for both facilities.

The results do not contradict the predicted pattern, although

Table 5.16 - Attitudes about Waste Facilities

a. Tacoma Landfill Site

Community		Attitude Rating on scale of -4 to +4 of Facility: Landfill Attitude	Incinerator Attitude	Difference of means
Host N=26	Average (-4 to +4)	-1.65	-2.04	non-sig.
	Variance	(4.40)	(4.84)	(non-sig.)
Control N=23	Average (-4 to +4)	-2.57	-2.04	non-sig.
	Variance	(2.89)	(4.13)	(non-sig.)
Difference of means		marg.sig. (non-sig.)	non-sig. (non-sig.)	

b. Salem Incinerator Site

		Attitude Rating of Facility: Landfill Attitude (variance)	Incinerator Attitude (variance)	Difference of means
Host N=30	Average (-4 to +4)	-3.39	-0.53	sig.
	Variance	(0.98)	(6.05)	(sig.)
Control N=17	Average (-4 to +4)	-2.59	-0.88	sig.
	Variance	(5.13)	(4.61)	(non-sig.)
Difference of means		marg.sig. (sig.)	non-sig. (non-sig.)	

Difference of Means test significant at 95%

Boxes indicate type of facility in the host community at that location

not all differences are statistically significant. Some points are indicative though:

1. Each host community expresses the least negative attitude about its own facility, (Tacoma rates its landfill at -1.65, and Salem rates its incinerator at -0.53) while both are most negative about the other type of facility (Tacoma host rates an incinerator at -2.04, while Salem host rates a landfill at -3.39).
2. The non-affected communities have the most negative attitudes about both facilities, although the control groups may be only slightly more negative about their waste facility (Tacoma control respondents rate a landfill at -2.56 versus the host group's rating of -1.65 Salem control respondents rate an incinerator at -0.88 versus the host group rating of -0.53).
3. Although host communities are more positive about their facility than their respective control, the spread of attitudes is wider as indicated by the variance of the host (4.4) versus control (2.89) in Tacoma, and host (6.05) versus control (4.61) in Salem.

5.3.5 Newspaper Reports about Waste Facilities and Negative Impact Beliefs among Residents.

The purpose of this content analysis is to test the influence of media reporting of facility impacts on the impact beliefs among residents. Two indicators were used to test the influence of media reports:

- the number of times per week that survey respondents

read newspapers and watch news on TV;

- the ratio of the frequency of impacts and benefits mentioned in newspaper reports to the frequency of impact beliefs mentioned or rated by residents in the survey.

The first indicator is used to test whether newspaper contents is a possible route of opinion influence, that is, whether a majority of people read the newspaper frequently. The second indicator is used to test a possible influence on impact beliefs. Host and control groups' beliefs are not differentiated here, because the salient impact beliefs do not significantly differ; only the host group's specific impact belief ratings and statements are considered.

A frequency analysis shows that a majority of respondents in both host and control communities report reading the newspaper five or more times per week (Table 5.17a). Thus, newspaper reports are a probable source of information to form impact beliefs among residents. The percentage of respondents who read the newspaper and watch TV news more than 5 times per week are similar for all groups (see Table 5.17b). Moreover, the cross tabulation of newspaper readers and TV news watchers (Table 5.17c) shows that about 70 to 87% of frequent TV watchers also frequently read newspapers in Tacoma and Salem. Therefore, newspaper content reaches a substantial percentage of people including a majority of those who frequently watch TV news. Thus by omitting the TV content analysis because of the limited time available for this study will not jeopardize the significance of the newspaper content analysis for testing media influence.

Table 5.17 - Content Analysis - Waste Facility Impacts and Benefits

a. Newspaper Readership

Site/Community		N	Proportion of Residents who read newspaper less than 5 times	more than 5 times	Difference of proportions (significant at 95%)
Tacoma	Host	29	24.2 %	75.8 %	sig.
	Control	24	41.7 %	58.4 %	non-sig.
Salem	Host	29	22.7 %	77.3 %	sig.
	Control	23	21.6 %	78.3 %	sig.

Table 5.17 - Content Analysis

b. News from Newspaper versus TV News

Site/Community		N	Proportion of Residents who per week Read paper more than 5 times	Watch TV more than 5 times	Difference of proportions (significant at 95%)
Tacoma	Host	29	75.8 %	90.0 %	non-sig.
	Control	23	58.4 %	69.2 %	non-sig.
Salem	Host	29	77.3 %	80.7 %	non-sig.
	Control	25	78.3 %	86.3 %	non-sig.

Table 5.17 - Content Analysis - Waste Facility Impacts and Benefits

c. Cross Tabulation of Frequent Paper Readers with Frequent TV News Watchers in Host Communities

Tacoma Host Community

N=29	Newspaper Readers Frequency per week	
	less than 5 times	more than 5 times
TV Watchers		
less than 5 times	0	3
more than 5 times	7	19

Salem Host Community

N=29	Newspaper Readers Frequency per week	
	less than 5 times	more than 5 times
TV News Watchers		
Frequency per week less than 5 times	3	3
more than 5 times	3	20

Table 5.18a - Content Analysis of Newspaper Articles about Landfill Comparison of Media Frequency with Surveyed Frequency of Impact Beliefs

	Mentioned Frequency % of articles	Proportions of Respondents Similar to Frequency Mentioned in Newspaper Articles
N=	62	
Nuisances		
-noise	-	
-odor	-	
-view	-	
-litter	-	
-traffic	-	
-animals	-	
Health Risks		
-air	55%	55% similar proportion
-water	100%	
-accident	100%	
Environment Change	14.5%	
-air quality	-	
-water quality	36%	
-wildlife habitat	-	
Economic Impacts		
-property values	52%	48% similar proportions
-development	-	
-employment	-	
-taxes	-	
-costs	100%	
Social Impacts		
-image	100%	
Political Impacts		
-control	23%	
-fairness	-	
-confidence		
-owner	73%	
-local gov't	100%	
-environ. agency	33%	22% similar proportions
-information	100%	
Benefits		
-need/service	27%	26% similar proportions
-convenience	-	
-energy	13%	
-better method	-	
14 facility impacts are frequently mentioned		4 of total 29 impacts are similarly frequently mentioned by respondents

Differences significant at 95% confidence interval
Insignificant frequencies are denoted by -

Table 5.18b - Content Analysis of Newspaper Articles about Incinerator Comparison of Media Frequency with Surveyed Frequency

	Media Frequency % of articles	Proportions of Respondents Similar to Frequency in Newspaper Articles
N=	161	
Nuisances		
-noise	-	
-odor	-	
-view	-	
-litter	-	
-traffic	-	
-animals	-	
Health Risks		
-air	37%	23% similar frequency
-water	-	
-accident	-	
Environment Change	18%	
-air quality	-	
-water quality	-	
-wildlife habitat	-	
Economic Impacts		
-property values	-	
-development	-	
-taxes	24%	
-costs	66%	
Social Impacts		
-image-waste	48%	56% similar frequency
-pollution	-	
Political Impacts		
-control	-	
-fairness	21%	
-confidence		
-owner	-	
-local gov't	58%	65% similar frequency
-environ. agency	-	
-information	13%	
Benefits		
-need/service	22%	
-convenience	-	
-energy	42%	
-better method	16%	18% similar frequency
-employment	-	
14 impacts frequently mentioned		4 of total 29 impacts are similarly frequently mentioned as negative impacts by respondents

Differences significant at 95% confidence interval
Insignificant frequencies of under 18% are denoted by -

The second phase consisted of compiling and analysing all newspaper articles about each waste facility and similar facilities in the local press. The time period for the content analysis was chosen to cover recent events up to the time of the beliefs and attitude survey.

In Tacoma, the official library records of the Tacoma News Tribune were not available; as a result, a total of 62 articles was obtained from a private collection of Tacoma News Tribune reports and from a computer search of related Seattle Times articles. The articles spanned the period of June 1985 to March, 1987, when the attitude survey was completed.

In Salem, a complete record of all reports in the Salem Statesman - Journal was copied; 161 articles spanned the entire siting process from January 1981, to January, 1987, when the attitude survey was completed.

The impacts mentioned in the newspaper articles were coded by article. The coding proceeded by identical categories that were used to code the salient beliefs in the survey (see Appendix 5.B1). The proportion of mentioned impacts was then calculated by dividing the recorded frequencies by the total number of articles. The results show the proportion (%) of the total number of articles that mention facility impacts. These percentages were compared first, with the proportions of salient impact beliefs for combined host and control groups and then with the negative impact beliefs ratings and impact statements among host community respondents. The results are summarized in Table 5.18 below for those impact and benefit categories that occur in similar

frequencies. The number of similar proportions (indicated in the tables by non-significant differences) between newspaper reports and impact beliefs proportions are summarized below each column. Similar proportions indicate some association between the frequency of mention in newspaper reports and among residents' impact beliefs.

In none of the belief categories does the proportion of insignificant differences exceed 25%; the frequency of similar proportions ranges between 15 and 20%. News content and specific beliefs are insignificantly different for three impacts at each site: air emissions, property values and lack of confidence in the environmental agency in Tacoma, and health risks from air emissions, community image and lack of confidence in the local government impacts in Salem.

This brief analysis shows very little consistent connection between newspaper content and waste facility impacts and the patterns of impact beliefs among respondents in host and control communities. Although news reports may exaggerate underlying beliefs, this effect may have a highly selective and irregular influence. The erratic differences between news content and impact beliefs make further analysis very difficult without substantial additional time and effort. The rudimentary evidence presented here does not indicate newspaper coverage to be significantly associated with either salient or specific beliefs about either waste facility site.

5.3.6 Summary-Beliefs and Attitudes about Waste Facilities

Spontaneous Concerns and Benefits:

The spontaneous concerns about waste facilities in communities are similar among host and control communities. The concerns about landfills include nuisances (noise, odors, traffic, birds) and health hazards (water contamination and explosion risks); benefits comprise the convenience of disposal (see Figure 5.2, upper right hand box).

The spontaneous beliefs about the garbage burner focus on noise, odor, traffic, air quality impacts, and on the benefits of energy recovery(see Figure 5.3). Control-respondents value the energy recovery from the garbage burner more than the host-respondents, but the host-residents near the landfill recognize the convenience of waste disposal more than the controls.

The spontaneous concerns were fairly consistent with observed physical emissions, except for the concern about odor at the garbage burner, where none was detected. Thus, this concern among host-residents appears to be a remnant of commonly held beliefs about odors from waste facilities.

Impact Beliefs and Resulting Attitudes about Facilities:

Landfill: A significant portion of host-community residents believes that the landfill harms the community image, causes serious nuisances, health hazards, and general environmental degradation, and depreciates property values. The resulting attitudes depend on the following impact beliefs (in descending order of importance, see Figure 5.2):

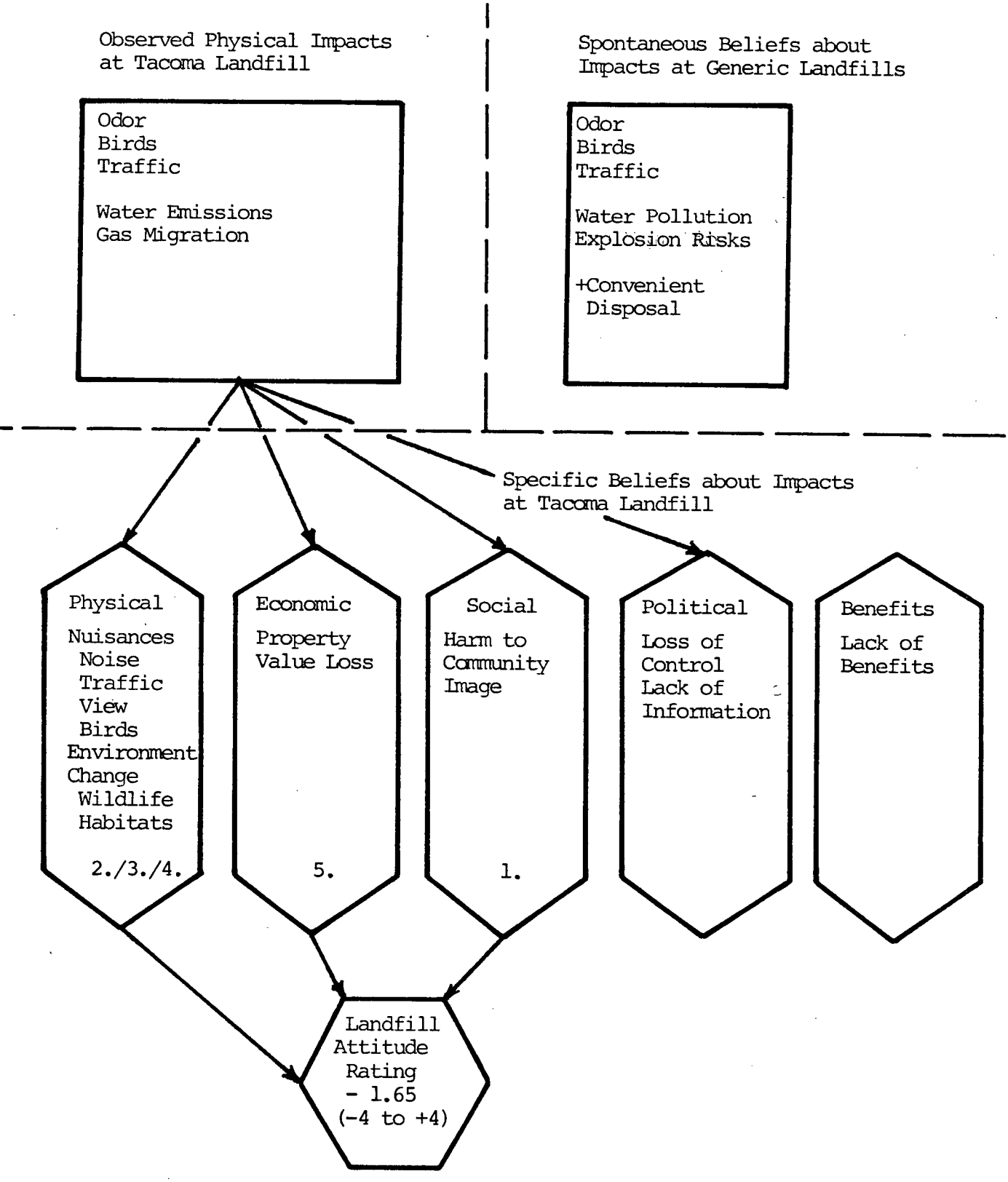


Figure 5.2 - Tacoma Landfill - Summary of Impacts, Beliefs and Attitudes

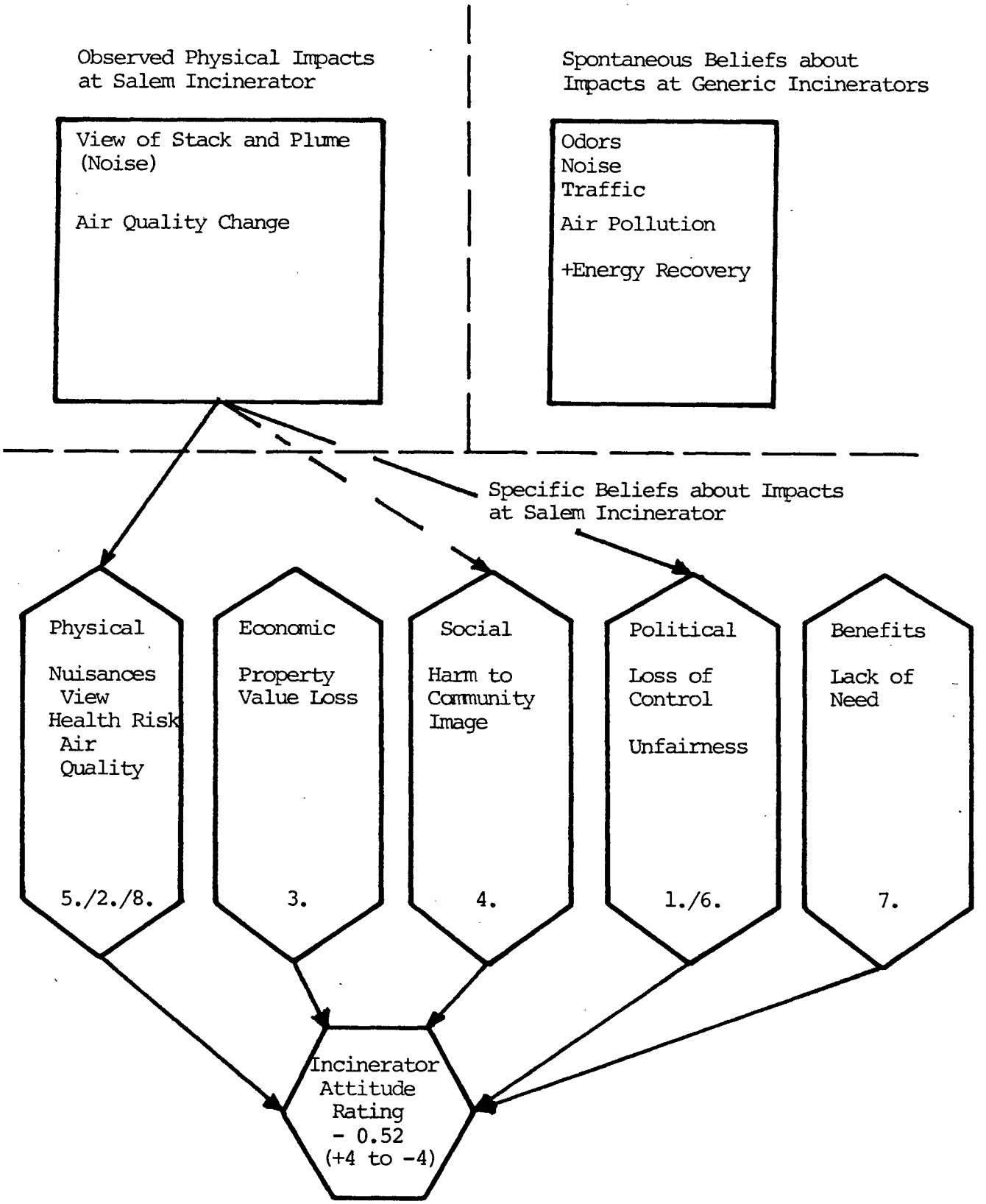


Figure 5.3 - Salem Incinerator-Summary of Impacts, Beleifs and Attitude

1. image impact
2. nuisances (noise traffic, birds)
3. health risks (water contamination)
4. environmental impact (wildlife)
5. economic impact through property value losses

Because most residents moved in after the siting and beginning of the operation 25 years ago, the effects of the siting process (loss of control and fairness) are not pronounced any more. The absence of significant siting process impacts is therefore expected. Residents' beliefs about specific nuisances and health risks are clearly identified and linked to physical emissions. But beliefs about image and property value impacts are also associated with physical indicators, i.e., with view and distance from the site. Newspaper content was not shown to associate with residents impact beliefs.

Incinerator: Residents' attitudes about the incinerator depend on the following impact beliefs about the facility in descending order of importance, (see Figure 5.3).

1. loss of control
2. health risks due to air emissions
3. property value losses
4. image impact
5. nuisance (view)
6. loss of fairness
7. lack of need
8. environmental change in air quality.

Although physical impacts (health hazards and nuisances) are significant, the political impacts, along with image and property

value losses, are more important at this new facility. This is likely due to the very recent siting experience between 1983 and 1985.

The concerns about physical effects are less specific at the garbage burner because there are fewer obvious nuisances, except for the mere view of the plant. The beliefs about specific physical impacts do not depend on the detected physical effects (residents who believe there is a negative view are not necessarily exposed to the actual view), but beliefs about non-physical impacts, such as image, fairness, local control, and confidence in the owner/operator, correspond with the physical view of the facility. Newspaper content did not associate with the residents impact beliefs.

Attitudes: Host-communities tend to rate waste facilities higher than control groups, but the spread among host-residents' attitudes is wider. All groups, except the landfill host-community, rate the incinerator more favorably than the landfill. However, both facilities are considered undesirable neighbors.

In summary, the results from the analysis support the following conclusions:

1. There is a connection between facility physical impacts and residents' salient and specific beliefs about facility impacts. Salient impacts comprise only obvious physical impacts, such as nuisances, and health risks from water and air emissions. The specific beliefs, however, include the entire set of physical and

non-physical impacts including economic, social and political impacts. Thus, underlying the obvious and well documented impacts is a larger set of beliefs about waste facility impacts that cannot be entirely addressed by physical methods.

2. The perception of non-physical impacts depends on the exposure to obvious physical impacts. Thus, the impacts on community image, control, property values etc. increase if people are exposed to view, odor, noise etc. Apparent physical impacts trigger perceptions of non-physical effects more than they do the direct perception of the physical impacts. Therefore, residents appear to interpret the perceived physical impacts in terms of their economic property value, social (image), and political (control, fairness) meaning to themselves. This has a powerful implication for the use of nuisance reduction and screening to simultaneously reduce non-physical impact beliefs.
3. Although attitudes about facilities are correlated with impact beliefs, they are not worse in the affected host community than elsewhere. Hence, some form of adaptation may take place.

5.3.7 Effects of Facility Impact Beliefs and Attitudes on Neighborhood Beliefs and Attitudes

The causal connection between facility impacts beliefs and attitude with neighborhood beliefs and attitude ratings can be tested by three criteria:

1. The facility impact beliefs and neighborhood ratings are measured on the same dimensions. The association between these two beliefs on the same dimensions tests whether the beliefs about the neighborhood may be affected by the facility.
2. The rating of significant negative (i.e., unacceptable) beliefs about the neighborhood on neighborhood rating dimensions can be tested by the differences of proportions between host and control neighborhood beliefs.
3. The rank correlation of neighborhood belief ratings with neighborhood attitude indicates an influence of beliefs on attitude.

The second condition is the least indicative, because facility impacts may simply diminish neighborhood belief ratings without making conditions "unacceptable;" that is, a loss may occur without the situation becoming intolerable. In fact, less than acceptable conditions would constitute a reason to move for some residents and would through self-selection of less sensitive residents result in an overall better average rating in the community. The values of these indicator variables are tabulated in Tables 5.19 and 5.20 for the landfill site in Tacoma and in Tables 5.21 and 5.22 for the incinerator in Salem.

In Tacoma, very few impact dimensions exhibit enough association to confirm some connection: noise, odors and air quality, wild life habitat impacts and loss of confidence come the closest because they meet criteria (1) and (3) (above). While many neighborhood ratings rank - correlate with neighborhood attitude, (noise, odor, view, air and water contamination, resources, development, loss of confidence in the local government, loss of fairness and loss of information about development), many of these dimensions lack at least one other connection. Thus, overall, the effects of landfill impact beliefs on beliefs and attitudes about the host neighborhood are small, because only odor and air quality impacts consistently meeting all three criteria. This is corroborated by the lack of significant difference in neighborhood attitude between host and control groups and by the lack of correlation between host community attitudes about the facility and attitudes about the neighborhood (see Table 5.20a).

In Salem, complete connections of impact beliefs and neighborhood attitude exist for air contamination, air quality, employment, neighborhood image impacts, lack of fairness and loss of confidence in the local government. All of these are significant negative impact beliefs among host residents (see Table 5.12c).

Although host and control respondents rate their attitudes about their neighborhoods similarly (see Table 5.23), the host respondents' attitude about the incinerator rank - correlates significantly with their neighborhood attitude (G-K gamma = 0.55,

Table 5.19 - Tacoma Landfill - Association of Facility Beliefs with Beliefs and Attitudes about Neighborhood

Impacts	Neighborhood Beliefs (negative)	Association of Neighborhood Beliefs with Negative Impact Beliefs about Landfill	
Nuisances	N=33	N=20-23	
Noise	n.sig.	sig.	(←--)
Odor	n.sig.	sig.	(←--)
View	n.sig.	n.sig.	
Litter	n.sig.	n.sig.	
Traffic	n.sig.	n.sig.	
Animals	n.sig.	n.sig.	
Health Risks			
air pollution	n.sig.	n.sig.	
water pollution	n.sig.	n.sig.	
accident risks	n.sig.	n.sig.	
Environmental Change			
air quality	n.sig.	sig.	(←---)
water quality	n.sig.	n.sig.	
wildlife hab.	23%	sig.	←---
Economic Impacts			
Property Values	n.sig.	n.sig.	
Development	n.sig.	n.sig.	
Employment	25%	n.sig.	
Taxes	23%	n.sig.	
Social Impacts			
Image	n.sig.	n.sig.	
Political Impacts			
Control	n.sig.	n.sig.	
Confidence			
Local Gov't	n.sig.	sig.	(←---)
Fairness	n.sig.	n.sig.	
Information	n.sig.	n.sig.	
Significance Criteria	Negative Proportion >18% at 95%	Chi square significant at 95%	

Arrows point out significantly associated beliefs;
Arrows in brackets are marginally associated.

Table 5.20 - Tacoma Landfill - Correlation of Beliefs about Neighborhoods with Attitudes about Neighborhood in Host and Control Communities

Impacts		Comparison of Host and Control Community Beliefs about Neighborhood	Rank Correlation of Neighborhood Beliefs with Attitude	
			Host	Control
Nuisances		N=33 vs 28	N=20	N=21
Noise		n.sig.	0.7	n.sig.
Odor	---→	HC<CC	0.74	n.sig.
View		n.sig.	0.57	0.72
Litter		n.sig.	0.6	0.57
Traffic		n.sig.	n.sig.	n.sig.
Animals		n.sig.	n.sig.	n.sig.
Health Risks				
air pollution	---→	HC<CC	0.89	n.sig.
water pollution	---→	HC<CC	0.64	n.sig.
accident risks		n.sig.	0.47	0.54
Environmental Change				
air quality	---→	HC<CC	0.85	sig.
water quality	---→	HC<CC	0.78	0.64
wildlife hab.		HC<CC	n.sig.	n.sig.
resources	---→	HC<CC	0.61	n.sig.
Economic Impacts				
Property Values		n.sig.	0.88	0.48
Development		n.sig.	0.44	n.sig.
Employment		n.sig.	n.sig.	n.sig.
Taxes		n.sig.	n.sig.	n.sig.
Social Impacts				
Image		n.sig.	0.63	0.64
Political Impacts				
Control		n.sig.	n.sig.	n.sig.
Confidence				
Local Gov't		n.sig.	0.77	n.sig.
Fairness		n.sig.	0.77	n.sig.
Information		n.sig.	0.64	n.sig.
Significance Criteria		Differ. of prop. P<0.05	Goodman-Kruskal Gamma, p<0.05	

HC = host community, CC = control community
Arrows point out significantly correlated beliefs, arrows in brackets are marginally associated.

Table 5.21 - Salem Incinerator - Association of Facility Beliefs with Beliefs and Attitudes about Neighborhood

Impacts	Neighborhood Beliefs (negative)	Association of Negative Beliefs about the Community with Beliefs about Facility Impacts
Nuisances	N=33	N=16-25
Noise	n.sig.	n.sig.
Odor	24%	n.sig.
View	n.sig.	n.sig.
Litter	n.sig.	sig.
Traffic	n.sig.	n.sig.
Animals	n.sig.	sig.
Health Risks		
air pollution	24%	marg.sig.(<---)
water pollution	n.sig.	n.sig.
accident risks	n.sig.	sig.
Environmental Change		
air quality	21%	sig. <---
water quality	n.sig.	n.sig.
wildlife hab.	n.sig.	n.sig.
resources	n.sig.	n.sig.
Economic Impacts		
Property Values	21%	n.sig.
Development	35%	n.sig.
Employment	48%	sig. <---
Taxes	59%	n.sig.
Social Impacts		
Image	21%	sig. <---
Political Impacts		
Control	n.sig.	n.sig.
Confidence		
Local Gov't	36%	sig. <---
Fairness	28%	sig. <---
Information	29%	n.sig.
Significance Criteria	Negative Proportion >18% at 95%	Chi square significant at 95%

Arrows point out significantly associated beliefs;
Arrows in brackets are marginally associated.

Table 5.22 - Salem Incinerator - Association of Facility Beliefs with Beliefs and Attitudes about Neighborhood

Impacts		Comparison of Beliefs about Community in Host and Control Groups Host vs. Control	Rank Correlation of Neighborhood Beliefs with Attitude	
Nuisances		N=33 23	HC N=25	CC N=17
Noise		n.sig.	0.46	0.75
Odor	--->	HC<CC	0.38	0.53
View		n.sig.	0.67	0.48
Litter		n.sig.	0.4	0.9
Traffic	--->	HC<CC	0.44	0.72
Animals		n.sig.	n.sig.	0.76
Health Risks				
air pollution	--->	HC<CC	0.56	0.71
water pollution	--->	HC<CC	0.44	0.71
wildlife hab.		n.sig.	n.sig.	n.sig.
Economic Impacts				
Property Values		n.sig.	n.sig.	n.sig.
Development		HC<CC	n.sig.	n.sig.
Employment	--->	HC<CC	0.36	n.sig.
Taxes		n.sig.	n.sig.	n.sig.
Social Impacts				
Image		n.sig.	0.44	0.95
Political Impacts				
Control		n.sig.	0.41	0.95
Confidence				
Local Gov't	--->	HC<CC	0.51	n.sig.
Fairness		n.sig.	n.sig.	n.sig.
Information	--->	HC<CC	0.47	n.sig.
Significance Criteria		Difference of proportions P<0.05	Goodman-Kruskal Gamma, p<0.05	

Legend: HC = host community, CC = control community
Arrows point out significantly correlated beliefs, arrows in brackets are marginally associated.

Table 5.23 - Attitudes about Neighborhood and Correlation with Attitude about Waste Facility

Average ratings on an attitude scale of 1 (worst) to 7 (best) with mid-point at 4.0; standard deviations in parentheses.

a. Tacoma Landfill

		Attitude in the Community (on scale from 1-intolerable to 7-excellent)		
		Host	Control	Difference
	N =	33	27	of means
Attitude about own neighborhood	average	5.24	5.63	CC>HC sig.
	std.dev.	(1.32)	(0.97)	non-sig.
Attitude about last neighborhood lived in	average	3.52	4.19	CC>HC sig.
	std.dev.	(1.34)	(1.04)	non-sig.
Attitude about other neighborhoods	average	3.64	3.67	non-sig.
	std.dev.	(1.03)	(1.07)	non-sig.

Correlation of Attitude about Facility with Attitude about Community

N = 25

Community Attitude with Facility Attitude — Rank order G-K Gamma = 0.33 non-sig. at 95%

Table 5.23b - Attitudes about Neighborhood and Correlation with Attitude about Waste Facility

Average ratings on an attitude scale of 1 (worst) to 7 (best) with mid-point at 4.0; standard deviations in parentheses.

b. Salem Incinerator

		Attitude in the Community (on scale from 1-intolerable to 7-excellent)		
	N =	Host 33	Control 23	Difference of means
Attitude about own neighborhood	average	5.24	4.95	non.sig.
	std.dev.	(1.06)	(1.02)	non-sig.
Attitude about last neighborhood lived in	average	3.59	3.82	non-sig.
	std.dev.	(1.33)	(1.15)	non-sig.
Attitude about other neighborhoods	average	3.58	3.48	non-sig.
	std.dev.	(1.03)	(0.99)	non-sig.

Correlation of Attitude about Facility with Attitude about Community

N = 29

Community Attitude with Facility Attitude — Rank order G-K Gamma = 0.55 sig. at 95%

signif. = 0.002, N = 29), while the control respondents' attitude about the incinerator and their neighborhood is not correlated (G-K Gamma = 0.06, signif. = 0.85, N = 17). It is therefore safe to conclude that a cause-effect link probably exists between the host residents impact beliefs and attitude about the incinerator and their beliefs and attitudes about their neighborhood. However, the negative attitude about the waste facility does not diminish the attitude about the neighborhood. Residents seem to adapt their attitude to the condition in the host community with the facility.

5.3.8 Awareness, Attitude and Behavioral Response

The goal of this section is to quantify residents' actions in response to the facility and test for associations between attitude and awareness of the facility and the resulting actions.

Two different approaches are used; the first method statistically analyses the respondents' stated attitude, awareness and opposition activities, while the second approach utilizes real estate sales data to test if prices, days on market, or number of sales are affected.

1. Attitude, Awareness and Actions.

In the last section of the survey, host community respondents were asked five questions about their awareness, the effects of facility impacts on their behavioral decisions, and about their opposition activities. Only 22 and 30 complete responses were received, respectively, in Tacoma and in Salem, because respondent fatigue appeared to set in. The question about respondents'

opinion of property value effects (see question 24 in Appendix 5.A) had a particularly poor response rate (10%); it is omitted from the following analysis. The other results are tabulated (Table 5.24) and discussed below.

Annoyance with the facility is used here as the indicator for attitude. The proportions of annoyed respondents are not significantly different at 40 and 60% at both landfill and incinerator sites. Awareness of the facility before moving to the comunity is strongly influenced by how long it has been operating. In Tacoma about 50% of the respondents were aware of the facility, only 10% were not aware of it before moving in; the balance moved in before the landfill. In Salem, 70% lived in the host community before the facility was built two years ago, while 17% were aware of the incinerator before moving in and 13% were unaware of it. This distribution is typical of expected conditions for a recently sited facility (see Chapter 2).

Further questions reveal the host community's behavior in response to the facilities:

- The facility effects are rated to be as expected by 40% in Tacoma and by 54% in Salem. However, 40% of respondents in Salem think the facility affects them less than expected, compared with 25% in Tacoma, whereas 35% in Tacoma state the landfill has affected them more than expected compared with only 4% (insignificantly different from zero) in Salem.
- 60% of respondents in Tacoma and 40% in Salem, would move into the community again despite the facility. Whereas

Table 5.24 - Awareness, Annoyance and Behavioral Response in Host Communities

Host Community Proportion of residents who state they are	Tacoma Landfill			Salem Incinerator		
	N = 33					
Annoyed	yes			yes		
	42.4%			52.9%		
	N = 22			N = 28		
Aware of facility before moving in	yes	no	moved in before	yes	no	moved in before
	50%	10%	40%	17%	13%	70%
	N = 24			N = 27		
Judge how the actual facility affected them compared to what they expected	same	more	less	same	more	less
	40%	35%	25%	55%	4%	1%
	N = 24			N = 27		
Would move in again	yes	no	n.a.	yes	no	n.a.
	60%	34%	6%	40%	39%	21%
	N = 22			N = 19-25		
Undertook these Opposing Activities	did	thought about	did not consider	did	thought about	did not consider
Gather Info.	9%	21.7%	69.6%	15.8%	36.8%	47.4%
Go to meetings	<10%	5%	76.2%	44%	12%	44%
Complain	13%	7%	75.0%	52%	12%	36%
Legal Action	5%	10%	90.9%	40%	20%	40%
Move out	-	9%	86.4%	(4.2%)	12.5%	83.3%

34% in Tacoma and 39% in Salem (no significant difference) would not move in again.

- Opposition activities are commonly stated in Salem, but consist primarily of attending meetings (44%) filing complaints (52%), and taking legal action (40%), while moving out is, at best, only considered by 12.5% but not actually carried out. At the established landfill in Tacoma, gathering information (9%) and complaining (13%) are the only significant actions, but moving out is considered by 9%, while about 13 to 24% state they have considered going to meetings, complaining and gathering information. Thus, mild to serious forms of opposition (attending meetings, complaining and legal action) are significantly more frequent among incinerator host community residents, probably because many were there before the facility was built and because the siting happened recently.

The connections between attitude, awareness and actions were tested with chi-square of cross-tabulated data on annoyance, awareness and oppositional behavior. The significant dependence of annoyance and awareness with actions are listed in Table 5.25.

Neither annoyance nor awareness of the facility are associated with Tacomans' actions. In Salem, however, stated annoyance associates with reluctance to move into the neighborhood again, with considering moving out, or mildly opposing activities (complaining, gathering information and attending meetings).

Table 5.25 - Association of Annoyance, Awareness and Action in Host Communities

Expectations of Impacts and Actions	Association with Annoyance (Attitude) with the facility	Awareness of the facility before moving in
a. Tacoma Landfill		
Facility Effects more or less than expected	n.sig.	n.sig.
Would not move in again	n.sig.	n.sig.
Opposition Activity		
move out	n.sig.	
legal action	n.sig.	
complain	n.sig.	
gather information	n.sig.	
attend meetings	n.sig.	
b. Salem Incinerator		
Facility Effects more or less than expected	n.sig.	n.sig.
Would not move in again	sig.	n.sig.
Action		
move out	sig.	
legal action	n.sig.	
complain	sig.	
gather information	sig.	
attend meetings	sig.	

Chi-square tests significant at 95%

In summary, mild opposition activities such as attending meetings, filing complaints and taking legal action are reported by 40 to 50% of respondents near the newer incinerator, while only 10 to 15% of the residents near the old landfill engage in these activities. In contrast, more people in Salem lived there before the facility was recently built, but very few think the incinerator has affected them more than expected. An equal 35 to 40% of host community respondents at both locations state they would not move into the neighborhood again if they had the choice.

Finally, stated annoyance with the facility significantly influences action only near the newer incinerator; no such association was found in the older landfill host community. Awareness was not associated with annoyance or opposing action and, hence, seems irrelevant to the behavioral response.

5.4 The Effects of Facility Impacts on Residential Real Estate in the Host Community

5.4.1 Significance

Real estate transactions in the host community may be affected in three ways by facility impacts. Residential property sales prices, length on the market, and the number of sales may reflect residents responses to the facility impacts (see Chapter 2). All indicators may reflect physical and non-physical impacts or siting events perceived by host community residents as potential sellers and by those potential buyers considering properties in the host community. It is therefore important in the analysis to separate the periods of actual physical presence

of impacts from events in the siting process that cause impact anticipation.

Two types of real estate analyses were conducted: multiple regression to test for significant facility impact on property values and property time on the market and comparison of number of listings and sales in host communities (see Table 5.26).

5.4.2 Data Collection and Analysis

a. Multiple Regression Analysis of Sales Price and Time on Market

First, multiple regression of housing variables and facility impacts on the sales prices and the days on the market were carried out at both sites. Multiple listing service (MLS) records were used as data sources for housing characteristics, sales prices and time on the market (Tacoma-Pierce County Board of Realtors, 1983 to 1986; Salem Multiple Listing Service, 1982 to 1987). The number of residential listings and sales in both host communities were compiled for MLS data to compare with trends in the metropolitan area and to relate to specific siting and impact events.

In Salem, the 145 listings between the 1st Quarter 1982 and the 1st Quarter 1987 included all property put up for sale, including sold, expired, withdrawn or terminated listings. In Tacoma, only property sales were available; a total of 665 objects sold between the 1st Quarter 1983 and the 4th Quarter 1986 were coded and included in the analysis. This large number was considered adequate for the analysis. Specifically, eight housing characteristics, eight impact variables, and two dependent

Table 5.26 - Real Estate Analysis - Methods

Indicator	Method	Criterion Basis
Sales Price and days on the market	Multiple Regression of housing and facility impact variables on price and time on market with SPSS-stepwise	Significance of facility impacts in hedonic equation for prices and time on market
Number of property listings and sales	-Chi-square of cross-tables of number of sales by quarter and year	significance of time for number of sales
	-comparison of number of listings and sales in host community with area listings and sales and after siting events	association of number of sales in host community

variables (price and days on market) were listed for each single family residential property (see Table 5.27). Butler (1982) shows that a restricted number of hedonic indices for the multiple regression equation usually provides insignificantly lower explanatory power and, hence, are sufficient for the analysis. The primary reason was the interrelation of many variables, e.g., condition with neighborhood rating, density, etc. Thus, for property value analysis in a single host community the condition, size of lot and house, age, and amenities (garage, basement and fireplace) were considered adequate to represent much of the variation within one community. The analysis was done separately for the three substantially different neighborhoods in Tacoma to avoid large between- neighborhood differences.

The next step consisted of coding, for each sales property, the physical impacts including distance and direction from the facility, nuisances, health risks, and environmental change. Non-physical impacts were not included because their spatial boundaries could not be determined.

Multiple regression analyses were run with the UBC-SPSSX program with stepwise selection of independent variables. Histograms and normal probability plots of standardized residuals were generated to check the assumption of normal distribution, while plots of standardized residuals versus predicted values were drawn to check the assumptions of linearity and homogeneity of variance, and plots of standardized residuals versus all significant independent variables were used to check for homogeneity of variance (SPSS Guide, 1986).

Table 5.27 - Multiple Regression Analysis of Facility Impacts on Property Values in Host Communities

Dependent Variables: Sales Price
Days on Market

Independent Variables: Property Characteristics

- Number of bedrooms
- Age
- Floorspace
- Condition
- Amenities - Fireplace
  - Basement
  - Garage
- Lot Size

Facility Impacts

- Distance
- Direction
- View
- Odor
- Noise
- Air quality
- Water quality
- Accident risk
- Wildlife habitat

Hedonic Price Equation in linear form:

$$\$ \text{ price} = Bo + B1 * X1 + B2 * X2 + \ldots + Eo$$

Bo....Bn = Coefficients to be estimated

Eo = error term

Comparison and Time Sequence Analysis of Residential Property Listings and Sales in the Host Community

The approach was basically to compare host community residential property listings and sales, before and after the facility siting, with the listings and sales for the larger area to detect any changes in the host community that may have been caused by waste facility impacts. The limited amount of data, however, restricted a complete comparison at both sites. In Tacoma, the listing and sales data were not available back to the siting date in the 1960's; the number of sales for the host community is therefore compared with area listing and sales numbers between 1983 and 1987 (Tacoma-Pierce County Board of Realtors, 1987). Two significant facility impacts (water pollution and methane gas migration) were discovered during this period. Significant changes in response to these events should be indicated by the available data. The number of sales in the host community are tested with chi-square for significant association with specific events.

In Salem, residential property listings and sales numbers were derived from the MLS quarterly Sold Books (Salem MLS Bureau, 1982 to 1987) for the host community (within 3km's of the incinerator), sales area 3 (northern Salem and Keizer), and the Salem metropolitan area. These data are compiled in graphs and related to siting events, e.g., site announcement, referendum vote, land use decision appeals, etc. The data are analysed by chi-square tests for association of numbers of listings and sales with specific events.

5.4.3 Results

a. Tacoma

Multiple Regression Analysis of Sales Price and Days on Market

The three areas in Tacoma (Orchard, Area No. 10, Fircrest, Area No.6 and County, Area No.5, Tacoma Real Estate Research Committee, Fall, 1986) are treated as separate neighborhoods throughout the analysis because of their distinctly different ages and characters.

The price and days on market are both regressed on year and quarter of listing as well as eight housing characteristics and eight physical impact variables. Table 5.28 lists the significant independent variables and their partial correlation coefficients by neighborhood area.

All three multiple regression equations are highly significant and generate significant explanation of sales price variation with R-squared values between 0.73 and 0.77. In contrast, explanatory power for days on the market is low (R-squared values between 0.015 to 0.07).

Only in the Orchard area are any facility impacts (explosion risk and air quality) significant in explaining price variation, but their signs are positive and thus contradict the expected negative effect of such facility impacts on price. Closer scrutiny revealed that about 10 to 15 newer homes were recently built within the explosion risk and air quality (and odor) impact areas (along 48th and 49th Ave and Gove and Mullen Streets). These houses sell at $55,000 to $60,000, which is substantially

Table 5.28 - Tacoma Landfill - Host Community Residential Real Estate Sales, 1983 - 1984 - Multiple Regression Analysis Results

Dependent Variable	Significant Independant Variables	Multiple Regression and Partial Correlation Coefficients
Area 5 - County		
Sales Price		R^2 = 0.74 significant
	Square feet	0.69
	Age	-0.51
	Basement	-0.28
	Quarter of Sale	-0.21
	Condition	-0.21
Days on Market		R^2 = 0.07 significant
	Age	-0.21
	Year of Sale	-0.21
Area 6 - Fircrest		
Sales Price		R^2 = 0.73 significant
	Square feet	0.74
	Age	-0.28
	Lot Size	0.25
	Quarter of Sale	0.17
	Condition	0.17
Days on Market		R^2 = 0.067 significant
	Square feet	0.14
	Quarter of Sale	0.20
	Year of Sale	-0.19
Area 10 - Orchard		
Sales Price		R^2 = 0.77 significant
	Condition	0.67
	Square feet	0.40
	Age	0.30
	Fireplace	0.37
	Number of bedrooms	0.32
	Explosion risk	+0.25
	Garage	0.15
	Air Quality Impact	+0.13
Days on Market		R^2 = 0.015
	List Date	0.014

Results: No facility impacts with correct signs significantly explain variation in sales prices or days on market

See Table 5.C25a in Appendix 5.C for detailed results.

higher than the average price of $42,920 for area 10. This new development is therefore likely to cause the apparent, but spurious effect of explosion risk and air quality on sales price. Since no facility impacts are significant in either of the other areas 5 and 6, the landfill does not appear to affect property values or time on the market in the landfill host community in Tacoma.

Time-Sequence Comparison of Listings and Sales

The curves in Figures 5.4 a,b,c show the number of residential listings and sales in each area in the landfill host-community. Two significant landfill impact events are indicated on the time scale (discovery of tainted well water and of methane gas migration at explosive levels). By comparing these curves visually, there seems to be no significant discrepancy between host community sales trends and general area listing and sales trends. Although Area 10 sales increase during mid 1986 when methane gas was discovered, a similar increase did not occur in the immediate host community.

The number of sales in the host community show significant association with quarter and year (chi square 25.5, DF=8, N=621) for the three areas combined, but only marginal association for the Orchard area alone, and no association for Fircrest or County alone (see Appendix 5.C1). Significant facility related events in the second quarter of 1985 and 1986 do not coincide with the fluctuations. It can be concluded that the Tacoma landfill has no detectable effect on the number of sales in the host community.

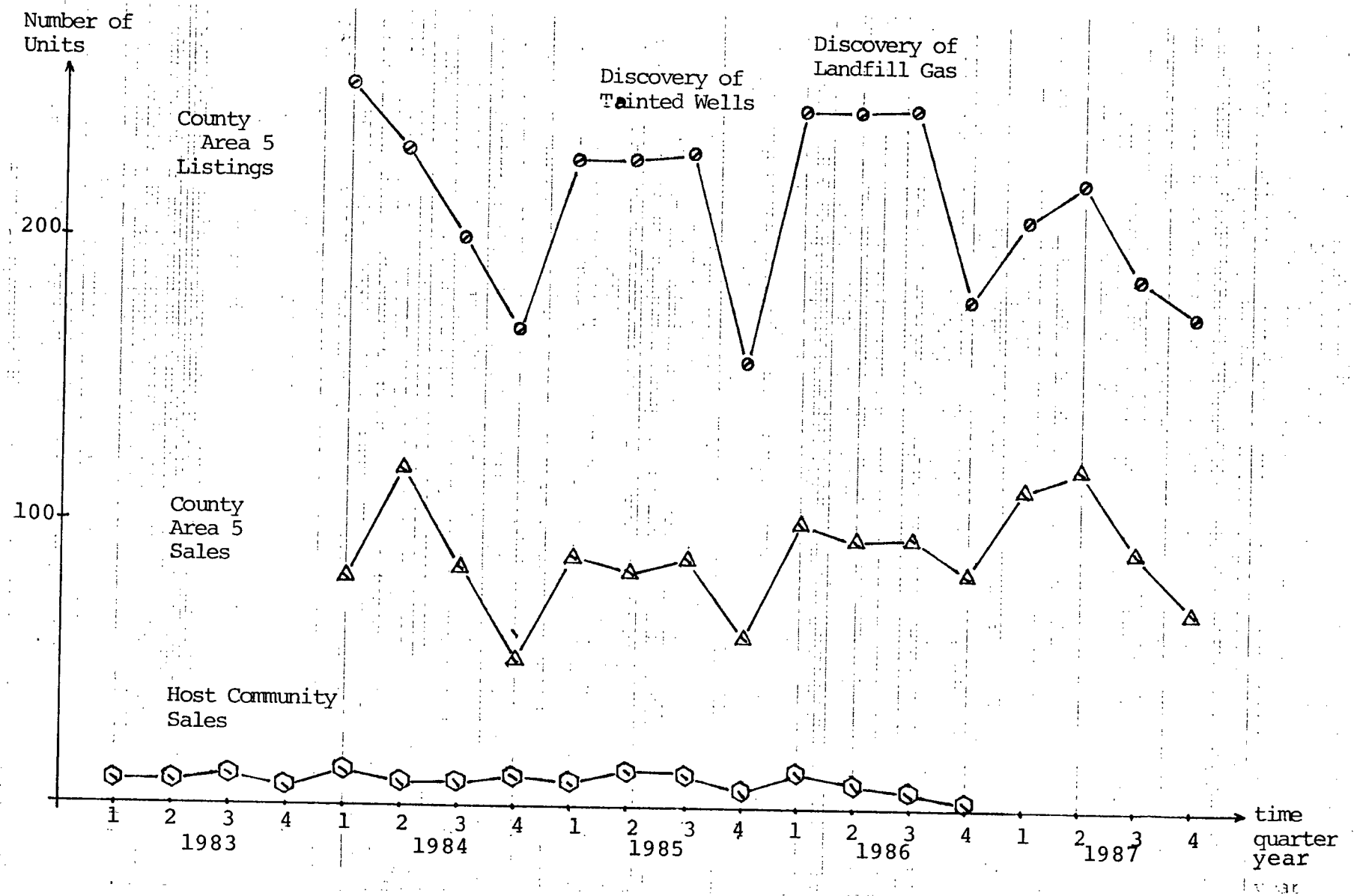


Figure 5.4a - Tacoma - Area 5 "County" - Residential Listings and Sales

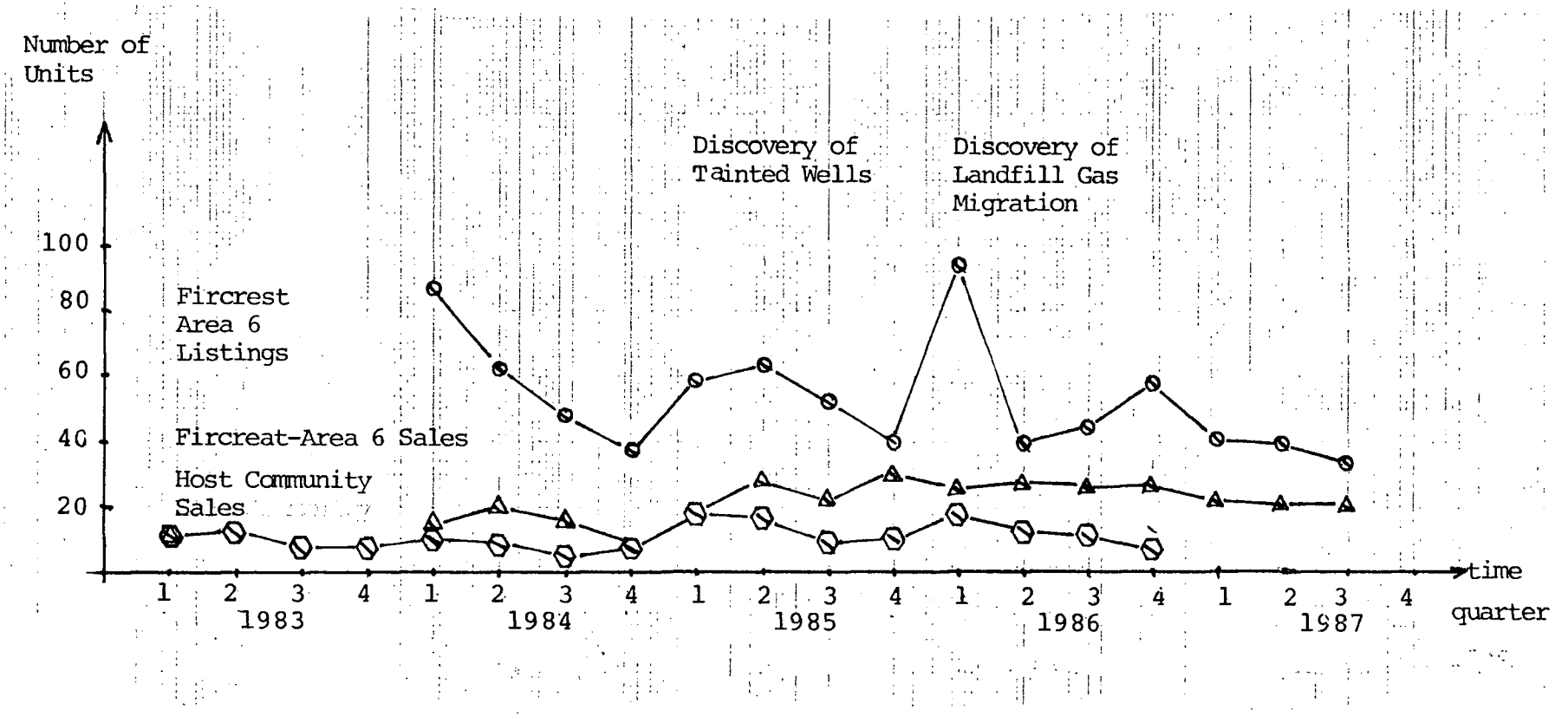


Figure 5.4b - Tacoma - Area 6 "Fircrest" - Residential Listings and Sales

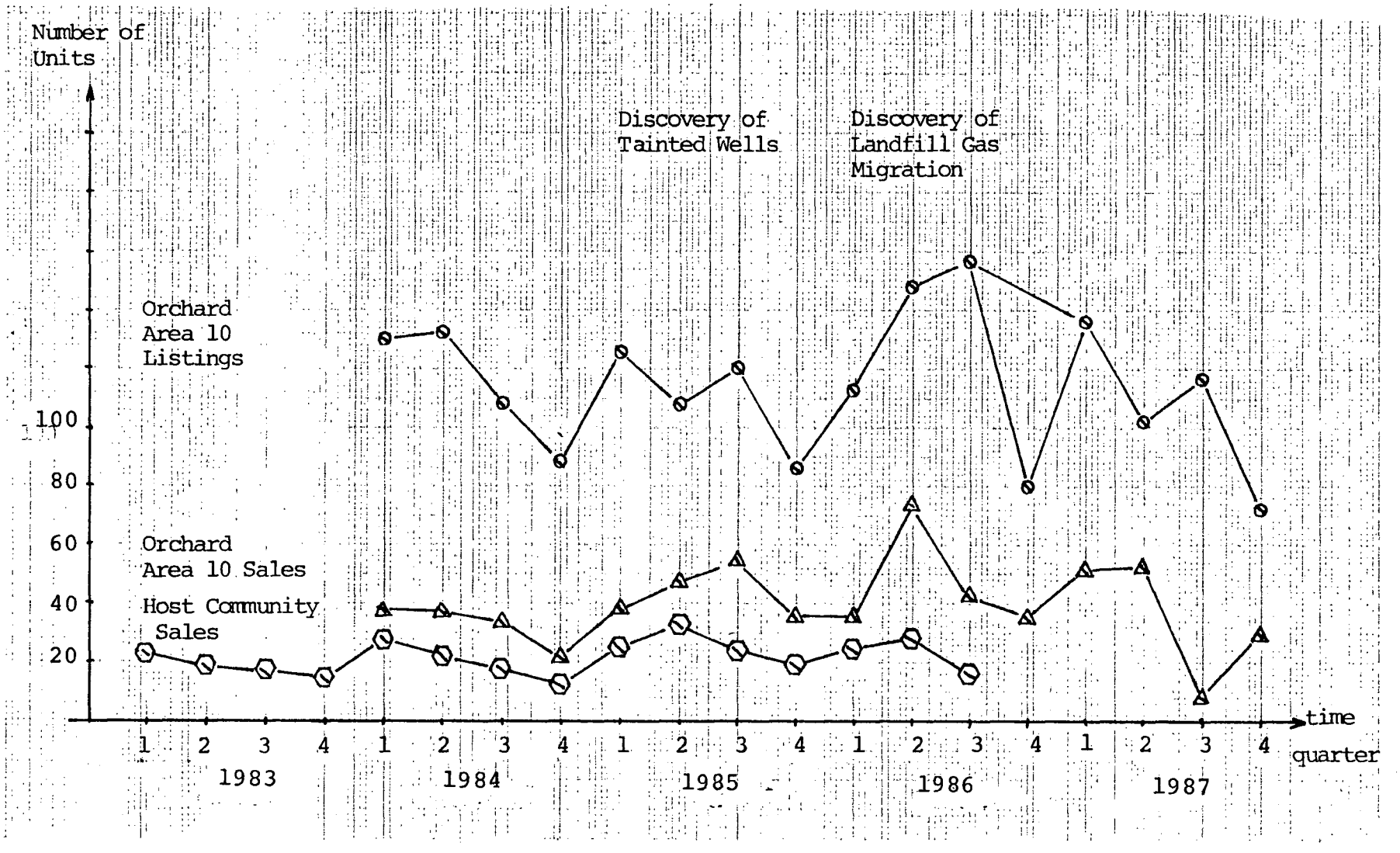


Figure 5.4c - Tacoma - Area 10 "Orchard" - Residential Listings and Sales

Salem

The multiple regression of price and days on market on property characteristics, facility impacts and time of listing was calculated for three periods:

- 1983 to 1987 to include both siting and operational phases together, - 1983 and 1984 to cover the siting process before any construction or physical impacts, - and 1985 to 1987 to cover the construction and operation phase separately.

The validity of the assumptions of normal distribution and homoscedasticity were tested for the significant variables. The results are listed for the three time periods in Table 5.29.

Explanatory power of sales prices is good with R-squared values at 0.44 to 0.54. Variation in days on the market is less well explained with R-squared values between 0.0153 and 0.5.

None of the facility impact variables is significant in explaining variation in prices or time on the market during any of the three siting phases. Thus, subject to the assumptions of the model, an influence of the incinerator on residential properties cannot be confirmed.

Time-Sequence Comparison of Listings and Sales

The graphical comparison of Salem listings and sales, area 3 listings, and host community listings by quarter from 1982 to 1986 (Figure 5.5) shows a conspicuous jump in host community listings in the third quarter of 1983. This jump is not reflected in the listings or sales in the larger areas and warrants further investigation.

Table 5.29 - Salem Incinerator - Host Community Residential Real Estate Sales, 1983 - 1987 - Multiple Regression Analysis Results

Dependent Variable	Significant Independant Variables	Partial Coefficients	
Period: Siting to Present 2nd Quarter 1983 to 1st Quarter 1987			
Price		R^2 = 0.44	Significant
	Square feet	0.30	
	Lot Size	0.37	
	Number of bedrooms	0.23	
Days on Market		R^2 = 0.07	Significant
	Garage	-0.27	
Period: Construction and Operation to Present-1st Quarter 1985 to 1st Quarter, 1987.			
Price		R^2 = 0.54	Significant
	Lot Size	0.70	
	Age	-0.42	
Days on Market		R^2 = 0.050	Significant
	Price	0.55	
	Basement	0.50	
	List Date	-0.44	
Period: Siting-2nd Quarter, 1983 to 4th Quarter, 1984			
Price		R^2 = 0.52	Significant
	Square feet	0.39	
	Lot Size	0.40	
	Number of bedrooms	0.36	
	List date	-0.27	
Days on Market		R^2 = 0.015	Significant
	Garage	-0.35	
	Condition	0.28	

Results: No facility impact significantly explain variation in Sales price or days on market.

See Table 5.C25b in Appendix 5.C for detailed results.

The number of listings by quarter does not significantly depend on the year, but 1983 and 1984 both show higher number of listings (33 and 31 versus 11 to 17 for 1982, 1985 and 1986). The 3rd quarter in 1983, as well as the first three quarters in 1984 show noticeably higher listing frequencies than the same quarters in other years (see Figure 5.5 below). The quarterly frequencies of listings in the host community are shown in Figure 5.6.

The significant siting decisions and events are entered into the graph also. Some of the major announcements and decisions precede quarters with higher listing numbers, e.g., the announcement of the land use change approval for the incinerator site in the late second quarter, 1983 proceeds the listing of 18 properties in the third quarter. First quarter, 1984 listings are higher than any other first quarter. Moreover, no other likely cause for the sudden jumps could be identified, because average prices remained fairly constant (see Figure 5.7) throughout the time period.

The listing frequencies for the same quarter in each year were tested for significant differences of proportions. The third quarter, 1983 listings are significantly above the third quarter 1985 and 1986 listings, but they are not significantly different from the 1982 and 1984 figures (at 95% confidence interval). Finally, the fate of the listings were evaluated to test if the same proportions of listings placed during the siting process (1983 and 1984) actually sold. A chi-square analysis of cross tabulated date of listings "sold" and listings "expired, withdrawn or terminated" shows a significant dependence of number of sales

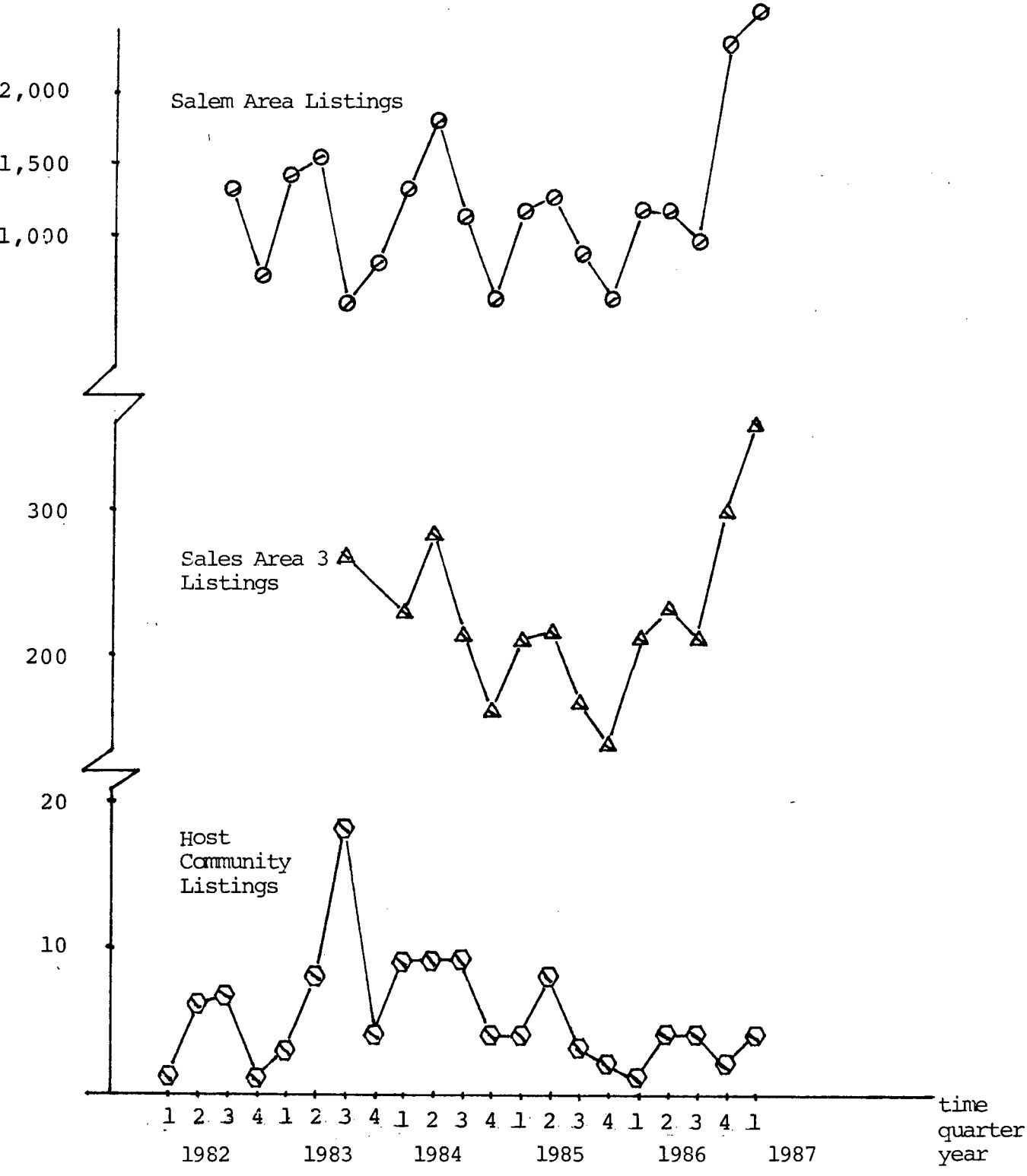


Figure 5.5 - Comparison of Listings and Sales in Salem and in the Host Community

Figure 5.6 - Incinerator Host Community Quarterly Frequency of Residential Property Listings during Siting Process, 1982 to 1987

Year	Quarter	Number of Residential Property Listings in Host Community	
1982	1	1 +X	
	2	6 +XXXXXX	
	3	7 +XXXXXXX	
	4	1 +X	
1983	1	3 +XXX	
	2	8 +XXXXXXXX	← Facility Announced
	3	18 +XXXXXXXXXXXXXXXXXX	
	4	4 +XXXX	
1984	1	9 +XXXXXXXXX	← Referendum Vote
	2	9 +XXXXXXXXX	← Opposition and
	3	9 +XXXXXXXXX	Land Use Appeals
	4	4 +XXXX	
1985	1	4 +XXXX	
	2	8 +XXXXXXXX	← Construction begins
	3	3 +XXX	
	4	2 +XX	
1986	1	1 +X	
	2	4 +XXXX	← Operation begins
	3	4 +XXXX	
	4	2 +XX	
1987	1	4 +XXXX	

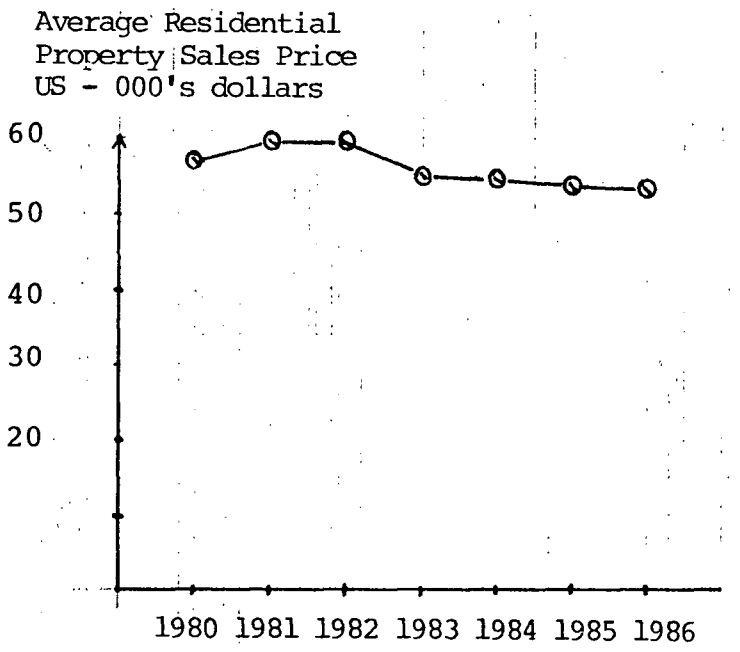


Figure 5.7 - Salem Average Sales Prices of Residential Properties;
Source: Salem MLS Bureau, Feb. 1987

Table 5.30 - Salem Host Community Residential Property Listings and Outcomes by Year

Number of Residential Properties

		Year				
		1982	1983	1984	1985	1986
Total Listed	103	11	33	31	17	11
Outcome						
Sold	40	1	7	13	13	6
Expired or Terminated	63	10	26	18	4	5

Chi square statistic: significant

and expired listings on the year of listing (Table 5.30). Specifically, the number of listings placed during 1983 and sold is lower and the number of expired listings is higher than expected.

The indications from this analysis are that the number of residential real estate listings increase because of siting decisions, but the number of actual sales do not. The listing frequency is elevated during the siting process in anticipation of the facility. However, the listings seem to stabilize after the facility is built and operating, that is, when the physical impacts are present.

5.4.4 Property Value Impact - Summary

Property sales prices and days on the market appear to be independent of landfill and incinerator physical impacts. In Tacoma, no effects of the landfill on property sales or listings could be detected. The number of residential properties listed for sale in the incinerator host community increase in response to the announcement of the incinerator site and to the crucial decisions during the siting process. During construction and the first year of operation the frequencies of listings and sales seem to stabilize.

The results confirm that waste facilities have, as predicted, insignificant effects on property values. The results show only a minor behavioral response, i.e., through a higher number of property listings in response to the announcement of a new waste disposal facility.

5.5 Chapter Summary - Beliefs, Attitude and Opposition to Waste Facilities in Residential Neighborhoods.

Facility physical impacts and residents' beliefs and attitudes are combined to test the hypothesized relationships among the beliefs, attitudes and actions in the host community. Figures 5.8 and 5.9 show the variables and the tested relationships. The findings are summarized and discussed in the following subsections.

5.5.1 Physical Impacts, Newspaper Coverage, and Residents' Beliefs

The relationships of physical impacts and newspaper articles with residents' spontaneous (salient) and specific beliefs reveal the influence of external variables on the belief structure.

Physical impacts do not appear to determine the salient belief set, although at the older landfill site (Tacoma) the salient impact beliefs well reflect the observed physical impacts (noise, odor, traffic, birds, water contamination, and explosion risks). At the new incinerator site in Salem, the spontaneous beliefs (noise, odor, traffic, air quality impacts, property value impacts) exaggerate the observed physical impacts (view, some noise and traffic and air emissions, but no odor). The discrepancy in Salem may occur because of the short time (about one year) residents have actually experienced the facility. In contrast, residents of Tacoma have had 25 years to grow accustomed to the landfill.

Although the spontaneous belief sets in both host-communities reflect only physical impact elements, the specific beliefs

comprise physical and non-physical impacts, i.e., economic, social and political impact beliefs. The difference appears to stem from an impact belief shift between spontaneous, general beliefs about waste facilities and the specific beliefs that residents hold about the specific facility they are familiar with. This belief shift can result in an incomplete or erroneous focus of siting efforts, because only spontaneous beliefs may be elicited (e.g., in public hearings), but non-physical impacts may be very important in determining attitudes about the facility.

Specific impact beliefs depend both on physical impacts and on spontaneous beliefs at both sites. Physical impacts associate not only with similar physical impact beliefs but also significantly with non-physical impacts and specifically with economic (property values), social (image), and political (loss of control, confidence, and fairness) impacts.

Particularly obvious physical impacts, (e.g., nuisances, odor, noise, view) can stimulate, or trigger, economic, social or political impact beliefs, as well as physical impact beliefs. These relationships are shown as solid arrows in the cause-effect diagram (Figure 5.8 and 5.9). The trigger effect therefore corroborates the old adage of "out of sight - out of mind." As a result, the reduction of obvious trigger impacts may be effective in reducing possibly more important non-physical impacts.

The contents of newspaper articles about the facilities do not associate with either spontaneous or specific impact beliefs at either site. Although the test does not support a significant connection, the influence of media reporting cannot be rejected.

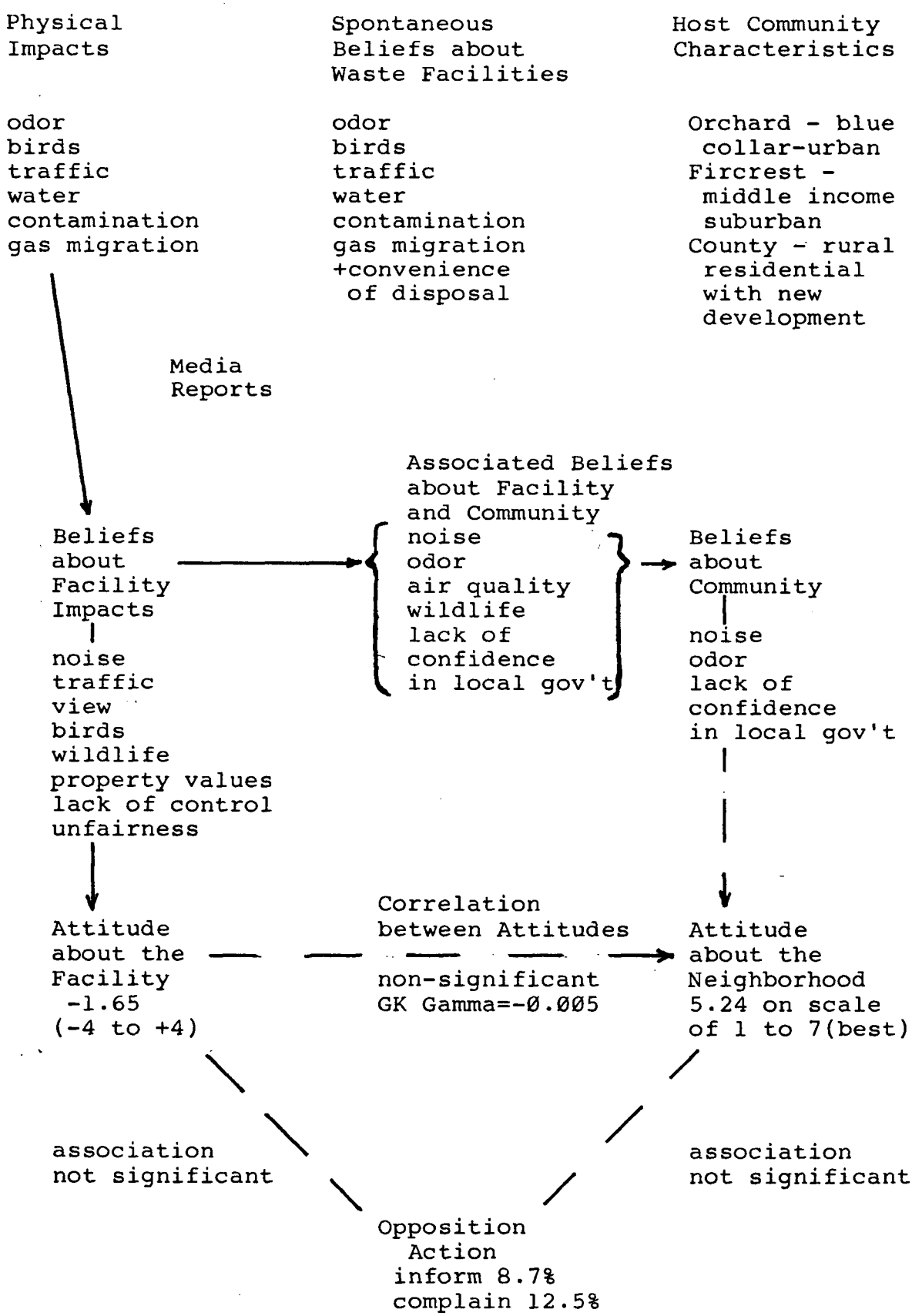


Figure 5.8 - Tacoma Landfill-Summary of Beliefs, Attitudes and Opposition Activities

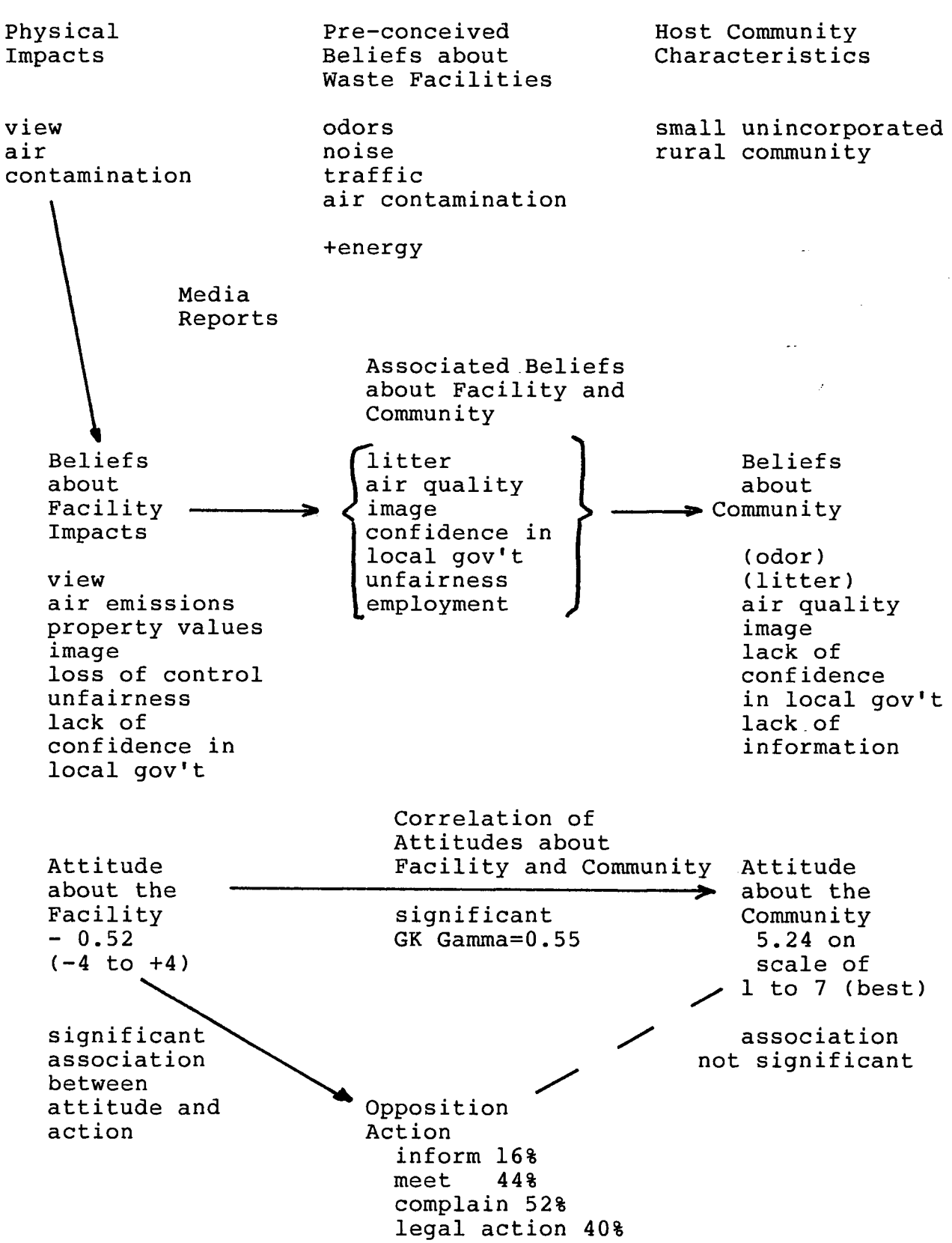


Figure 5.9 - Salem Incinerator - Summary of Beliefs, Attitudes and Activities

Television reports were not tested, but could play a significant role. Furthermore, complex influences were not tested in this simple content analysis. But the numerous significant differences identified here between newspaper impact frequencies and impact belief frequencies do not support a significant association.

5.5.2 Residents' Beliefs, and Attitudes about Waste Facilities and Beliefs and Attitudes about Neighborhoods.

Specific negative impact beliefs at both facilities comprise physical, economic, social and political elements. Certain significant negative facility impact beliefs in each category correlate significantly with residents' attitudes about the landfill and the incinerator. Thus, these beliefs may affect the resulting attitudes. The negative impact beliefs for physical impacts are equal at both sites, but all non-physical impact beliefs are more negative in Salem than in Tacoma. The correlations of all impact beliefs with attitudes are stronger in Salem than in Tacoma. Therefore, the much shorter time since siting and construction and the unique presence of the incinerator in the host community may generate the stronger correlations in Salem. In contrast, the landfill in Tacoma is much older and is located in a community with other industrial facilities.

The residents' attitudes indicate that both host communities are more favorable about their facility than any other respondent group (controls from the same area as well as hosts and controls from the other site). Moreover, both host groups think the other facility is less desirable than their own, in Salem quite significantly. Although controls are more negative about the

facility than host residents, control attitudes are more uniform, whereas host attitudes spread over a wider range. Finally, despite more negative impact beliefs and stronger belief - attitude correlations among Salem host residents, their attitude about the incinerator is higher (-0.53 on a scale of -4 to +4) than Tacoman host residents' attitudes about the landfill (-1.65).

A further consequence of waste facilities may be measured in residents' beliefs and attitudes about the neighborhood (see Figures 5.8 and 5.9). A statistical connection between beliefs about facility impacts and neighborhood characteristics and between attitudes about the waste facility and the neighborhood reinforces the potential for a causal effect of the waste facility on the host residents' attitude about their neighborhood. In Salem, these connections were significant, while in Tacoma the connection of facility impact beliefs to the neighborhood beliefs and to neighborhood attitude were weak.

Relatively few impact dimensions showed a likely connection between facility impact beliefs and correlation with neighborhood attitudes. In Tacoma, four impact beliefs (odor, air quality, water quality, land and resources) related to attitude about the neighborhood. While in Salem six impact beliefs (odor, air contamination, air quality, employment, community image, and loss of confidence in the local government) are statistically connected to neighborhood attitude. These results show a possible pathway from facility impacts to neighborhood attitude and emphasize the meaning of the facility for the host community in Salem.

Moreover, the attitude about the new incinerator correlates

with attitude about the neighborhood in Salem, although the attitudes do not correlate in Tacoma.

5.5.3 Attitude and Action

The final set of indicators of facility impacts consists of opposition activities. Respondents in both host communities engage in mild forms of opposition (gathering information, attending meetings, and filing complaints). Salem residents are more active by a 3 to 1 ratio. Moving out is considered in both locations, but not verified in the number of sales. Legal action has been undertaken at both locations. In Salem, the land use change was twice appealed, but both times the motion failed; in Tacoma civil suits against the city for water well contamination and gas migration are pending.

In contrast, the proportions of negative beliefs and correlations to facility attitude are weaker at the older landfill site; a correlation of attitude about the facility and attitude about the neighborhood is absent. Yet the landfill certainly generates more serious physical impacts in the community (odor, view, noise, explosion risks, water quality impacts) than does the incinerator (view, noise, slight air quality changes). The proportions of enraged residents are practically equal for the old landfill and the new incinerator. In Tacoma, there is, however, no evidence to support a connection of the residents' attitudes with opposition behavior. In Salem, this connection was significant. Finally, neighborhood attitudes do not differ among host and controls as well as among both host groups.

Although the analysis corroborates a pathway between facility impacts, impact beliefs and residents attitudes, it shows no significant difference in the resulting attitudes about the communities. Two reasons may cause this result. Either residents adapt to the undesirable facility over time and modify its relative importance in determining their attitude, or, the more sensitive residents move out to be replaced by less sensitive people.

Property values are not affected by any physical facility impacts. Furthermore, the real estate analysis does not indicate a higher number of sales in either host community in Tacoma or Salem, although there is an indication of more frequent residential property listings during facility siting in Salem. Thus, household moving and replacement does not appear to be a significant mechanism to explain the adaptation of attitude about a waste facility, or about the neighborhood. In conclusion, personal attitude adaptation to the waste facilities appears to occur after the facility is built.

There is a significant and plausible connection of facility physical impacts through beliefs about facility impacts to attitudes about the waste facilities and the neighborhoods to the opposing actions. However, the attitudes about the facilities and the neighborhoods in the host community is, if anything, better than in other communities. Thus, contrary to the expected results people adapt to the situation. Based on the real estate analysis, this adaptation takes place within the host community and not through replacement of the more sensitive residents by less

sensitive ones.

Finally, there is a clear connection between facility appearance and the economic, social and political meaning of the facility for the host community. Physical impacts are interpreted by their economic, social and political meaning. The findings show that residents translate physical impacts into beliefs about physical and non physical (economic, social and political) effects. These beliefs furthermore correlate with overall attitude about the facility. The attitude is related to opposition activities. Thus, the cause-effect linkage is established between objective facility impacts to opposition activity in the host community. The description and explanation will be used to design effective impact reduction measures to enhance community acceptance in the next chapter.

CHAPTER 6 - IMPACT REDUCTION MEASURES and PRIORITIES FOR FACILITY ACCEPTANCE

6.1 Facility Siting Measures to Enhance Acceptance Design, Costs and Reduction Effects

This chapter tests the theoretically derived approach and methods for obtaining host comunity acceptance. Based on the findings in Chapters 4 and 5 on the interaction between facility impacts, residents' beliefs, attitude and response, specific siting methods are derived in the context of the theoretical approach to address the host community's concerns about landfills and incinerators. A set of measures is designed to address each type of impact using four methods: prevention, control, mitigation and compensation. The costs and reduction of the impacts are determined for each measure based on site specific conditions at the Tacoma landfill and the Salem incinerator. Subsequently, the siting measures, along with the cost and effect information, are presented to residents to test for preferences and to determine effectiveness in increasing host community acceptance.

The goal of this chapter is to test preferences about siting measures and to determine their effect on facility acceptance. Three specific hypotheses are tested in interviews with residents in host and control communities:

- Facility impacts decrease in sequence of importance from health risks to impacts on community image and control, to nuisances and property value losses. Thus, health, political control and social significance are heavily

weighted (see Table 6.1).

- Measures that reduce impacts are preferred over compensation. Measures that eliminate the cause are preferred over those that control the impacts or mitigate the damage. Thus, the predicted ranking of siting measures is first, prevention, followed, by control, mitigation and, finally, compensation. Preventive impact reduction is preferred despite higher costs because it best reduces the loss at the cause or source.
- Measures that reduce important impacts will lead to a better attitude about the facility and, hence, better acceptance than compensation measures, such as property value guarantees.

In order to test these statements, sets of specific measures are derived in the following section to validly represent the conditions at each study site. In the last section, these measures are tested in host and control communities.

6.1.1 Waste Facility Impact Reduction Methods

The set of methods is limited to the options under control of the facility proponent and the local government responsible for waste disposal. Methods that entail changes to the basic production and consumption patterns prior to the discarding of waste materials are therefore excluded.

The choice of reduction methods is therefore confined to the waste disposal-host community system as defined for this study (see Figure 6.1). The definitions of operational methods are

Table 6.1 - Summary of Significant Beliefs about Facility Impacts in Host Community

a. Landfill

Impacts	Proportion of Residents who believe this impact is present (Survey 1) N=33	Ranking - Strength of Correlation with Attitude about the facility
Nuisances	66%	2
Health risks from water emissions	52%	3
Property value loss	41%	4
Harm to image	41%	1

b. Incinerator

	Survey N=34	
Nuisances	41%	5
Health risks from air emissions	32%	2
Property value loss	38%	3
Loss of Control	42%	1
Harm to image	41%	4
Fairness	44%	6

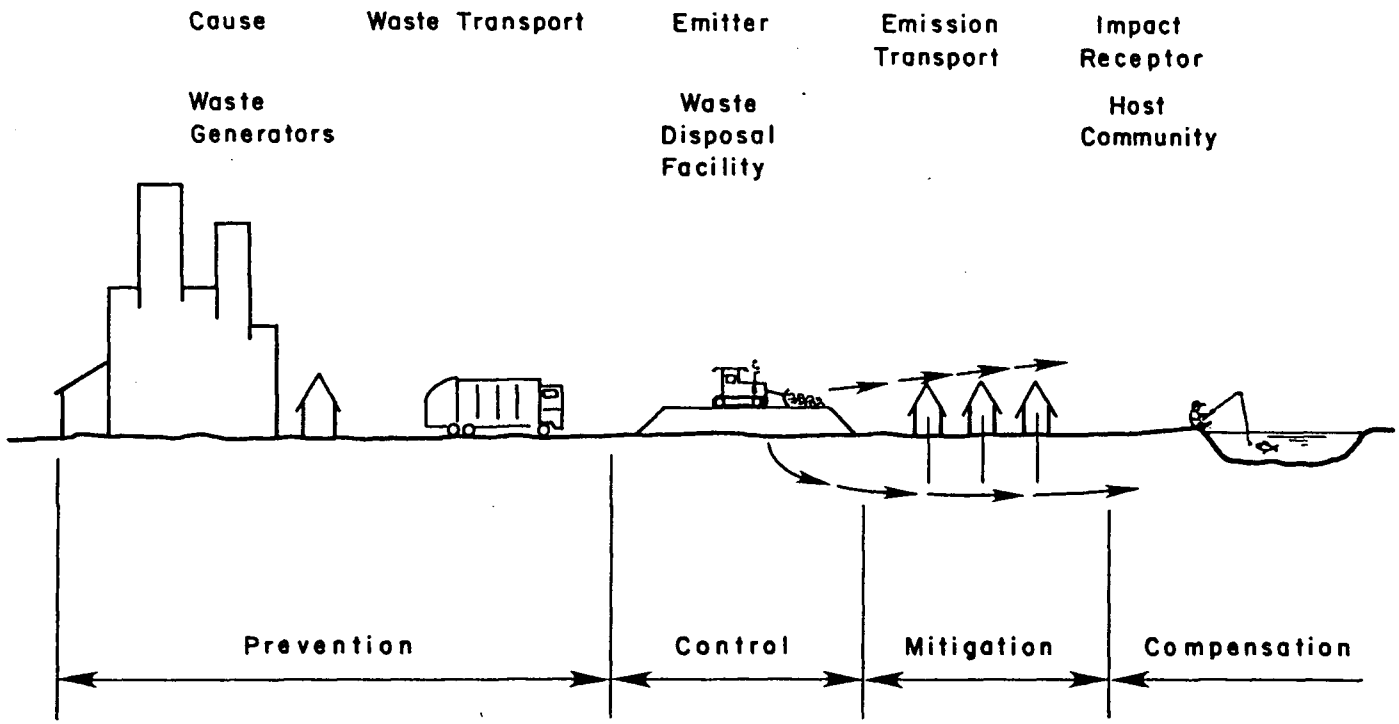


Figure 6.1: Impact Reduction Methods in the Waste Disposal System

repeated here (see Chapter 3): These conditions are stipulated to determine specific impact measures:

1. Each measure fits only one definition of either prevention, control, mitigation or compensation as derived in Chapter 3. This condition prevents overlap.
2. Each measure must positively address one single type of impact to avoid influencing acceptance through side effects on other dimensions; in particular non-specific "motherhood" measures and concepts, such as "recycling" and "pollution control", are avoided.
3. Each measure is quantifed to the extent possible in terms of costs and reduction effects.

Various case studies of facility siting attempts (O'Hare, 1983, Becker, 1982, Boyle, 1982, Carnes, 1982, Centaur Associates, 1979, Wisconsin Facility Siting Board, 1987) were reviewed to establish a list of siting measures. From this list, sets of measures to specifically address significant facility impacts (Table 6.1 and Chapter 5) were selected according to the above stated three criteria. The final set of measures is summarized in Table 6.2a for the landfill and 6.2b for the incinerator site. In the following, these measures are described in detail. The design costs and reduction effects apply to the specific landfill in Tacoma and incinerator in Salem.

For the design and costing of these measures, the total per capita municipal solid waste generation rate of 600kg per capita per year is used. Engineering estimates of costs and reduction effects on impacts were made where reliable data and methods

Table 6.2 - Set of Siting Methods and Impact Reduction Measures

a. Landfill

Responsibility for Change Adaptation shifts to Host Community Residents --->

<--- Responsibility shifts to Proponent

Impact	Source	Prevent	Control	Mitigate	Compensate
Nuisances					
Noise	Birds	cover more frequently putrescibles	berms	double-paned windows	10% of property value
	Equipment	mufflers	berms	double-paned windows	10% of property value
Odor	landfill gas	cover more frequently	install gas collection and cap system	double-paned windows and air conditioning	10% of property value
Health Risks					
Water	leachate	separate and compost organic matter prior to landfilling	line and cap landfill, collect and treat leachate	monitor and take remedial action by counterpumping and treatment if necessary	provide alternate water supply from city system
Loss of Image	"waste" "pollution"	(not applied)	design and landscape the site and buffer as park	zone and offer 10% property price reduction to attract desirable development	build a community center
Loss of Control		long-term community planning with resident participation	negotiation of siting agreement with resident participation	monitoring committee with resident participation	decision on use of facility property taxes by host-community
Loss of Fairness		lottery among suitable sites as fair site selection	everyone else pays more for prevention & controls	free disposal & good neighbor services for host community	sewer system

Table 6.2 - Set of Siting Methods and Impact Reduction Measures

b. Incinerator

Responsibility for Change Adaptation shifts to Host Community Residents ---> <--- Responsibility shifts to Proponent

Impact	Source	Prevent	Control	Mitigate	Compensate
Nuisances View	stack plume	reduce stack height and plume	screen stack on site with trees	screen residents at home with trees	10% in property values
Health Risks Air	stack emissions	separate waste prior to burning to reduce compounds that cause emissions	additional filtration after baghouse to remove particulate, cool temperat.	monitor ambient air and reduce burning rate if necessary by 10 to 20%	sewer system
Community Image	"waste and pollution"	not applied	design and landscape site and buffer as park	zone area and give 10% price discount to attract desirable development	community center
Loss of Control		long-term community planning with resident participation	negotiation of siting agreement with resident participation	monitoring committee with resident participation	decision on use of facility property taxes by host-community
Loss of Fairness		lottery among suitable sites as fair site selection	everyone else pays more for prevention & controls	free disposal & good neighbor services for host community	sewer system

permitted, for landfill groundwater emissions and incinerator air emissions, both reduction effects and costs were estimated, because objective measures of emissions were available to predict impact reduction effects. Nuisance and image impact measures were designed and costs were estimated, but the lack of objective indicators precluded determining the reduction effects. For other measures to address control and fairness impacts, the costs were either unpredictable or very low and, hence, were omitted. Effects were also not objectively predictable.

Groundwater Emissions from Landfill Leachate

Prevention of leachate is partially achieved through removal of contaminants prior to disposal. The mechanical separation of the organic fraction of the waste stream directly reduces the biodegradable fraction (BOD) in the waste stream (PLM, 1986; Bilitewski, 1985). Subsequent composting of this fraction converts degradable organics to basic components (C,H,O,N,P), binds some metals to the residual organic matter (Dyer and Razvi, 1987) and volatilizes some organics during the exposure to air. The preventative separation and treatment thus substantially reduces the leachable contaminants prior to the landfill. Separation of organic matter also reduces gas production and, possibly, nuisances. Any reference to these corollary effects (in the presentation to respondents) will be avoided to focus attention only on the leachate reduction effect.

The additional cost per person for prior separation net of

present landfill costs is estimated at $13 per person per year. The separation of organic matter can safely be estimated to reduce leachate emissions (biologically degradable matter - BOD, ammonia - NH_3, heavy metals, and organic compounds) by 50% (see Appendix 6.1A).

Emission control consists of liner systems at the bottom and top of the filled cells, with collection and treatment of the leachate. Although liner systems are very effective in initially reducing infiltration and collecting leachate, systems failures increase significantly after 15 to 20 years life (Massmann and Freeze, 1987). Treatment of the collected leachate can be designed to remove specific major constituents in the effluent.

The construction of a leachate collection liner, top cover, and leachate treatment system increases the disposal cost to each resident by $16.00 per year.

The leachate emission through designed leachate controls is estimated to be 90% in the first 15 years. Due to possible risks of leaks occurring, the reduction effect drops to 50% after 15 years (see Appendix 6.A2).

Mitigation measures comprise monitoring of the compliance boundary and pump-and-treat remedial action for contaminated groundwater if necessary.

Mitigation calls for monitoring of up-and downgradient leachate wells and some downgradient water wells. Assuming immediate detection of leachate contaminants in year 1 followed by 20 years of treatment with activated carbon

sorption, the costs for this method come to approximately $1.00 per capita per year (see Appendix 6.A3). If remedial action becomes effective 6 months after first detection at the boundary, then an area of about 100m down the flow line will be effected for a period of 15 to 20 years.

Compensation in kind consists of drinking water monitoring at the recipient wells with supply of alternate water if contamination occurs.

Here, the measure consists of monitoring downgradient drinking waterwells and two upgradient wells to test the background. After five years, 20 to 25 drinking wells in the plume become tainted and have to be replaced by alternate water supplies.

It is assumed that detection occurs before excessive health risks occur (i.e., before an additional risk of 1 in 1 million has occurred) and that the alternate source is at or below the original background levels in the tainted wells. Tainted wells continue to be monitored throughout the life of the facility. The costs amount to $0.35 per capita per year.

Landfill Nuisance Reduction of View, Noise, Birds

The costs are estimated for these measures; the impact reduction effects were not considered adequately reliable and predictable to be included for nuisances.

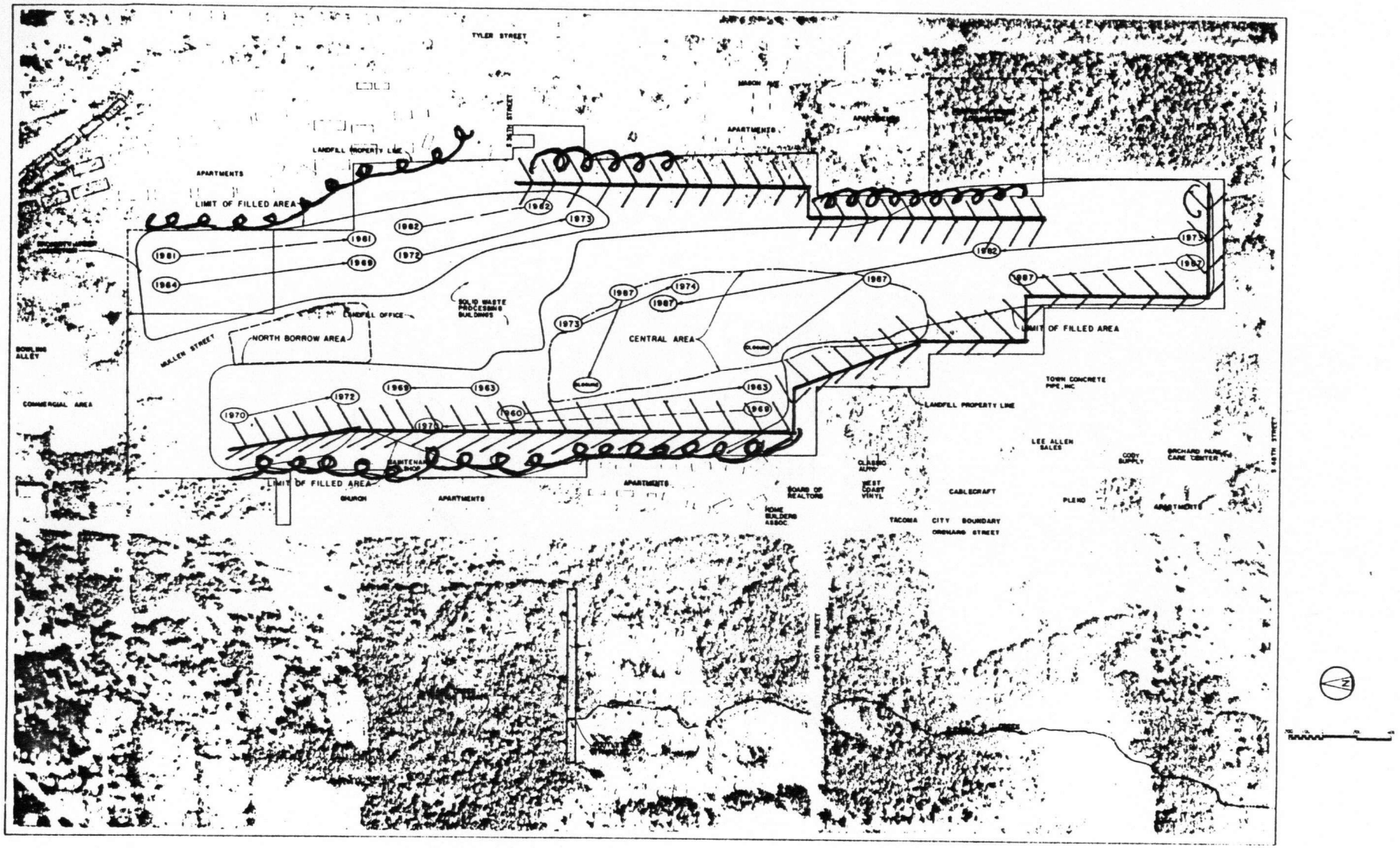
Prevention reduction of noise is achieved through use of quieter equipment and speed limitations on access roads while view, birds and odors may be somewhat reduced through

frequent covering. Additional noise control equipment and twice daily cover increases operating costs per year at the Tacoma landfill by $57,750 or $0.20 per capita per year. While equipment noise levels may decrease by 6 to 10 dBA, at the source, and the effect of frequently covering refuse reduces the view of open garbage, the reduction of birds and odors is marginal.

Control measures comprise on-site construction of berms, and planting of vegetation screens. Noise and view are thereby substantially reduced, particularly for closer residences, while odors may be improved through channeling of air flows. The location of the berms and vegetations screen reduces noise by about 11 dBA for residents at 100m distance from the site boundary (or 200m from the active fill area). The tree barrier screens the site entirely for all residents except those on the crest at the northeast corner (see map, Figure 6.2). These people will still be able to see the active fill area over the tree tops. The costs per city resident amount to $1.20 per year (see Appendix 6.B2) over 20 years.

Mitigation at the receptors includes double glazed windows to reduce noise, air conditioning to reduce odor, and trees to screen views. In contrast to the control measures, the trees are placed at the residents homes.

Double glazed windows reduce noise by 5dBA. Trees virtually eliminate views of the landfill. The total cost amounts to $1.00 per capita and year for estimated 1,000 houses and 400 apartments (see Appendix 6.B3).



Berms Tree and Vegetation Screen

Figure 6.2: Landfill - Nuisance Control Measures

Compensation of property value losses at 10% is derived from common values used for property depreciation through noise impacts along busy roads (Zeiss, 1984b).
For an area equivalent to 76 one acre plots around the circumference of the landfill, 10% value is equal to $69,100 per year, or $0.25 per capita per year.

Incinerator Air Emissions Reduction

Prevention occurs through separation of the burnable fraction because heavy metals, chlorides and organic contaminants are removed as discrete particles and as bound concentrations in the screen (undersize) residue. Thus, the mass flux of contaminants in the burnable fraction, as the input into the incinerator, is reduced and results in a net reduction of air emissions.
The estimated additional costs for the separation systems at $19 per resident per year do not include any cost savings to the incinerator operation. Although the overall reduction of the contamination in the fuel fraction entering the incinerator amounts to at least 50%, this effect does not carry through to a proportional reduction in emissions. The operation of air filters substantially reduces emissions so that the net effect of separation is estimated to be, at best, 10 to 20% of present (already low) emissions (see Appendix 6.C1).
Control of air emissions consists simply of best available filtration between boiler and stack discharge.

A second scrubber is added to further remove small particulate under 5 microns, and to further lower temperatures. These additional effects will result in further removal of heavy metals and organic emissions because, at lower temperatures, these constituents will tend to condense, sorb to particulates and be filtered out with them. An additional reduction of 10% of the present emission rate is estimated at a cost of $2.50 per person per year (see Appendix 6.C2).

Mitigation is based on monitoring and burn rate reduction if necessary. Alternatively, stack height could be increased to enhance dispersion, but this option may be considered a control measure and, hence, was rejected. But the reduction of burning rates may have side effects through reduction of traffic and noise.

The costs for air quality monitoring and pro-rated disposal cost increase due to a decreased burning rate are calculated separately:

Monitoring cost	$0.55 per capita per year
Disposal price increase	$2.05 to $4.61 per capita per year
Total cost	$2.60 to $5.16 per capita per year

The effects on air emissions are assumed to be proportional to the reduction in the burning rate of 10 to 20% (see Appendix 6.C3).

Compensation is offered through a guarantee of property

values up to 10% of assessed property equivalent to a nuisance compensation value to reflect the minor effects of air quality change.

This property value guarantee extends to the number of homeowners who actually sell their property. Based on the number of homes listed for sale during 1983 to 1986 in the host community in Salem, it is assumed that 100 homes at a maximum price of $196,660. per home each would be compensated. Thus the total cost at 5% interest rate, amortized over 5 years, equals $448,385 per year, or $1.45 per capita per year (see Appendix 6.C4).

Incinerator Nuisances: View Reduction of the Incinerator Stack

The costs for these measures are estimates only, because; the view reduction could not be accurately defined or described. Where possible, the effects are indicated qualitatively.

View prevention can be achieved through reducing the stack height so it does not exceed the tree line, especially for more distant residents. Further, the dehumidification of the exhaust gas reduces the visible steam plume. However, an equal virtual height of the source with the shorter stack must be achieved through higher exhaust velocities to offset the effect of a reduced stack height on dispersion. Furthermore, the shorter stack configuration makes the exhaust dispersion more susceptible to wind velocity variation.

In order to eliminate the vapor plume under worst case

conditions, the saturated exhaust gas is cooled and dehumidified in a heat exchanger (with ambient air) and then mixed with the warmed, dry ambient air. The mixture can then be discharged into ambient air at 0 degrees Celsius and 80 to 100% relative humidity without plume formation.

The cost of this system includes higher energy costs to increase stack gas exit velocity, investment and operating costs for the heat exchange system. These costs amount to $1.00 per person per year (see Appendix 6.D1).

View control of a tall stack through screening at the site is virtually impossible for viewers beyond a very short distance. This measure is therefore very ineffective for an objective impact reduction. Initially, tall trees of 9 to 12 metres will cover only the bottom 1/3 of the building and only 1/10 of the stack and plume. The distance from the site boundary effectively screened by these trees is only 6 to 12 m for the stack and 17 to 33 metres for the building (see Appendix 6.D2). With a growth rate of 0.30m per year, the screen distance increases approximately by 1/3 over 10 years. The on-site view control with a tree screen is very ineffective because it covers only ground level objects (trucks, equipment), but the costs are higher than for mitigation because of the unit cost for tall trees. The total cost amounts to $0.20 per capita per year (see Appendix 6.D2).

View mitigation, however, with trees at the receptors is more effective, but requires substantially more trees because this

method requires multiple screen lines of increasing circumference up to 5 km from the site (see Appendix 6.D3). However, the screened distance increases dramatically with the distance of the tree screen from the facility so that shorter (5 to 6m) trees can be used at $60 per tree. The cost of view mitigation comes to $0.02 per capita per year, or less than on-site screening. The screened distance ranges from 41m at 1 km distance to 125m at 3km (see Appendix 6.D3).

Compensation of 10% of property value is based on view as a nuisance impact. An immediate impact field was determined as a circle with an 800m (½ mile) radius from the stack. In the eastern half circle, 78 residential lots carry an average value of (US) $46,028 each; (Salem MLS Bureau, 1987). The western half-circle comprises 243 acres of farmland at (US) $2,000 per acre (pers. comm. E. Forrest, 1988).

Based on these values, the 10% compensation amounts to $0.15 per capita per year for each county resident (see Appendix 6.D4).

Non-Physical Impact Reduction Measures

Reduction of Loss of Control over Changes in the Community

Addressing the loss of control requires that the host community participate in the decision-making process, and, as a corollary, even structure and determine the process itself, as it may affect the outcome. Generic approaches to reduce loss of control cannot be based on or imply specific outcomes of a consultation process. The measures compiled here vary the time of

resident input into the siting process, and, hence, also in the degree of possible influence on the outcome:

Prevention of loss of control is addressed through participation in a long-term plan for the facility in the community, thus including location, design, construction and operational phases.

The participation could be organized in a process for public input into a comprehensive community plan. The time between planning for the facility and the begining of construction is large, possibly five to ten years. This process allows a broad range of issues to be addressed and gives the community a long period for adapting to the changes. Although this arrangement could result in prolonged opposition, the actual decision to locate the facility in the community is assumed to have been made irrevocably before the planning process begins.

Control measures to limit the loss of control comprises negotiations over a siting agreement for a specific facility and site design.

The participatory control is confined to addressing specific measures in the short term before facility construction. Both the range and time frame are limited, but sufficient to address specific facility design, property values, monitoring and replacement of water supplies, and overview committees (Wisconsin Facility Siting Board, 1987).

Mitigation entails participation in an overview committee to monitor the operation.

The activities cover only mitigation of actual nuisances, releases or damages under the given design. Changes to the initial design and operation are not considered by such a committee (see Wisconsin Facility Siting Board, 1987).

Compensation for loss of control after the fact is achieved in kind by allowing the host community only to decide on possible uses of additional taxes generated by the facility. The control here is not over the facility but over the funds for other services or improvements. Thus the measure is a compensation for lack of control over the facility through control over an alternate good, viz. the taxes. This is therefore a type of compensation in kind.

Reduction in Harm to the Community Image

"Image" is defined as the abstract image of the community which may depend among other things, on the visual image. Changing or influencing the abstract image of a community within the scope of the waste agency, however, is limited to the physical image. Thus, a preventive measure for image impact, apart from removing the facility altogether, could not be found. As a result, the set of measures is restricted to control, mitigation and in-kind compensation of impacts to the physical image and, in consequence, to the abstract community image:

Control of image impact consists of designing an attractive site and a buffer zone with desirable features (trees, ponds, etc.).

The design approach is limited to the purely physical image.

Landfill

Image control at the landfill comprises the construction of playing fields, a golf course with clubhouse, and park area. These amenities are planned on the filled area and concentrated along the outer perimeter (see Figure 6.B). The construction begins with circumferential screening and then follows the sequence of landfilling activities with a three to five year time lag to allow for settling of the fill before construction. A total area of 120 acres is used for playing fields and clubhouse (20 acres) and golf course and circumferential screen (100 acres). The cost amounts of $0.80 per capita per year (see Appendix 6.E1).

Incinerator

The image control at the incinerator comprises a 70m wide buffer strip around the square, 15 acre site. The buffer facilities are built with the facility. The costs add to the construction costs. The per capita cost is therefore recovered through equal per capita payments over the 20 year life of the facility equivalent to the present value of $917,000 or $0.30 per capita per year (see Appendix 6.E1). In order to simplify the survey design by using a single value at both sites, the higher cost of $0.80 at the landfill was used.

Mitigation of image impacts occurs through providing incentives for attractive development immediately around the site. Denser zoning and property price discounts are

intended to plan for and attract desirable development. Although zoning and land value discounts are not certain to attract desirable development in any community, they are likely to function in a typical host community because of its advantageous location relative to the central urban area and to access roads.

Thus, zoning for high priced single family homes and a 10% property value discount are adapted here as image mitigation measures.

Landfill

The land around the circumference (4,826m) of the landfill site hypothetically divided into 76 one acre plots. This land is zoned and offered at 10% reduced prices to developers to spur a desirable development (e.g., attractive single family residential) around the site. The straight land value is discounted by 10% for a total value reduction of $859,560 over 20 years or $0.70 per capita per year.

Incinerator

The incinerator site is in a new host community and, therefore still somewhat removed from the urban growth boundary. Furthermore, the area calls for rural residential development of large houses on minimum two acre plots. Therefore, both land and houses are subsidized in Salem to rapidly generate development around the site. In addition to the land value ($104,000 for 32 acres), the value of 16 houses ($80,000 each) is subsidized by 10% for a total cost

of $138,400, or $0.04 per capita over 20 years (see Appendix 6.E2).

Since the exact timing of the development relative to the construction of the facility is not determinable, a cost of $0.70 per capita per year is used for this mitigation measure. The maximum cost will occur if the development incentives are used in later stages (see cost at the landfill).

Compensation in-kind of the image impact is offered in-kind through construction of a community or recreational hall as an alternative benefit to boost the community image. Community and recreation centres are considered desirable and needed facilities in small towns (Hodge and Qadeer, 1983). Thus, such a facility will likely add to the community image. As an alternate, desirable facility, it is a form of in-kind compensation. The maximum cost is calculated with the cost of ½ acre of land at $56,550 (or $2.60 per square foot) and a 10,000 square foot building for $1,000,000 ($100 per square foot, pers. comm. F. Dela-Lana, 1988). Thus, the cost per resident and year amounts to $0.30 per capita per year.

Reduction of Unfairness of Hosting the Facility

The goal of fairness measures is to redistribute the "costs" of the facility rather than reduce the levels of specific impacts in the host community.

Prevention of unfairness is achieved by carrying out a fair selection of a site through a lottery to ensure that each site has an equal chance of being selected and hence, one site is not

unfairly singled out. All sites are assumed physically adequate. Thus, each site has an equal chance of being picked. The choice does not depend on political influence or personalities of decision-makers. Finally, the lottery occurs during the selection process, after preliminary evaluation of numerous sites, but before detailed design of a specific site. The lottery selection is therefore preventive from a host community's perspective.

Control of unfairness requires that all waste generators outside the host community pay slightly more to reduce impacts and participate in waste (and, hence, impact) reduction. These measures occur after the site selection and, hence, simply limit the degree of unfair impact-benefit distribution. The degree of unfairness depends on the specific impacts and benefits. Since these intangibles are difficult to quantify, the effect of control on unfairness is not determinable. However, the fact that the host community suffers while other waste generators benefit (see Kanneman, Knetsch and Thaler, 1986) is addressed by the increased cost to the beneficiaries in order to reduce impacts(costs) to the host community, thus, reducing the gain to one group and the loss to the other simultaneously.

Mitigation of the unfairness provides for alternate environmental goods. In this category, a sewer system for the host community was chosen to reduce the unfairness of environmental impacts, by installing sewer infrastructure to enhance water quality. Sewer systems are, in general considered to be desirable services in rural communities (Hodge and Qadeer, 1983). Moreover, a sewer system was specifically promised the host community of Brooks for

hosting the incinerator. Although the promise was later withdrawn, it swayed some residents to support the facility during the siting process.

Compensation of unfairness through free waste collection disposal and good neighbor services reduces the residents' costs in exchange for bearing the impacts. This measure is a form of compensation through waste disposal as the service provided by the facility. Although this measure redistributes the costs from the host community to other waste generators rather than redistributing actual impacts, there is a close connection between the disposal service and the facility impacts.

Thus, rather than reducing facility impacts through monetary costs to the users, this measure provides alternate benefits to the host community through cost redistribution.

6.1.2 Summary of Siting Measures

The siting measures are listed by type of impact and type of method in the following Tables 6.3a to g. Costs are summarized for health risk, nuisance and image impact measures, where the design of physical changes permitted engineering cost estimates. The additional costs range between $0.03 and $19 per capita per year. The maximum additional cost of $19 is equivalent to a one to two percent rise in property taxes or equivalent to an eleven to sixteen percent increase in residential garbage pick up rates in Tacoma and Salem. Thus, the additional costs for siting measures constitute small increases relative to the present residential tax and service charges.

Table 6.3a - Set of Methods to Address Health Risks from Water Emissions

Ways of reducing water emissions from the landfill	Effect in reducing emissions	Cost to each resident in taxes per person
Prevention		
Separate rotting organic matter from the garbage and treat it before placing them in the landfill to reduce leachate production	50% reduction	$13 per year
Control		
Install bottom liner and top cover, collect and treat leachate to reduce emissions to groundwater	90% in first 15 years, 50% after that	$16 per year
Mitigation		
Undertake leachate and groundwater monitoring on site and take remedial action to pump out and treat contaminated groundwater if necessary	groundwater is contaminated in a small area for 10 to 15 years, gets better after that	$1.00 per year
Compensation in-kind		
Monitor the water wells and connect those houses to other wells or to the city water supply free if their wells become contaminated from landfill leachate.	groundwater is contaminated but drinking water is safe	$0.35 per year

Table 6.3b - Set of Methods to Address Landfill Nuisances

Ways to reduce landfill nuisances	Costs to each resident per person
Prevention	
Install better mufflers, use quieter equipment to reduce noise, cover refuse frequently to prevent birds	$0.20/year
Control	
Construct berms on site to shield houses from noise and view	$1.20/year
Mitigation	
Install double glazed windows, air conditioners and screen residents houses with trees to reduce noise, odor and view	$1.00/year
Compensation	
Compensate homeowners with the dollar equivalent of 10% of property value	$0.25/year

Table 6.3c - Set of Methods to Address Health Risks from Incinerator Air Emissions

Ways of reducing air emissions from the garbage burner	Effects in reducing air emissions	Cost to each resident in taxes per person
Prevention		
Separate the garbage and remove contaminants before burning to reduce the emissions to air	20% reduction	$19 per year
Control		
Install the best available air filtration equipment to reduce air emissions in the exhaust air	10% reduction	$2.50 per year
Mitigation		
Monitor air emissions in the air around the plant and reduce the amount of garbage that is burned if the measured emissions are significant	10 to 20% if proven necessary	$2.60 to $5.20 per year
Compensation		
Compensate homeowners with the dollar equivalent of 10% of property value	no risk to property prices	$1.45 per year

Table 6.3d - Set of Methods to Address View

Ways to reduce the view of the garbage burner

	Cost to each resident per person
Prevention	
Reduce stack height and prevent a visible plume from occurring	$1.00/year
Control	
Screen stack and plume with high trees around site	$0.20/year
Mitigation	
Screen residents with trees at their homes	$0.02/year
Compensation	
Compensate homeowners with the dollar equivalent of 10% of property value	$0.25/year

Table 6.3e - Set of Methods to Address Loss of Control

Ways of addressing loss control of the community

Prevention

Establish a long-term zoning plan for the facility in the community with participation of the residents

Control

Make the facility proponent negotiate with community residents to reach a siting agreement on design, operation and impacts, otherwise binding arbitration will decide

Mitigation

Form a monitoring committee of host community residents and the owner/operator to monitor the operation, investigate complaints, and address problems and decide on changes

Compensation

Allow the host community to decide on the use of the extra taxes from the facility

Table 6.3f - Set of Methods to Address Image Impacts

Ways of addressing harm to the community image	Cost to each resident in taxes per year
Control	
Design and landscape the site and surrounding buffer zone as a park with trees, ponds, golf course, playing fields, etc.	$0.80 per year
Mitigation	
Zone area and provide incentives to encourage attractive development around the site	$0.70 per year
Compensation in-kind	
Build an attractive facility in the community, such as a community hall or recreation center	$0.30 per year

Table 6.3g - Set of Methods to Address Unfairness

Unfairness of having the facility in the community

Prevention

Ensure a fair selection by lottery choice of the site from among numerous sites

Control

Make everyone outside the host community pay slightly more for the necessary emission controls

Mitigation

Provide free waste collection and disposal, snow clearing and road maintenance for the host community

Compensation

Provide a community hall or recreation centre for the host community

The costs for different methods do not fit a consistent pattern; while prevention is most expensive for reducing incinerator air emissions ($19 per year), it is the cheapest method to reduce landfill nuisances ($0.20 per year). Control measures range from most expensive ($16 per person per year for landfill leachate control) to the second most expensive ($0.20 per person per year for view control at the incinerator). Mitigation ranks second most expensive ($2.60 to $5.16 per person per year for air emissions at the incinerator) to cheapest ($0.02 per person per year for view mitigation at the incinerator). Compensation measures are consistently the cheapest or second cheapest method at $0.15 to $1.45 per year.

For landfill leachate, control measures are objectively more effective than prevention, mitigation and in-kind compensation. For reducing incinerator emissions, prevention is the most effective measure, followed by mitigation and control. Compensation eliminates only property value losses for both cases.

The ranking of costs and effectiveness of methods are summarized in Table 6.4 because these data are important for the preference ranking of methods in the following sections. For landfill leachate and incinerator air emissions, the cost ranks coincides with the effectiveness rank of the measure.

6.2 Preferred Siting Measures and Their Effects on Attitude and Acceptance

6.2.1 Introduction

The objective of this section is to establish preferences for the use of impact reduction measures and test for their effect on

Table 6.4a - Ranking of Health Risk Measures by Cost and Effectiveness

Health Risk Reduction Measures	Landfill Leachate		Incinerator Air Emissions	
	Cost Rank	Effect Rank	Cost Rank	Effect Rank
Prevention	2	2	1	1
Control	1	1	3	3
Mitigation	3	3	2	2
Compensation	4	4	4	4

Legend: e.g. 1 = highest cost or most effective

Table 6.4b - Ranking of Nuisance Measures by Cost

Nuisance Measures	Landfill	Incinerator
	Cost Rank	Cost Rank
Prevention	3	1
Control	1	2
Mitigation	2	4
Compensation	3	3

Table 6.4c - Ranking of Community Image Measures by Cost

Image Measures	Cost Rank
Control	1
Mitigation	2
Compensation	3

facility acceptance in host and control communities. The interviews test three hypotheses (see the introduction to this chapter):

- the weighting of facility impacts is highest for health risks, followed by control and community image impacts, nuisances and property values;
- impact reduction is preferred over mitigation and compensation;
- impact reduction generates better acceptance of waste facilities.

The detailed interviews were specifically conducted among strongly oppositional and general host community respondents and among random control residents in Tacoma WA, and North Vancouver, B.C. for the landfill and in Salem OR, and Burnaby, B.C. for the incinerator (see Table 6.5). There are fewer control community residents in the samples because of less willingness to participate in the survey. Strongly opposed residents were picked from small groups of 5 to 10 well identified individuals who had actively opposed the facilities. General host and control residents were randomly selected from the list of respondents from the first survey (Survey 1) of facility impacts in 1987 (see Chapter 5).

This initial test is accomplished with interviews of host and control community residents at existing sites. Although the set of impact reduction measures contains specific and accurate methods, costs and reduction effects, the perspective of host and control communities may differ. Host communities already have a facility and, to a degree, may have already adapted to its

Table 6.5 - Sample Size for Acceptance Measure Interviews

Site	Community Host	Control	Total
Landfills			
Tacoma, WA	4	3	7
North Vancouver, B.C.	8	3	11
Total Landfill	12	6	18
Incinerators			
Salem, OR	7	4	11
Burnaby, B.C.	8	3	11
Total Incinerator	15	7	22
Total Survey	27	13	40

presence. In contrast, the control communities are not even confronted with a realistic possibility of having to address the issue. Control groups, are, however, representative of a potential host community, because they represent residents who live on the urban boundaries.

The interview contained multiple questions on each issue to establish impacts preferences for reduction measures and effects on resulting attitude:

- The first section (questions 1 through 12 in questionnaire, Appendix 6F) comprises a set of questions from the first survey (survey 1) about facility impact beliefs and attitudes to establish respondents' present beliefs and attitude about the facility and to test for changes over the last year since the beginning of 1987.
- The second set of questions (#11 and #12) require a ranking of concerns and a swing weighting of methods that address different types of impacts.
- The third set (questions 13, 14 and 15) elicit, first, preference ranking of general impact reduction approaches: Then, judgments of the changes in acceptability (question 15) and preferences among specific sets of reduction measures (prevention, control, mitigation, compensation), to address the most important impacts. Specific dollar costs and impact reduction effects are provided as a basis for respondents' preferences in question 15 (see Table 6.3a to h).
- The last set of questions addresses the changes in

attitude about the facility including optimal siting measures to address important impacts (questions 16 and 17). Finally, respondents are asked to rate overall facility acceptability under best circumstances, that is, with a fair selection, best available technology and regulation, definite and limited facility life, and with the three most preferred impact reduction measures (question 19).

The test instrument is intended to assess impact beliefs and attitude, establish impact reduction weighting, elicit preferences among specific siting measures with knowledge of effects and costs, and indicate the resulting change in attitude about each waste facility.

6.2.2 Acceptance Measures - Results.

Validation

The sample of interview respondents is compared with the sample of host community respondents in the first survey (survey 1 in Chapter 5) to validate representativeness of the results for typical host communities. Household characteristics, familiarity with the facilities, impact beliefs, and attitude ratings about the facilities are compared.

Household characteristics comprise type of home, ownership, presence of children under 18, education, and income. The proportions of these characteristics among the combined sample of respondents at both landfill sites and both incinerator sites are compared with the respective host community samples at the Tacoma

Table 6.6 - Comparison of Acceptance Interview Sample with Community Impact Survey (Survey 1) Sample by Demographics

a. Landfill

Characteristics	Proportion of Interview Sample N=18	Proportion of Survey 1 Sample N=33	Test of Difference of proportions
Type of Home			
Single Family	72%	69%	not sig.
Ownership			
own	89%	58%	significant
rent	11%	42%	significant
Children under 18 in household			
no	71%	67%	not sig.
yes	29%	33%	not sig.
Education			
High school graduates	88%	66%	significant
College graduates	30%	35%	not sig.
Income			
under $15,000	12%	10.3%	not sig.
$15,000 to $30,000	41%	41%	not sig.
over $38,000	41%	48%	not sig.

Table 6.6 - Continued -

b. Incinerator

Characteristics	Proportion on Interview Sample N=18	Proportion on Survey 1 Sample N=34	Test of Difference
Type of Home			
Single Family	90.5%	86%	not sig.
Other	9.5%	14%	not sig.
Ownership			
own	95.5%	86%	not sig.
rent	4.5%	14%	not sig.
Children under 18 in household			
no	68.2%	64%	not sig.
yes	31.8%	36%	not sig.
Eductation			
High school graduate	81%	87%	not sig.
College graduates	33.3%	43%	not sig.
Income			
under $15,000	10.6%	26.3%	significant
$15,000 to $30,000	37.4%	30%	not sig.
over $30,000	52%	43%	not sig.

Table 6.7 - Comparison of Familiarity with Waste Facilities among Interview Respondents and the Host Community

a. Landfill — Familiarity Rating (between 1-unfamiliar and 7-familiar).

	Interview Respondents N=18	Survey 1 Host Community N=33	Test of Difference of Means
Average	5.6	5.72	not sig.
Stand. Deviation	1.34	1.52	
b. Incinerator	N=22	N=34	
Average	4.52	5.03	not sig.
Stand. Deviation	1.82	1.7	

landfill and the Salem incinerator. Table 6.6 shows the specific values and the results of the difference of proportions tests as a 95% confidence level. In the landfill sample, there are significantly more homeowners (89% versus 58%) and more high school graduates (88% versus 66%) then in the original host community sample. At the incinerator sites, there are marginally fewer interview respondents in the lower income (under $15,000 per year) bracket than in the first survey sample. These differences reflect the greater interest and willingness of homeowners, high school graduates and middle income households to express opinions about their neighborhood and the environment. The effect of these noted differences, however, is to increase the sensitivity and the opposition to facility impacts (Madisso, 1985). Therefore, the sample is biased slightly negatively against the facility, as expected would occur through the inclusion of oppositional residents.

Familiarity with both types of facility operation and impacts was rated by each respondent. The averages and the results of the difference of means (t-test) are listed in Table 6.7a for the landfill and 6.7b for the incinerator.

The beliefs about negative impacts were measured with the same set of statements about the facility as were used in the first survey (see Chapter 5 and Appendix 5.A). The proportions of significant negative beliefs in both surveys are compared in table 6.8a and b. Property value losses (80% versus 41%) and harm to the community image (100% versus 41%) are held to be more negative by the interview respondents than by the respondents in the first

Table 6.8 - Comparison of Beliefs about Waste Facilities among Interview Respondents and Survey Respondents

a. Landfill

	Proportion of Respondents who think the waste facility has these impacts		
	Interview N=18	Survey 1 N=33	Test of Difference of proportions
Nuisances	80%	66%	not sig.
Health risks from water emissions	67%	52%	not sig.
Property value loss	80%	41%	significant
Harm to image	100%	41%	significant

b. Incinerator

	Interview N=18	Survey N=34	Test of Difference
Nuisances	32%	41%	not sig.
Health risks from water emissions	37%	32%	not sig.
Property value loss	47.4%	38%	significant
Loss of Control	49%	42%	not sig.
Harm to image	63.2%	41%	significant
Fairness	32%	44%	significant

Table 6.9a - Comparison of Attitude about the Waste Facility among Interview Respondents and the Host Community

a. Landfill	Attitude bout Facility on scale of -4-very undesirable to +4 very desirable			
	Interview Respondents N=18		Survey 1 Host Community N=33	Test of Difference of Means
Average	-3.6	<	-1.65	Significant
Standard Deviation	0.7	<	2.2	Significant
b. Incinerator	N=22		N=34	
Average	-1.91	<	-.53	marginally sig.
Standard Deviation	2.5		2.4	not sig.

Table 6.9b - Comparison of Annoyance with Waste Facilities among Interview Respondents and the Host Community

a. Landfill	Interview Respondents N=18	Host Community N=34	Test of Difference of Proportions
Annoyed, bothered or concerned	60%	42%	not sig.
b. Incinerator	N=22	N=34	
Annoyed, bothered or concerned	60%	53%	not sig.

survey. This is possibly because actively opposed respondents were intentionally selected and included in the interview sample.

All impact beliefs at the landfill are more frequently negative (nuisances, health risks, property value losses, harm to the community image) in the interview sample, as are health risks, property value losses, and image impacts at the incinerator. However, only property value losses and community impacts in the interview samples statistically significantly exceed the beliefs in the first survey.

The profile of perceived facility impacts among the interview sample is similar to that of the survey respondents in both host communities but slightly more negative about some impacts, particularly property value and community image impacts.

The attitude about the facilities is indicated by the average rating score of the facility (from -4 to +4) and by the proportion of respondents who are concerned, annoyed or bothered by the facility. In Table 6.9, the comparison and test of difference of means (t-test) and proportions indicates no significant differences in the number of annoyed residents, but, the overall attitude among interview respondents is more negative than that of the host community sample in survey 1. The more negative attitude is expected due to the inclusion of active opposition in the sample.

The comparison of interview and survey samples shows among interview respondents characteristics of similar or slightly more negative beliefs and attitude about the waste facilities. The respondents are therefore probably more reluctant to accept the

facilities than the host communities in general.

Results

The results are presented in the sequence of the tested issues: importance of impacts, priorities for methods to reduce impacts and the effect of impact reduction methods on the acceptance of the facility.

The first section presents results on the importance of impacts and preferences for impact reduction methods.

6.2.3 Impact Ranking and Reduction Priorities

The ranking of impacts for a specific facility shows (Table 6.10a and b) in descending order, the importance of specific impacts. At the landfill, health risks from water emissions, odors, noise, property value losses, and views are most important. At the incinerator, health risks from air emissions, odors, property value losses, noise and harm to the community image are considered important.

Impact reduction priorities are determined implicitly in a second procedure that ranks the preferences of specific impact reduction methods. Respondents are asked to rank the 6 combinations of each, the prevention and control measures, for health risk, nuisance, property value guarantee, control, image and fairness measures. By this method, the weight attributed to each type of impact is determined for the realistic possibilities to address the impacts.

In the landfill sample, the priorities favor methods that address in decreasing order of importance, loss of control, the

Table 6.10 - Impact Priorities at Actual Facility Sites

a. Landfill Impact Priorities

Percentage of respondents who are concerned about the impacts at the landfill

	Proportion of Responses %	Rank
Health Risks - water emissions	25.5	1
Accidents	3.9	6
Views	9.8	4
Odors	23.5	2
Noise	11.8	3
Prop. Values	11.8	3
Control	3.9	6
Image	5.9	5
Fairness	3.9	6

b. Incinerator Impact Priorities

Percentage of respondents who are concerned about the impacts at the incinerator

	Proportion of Responses %	Rank
Health Risks - air emissions	27.3	1
Views	7.3	5
Odors	21.8	2
Noise	9.1	4
Prop. Values	12.7	3
Control	5.5	6
Image	9.1	4
Fairness	7.3	5

health risks from water emissions, image, nuisances, fairness and property values. The apparent priority at the incinerator favors reduction of health risks from air emissions, then community image, control, property values, and, least preferred, fairness and nuisance measures (see Table 6.11). Thus, the weighting of specific impacts and realistic reduction measures indicates priorities among types of facility impacts. Although these priorities are not consistent with stated negative impact beliefs (see section on validation in this chapter and Chapter 5), they reflect expected priorities for impact reduction at new facility sites. At both sites, health risks, control and image impacts are top priorities, followed by nuisances at the landfill, property value losses and fairness.

6.2.4 Preferences for Impact Reduction Methods

This section presents results to test preferences for the use of prevention, control, mitigation and compensation measures to make the waste facilities more acceptable.

The results show clear and statistically significant order of preference in the following order (see Table 6.12):

		Cost Rank
1.	Prevention	1
2.	Control	2
3.	Mitigation	3
4.	Compensation	4

The frequency distribution of preference ranks clearly distinguishes

Table 6.11 - Priorities for Impact Reduction for a New Facility

a. Landfill

Percentage of respondents who consider reduction of this impact a high priority for siting

	Proportion of Responses %	Rank
Health Risks - water emissions	24.1	2
Nuisances	13.0	4
Prop. Values	11.1	5
Control	25.9	1
Image	14.8	3
Fairness	11.1	5

b. Incinerators

Percentage of respondents who consider reduction of this impact a high priority for siting

	Proportion of Responses %	Rank
Health Risks - air emissions	26.6	1
Nuisances	4.7	5
Prop. Values	17.2	3
Control	17.2	3
Image	25.0	2
Fairness	9.4	4

Table 6.12 - Preferences for General Impact Reduction Methods

Prevention

Number of people who pick the method as their choice

	Percent of sample %	Count	
First choice	82.1	32	+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
Second choice	15.4	6	+XXXXXX
Third choice	2.6	1	+X
Fourth choice	0.	0	+

The proportion of respondents who pick prevention as their first choice is significantly over 50% (at 95% confidence level)

Control

Number of people who pick the method as their choice

	Percent of sample %	Count	
First choice	10.5	4	+XXXX
Second choice	65.8	25	+XXXXXXXXXXXXXXXXXXXXXXXXX
Third choice	21.1	8	+XXXXXXXX
Fourth choice	2.6	1	+X

The proportion of respondents who pick control as their second choice is significantly over 40% (at 95% confidence level)

Mitigation

Number of people who pick the method as their choice

	Percent of sample %	Count	
First choice	2.6	1	+X
Second choice	17.9	7	+XXXXXXX
Third choice	69.2	27	+XXXXXXXXXXXXXXXXXXXXXXXXXXX
Fourth choice	10.3	4	+XXXX

The proportion of respondents who pick mitigation as their third choice is significantly over 45% (at 95% confidence level)

Compensation

Number of people who pick the method as their choice

	Percent of sample %	Count	
First choice	5.3	2	+XX
Second choice	7.9	3	+XXX
Third choice	2.6	1	+X
Fourth choice	84.2	32	+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

The proportion of respondents who pick compensation as their fourth choice is significantly over 60% (at 95% confidence level)

See table with corresponding number in Appendix 6.H for detailed statistics

prevention as the best method despite its highest cost and ranks compensation as the worst, despite the lowest cost to each resident. Thus, the priorities for methods for impact reduction run opposite to the order of the costs.

The ranking of specific measures to address health risks and image impacts was tested to corroborate the general preference. Each method to reduce health risks and image impacts is listed, respectively, in Table 6.13a and 6.13b according to how frequently it was picked by respondents as the first through fourth preference. The distribution of ranking choices shows the preference for prevention over control over mitigation over compensation measures. The number of times the measures were picked correspond with the predicted sequence of preference, because prevention is most frequently chosen first, control second, mitigation third, and compensation fourth. This preference holds for both physical impacts (air and water emissions) and for non-physical impact reduction (community image effects).

The preferences for impact reduction to make waste facilities more acceptable clearly support the predicted priorities for prevention, control and mitigation over compensation, contrary to the cost ranks, that would lead to an opposite prediction of preference sequence. Thus, within the range of additional costs from $0.03 to $20 per year, the costs to each resident are unimportant for the preferences among measures.

Finally, the results show the same basic preference for prevention at both facilities and for both physical and

Table 6.13 - Preferences for Specific Impact Reduction Methods

a. Health Risk Reduction Measures

First preference

Number of respondents who pick the measure as their first choice

	HIST%	COUNT	
Prevention	60.9	14	+XXXXXXXXXXXXXX
Control	34.8	8	+XXXXXXXX
Mitigation	4.3	1	+X
Compensation	0.	0	+

The percentage of respondents who pick prevention as their first choice is significantly over 25% at 95% confidence level

Second preference

Number of respondents who pick the measure as their second choice

	HIST%	COUNT	
Prevention	17.4	4	+XXXX
Control	43.5	10	+XXXXXXXXXX
Mitigation	34.8	8	+XXXXXXXX
Compensation	4.3	1	+X

Third preference

Number of respondents who pick the measure as their third choice

	HIST%	COUNT	
Prevention	18.2	4	+XXXX
Control	22.7	5	+XXXXX
Mitigation	54.5	12	+XXXXXXXXXXXX
Compensation	4.5	1	+X

The percentage of respondents who pick mitigation as their third choice is significantly over 25% at 95% confidence level

Fourth preference

Number of respondents who pick the measure as their fourth choice

	HIST%	COUNT	
Prevention	0.	0	+
Control	4.5	1	+X
Mitigation	4.5	1	+X
Compensation	90.9	20	+XXXXXXXXXXXXXXXXXXXX

The percentage of respondents who pick compensation as their third choice is significantly over 50% at 95% confidence level

See table with corresponding number in Appendix 6.H for detailed statistics

Table 6.13 - Preferences for Impact Reduction Methods

b. Community Image Impact Reduction Measures

First preference

Number of respondents who pick the measure as their first choice

	HIST%	COUNT	
Prevention	0.	0	+
Control	84.6	11	+XXXXXXXXXXX
Mitigation	7.7	1	+X
Compensation	7.7	1	+X

The percentage of respondents who choose control as first preference is significantly over 45% at 95% confidence level

Second preference

Number of respondents who pick the measure as their second choice

	HIST%	COUNT	
Prevention	0.	0	+
Control	15.4	2	+XX
Mitigation	46.2	6	+XXXXXX
Compensation	38.5	5	+XXXXX

Third preference

Number of respondents who pick the measure as their third choice

	HIST%	COUNT	
Prevention	0.	0	+
Control	0.	0	+
Mitigation	46.2	6	+XXXXXX
Compensation	53.8	7	+XXXXXXX

See table with corresponding number in Appendix 6.H for detailed statistics

* No prevention measure was offered as a choice.

non-physical impacts.

6.2.5 The Effects of Acceptance Measures on Acceptance

The results compare the effects on facility acceptance of property value guarantees measures with the effects of a combination of the three most preferred reduction measures as identified by each respondent.

Effects of Property Value Guarantee on Acceptance

The fairness of property value guarantees as a siting measure was tested in host and control communities at the Tacoma landfill and the Salem incinerator. The survey question and the results are shown in Table 6.14.

The results show that approximately 50% of the respondents consider the facility with property value guarantees a fair solution. Conversely, however, 50% of the respondents in host and control groups at both landfill and incinerator do not accept property value guarantees as fair compensation for hosting an intolerable facility. These results do not differ significantly throughout host and control groups of both sites.

The opinions on fairness of property values are cross-tabulated with the significant negative beliefs about facility impacts held by the respondents. At the Tacoma landfill there appeared no significant association between perceived impacts and opinion on property value guarantees (see Appendix 6.G). This is probably because the facility has been located in the neighborhood for 25 years. In this time, most people have adapted to the situation with the landfill and do not experience the

Table 6.14 - Fairness of Property Value Guarantees

Facility owner/operator guarantees affected property owners assessed market slaes value.

Question: Assume the situation in your neighborhood becomes intolerable because of the waste facility's impacts. The owner/operator offers to compensate you for any property value losses you may experience in selling your home.

Do you consider this offer to be (please mark one)

Completely fair	acceptable	Somewhat unfair	very unfair
_____	_____	_____	_____

Results:

Tacoma Landfill

		Fair	Unfair	Difference of proportions
N = 34	Host	44.8%	55.2%	not sig.
N = 26	Control	46.1%	53.9%	not sig.
		non-sig.	non-sig.	

Completely fair	acceptable	Somewhat unfair	very unfair
_____	_____	_____	_____

Results:

Salem Incinerator

		Fair	Unfair	Difference of proportions
N = 33	Host	51.6%	48.5%	not sig.
N = 25	Control	40.9%	58.7%	not sig.
		non-sig.	non-sig.	

impacts as distinct and significant losses. Put differently, they have shifted their reference point.

At the newer incinerator site, however, the cross-tabulation of negative impact beliefs with opinion of property value guarantees shows a clear and statistically significant pattern (see Table 6.15). Respondents in the Salem host community who are annoyed with the facility and those who believe the facility causes health risks, depresses property values, harms the community image, or decreases confidence in the local government consider compensation through property value guarantees significantly less acceptable than other residents. This means that property value guarantees tend not to make waste facilities acceptable to those who are most opposed. This applies even to people who believe there are impacts on property values.

Because property value guarantees do not address the primary impacts (health risks, image impacts, loss of confidence) per se, but, rather, reduce consequential losses to property values, they do not address the cause or source of the opposition.

Effects on Acceptance of Health Risk and Image Reduction Measures

The results in this section show, first, the effect of individual health risk and image impact reduction measures on acceptance, and, second, the level of acceptance of waste facilities with a combination of three most preferred reduction measures.

The effects on acceptance of prevention, control, mitigation and compensation measures for health risks and image impacts were

Table 6.15 - Effects of Property Value Guarantees on Acceptance of Facility Impacts at a New Incinerator

Sample N=33

Host Community Residents		Proportion of Respondents who consdier Property values	
		fair	unfair
Annoyed by Facility	yes	35.3%	64.7%
	no	68.8%	31.3%
		Chi Square significant	

Respondent believes the facility negatively affects		Proportion of Respondents who consdier Property values guarantees	
		fair	unfair
Property Values	yes	38.5%	61.5%
	no	85.7%	14.3%
		Chi Square significant	
		fair	unfair
Comunity Image	yes	31.3%	68.8%
	no	64.3%	35.7%
		Chi Square significant	
		fair	unfair
Health Risks	yes	12.5%	87.5%
	no	60.0%	40.0%
		Chi Square significant	
		fair	unfair
Confidence in Local Government	yes	11.1%	88.9%
	no	66.7%	33.3%
		Chi Square significant	

evaluated individually at the landfill and the incinerator sites. The results are shown as frequencies of responses in Table 6.16a for health risk measures and Table 6.16b for image impact measures. From inspection of the frequency densities it is apparent that the improvement of acceptance is much higher for prevention measures and decreases in the sequence from prevention to control to mitigation to compensation. This finding is statistically validated by testing for difference of proportions between the responses that indicate some positive effect on acceptance and those that indicated no difference for each measure. These indicate that prevention, control and mitigation measures have significant positive effects on acceptability, while compensation was significantly less or none at all. These findings show the positive effect of impact reduction measures on acceptance and confirm the sequence of preference of prevention over control over mitigation over compensation as was found in the last section.

By integrating the respondents' three most desirable impact reduction measures into the siting scenario, respondents' acceptance levels of the facility with the combined, best available measures were elicited. The specific combination of reduction measures resulted from each respondent's previous selection and weighting of the measures. The frequency distribution of the presented impacts reduction measures and of the respondents' acceptance ratings are illustrated in Tables 6.17a for the landfill and in Table 6.17b for the incinerator scenario.

Table 6.16 - Effects of Reduction Measures on Facility Acceptance

a. Health Risk Reduction Measures

Prevention

Number of residents who think the measure makes the facility more acceptable

	% HIST%	count COUNT	Total %	Difference of Proportions
no difference	4.3	1 +X	4%	significant
slightly more	30.4	7 +XXXXXXX		
more	13.0	3 +XXX	96%	
much more	52.2	12 +XXXXXXXXXXXX		

Control

Number of residents who think the measure makes the facility more acceptable

	%	count	Total %	Difference of Proportions
no difference	8.7	2 +XX	9%	significant
slightly more	34.8	8 +XXXXXXXX		
more	17.4	4 +XXXX	91%	
much more	39.1	9 +XXXXXXXXX		

Mitigation

Number of residents who think the measure makes the facility more acceptable

	%	count	Total %	Difference of Proportions
no difference	21.7	5 +XXXXX	22%	significant
slightly more	26.1	6 +XXXXXX		
more	17.4	4 +XXXX	78%	
much more	34.8	8 +XXXXXXXX		

Compensation

Number of residents who think the measure makes the facility more acceptable

	%	count	Total %	Difference of Proportions
no difference	63.6	14 +XXXXXXXXXXXXXX	64%	significant
slightly more	0.	0 +		
more	13.6	3 +XXX	36%	
much more	22.7	5 +XXXXX		

See table with corresponding table in appendix 6.H for detailed statistics

Table 6.16 - Effects of Reduction Measures on Facility Acceptance

b. Community Image Reduction Measures

Control

Number of residents who think the measure makes the facility more acceptable

	%	count	Total %	Difference of Proportions
no difference	7.7	1 +X	8%	significant
slightly more	23.1	3 +XXX		
more	38.5	5 +XXXXX	92%	
much more	30.8	4 +XXXX		

Mitigation

Number of residents who think the measure makes the facility more acceptable

	%	count	Total %	Difference of Proportions
no difference	15.4	2 +XX	15%	significant
slightly more	38.5	5 +XXXXX		
more	30.8	4 +XXXX	85%	
much more	15.4	2 +XX		

Compensation

Number of residents who think the measure makes the facility more acceptable

	%	count	Total %	Difference of Proportions
no difference	30.8	4 +XXXX	31%	not significant
slightly more	38.5	5 +XXXXX		
more	23.1	3 +XXX	69%	
much more	7.7	1 +X		

See table with corresponding table in appendix 6.H for detailed statistics

For both facilities, the combined acceptance measures positively affect acceptance levels. In the landfill group, the proportion of accepting respondents in the host community rises from 50% with property value guarantees to 64% with the combined measures. At the incinerator, the acceptance level for combined measures increases to over 85%. For the combined host community samples, these acceptance levels are significantly higher than the 50% obtained with property value guarantees.

The comparison of acceptance with the annoyed respondents is achieved by cross tabulation (see Table 6.18a and b). The tables show that the measures increase acceptance similarly among annoyed and unannoyed residents, because the chi-square measure does not indicate a significant dependence on annoyance of the effect of reduction measures. Thus, the combined reduction measures are more effective than property value guarantees in achieving acceptance among initially annoyed residents.

6.2.6 Summary and Conclusions

The priorities for impact reduction at new waste facility sites show the ranking of impacts by importance: health risks from air and water emissions are most important, followed by loss of community image and control, property value impacts and finally, nuisances and unfairness (see Table 6.11). This ranking shows that social and political impacts rank right below health concerns on a scale of impacts that must be addressed in a facility siting process.

The set of methods to address facility impacts consists of

Table 6.17 - Acceptance with Combined Acceptance Measures

a. Landfill

Host community

	Willing to accept landfill with combined acceptance measures		Difference of Proportions
	% of sample	Count	
No	36.4	4 + XXXX	No significant difference
Yes	63.6	7 + XXXXXXX	

Control community

	% of sample	Count	
No	42.9	3 + XXX	No significant difference
Yes	57.1	4 + XXXX	

b. Incinerator

Host community

	Willing to accept incinerator with combined acceptance measures		
	% of sample	Count	
No	14.3	2 + XX	Significant difference
Yes	85.7	12 + XXXXXXXXXXXX	

Control community

	% of sample	Count	
No	50.0	4 + XXXX	No significant difference
Yes	50.0	4 + XXXX	

See table with corresponding number in Appendix 6.11 for detailed statistics.

Table 6.18 - Effect of Combined Impact Reduction Measures on Acceptance

a. Landfill

		Will accept the facility with the combined impact reduction measures	
		Yes	No
Is presently annoyed, bothered or concerned about facility	N=15		
Yes	67%	60%	40%
No	33%	80%	20%

Chi-square=0.6, not significant at 95%

b. Incinerators

		Will accept the facility with the combined impact reduction measures	
		Yes	No
Is presently annoyed, bothered or concerned about facility	N=19		
Yes	37%	86%	14%
No	63%	67%	33%

Chi-square=0.83, not significant at 95%

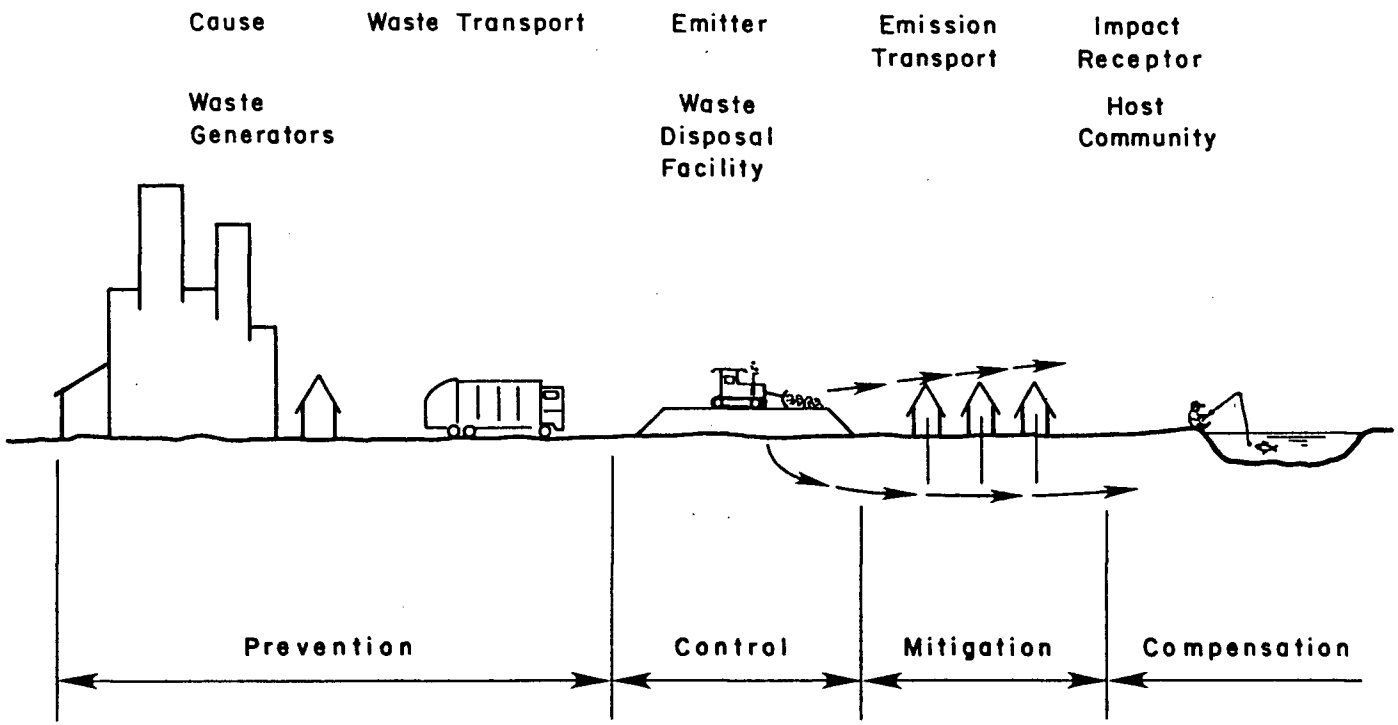
prevention, control, mitigation and compensation. In this sequence, these measures reflect an increase in distance or time from the cause or source of the facility impacts to the point where action is taken to reduce the effects. Increasing distance or time furthermore implies an increasing gap of responsibility between cause and effect. For example, separation removes potential contaminants before the waste is disposed of, while emission controls limit the release of contaminants on site.

The clearly preferred ranking of these approaches is in this sequence:

1. Prevention
2. Control
3. Mitigation
4. Compensation

These results support the hypotheses that, first, reduction of impacts in kind is more effective than compensation, and, second, that addressing the impact as close to the source or cause is preferred over control or mitigation (see Figure 6.3). This confirms the preference towards reducing responsibility, decreasing distance and time between cause and impact reduction interventions.

These preferences hold true despite the higher costs for prevention and control in the range up to $20 per person per year. Moreover, prevention is preferred over control measures even when controls are more effective in reducing the impact on an objective scale (e.g., leachate emissions from a landfill). Thus, strong preference favors eliminating the cause at the source rather than



	Prevention >	Control >	Mitigation >	Compensation
Preference Rank	1	2	3	4

Figure 6.3: Priorities for Impact Reduction in the Waste Disposal System

dealing with the downstream effects. This preference holds even in cases where the latter is cheaper and more effective.

The same ranking of methods is found when the effect of measures on facility acceptance is tested. The most positive change in acceptance occurs with prevention measures, followed by control mitigation and compensation. The effect of compensation on acceptance is usually small or negligible. Thus, better acceptance is enhanced by the most direct reduction of the impact as close to the source (i.e., the waste generators) as possible.

Finally, through combining prevention and control measures to address important impacts in the best practical way, the overall acceptance of the facility can be significantly increased to approximately 60 to 80% of the host-community. This result is substantially higher than the 50% acceptance achieved with property value guarantees. These results, too, show the effectiveness of in-kind reduction over compensation.

In summary, waste facility acceptance is best achieved by addressing the impacts rather than offering compensation (in the range tested here) i.e., as a percentage of property values or community amenities. The closer to the source or causal origin the impact reduction occurs, the more acceptable the impact, and, hence, the more acceptable the facility will become to the affected persons. If the siting agency is seen to be using prevention and control measures to their best extent and to eliminate significant health risks, then 60 to 80% acceptance among residents of the host community is possible.

The results of this chapter show that residents in possible

host communities hold distinct opinions about the importance of facility impacts and have clear preferences about methods to address their concerns. Furthermore, people become more accepting of the facility if they are convinced efforts are being made to reduce impacts that concern them.

In summary, this chapter has established relative weights of facility impacts, and, then, defined a predictable dimension that determines the effectiveness of siting measures on acceptance. Thus, the results offer a guideline for designing and siting waste disposal facilities for acceptance. In the next chapter, various siting measures are combined into an optimal siting approach.

CHAPTER 7 - SUMMARY and CONCLUSIONS

This chapter summarizes hypotheses, and results and draws conclusions for the siting process. The issues of typical siting conflicts are derived for a defined urban waste disposal system. Then, goal, hypotheses, and results are summarized. Finally, conclusions are drawn for the siting of waste disposal facilities.

7.1 Waste Disposal System and Siting Scenario

The typical urban waste disposal system consists of a large urban area as the waste generating source. The municipal solid waste (MSW) is then transported to a waste disposal facility where the disposal process generates emissions. The interaction of the waste facility, as the emittor, with the host community, as the receptor, generates impacts (see Figure 7.1).

Rural communities on or beyond the urban growth boundary are often selected as host communities because they meet typical siting criteria of low density, inexpensive land, good accessibility to the waste generation centroid. Some characteristics and beliefs of such potential host communities conflict with the presence of a large urban waste disposal facility; the small rural environment that is believed to be clean, familiar, under control, diverse and stable is confronted with a large, unfamiliar, polluting, uncontrollable single land user, the urban waste disposal facility.

In response to the threat of these changes, host communities often strongly oppose attempts to site waste disposal facilities because of physical, economic, social and political impacts.

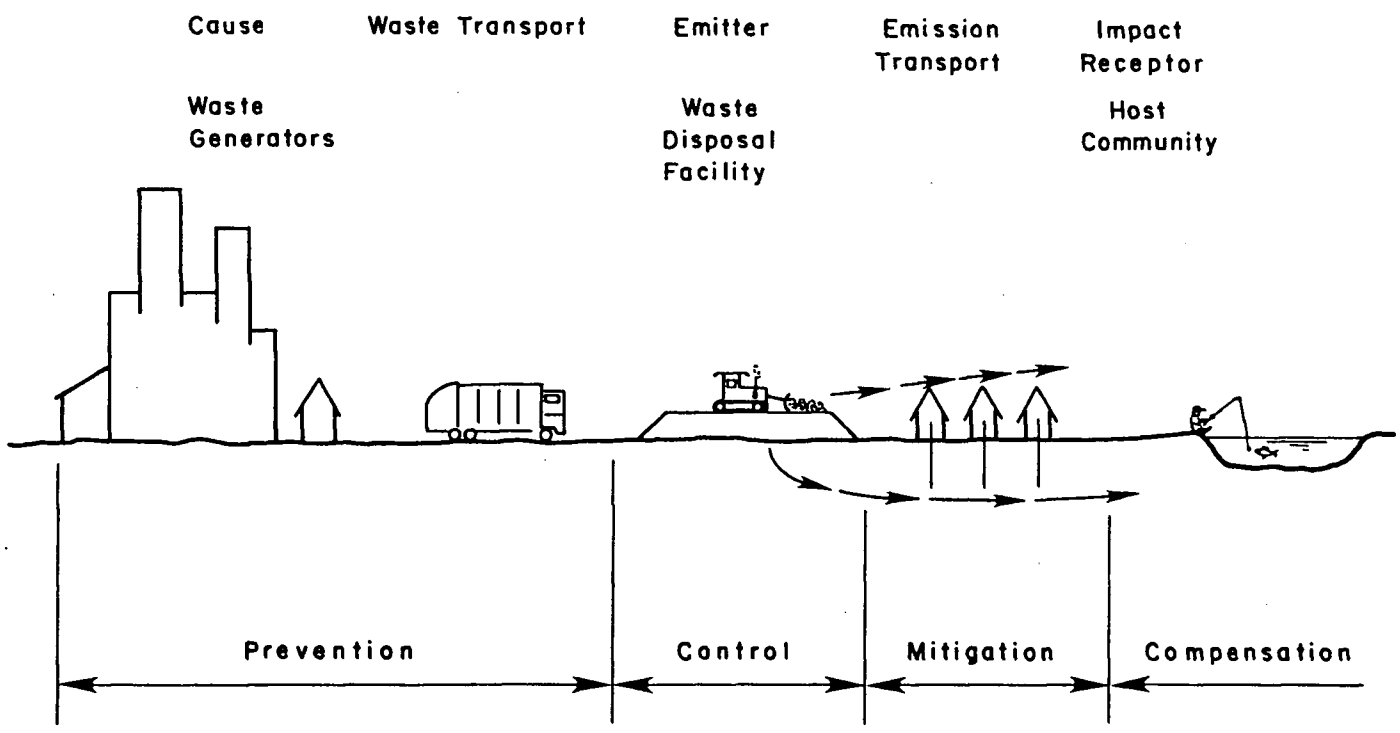


Figure 7.1 - Waste Disposal System

Because the reasons often appear irrational, the opposition is called the Not-in-My-Backyard (NIMBY) Syndrome. As a result, waste facilities are often delayed or prevented with considerable cost in time, effort, money and stress to facility proponent, waste agency, host community, and environmental agency.

7.2 Thesis Goal, Objectives and Methods

The goal of this thesis is to develop an approach to more effective siting of waste disposal facilities. The specific objectives are (1) to define a complete set of facility impacts and benefits and establish an impact model to explain and predict the resulting host community attitude and opposition activities, and (2) to derive and test a systematic approach to gaining host community acceptance.

The methods consist of conceptual analyses of the literature to establish specific hypotheses, physical prediction, measurements and validation of physical impacts, technical design and engineering cost estimates, surveys and interviews of residents' beliefs, attitudes, actions and preferences (see Table 7.1).

The results and conclusions are presented subject to the assumptions and limitations of the methods. Critical assumptions are stated and, when necessary, are tested in the chapters where the methods are described.

Table 7.1 - Methodology of Thesis Research

Phase I		
Chapter 1:	Study Site Selection and Description	Facility Survey
Chapter 2:	Set of Facility Impacts	Literature Review
Chapter 3:	Impact Model	Conceptual Analysis
	Acceptance Criterion	Conceptual Analysis
	Acceptance Approach	Conceptual Analysis
	Priorities for Acceptance Methods	Conceptual Analysis
Phase II		
Chapter 4:	Physical Impact Analysis	Physical Measurement and Validation
Chapter 5:	Beliefs, Attitudes and Action	Written Survey in Host and Control Communities
		Content Analysis of Media
		Real Estate Sales Analysis
Phase III		
Chapter 6:	Set of Practical Acceptance Measures	Technical Design of Prevention, Control, Mitigation and Compensation Measures
	Preferences for Acceptance Methods and Acceptance	Interviews with Host and Control Community Representatives
Chapter 7:	Summary Conclusions Implications	Deduction from Results in Previous Chapters
Chapter 8:	Siting Policy Issues, recommendations and Future Research	Deduction from Results in Chapter 7

7.3 Summary:

Hypotheses and Results

The following summary of hypotheses, results and conclusions is presented as a brief synopsis in three sections: (1) facility impacts and resulting beliefs among residents, (2) residents' attitudes and opposition actions, and (3) systematic approach to facility acceptance in the host community.

7.3.1 Facility Impacts and Resulting Beliefs among Residents

Hypotheses

A. Waste disposal facilities in typical host communities generate a set of physical and non-physical impacts. Physical impacts comprise health risks, nuisances and general environmental change; non-physical impacts consist of economic, social and political impacts (see Table 7.2).

B. Residents' general beliefs about landfills and incinerator impacts may differ from host community residents specific beliefs about particular facility impacts.

C. Physical impacts cause non-physical impacts through interpretation as residents' beliefs. There is a connection between exposure to physical impacts and residents perception of non-physical impacts.

D. Non-physical impacts are equally important as physical impacts in determining residents' attitudes about waste facilities.

Table 7.2 - Waste Facility Impacts and Benefits

Impacts:	
Physical:	Nuisances - Noise, odor, view
	Health - air and water emissions, accident and explosion risks
	Environmental Change - air and water quality degradation, wildlife habitat loss
Economic:	Residential property value depreciation
	Retardation of residential development
	Taxes for Infrastructure and Services
Social:	Stigma to community image due to association with "waste" and "pollution"
Political:	Loss of control
	Unfairness
	Lack of confidence in owner/operator, local politicians, environmental agency
	Lack of information and familiarity
Benefits:	Waste Disposal Service
	Convenience
	Energy Recovery
	Employment
	Taxes

Results

The observed impacts comprise health risks from air and water emissions, nuisances from odor, noise, views and animals, and changes in air and water quality. At landfills, health risks from groundwater contamination and air emissions affect downstream areas in the immediate vicinity, i.e., within 1,000 from the site boundary. Landfill gas generates explosion risks within 100 to 200m from the site and slight air quality risks to health from volatile organics up to 1,000 m from the site. Odor, noise, and birds cause nuisances within 200 to 300m from the site boundary.

At the incinerator, the exhaust gas emissions theoretically affect air quality in the prevailing wind directions. The effects are, however, negligible in terms of health risks except at the location of maximum ground level concentration of 700 to 3,000m from the site. At these locations the estimated additional health risks from the verified emissions are less than 1 in 1 million. Hence, the air emissions constitute merely an ambient air quality loss in the prevailing wind directions for a facility with particulate filtration, gas scrubbing and a high stack. Nuisances from view of the stack and vapor plume extend up to 5 kilometres in all directions. Topography and vegetation screen the view only if the barriers are close to the observer. Significant noise is confined to an area within 100m from the site, but facility noise can be detected up to 800m from the site depending on screening and background noise level. No odor was detected from the plant. The physical impacts are summarized for typical landfills and

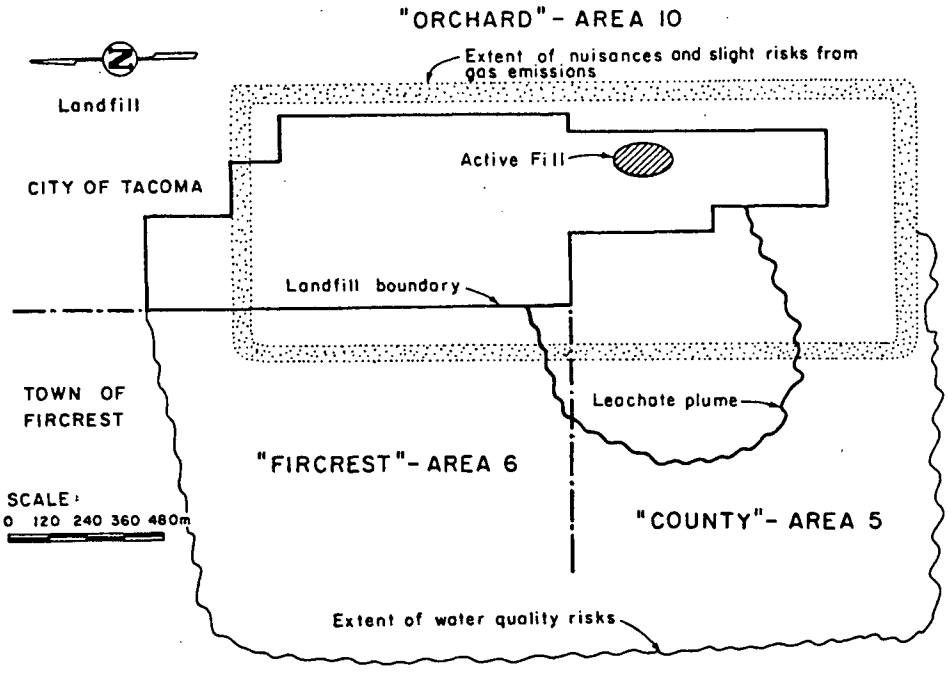


Figure 7.2a: Landfill Physical Impact Footprint

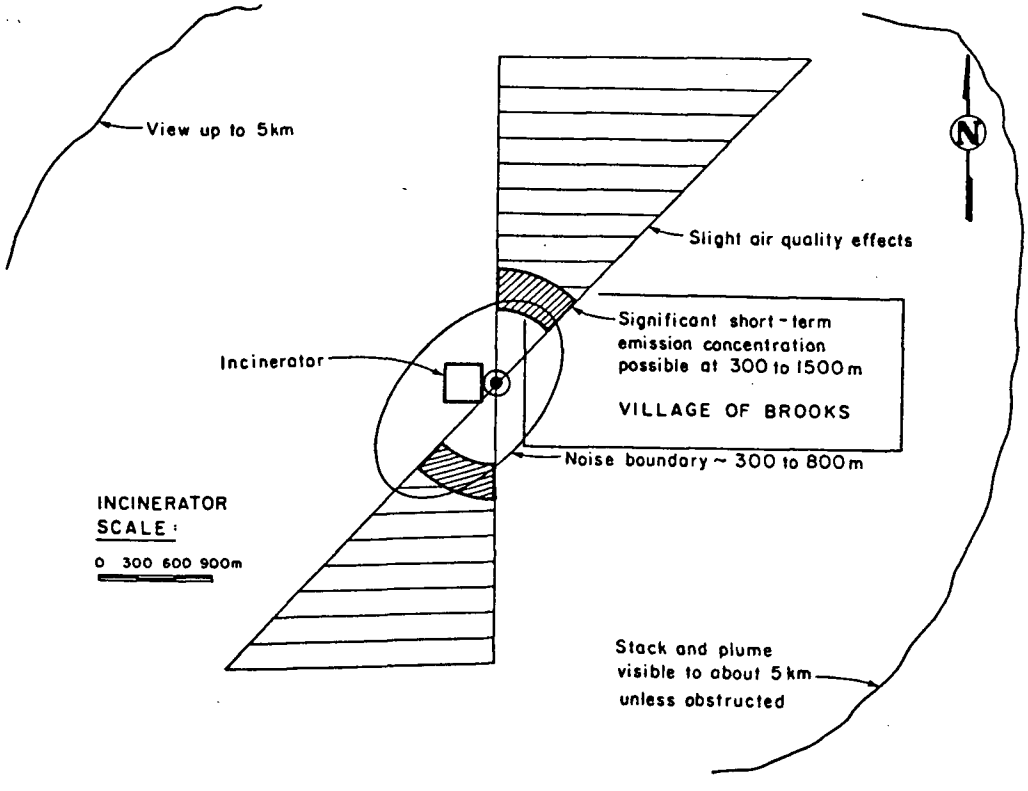


Figure 7.2b: Incinerator Physical Impact Footprint

incinerators in Figures 7.2a and b.

In the host community, residents believe that landfills affect community image, create nuisances (animals, odor, traffic, noise, view), health risks from water and air emissions, water and air quality changes, and property value losses.

Incinerators are perceived by the host community to cause loss of control, health risks from air emissions, property value and image losses, nuisances and unfairness.

Residents' spontaneous beliefs about generic landfills and incinerators consist of purely physical impacts. In contrast, their beliefs about impacts from specific, familiar facilities include non-physical impacts of property value losses, loss of community image and control, unfairness.

At both landfills and incinerators, the beliefs about physical and non-physical impacts depend on the residents' exposure to physical impacts. People who can see, hear or smell the facility hold more negative beliefs about facility impacts on image, unfairness, property values and nuisances than unexposed residents. Thus, nuisances can trigger or aggravate negative perceptions.

In landfill and incinerator host communities both physical and non-physical impacts correlate significantly with attitude about the waste facility.

Physical impacts, residents' beliefs and the significant associations are summarized in Figures 7.3a and b.

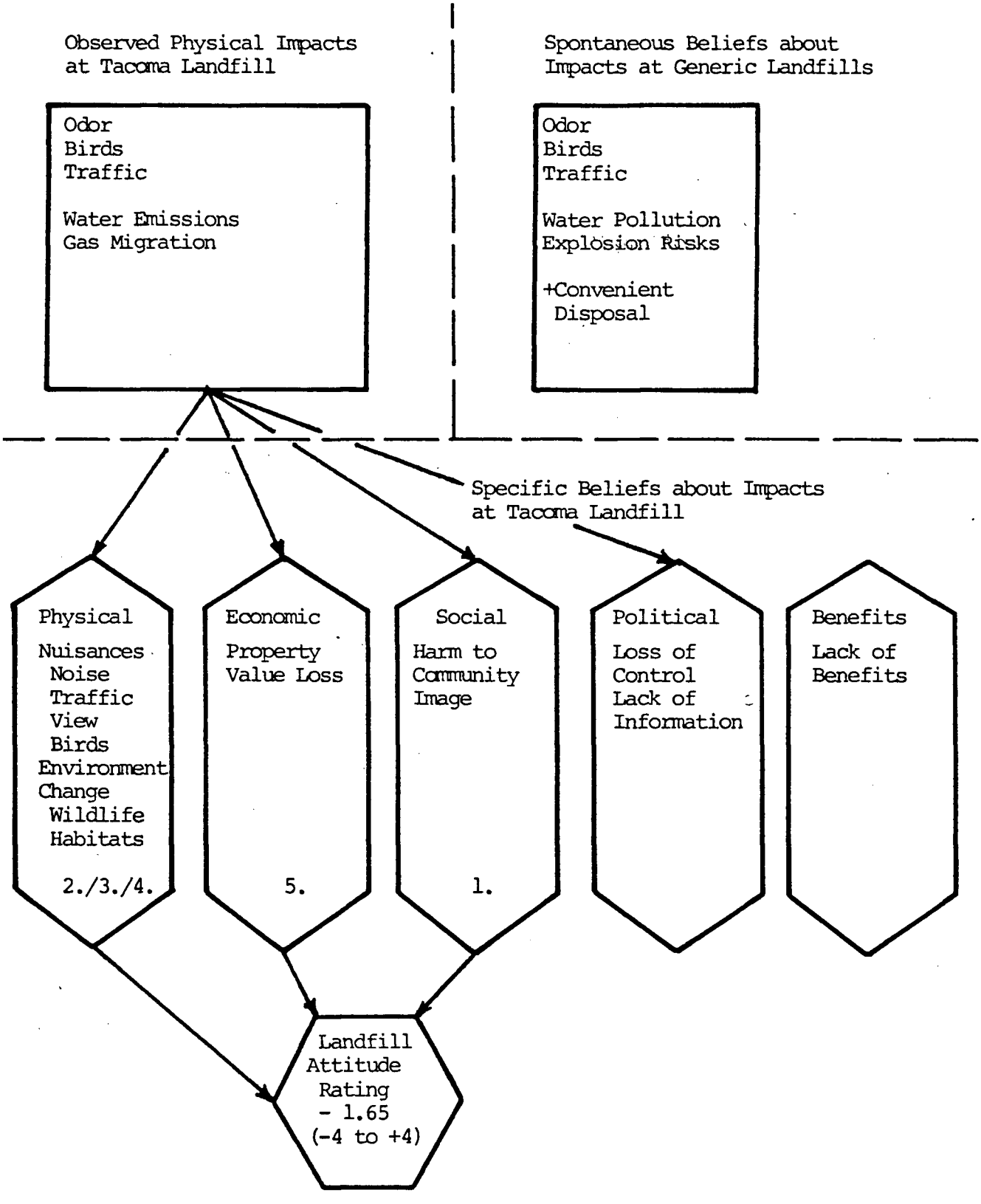


Figure 7.3a - Landfill - Summary of Impacts, Beliefs and Attitudes

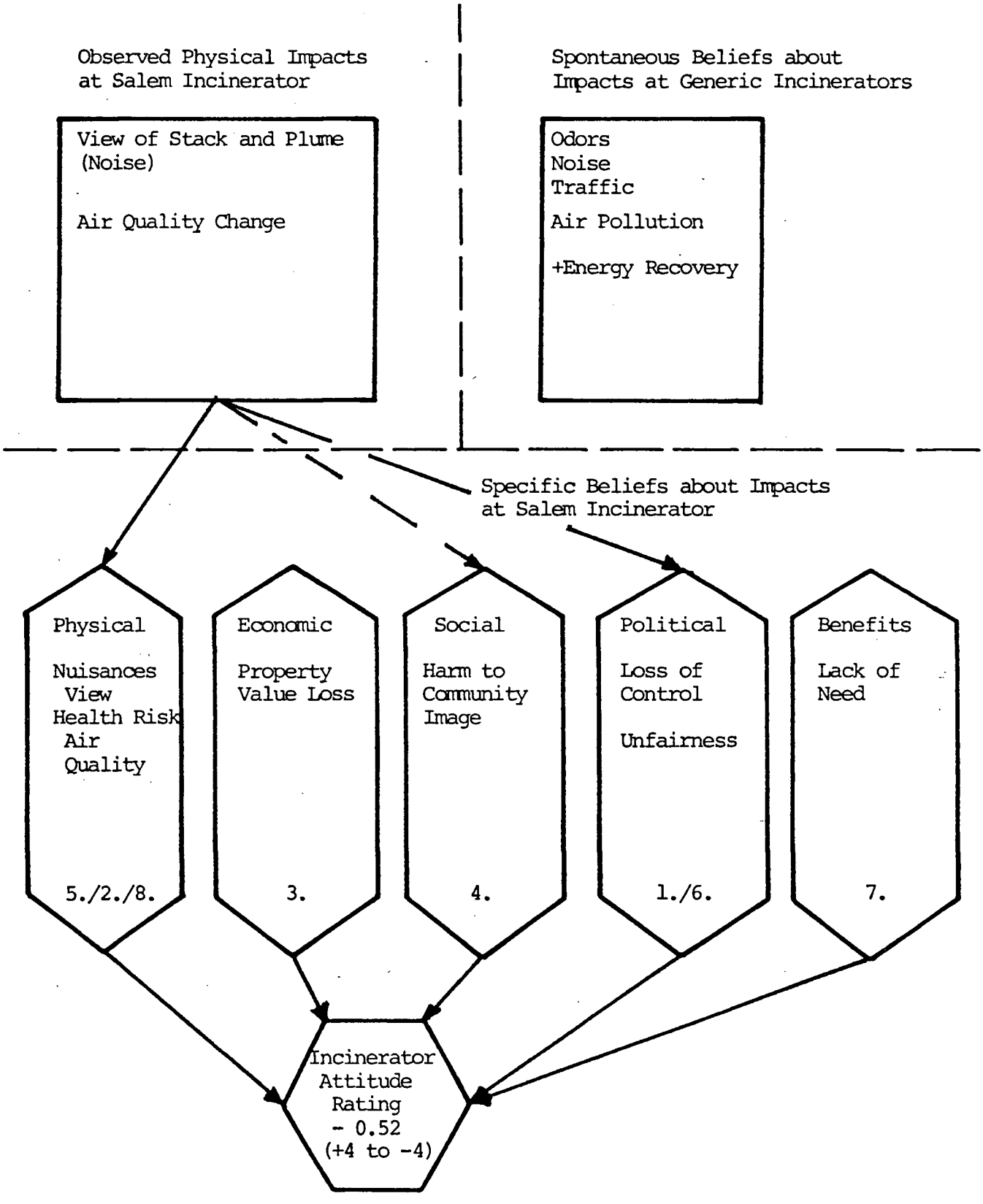


Figure 7.3b - Incinerator - Summary of Impacts, Beliefs and Attitudes

7.3.2 Residents Attitude and Opposition

Hypotheses

A. Host community attitude about waste facilities is most negative before and during facility siting. Thereafter, the attitude improves either through replacement of residents with negative attitudes or through personal adaptation to the conditions with the facility.

B. Attitude about the facility is associated with opposition activity. Opposition activity as exit (moving away), or voice (gathering information, attending meeting, filing complaints or taking legal action) is expected to be stronger during the siting process then after the facility is built.

Results

Attitudes about landfills and incinerators are best in host communities; residents in control communities are more negative about waste facilities (see Table 7.3).

Although the landfill impacts are more severe than the incinerator's due to the presence of health risks and obvious nuisances, opposition activity is significantly stronger in the newer incinerator host community. Whereas 5 to 10% of respondents gather information, attend meetings and complain at the 25 year old landfill, nearly 50% are active near the 2 year old incinerator.

Exit opposition is measured by property values, days on the market and number of listings and sales in the host community.

Table 7.3 - Attitudes about Waste Facilities

a. Tacoma Landfill

Community		Attitude Rating on scale of -4 to +4 of Facility: Landfill Attitude	Incinerator Attitude
Host	N = 26	-1.65	-2.04
Control	N = 23	-2.57	-2.04

b. Salem Incinerator Site

Community		Landfill Attitude	Incinerator Attitude
Host	N = 30	-3.39	-0.53
Control	N = 17	-2.59	-0.88

Note: Boxes designate the facility used at the respective study sites.

Neither landfill nor incinerator impacts have any effect on property values or the days on the market for residential properties. The number of MLS listings was marginally significantly higher after the announcement of the incinerator site, but not during construction and the first year of operation. The number of sales was not affected at all. Thus, opposition activity is significant at the newer incinerator site during siting and consists of milder forms of voice and exit opposition (gathering information, attending meetings, listing of properties). At the older landfill, none of these activities was nearly as frequent. Finally, the association of attitude about the incinerator with opposition activity is significant, while no significant association is present in the landfill host community.

The adaptation to the facility is reflected in the peak of opposition through the process. During the siting process, many residents are active in minor opposition activities, including information gathering, filing complaints and attending meetings. Fewer take legal action or consider moving. After the facility is in place, however, opposition dies down without any significant numbers of household moves. Nor are there any significant effects on property values as a result of facility physical impacts. Thus, most residents respond by minor activities in the siting process, but do not move or continue action when the facility is operational, unless new events cause major impacts (spills, accidents) occur. Thus, the behavioral response to waste facilities is predominantly through voice prior to the construction.

7.3.3 Systematic Approach to Facility Acceptance

Hypotheses

A. Impact reduction in kind is a more effective method than compensation to increase host community acceptance.

B. The effectiveness of impact reduction measures for host community acceptance decreases in the following order: 1.) prevention 2.) control, 3.) mitigation, 4.) compensation.

Results

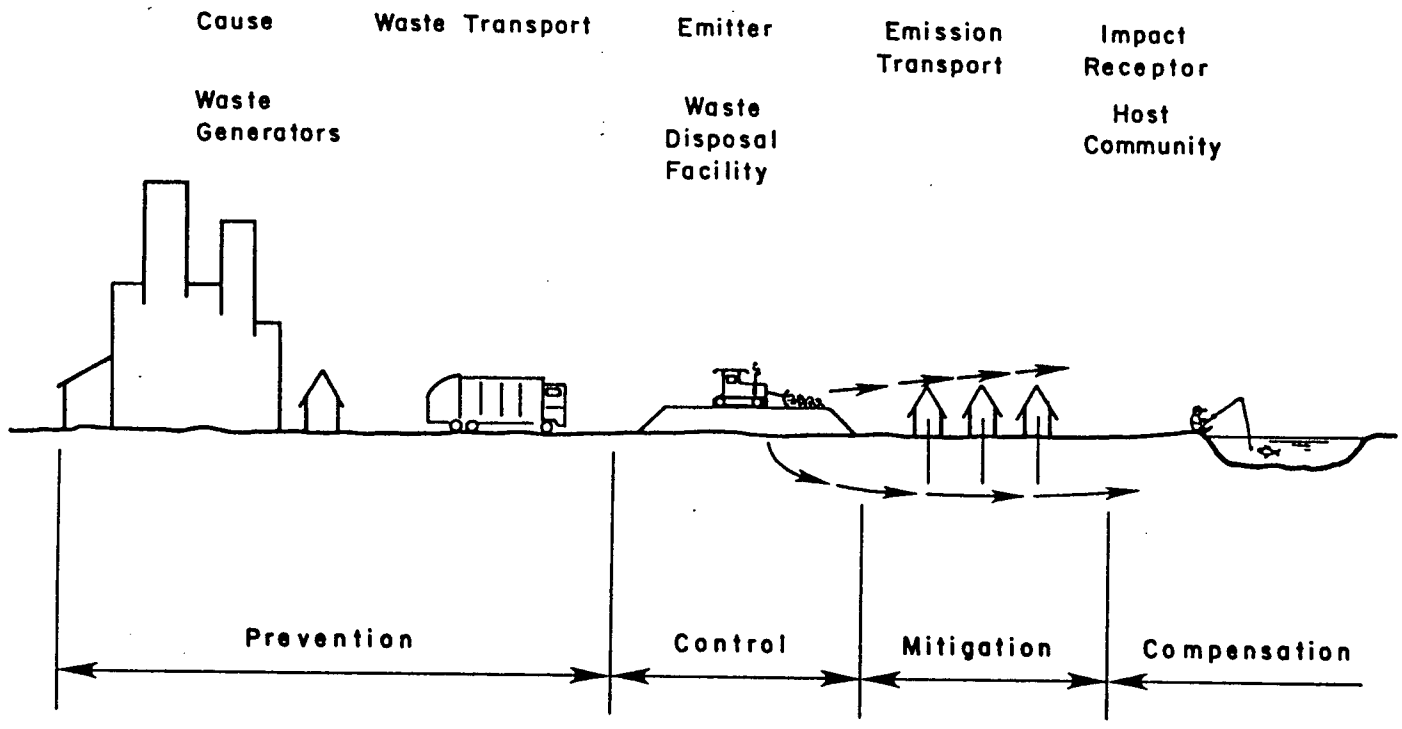
Residents in host and control communities at landfills and incinerators strongly prefer that the following order of methods be used to address facility impacts (see Figure 7.4 and Table 7.4):

1. Prevention
2. Control
3. Mitigation
4. Compensation

This preference ranking holds true for the general approach and for specific methods to address physical (health risks) and non-physical (image) impacts at landfills and incinerators.

Furthermore, a significantly larger proportion of respondents think that impact reduction (prevention, control and mitigation) measures make the facility more acceptable than the proportion of respondents who think compensation makes the facility more acceptable.

These preferences hold true despite higher costs for



	Prevention	> Control	> Mitigation	> Compensation
Preference Rank	1	2	3	4

← ACCEPTANCE INCREASES FOR MEASURES CLOSER TO CAUSE

Figure 7.4: Preference for Impact Reduction as a Rule to Increase Acceptance

Table 7.4 - Preferences for General Impact Reduction Methods

Prevention

Number of people who pick the method as their choice

	Percent of sample %	Count	
First choice	82.1	32	+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
Second choice	15.4	6	+XXXXXX
Third choice	2.6	1	+X
Fourth choice	0.	0	+

The proportion of respondents who pick prevention as their first choice is significant at 95%

Control

Number of people who pick the method as their choice

	Percent of sample %	Count	
First choice	10.5	4	+XXXX
Second choice	65.8	25	+XXXXXXXXXXXXXXXXXXXXXXXXX
Third choice	21.1	8	+XXXXXXXX
Fourth choice	2.6	1	+X

The proportion of respondents who pick control as their second choice is significant at 95%

Mitigation

Number of people who pick the method as their choice

	Percent of sample %	Count	
First choice	2.6	1	+X
Second choice	17.9	7	+XXXXXXX
Third choice	69.2	27	+XXXXXXXXXXXXXXXXXXXXXXXXXXX
Fourth choice	10.3	4	+XXXX

The proportion of respondents who pick mitigation as their third choice is significant at 95%

Compensation

Number of people who pick the method as their choice

	Percent of sample %	Count	
First choice	5.3	2	+XX
Second choice	7.9	3	+XXX
Third choice	2.6	1	+X
Fourth choice	84.2	32	+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

The proportion of respondents who pick compensation as their fourth choice is significant at 95%

prevention and control measures of up to (Can.- 1988) $20 per person per year.

Finally, 70% acceptance is achieved in host communities by incorporating prevention and control measures to address the respondents' three major concerns about the facility. In contrast, only 50% acceptance is achieved with property value guarantees only. However, among control respondents, prevention and control measures achieve 50% acceptance, approximately the same level as for property value guarantees only.

As a general approach, the reduction of impacts is a more effective way than compensation of damages (e.g., as property value guarantees) to make the facility acceptable. Optimally, impacts should in first priority be prevented before they occur, then controlled at the site, then mitigated, and, finally, compensated only if the previous methods are exhausted. Generally stated, a measure is more effective the earlier in the siting process and the further away from the host community it can be implemented. This general rule holds true for physical (health risks) and non-physical (community image and loss of control) impacts (Figure 7.3).

Thus, the empirical tests confirm two basic principles for siting:

1. People are generally not willing (or able) to trade off changes (i.e. facility impacts) to their present quality of life for other benefits (money or in-kind compensation). Therefore, compensation is inferior to impact reduction for facility siting. This is consistent

with the prospect theory which states that the value of losses loom larger than the value of equal gains.

2. Methods for reducing impacts are not equivalent. Methods that prevent impacts (losses) from occurring are preferred over methods that control or reduce the impact damage. Thus, a strong emphasis on avoiding any change requires the responsible waste agency or waste generators to take responsibility as close to the source as possible to eliminate impacts in order to enhance tolerance for waste facilities in host communities.

An optimal set of prevention and control measures to address the three major concerns gains acceptance from 70% of the host community residents and from 50% of the control residents. Although, this combination of measures may not achieve complete acceptance, as defined by the absence of major opposition, it is more effective in host communities than a simple compensation approach with property value guarantees.

7.4 Conclusions for Waste Facility Siting

The conclusions for waste facility siting are drawn here based on the results of testing hypotheses at the two study sites with the available methods. Thus, the conclusions are valid but subject to the limitations and assumptions that apply to the study sites and methods.

The conclusions are presented in three parts that correspond with the sections for hypotheses and results: (1) Physical impacts and Host Community Beliefs, (2) Attitude and Action, and (3)

Acceptance Approach and Methods.

7.4.1 Overview

The study shows a pathway for the effects of municipal solid waste facilities from physical emissions through host community beliefs and attitudes to opposition action. The results thus confirm a rational system for interpreting the physical presence of the facility into meaningful beliefs and attitudes in the host community. The existence of a rationale in the host community to evaluate and process the siting of a waste facility is important because it allows the waste agency and the proponent to take preemptive action with predictable results of making noxious facilities more acceptable.

7.4.2 Facility Impacts and Host Community Beliefs

Facilities generate beliefs about physical, economic, social and political effects on typical host communities. The concerns about property values, community image, control and fairness are equally important as health risks and nuisances to the host community. Furthermore, non-physical impacts strongly affect the attitude about the facility. Therefore, the siting process must address non-physical (economic, social and political) impacts with the same priority as physical impacts.

Spontaneous, generic beliefs about landfills and incinerators focus on common, physical impacts of nuisances, health risks and environmental quality, while specific beliefs in host communities include a more complex set of physical and non-physical (economic, social and political) impacts.

Thus, special effort and care are required to identify a complete set of concerns because spontaneously mentioned concerns do not reveal the true underlying beliefs that may determine attitude about the facility. Simple, open-ended questions about concerns will not gather a complete set of beliefs. Residents must at least be given the opportunity to identify non-physical impacts in a list.

Awareness of non-physical impacts is triggered by residents' exposure to obvious physical impacts (e.g., view, noise, odor). This is consistent with the notion of the facility as the cause of physical impacts that, however, are interpreted as economic, social and political terms by the host community. Thus, the reduction of apparent physical impacts, especially nuisances, can be used to reduce the level of impact perceived by host communities. In essence, "out of sight, out of mind" works for waste facilities.

In siting a waste facility, the host communities' rationale of interpreting the physical presence of the facility into economic, social and political impacts should be understood. In order to gain better acceptance, a full range of specific underlying concerns must be elicited; simple questions about concerns will get flat response sets of obvious, physical impacts. The trigger connection of obvious physical impacts (nuisances) with non-physical impacts allows the proponent to reduce opposition with simple screening and nuisance reduction.

7.4.3 Attitude and Opposition Action

Community attitude about waste facilities is worst before the facility is built. Attitude and action are clearly associated during the siting phase. The negative attitude results in opposition. However, attitude improves and action subsides as the community adapts to the new situation. The acceptance process entails several stages (disbelief, anger, bargaining, depression, acceptance) and causes stress. Therefore, siting efforts must attempt to help the community adapt through stress reduction.

By incorporating some community control over the type, size, rate and schedule of the facility impacts, by minimizing impacts, and by acknowledging concerns, the proponent can reduce stress and help the community adapt. Methods of tangible impact reduction and coping support to deal with change adaptation are both important. Special efforts must be made in the siting process to first, reduce the size of the change, and, second, to ease the host community through the stages of accepting change.

7.4.4 Acceptance Approach and Methods

Reduction of specific facility impacts is more effective than compensation for gaining host community acceptance. Thus, the community is more concerned about cutting the losses than about increasing gains, as predicted by applying the prospect theory.

The preferences show that the causal connections (see Figure 7.2) are relevant for predicting the effect of impact reduction methods on acceptance. Acceptance is enhanced by choosing methods by the following criteria:

1. Methods should be as close to the source, i.e., as far outside the disposal facility host community as possible or as long before the siting as possible;
2. Impact reduction should occur in the jurisdiction and under responsibility of the waste generators.

The preference ranking for acceptance is hardly affected by cost differences in the range of $20 per person per year, nor does it stritly follow objective engineering estimates of impact reduction effect.

Thus, the effectiveness of using the basic intuitive cause-effect connection for predicting and gaining acceptance is very strong. Combined prevention and control measures to address major concerns significantly increase acceptance in host communities.

7.4.5 Summary and Contribution

The research establishes a set of important waste facility physical and non-physical impacts. The research identifies and priorizes specific typical impacts and determines their influence on attitude and opposition. The level and adaptation of attitude and opposition are determined and related to the siting process and facility impacts.

The results connect physical impacts with host community beliefs, attitudes and opposition action to show a rational framework of related elements that influence the opposition level. The impact model combines facility impacts in order to define the criterion for acceptance.

Acceptance is defined by the absence of significant opposition effort. The approach to acceptance is theoretically derived and requires impacts to be effectively reduced to below the tolerance level of a host community, rather than compensating for impacts with other benefits. Thus, a rational guideline for gaining acceptance is defined for addressing physical and non-physical impacts.

By applying this principle to the waste disposal system, four specific methods of addressing facility impacts are identified: prevention, before the facility control at the facility, mitigation outside the facility, compensation of losses. Empirical tests show that impact reduction are more effective then compensators. Acceptance decreases with measures in the above order, that is, remedies closest to the source or cause are most effective. Thus, the cause-effect mechanism and the location of the impact reduction remedy on distance and time scale relative to the source, or, conversely to the receiving host community determine the effect on facility acceptance in absence of acute health risks and within the range of costs (up to $20 per person per year). The contribution of this thesis to scientific research lies in the definition of concepts and testing of relationships that explain the complex interaction of physical changes from technical works with the human environment.

The qualitative model and empirical tests provide the basis for identifying and predicting effects of policies and methods to make noxious facilities more compatible and acceptable. The principle and specific methods to obtain acceptance are

theoretically derived and validated.

The explanations are formulated so as to provide predictive dimensions for selecting specific acceptance measures. The predictability for gaining acceptance is unique and very important for engineers who deal with the effects of technical works on communities.

CHAPTER 8 - TOWARDS a POLICY for WASTE FACILITY SITING - ISSUES, RECOMMENDATIONS and FUTURE RESEARCH

This chapter summarizes the siting scenario to identify principal siting issues, then compiles the conclusions into recommendations for a siting process and, finally, outlines research perspectives.

8.1 Waste Facility Siting Policy Issues

The following outline of costs and benefits (see Table 8.1) lays out the interests of the main actors in the siting process: the facility proponent and the host community. A local government and a private facility proponent have similar interests and are treated similarly here for reasons explained below. Exceptions to this assumption are noted.

8.1.1 Discrepancy between Proponent and Host Community Costs and Benefits.

The main benefit of waste disposal facilities consists of the disposal of urban solid waste and the prevention of public health deterioration. This benefit is undisputedly large and accrues to society as a whole.

Thus, the goal of the responsible waste agency is to provide the disposal service cost-effectively to the residents in its jurisdiction. Since the large majority of beneficiaries (waste generators) far outweighs the people in a typical, rural host community, the incentive is high for the facility proponent to site, build and operate waste disposal facilities at lowest cost.

Furthermore, once the facility is sited, it becomes

Table 8.1 - Comparison of Consequences to Proponent and Host Community for Conventional and Alternative Siting Approaches

	Siting Approach	
	Conventional Approach with Required Emission Controls	Alternative Approach with Impact Reduction through Prevention and Control
Outcome	Sited against opposition results in delay	Sited with less delay
Facility Proponent Costs	Old, obsolete waste facility operates longer over capacity, continues to pollute	Old inferior facilities close sooner and reduce overall impacts
	Siting costs and effort high risk of losing is high	Siting costs and effort lower
	Public image loss regardless of outcome	facility cost and operation higher
	Chance of having to move to suboptimal site with higher transport and impacts costs	public image better
		better chance of getting physically optimal site
Benefits	Low risk income for 20 years	low risk income over 20 years
	Increasingly valuable asset in disposal capacity	increasingly valuable site stays more viable over time
	Low money disposal cost	
Host Community Costs		
	Large opposition effort and cost	less effort and costs
	chance of facility imapcts	lower facility impacts
	demoralization loss is larger if facility is sited over opposition	less demoralization due to lower change acceptance,
	More residents affected over time after development occurs	more control and fairness
		more residents affected, but at lower impact levels
Benefits	Chance of preventing facility impacts to avoid change	higher disposal costs
	Community control and bond	
	Lower disposal costs	

potentially a constant source of income and an increasingly valuable asset to the waste agency and/or the facility proponent due to the increasing scarcity value of sited waste facilities. The lower the actual cost of the facility, the larger the potential scarcity rent to the owner (Dunbar and Berkman, 1987).

In contrast, the host community sees the facility mainly as a set of impacts or losses with very small benefits. From this perspective, there is no incentive to accommodate the facility, because waste disposal is ensured. Thus, hosting a regional waste facility is simply taking a loss.

Moreover, the host community also likely sees from its parochial perspective only the facility impacts and entirely discounts possible gains that occur elsewhere due to the use of money saved through cheaper waste disposal operations. While additional property taxes may accrue to the local government from development as a result of additional services provided with cost savings, this additional revenue does not necessarily benefit the host community. Thus, the wider view of the local government may focus away from the value of the losses to the host community.

Finally, the waste agency may perceive additional waste facility costs as large sums of money, while host community residents may perceive the costs as small per capita sums. A $20 per year per capita cost increase translates into $4,000,000 per year for a municipality of 200,000 residents.

8.1.2 Disparity of Values

Although waste agencies acknowledge facility impacts in the

host community, they, at best, act as agents for the host community, because they are not personally affected. Therefore, as agents, waste agencies will value losses in a host community and gains elsewhere in their jurisdiction more equally than the personally affected host community residents (see Chapter 3, Kahneman and Tversky, 1979, and Marshall et.al., 1986) who weigh losses more heavily than gains. Moreover, the costs for impact reduction may be framed as a willingness-to-pay value for waste agency decision makers, which is necessarily substantially lower than the compensation demanded value the host community attributes to facility impacts as losses. This value discrepancy is illustrated by the difference between the two value curves in Figure 8.1.

Therefore, honestly concerned waste agencies and facility proponents will still undervalue facility impacts in comparison to the loss value experienced in the host community. Moreover, benefits generated by using money saved on waste disposal to provide other municipal services will be valued more positively by a local government than by the host community.

8.1.3 Motives for Strategic Behavior in Siting Processes

As a result of the different values and the different perspectives, the facility proponent will tend to discount facility impact value and emphasize the opportunity costs of more expensive waste facility operations, while the host community tends to focus entirely on the loss value of facility impacts.

If the loss of public image due to the siting approach of the

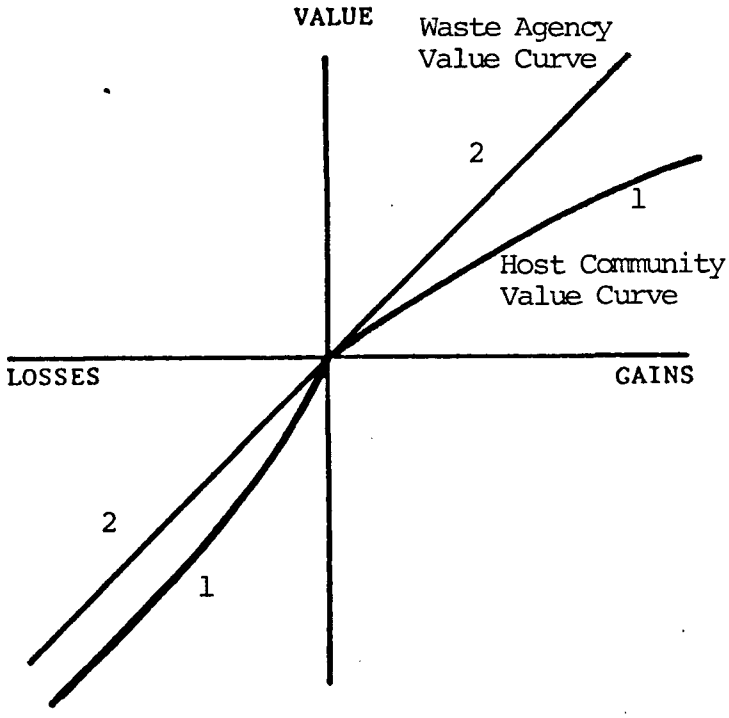


Figure 8.1: Disparity between Values of Waste Agents and Affected Host Communities

waste agency is confined to a small host community, then the agency will attempt to achieve siting by downplaying facility impacts and emphasizing the opportunity costs of delaying an optimal site in order to achieve the minimum level of acceptance at the lowest costs. Conversely, the host community will exaggerate the facility impacts in order to prevent the facility at the site or, as second best, to obtain better impact controls. These strategic positions tend to diverge. Hence, the outcome of the siting process often hinges on the legal entitlement (as for the Salem incinerator). Thus, the waste agency with proper statutory powers is often legally allowed in its own jurisdiction to expropriate land, rezone land use, construct and operate the facility over the host community opposition and without compensation for facility impacts providing the facility meets health regulations. This constitutes a legal entitlement to the facility proponent by the liability rules (see Chapter 3, Calabresi and Melamed, 1972).

The two different positions conventionally result in a lengthy and divisive siting process. The costs in time, effort and money to both sides is significant, but the major cost to society of the delay may be in the continued use of an older, inferior waste disposal facility beyond its original capacity, or, alternatively in the higher transport costs for hauling waste to a more distant alternative site.

8.1.4 Efficient Levels of Impact Reduction for Waste Facility Siting

In the face of the results of this research, the conventional

siting approach seems to focus too much on money cost minimization rather than on the overall waste and emission reduction.

The preferences among host and control communities favor more expensive prevention and control measures that reduce impact over cheaper compensation that offsets losses with alternative gains. In essence, this priority reflects a preference to have the party responsible for the cause of the impacts internalize as far as possible the external costs (i.e., the impacts) of waste disposal, and, optimally, to the point where impacts (losses) to the host community are zero.

On one hand, the opposing positions over waste facility impacts may be caused by the disparity of broad versus parochial perspectives and of willingness-to-pay versus compensation demanded values applied by waste agency and host community respectively. The efficient allocation of waste facility impacts therefore hinges on the comparison of impact reduction costs with impact costs (losses). A graphical illustration of the values and impact (reduction) levels is shown in Figure 8.2.

The present quantity of waste facility impacts is indicated with Qp. The cost of the impacts to a host community is indicated by the compensation demanded marginal value curve (CD-HC), while society values waste facility impacts by the willingness-to-pay to prevent impacts (WTP-S). The engineering impact reduction costs are indicated by the curve IRC which increases from right to left with decreasing emissions, or increasing emission control quantity. The present impact level (Qp) for old, inferior waste disposal facilities is inefficient, because it generates excessive

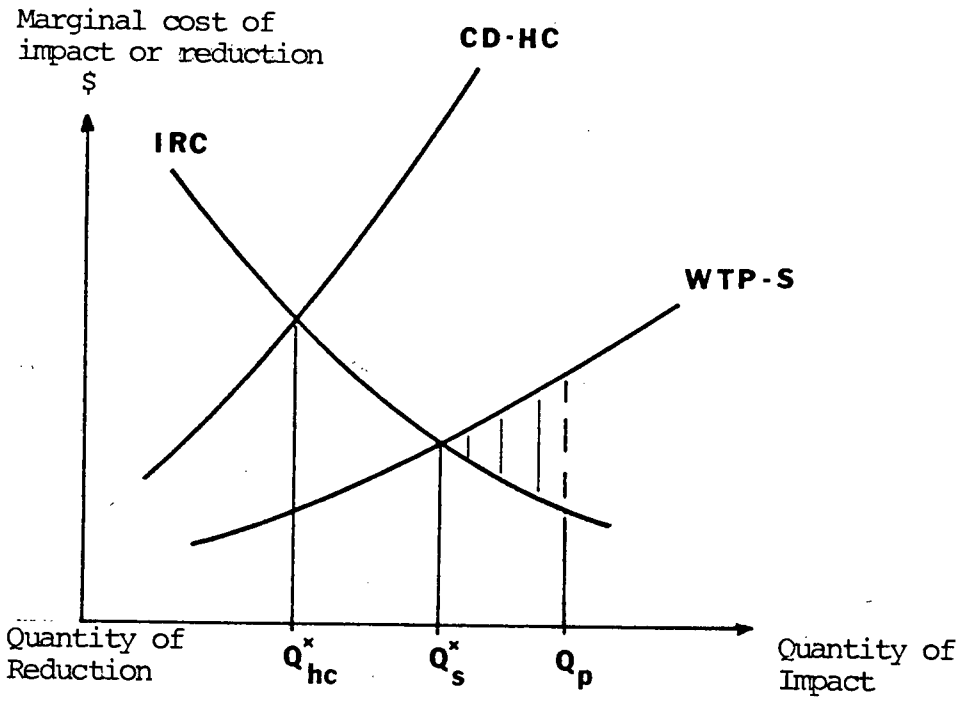


Figure 8.2: Difference of Values and the Optimal Level of Impact Reduction for Waste Facilities

impact losses, equivalent to the area between the marginal impact reduction costs (IRC) and the social impact cost (WTP-S), and even larger losses relative to the host community's compensation demanded loss value (CD-HC) curve. Thus, reducing emission quantities leads to a more efficient state despite higher impact reduction costs. The efficient level of impact (or, conversely, the amount of impact reduction), however, is not clearly defined. The minimum level of emission reduction is defined by the intersection of the impact reduction cost curve and the social WTP marginal costs (WTP-S) curve at Q^*_S. However, in order to implement waste facilities at new sites in host communities, the community's CD loss value is relevant to obtain acceptance and avoid opposition. Thus, the discrepancy in social and host community values may still prevent the determination of an optimal impact reduction level for waste facilities. This discrepancy between host community and society's values may be very small, as is indicated by the fact that control community respondents hold more strongly negative beliefs about waste facility impacts and express preferences for prevention and control measures at higher costs over compensation for waste facility impacts. However, the crucial inefficiency of waste disposal at obsolete facilities hinges on society's value of environmental impact levels. If people in society, although not affected personally, perceive facility impacts as losses, then the higher compensation demanded value may apply. Otherwise, lower WTP values may determine the efficient level of impact reduction. Thus, the social and host community curves may be very close or actually coincide, as

indicated by the data in Chapter 6.

The results of this thesis indicate that prevention and control measures are the most effective ways of reducing CD loss value in the host community and, furthermore, that these methods are also preferred by unaffected control residents (society at large) in the same (WTP) cost range of up to $20.- per person per year (see Chapter 6). Thus, within the cost range, host community and general population preferences for impact reduction methods coincide and indicate that more impact reduction is desired to make facilities more acceptable.

Residents at the landfill and incinerator sites feel that the loss value of the facility impacts exceeds the value of the extra impact reduction costs. Therefore, the level of impact reduction is too low; by increasing the "quantity of impact reduced" (see right to left horizontal axis in Figure 8.2) the optimal point would be reached at the intersection of CD-HC and IRC. Furthermore, because waste facilities generate many types of impacts, it is efficient to identify and address particularly important ones.

Most effective, however, is the use of impact reduction methods to address non-physical control, fairness and image issues, because the WTP cost for these measures is very low compared, for example, to technical emission prevention and control measures, while their impact (loss) reduction effect in the host community is high. The high significance of the non-physical impacts for the host-community's self-image allows the waste agency to use financially inexpensive control, fairness

and image control measures to substantially reduce the impact value in the host community.

The measurement of society and host community reference points and demand curves could be achieved with contingent valuation methods or with preference ranking of specific sets of measures, as used for this research. The effort to obtain complete sets of data, for multiple dimensions and the "lumpiness" of impact reduction costs makes a pure approach somewhat difficult. The approach of putting facilities out for bid (O'Hare et al., 1983) with subsequent negotiations for compensation packages establishes the least costly intersection of CD-HC with IRC and overcomes the problem of establishing complete demand curves and lumpiness.

Thus, without predicting the exact level of optimal control, the results indicate that by clearly identifying the host community's concerns about physical and non-physical impacts, small additional expenditures correctly used for prevention and control will be very effective in achieving initial host community acceptance and thereby allow a socially more efficient level to be achieved.

The central issue remains, however, that the siting of a waste facility may be considered a loss to a new, sensitive host community. The fact that a new facility will cause lower impact levels than an older facility and that host communities tend to adapt to the presence of the facility over time have no effect on the perception of the loss from the perspective of a new host community. The new host community's sensitivity to taking a loss

therefore prevents society from moving towards overall less costly waste disposal. Since there is a net social benefit from discontinuing old, inferior waste disposal in favor of new facilities, there are important reasons for the waste agency to do more than in the past to overcome the initial sense of loss in the host community. Specific measures to achieve acceptance are summarized in the following section.

8.2 Recommendations for Siting Measures

The order of recommendations follows the established sequence of effectiveness. First, the requirements of a basic legal entitlement are identified, then long-term, preventive measures are described, followed by short-term, specific items.

8.2.1 Entitlement and Protection Rules

The entitlement establishes the distribution of legal rights. In the case of a waste facility, entitlement pertains to the proponent's rights to build and operate a facility that may cause external impacts and to the host community's rights to be free of facility impacts. Entitlements can be protected by rules that determine the remedies available to the harmed party. Entitlements can be set in many different ways, e.g., by common law or statutory law, contractual agreement convention. In the following, it is assumed that the political body responsible for land use and environmental legislation sets the entitlement as statutory law. Thus, waste agency, facility proponent, host community and environmental agencies would be legally bound.

The foregoing analysis illustrates that the original

entitlement may determine the outcome of a siting process because it may give the proponent the right to proceed without adequate impact reduction, or it may give the host community the right to prevent the facility unless all impacts are eliminated regardless of cost. Thus, it is important to set the entitlement to achieve an optimal, or efficient outcome. This goal comprises two objectives.

First, the entitlement must be set to eliminate incentives for strategic behavior by the proponent and the host community. While the proponent may down-play the facility impacts and exaggerate impact reduction costs in order to achieve a lower cost solution, the host community residents may exaggerate the impacts and the costs and downplay impact reduction in order to render the project at the site more costly and, possibly, prevent the project from proceeding at the site in their community. The original entitlement must be set so that both parties (and any other involved parties) will have no incentive for strategic biases in identifying and valuing the impacts and reduction measures. Some useful insights and guidelines for the use of legal rules to avoid strategic behavior are given by Brady (1988). Brady's requirement that sequential decisions by actor (proponent) and victim (host community) be eliminated is met by the negotiation of a siting agreement before facility construction, because the impacts, reduction measures, corrective and remedial action for foreseeable events and damage are agreed on prior to the proponent's action.

Further, the possibility of strategic behavior in negotiations must be reduced. This can be achieved if the rights

of proponent and host community are clearly defined in the original entitlement and some mechanism is defined for deciding controversial issues. For example, Wisconsin law requires that both sides present submissions to binding arbitration if impasses cannot be resolved (Wisconsin Facility Siting Board, 1987), without, however specifically defining the entitlement rule to be used in the arbitration.

The second objective of entitlement is, therefore, to specifically set the distribution of rights and the protection rule that will lead to efficient outcomes. From an economic stance, this rule should require that the waste facility externalities (impacts) on the host community be reduced to the point where marginal costs for impact reduction be made equal to the marginal value of avoided impacts. As derived in the previous section, the disparity of proponent and host community values and the concentration of impacts in the host community make impossible the simple application of this economic principle. Thus, the economic principle could be interpreted quite differently by different arbitrators and could result in widely differing outcomes. An operational entitlement must therefore define which and whose values are relevent.

Finally, the effectiveness of an entitlement rule must be put into perspective. Although a rule may determine the objective outcome, e.g., by allowing a facility to be built, and operated, it will not necessarily limit the sense of loss and the resulting opposition behavior in the host community. As Ellickson (1987) shows in the case of cattle control liability in Shasta County,

California, the social control over cattle ranchers puts the burden of responsibility clearly on the ranchers for preventing cattle from breaking out and eating farm crops despite an explicit legal entitlement rule to the opposite.

So, too, in the case of waste facility impacts, the preferences among affected host community residents and unaffected control residents favor the internalization of impact reduction responsibility and costs by the waste agency and facility proponent. Waste reduction and recycling programs, and the more frequent use of strict liability rules for waste facility impacts indicate this tendency among policy makers and local governments (see e.g., CERCLA Legislation, 1980).

Thus, host community acceptance may hinge on the degree to which the responsible waste agency is able and willing to integrate impact reduction measures to reach impact levels well below the level determined by marginal willingness to pay of the facility proponent in order to match the host community's compensation demanded value.

There is simply no incentive for any community to take a loss through hosting a waste facility. Moreover, the distributional unfairness and loss of control add to the perceived loss which occurs in hosting a facility to serve a large metropolitan population. This loss perception may determine opposition activities more than a formal entitlement rule (Ellickson, 1987). This research indicates some directions for assigning entitlements that will lead to more effective siting and a more efficient end state.

New facilities must be allowed to proceed if they reduce overall impacts, thus making them preferred over older facilities. However, to implement impact prevention, there must be a priori responsibility for impact reduction. The degree of required impact reduction health and nuisance standard requirements is not defined. Host community residents seem willing to accept impacts if the waste agency and facility proponent are seen to be doing their best to address community concerns. Thus, a requirement for using best available prevention and control measures would be an effective condition for entitlement.

Some residents tend to interpret a negative change, such as a waste facility, as the indication of worse changes and therefore attach more weight to the event. This fear seems to be justified by urban growth patterns (see Chapter 2) that result in the clustering of noxious facilities. Therefore, to counter this fear, the facility operation should be limited to the level at the time of siting and not be allowed to expand or deteriorate without expressed acceptance. Furthermore, the facility life should be defined and limited so that it cannot be extended without community assent. Finally, the rule should require a fair distribution of waste facilities among waste generating communities. Basically this means that each community should be required to host one waste facility for a certain time period.

The proponent should be allowed entitlement to proceed with the facility if best available prevention and control is used to reduce facility impacts. Conversely, the host community is entitled to lowest possible levels of impacts and to be free from

changes to the original capacity or duration. The protection rule is through the liability of the proponent to operate the facility only with best available impact reduction measures. The additional costs are carried by all waste generators equally.

However, community adaptation over time may allow the waste agency to expand scope or life of the facility if the host community is convinced of the tolerable impact level. However, a priori, the entitlement allows no changes, except if approved by the host community.

8.2.2 Waste Management Plan

Well before the current disposal sites reach capacity, a waste management plan for the metropolitan area should be established. The plan should identify source-based waste reduction options that focus on, first, the reduction of potential contaminants, e.g., batteries, (mercury, cadmium) household special wastes (pesticides, solvents, paints, etc.) in the waste stream. Further, the volume of waste should be addressed through conventional source separation of paper, cans, and bottles. Waste reduction programs should progressively increase the removed materials over the period until new disposal facilities are required.

Reduction goals of 10% to 20% by volume are achievable over three to five years (pers. comm. B. Platt, 1988). Methods for treatment of the remaining collected waste stream, such as mechanical separation and composting with estimates of costs and reduction effects should be incorporated in the plan. Finally,

the needs for dedicated waste disposal facilities should be identified, but the choice of specific sites should be avoided. Resident participation in establishing the plan should be encouraged and facilitated.

The goal of the plan is to implement preventive measures and demonstrate a commitment to progressively avoiding waste, emissions and facility impacts. Thus, prevention of impacts and loss of control is to be put in place as close to the waste generating source and well before the actual siting process.

8.2.3 Community Plans

Long-term planning in potential host communities should be carried out. Through an initial screening process to identify suitable areas, a large set of host communities for specific facilities should be identified. Areas should be screened for physical characteristics and for similar, existing land uses, such as industrial and noxious facilities.

Potential host communities should be offered funds and support to establish community plans if they are willing to incorporate waste facility sites and buffer zones in suitable areas. Community participation and input are a pre-requisite. Extensive information to the host community about the plan and long-term impact reduction measures are essential. The community commits only to properly zoning a site in compatible and, in the long-term, well prepared areas. The actual approval, however, is subject to specific negotiations and design features.

8.2.4 Siting Process

At least two years before the construction is to begin, representatives from the potential host communities should be contacted. The facility proponent should propose to initiate negotiations with representatives from the directly affected host community. The goal for these negotiations is to establish an agreement over a package of specific prevention, control, mitigation and compensation measures to address host community concerns. The allotted time frame should be at least 4 to 6 months. Funds to obtain technical and legal expertise should be made available to the host community. Full disclosure of study results and a defined, limited life for each facility are offered as starting points for the negotiations. Furthermore, the facility emissions must be guaranteed to meet or exceed health and aesthetic requirements. The negotiations can include any subject related to the facility. If no agreement can be reached within six months, then the decision is made by binding arbitration based on submissions by both sides.

The negotiation of specific conditions and impact reduction measures gives the host community some control over the facility. The process further provides information and time to enable the host community's adaptation. Finally, the siting agreement can institute a supervisory committee with host community participation to oversee the operation, investigate complaints, and decide on changes. Thus, a siting agreement can institute an element of on-going control by the host community over the facility.

8.2.5 Waste Disposal System Measures

As a first priority, the disposal system must incorporate preventive measures to separate and treat the waste stream to reduce the waste volume and the amount of potential contaminants delivered to the disposal facility. This is essential to address the health risk and community image concerns, as shown in Chapter 6.

Mechanical separation plants in conjunction with composting facilities reduce the mass flows of potential contaminants to incinerators and reduce waste volume and amounts of mobile contaminants in landfills (see Chapter 6). Achievable waste volume reductions range up to 60% to 70%, while contaminant fluxes can be reduced by approximately 50%. In addition, however, the separation facilities must be acceptably sited. Because separation plant impacts are similar to light industrial facilities (in traffic), the use of proper controls at these sites is essential to gain acceptance.

Facility Design Measures

Emission control in the facility is often the most effective way to reduce physical impacts. However, the fact that this approach does not reduce the cause (waste and contaminants) prior to their entering the host community makes the emission control approach less desirable than prevention. Nonetheless, emissions can be reduced below uncontrolled levels by up to 90 to 95% with special control systems.

Health Risks

The crucial criterion for facility acceptance is how much emissions must be reduced (below regulatory health standards) to become acceptable. Obviously, from the host community's perspective, zero emissions are required, while from a technical perspective, the proponent must make a tradeoff between cost and emission level without ever being able to completely eliminate emissions. Since zero emissions cannot be attained, it seems impossible for the proponent to gain acceptance. The mitigating factor in this dilemma is the effect on the host community attitude of using best available technology.

Best available technology must reduce emissions below known standards for health risks. Further reduction not only decreases risks further, but conveys the concern by the proponent for the host community. Thus, confidence is enhanced if the proponent is seen as "doing his or her best" to address concerns beyond the minimum required.

"Doing one's best" is not a definitive criterion. Moreover, the tolerance for residual impacts depends on the scientific certainty and personal familiarity with the impacts. Thus, more certain and better known impacts require less extensive efforts to reduce impacts beyond required levels than do uncertain impacts (e.g., dioxins).

Fortunately for the proponent, residents in host and control communities are virtually indifferent to the higher costs (within the range of up to $25 per person per year) for best available emission controls as long as the controls are necessary to address

a concern. Thus, the additional costs for best available emission controls are acceptable.

Community Image and Nuisances

The facility impact on the community image is associated with the physical image of the facility as portrayed through nuisances. The elimination of obvious signs of "waste" and "pollution" is the preferred measure to address image impacts (see Chapter 6). Thus, attractive design of buffer zones and screens with careful operation of the facility to prevent nuisances will be effective in enhancing acceptance.

The construction of park like buffer zone and screening should occur shortly before the facility is built so these measures are framed as integral gains to the host community.

Monitoring and Mitigation

Monitoring programs for emissions and ambient air and water quality are the last level of protection against impacts. Further, contingency response to possible events must be planned and budgeted.

8.2.6 Summary

The recommendations for a siting approach range from defining basic legal entitlements to set the rules for the siting process through the use of long-term waste management and community planning to prevent impacts, to recommending specific measures for the siting process and facility design. The principle is simply to make changes in the waste disposal system prior to the facility siting and outside the host community to reduce the impacts on the host community.

8.3 Future Research

8.3.1 Setting of Entitlements for Waste Facility Siting

Facility siting conflicts are prolonged in part because of conflicting or unclear entitlements. While the facility proponent considers the construction and operation of a waste facility legally their right, host communities often hold the opposing view that they are entitled to be free of waste facilities.

Since waste facilities are necessary, some form of entitlement should be specified to protect host communities' and proponents' rights and to set rules for negotiated siting agreements so that siting processes can proceed. Thus, the entitlements must achieve efficient outcomes and prevent strategically biased behavior by the negotiating parties.

8.3.2 Generalizations of the Impact Model

The impact model and the acceptance criterion can be generalized and evaluated for other types of facilities. The spectrum of impact combinations ranges from pure physical impacts without social stigma or uncertainties to physically non-reducible, high risk facilities. The weights and magnitudes of impacts can be tested and incorporated into a validated acceptance model and criterion.

8.3.3 Predictive Acceptance Model

Further work is needed to accurately, operationally, and reliably define the acceptance criterion and determine weights and

variables in a quantified predictive model to find combinations for a priori acceptance. The qualitative and quantitative significance of acceptance measures must be further evaluated.

1. Possibilities for Trading off Losses for Alternative Benefits.

   As a pre requisite, the potential for trade-offs of environmental goods (or losses due to impacts) with other types of benefits must be examined. If the loss(es) occur on certain dimensions or vectors, then the compartmentalization of accounts (see Chapter 3) requires that compensation through other goods will not address the loss. However, within a narrow band, similar offsetting goods may be effective, if they are close enough in kind to the original loss dimension. A systematic evaluation of a range of different compensation goods that are varied in size and in kind will reveal the differences in offsetting an original type and size of loss (impact).

2. Host Communities' Reference Point for Evaluating Gains and Losses

   The net impact of waste facilities depends on the host community's reference point. Although the status quo before the facility siting is a likely reference point for the host-community, the condition in other communities could influence residents expectations. The location of the reference point is necessary to determine how far impacts must be reduced in order to gain acceptance.

3. Acceptance Criteria

Acceptance requires further definition in order to be used in a predictive model. Further, a tolerance range for acceptable changes needs to be determined, so change increments can be managed within the tolerance range.

8.3.4 Implications for Site Selection

The conclusions of this research are to be translated into requirements for site selection process with the goal of finding physically optimal sites that are or can be made acceptable to the community.

In more specific terms, the site must be selected so that the loss value of the impacts to the host community will be low and so that use of impact reduction measures will be effective in reducing the net impact (including change resistance) to minimize the net loss to the host community. Thus, the sites must be designed to accommodate impact reduction rather than compensation approaches.

Preventive and control impact reduction, however, reduces the significance of site-specific features for the attenuation of emissions (e.g., soils to prevent leachate migration). Thus, impact prevention may increase the availability of physically suitable sites while reducing the size and number of required sites for ultimate disposal (e.g., for landfilling of residues). Therefore, the site selection may focus more on non-physical issues such as fairness and social image, rather than on physical site criteria. In essence, both physical and non-physical site selection criteria and indicators must be identified to minimize

host community sensitivity to facility impacts and to make impact reduction most effective.

Natural impact attenuation features (soils, topography, proximity to water, wind directions, etc.) are normally taken into account, but some non-physical impacts may be minimized in the site selection as well. Fairness is enhanced by selecting sites within the political boundaries of the waste generating source. Further, the image impacts can be minimized by selecting areas of similar land use. Preferably, the area will already be developed and stable. While incinerators may fit well into urban industrial areas because of their similarity, landfills are unique in operation and appearance, except in comparison to such activities as gravel pits. However, the presence of gravel layers exclude landfills in these areas. Because of low, ground-oriented operations, landfills lend themselves to image control throught park-like landscaping and screening as well as to recreational end uses. Thus, proper design and management of image control measures can achieve compatibility. Therefore, the site selection must identify areas where this approach is possible and desirable.

Furthermore, the beneficial use of energy and by-products from waste may influence the location. If energy or products can be used in the host community economy, then the need for the facility will increase.

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APPENDICES

The following appendices are numbered according to the chapters they refer to. For example, Appendix 1 provides supporting material referred to in Chapter 1. Because Chapters 2,3,7 and 8 require no additional materials, the appendices with these numbers are omitted.

Appendix 1.A - Landfill Survey - List of Responsible Waste Agencies and Landfill Sites

Waste Agency	Landfill Sites
City of Calgary, Calgary, Alberta	East Calgary Landfill West Calgary Landfill
City of Edmonton, Edmonton, Alberta	Clover Bar Landfill
City of Eugene Eugene, OR.	Landfill
City Sanitary Service McMinnville, OR.	Yamhill County Landfill
King County, WA Department of Public Works Seattle, WA	Cedar Hills Landfill
District of North Vancouver North Vancouver, B.C.	Premier Street Landfill
Metro Portland Portland, OR.	Reidel Waste Disposal Leichner Landfill - Vancouver; WA
City of Regina Regina, Saskatchewan	Regina Sanitary Landfill
Township of Richmond Richmond, B.C.	Richmond Landfill
Roseburg County, OR. Environmental Health Dept. Roseburg, OR.	Roseburg Landfill
City of Spokane, Spokane, WA.	Southside Landfill Northside Landfill
District of Surrey Surrey, B.C.	Port Mann Landfill
City of Tacoma Tacoma, WA.	Tacoma City Landfill
Thurston County Health Dept. Olympia, WA.	Thurston County Landfill
City of Vancouver Vancouver; B.C.	Burns Bog Landfill

City of Winnipeg Winnipeg, Manitoba	Brady Road Sanitary Landfill Summit Road Sanitary Landfill Kilcona Park Sanitary Landfill
Alameda County Oakland, CA.	(Alameda County Landfill)
City of Sacramento Sacramento, CA.	(28th Street Landfill)
Ventura Regional Sanitation District Ventura, CA.	(Santa Clara Landfill) (Toland Road Landfill)

( ) - non-physical characteristics only included in data.

Appendix 1.B

Q U E S T I O N N A I R E

West Coast Waste Disposal Facility Survey

A. Facility Characteristics

1. Facility name _____

2. Type (mark one)
   - Municipal Waste Landfill _____
   - Municipal Waste Incinerator _____
   - Hazardous Waste Landfill _____ Class _____

3. Age _____ years

4. Capacity per year at present _____ ØØØ tonnes/tons per year

5. Remaining capacity or life approximately _____ years

6. Depth of the Filled Area _____ m/ feet in _____ layers

7. Waste Stream Composition (please mark one)
   - domestic garbage _____
   - sludges
     - sewage _____
     - industrial _____
   - gypsum board _____
   - other _____
     _____
     _____

8. Source of the Waste Stream
   - own municipality _____
   - own and neighboring municipalities _____
   - own municipality and large city _____
   - own and neighboring municipalities and a large city _____

B. Environmental Controls

- Landfill

1. Leachate collection system (please mark applicable design)

designed synthetic or clay liner _____

natural impervious layer _____

please give soil type _____

collection pipe or ditch system _____

circumferential _____

grid under landfill _____

2. Leachate Treatment (please mark one)

- on site _____
  by (please mark one)
  - recirculation onto landfill _____
  - spray irrigation _____
  - lagoon or aeration ponds _____
  - other (list) _____

- pumped to sewage treament plant _____

  (please mark one) primary _____ secondary _____

- discharged into surface water _____

- no treatment or discharge _____

3. Gas Collection (please mark applicable design)

surface flares _____

deep collection wells or horizontal collection pipe system with flares _____

deep well collection and gas utilization for energy production _____

4. Visual Screening

	natural	installed/planted
Barriers	_____	_____
Trees	_____	_____
Grass and shrubs	_____	_____

5. End use - has an end-use been determined for the site

after closure yes _____ no _____

what is the determined end-use of the facility ?

_____

C. Site

1. topography (mark one)
   - hilly _____
   - flat _____
   - ravine _____

2. forestation
   - woods _____ % of cicumference
   - shrubs and high grass _____ % " "
   - low grass _____ % " "

3. distance to closest surface water _____ m / feet

4. groundwater depth _____ m / feet below fill bottom

5. soil under site relatively permeable _____ impermeable _____

6. climate

annual precipitation _____ mm/ inches per year

annual evapotranspiration _____ mm/inches per year

D. Host Community

1. Land-uses immediately next to the facility

a. please give the percentage of the site circumference surrounded by the following land-uses (approximately)

residential _____ % of the site circumference

industrial _____ % of the site circumference

agricultural _____ % of the site circumference

undeveloped _____ % of the site circumference

b. please give the approximate distances from the site boundary

residential _____ m / feet from the site boundary

industrial ------- m / feet from the site boundary

~~c. distance to the closest residential dwellings _____ m / feet~~

d. approximate number of dwellings within 1.5 kms or 1 mile _____

- type of dwellings

single family owner occupied	_____ %
single family or duplex rental	_____ %
condominium - owner occupied	_____ %
rental apartments	_____ %

e. approximate value of single family dwellings _____ $

2. Character of the host-community (please mark one)

	original	present
- agricultural / rural	_____	_____
- rural residential	_____	_____
- suburban residential	_____	_____
- industrial	_____	_____

- other (please list) _____

3. Distance of the host-community from the nearest city or town _____ kms / miles

4. Host-community income levels

(please mark the one that best characterizes the community)

lower to lower middle _____

lower middle to middle _____

middle to upper middle _____

upper middle to high _____

5. Is there any active opposition to the facility?

yes _____ no _____

Has legal action been taken? yes _____ no _____

grounds _____

Number of complaints _____/ year or month

please list reasons _____

_____

_____

Do you keep a complaint file? ___ yes

___ no

6. Was there any public participation when the site was chosen?

_____ yes _____ no

Comments _____

_____

_____

_____

Name and Title _____

Thank you for your time and effort.

Appendix 4.A.

View Impact Screening

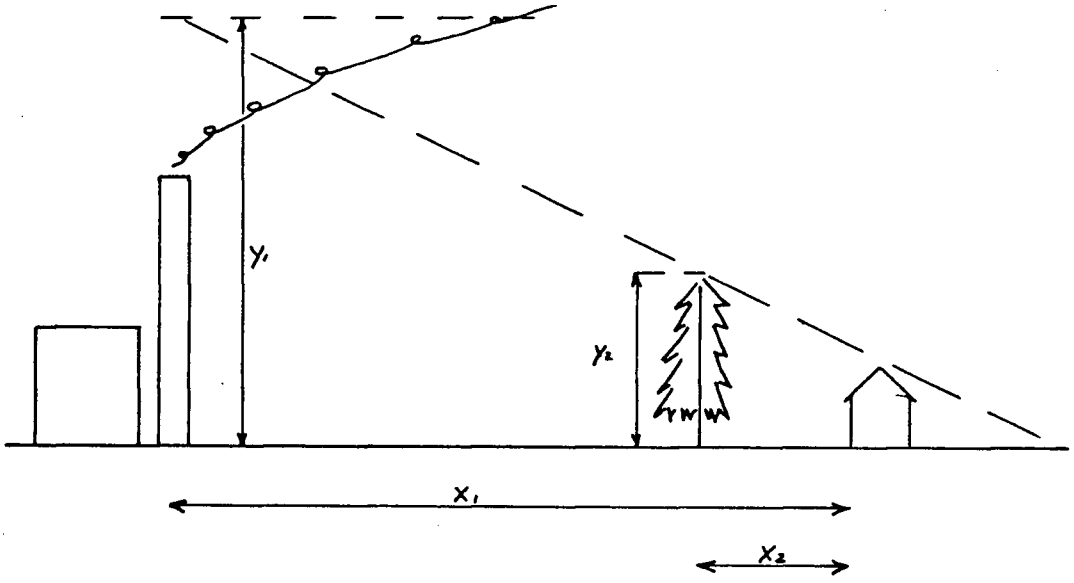


Figure 4.A1 - Effect of View Screening Objects

$$\frac{x_1}{y_1} = \frac{x_2}{y_2} \qquad \frac{y_2}{y_1} = \frac{x_2}{x_1} \qquad x_2 = x_1 \frac{y_2}{y_1}$$

if y_1 = 110m

and y_2 = 10m

and x_1 = 2,000m

then x_2 = 181 metres

at 2,000m, the tree screen must be within 180 metres of the observer.

Or, conversely, if a 10m tree is within d distance of the stack and plume (H = 110m), then the screened distance behind the tree is $x_2 = \frac{d\ 10m}{110m-10m} = \underline{\underline{d\ 0.1}}$

that is, one tenth of the distance to the stack.

Appendix 4.B

Noise Impact Measurement

Noise measurements were conducted with a CEL Model CEL-393B precision sound meter with a frequency analyser and CEL-177 calibrator. The sound meter was mounted on a tripod at 1.5 m above ground level. Before each measurement session, the battery voltage and the calibration were checked. The distance was measured with a rangefinder at each measurement location. The location, topography, vegetation and obstacles were documented with photographs at each location.

Measurements were usually taken over 20 to 30 minute periods in intervals of 5 minutes. Unusual background disturbances such as plane overflights, trains, conversations with curious by-passers were identified and excluded. The results were stored and read out at the end of the session. Three values were regularly obtained:

- range of distant slow A-weighted sound pressure levels (dBA)
- equivalent sound pressure levels (Leq) in 5 minute intervals.
- impact peaks

Frequencies were measured with linearly weighted sound pressure levels in a range of frequency bands from 32Hz to 8 kHz (see Figure 4.3).

The measurement conditions comprise location (distance and topography), weather conditions (pressure, wind direction and speed, humidity, and temperature), and time (facility operations and background noise) were selected to obtain representative

results for the facility:

Location

The expected shape of the noise impact area was qualitatively estimated based on engineering judgment. Three or four locations were chosen at the site boundary to obtain source levels. An equal or larger number of locations were chosen in the host-community in directions that corresponded to the site boundary locations. The measurement locations are indicated on Figures 4.4 and 4.5 in the text.

Weather

Noise measurements were carried out under typical weather conditions for winter and summer seasons. The typical wind directions and wind speeds (see cite climate descriptions, Section 1.2) were usually present and were verified with on-site measurements. Barometric pressure was recorded, but was not considered important as a criterion for noise measurements. The weather conditions are compared in Table 4.B1 (below) with typical conditions.

Time

Operational routines and background noise fluctuations required that the sound levels be measured at different times during the day. Early morning (5 to 7 am), late morning (10:30 to noon), afternoon (3 to 5 pm) and night (11 pm to 1 am) were the usual times. The landfill operation was busiest at 10 am and 2 pm, when the municipal vehicles completed their routes. The flow

of vehicles at the incinerator was usually very steady throughout the day. Although the incinerator operates at constant noise levels throughout 24 hours a day, measurements had to be taken during the day to include outside operations and ash handling as well as during the night to get the plant noise with minimal background noise. A significant difference in noise levels between day and night at the site boundary would indicate that background levels are close to and may affect the plant noise; the noise readings would then have to be corrected to subtract the background component. Background noise level variation did not significantly affect the site boundary measurements (S1 and S2), but did expand threshold boundaries during late night hours.

Since the objective was to obtain noise measurements that would represent a typical waste facility on a flat plane, all locations were chosen to avoid significant reflections by a) placing the microphone as close to the source as possible, but staying outside a radius of twice the length of the largest source dimension to avoid directional radiation effects of short waves (Beranek, 1971) in order to treat the facility as a uniform point source, and b) by locating the noise meter away from any large reflecting objects that did not inherently belong to the waste facility.

The photographs below (Figures 4.B1 and 4.B2) show the site boundary measurement locations for landfill and incinerator. Table 4.B2 compares the longest source dimension with the distances to site boundary measurement points. The calculation of wave lengths gives the range of frequency sounds that may be

Figure 4.B1 - Landfill Noise Measurement Locations on Site Boundary

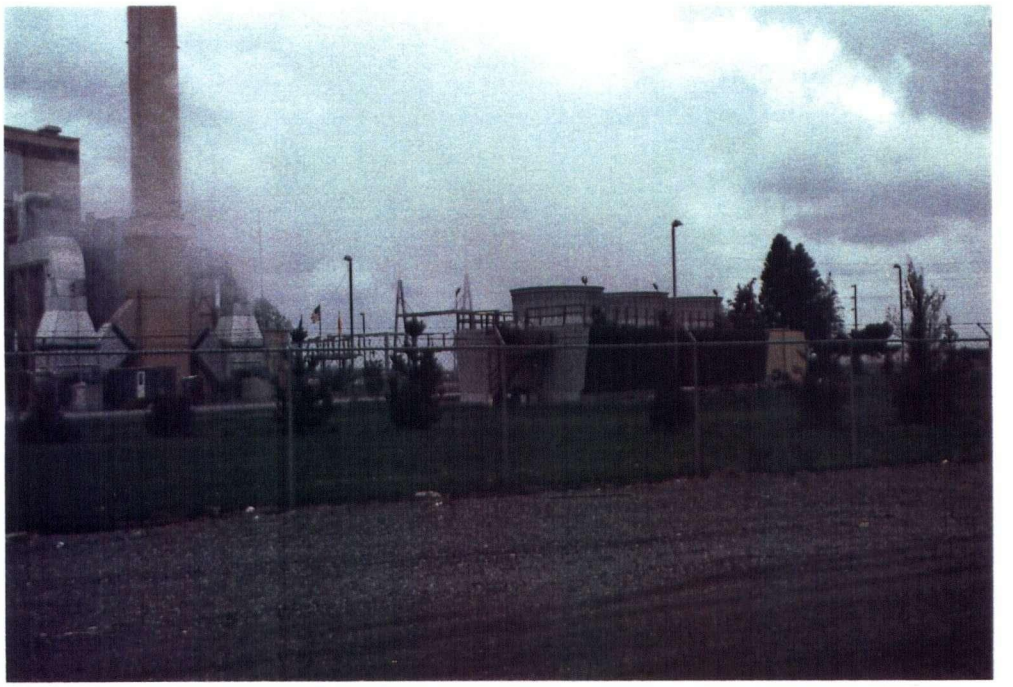


Figure 4.B2 - Incinerator Noise Measurement
Locations on Site Boundary

Table 4.B1 - Weather Conditions for Noise Measurements

a) Tacoma City Landfill

Location Site	Date 1987	Wind Direction	Speed M/S	Noise Level (L_{eq}) dBA	Conditions
W1	Feb. 24	NNE	5	61-65	busy
	Feb. 24	NNE	5	54-57.5	quiet
	Feb. 25	NE	3.5	58-64	busy
	Mar. 7	NNE	4.5	59-71	Saturday, wet roads.
	Mar. 7	NNE	4.5	60-65	busy, 10-25 veh./minute
	Mar. 8	OO	0.0	54.5-58.3	birds only
				47-48	background only
	Aug. 25	W	3.0	52-56	quiet
W2	Feb. 24	NNE	5.0	63-66.5	birds alone
	Feb. 25	NE	3.5	66-70	plane over flights
	Feb. 25	W	3.5	60-70	plane range 42.5 to 73.5
W3	Feb. 24	NNE	5	56.5-66	
	Feb. 25	NE	3.5	62.5-64	plane over flights
	Aug. 25	W	light	51.5-53.5	range 48 - .5'6' dBA background 47-48 dBA
Community					
C1	Feb. 25	NE	3.5	51-55.5	
	Mar. 6	SW	3.0	56-63	
	Mar. 8	SSE	3-4.0	49-54	
	Aug. 26	W	3	<38 dBA	background only
	Aug. 26	W	3	50-73	cover material handling

Table 4.B1 - Weather Conditions (Cont.)

Location Site	Date	Wind Direction	Speed M/S	Noise Level	Conditions
C2	Mar. 10	N/NE	light	53	background. 48-50.5 traffic
C3	Mar. 6	W-WSW	3	-	background only 50-55 (construction)
	Mar. 10	N/NE	light	53.4-57.2	quiet - background - 50.4 dBA
	Aug. 25	W/NW	light	49.5	44.5-51.5
	Aug. 26	W	3	<42-47	background only
C4	Mar. 6	SW	4-6	54-56.5	without traffic = 50 dBA
	Mar. 8	SSE	3-4	44.5-47	Sunday - priv. reh. only
	Aug. 26	W	3	<39	background only

Table 4.B1 - Weather Conditions (Cont.)

Location Site	Date	Wind Direction	Speed M/S	Noise Level	Conditions
C2	Mar. 10	N/NE	light	53	background. 48-50.5 traffic
C3	Mar. 6	W-WSW	3	-	Background only 50-55 (construction)
	Mar. 10	N/NE	light	53.4-57.2	quiet - background - 50.4 dBA
	Aug. 25	W/NW	light	49.5	44.5-51.5
	Aug. 26	W	3	<42-47	background only
C4	Mar. 6	SW	4-6	54-56.5	without traffic = 50 dBA
	Mar. 8	SSE	3-4	44.5-47	Sunday - priv. reh. only
	Aug. 26	W	3	<39	background only

Table 4.B1 - Weather Conditions for Noise Measurements

b) Salem Incinerator

Location S1 Distance from Source: 90 m

Season	W					
Wind Dir./Speed	NNE/1.5	N/Calm	SSE/1.5	-	NNE/3.3	Calm to WSW/light
Date	21.1.87	22.1.87	8.2.87	11.2.87	23.3.87	24.3.87
Time	7 am	12 pm	11pm-12am	11:30am	4pm	11am-12pm
Leq	56.4 dBA	62 dBA	58-59	60	61.5	55-57
Range	55-57 dBA	57-60		58-60	56-70	52-62
Background	traffic	train	traffic	box car compressors	traffic	
Season	Summer					
Wind Dir./Speed	N/5.3	S/1.3	calm			
Date	19.8.87	20.8.87	27.8.87			
Time	4:30pm	12:45 pm	5:45 am			
Distance	80 m	80 m				
Leq	45-46(53)	43-46.5	56.4			
Range	43-37	42-53	55-58			
Background	train-60 dBA	traffic-low	traffic-low			

Location -	S2	Distance - 60m					
Season	W	W	W				
Wind Dir./Vel.	NNE/1.5	SSE/3.1	N/Light	-	calm	NNE/3.3	SSE/1.5
Time	7:45am	7:30am	12:45pm	11:30am	1pm	4:30pm	11pm
Date	21.1.87	9.2.87	22.1.87	11.1.87	24.3.87	23.3.87	8.2.87
Leq	64.4	64.6	61.0	69.0	62.5	62.0	63.5
Range			61-65	69-70	60-69	61-63	62-64
Background noise			traffic	box car compressors high	-	traffic-low	

Season - summer				
Wind Dir./Speed	calm	S/1.5	N/3.3	
	6am	12:45pm	4:30pm	
	27.8.87	20.8.87	19.8.87	
	63.4	52.5	52-54	
	53.5-56.5	50-54	50-57	

Location -	C1	C1	C2
Season	S	S	
Wind Dir./Vel.	Calm	N/3.3	WSW/1.5
Temperature Distance	200m	200m	500m
Time	6am	6pm	6:45pm
Date	27.8.87	19.8.87	20.8.87
Leq	55	40.3-43.4	no plant noise
Range	53.5-56.6	37-44	38-42
Background noise	traffic trucks	traffic	traffic
	S/1.5		S/1.5
	13:30		13:30pm
	20.8.87		20.8.87
	slight		no plant noise
	36-37		<39

Location -	C3			C4		
Season	Winter			Winter		
Wind Dir./Vel.	Calm	NNW/3.3		calm		
Temperature Distance	300m			200m		
Time	5:30am	16:40pm		6am		
Date	24.3.87	23.3.87		24.3.87		
Leq	52.5	55.5-56.0		54.0		
Range	49.5-55.5	53-62		51.5-55.0		
Background noise				traffic		
	Summer			Summer		
Wind Div./Speed m/s	S/1.3	S/1.3	S/1.3	S/1.3	calm	S/1.3
	6:45am	1:30pm	2:10pm	6:45am	5:30am	7:10pm
	20.8.87	20.8.87	20.8.87	20.8.87	10.8.87	20.8.87
	48-52	39-40	39-40	48-53	55.0	38.45
	traffic	traffic	traffic	traffic	traffic	

Location -	C5			
Season	Summer			
Wind Dir./Vel.m/s	Calm	S/1.3	S/1.3.5	S/1.3
Temperature				
Time	6:25am	7:15am	1:30pm	7:10pm
Date	27.8.87	20.8.87	20.8.87	20.8.87
Leq	no plant noise	slight	no plant noise	slight
Range	54-56	44-46	39-41	36-38
Background noise	traffic	traffic	traffic	traffic

	C6 Summer	C7 Summer		
Wind Dir./Speed m/s	S/1.3	calm	S/1.3	S/1.3
	6:45am	6:35am	7am	13:30pm
	20.8.87	27.8.87	20.8.87	20.8.87
	slight GB noise	slight GB noise	no GB noise	no GB noise
	<43 dBA traffic	53-55	42-46	36-40

Location -	C8	C9
Season	W	W
Wind Dir./Vel.	WSW/light	WSW/light
Temperature		
Time	12pm	12pm
Date	24.3.87	24.3.87
Leq		
Range	46.5-50.0	44-46
Background noise	traffic	

Table 4.B2 - Noise Measurement Locations

Tacoma Landfill Largest Source Dimension Object		Distance to Site Boundary Measurement Points Location	Distance	Multiple
max. 10 m	Trucks Compactor	W1 -	90 m	9x
		W2 -	60 m	6x
		W3 -	55 m	5.5x
Salem Incinerator			**Distance from centre**	
max. 70 m	South side of incinerator building	S1 -	183 m	2.6m
		S2 -	152 m	2.2x

affected by objects with small dimensions (e.g. trees, cars, etc). The low frequencies up to 1 KHz are predominant from waste facilities. For frequencies above 500 Hz, there is clearly a strong possibility of reflection on trees, poles, etc. The measurement locations were chosen to avoid these objects. Furthermore, the main noise frequencies of waste facilities were under 1,000 Hz. Therefore, only marginal influence from reflecting obstacles is present.

The sound pressure level p2 at distance r2 can be estimated from a measured sound level p1 at distance r1 by the following general relationship (Mestre and Wooten, 1980):

$$L_{p2} = L_{p1} - 20 \log \frac{r2}{r1} - Ae \qquad (4.1)$$

Sound pressure at r2	Sound level at r1	Wave divergence	Excess attenuation

The first term represents the measured sound pressure level, the second term is the reduction of sound level due to divergence of the sound waves from a point source over a hemispherical surface on a flat rigid surface with increasing distance ratio of r1/r2, and the third term represents attenuation by atmospheric and environmental conditions. Only excess attenuation from vegetation and barriers are included in these rough estimates, because atmospheric wind and temperature gradients are not constant, while air, rain and fog attenuation are small for low frequencies at relatively short distances. For a frequency of 500 Hz, at 200 m and 80% humidity, the excess attenuation due to air

is calculated:

Air Excess Attenuation (4.2)

$$Ae = 7.4 \frac{f^2 r}{\theta} \times 10^{-8}$$

f = frequency = 500 Hz

r = distance = 200 m

θ = relative humidity = 80%

Ae = 0.05 dB is very small and therefore neglected.

Vegetative attenuation is given by the empirical formula.

Ae v = (0.18 log f - 0.31) r for grass and shrubs. (4.3)

Ae v = 0.01 f 1/3 * r for trees (4.4)

Barrier attenuation is given by the difference in path lengths divided by the wavelength to give the Fresnel number:

delta = A + B - C in m

$$N = \frac{\text{delta}}{\text{lamba}} = \frac{A + B - C}{\text{wave length}} \quad (4.5)$$

For an infinite barrier, attenuation is charted in Mestre and Wooten (1980, page 4-23) from experiments.

By applying these attenuation calculations to the site measurements, verification of community noise levels are obtained for a mid-range frequency of 250 Hz in Table 4.B3

Conversely, the distance to background noise level can be estimated by assuming for general site conditions, that only wave divergence reduces sound levels with distance:

Formula for Noise Attenuation by Wave Divergence Only.

$$Lb = Ls - 20 \log\left(\frac{rb}{rs}\right) \quad (4.6)$$

$$\frac{Ls - Lb}{20} = \log\left(\frac{rb}{rs}\right) \qquad 10\wedge\left[\frac{Ls-Lb}{20}\right] = \frac{rb}{rs}$$

$$rb = 10 \quad \exp \frac{Ls-Lb}{20} * rs$$

Distance to background level noise due to wave divergence.

The results are shown in Table 4.B4.

Table 4.B3

a. Tacoma Landfill - Noise Attenuation from Site to Community

Distances to Facility	W 100m	C 140m
Wave Divergence	-2.92 dB	
Vegetation Shrubs and trees	-3.65 to - 4.87 dB	
Barriers	none	
Total	-6.57 to - 7.8	

Distances to Facility	W2 60m	C2 300m
Wave divergence	-14 dB	
Vegetation	negligible	
Barrier barely interesects line of sight	-5 to - 7 dB	
	-19 to - 21 dB	
Total	-19 to - 21 dB	

Distances to the Facility	W3 60m	C3 400m
Wave divergence	-16.5 dB	
Vegetation - low grass	negligible	
Barriers	none	
Total	-16.5 dB	

Table 4.B3

b. Salem Incinerator

Distances to Waste Facility	S1 90m	C8 350m	C9 800m
Wave Divergence		-11.8 dB	-19 dB
Vegetation		negligible	
Barriers		none	none
Total		-11.8 dB	-19. dB

Distances	S2	C4	C1	C3	C2
	60m	200m	200m	300m	550m
Wave Divergence		-10.5	-10.5	-14	-19.25
Vegetation		negligible - elevated source			
Barriers		-	-	-	-
Total		-10.5	-10.5	-14	-19.25

Distances to Waste Facility	S2 60m	C7 200m
Wave divergence	-10.5	
Vegetation	negligible - elevated source	
Barriers - 1 row houses does not cover elevated source	negligible	
Total	-10.5 dB	

Table 4.B4 - Distances from Site Boundary to Background Noise Levels due to Wave Divergence

Landfill

Location and Distance		Measured Facility Noise dBA	Background Noise Levels dBA	Distance to Background
W1	100m	61	47	500m
W2	60m	65	47	475m
W3	55m	61	47	275m
Incinerator				
S1 South	100m	60	46	500m
S2 north east	60m	62	4.5	425m
S2 east	60m	62	4.5	425m

Appendix 4.C1 - Landfill Gas Impacts

The dispersion of landfill gas from the ground level emission area is assumed to follow a Gaussian model of the eddy diffusion process. The landfill is assumed to be an infinitely wide source so edge dispersion effects are ignored. Since the range of interest is only about 200 m and the sides of the landfill are up to 1.6 km long, edge effects are bound to be small.

For a linear source, the concentration is given by (Mestre and Wooten, 1980):

$$C(x,z) = \frac{2q}{\sqrt{2\pi}\,\sigma_z\,\bar{u}} \exp\left[-\frac{1}{2}\frac{(z-H)^2}{\sigma_z^2}\right] \qquad (4.7)$$

with C(x,z) = concentation of right angle distance x to line source in g/m3
q = pollutant flux per unit length of the source in g/s-m
U = wind speed in m/s
σ_z = vertical standard deviation
H = virtual height
Z = height of receptor above ground

The source emission flux was approximated by the mass of pollutant present in a box of 1 m width and 0.1 m height and a length equal to the wind speed in meters. The pollutant mass in this unit emission box is calculated from the surface level concentration of approximately 1% of the landfill gas concentration measured in gas wells. Furthermore, the source is assumed at groundlevel, whereas the centroid of the emission box is at 0.05 m height; this inaccuracy is disregarded here, because the resulting error in the estimated concentration is less than 5%.

Concentration reduction due to elevated source at H(m) of an exagerated value of 0.5 m to test the effect:

Reduction factor: $\exp \quad -\frac{1}{2}\left[\frac{H}{\sigma z}\right]^2$ at H = 0.5m (4.8)

at F Stability

x =	100m	200m
σz =	1.5m	3m
exp	0.95	0.99

The resulting reduction is less than 5%. Hence the box height assumption will not seriously affect the resulting concentration estimates.

The formula can be simplified further for a groundlevel receptor because the exponent term becomes unity for a height of zero. Calculation of the values of this term for 1.5 m height at 100 and 200 m for A, D and F stability are listed below:

$\text{Exp}\left[-\frac{1}{2}\left[\frac{z}{\sigma z}\right]^2\right]$ at z = 1.5 m (4.9)

	100m	200m
A stability	1.0	1.0
D stability	0.96	0.98
F stability	0.61	0.88

The results show less than 5% effect of the 1.5 m receptor elevation for distances over 100 m and for all but the most stable (F) conditions.

Table 4.C1 - Key To Stability Categories

	Day			Night	
	Incoming Solar Radiation			Cloud Cover	
Surface Wind Speed at 10m (m/s)	Strong	Moderate	Slight	Mostly Overcast	Mostly Clear
Class a	(1)	(2)	(3)	(4)	(5)
< 2	A	A-B	B	E	F
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
> 6	C	D	D	D	D

Source: D.B. Turner. Workbook of Atmospheric Dispersion Estimates. Washington, D.C.: HEW, 1969.

Note: The neutral class, D, should be assumed for overcast conditions during day or night. Class A is the most unstable and class F is the most stable, with class B moderately unstable and class E slightly stable.

Landfill Emission Model

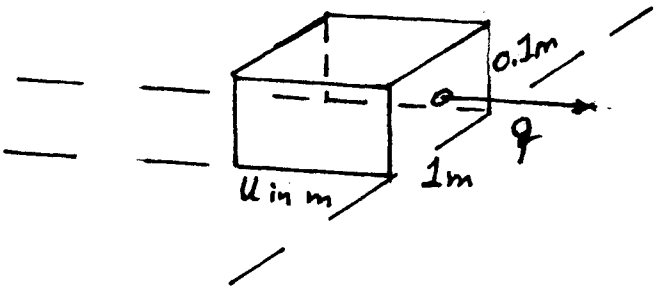


Figure 4.C.2.

Under these assumptions, the simplified, ground level concentration formula is

$$C\ (x,o,o) = \frac{2q}{\sqrt{2\pi}\,\sigma_z\,\bar{u}} \qquad (4.10)$$

The ground level concentrations are calculated for distances of 100, 200 and 300 m from the emission source, i.e. (the landfill boundary) and for four stability classes. Table 4.C below summarizes the data and results.

Table 4.C1 - Standard Deviations and Concentration per Unit Emission (lg/s-m) for a Linear Ground Level Source

Stability Class	Distances 100m		200m		300m	
	Std. Dev. [ ]	Conc. g/m3	Std. Dev.	Conc. g/m3	Std. Dev.	Conc. g/m3
	z [m]	C	z	C	z	C
A	15	5.4×10^{-3}	30m	2.7×10^{-3}	55m	1.5×10^{-3}
C	7.5	1.1×10^{-2}	15m	5.4×10^{-3}	22.5m	3.5×10^{-3}
D	4.5	1.8×10^{-2}	8.5m	9.4×10^{-3}	13m	6.0×10^{-3}
F	1.5	5.3×10^{-2}	3.0m	2.6×10^{-2}	4.5	1.8×10^{-2}

Stability Class	Distances 500m		1,000m	
	Std. Dev. [ ]	Conc. g/m3	Std. Dev.	Conc. g/m3
	z [m]	C	z	C
A	110m	7.3×10^{-4}	400m	2.0×10^{-4}
C	33m	2.4×10^{-3}	65m	1.23×10^{-3}
D	19m	4.2×10^{-3}	32m	2.5×10^{-3}
F	7.5m	1.1×10^{-2}	14m	5.7×10^{-3}

Notes: Standard deviations are from Turner, 1969 in Wark and Warner, 1980.

The results are plotted in Figure 4.8.

Table 4.C2 - Tacoma Landfill - Methane Concentrations in Landfill Gas Probes

Probe No.	Methane Concentration in % Depths of Wells			
	1.8m	6.1m	12.2m	18.3m
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
6	0	0	0	55
7	2			0
8	2	20	55	0
9	0	45	48	0
10	0	0	0	0
11	0	2	0	0
12	0	15	5	2
13	20	0	0	50
14	20	50	55	55
15	5	50	50	
16	15	58	7	35
17	0	0	0	0
18	0	0	0	0
19		0	0	0
26	0	0	0	
27	0	0	0	0
28	0	0	0	
29	0	0	0	
30	0	0	0	
31	0	0	0	
32	35	38	0	
35	33	0	33	33
36	53	53	20	45
37	45	55	55	
38	45	50	55	45
40		50	50	0
41	5	35	0	0
42	25	55	55	50
44	18	25	0	5
45	2	45	50	40
46	20	30		
47	7	17		
49	50	40	45	0

Table 4.C2 - Tacoma Landfill - Methane Concentrations in Landfill Gas Probes - Continued

Probe No.	Methane Concentration in % Depths of Wells			
	1.8m	6.1m	12.2m	18.3m
52 50	45	40		
53	0	57	55	50
54	50	55	55	45
55	38	45	52	0
56	50	55	55	27
57	55	60	60	60
58	55	2	0	0
59	27	60	60	63
60	17	10	3	0
60A	0	55	50	0
61	15	45	8	3
62	2	25	50	47
65	0	15	32	38
66	25	38	35	38
67	0	3	0	2
70	0	0	0	0
71	0	0		
72	0	0	0	
73	0	0	0	0
74	5	20	20	30
75	0	0	0	0
76	A50	B50	C55	D55
77	10	55	55	45
L-1	30	25		
L-2	0	2	23	
CC-1	0	5	55	

Appendix 4.C2 - Landfill Gas Emission Rate and Concentration

Landfill gas concentrations in the landfill are determined with the measured concentrations of methane and VOC's at the flare inlet (average of two, Black and Veatch, 1987):

	Gas in Landfill Concentration Micro g/m3
Benzene	1,750
Ethylbenzene	18,500
Toluene	100,000
Methylene Chloride	40,000
Vinyl Chloride	12,000
1,1 Dichloroethene	100
1,2 - trans-dichloro-ethene	19,500
methane (in gas probes see Table 4.C3)	10-50%

For a preliminary estimate, the emission rate of all landfill gas components at the landfill surface is assumed to be proportional to the maximum emission rates measured at the site for total hydrocarbons between 1.5 and 3,700 mg/min-m^2.

Using Young and Parker's (1984) dilution value of 1:100 landfill to surface dilution results in the gas concentration in the lowest layer of air above the landfill. By assuming a windspeed of 3 m/s and a landfill surface layer emission "box" of 0.1m height by 1m width across an average strip of 413m length (landfill width), the total emission rate per m width is calculated by:

$$Mg = U\ m/s * 0.1m * 1m * C \text{ or } 0.3 \frac{m3}{s} * C\ (g/m3)$$

Using methane at 0.5% as the indicator concentration, the total emission rate is estimated:

$$M_m = 0.3\ m^3/s * 3.26g/m^3 = 0.98g/s\text{-}m \text{ width}$$

Calculated backwards, the unit surface emission rate is estimated:

$$\frac{M}{413m} = \frac{0.98\ g}{413ms} = 2.37\ mg/s\text{-}m^2 \text{ or } 140\ mg/min\text{-}m^2 \text{ of methane}$$

This is within the range of measured unit surface emission rates in hot spots of (1.5 to 3,700 mg/min-m^2) during gas extraction and flaring. Thus, since without gas extraction the surface emissions may have been significantly higher, the assumed emission rates are reasonable to assess the impacts prior to as well as after the installation of the extraction system.

Finally, the mass balance of emitted methane at 140 mg/min-m^2 over the landfill surface of 177 acres (716,850m^2) is equivalent to 100.4 kg/min. methane. This measured value compares with an estimated landfill gas production of one to two cfm/per well per foot depth for one well per acre (Schumacher, 1983). Assuming an average depth of 10m (33 feet), the total landfill gas production is therefore:

$$M_{LG} = 177 \text{ wells} * 33 \text{ feet depth} * 2 \text{ cfm gas/foot depth}$$

$$= 11{,}682 \text{ cfm, or } 5.56\ m^3/s \text{ of landfill gas}$$

at 50% concentration, this equals 1.81 kg methane/s. or 108.8 kg methane per minute.

The assumed surface emission rate is therefore consistent with total gas production.

Appendix 4.D - Air Quality Impact Modelling for Salem Incinerator

1. Wind Speed at Stack Height of 80m from Measured Wind Speeds at 10m Height.

The average wind speed at the stack height of 78.64m, or about 80 metres, can be estimated from the measured average wind speed of 3 to 4 m/s at 10 metres height with the relationship (Wark and Warner; 1980) to reflect the wind speed profile:

$$\frac{U}{U_1} = \left(\frac{Z}{Z_1}\right)^p \quad \text{with } p = \frac{n}{2-n} \text{ in a rural setting} \qquad (4.11)$$

and n = function of the stability

for a moderate inversion
n = 0.33 p = 0.2

for a strong inversion
n = 0.50 p = 0.33

In the long - term, moderate inversion conditions are the most frequent and consistent scenario:

$$U_{80m} = 3.0 \text{ m/s} * \left(\frac{80m}{10m}\right)^{0.2} = 4.5\text{m/s at 80m height.} \qquad (4.12)$$

A difference in wind velocity due to height may reduce the effective source height (see Appendix Section 2), but also reduces the maximum ground level concentrations because of intensified eddy diffusion. The magnitude of these potentially offsetting effects is checked by comparing the results for maximum concentrations at 3 m/s and 5 m/s wind speeds:

Wind Speed U $\left(\frac{m}{s}\right)$	3	5
Effective height H (m)	110m	98m
Maximum Concentration at stability class C [mg/m3 per g/s emission]	4.0×10^{-3}	2.6×10^{-3}
Relative Concentration %	100	65

The difference of 35% is significant, yet for the dispersion model, constant wind speed is assumed (Wark and Warner, 1980). In order to obtain conservative concentration estimates, a wind speed of 3 m/s is selected as the base case for dispersion estimates.

2. Virtual Stack Height

The complex form of the plume after exiting the stack is simulated by a virtual source on the centerline of the plume, behind the stack so that the plume becomes rotationally symmetrical around the centerline axis through the virtual source. The height of the virtual source is equal to the stack height plus the rise of the plume. The plume rise is caused by the momentum and the temperature buoyancy.

Holland's formula (Wark and Warner, 1980) was originally chosen, because it requires the least data and gives good estimates for tall stacks:

$$\text{delta-h} = \frac{V_s * d}{u} \left[1.5 + 0.0096 \frac{Qh}{V_s * d} \right] \qquad (4.13)$$

The data are obtained from the Air Dispersion report for the Salem incinerator (Seton, Odell, Johnson 1984):

V_s = stack gas exit velocity = 19.02 m/s

d^s = stack exit diameter combined = 1.72m

u = wind speed at stack height = 3 m/s

T_s = 116 deg C

Q_h = heat emission rate = $m\ C_p\ (T_s - T_a)$

$$\text{with } m = \frac{v * p}{4\ RT_s} = \frac{44.42\ m^3/s * 1{,}013\ mb}{1{,}102.4\ mb\ m^3/kg} \qquad (4.14)$$

$$m = 44.42 * 0.92 \qquad = 40.87\ kg/s$$

$$Q_h = 40.87\ kg/s * 1.2\ KJ/kg\text{-}degC * (389-288)$$

$$= 4953.4\ KJ/s$$

With this heat emission rate, the plume rise with Holland's formula (equation 4.7) becomes

at u=3 m/s:

$$\text{delta-h} = \frac{32.71\ m^2/s}{3\ m/s} * 2.95 = \qquad 32.16m$$

at u=5 m/s

$$\text{delta-h} = \frac{32.71\ m^2/s}{} * 2.95 = \qquad 19.30m$$

However, two other plume rise calculations reveal different results:

Carson and Moses

at 3 m/s:

$$\text{delta-h} = -0.029\ \frac{V_s * d}{u} + 2.62 * \sqrt{Q_h}/u = 61.43m \quad (4.15)$$

at 5 m/s:

$$\text{delta-h} = \qquad 36.89m$$

Yet another method was developed by Concawe:

at u = 3 m/s:

$$\text{delta-h} = 4.71\ \frac{\sqrt{Q_h}}{(u)^{\wedge\ 0.694}} = \qquad 95.5m \quad (4.16)$$

at u = 5 m/s:

$$\text{delta-h} = \qquad 67.7m$$

Discrepancies in this order are not exceptional (Wark and Warner, 1980). The choice of the method should reflect worst case conditions and can be verified by on-site observations. For these calculations, the Holland model is used, but in full awareness of

the conservative nature of this assumption. However, taking a possibly higher wind velocity into account (e.g. 5m/s), the chosen heat rise of 30 m would be a reasonable compromise of all models.

The effective height is the stack height plus the heat rise, or stack height of 79 m plus 30 m equals 109 m. This height is then used to determine maximum concentrations for normal conditions with A to C stabilities and for trapping conditions with stabilities of D to F.

3. Emission Dispersion

Gaseous Dispersion

The Gaussian dispersion model for an elevated emission source and groundlevel receptor superimposes two concentration curves to represent reflected concentrations after the plume impinges at groundlevel. The two curves have centers at H, the virtual height, and -H, for the reflected concentration. For groundlevel, centerline concentrations (y=0, z=0), the formula simplifies to the following (Wark and Warner, 1980):

$$C(x,0,0) = \frac{Q}{\pi \bar{u} \sigma_y \sigma_z} \exp\left[-\frac{1}{2}\left(\frac{H^2}{\sigma_z^2}\right)\right] \qquad (4.17)$$

Q = emission rate

u = wind velocity

H = virtual height

σ x,y,z - standard deviations as functions of x,y,z

For trapping conditions, the inversion layer acts as a lid which limits the rise of the upper plume boundary. At distance x_L the upper plume edge is reflected downward until, at distance $2x_L$,

complete mixing between the inversion layer and the ground has taken place. Up to x_L, the standard dispersion concentration is applicable. Beyond $2x_L$, the concentration becomes simply a function of y:

$$C(x,y,0) = \frac{Q}{\sqrt{2\pi}\,\sigma_y L U} \exp\left[-\frac{1}{2}\left(\frac{y^2}{\sigma_y^2}\right)\right] \tag{4.18}$$

Between x_L and $2x_L$, a straight line plot between the respective concentrations in a log-log plot of concentration versus distance is a suggested approximation (Turner, 1969).

The results are shown in the log-log graph of concentrations per unit emission mass per time and distance (see Chapter 4).

Particulate Dispersion

The particulate dispersion equation is modified to reflect the settling velocity of particles. The groundlevel, centerline concentration formula includes a term for the settling motion:

$$C(x,0,0,H) = \frac{Q_p}{2\pi U \sigma_y \sigma_z} \exp\left[-\frac{1}{2}\left(\frac{H-(V_t \frac{x}{u})}{\sigma_z}\right)^2\right] \tag{4.19}$$

Q_p = particulate emission rate is g/sec

V_t = terminal settling velocity of a particle size

Deposition is therefore given by the concentration times the settling velocity V_t:

$$W = \frac{Q_p V_t}{2\pi U \sigma_y \sigma_z} \exp\left[-\frac{1}{2}\left(\frac{H-(V_t \frac{x}{u})}{\sigma_z}\right)^2\right] \tag{4.20}$$

In order to find the total deposition rate, the settling velocity is weighted by the mass fractions in four particle size ranges of the particle size distribution (Hahn et al., 1987) and settling velocity curves for particles (Wark and Warner, 1980):

35% at an average diameter of 1.0 microns and V_t = 0.014 cm/s

39% at an average diameter of 2.5 microns and V_t = 0.09 cm/s

18% at an average diameter of 9.0 microns and V_t = 0.25 cm/s

8% at an average diameter of 14.0 microns and V_t = 0.6 cm/s

This distribution results in a weighted average settling velocity V_t of 0.13 cm/s.

This value is applied in the particulate dispersion model to determine particulate concentrations and deposition rates.

4. Health Risks from Incinerator Emissions - Sensitivity Analysis

Resulting health risks are calculated for various scenarios in Table 4.22, (in text):

Base case - wind speed u = 3 m/s
- long-term average concentration = 1h average
- no VOC emissions

Wind-Speed - wind speed u = 5 m/s
- long term average concentration = 1h average
- no VOC emissions

Long term - wind speed u = 3 m/s
- long term averages:
  1. equals 3h average at 0.9 * 1h average
  2. equals 8h average at 0.75 * 1h average
  3. equals 24h average at 0.4 * 1h average
- no VOC emissions

VOC - Emissions present:
- wind speed u = 3 m/s
- long term average concentration = 1 h average

- VOC emissions prorated from Toronto tests

The concentrations of PCB and benzo (a) pyrenes are determined by prorating the concentration ratios of PCB plus chlorobenzenes (CB) plus chlorophenols (CP) from Toronto to the Salem concentrations.

Derivation of Possible Volatile Organic Compound Concentrations in Incinerator Emissions

Emission Concentrations (Ozvacic et al., 1985)

Toronto - Incinerator Average of 3 Tests

	Refuse ng/g	%	Emission Concentrat. ug/Nm3	Emission Factors mg/tonne refuse	%
PCB + CB + CP			9.55		
PCB	611	61%		1	1%
CB	39	4%		35	29%
CP	355	35%		83	70%
SWARU					
PCB + CB + CP			30.0		
PCB	116	18%		18.3	7%
CB	8	1%		181.3	71%
CP	529	81%		56.0	22%

Incinerator Emission Factor (Peterson, 1987)

CP's	25 ug/MJ	at 8,000 MJ/tonne	= 200 mg/tonne
CB's	10 ug/MJ	at 8,000 MJ/tonne	= 80 mg/tonne

Approximation of Possible VOC Emissions

	Approximate Percentages	Emission Rate per energy unit	Concentration microgram/Nm3	Rate g/s
PCB	20%	5-10 mg/MJ	7.5-15	$2.5\text{-}5.0\times10^{-4}$
CP	60%	10-25mg/MJ	19-39	6.3×10^{-4} to 1.3×10^{-3}
CB	20%	5-10Mg/MJ	7.5-15	$2.5\text{-}5.0\times10^{-4}$
Total CP + CB + PCB			34-69	

Appendix 4.E - Water Quality Impacts - Groundwater Contaminant Transport Modelling

The basic transport model consists of the analytical solution to the boundary value problem in a one dimensional flow field with a linear source across a flowfield with parallel flowlines. The solution is the ratio of the concentration at distance x from the source at time t, given flow velocity V (V_c for retarded flow), dispersivity alphas = 0.1 to 100 m for the strata, and diffusion coefficient for the contaminant in water D. The resulting analytical solution takes the form of (Freeze and Cherry, 1979):

$$\frac{C(x,t)}{Co} = \frac{1}{2}\left[\operatorname{erfc}\frac{x - \bar{V}.t}{2\sqrt{D_x^* t}} + \underbrace{\exp\frac{\bar{V}.x}{D^*}.\operatorname{erfc}\left(\frac{x + \bar{V}t}{2\sqrt{D_x^* t}}\right)}_{= 0 \text{ if } \frac{x}{D^*} >> 200}\right] \quad (4.21)$$

The model can accomodate contaminant decay and retardation in the soil due to ion exchange, absorption, volatilization, biological decay, oxidation etc. Volatilization is the most significant retardation mechanism for most volatile organics from solution (USEPA, 1979 and Callahan, 1979), but in a deep aquifer, the pore spaces may become saturated. Convective transport of the gas phase is unlikely because bouyancy forces and temperature gradients are small. For the conservative transport model, volatilization is not considered a major removal mechanism for dissolved organics in a deep aquifer. Sorption, however, may be a retardation factor, depending on the organic content of the soil. The range of soil organic contents is reported between 0.02 for subsurface and 0.7% for typical surface soils in USEPA (1987).

Tills may contain such organic matter. Therefore, sorption retardation is included in the model for 0.1% and 1% organic content in the soil, while ion exchange, oxidation and biological decay are omitted, because they are not likely removal processes for volatile organics in groundwater.

Retardation due to sorption is modelled as a reduction in contaminant velocity by the following formula (Freezea and Cherry, 1980):

$$\frac{V}{\bar{V}_c} = 1 + \frac{rho}{n} b\, k_d = R_s \quad \text{retardation factor due to sorption} \qquad (4.22)$$

The partitioning coefficient k_d is taken as the octonol-carbon partitioning factor $K_{oc}*f_c$

The resulting contaminant transport velocity V_c is $\frac{V}{\bar{R}}$ the retarded velocity. This velocity in plugged into the analytical solution.

Vertical Contaminant Transport from the Landfill to the Groundwater Table.

In order to estimate the range of transport times through multiple layers of strata with different conductivity values, a hydraulically equivalent, homogenous, anisotropic layer is calculated (Freeze and Cherry, 1980):

$$Kz = \frac{d(total)}{\sum Ki\ di} \qquad \begin{array}{l} di = \text{thickness of layer } i \\ Ki = \text{conductivity of layer } i \end{array} \qquad (4.23)$$

with layers:	thickness	conductivity
1. Vashon till	3.6 m	1×10^{-8} m/s
2. Vashon Outwash	7.8 m	5×10^{-5} m/s
3. Calvos Sand	7.8 m	5×10^{-4} m/s

maximum conductivity with complete till layer:

$$Kz\ max. = \frac{19.2\ m}{3.6 * 10^{-8}\ m/s} = 5.33 * 10^{-8}\ m/s \text{ for complete till layer}$$

minimum conductivity without till layer, but assuming same overall thickness:

$$Kz\ min. = \frac{19.2\ m}{2.43 * 10^{-5}\ m/s} = 7.88 * 10^{-5}\ m/s \text{ for no till}$$

For hydraulic heads of unity for vertical downward movement, discharges q range between $5.33 * 10^{-8}$ m/s with a complete till layer, to $7.88 * 10^{-5}$ m/s without the till layer.

It follows from the formula for flow velocities (v = q/n), that with porosities n between 0.2 and 0.4, the resulting velocities range between $1.33 * 10^{-7}$ and $3.94 * 10^{-4}$ m/s for the respective configurations with and without the till layer (see Table 4.24 in text).

Mass Flux of Vinyl Chloride in Groundwater

In order to check the plausibility of landfill leachate contamination of downgradient wells, the amount required to contaminate groundwater aquifer and the amount discharged across the landfill boundary per day are determined and compared:

A. Mass required to contaminate aquifer volume:

- Assume a volume of $10m^3$ in the landfill saturated with water, and leachate saturated with winyl chloride:

  $10\ m^3$ (say) 0.5 porosity = 5,000l

  at 2,670 mg/l equals <u>13.35 kg</u> vinyl chloride

- Assume a $1\underline{m}^2$ column from bottom of landfill to groundwater table with residual saturation of (say) 20%, saturated with

vinyl chloride:

$1m^2$ * 20m depth at n = 0.3 and 20% residual

equals 1,200l at 2,670 mg/l equals 3.204 kg

. Assume the entire aquifer (older gravel) depth is contaminated with highest observed concentration (80 ug/l) of vinyl chloride over distance from the landfill centerline to 1m before the tainted wells, say over 1,000m: for a strip of aquifer 1m width, 15.24m deep, 1,000m long, and with a porosity of n = 0.3, the volume is given:

1m * 15.24m * 1,000m * 0.3 = $4,575m^3$

or $4.575 * 10^6$ l at 80 ug/l = 366 g/m-width of aquifer.

B. Flux

. Aquifer discharge at landfill boundary

q = V*n = 0.61 m/day *0.3 = 0.18m/day without retardation

over entire cross section of aquifer $15.24m^2$

$15.24m^2$* 0.18m/day = $2.79m^3$/day = 2,790 l/day

at 80 ug/l = 223.1mg/day - m width vinyl chloride

maximum flux: 223.1 mg/day vinyl chloride

at 2,670 mg/l concentration in leachate, only 0.08 l of leachate is required.

. Area required for vertical leachate discharge to groundwater Table:

Assume no till layer, then vertical velocity equals 7.88 * 10^{-5}m/s

10^{-5} m/s and porosity n = 0.3, then discharge is:

g = 7.88 * 10^{-5} m/s * 0.3 = 2.36 * 10^{-5} m/s

Therefore to get about 0.1 l/day leachate discharge, requires

an area of

$0.1\ l/day * 2{,}039\ l/day = \underline{5 * 10^{-5}}\ m^2$.

Thus, it is definitely possible that small leachate discharges to the aquifer can contaminate the aquifer to the observed levels.

Appendix 4.F - Health Risk Assessment Methodology

The method for determing health risks follows the USEPA (1986) Superfund Public Health Assessment Manual with minor adjustments for exposure duration.

The method requires data of maximum and long-term pollutant concentrations (in mg/m^3 or mg/l) at exposure locations for air and water. These concentrations are converted to Sub-chronic and Chronic Daily Intakes (SDI, CDI, in mg/kg-body weight) through average uptake rates of 20 m^3/day for air inhalation and 2 l/day water consumption for an average bodyweight of 70 kg, or 0.29 m^3/kg - bodyweight of air and 0.029 l/kg - bodyweight of water.

Here, exposure time ratios are plugged into the analysis to reduce daily uptake results. For example, prevailing winds at the incinerator site last 10 months of a year, hence the exposure factor is 10/12 = 0.83 which linearly reduces the average daily uptake over the year.

Finally, carcinogenic risks and non-carcinogenic risks are estimated separately. Carcinogenic risks are determined by multiplying CDI's (in mg/kg) with respective potency factors (kg/mg) and (for low risks) summing all risks. This linear combination disregards all possible antagonistic or synergistic effects various carcinongens may have. Non-carcinogenic compounds are separated and their sub-chronic and chronic concentrations are divided by established acceptable intakes (AIS and AIC) levels. The resulting quotients are summed separately. If either total exceeds unity, then a non-carcinogenic health risk is assumed present.

Questionnaire

Your Neighborhood and its Facilities

I. Your Neighborhood

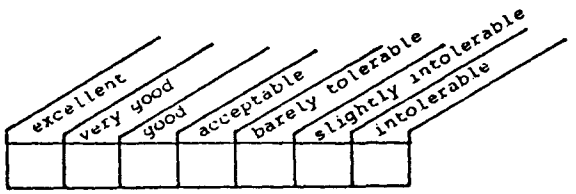
1. In general, do you favor or oppose more residential development in your neighborhood?

   I am (please mark one)

totally opposed	somewhat opposed	indifferent	somewhat in favor	totally in favor
____	____	____	____	____

2. Overall, what is your attitude towards your neighborhood?

   Please mark one of the points below:



3. When did you move into your neighborhood?

   Month _____ Year _____

4. Please list the name of your neighborhood and your street name and number (to the closest hundred):

   Neighborhood _____

   Street _____

   Number (to the closest hundred) _____

5a. What did you particularly like about this neighborhood that made you decide to move here?

_____

_____

_____

5b. Has anything changed since you moved in to make you like living here better?

_____

_____

6a. When you moved in to your present neighborhood, what did you particularly dislike about the neighborhood you live in now?

_____

_____

_____

6b. Has anything changed since you moved in to make you more dislike living here ?

_____

_____

7a. How does your present neighborhood compare to the last one you lived in? (please mark one)

much better	slightly better	about same	slightly worse	much worse
____	____	____	____	____

7b. How does your neighborhood compare with other neighborhoods in your area? (please mark one)

much better	slightly better	about same	slightly worse	much worse
____	____	____	____	____

8. How do you rate your neighborhood in terms of the items in the list below?

	excellent	very good	good	acceptable	barely tolerable	slightly intolerable	intolerable
Nuisances							
noise	1	2	3	4	5	6	7
odors	1	2	3	4	5	6	7
visual impression	1	2	3	4	5	6	7
litter	1	2	3	4	5	6	7
traffic	1	2	3	4	5	6	7
scavenging animals	1	2	3	4	5	6	7
Health Hazards							
air contamination	1	2	3	4	5	6	7
water contamination	1	2	3	4	5	6	7
risks of industrial accidents, explosions, fires, etc.	1	2	3	4	5	6	7
General Environmental Quality							
air quality	1	2	3	4	5	6	7
water quality	1	2	3	4	5	6	7
wildlife habitats	1	2	3	4	5	6	7
availability of land and natural resources	1	2	3	4	5	6	7
Economic Factors							
property values	1	2	3	4	5	6	7
development potential	1	2	3	4	5	6	7
employment	1	2	3	4	5	6	7
taxes	1	2	3	4	5	6	7
other _____	1	2	3	4	5	6	7

[continue] Question 8.:

How do you rate your neighborhood in terms of the items in the list below?

	excellent	very good	good	acceptable	barely tolerable	slightly intolerable	intolerable
Community Reputation							
community image	1	2	3	4	5	6	7
control over development	1	2	3	4	5	6	7
confidence in the local government	1	2	3	4	5	6	7
fair treatment of residents	1	2	3	4	5	6	7
information about development in the neighborhood	1	2	3	4	5	6	7
quality of municipal services	1	2	3	4	5	6	7
Location relative to job, shopping, downtown, schools,	1	2	3	4	5	6	7
other (list) _____	1	2	3	4	5	6	7

II. Your Home and Household

9. Please mark the type of home you live in.

single family house _____ townhouse _____

duplex _____ condominium _____

apartment _____ trailer _____

other (please fill in) _____ _____

10. Do you own or rent your home?

own _____ rent _____

11. Do any children (under 18) live in your household?

yes _____

no _____

12a. How many times per week do you get to read the paper, listen to the news on the radio or watch the news on TV?

read paper _____ times per week

watch news on TV _____ times per week

b. Which local newspaper(s) do you read regularly ?

_____

c. Which TV channel(s) do you watch the news on?

Please fill in the channel, station letters, or the newscaster's name: _____

13a. What business or profession do you usually work in or have you usually worked in?

_____

b. What is the title of your job?

_____

c. What was the name and type of the school, and the last year you attended? (including trade school, vocational school, etc.)

School _____, _____ th year

What is the most recent degree or diploma you received?

_____

d. Which range best represents your household's total yearly income from all sources for last year (before taxes and deductions)? Please include all sources of income and everyone in the household that works in your estimate.

_____ a. up to $9,999

_____ b. $ 10,000 to $ 14,999

_____ c. $ 15,000 to $ 19,999

_____ d. $ 20,000 to $ 29,999

_____ e. $ 30,000 to $ 49,999

_____ f. over $ 50,000

III. Facilities in Your Neighborhood

This section asks questions about your opinion about the industries and municipal facilities needed to support the residents in large urban areas.

14. Are any of the six facilities (listed below) or any other municipal, industrial or government facilities (including highways and major roads, railway lines, airports, plants, etc.) located in your neighborhood or close to where you live?

Please mark any that are located close to you and estimate the straightline distance from your home:

	no	yes	If yes, how far from your home?
a gravel pit	_____	_____	_____ miles
a garbage fill	_____	_____	_____ miles
an electrical power plant	_____	_____	_____ miles
a garbage burner (incinerator)	_____	_____	_____ miles
a chemical plant	_____	_____	_____ miles
a hazardous waste disposal facility	_____	_____	_____ miles

Please list any other facilities that are located in your neighborhood or close to you:

facility	distance (please mark units)
_____	_____ miles
_____	_____ miles
_____	_____ miles

15. How familiar are you with the six listed facilities and with other facilities that may be located close to you?

Please rate your familiarity on a scale of totally familiar (7) to totally unfamiliar (1) for each type of facility on the list and for any facility you may have listed in the last question.

	totally unfamiliar			neither/ not sure			totally familiar
a gravel pit where gravel is dug up	1	2	3	4	5	6	7
a garbage fill where garbage is filled and covered	1	2	3	4	5	6	7
an electrical power plant that burns oil to generate electricity	1	2	3	4	5	6	7
a garbage burner that burns garbage and produces energy	1	2	3	4	5	6	7
a chemical plant that produces pesticides	1	2	3	4	5	6	7
a hazardous waste disposal facility where chemical wastes are treated and buried	1	2	3	4	5	6	7

Please list and rate the facilities close to you (from the last question 14):

_____	1	2	3	4	5	6	7
_____	1	2	3	4	5	6	7
_____	1	2	3	4	5	6	7

16. Assuming that any one of the facilities listed below were to be built in your neighborhood; that is, within 1 mile from where you live. In each case, the facility will be large enough to serve the entire metropolitan area you you live in or close to.

Please rank how desirable you consider each type of facility to be if it were built in your neighborhood

Mark a "1" next to the most desirable facility and a "2" next to the next most desirable facility and so on until you have gone through the list and assigned the least desirable facility the highest number. If there are any facilities close to you but not on the list, please add them in the empty spaces at the end and rank them too:

- a gravel pit _____
- a garbage fill _____
- an electrical power plant _____
- a garbage burner _____
- a chemical plant _____
- a chemical waste disposal facility _____

Other facilities close to you:

_____ _____

_____ _____

17a. A Garbage Landfill

Please assume that a garbage landfill to serve the entire metropolitan area were to be built within 1 mile from where you live.

What would annoy, bother or concern you about the garbage landfill and how would you benefit by having the facility located in your neighborhood?

Concerns _____ Benefits _____

17b. A Garbage Burner

Please assume that a garbage burner to serve the entire metropolitan area were to be built within 1 mile from where you live.

What would annoy, bother or concern you about the garbage burner and how would you benefit by having the facility located in your neighborhood?

Concerns _____ Benefits _____

17c. A Hazardous Waste Disposal Facility

Please assume that a hazardous waste facility to serve the entire metropolitan area were to be built within 1 mile from where you live.

What would annoy, bother or concern you about the hazardous waste disposal facility and how would you benefit by having the facility located in your neighborhood?

Concerns _____ Benefits _____

18. Does any one of the facilities close to you annoy, concern, or bother you in particular?

Yes ____ , if yes please fill in the name of the facility and proceed to the next question:

_____

Please consider this one facility in the next questions !

No ____ , if no, please consider the one facility that is highlighted in orange on the list of six below:

- a gravel pit where gravel is dug up
- a garbage fill where garbage is filled and covered
- an electrical power plant that burns oil to generate electricity
- a garbage burner that burns garbage and produces energy
- a chemical plant that produces pesticides
- a hazardous waste disposal facility where chemical wastes are treated and buried

Please assume this facility were located in your neighborhood and consider this one facility in the next questions!

19. Please fill in the name of the facility you identified or were asked to consider in the last question (question 18):

_____

Please consider in detail the specific effects of this one facility on your neighborhood.

a. Does the facility cause nuisances in the neighborhood ?

	no effect	intolerable	slightly intolerable	barely tolerable	acceptable	fair	good	excellent
noise	0	1	2	3	4	5	6	7
odors	0	1	2	3	4	5	6	7
unpleasant views	0	1	2	3	4	5	6	7
litter	0	1	2	3	4	5	6	7
traffic	0	1	2	3	4	5	6	7
birds and animals	0	1	2	3	4	5	6	7

b. Does the facility create any health hazards in the neighborhood ?

Health Hazards due to								
air contamination	0	1	2	3	4	5	6	7
water contamination	0	1	2	3	4	5	6	7
risks of accidents, explosions, fires, etc.	0	1	2	3	4	5	6	7

c. Does the facility affect the general environmental quality in the neighborhood?

General Environmental Quality								
air quality	0	1	2	3	4	5	6	7
ground or surface water quality	0	1	2	3	4	5	6	7
quality of wildlife habitats	0	1	2	3	4	5	6	7
availability of land and natural resources	0	1	2	3	4	5	6	7

d. Does the facility influence the economic factors in the neighborhood?

Economic Factors	no effect	intolerable	slightly intolerable	barely tolerable	acceptable	fair	good	excellent
property values	0	1	2	3	4	5	6	7
development potential	0	1	2	3	4	5	6	7
employment	0	1	2	3	4	5	6	7
taxes	0	1	2	3	4	5	6	7

e. Does the facility affect these neighborhood issues?

Neighborhood Issues								
neighborhood image	0	1	2	3	4	5	6	7
local control over development	0	1	2	3	4	5	6	7
confidence in the local government	0	1	2	3	4	5	6	7
fair treatment of residents	0	1	2	3	4	5	6	7
confidence in the owner/ operator of the facility	0	1	2	3	4	5	6	7
quality of municipal services	0	1	2	3	4	5	6	7
confidence in the environmental protection agency	0	1	2	3	4	5	6	7
other (list) _____	0	1	2	3	4	5	6	7

20. Please transfer the name of the one facility you identified or were asked to consider in question 18:

_____

Please consider the following statements about this one facility and indicate to what extent you disagree or agree with them:

a. The fact that the facility is located in the neighborhood is fair.

1	2	3	4	5
strongly disagree	disagree	not sure	agree	strongly agree

b. The facility depresses the property values in the neighborhood.

1	2	3	4	5
strongly disagree	disagree	not sure	agree	strongly agree

c. The facility operators are doing their best to protect the neighborhood from negative impacts.

1	2	3	4	5
strongly disagree	disagree	not sure	agree	strongly agree

d. The mere presence of the facility harms the image of the neighborhood regardless of the physical impacts.

1	2	3	4	5
strongly disagree	disagree	not sure	agree	strongly agree

e. The neighborhood needs the facility.

1	2	3	4	5
strongly disagree	disagree	not sure	agree	strongly agree

f. The environmental agency prevents any environmental damage, harm to human health and nuisances from occurring in our neighborhood.

1	2	3	4	5
strongly disagree	disagree	not sure	agree	strongly agree

g. The facility is a nuisance (noise, odors, unpleasant views, litter, traffic, etc.) for the neighborhood.

1	2	3	4	5
strongly disagree	disagree	not sure	agree	strongly agree

h. The best available technology is being used at the facility to prevent any impacts on the neighborhood.

1	2	3	4	5
strongly disagree	disagree	not sure	agree	strongly agree

i. The facility constitutes a health hazard for the neighborhood.

1	2	3	4	5
strongly disagree	disagree	not sure	agree	strongly agree

j. The residents in the neighborhood are well informed about the facility and its operation.

1	2	3	4	5
strongly disagree	disagree	not sure	agree	strongly agree

k. The facility degrades the general environmental quality (air quality, ground or surface water quality, wildlife habitats, availability of land and natural resources) in the neighborhood.

1	2	3	4	5
strongly disagree	disagree	not sure	agree	strongly agree

l. The facility generates significant benefits (taxes, jobs, development potential) in the neighborhood.

1	2	3	4	5
strongly disagree	disagree	not sure	agree	strongly agree

m. The local government is doing its best to protect the neighborhood.

1	2	3	4	5
strongly disagree	disagree	not sure	agree	strongly agree

n. The residents in the neighborhood voluntarily accept the facility.

1	2	3	4	5
strongly disagree	disagree	not sure	agree	strongly agree

o. The facility generally generates pollution and waste in the neighborhood.

1	2	3	4	5
strongly disagree	disagree	not sure	agree	strongly agree

p. The facility is located in the environmentally best available site.

1	2	3	4	5
strongly disagree	disagree	not sure	agree	strongly agree

q. The facility enhances the level of municipal services in the neighborhood.

1	2	3	4	5
strongly disagree	disagree	not sure	agree	strongly agree

21. Consider the situation where each of the facilities listed below were to be located near you, that is within 1 mile or 1.6 kilometres from where you live. In each case, the facility will be large enough to serve the metropolitan area you live in.

How desirable or undesirable are these facilities to you if they are located in your neighborhood ?

	very desirable				neither/ not sure				very undesirable
gravel pit	+4	+3	+2	+1	0	-1	-2	-3	-4
garbage dump	+4	+3	+2	+1	0	-1	-2	-3	-4
garbage burner	+4	+3	+2	+1	0	-1	-2	-3	-4
electrical power plant	+4	+3	+2	+1	0	-1	-2	-3	-4
chemical plant	+4	+3	+2	+1	0	-1	-2	-3	-4
hazardous waste disposal facility	+4	+3	+2	+1	0	-1	-2	-3	-4

Please list other facilities near you and rate them too:

_____	+4	+3	+2	+1	0	-1	-2	-3	-4
_____	+4	+3	+2	+1	0	-1	-2	-3	-4

Please answer the questions in this column only if you live close to the facility you identified in Question 18:

If you do not live close to a facility, skip forward to Question 27 on the next page (page 9) ---> --->

22. Were you aware of the facility when you decided to move in?

Yes _____ No _____ Moved in after the facility _____

23. Has the facility affected you more or less than you expected?

much less	less	slightly less	about as expected	slightly more	more	much more

24. Were you able to purchase or rent your home for less because the facility was there?

yes 15 - 20% less	yes 10 - 15% less	yes 5 - 10% less	no, no less	don't know
_____	_____	_____	_____	_____

25. Given what you know now about the facility and its operation, would you buy or rent your home and move into this neighborhood again if you were faced with the decision now ?

yes, for sure	yes, probabaly	don't know	not likely	definitely not
_____	_____	_____	_____	_____

26a. Did you consider or take action to oppose the facility in your neighborhood?

	Yes, I did	I intend to	I considered it	Did not consider this option
Move out				
Take legal action				
Complain				
Gather information				
Attend Meetings				
Ignore the facility and not let it bother me				

26b. If you took any action, please describe briefly what you did and what response or results you obtained:

_____

_____

---> Skip to here if there is no facility close to you

The last question is for all respondents:

27. Assume that the situation in your neighborhood becomes intolerable because of a facility's impacts. The owner/operator offers to compensate you for any property value losses you may experience by selling your house if you decide to move within three months.

Do you consider this offer to be (please mark one)?

completely fair	acceptable	somewhat unfair	very unfair
_____	_____	_____	_____

Why? _____

Thank you very much for your time and effort.

Please make comments about the questionnaire itself in the space below:

Was the questionnaire too long? too complex? Were the questions interesting or challenging?

_____

_____

_____

_____

I M P O R T A N T

Please put the completed survey form in the envelope and drop it in the mail by Monday, February 16, 1987.

Thank you again for your time and effort. Your opinions are a valuable contribution to the research.

Appendix 5.B1 - Facility Impact Coding List for Open-Ended Survey Questions about Neighborhood Beliefs and Facility Concerns, and for Newspaper Content Analysis

Impact	Coding
Noise	01
Odor	02
Views	03
Litter	04
Traffic	05
Animals birds	06
rats	07
insects	08
General Environm. Qual.	10
air quality	11
water quality	12
land/soil	13
energy	14
resources	14.5
wildlife habitats	15
Health/Safety	16
air pollution	17
water pollution	18
accidents,explosions	19
Economic factors	20
property values	21
mortgage rates	22
development potential	23
employment	24
taxes	25
disposal costs	26
utility rates	27
revenues	28
Community image	30
rural image	30.5
"garbage, waste"	31
" implicit	31.1
"pollution, contamin."	32
" implicit	32.1
"risk, disease"	33
" implicit	33.1
waste reduction	34
resource recovery	34.5
Technical control	35
Regulation	35.5
Mitigation	36
Monitoring	36.5
Compensation-prop.value	37
Compensation-in-kind	38
Compensation-other	39

Impact	Coding
Location/access	40
job	41
shopping	42
schools	43
access to downtown	44
access to highway	45
Neighborhood	50
old/established	51
new	52
density/space/privacy	53
home/house/dwelling	54
neighbors/relatives	55
crime	56
other houses/upkeep	57
land-farm-zoning	58
New development	60
multifamily/rental	61
shops	62
schools	63
landfill	64
incinerator	65
cannery	66
railroad	67
gravel pit	68
airbase	69
quality of municipal services	70
roads	71
need for waste disposal	72
better method	73
convenience	74
pressure on infrastructure	75
need for residual disp.	76
general opposition	80
would move	81
just knowing it there	82
benefits	83
Political impacts	90
loss of control	91
confidence owner	92
confidence local govt.	93
confidence environm. ag.	94
Familiarity information	95
unknown or uncertain	96
long-term	97
unfair	98
technology or site	99

Appendix 5.C - Community Opinion Survey 1 - Tables of Detailed Statistics Results

The following tables are numbered so as to correspond with tables in Chapter 5. For example, Table 5.C5 in the appendix supports Table 5.5 in Chapter 5.

Table 5.C5 - Tacoma Host Community Chi-Square Test of Demographics in Survey Sample versus Impact Beliefs

N=18-24

	Time in Nh	Type of home	Rent own	Children in home	Education	Income
Significant Impact Ratings						
Noise	n.s.	n.s.	n.s.	n.s.	n.s.	sig. low> high
Odor	n.s.	n.s.	n.s.	n.s.	n.s.	sig. low> high
View	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Traffic	n.s.	n.s.	n.s.	marg.	n.s.	n.s.
Animals	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Air Poll.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Water pol.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Accidents	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Air Qual.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Water Qual.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Wildlife	n.s.	sig. SF>Apt.	n.s.	n.s.	n.s.	n.s.
Property Values	n.s.	n.s.	n.s.	n.s.	n.s.	sig. med.> low
Image	n.s.	n.s.	n.s.	n.s.	n.s.	marg.sig. med.> low
Significant Impact Statements						
Nuisance	n.s.	n.s.	n.s.	n.s.	n.s.	sig. med>high
Environ. Change	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Image	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Control	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Fairness	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Lack of Informat.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Lack of Need	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Chi-square and Fisher Exact tests significant if $p<0.05$

Table 5.C7 - Salem Host Community Chi-Square Test of Demographics in Survey Sample versus Impact Beliefs

N=16-26

	Time in Nh	Type of home	Rent own	Children in home	Education	Income
Significant Impact Ratings						
View	n.s.	n.s.	n.s.	n.s.	n.s.	sig. low> high
Traffic	n.s.	n.s.	n.s.	marg.sig. none>children	n.s.	n.s.
Air Poll.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Air Qual.	n.s.	sig. SF>Apt.	n.s.	n.s.	n.s.	n.s.
Property Values	n.s.	n.s.	n.s.	n.s.	n.s.	sig. med.> low
Image	n.s.	n.s.	n.s.	n.s.	n.s.	marg.sig. med.> low
Control	n.s.	sig. SF>other	n.s.	n.s.	n.s.	n.s.
Fairness	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Significant Impact Statements						
Nuisance	n.s.	n.s.	n.s.	n.s.	n.s.	sig. med>high
Health Risks	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Environ. Change	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Property Values	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Image	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Control	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Fairness	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Lack of Need	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Chi-square and Fisher Exact tests significant at 95%

Table 5.C8a - Tacoma Landfill - Survey Sample Demographics versus Physical Impacts

	View	Odor	Noise	Air Poll.	Water Poll.	Acct. Risk	Air Qual.	Water Qual.	Wild-life
Time in Neighborhood	n.s.	sig <5>	sig <5>	sig <5>	n.s.	n.s.	sig	n.s.	h.sig
Education	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Income	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Type of home	n.s.	h.sig apt >sf	sig apt >sf	h.sig apt >sf	n.s.	n.s.	h.sig apt >sf	sig apt >sf	sig sf>apt
Rent or own	m.s.	sig rent> own	sig rent> own	sig rent> own	n.s.	n.s.	sig rent> own	sig rent> own	sig rent> own
Children in household	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Chi-square and Fisher exact tests significant if $p<0.05$

Table 5.C8b - Salem Incinerator - Survey Sample Demographics versus Physical Impacts

N= 26-34

	Impacts View	Odor	Noise	Air Poll.	Water Poll.	Acct. Risk	Air Qual.	Water Qual.	Wild-life
Time in Neigh borhood	n.s.	sig over 5 years under 5 years	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Education	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Income	sig. high > low	n.s.	n.s.	h.sig. low> high	n.s.	n.s.	n.s.	n.s.	n.s.
Type of home	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Rent or own	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	sig rent> own	n.s.	n.s.
Children in house-hold	n.s.	n.s.	n.s.	m.sig no child >child.	n.s.	n.s.	n.s.	n.s.	n.s.

Chi-square and Fisher exact tests significant at 95%

Table 5.C16a - Content Analysis of Newspaper Articles about Landfill Comparison of Media Frequency with Surveyed Frequency

	Mentioned Frequency % of articles	Difference of Proportions to Salient Beliefs	Belief Ratings	Belief Statements
N=	62	61	23	29
Nuisances				<sig
-noise	-	<sig	<sig	n.a.
-odor	-	<sig	<sig	n.a.
-view	-	<sig	<sig	n.a.
-litter	-	<sig	<sig	n.a.
-traffic	-	<sig	<sig	n.a.
-animals	-	<sig	<sig	n.a.
Health Risks				<sig
-air	55%	>sig	55%	n.a.
-water	100%	>sig	>sig	n.a.
-accident	100%	>sig	>sig	n.a.
Environment Change	14.5%	10%	n.a.	<sig
-air quality	-	<sig	<sig	n.a.
-water quality	36%	<sig	<sig	n.a.
-wildlife habitat	-	<sig	<sig	n.a.
Economic Impacts				
-property values	52%	>sig	48%	41%
-development	-	-	<sig	n.a.
-employment	-	-	-	n.a.
-taxes	-	-	-	n.a.
-costs	100%	>sig	>sig	n.a.
Social Impacts				
-image	100%	>sig	>sig	>sig
Political Impacts				
-control	23%	>sig	<sig	>sig
-fairness	-	-	-	-
-confidence				
-owner	73%	>sig	>sig	>sig
-local gov't	100%	>sig	>sig	>sig
-environ. agency	33%	>sig	22%	24%
-information	100%	>sig	>sig	>sig
Benefits				
-need/service	27%	26%	n.a.	<sig
-convenience	-	<sig	n.a.	n.a.
-energy	13%	>sig	>sig	n.a.
-better method	-	-	-	-
Not significantly different		2 of 23 = 8%	3 of 20 = 15%	2 o 11 = 18%

Legend
<sig=belief frequency significantly larger than newspaper freq.
>sig=newspaper frequency significantly larger than belief freq.
Differences significant if $p<0.05$

Table 5.C16b - Content Analysis of Newspaper Articles about Incinerator Comparison of Media Frequency with Surveyed Frequency

	Media Frequency % of articles	Difference of Proportions to Salient Beliefs	Belief Ratings	Belief Statements
N=	161	57	23	33
Nuisances				<sig
-noise	-	-	-	n.a.
-odor	-	<sig	-	n.a.
-view	9%	-	<sig	<sig
-litter	-	-	-	n.a.
-traffic	11%	<sig	<sig	n.a.
-animals	-	-	-	n.a.
Health Risks				
-air	37%	29%	-	24%
-water	-	-	-	n.a.
-accident	-	-	-	n.a.
Environment Change	18%	12%	-	n.a.
-air quality	5%	<sig	<sig	<sig
-water quality	-	-	-	n.a.
-wildlife habitat	-	-	-	n.a.
Economic Impacts				
-property values	1%	<sig	<sig	<sig
-development	-	-	<sig	n.a.
-taxes	24%	>sig	-	n.a.
-costs	66%	>sig	>sig	n.a.
Social Impacts				
-image-waste	48%	>sig	56%	49%
-pollution	8%	<sig	<sig	<sig
Political Impacts				
-control	-			
-fairness	21%	>sig	<sig	<sig
-confidence				
-owner	11%	>sig	<sig	18%
-local gov't	58%	>sig	65%	>sig
-environ. agency	10%	>sig	<sig	<sig
-information	13%	>sig	<sig	<sig
Benefits				
-need/service	22%	>sig	n.a.	<sig
-convenience	-	>sig	n.a.	<sig
-energy	42%	>sig	>sig	n.a.
-better method	16%	18%	n.a.	n.a.
- employment	10%	18%	>sig	n.a.
Not significantly different		4 of 17 = 24%	2 of 16 = 13%	3 of 16 = 19%

Legend
<sig=belief frequency significantly larger than newspaper freq.
>sig=newspaper frequency significantly larger than belief freq.
Differences significant if $p<0.05$

Table 5.C25a - Tacoma Landfill - Host Community Residential Real Estate Sales, 1983 - 1988 Multiple Regression Results

Variables	Partial Correl. Coeff.	Partial F	Signif	Assumptions	
	Area 5 - University Place				
Dependant: Sales Price - R squared = 0.74					
on		78.8	0.0000	Normality	good
Square feet	0.69	10.7	0.0000	Const. Var.	good
Age	-0.51	-6.8	0.0000	"	fair
Basement	-0.28	-3.3	0.0011	"	moderate
Quarter of Sale	-0.21	-2.5	0.0133	"	good
Condition	0.21	2.5	0.0153	"	moderate
Dependant: Days on Market-R squared= 0.07				Normality	poor
on					
Age	-0.21	-2.5	0.0139		poor
Year of Sale	-0.2	-2.4	0.0190		moderate
	Area 6 - Fircrest				
Dependant: Sales Price - R squared = 0.73					
on		98.9	0.0000	Normality	moderate
Square feet	0.74	14.5	0.0000	Const. Var.	poor
Age	-0.28	-3.9	0.0002	"	moderate
Lot size	0.25	3.4	0.0009	"	moderate
Quarter of Sale	0.17	2.3	0.0210	"	moderate
Condition	0.17	2.3	0.0214	"	poor
Dependant: Days on Market-R squared =0.067				Normality	poor
on					
Square feet	0.14	1.8	0.0734	Const. Var.	fair
Quarter of Sale	0.20	2.8	0.0063	"	fair
Year of Sale	-0.19	-2.6	0.0106	"	fair
	Area 10 - Orchard				
Dependant: Sales Price-R squared=0.77		143. 3		Normality	good
on		143.3	0.0000		
Condition	0.67	16.5	0.0000	Const. Var.	fair
Square feet	0.40	8.1	0.0000	"	good
Age	0.30	-5.8	0.0000	"	moderate
Fireplace	0.37	7.4	0.0000	"	-
Bedrooms	0.32	6.3	0.0000	"	moderate
Risk	0.25	4.8	0.0000	"	-
Garage	0.15	2.8	0.0047	"	-
Air Quality	0.13	2.4	0.02	"	-
Dependant: Days on Market-R squared=0.015				Normality	poor
on		6.1	0.014		
List date	-0.13	-2.5	0.014		poor

Table 5.C25b - Salem Multiple Regression Results

Variables	Partial Correl. Coeff.	Partial F	Signif	Test of Assumptions	
	2.Q. 1983 - 1.Q. 1987				
Dependant: Sales Price - R squared = 0.44					
on		24.2	0.0000	Normality	poor
Square feet	0.30	2.92	0.0045	Const. Var.	moderate
Lot size	0.37	4.67	0.0000	"	poor
Bedrooms	0.23	2.16	0.0338	"	moderate
Dependant: Days on Market-R squared = 0.073					
on				Normality	poor
Garage	-0.27	-2.62	0.0104		
	1.Q. 1985 - 1.Q. 1987				
Dependant: Sales Price-R squared = 0.54					
on		15.16	0.0000	Normality	poor
Lot size	0.70	4.57	0.0002	Const. Var.	poor
Age	-0.42	-2.19	0.0393	"	poor
Dependant: Days on Market-R squared=0.50					
on		7.0	0.0020	Normality	poor
Price	0.55	2.98	0.0071	Const. Var.	poor
Basement	0.50	-2.67	0.0144		
Year of Sale	-0.44	-2.22	0.0375	"	poor
	2.Q. 1983 - 4.Q. 1984				
Dependant: Sales Price-R squared=0.52					
on		17.2	0.0000	Normality	poor
Square feet	0.39	3.2	0.0024	Const. Var.	fair
Lot size	0.40	3.3	0.0016	"	poor
Bedrooms	0.36	2.9	0.0061	"	moderate
List date	-0.27	-2.1	0.0371	"	poor
Dependant: Days on Market-R squared=0.153					
on			0.0082	Normality	poor
Garage	-0.35	-2.8	0.0062		-
Condition	0.28	2.2	0.0321	-	

Appendix - Impact Reduction Measures - Cost Estimates and Reduction Effects

Note on Calculation of Annualized, per Capita Costs

Capital investments are annualized by capital recovery, at 5% real interest per year compounded annually over 20 years, hence the capital recovery factor is C * 0.08024 per year.

Mobile equipment costs are annualized by capital recovery at 5% real interest per year compounded annually over 5 years, with a resulting capital recovery factor of C * 0.23. Inflation is omitted because it is assumed to be constant and consistent for all measures. Hence, there are no differences in the calculated costs.

Total annualized costs are expressed as unit costs per metric tonne ($/m tonne) and converted to costs per year per capita by multiplying unit costs per tonne by the solid waste generation rate of 0.6 m tonne/capita-year. Thus for 170,000 m tonnes per year disposal capacity, the costs are spread over 283,335 residents.

Appendix 6.A1

PREVENTION of LANDFILL LEACHATE EMISSIONS THROUGH SEPARATION and COMPOSTING of ORGANIC FRACTION

System Description

The processable waste without bulk items is shredded and ballistically classified by particle size and density into a light, mainly paper and plastic fraction (40% by weight), a wet, mainly organic fraction (43% by weight) and a residual (15%) fraction. Ferrous metals (2%) are removed magnetically. The light fraction is baled and landfilled; the residue is directly landfilled. The wet, mainly organic fraction is composted on site to reduce the readily degradable biological content to more stable organic (humic and fulvic) acids. In the compost process, a weight loss of 33% occurs through evaporation of water and degradation of organic matter (see flowchart in figure 6.A.1).

The flowchart below (figure 6.A.1) shows the waste flows that produce a mass flow of 170,000 metric tonnes per year equal to raw waste mass placed in the landfill at present. The mass loss of about 10% in the composting process is compensated by a larger raw waste stream.

Separation and Composting Costs

A basic cost model was constructed to predict the separation costs. Some assumptions were made to calculate conservatively high costs for urban site conditions in Canada:

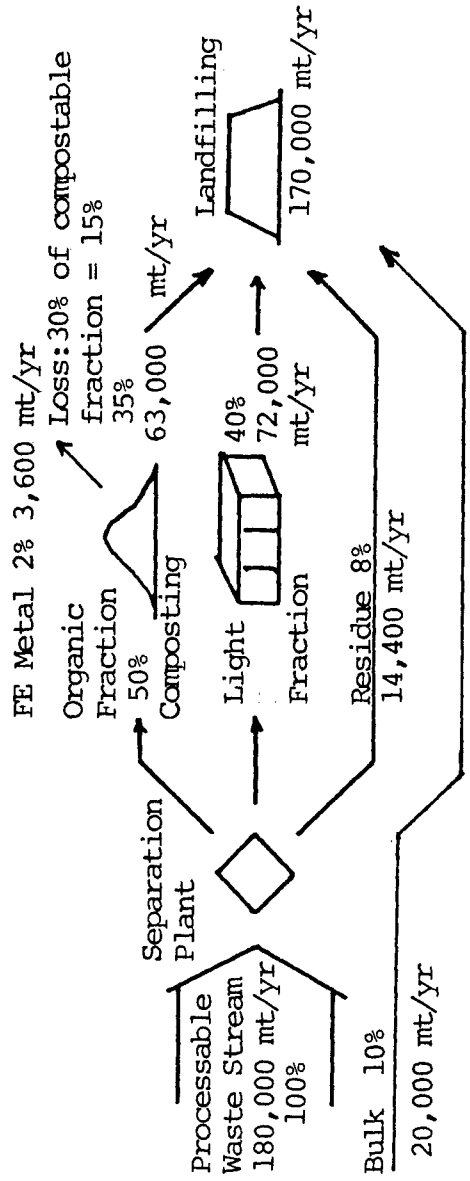


Figure 6.A1: Separation and Composting of Organic Fraction to Reduce Leachate Emissions from Landfill

Assumptions:

Operation

Capacity	60 tonnes/hour
Efficiency	83%

Capital Cost

Land and Building	$5.5-10^6$	(AEC, 1988).
Machinery	$19-10^6$	(AEC, 1988).
Materials Handling Equipment (bins, tractors, loaders)	$1.8-10^6$	(Finning Tractor,1988).

Operating and Maintenance Costs

Personnel -	10.0	per shift in plant	(AEC, 1988).
	1.5	per shift at compost	
	1.0	per shift at scales	
	12.50	per shift for 2 shifts =	25.00
		management and office =	2.50
		Total	27.50

Administration and taxes -	1.5% of annual capital cost
Insurance -	1.5% of annual capital cost
Building maintenance -	1.0% of building cost
Machinery maintenance -	4.0% of machinery cost
Energy - required	32 kWh/tonne (PLM, 1986)
- electricity cost	$0.025/kWh (B.C. Hydro, 1986)
Residual and bulk disposal	$25.-/tonne
(as for present waste disposal)	
Revenue - Ferrous Metals	$60.-/tonne (pers. comm. Pacific Metals, 1988).

The summary of the results follows.

Compost Separation Plant PLM Brini System

Waste Stream	tonnes/year		200000.00
Bulk items in % of WS	10.00		20000.00
Process Waste	tonnes/year		180000.00
Days per year operating		300.00	
Unit capacity	6.00	60.00	
Hours per shift		8.00	
Efficiency %		83.00	
Shifts per day required		1.50	180000.00
Shifts run average		2.00	

Products in % of the Processable Waste			%	(% of total waste)
	RDF	Fuel	40.00	36.00
	Organic	Fraction	43.00	38.70
	Ferrous	Metals	2.00	1.80
	Paper	Low Grade	0	0
		High Grade	0	0
		Corrugated	0	0
Residual			85.00	76.50

Compost Separation Plant

Capital Investment

Building plus land		$ 5,500,000.-
Machinery		$19,000,000.-
		$24,500,000.-
Annual Captial Recovery (0.0802)		$ 1,970,000.-
Materials Handling Equipment		$ 1,800,000.-
Annual Capital Recovery (0.23)		$ 410,000.-
Total capital costs per year		$ 2,380,000.-
O + M Costs		
Personnel	- 27.5 positions at $40,000/year	$1,100,000.-
Administration	- 1.5% of capital investment	$ 367,050.-
Insurance	- 1.5% of capital investment	$ 367,050.-
Maintenance	- Building - 1% of cost	$ 55,000.-
	- Machinery - 4% of cost	$ 760,000.-
Energy	- 32 KWh/mt times $0.025/KWh	$ 192,000.-
Residue disposal at $25.-/m tonne		$3,825,000.-
Total O + M Costs		$6,666,100.-
Revenues		
Ferrous Metal at $60m/tonne		$ 216,000.-
Total Plant Costs less Revenues		$8,830,100.-
Plus Bulk Waste Disposal at $25/m tonne		$ 500,000.-
Total Costs per year		$9,330,100.-
Costs per tonne		$ 46.65.-
Costs per capita per year		$ 28.00.-

The total cost for separation and composting amounts to $46.65 per tonne of waste stream. From this amount, the present landfilling cost of $25. - per tonne must be subtracted:

Unit separation and composting cost	$46.65
Present unit landfilling cost	$25. -
	$21.65/tonne

At 0.6 tonne per capita per year waste generation, the additional cost is therefore $13.00/capita per year

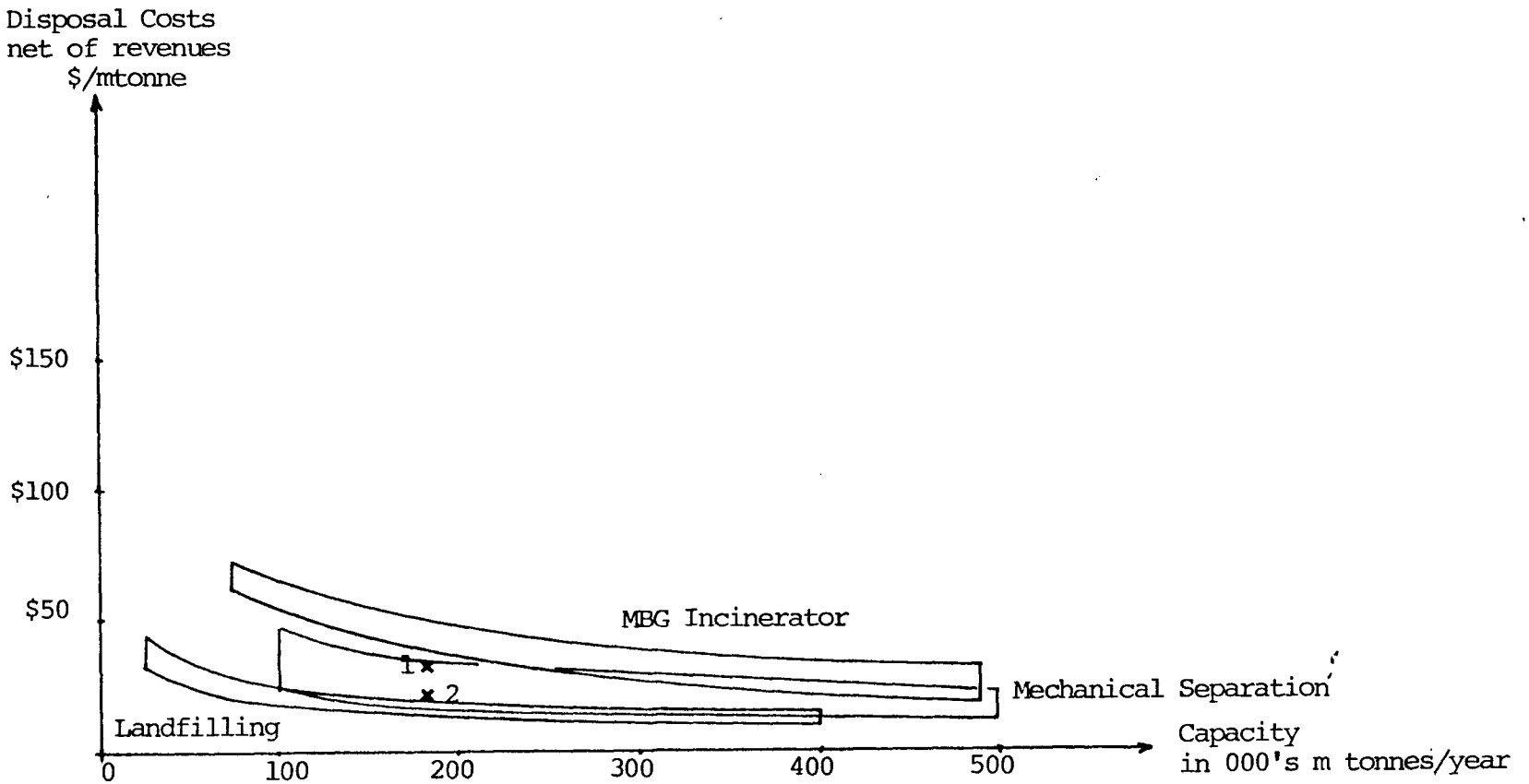
Cost Model Validation

Individual elements and values are obtained from the PLM system's Canadian representative (Advanced Ecology Corporation, Ltd.) and directly knowledgable sources (B.C. Hydro, Pacific Metals).

The predicted processing cost results from this model (Zeiss, 1986) were compared with updated results from a disposal cost analysis from Germany (see figure 6.A2 UBA-F.R.G. 1982, after Ludwig, 1984). Because the graph shows costs net of energy revenues, the energy value of 8GJ at $1.50/GJ is subtracted from the estimated separation cost to make them commensurate:

Estimated separation cost	$46.65	
less	12. -	Energy Value
	$34.65	per tonne.

Finally, the sensitivity analysis shows the separation costs to be most sensitive to waste stream tonnage and, secondly, capital cost (see figure 6.A3). Because these two factors are well defined with reliable cost values, the model results are likely fairly accurate.



Legend: 1 - Separation of Organic Fraction and Composting
2 - Separation of RDF (fuel) Fraction

Figure 6.A2 - Disposal Cost Validation with General Disposal Costs: after UBA-FRG Materialien, 1982.

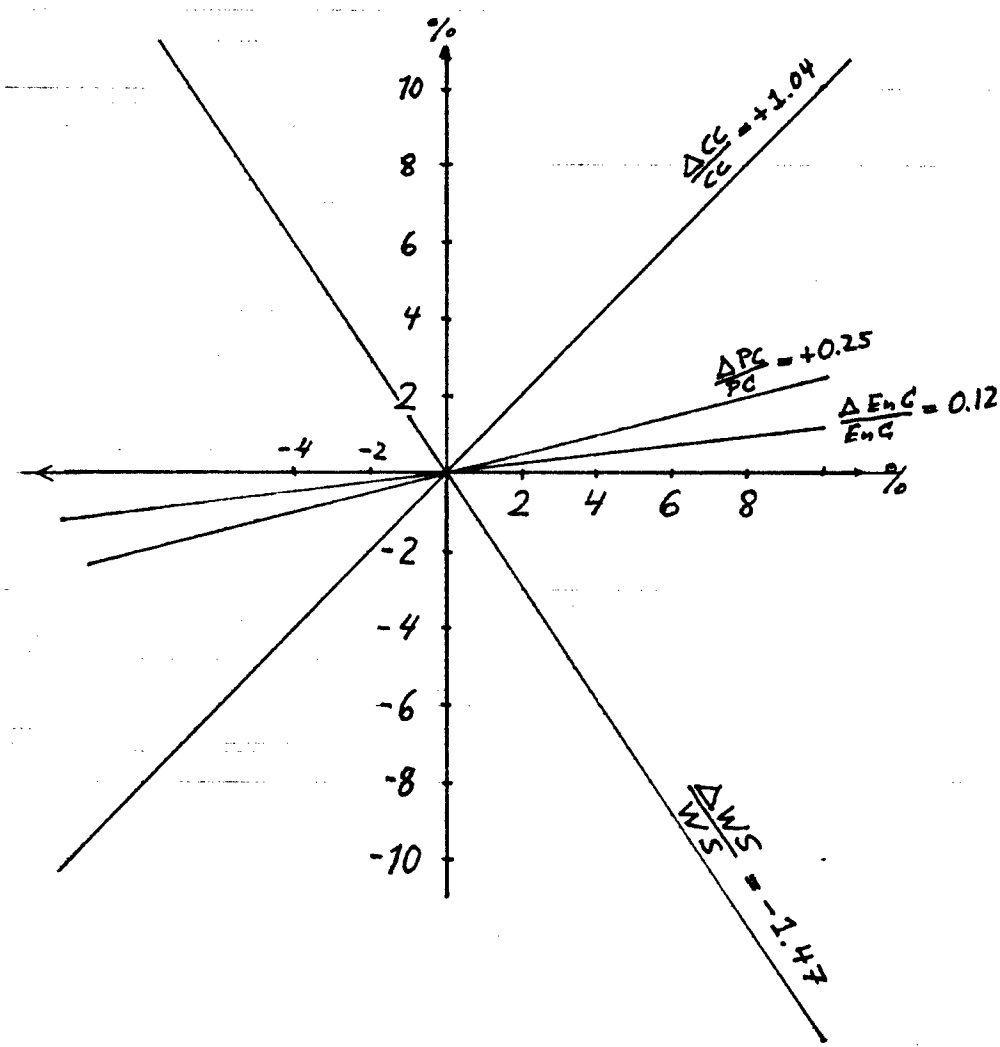


Figure 6.A3: Sensitivity Analysis for Mechanical Separation Plant Costs

Reduction of Leachate Emissions to Water through Separation

Potential leachate contaminants consist of BOD/COD, NH_3, heavy metals (Fe, Mn, Cd, Cr, Cu, Pb, Ni, Zn), volatile organics (e.g. vinyl chloride), and polycyclic aromatic hydrocarbons (PAH's, e.g. benzo (a) pyrene, etc.). The effect on leaching of separation and composting of the organic fraction is described briefly.

Organic Matter

The separation and aerobic degradation of organic matter (40% by weight of the waste stream with 50 to 70% of putrescible matter) eliminates leachable organic matter by conversion to energy (heat) and to more stable and better bound forms (humic and fulvic acids). Nitrogen and phosphorous are used simultaneously in the growth process to the point where these nutrients may be the limiting factors in the compost process. Nitrogen in excess of a carbon to nitrogen ratio of 15-30 to 1 is removed through ammonia volatilization. With a four to six month composting period, the temperature of composted soil decreases and indicates the completion of biological activity (Bilitewski, 1985). Thus, a significant reduction of easily leached organic matter in the landfill results from this process. Since the organic fraction contains most of the easily degradable organic matter (food, yard wastes), a 50% reduction of organic matter and of available nitrogen and phosphorus is assumed.

Heavy Metals

Metals (except cadmium) in the waste stream tend to concentrate in the smallest particle size ranges of the organic and residue fraction (Edner, 1985, Bilitewski, 1985, Krauss, 1985). Thus, separation enriches the compostable fraction with metals (except cadmium). Furthermore, metal concentrations tend to increase marginally during composting through weight loss of the compost fraction. Using metal concentrations in the compost similar to those reported in Bilitewski (1985) and Krauss (1985), actual leachate tests (Dyer and Razvi, 1987) show a metal retention of 96.8% of applied metals at 100% compost soil content after application of 60 inches (1.5m) of water. The metal concentrations in the leachate were shown to be below Drinking Water Standards. Furthermore, very low amounts of the metals are taken up by plants. The observed retention of metals in the soil is explained by the association of metals with colloidal particles, and the entrapment of colloidal particles in the soil. pH control, however, is identified as a major factor in maintaining the metal retention in the soil.

Assuming over 50% concentration of leachable metals in the compost fraction (Bilitewski, 1985) and total metal leachability of under 4% from this fraction, a 50% reduction in heavy metal leaching should result from the separation-composting waste treatment.

Volatile Organics and PAH's

Low concentrations of VOC's were measured in municipal wastes in the range of 10 to 1,600 mg/g refuse for chlorophenols,

chloro benzenes, PCB's, and dioxins and furans (Ozvacic et.al., 1985). In the composting process, a continuous heat and moisture transfer occurs from inside to outside of the windrows; the piles are turned frequently at the beginning of the process. Mixing and exposure to air at temperatures up to 60°C over 3 to 6 months are highly likely to eliminate materials with volatilization half-lives of under 5 to 6 hours from aqueous solutions (USEPA, 1979).

PAH's have been shown to be reduced by factors of two to five times over a three to six month composting period (Bilitewski, 1985) and by 50% in Hagenmeier (1983). Since burn tests show a substantial reduction (by 97%) of PAH emissions in separated RdF compared with raw waste, it is likely that PAH's are concentrated in the organic fraction. Thus, the PAH reduction in the compost fraction is likely to reduce the overall PAH concentrations in the landfill by 50%.

These reduction effects are estimates only. Further reduction by separate placement in the landfill and special leachate collection and treatment is possible, but not included here. Furthermore, the volume reduction through processing of a given waste stream is disregarded.

Appendix 6.A2

Landfill-Liner, Cover, Leachate Treatment System through installation of a double liner, single cover, leachate collection system and treatment in aerated lagoons.

A. Leachate Flows
Maximum Flow

Use 25 year max. 24h precipitation (US-Federal Register, 1982). This is consistent with design basis for liner system.

For Tacoma Landfill, use Seattle Tacoma Airport data: 3.74 inches/24h (NOAA, 1985) = 95mm/24h, at 30% infiltration, leachate production is 28.5mm/24 hours over 170 acres (at 4,043 m^2/acre) equals 687,370m^2 maximum. This results in a maximum leachate generation of 19,590m^3/day or 5.367-mgal/day.

This peak flow is relevant for the hydraulic design of the system. It is assumed that the flow can be stored in the liner and collection system. The treatment system is designed for the average flow in the highest month with a security factor of at least 2. The averages of maximum monthly precipitation at Sea-Tac Airport occurs in December at 6.33 inches per month. This value translates into 160.8 mm precipitation and with an infiltration rate of 30%, into 48.25 mm/month leachate production. Over the landfill surface of 170 acres or 687,370 m^2, the average maximum daily flow of 1,106 m^3/day is obtained, equivalent to approximately 307,220 U.S. gallons per day.

Total annual precipitation in Tacoma is 37 to 38 inches/year or 940 to 965mm/year.

Evapotranspiration = 10.2"/year, or 260mm/year.

Infiltration is 30% of precipitation (Black and Veatch, 1987),

or 282mm/year over 687,370m^2, results in an average leachate production of 193,840m^3/year or 531m^3/day, equals 147,500 US gal/day average.

Leachate Collection, Double Bottom Liner and Top Cover

The costs for a liner, cover and leachate collection system are estimated for the Tacoma landfill site as a new installation. The costs are then validated by comparison with the USEPA cost estimates for landfill liner systems (U.S. Federal Register, 1982).

The detailed landfill liner costs are based on a basic design comprising 24 cells of 10m depth and approximately 7 acres surface each. The construction is assumed to occur at the rate of one cell per year over the life of the landfill.

The costs are summarized here for the basic design shown in Figure 6.A1 and based on recent unit costs in Glebs (1988):

	$(1988)
Site Excavation	
average 2m deep over entire site (687,370m^2)	
at \$5.-/m^3	\$ 6,873,700.-
Clay bottom liner -	
1.5m thick over entire site	
clay hauled in and placed at \$10/m^3	\$10,410,550.-

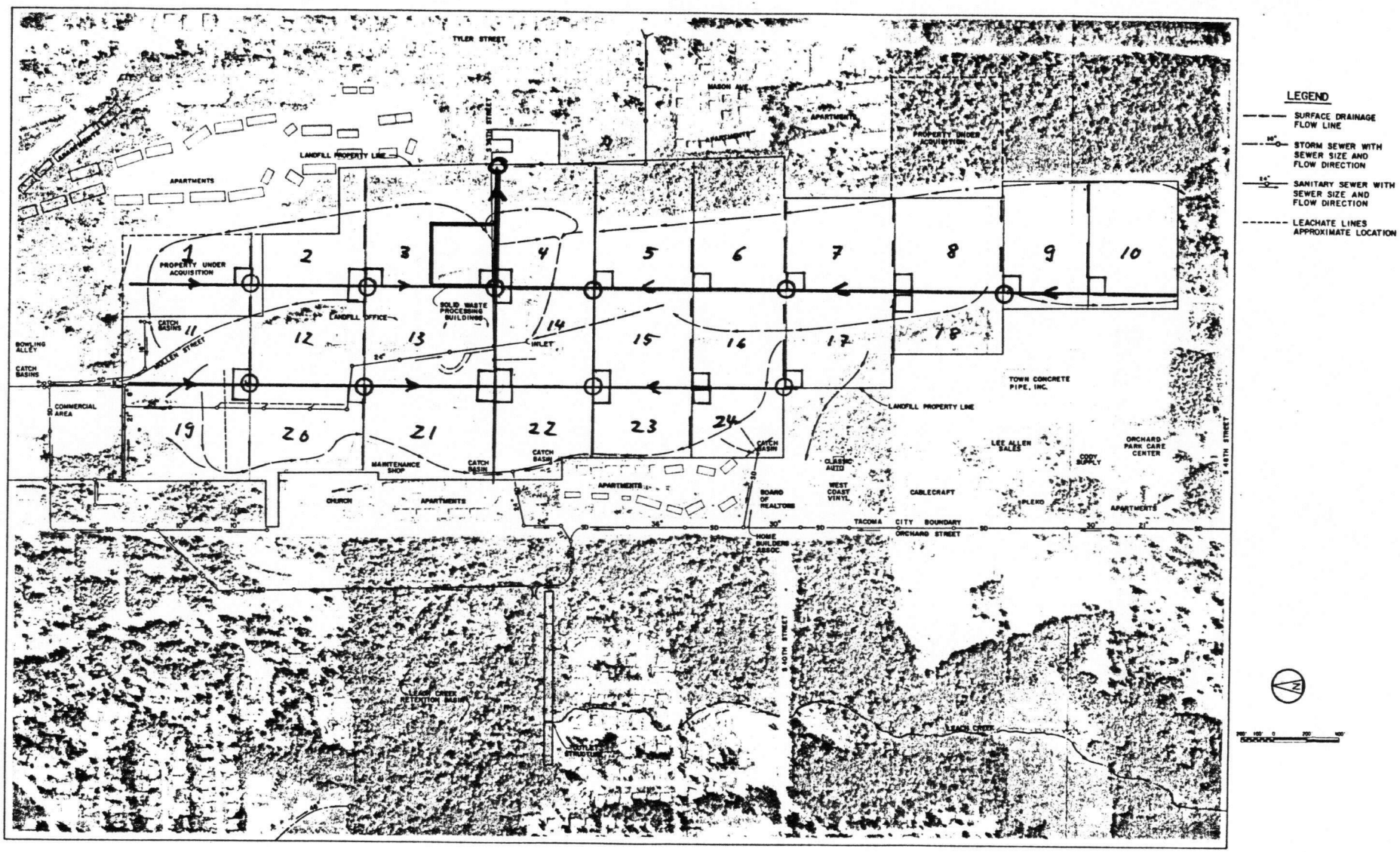


Figure 6.A1 - Leachate Collection System

Synthetic bottom liner -	
80 mil HDPE at $15.5/m^2	
over entire site with 25% extra	
for side slopes	$13,318,000.-
Top Synthetic Liner -	
60 mil HDPE over entire site at $15.50/m^2	$10,654,240.-
Sand Blanket	
30cm thick over entire site at $12.35/m^3	$ 2,546,706.-
Cell Leachate collection pipe	
6" over length of cell (170m x 24 cells)	
at $9/m	$ 36.820.-
Trunk collection pipe	
12" to 24", total 3,520m at	
$18/m	$ 63,360.-
Ditching for Trunk lines	
3,520m at $6.75/m	$ 23,760.-
Manholes and pumps	
10 at $33,000.- each	$ 330,000.-
Lysimetres	
1 for each cell at $1,560 each x 24 cells	$ 37,440.-
Storage tanks	
1 each for 10,000 US gallons per cell x 24	
at $20,500 each	$ 492,000.-
Total Capital Investment	$44,686,470.-

Over 20 years, the yearly capital investment (without inflation) is equal to $2,234,325.- or $13.15 per metric tonne, or $7.90 per

capita per year.

In comparison, the installation cost for a landfill liner system for a capacity of 170,000m tonnes per year is extrapolated from US Fed. Register (1982) at (US-1982) $10/m tonne, and converted at 5% annual inflation and 1.3 exchange rate to Canadian 1988 $17.50/m tonne, or $10.50 per capita per year.

The former estimate is made for site specific design and recent actual bid costs (Glebs, 1988). However, to be conservatively safe, the latter, higher value of $10.50 per capita per year will be used.

Leachate Treatment

The system comprises treatment steps to eliminate VOC's through activated carbon filtration, followed by aerated lagoon removal of BOD and ammonia.
A granula filtration step preceeds the carbon filtration to remove solids that may clog the system.

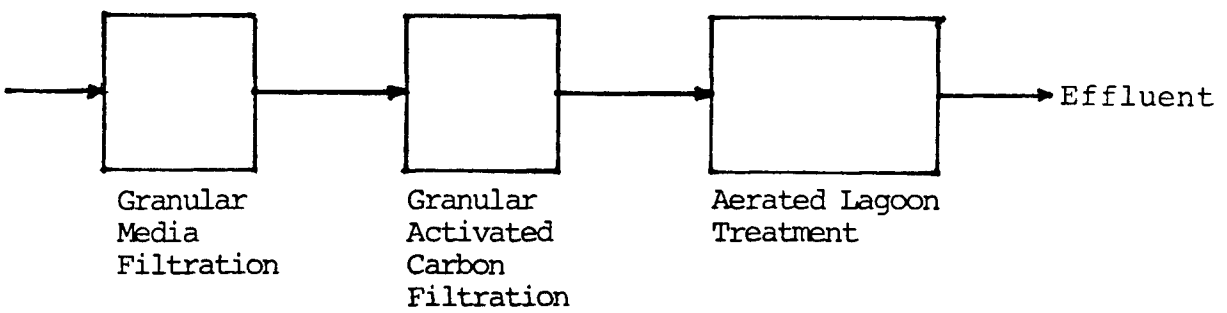


Figure 6.A2 - Leachate Treatment System

Leachate Treatment Calculation

For an aerated lagoon design, typical leachate characteristics and completely mixed-no recycle design equations are used to verify the capacity for 90% removal efficiency for BOD and ammonia:

Typical Characteristic

	Leachate	Sewage
BOD_5 (new)	9000 mg/l	220 mg/l
NH_4+-N (old)	500 mg/l	25 mg/l
Kinetic Coefficients - BOD^5 (Wong and Mavinic, 1984)		
K	1.12/day	5.0/day
Ks	63.8 mg/l	60 mg/l
Y	0.51 mg/mg	0.6 mg/mg
K_d	0.018/day	0.06/day
Temperatures		
Waste-winter (National Weather Service, 1986).	10^oC	15^oC
Air		
-winter	5^oC	
-summer	15^oC	

In order to use cost estimates (USEPA, 1984 for aerated lagoons for domestic sewage, the ratios of important system characteristics for leachate and sewage systems are estimated.

Assume a design retention time of 7 days for sewage, and 20 days for leachate to allow for nitrification to occur.

Then, for 90% removal efficiency,

Leachate	Sewage
So = 9,000 mg/l	220 mg/l
Se = 900 mg/l	22 mg/l
= 20 days	7 days

Biomass

X = 3,000 to 3,500 mg/l MLUSS	75 to 81 mg/l
Lagoon volume	
$1{,}106m^3$/day x 20 days = $22{,}112m^3$	$1{,}106m^3$/day x 7 days = $7{,}742m^3$
Lagoon surface at 3m depth	
$\frac{22{,}112m^3}{3m} = 7{,}371m^2$	$\frac{7{,}742m^3}{3m} = 2{,}581m^2$

Resulting Treatment Temperatures

$$Tw = \frac{A * f * Ta + Q * Ti}{A * f + Q}$$

$Q = 1{,}106 m^3/d$

$f = 0.5$ (Metcalf and Eddy, 1979)

A = lagoon surface, leachate = $7{,}371 m^2$; sewage = $2{,}581 m^2$

Tw - winter	= 6^oC	9.6^oC
Tw - summer	= 14^oC	15^oC

Temperature could have a significant effect on treatment efficiencies. Since no actual data is available, safety factors will be calculated for the system.

Efficient Quality $$S_e = \frac{K_s(1 + \theta k_d)}{\theta(YK - k_d) - 1}$$

Se design = 8.62 mg/l BOD_5	4.4mg/l

Minimum retention time to meet 90% efficiency

$$\frac{1}{\theta \min} = Yk - k_d$$

$$\theta \min = \frac{1}{Yk - k_d}$$

θ min = 1.81 days	0.34 days
$SF = \frac{\theta \text{ design}}{\theta \min} = 11$	= 2.1

In both systems, a large safety factor for BOD removal is designed into the system.

For the leachate system, ammonia removal is of major concern, particularly for "older" leachates.

The ammonia removal efficiency of 90% is checked here for the leachate system only. The volatilization of ammonia accross the surface is ignored here, but adds to the removal efficiency.

No = 500 mg/l - with 90% efficiency = Ne = 50mg/l

θ = 20 days

Assume maximum specific growth rate (μm) = 0.3/day

(Metcalf and Eddy, 1979, Table 12-9).

$T_{min.}$ = 6°C DO = 1.5mg/l pH = 7.0 K_{02} = 1.3

corrected for temperature, DO, pH:

$$\mu'm = (\mu m) * e^{0.008T-15} * \frac{DO}{K_{02}} + DO\,[1+0.833\,(7.2-pH)]$$

μm = 0.17

$$k^1 = \frac{\mu'm}{y} \qquad \text{assume y (min) = 0.1}$$

$$k^1 = \frac{0.17}{0.1} = 1.7/\text{day} \qquad k_d = 0.04$$

Hence, minimum required retention time.

$$\theta\,\text{min} = \frac{1}{Yk - kd} = \frac{1}{0.13} = 7.7 \text{ days at } 6^{\circ}C$$

$$\text{Safety factor} = \frac{20 \text{ days}}{7.7 \text{ days}} = \underline{\underline{2.6}}$$

Oxygen requirements:

$$O_2 \text{ kg/d} = \frac{Q(So-Se)}{f} - 1.42\ Px + 4.57\ Q(No-Ne)$$

BOD for soluble BOD conversion with $f = 0.68 \times BOD_L = BOD_5$

Leachate	Sewage
$\frac{1{,}106 m^3/d * 8{,}975 g/m^3}{0.68} = 14{,}591$ kg/day	$\frac{1{,}106 * 210 g/m^3}{0.68} = 342$ kg/d

Biological solids wasted Px = X * Q

$3{,}400\ g/m^3 * 1{,}106 m^3/day = 3{,}761$ kg/d $*81 g/m^3 * 1{,}106 m^3/d = 90$ kg/d

Nitrification

$4.57 * 1{,}106 m^3/d * 450 g/m^3$ = 2,275kg/day	$4.57 * 1{,}106 m^3/d * 22.5 g/m^3$ = 114 kg/d.

Total O_2 requirements:

O^2 kg/d = BOD - 1.42 pX + 4.57 Q (No-Ne)

= <u>11,525 kg/day</u>	= <u>328 kg/day</u>

Oxygen Power Requirements

CL = 1.5 mg/l C Sat. (T = 14°C) = 8.8mg/l
= 0.6 for leachate, x 0.85 for sewage
= 0.9 for leachate, 1.0 for sewage

Correction factor $f = \frac{\beta * Csat - CL}{9.17} * 1.024^{T-20} * \alpha$

Leachate	Sewage
0.36	0.71

Field transfer rate

$$N = No * f$$

$$No = 2.0\ kgO_2/KWh$$

$N = 0.73kg\ O_2/kWh * 24h/d$ $N = 1.42kg\ O_2/kWh * 24h/d$

$= 17.5\ kgO_2/kW * d$ $= 34.1\ kg\ O_2/kW * d$

Energy required

$\frac{11,525kg/d}{17.5kg\ O_2/kWd}$ $\frac{328kg/day}{34.1kgO_2/kWd}$

= 659 KW = 10KW

Mixing Requirements

Leachate	Sewage
Volume = $22,110m^3$	$7,742m^3$
at $15KW/1,000m^3$ (Metcalfe and Eddy, 1979)	at $15KW/1,000m^3$
= 332 KW	= 116 KW

Comparison of treatment design factors

	Leachate	Sewage	Ratio Leachate/sewage
Volume	$22,110m^3$	$7,742m^3$	2.9x
Energy	659 KW	116 KW	5.7x
	(O_2 supply)	(mixing)	

Therefore, a ratio of 3 x will be used for capital costs and a ratio of 6x will be used to estimate operating costs for aerated lagoon treatment of leachate over domestic sewage.

Equivalent Flows for Cost Calculation

	Leachate		Ratio		Equivalent Sewage
Capital					
	$1,106m^3/d$	*	3	=	$3,318m^3/d$
				=	922,000 US gal/d
			equals (say)		1m gal/day
Operator	$1,106m^3/d$	*	6	=	$6,636m^3/d$
			will use		1,843,350 US gal/day

Aerated Lagoon Costs (USEPA, 1984):

	US (1980)-$		Can. (1988) $
Capital investment	300,000		$600,000
		per year =	$ 48,150.-
Operating	$52,000		$104,000.-
Total per year			$152,150.-
per m tonne			$0.90/m tonne
per capita			$0.54/capita-year

Granular Media Filtration

	US (1980)-$	Can. (1988) $
Capital	$850,000.-	$1,700,000
	per year =	$ 136,410.-
Operating	$ 50,000.-	$ 100,000.-
Total		$ 236,410.-
per m tonne		$1.40/m tonne
per capita per year		$0.85/capita-year

Granular Activated Carbon System

Capital	$1,000,000.	$2,000,000
	per year =	$ 160,500.-
Operating	$ 110,000.-	$ 220,000.-
Total per year		$ 380,500.-
per m tonne		$2.25/m tonne
per capita per year		$1.35/capita-year

Sewer Discharge Costs (Gleb, 1988):

Total annual leachate generation of 194,000m^3/year at $4/$m^3$	$776,000/year
per m tonne	$4.56/m tonne
per capita per year	$2.74/capita year

Leachate Liner, Collection and Treatment Cost Summary

Totals - per capita per year

Liner, Collection System	$10.50/capita-year
Leachate Treatment	$ 2.75/capita-year
Discharge costs to sewer	$ 2.75/capita-year
	$16.00 per capita-year

Removal Efficiency

Based on empirically established treatment coefficients, the expected removal efficiencies for most leachate contaminants (BOD/COD, TSS, NH_3, Fe, Mn, Zn) are over 90% (Uloth and Mavinic, 1977, Graham and Mavinic, 1979, Zapf-Gilje and Mavinic, 1981, Keenan et.al., 1984, Robinson, 1985).

Therefore, a minimum removal efficiency of 90% is applied here for the standard pollutants. Since the VOC's are of concern here, the reduction due to volatilization during aeration likely to effectively reduce concentrations is estimated:

Use volatilization only -

Half lives of Benzene, Toluene in aqueous solution (USEPA, 1979):

$t_{\frac{1}{2}} = 5$ hours

Assume First-order reaction

$$\frac{dC}{dt} = -\lambda C \quad \text{with } \lambda = \frac{0.692}{t_{\frac{1}{2}}}$$

hence $\text{Ln} \frac{Co}{C} = \lambda t$, t = residence time

for 90% removal, $\frac{Co}{C} = 10$

and λ ($t_{\frac{1}{2}} = 5$ hours) = 0.14/hour (USEPA, 1979)

hence,

$$2.3 = 0.14 * t$$

t required for 90% removal = $t = \frac{2.3}{0.14/\text{hour}} = 16.62$ hours

or, the safety factor with a hydraulic retention time of 20 days = 480 hours

$$\text{is} \quad SF = \frac{480 \text{ hours}}{16.62 \text{ hours}} = \underline{\underline{29x}}$$

Thus, over 90% removal rate is highly probable.

Appendix 6.A3

Monitoring and Treatment at Landfill Boundary

- Frequency depends on groundwater velocity =

Maximum velocity (unretarded) - = 7.06×10^{-6} m/s

1 Month = $2.592.10^{6}$s

Travel distance per month = 18.3m

Judgment to monitor wells at landfill perimeter (17) and 4 municipal wells every month, to allow maximum migration outside the boundary of 18.3m between sampling.

Private wells are monitored every 3 months in addition.

- Elements to analyse

pH, conductivity, TSS., BOD/COD, NH_3-N, Metals (Fe, Mn, Pb, Hg), Cl^-, organics (vinyl chloride, methylene chloride, trichlorethylene, benzene, toluene, 1,2 - dichloroethene, 1,2 - trans-dichloroethene).

- Wells: Downgradient: TL-1 (A,B,C), TL-4, TL-8(A, B,C), TL-9, (A,B), TL-11, L1, L2, L3 = 13 wells

  Upgradient: TL-12, TL-15, TL-17, LW-1, = 4 wells

  - 4 municipal wells = 4 wells

  21 wells every month plus every 3 months for VOC's

  - 17 private wells = 17 wells every 3 months

- Monitoring Costs

  Per well - basic cost including preparation and analysis $122.-/sample

  - organics (-purge-trap-GC/MS) $200.-/sample

Source: pers. comm. A. Maynard, ASL, Inc., 1988.

- 13 downgradient, 4 upgradient, 4 municipal

	=21 wells - 12 */year at $122 =	$30,744.-/year
Private =	17 wells - 4*/year at $122 =	$ 8,296.-/year
	20 wells - 4 */year at $200.- =	$16,800.-/year
	Monitoring	$55,840.-/year
	Sampling 1 person - 24 days/year	$ 3,000.-/year
		$58,840.-/year
		Or $0.21 per capita per year.

- Counter-pumping and Treatment

Assume detection in year 0 and pump 20 years - cost per metric tonne (US-Fed. Reg. 1982) is between $0.50 to $1.0 per metric tonne, use (US) $0.75 (1982) per metric tonne to 1988 Can. $ = $0.75 * 1.74 = $1.31/m tonne

Costs -	Monitoring	$0.21/tonne
	Counter pumping and treatment	$1.31/tonne
		$1.52/tonne
	or	$0.88 per capita per year

Reduction Effects

If detection is immediate and remediation action rapid, then pollutants can be reduced through pumping, i.e. dissolution from a separate phase within 15 to 20 years (USEPA, 1987). Thus, a small volume of the aquifer remains unusable for this period.

Appendix 6.A.4

In-Kind Compensation: Monitoring of drinking water wells and Alternate Water Supply

- Monitoring

4 municipal wells and 17 domestic wells plus 2 background wells equals 23 wells once monthly

23 wells * 12 months * $322/sample = $88,872.-/year

- Alternative Water Supply

for 17 wells $82,000. - in year 5 (Black and Veatch, 1987)

equivalent to a PV of $64,250.- in year 1

or (A $64,250, 5%, 20) = $ 5,165.70/year

Total per year: $94,037.-/year

or $0.55 per metric tonne

or $0.35 per capita per year.

Appendix 6.B1

Landfill Nuisance Prevention

- Equipment noise control

2 Compactors "Detroit" Model 71 and 92

Noise levels at 15m to rear: 87dBA

The installation of improved intake and cooling fan silencers, enclosure of engine block and casings, and improved mufflers reduce the noise levels at source by 6 to 10dBA (Miller, 1980), down to 77 to 81dBA.

The added costs consist of retrofitted equipment (about $1,150. -, from Miller, 1980), and additional fuel and maintenance costs , for a total costs over the life of the equipment (5 years) of $8,937. - (Miller, 1980), or $0.01 per capita per year.

- Frequently cover refuse

Assume twice daily cover - doubles amount of required fill material, therefore at a daily capacity of 490m tonnes and a density of 0.5m tonne/m^3 in 10m lift, need cover material for two faces of 100m^2 each, or 200m^2 and 15cm (6 inch) thickness, or 30m^3 more per day. At $5.50/$m^3$ for material, hauling and tipping, the extra cost is $165.-/day for 350 days/year = $57,750.-/year or $0.34 per metric tonne, or $0.21 per capita per year.

Appendix 6.B2

Landfill-Nuisance Control

Berms, Trees and Vegetation around Landfill (see Figure 6.2):

- Berms

Total length of 2,900m

cross-section: 9m high with 2 to 1 slopes, 2 m wide crest

Total Volume: $180 \frac{m^3}{m} * 2{,}900m = 522{,}000m^3$

Total surface: $42.2 \frac{m^2}{m} * 2{,}900m = 122{,}380m^2$

Material hauling and tipping	at $\$5.5/m^3$	=	\$2,871,000.-
grading, smoothing	at $\$2. /m^3$	=	\$1,044,000.-
Vegetation on Berms	at $\$2/m^2$	=	\$ 244,760.-
Total Berms			\$4,159,760.-

- Trees

Double row of 5 to 6m tall trees on offset 8.5m centres

requires 2900m 8.5 = 342.0 trees per row times 2 rows

= 684 trees at \$60/tree = \$47,040.-

- Trees and heavy vegetation on NE slope:

Double row of 5 to 6m trees on 8.5m centres

along 700m 8.5m = 83 * 2 = 166 trees
at \$60/tree = \$ 9,960.-

plus shrubs and bushes over 700m

by 4.25m strip at $\$21.50/m^2$ = \$63,963.-

Total trees and vegetation on slope \$73,923.-

Cash Flow:

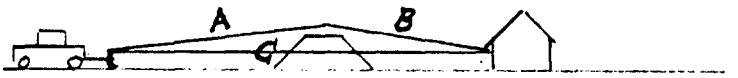
Assume nuisance control would be built at beginning of a 20 year life and amortized over 20 years, hence:

(A/P, 5%, 20) = $4,274,723 * 0.0804 = 343,881.-/year

or $2.03 per metric tonne

or $1.21 per capita per year.

Noise Attenuation by Berms



δ = A + B - C

δ = 100.28 + 50.56 - 150m = 0.84m

λ (for 250 H_z) = 1.36m

$N = \frac{\delta}{\lambda} = \frac{0.84m}{1.36m} = 0.62$ see graph pg: 4-23 Rau & Wooten,

Attenuation = 11 dBA

Incinerator Nuisance Control:

Tree Screen with one row of 9 to 12m trees and two rows of 5 to 6m trees.

Site Circumference: 1,030m

Tall trees: 100 on 10m centres at $5,000/tree = $500,000.-

Medium trees: double row on 8.5m centres over 1,030 m equals 122 times 2=244 trees at $60/tree = $ 14,640.-

$514,640.-

or $ 41,325.-/year

or $0.25 per m tonne

or $0.15 per capita -year

Appendix 6.B3

Landfill Nuisance Mitigation

- Noise and odor reduction in homes with double-paned windows and air conditioning
- View control with trees on residents' property

Per house - 2,000 square feet with 3 bedrooms and 10 windows

Double paned windows installed	- $3,000
Air conditioning installed	- $1,000
Trees - 10 per home at $60/tree	- 600
Total	$4,600 - per home

Three rows of 304 houses on 76 acres adjoining the landfill at 4 units per acre equals 1,000 houses plus 400 apartments at ½ cost equals a total mitigation cost of $5,520,000.-

Cash flow:

Installation spread over 20 years at $276,000.- per year

or $1.63 per metric tonne,

or $1.00 per capita per year.

Noise reduction:

Noise reduction through an additional window pane is estimated at 5dBA's (CMHC, 1981), assuming residences are exposed on one exterior wall, consisting of three elements:

- windows of 25% of floorspace
- exterior wall of 65% of floorspace
- exterior door of 15% of floorspace

Thus, by replacing a single, 2 pane with double glaxed (3mm + 3mm) windows at 20mm interspace spacing, the AIF is increased by 5 dBA.

Appendix 6.B4 - Compensation for Landfill Nuisances with 10% of Property Values

Affected area: 76 plots of 1 acre each

at $2.60 per square foot

1 acre (43,500 sq. feet) is valued at $113,100.-/acre

10% of value is $11,310.-/acre

for 76 acres is equal to $859,560.-

at 5% real interest over 20 years equals $69,100.-/year

or $0.41 per metric tonne

or $0.25 per capita per year

Appendix 6.C1

Prevention of Incinerator Air Emissions Through Separation of Refuse Derived Fuel

System Description

The processable waste stream (i.e. without bulk items) is shredded and ballistically classified into a refuse-derived fuel (RDF) fraction of 60% by weight, an organic fraction of 30%, a residue fraction of 8% and ferrous metals of 2% (see figure 6C.1).

The waste stream into the separation plant is determined so the total heat value into the incinerator is constant:

Present: 170,000 mt/yr at 8 GJ/mt = $1.36.10^6$ GJ/year

RDF: Need total $1.36*10^6$ GJ/year

RdF unit heat value (say) 12 to 13 GJ/mt

RdF mass flow: 105,000 to 113,300 mt/year

if 60% RdF equals 110,000 mt/year, then

total waste stream equals $\frac{110,000 \text{ mt/year}}{0.6}$ = 183,300 mt/year

use a raw processable waste stream of 180,000 mt/year.

The RdF is burned directly in the incinerator and produces 15% (of the RdF mass) ash by weight. The ash is landfilled. The organic fraction is assumed to be composted and landfilled as cover material. The residue (8%) is directly landfilled. Hence, the mass balance of landfilled material with separation prior to burning is as follows.

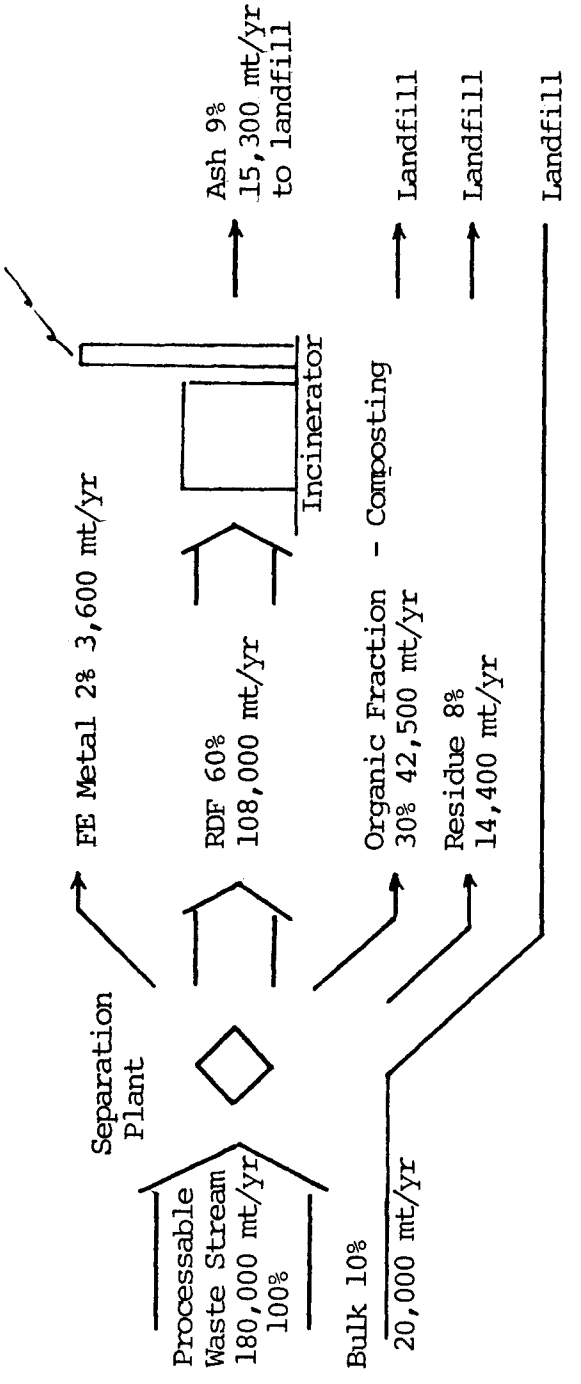


Figure 6.C1: Separation of Fuel Fraction to Reduce Incinerator Air Emissions

Landfilled Mass (basis raw waste stream = 100%)

	Incineration	RDF Separation
Bulk	10%	10%
Ash	33%	9%
Compost		20%
Residue		8%
	43%	47%

The somewhat higher weight of landfilled material with separation may be offset by the use of compost soil as cover material, thus requiring less cover material to be hauled in. The effects of the landfilled material on leachate quality and control are acknowledged here, but are outside the scope of this thesis.

Separation and Composting Costs

A basic cost model was constructed to predict the separation costs. Some assumptions were made to calculate conservatively high costs for urban site conditions in Canada:

Assumptions:

Operation

Capacity 60 tonnes/hour

Efficiency 83%

Capital Cost

Land and Building $5.5-10^6$

Machinery $19 * 10^6$ (AEC, 1988).

Materials Handling

Equipment (bins,

tractors, loaders) $1.8.10^6$ (Finning Tractor, 1988).

Operating and Maintenance Costs

Personnel - 10.0 per shift in plant (AEC, 1988).

1.0 per shift of scales

11.50 per shift for 2 shifts = 23.0

plus - management and office = 2.5

Total - = 25.50

Administration and Taxes - 1.5% of annual capital cost

Insurance - 1.5% of annual capital cost

Building maintenance - 1.0% of building cost

Machinery - 4.0 % of machinery cost

Energy - required 32. kWh/tonne (PLM, 1986)

- electricity cost $0.025/kWh (B.C. Hydro, 1986)

Residual and bulk disposal $25.-/tonne

(as for present waste disposal)

Revenue - Ferrous Metals $60.-/tonne (pers. comm. Pacific Metals, 1988).

The summary of the results follows.

RDF Separation Plant PLM Brini System

Waste Stream	tonnes/year		198000.00
Bulk items in % of WS	10.00		19800.00
Process Waste	tonnes/year		180000.00
Days per year operating		300.00	
Unit capacity	5.00	50.00	
Hours per shift		8.00	
Efficiency		83.00	
Shifts per day required		1.80	180000.00
Shifts run average		2.00	

Products in % of the Processable Waste			%	(% of total waste)
	RDF	Fuel	60.00	54.00
	Organic	Fraction	30.00	27.00
	Ferrous	Metals	2.00	1.80
	Paper	Low Grade	0	0
		High Grade	0	0
		Corrugated	0	0
Residual			33.00	29.70

RDF Separation Plant

Capital Investment

Building plus land		$ 2,700,000.-
Machinery		$19,000,000.-
Total		$21,700,000.-
Annual Captial Recovery (0.0802)		$ 1,745,000.-
Materials Handling Equipment		$ 1,800,000.-
Annual Capital Recovery (0.23)		$ 410,000.-
Total annualized capital costs		$2,155,000.-
O + M Costs		
Personnel	- 26.0 positions at $40,000/year	$1,040,000.-
Administration	- 1.5% of capital investment	$ 325,500.-
Insurance	- 1.5% of capital investment	$ 325,500.-
Maintenance	- Building - 1% of cost	$ 27,000.-
	- Machinery - 4% of cost	$ 760,000.-
Energy	- 32 KWh/mt times $0.025/KWh	$ 192,000.-
Residue disposal at $25.-/m tonne		$1,485,000.-
Total O + M Costs		$4,155,000.-
Revenues		
Ferrous Metal at $60m/tonne		$ 216,000.-
Total Plant Costs less Revenues per year		$6,094,000.-
per metric tonne		$ 31.00
per capita per year		$ 18.60

The total cost for RDF separation composting amounts to $31.00 per tonne of waste stream.

Additional costs for hauling and disposal of organic fraction and residue are assumed to be offset by lower ash hauling.

In computing the net cost difference for separation should consider all operational advantages of burning RdF rather than raw waste:

1. More homogeneous fuel generates higher combustion efficiency;
2. Storability to permit energy production to follow the energy demand (high in winter, low in summer) rather than the waste generation (high in spring and late summer, low in winter);
3. lower emissions require less filtration operating costs
4. lower ash content reduces ash handling costs.

These factors could lead to a reduction in incinerator operating costs, but are ignored here to obtain a conservatively high separation cost estimate:

Unit RDF separation cost	$31.00/tonne
At 0.6 tonne per capita per year waste generation, the additional cost is	$18.60/capita

Air Emission Reduction through RdF separation

Potential contaminants in incinerator emissions comprise acidic gases (HCl, HF, SOx, NOx), heavy metals (Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Zn), VOC's (PCB's, chlorophenols, Ozvacic et al. 1985), PAH's (benzo (a) pyrenes, dibenzo dioxins and furans, etc., Bilitewski, 1985).

The separation process reduces the mass flux of all potential contaminants into the incinerator, and, hence, reduces the emissions to air:

- Total chlorine and sulfur content in RDF is reduced to under 50% of the content per unit heat value in the raw waste at slightly lower concentration (Bilitewski, 1985). Thus, slightly more than the proportional amount of chlorine and sulfur are removed with separation of the organic fraction. Thus, at 40 to 45% of the total chlorine and sulfer, remaining in the RdF, a reduction of 50% mass flux into the incinerator is achieved. The emission concentrations of HCl are shown to drop from 700 to 800 mg/Nm^3 down to 400 to $500mg/Nm^3$ as a result of separating prior to burning RdF in MGB incinerators (Edner, 1985).
- Heavy metal concentrations are shown to be reduced by 23% to 80% through RdF separation (Edner, 1985, Bilitewski, 1985). On the basis of heat content, the reduction factor is even greater (35% to 87%). The highest reduction effects are found for mercury, zinc and copper, the lowest for chrome and lead.

  Overall, a reduction of 50% in heavy metal flux per unit

heat content is feasible.

- While chlorophenol and chlorobenzene emissions of RdF combustion in MBG incinerators are at best marginally reduced in the combustion process, the reduction of chlorine content and the exposure to air in the opening, shredding and classifying process are likely to reduce VOC's in the RDF as reported in Ozvacic et al. (1985). Although dioxin and furan concentrations in the RdF feed and in the stack emissions in Ozvacic et al. are reported higher than for raw refuse, Bilitewski (1985) and Edner (1985) report substantially lower PAH stack emissions from RdF by a factor of 10 to 100. This reduction is probably due to the more homogeneous burning characteristics of RDF that result in better, more consistent temperature and combustion control.

  Thus, a reduction of 50% in emissions through separation is a reasonable value. The reduction of potential contaminants into the incinerator could theoretically proportionately reduce the emission rates. The high efficiency (90 to 95%) of the existing filtration system, however, mitigates the net effect of contaminant reductions in the fuel.

Thus, the separation is assumed to result in a 20% reduction of present air emission rates with dry-lime addition and a baghouse filter.

Appendix 6.C2

Control of Air Emissions through Best Available Incinerator Exhaust Filtration

An additional filtration step to increase the removal of particulate, acid gases and bound metals and organics is installed after the present quench reactor - bag house configuration. The suggested system comprises a scrubber with special liquid atomizing nozzles and centrifugal fan separator (see Figure 6.C2). The filtration effect is caused by the absorption of particles and gases into the very fine droplets through a large surface area. Additional cooling further enhances sorption of metals and organics to particulate and allows further filtration (see e.g. Velzy, 1985). A final heat exchange allows dehumidification.

The costs for this system are based on preliminary estimates from the manufacturer (Turbotak, 1988) and an operating costs for wet filtration processes (LMRP, 1985).

Capital Investment	
Additional Scrubber	
and installation	$1,000,000.-
Heat exchange system	$1,640,000.-
	$2,640,000.-
amortized over 20 years amounts to	$ 212,056.-/year
Operating Costs	
Scrubber (chemicals, power personnel)	
at $2.30/tonne	$ 394,400.-/year
Heat exchanger operating costs	$ 95,000.-/year
	$ 489,400.-
Total annualized costs	$ 701,456.-/year

or $4.15 per metric tonne

or $2.50/capita-year.

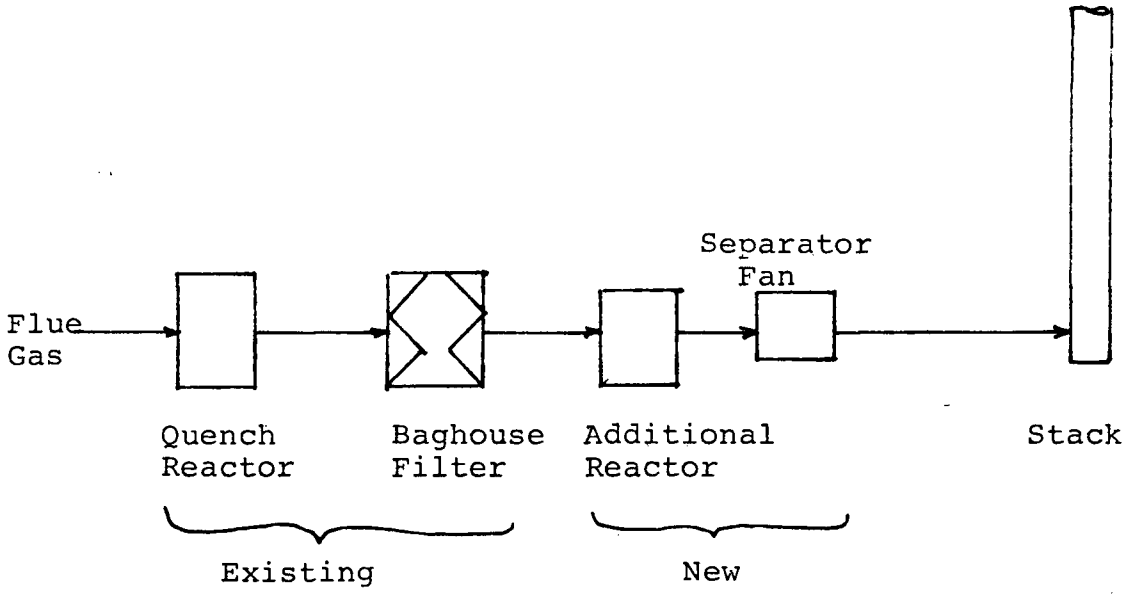


Figure 6.C2 - Incinerator Exhaust - Additional Filtration Step

Emission Reduction

Although the present filtration system removes over 90% of air contaminants, the subsequents scrubber process is designed to remove particles below 10 micron, which accounts for approximately 90% of the residual particulate. Special emphasis is placed on the fine particles because sorbed metals and organics are present in this size range. Through the additional cooling more gaseous contaminants will tend to condense onto the remaining particulate (Velzy, 1985). Thus, through removal of the particulate, more sorbed metals and organics will be removed too. Finally, acid gases are further reduced with an additional caustic scrubbing step.

Although specific test results for the effect of the added system are not available to empirically demonstrate the reduction, contaminant reduction is correlated with particulate removal and lower temperatures (EPS, 1986). Therefore, a 10% reduction in particulate, acid gases, heavy metals and organics is predicted for the modified system.

Appendix 6.C3

Air Quality Impact Reduction through Air Quality Monitoring and Reduction of Burning Rate

Location and Frequency

Ambient concentration maxima occur at 700 to 1,500 metres and, in the long-term, at 18 and 30km distance in prevailing wind directions (N and S/SE). Because of the accuracy of dispersion modelling, two locations at each modeled maximum in each of the two wind directions are monitored.

Hence, a total of 8 locations are periodically monitored on the National Air Pollutant monitoring cycle of every six days. Two continuous monitoring stations are installed at the short-term maxima locations. One measures background and one the downwind concentrations of NO_2, CO, SOx, and O_3.

Pollutants and Sampling

TSP and heavy metals (Cd, Cr, Cu, Mg, Mn, Pb and Zn) are collected with a high volume particulate filter. Gaseous pollutants (NO_2, CO, SO_2, O_3) are monitored continuously and recorded at two stations. HCl and HF are collected in a 24 hour impinger train, exchanged every 6 days (as for particulate sampling) and analysed in the lab.

Monitoring Costs

Equipment (pers. comm. M. Mennell, GVRD, 1988)

8 - High volume air samples at $1,800.-/pc.	=	$ 14,400.-
16 - Impinger trains at $3,100/pc.	=	$ 49,600.-
2 - Continuous monitoring stations at $175,000.-/pc.	=	$350,000.-
		$414,000.-

Sampling and Supplies 10,000.-/year

Analytical

-TSP and Heavy Metals

8 samples/week-52 weeks = 416 samples/year

Preparation	$12.-		
Analysis	$25.-		
Pb/Cd	$18.-		
	$55.-/sample * 416/ samples/yr	=	$ 22,880.-/year

-HCl/HF and Organics

HCl/HF analysis $16./sample * 416 samples/year $ 6,656.-/year

Organics - 2 samples/week = 104 samples/year * $200.- per sample $ 20,800.-/year

$ 60,336.-/year

Total-Equipment investment amortized over 5 years

(A/414,000.-, 5%,5) = 414,000.- * 0.23 =$ 95,624.-

-Annual Sampling Costs 60,336.-

$155,960.-

Total costs of 155,960.- per year and equal to $0.92 per metric tonne or $0.55 per capita-year.

b. Incineration cost increase due to burning rate decrease of 10%, from 170,000mt to 153,000mt per year.

Assume Capital investment for incinerator is

(US-1985) $50 Million (Marion County, 1985)

equals Can. $ $65 Million

Assume operation costs equal to energy revenues, (LMRP, 1985)

thus, prorated per tonne, the

capital costs constitute the cost difference

for a reduced burning rate:

$\$65 * 10^6$ amortized over 20 years:

$(A/\$65 * 10^6, 5\%, 20) = \$5,226,000.-/year$

Total cost per year is divided into the tonnage:

at 170,000 mt/year = $30.74/m tonne

Cost increase proportion to a 10% reduction in waste volume

is equivalent to 153,000 mt/year = $34.16/m tonne

Difference for 10% reduction = $ 3.42/m tonne

or at 0.6 mt/cap-yr = $ 2.05/cap-year.

20% reduction is equivalent

to 135,000 mt/year $38.43/m tonne

Difference for 20% reduction = $ 7.69/m tonne

or at 0.6 mt/capita per year = $ 4.61/capita per year

Total monitoring and 10 to 20% burn rate reduction costs

	10%	20%
monitoring costs	$0.55	$0.55
incineration cost increase	$2.05	$4.61
	$2.60 to	$5.16

per capita per year.

Appendix 6.C4

Compensation through Property Value Guarantees at the Incinerator

- 88 residential homes actually listed during 1983 to 1986
- will use 90 homes at maximum value of $196,660.
- 10% per home = $19,666 * 90 homes = $1,769,940.-
- Compensation cost occurs at beginning of project and is amortized over 5 years at 5%

  A/$1,769,940, 5%, 5 years = $403,546.-/year

  or $2.37 per metric tonne

  or $1.42 per capita per year.

Appendix 6.D1

Incinerator View Reduction

View Prevention through Stack Height Reduction
and Plume Prevention

Stack height reduction by 30m to 50m:

1. Virtual plume height must remain at 110m to ensure dispersion:

   Solving Holland's formula for exit velocity at a heat rise (h) of 110m-50m = 60m instead of 30m:

   results in the following result:

$$\frac{Vsd}{u} \left(1.5 + 0.0096 \frac{Q_h}{V_s d}\right)$$

$$Vs = \left(\Delta h - 0.0096 \frac{Qh}{u}\right) * \frac{u}{1.5d}$$

with h = 60m (required for dispersion)

$$Qh = mCp\ (Ts-Ta) = 87.12\ kg/s * 1.36\ kJ/Nm^3\text{-}^oC * (344-288)^oK$$

$$= 6{,}586.27\ KJ/S$$

u = 3m/s

d = 1.72m

$$\text{Required velocity } V = (60m - 21.08m) * \frac{u}{1.5d} = 45.26\ m/s$$

Incinerator View Reduction

2. Check Stack Diameter and determine Reynolds Number for Plumeless Operation.

   Flue gas mass flow: 44 m^3/s at 115^oC

   at density of 0.99 kg/m^3 equals 43.56 kg/s

Temperature with Heat exchanger = $70^{o}C$

hence density = 1.11 kg/m^3

dynamic viscosity (at $70^{o}C$) = 20.4×10^{-6} $N\text{-}s/m^2$ (from tables)

Mass flow with heat exchange and 1:1 ambient air mixing equals 2 times 43.56 kg/s = 87.12 kg/s at 1.11 kg/m^3 at $70^{o}C$, volume flow is 78.5 m^3/s hence for V = 45m/s, the required stack diameter is 1.5m.

Reynolds number

$$Re = \frac{1.11\ kg/m^3 * 45m/s * 1.5m}{20.4 * 10^{-6}\ N\text{-}s/m^2} = \underline{3.67 * 10^6}$$

3. Friction Loss in Short Stack:

$$L_f = f * \frac{L}{D} * \frac{V^2}{2g}$$

for Moody friction factor f:

stack inside cladding is welded steel, e = 0.003

at 1.5m diameter results in a relative roughness $\frac{e}{D}$ of 0.006, which

with Re = $3.67 * 10^6$ results in a Moody factor f of <u>0.018</u>.

4. Additional Power Required for Short Stack:

$$\text{Required Power} = W = m\left[\left(\frac{V_2^2 - V^2}{2}\right) + g\ (Z_1 - Z_2) - g * Lf)\right]$$

Hence, for the existing stack: m = 43.56 kg/s

v_1 = 6 m/s Z_1 = 3m

V_2 = 19 m/s Z_2 = 78m

Lf = 16.6m

$$Wp = 46{,}222\ \frac{kpm}{s} = \underline{453.15\ KW}$$

For the short stack: m = 87.12 kg/s

V_1 = 6 m/s Z_1 = 3m

V_2 = 45 m/s Z_2 = 50m

Lf = 37.1m

Wss = 87.12 kg/s * 1,820 m^2/s^2 = 158,569 kp m/s

= 1,554 KW

Difference in power required = 1,554-453 KW = 1,101 KW

5. Dehumidification through heat exchange and ambient air mixing:

Filtered flue gas at t = 126°C

Moisture = 0.17 kg/kg air

is passed through a heat exchanger with ambient air to cool and remove moisture. The ambient air (with low moisture content) is then mixed on a 1:1 ratio with the dehumidified flue gas (see diagram 6.D1).

The process is shown in the psychometric diagram (6.D2) below.

Flue gas = t_{hi} at 126°C and 0.17 kg/kg air.

Ambient air at t_{ci}; = 5°C and 90% humidity

or 0.00043 kg/kg air

Passage through heat exchangers at a 1:1 mass flow ratio results in an efficiency of exchange of 77% (Watson Co., 1988).

$$e = \frac{C_{fg}\ (t_{hi} - t_{ho})}{C_{air}\ (t_{hi} - t_{ci})} = 77\%$$

C_{pg} = 1.407 KJ/Nm^3 - deg.C

Cair = 1.298 KJ/Nm^3 - deg.C

Operating energy for fan at 1.3" WC Presure drop requires 25,473 $\frac{kpm}{s}$ = 250 KW.

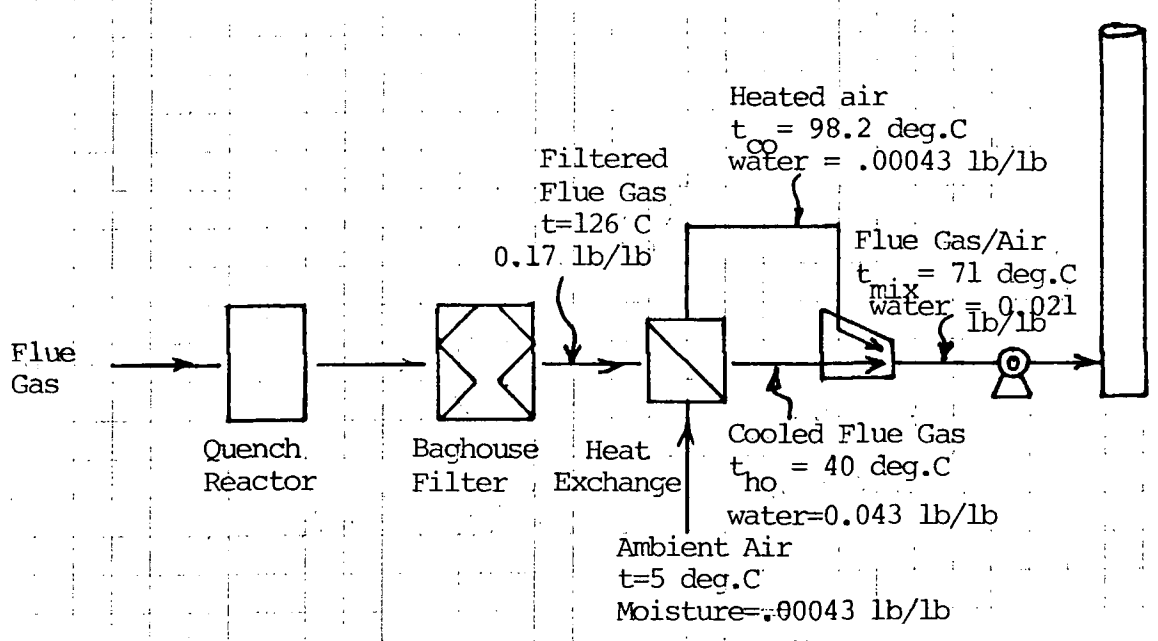
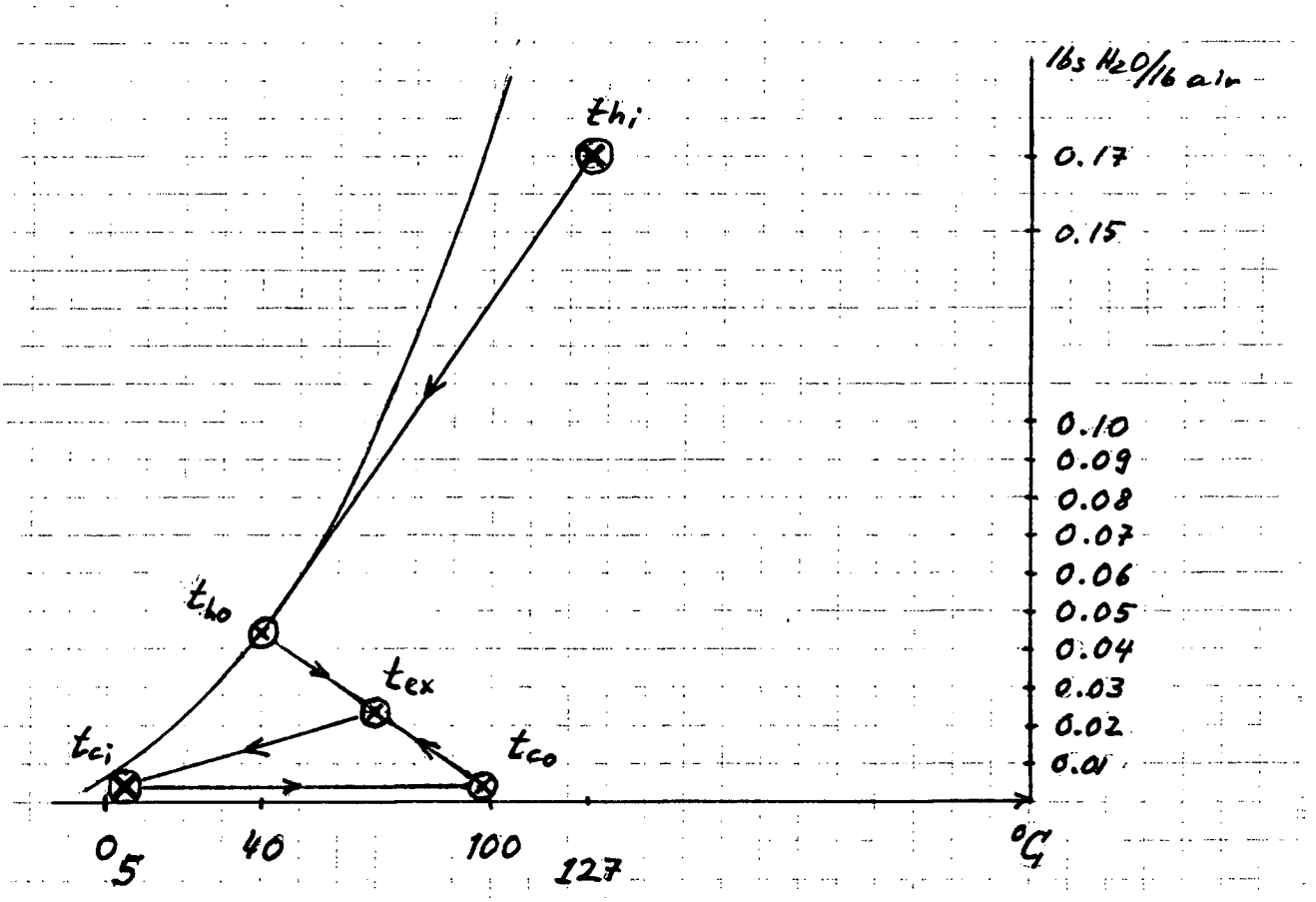


Figure 6.D1 - Heat Exchange and Dehumidification



Legend: t_{hi} = flue gas entering heat exchange
t_{ho} = flue gas after heat exchange
t_{ci} = ambient air at 5 deg.C. and 80% rel. humidity
t_{co} = ambient air after heat exchange
t_{mix} = 50/50% flue gas/ambient air mix

Figure 6.D2 - Diagram of Heat Exchange and Exhaust - Ambient Mixing Process

After heat exchange, the resulting flue gas temperature at exit is 40.05^{o}C and 0.043 kg/kg air moisture content (t_{ho}). Heated ambient air at 98.2 deg C and 0.0043 kg/kg moisture (t_{co}) is then mixed with the flue gas to a mixture at 71 deg C and 0.0215 kg/kg moisture content (tex).

This mixture can be exhausted to the atmosphere under worst case conditions (say) 0°C and 90% relative humidity without condensation, and, hence without a plume forming. This can be verified in the diagram by drawing a mixing line from t_{ex} the mixing point of flue gas and heated ambient air to outside air at t_{ci}.

Costs

3 Polyvinyl coated aluminum counterflow heat exchangers of 50,000 cfm each $156,000.- (Turbotek, 1988).

Additional ductwork, frames fan and installation $ 26,000.-

$182,000.-

Amortized over 20 years = $ 14,633.-/year

Additional operating costs:

energy: stack fans 1,101 KW

heat exchanger 250 KW

1,351 KW at 0.9 efficiency

equals 1,501 KW

for 7,000 hours/year

equals $10.5 * 10^6$ KWh

at $0.025/KWh equals $262,675.-/year

Total costs: $277,308.-/year

or $1.63 per metric tonne

or $1.00 per capita per year.

Appendix 6.D2

Incinerator - View Control

Tree Screen on Incinerator Site Boundary

Incinerator - Stack height = 80m

Stack and Plume = 110m

Building = 30m

Site Circumference: 1,030m

Trees - 9-12 metres on 8 metre centres

130 trees at $5,000.- $650,000.-

Cash Flow - Tree Screen

Expenditure is part of original capital investment and is amortized over 20 years:

(A/P, 5%, 20) = $650,000.- * 0.0804 = 52,290.-/year

or $0.31 per metric tonne

or $0.18 per capita per year.

Screen Distance

Facility and height	Object	Distance	Screen height	Screen Distance
Stack and Plume	110m	100m	10m	10m
Stack and Plume	110m	50m	10m	5m
Building	30m	100m	10m	50m
Building	30m	50m	10m	25m

Appendix 6.D3

Incinerator View Mitigation

Tree Screen of View Impact Areas (see View Map, figure 4.2).

Estimated required length of view screening equals 19,560m

Assume 25% of total circumference is exposed to residences results in linear exposed distance of 4,890m rounded to 5,000m.

Tree screen of single line of 5 to 6m trees on 6 metre centres requires 5,000m 6m = 835 trees

835 trees at $60.-/tree equals $50,100.-

Cash flow - single expenditure as initial capital investment, amortized over 20 years:

(A/$50,100, 5%, 20) = $4,030.- per year

or $0.02 per capita per year

Screen Effect

Facility Height	Distance to screen	Screen (Tree) Height	Screen Distance at 1.5m viewer height
110m	1,000m	6m	5.8m
110m	2,000m	6m	115m
110m	3,000m	6m	173

Appendix 6.D4

Incinerator - Compensation for View and Air Quality Impact.

10% of Value of Property within 800m (1/2 mile):

. Residential Lots - assume potential of

78 lots within 800m

at average price of (US) $46,028.- (Salem Multiple Listing Area 3).

Total Value: (US) $3,590,184.-

10% Value: $359,018.-

. Farmland - Area of half circle with radius 800m

$= 1.005 \times 10^6\ m^2 = 250$ acres

less ½ of site = 7 acres

243 acres

Value: US $2,000.- per acre (pers. com. E. Forrest Caldwell-Banker, 1988)

Total Value: US $486,000.- US $486,000.-

10% Value: US $ 48,600.-

Compensation Value: US $407,618.-

US $ * 1.3 = Can. $529,903.-

Can. $530,000.-

Cash Flow - Single expenditure as initial capital investment, amortized over 20 years:

(A/$530,000, 5%, 20) = 42,605.-/year

or $0.25 per metric tonne

or $0.15 per capita per year.

Appendix 6.E1

Image Control

a. Landfill - Golf course, clubhouse and playing fields built over the course of the landfill life

Approximate costing for these image controls uses three elements: vegetative screening with trees, low density landscaping and grass, and high density landscaping:

1. 20 acres (87,080m^2) - playing fields and clubhouse
   - entire area-basic landscaping at \$2.-/m^2 = \$175,000.-
   - 1/3 area intensive landscape at \$20/m^2 = \$580,000.-
   - Clubhouse of 10,000 sq ft at \$60/sq ft = \$600,000.-

   \$1,355,000.-

2. 100 acres (435,400m^2)-golf course
   - entire area - basic landscaping at \$2/m^2 = \$870,800.-
   - 20% green area (87,080m^2) - intensive landscaping at \$30/m^2 = \$2,612,400.-

   \$3,483,200.-

3. Screen of trees along 2,900m circumference in two rows at 8.5m centres:
   - 684 trees of 5 to 6m high at \$60/tree = \$41,040.-

Total \$4,879,240.-

After the initial tree screen around the circumference, the construction sequence follows the landfilling. Therefore, the costs are equally distributed throughout the life of the facility with an initial 3 to 5 year lag for settling of the first cell (see figure 6.E1):

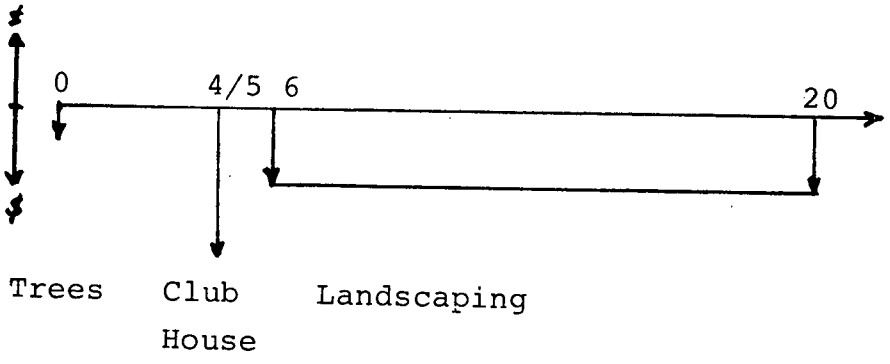


Figure 6.E1 - Cash Flow Profile for Landfill Image Control

The present value is estimated using a real interest rate of 5%. The present value of the cost is levelized and distributed over the life of the facility; the equivalent cost to each resident is calculated at a yearly waste contribution of 600kg per capita.

Present Value (P/F, 5%, N) = F $\frac{1}{(1+0.05)^n}$

Item	Cost	Year	PV
Trees	$ 41,000	0	$ 41,000
Clubhouse	$600,000	4/5	$ 481,868.-
Landscaping	$282,550/year	6 to 20	$2,293,505.-
		Total PV	$2,814,421.-

Levelized Unit Cost

(A/$2,814,421, 5%, 20 years) = $2,814,421 * 0.0804

= $226,288. -/year

or $1.33 per metric tonne

or $0.80 per person per year

b. Incinerator - park like buffer zone of 70 m width around site

A buffer zone of 70m width is used.

The total area of the buffer zone is 89,600m^2, or approximately 22 acres. Here playgrounds, a putting green, and sports track are set in a park landscape:

1. 22 acres (89,600m^2) basic landscaping at $2/m^2 = $180,000.-
2. 1/3 of area (30,000m^2) special landscaping at $20/m^2 = $600,000.-
3. Lighting, sprinklers = $ 75,000.-

4. Land value - 22 acres at $2,000/acre = $ 44,000.-

5. Trees - 1280m circumference - 2 rows at

   8.5m centres requires 300 trees

   at $60/tree = $ 18,000.-

   Total capital investment $917,000.-

   Capital Recovery per year $ 73,580.-

   or $0.45 per metric tonne

   or $0.30 per capita/year

Appendix 6.E2

Community Image Mitigation

Incentives to generate desirable development through 10% property value discount.

a. Landfill

Total area of 76 acres (64m wide strip) around landfill at $113,100.-/acre equals $8,595,600.-

10% of value equals $859,560.-

amortized over 5 years equals $195,980/year

equals $1.15 per metric tonne

or $0.70/capita per year for 5 years.

b. Incinerator

16 parcels of 2 acres each at US $2,500/acre (C$ 3250/acre)

equals a total value of (C$)	$104,000.-
plus 16 houses at $80,000 each	$1,280,000.-
Value	$1,384,000.-
10% equals	$ 138,400.-
at 5% for 20 years	$ 11,130.- per year
or	$0.07 per metric tonne
or	$0.04 per capita per year

Appendix 6.E3

Image Compensation - Compensation in-kind with a Community Hall - Recreation Centre

Land - 1/2 acre at $2.60 per square foot equals $56,550.-

Building - 10,000 square feet at $100 per sq. foot equals $2,000,000.-

PV = 1,056,550.-

$(A/P, 5\%, 20) = P \frac{0.13}{1.65} = P*0.0802 = \$84,735.-/\text{year}$

or $0.50 per metric tonne

$0.30 per capita per year over 20 years.

2. How familiar are you with these facilities?

Please rate how well informed you are about the facility, its operation and impacts on the scale of totally familiar (7) to totally unfamiliar (1):

a. a garbage fill where household garbage is filled and covered?

totally familiar						totally unfamiliar
7	6	5	4	3	2	1

b. a garbage burner that burns garbage and produces energy?

totally familiar						totally unfamiliar
7	6	5	4	3	2	1

3a. Please assume that a garbage landfill to serve the entire metropolitan area were to be built within 1 mile from where you live.

What would annoy, bother, or concern you about the garbage landfill and how would you benefit by having the facility located in your neighborhood?

Concerns	Benefits
_____	_____
_____	_____
_____	_____
_____	_____

3b. Please assume that a garbage burner to serve the entire metropolitan area were to be built within 1 mile from where you live.

What would annoy, bother, or concern you about the garbage burner and how would you benefit by having the facility located in your neighborhood?

Concerns	Benefits
_____	_____
_____	_____
_____	_____
_____	_____

II. Your Home and Household

4. Please mark the type of home you live in.

single family house _____ townhouse _____

duplex _____ condominium _____

apartment _____ trailer _____

other (please fill in) _____ _____

5. Do you own or rent your home?

own _____ rent _____

6. Do any children (under 18) live in your household?

yes _____

no _____

7a. What business or profession do you usually work in or have you usually worked in?

_____

b. What is the title of your job?

_____

c. What was the name and type of the school, and the last year you attended? (including trade school, vocational school, etc.)

School _____, _____ th year

What is the most recent degree or diploma you received?

_____

d. Which range best represents your household's total yearly income from all sources for last year (before taxes and deductions)? Please include all sources of income and everyone in the household that works in your estimate.

_____ up to $9,999
_____ $ 10,000 to $ 14,999
_____ $ 15,000 to $ 19,999
_____ $ 20,000 to $ 29,999
_____ $ 30,000 to $ 49,999
_____ over $ 50,000

8. Please consider the Burnaby Incinerator specifically.

a. Does this facility annoy, bother or concern you?

yes no

If yes, why? _____

b. Does this facility annoy, bother or concern you more or less than when it was first built or when you first moved in?

The facility bothers me

much less	less	about same	more	much more
____	____	____	____	____

9. Please consider the Burnaby Incinerator and the community where it is located as you know them.

Please indicate to what extent you disagree or agree with these statements:

a. The fact that the facility is located in the neighborhood is fair.

1	2	3	4	5
strongly disagree	disagree	not sure	agree	strongly agree

b. The facility depresses the property values in the neighborhood.

1	2	3	4	5
strongly disagree	disagree	not sure	agree	strongly agree

c. The facility operators do their best to protect the neighborhood from negative impacts.

1	2	3	4	5
strongly disagree	disagree	not sure	agree	strongly agree

Question 9 continued

d. Regardless of the physical impacts, the mere presence of the facility harms the image of the neighborhood.

1	2	3	4	5
strongly disagree	disagree	not sure	agree	strongly agree

e. The environmental agency prevents any environmental damage, harm to human health and nuisances from occurring in our neighborhood.

1	2	3	4	5
strongly disagree	disagree	not sure	agree	strongly agree

f. The facility creates odors in the neighborhood.

1	2	3	4	5
strongly disagree	disagree	not sure	agree	strongly agree

g. The facility creates noise in the neighborhood.

1	2	3	4	5
strongly disagree	disagree	not sure	agree	strongly agree

h. The facility creates unpleasant views (open garbage, birds, stack) in the neighborhood

1	2	3	4	5
strongly disagree	disagree	not sure	agree	strongly agree

i. The facility constitutes a health hazard for the neighborhood through air pollution.

1	2	3	4	5
strongly disagree	disagree	not sure	agree	strongly agree

j. The facility constitutes a health hazard for the neighborhood through water pollution.

1	2	3	4	5
strongly disagree	disagree	not sure	agree	strongly agree

Question 9 continued:

9k. The facility degrades the general environmental quality (air quality, water quality, wildlife habitats) in the neighborhood without necessarily causing health hazards.

1	2	3	4	5
strongly disagree	disagree	not sure	agree	strongly agree

l. The facility generates significant benefits (taxes, jobs, energy, development) in the neighborhood.

1	2	3	4	5
strongly disagree	disagree	not sure	agree	strongly agree

m. The local government is doing its best to protect the neighborhood.

1	2	3	4	5
strongly disagree	disagree	not sure	agree	strongly agree

n. The facility creates risks of explosions and accidents in the neighborhood.

1	2	3	4	5
strongly disagree	disagree	not sure	agree	strongly agree

10a. Do you favor any type of development in your community?

yes _____ no _____

b. If yes, what kind? _____

If no, what kind do you least oppose ? _____

_____

INTERVIEWER

11. Knowing what you now know about the [facility's] impacts, which ones of these are you most concerned about ?
    [lay out cards]
    Please pick out the impacts in the order you are concerned about them.

    1

    2

    3

    4

    5

    6

12. Consider the possibility that the [facility] were to be located now at the same site. Considering what you now know about the [facility] , which of these measures [lay out cards] would you most want your local government or the facility owner to do?

    Then which, then which? Please order the cards in the sequence you would want them reduced.

    1

    2

    3

    4

    5

    6

What was your reason for picking [1] over the others.

_____

_____

Question 13: Please read the scenario :

Assume that the capacity at the present waste disposal facility is running out. Your local government has located a new site in your community. The new facility is, however, likely to become offensive because of traffic, view, odors, as well as risks from air and water emissions. Your local government has four ways of addressing the problem.

Which method do you prefer ?

Please rank the best method with a "1", the next best with a "2", etc.

Methods to Reduce Facility Impacts:

	Cost to you per year in taxes per person	Rank
a. Compensation of impacts by paying money for damages	$ 3 to 5	____
b. Control of emissions by technical methods at the facility site	$ 10 to 15	____
c. Clean up of impacts or replacement of damages that actually occur	$ 5 to 10	____
d. Prevention of the impacts by eliminating the cause of the problem before it occurs	$ 15 to 25	____

INTERVIEWER

14. Consider the situation where the [facility] is again going to be built

HC: at its site in your neighborhood.

CC: at its present location.

You mentioned that [1. impact in Q.13] was of concern to you. Here are some methods to address that impact. If these changes were made and built into the facility, would they make the [facility] more acceptable to you?

Please consider each change and mark the one answer that best fits your opinion.

--> 2 separate impact method sheets for each respondent

15. You indicated you are concerned about [1.impact]. Here are four ways this kind of impact could be addressed. Please read the descriptions of costs and effects carefully and pick the method you prefer to have done most, then the next alternative, then the next by reading out the the letters.

[Then repeat for 2. impact]

Impacts	1._____	2._____
Methods	1._____	1._____
	2._____	2._____
	3._____	3._____
	4._____	4._____

Why do you prefer 1. over the others?

_____ _____

_____ _____

_____ _____

Q.14

Air contamination from the garbage burner

Here are some ways to address air pollution from the garbage burner. Please consider each one separately.

Method 1: Separate out contaminants from the garbage before burning it to reduce emissions

Would this method make the air contamination from the garbage burner more acceptable to you?

much more	more	somewhat more	no difference
____	____	____	____

Method 2: Install the best available air filtration equipment to reduce air emissions in the exhaust air

Would this method make the air contamination from the garbage burner more acceptable to you?

much more	more	somewhat more	no difference
____	____	____	____

Method 3: Monitor air emissions in the air around the plant and reduce the amount of garbage that is burned if the measured emissions are significant

Would this method make the air contamination from the garbage burner more acceptable to you?

much more	more	somewhat more	no difference
____	____	____	____

Method 4: Compensate homeowners with the dollar equivalent of 10% of property value

Would this method make the air contamination from the garbage burner more acceptable to you?

much more	more	somewhat more	no difference
____	____	____	____

16. Consider the situation where the facility is again to be built at its present site. The facility operator, however, decides to include the following measures in the design regardless if they are demanded or required:

SEE CARDS

a. With these changes to the facility as you know it, how would you rate your attitude about the facility ?

My attitude would be

much worse	worse	about same	better	much better
_____	_____	_____	_____	_____

b. With these changes, how desirable or undesirable would the facility be to you as as a neighbor ?

The facility with the changes would be

very desirable				so so				very undesirable
+4	+3	+2	+1	Ø	-1	-2	-3	-4

c. Would the facility with these changes annoy, bother or concern you more or less than it does now?

I would be

much more annoyed	more annoyed	about same	less annoyed	much less annoyed
_____	_____	_____	_____	_____

17. Please read the following scenario and then answer the question:

Assume that the present waste disposal facility is running out of capacity. So your local government establishes a list of seven suitable sites including one in your neighborhood, that is, within 1/2 mile of where you live.

The local government conducts a fair lottery among the seven sites and the site in your neighborhood is chosen for a period of 10 years.

The provincial environmental protection agency places and enforces strict requirements on the facility owner to use best available emission control equipment and operate the facility safely and cleanly regardless of cost. As a result, all health risks are reduced below significant levels, although some uncertainty remains about slight long-term effects.

Your local government and the facility owner ask you about your concerns in a survey questionnaire, take note of your views and address the impacts through these measures:

SEE CARDS

As a result, the impacts are reduced as far as possible, but slight effects may remain.

Under these circumstances do you consider the siting of the facility in your neighborhood to be (please mark one):

completely acceptable	barely acceptable	somewhat unacceptable	very unacceptable
_____	_____	_____	_____

Why? _____

_____

Thank you for your time and effort.

This is the end of the formal interview. You may rest assured that your opinion will be kept confidential. Please put your answer sheets in the plain envelope after you have made any comments about the interview itself.

Do you have any comments about the interview? Was anything important left out? Were the questions slanted?

_____

_____

_____

_____

Thank you for participating! You may keep the pen as a token of our appreciation.

Appendix 6.G - Tacoma Landfill - Fairness of Property Value Guarantees and Beliefs about Facility Impacts

Negative Beliefs about Facility Impacts	Association with Attitude About Property Value Guarantees as Fair Siting Measure
Nuisances	not significant
view	" "
odor	" "
noise	" "
traffic	" "
Health Risks	" "
water emissions	" "
air emissions	" "
accidents	" "
Environmental Change	" "
water quality	" "
air quality	" "
wildlife habitat harm	" "
Property Values	" "
Harm to Community Image	" "
Loss of Control	" "
Unfairness	" "
Confidence in Owner/Operator	marginally significant

Chi square or Fisher Exact test significant at $p < 0.05$, marginally significant at $p < 0.1$

Table 6.H12 - Preferences for General Impact Reduction Methods

Choice — Proportion of Respondents who choose this measure as their preference;

.PREVENT	MISS	FIRST	SECOND	THIRD
N= 39	1	32	6	1
MARG%		82.1	15.4	2.6
CUM%		82.1	97.4	100.0
LOWER		63.0	4.6	.0
UPPER		93.9	33.9	16.3

.CONTROL	MISS	FIRST	SECOND	THIRD	FOURTH
N= 38	2	4	25	8	1
MARG%		10.5	65.8	21.1	2.6
CUM%		10.5	76.3	97.4	100.0
LOWER		1.9	44.3	7.5	.0
UPPER		29.0	83.4	41.7	17.4

MITIGATE	MISS	FIRST	SECOND	THIRD	FOURTH
N= 39	1	1	7	27	4
MARG%		2.6	17.9	69.2	10.3
CUM%		2.6	20.5	89.7	100.0
LOWER		.0	5.7	48.1	1.9
UPPER		17.0	37.8	85.8	28.3

.COMPENSA	MISS	FIRST	SECOND	THIRD	FOURTH
N= 38	2	2	3	1	32
MARG%		5.3	7.9	2.6	84.2
CUM%		5.3	13.2	15.8	100.0
LOWER		.3	1.0	.0	64.4
UPPER		21.6	25.4	17.4	95.6

Table 6.H13 - Preferences for Specific Impact Reduction Measures

a. Health Risk Reduction Measures

Choice — Proportion of Respondents who choose this measure as their choice:

77.H.FIRST	MISS	PREVEN	CONTRO	MITIGA
N= 23	2	14	8	1
MARG%		60.9	34.8	4.3
CUM%		60.9	95.7	100.0
LOWER		34.3	13.5	.0
UPPER		83.4	61.6	26.3

78.H.SECOND	MISS	PREVEN	CONTRO	MITIGA	COMPEN
N= 23	2	4	10	8	1
MARG%		17.4	43.5	34.8	4.3
CUM%		17.4	60.9	95.7	100.0
LOWER		3.3	19.0	12.9	.0
UPPER		44.5	70.5	62.6	27.3

79.H.THIRD	MISS	PREVEN	CONTRO	MITIGA	COMPEN
N= 22	3	4	5	12	1
MARG%		18.2	22.7	54.5	4.5
CUM%		18.2	40.9	95.5	100.0
LOWER		3.4	5.5	27.3	.0
UPPER		46.1	51.2	80.0	28.4

80.H.FOURTH	MISS	CONTRO	MITIGA	COMPEN
N= 22	3	1	1	20
MARG%		4.5	4.5	90.9
CUM%		4.5	9.1	100.0
LOWER		.0	.0	66.2
UPPER		27.3	27.3	99.4

Table 6.H13 - Preferences for Specific Impact Reduction Measures

b. Community Image Impact Reduction Measures

Choice — Proportion of Respondents who choose this measure as their choice:

82.I.SECOND	CONTRO	MITIGA	COMPEN
N= 13	11	1	1
MARG%	84.6	7.7	7.7
CUM%	84.6	92.3	100.0
LOWER	48.4	.1	.1
UPPER	98.9	42.3	42.3

83.I.THIRD	CONTRO	MITIGA	COMPEN
N= 13	2	6	5
MARG%	15.4	46.2	38.5
CUM%	15.4	61.5	100.0
LOWER	1.1	15.3	10.6
UPPER	51.6	79.4	73.5

84.I.FOURTH	MITIGA	COMPEN
N= 13	6	7
MARG%	46.2	53.8
CUM%	46.2	100.0
LOWER	19.2	25.1
UPPER	74.9	80.8

Note - No Prevention measure was offered as a choice.

Table 6.H16 - Effects of Impact Reduction Measures on Acceptance

a. Health Risk Reduction Measures

Measure — Proportion of Respondents who think this measure would make them accept the facility:

ONEWAY TABULATIONS STRAT=IMPACT1:HEALTH
WITH .9500 CONFIDENCE INTERVAL

68.PREVENT1	MISS	NODIFF	SLMORE	MORE	MMORE
N= 23	2	1	7	3	12
MARG%		4.3	30.4	13.0	52.2
CUM%		4.3	34.8	47.8	100.0
LOWER		.0	10.1	1.7	25.9
UPPER		27.3	58.4	39.3	77.6

69.CONTROL1	MISS	NODIFF	SLMORE	MORE	MMORE
N= 23	2	2	8	4	9
MARG%		8.7	34.8	17.4	39.1
CUM%		8.7	43.5	60.9	100.0
LOWER		.5	12.9	3.3	15.9
UPPER		33.6	62.6	44.5	66.6

70.MITIGATE	MISS	NODIFF	SLMORE	MORE	MMORE
N= 23	2	5	6	4	8
MARG%		21.7	26.1	17.4	34.8
CUM%		21.7	47.8	65.2	100.0
LOWER		5.3	7.6	3.3	12.9
UPPER		49.4	54.0	44.5	62.6

71.COMPENS1	MISS	NODIFF	MORE	MMORE
N= 22	3	14	3	5
MARG%		63.6	13.6	22.7
CUM%		63.6	77.3	100.0
LOWER		36.3	1.9	5.9
UPPER		85.8	39.6	50.1

Table 6.H16 - Effects of Impact Reduction Measures on Acceptance

b. Community Image Impact Reduction Measures

Measure — Proportion of Respondents who think this measure would make them accept the facility:

74.CONTROL2	NODIFF	SLMORE	MORE	MMORE
N= 13	1	3	5	4
MARG%	7.7	23.1	38.5	30.8
CUM%	7.7	30.8	69.2	100.0
LOWER	.0	3.0	9.9	6.1
UPPER	43.8	61.0	74.6	68.2

75.MITIGATE	NODIFF	SLMORE	MORE	MMORE
N= 13	2	5	4	2
MARG%	15.4	38.5	30.8	15.4
CUM%	15.4	53.8	84.6	100.0
LOWER	.9	9.9	6.1	.9
UPPER	53.0	74.6	68.2	53.0

76.COMPENS2	NODIFF	SLMORE	MORE	MMORE
N= 13	4	5	3	1
MARG%	30.8	38.5	23.1	7.7
CUM%	30.8	69.2	92.3	100.0
LOWER	6.1	9.9	3.0	.0
UPPER	68.2	74.6	61.0	43.8

Table 6H.17 - Acceptance of Waste Facilities with Combined Prevention and Control Impact Reduction Measures

a. Landfill - Host Community

Proportion of Respondents who state they will accept a facility with Combined Measures

200.ACCEPT	NO	YES
N= 11	4	7
MARG%	36.4	63.6
CUM%	36.4	100.0
LOWER	10.9	30.8
UPPER	69.2	89.1

b. Incinerator - Host Community

Proportion of Respondents who state they will accept a facility with Combined Measures

200.ACCEPT	NO	YES
N= 14	2	12
MARG%	14.3	85.7
CUM%	14.3	100.0
LOWER	1.8	57.2
UPPER	42.8	98.2

c. Landfill - Control Community

Proportion of Respondents who state they will accept a facility with Combined Measures

200.ACCEPT	NO	YES
N= 7	3	4
MARG%	42.9	57.1
CUM%	42.9	100.0
LOWER	9.9	18.4
UPPER	81.6	90.1

d. Incinerator - Control Community

Proportion of Respondents who state they will accept a facility with Combined Measures

200.ACCEPT	NO	YES
N= 8	4	4
MARG%	50.0	50.0
CUM%	50.0	100.0
LOWER	15.7	15.7
UPPER	84.3	84.3

Table 6.H17 - Acceptance of Waste Facilities with Combined Prevention and Control Impact Reduction Measures

e. Landfill - Total

Proportion of Respondents who state they will accept a facility with Combined Measures

200.ACCEPT	NO	YES
N= 18	7	11
MARG%	38.9	61.1
CUM%	38.9	100.0
LOWER	17.3	35.7
UPPER	64.3	82.7

f. Incinerator - Total

Proportion of Respondents who state they will accept a facility with Combined Measures

200.ACCEPT	NO	YES
N= 22	6	16
MARG%	27.3	72.7
CUM%	27.3	100.0
LOWER	10.7	49.8
UPPER	50.2	89.3

g. Host Community - Total

200.ACCEPT	NO	YES
N= 25	6	19
MARG%	24.0	76.0
CUM%	24.0	100.0
LOWER	9.4	54.9
UPPER	45.1	90.6

h. Control Community - Total

200.ACCEPT	NO	YES
N= 15	7	8
MARG%	46.7	53.3
CUM%	46.7	100.0
LOWER	21.3	26.6
UPPER	73.4	78.7