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A Study of the Vegetation on Three Sanitary Landfills in Kalamazoo County

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A STUDY OF THE VEGETATION
ON THREE SANITARY LANDFILLS
IN KALAMAZOO COUNTY

by

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John Warren Rogers

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INTRODUCTION

The collection and disposal of solid waste is an increasing problem in many urban and rural communities. Many cities and counties have turned to sanitary landfills for disposal of solid waste. The sanitary landfill method of disposal requires (1) land areas that can be used for burying the refuse; and (2) close proximity to areas of high concentrations of populations to decrease the cost of hauling (Sorg and Hickman, 1968).

At present, most disposal systems require about one acre of land per one thousand people per year when the refuse is compacted to a depth of eight feet (Ehlers, 1965). The average amount of refuse produced each year is increasing at a rate of two percent per year. This compounded by a two percent population growth, results in an overall rate of increase of refuse production of about four percent each year (Thomas, Dean and Hopkins, 1970). United States urban populations have increased by about thirty percent in the last ten years (Census of Population, 1970). The net result is an increasing demand for sanitary landfill sites around urban areas.

Many studies have been done on the problems related to solid waste management such as maintenance, land use, and possible health hazards with several discouraging conclusions (California State Water Pollution Control Board, 1954, 1961; American Public Works Association, 1963; Merz and Stone, 1963, 1964; Eliassen, O'Hara, Monahan, 1957; Andersen and Dornbush, 1967; Rogers, 1969): (1) Many instances of ground water contamination due to leaching through of landfill substances; (2) Poor management and inconsistency of health control in the prevention of rodent populations, compaction of debris, and constraint of aerial surface litter. A national survey (U.S. Department of Health, Education and Welfare, 1968) gathered detailed information on 6,000 sites, and found that only about six percent of these met the minimum requirements for designation as "sanitary landfills." (3) Inadequate planning of land use resulting in construction hazards and explosions due to methane (CH_4) gas permeating over-laid structures (University of California, 1966). As a result, several states, including Michigan, have passed legislation to help control such problems.

Another national survey (Stone and Friedland, 1969) showed that there are several potential uses for landfill areas after the completion of landfill activities. Theoretically, 45 percent of the fills are used for recreational purposes, 9 percent industrial, 7 percent agricultural, and 2 percent open space. "Undetermined use " and "none" were cited in 26 percent of the cases. In view of the poor management, the latter is more likely higher in occurrence. The use of landfill sites for industry and housing projects should be restricted because of the emission of methane gas.

If landfill operations are increasingly filling up much of our countryside, and many are operating under poor management and are left abandoned, what effect are these landfills having on the general ecology of these areas? Do these landfills cause severe alterations in the dynamic balance of natural communities, retarding their abilities to restore themselves? Do landfills have any direct or indirect effects on the adjacent urban areas?

The purpose of this study is to begin to supply the answers to the above questions by: (1) observing the effects of landfill operations on the development of pioneer plant communities; an understanding of the plant community is the first level of study in the understanding of an ecosystem. (2) Comparing the relative rates of succession on an area affected by landfill operations and abandoned for ten years and an adjacent, abandoned, ten-year-old, unaffected area (denuded plot). (3) Considering the possible social and clinical ramifications inferred by the presence of certain pioneer species. (4) Offering possible ecological alternatives in the use and restoration of these areas.

Three landfills of varied ages on the edge of the Kalamazoo, Michigan urban area were chosen to study the relative rates of succession and the characteristics of pioneer communities: "KL" Avenue, one-year-old; Cork Street, three-years-old; Nazareth, ten-years-old; and a ten-year-old denuded plot, hereafter referred to by age.

GENERAL DESCRIPTIONS OF AREAS STUDIED

1-Year-Old Landfill

General Description of Field

The 1-year-old landfill located on "KL" Avenue, approximately two miles west of the City of Kalamazoo, Michigan, is a 90 acre tract situated in the northwest quarter of Section 21, T 2 S, R 12 W of Oshtemo Township, Kalamazoo County. The area is a 500 X 800 yard rectangular tract with its width parallel to "KL" Avenue, and with its long axis pointing due north. The tract is part of a glacial outwash plain which was originally covered by several feet of till (Martin and Straight, 1956). The elevation of the area is between 820 feet and 940 feet, with the sample plot situated on a flat plateau at an elevation of 929 feet (Fig. 1).

History

The area is a series of small rolling hills which were probably kames. The general topography of the area was largely produced by the effects of glacial waters during the Wisconsin retreat (Martin and Straight, 1956; Straw, 1971). The area is bordered to the northeast and west by a *Quercus* (Oak)-*Acer* (Maple)-*Carya* (Hickory) forest with *Populus* (Poplar) seedlings on the inner edge perimeters. If the field was once covered by a forest of this type, the time of clearing is unknown. A diagram of the area taken from a 1964 aerial photograph (Abrams, 1964) shows the general topography of the area prior to landfill operations (Fig. 2).

Before the area was purchased by Kalamazoo County, it was part of a small farm and was most likely used for pasture land. Later, the area was used by Oshtemo Township as an open-pit garbage dump. In 1968, Kalamazoo County purchased the land to be used for county landfill purposes (Freeland, 1971).

In May 1968, the County Landfill Operation began, using a new method for compacting the solid wastes. This method was called the "Area Ramp Method" (Fig. 3). Refuse was placed in an excavation to a desired height above the original ground level and then covered by two feet of excavated dirt from near-by hills. At present, the area is still in use (Freeland, 1971).

Physiography

The present features of the field are the effects of the excavation and bulldozing of the hills. The area has maintained its rolling-hill appearance with several, subtle differences in the elevation. An over-lay, taken from a 1971 aerial photograph (Abrams, 1971) depicts the topography after excavation was done during landfill operations (Fig. 1).

The general surface of the tract is a series of rolling hills, mostly skewed to the west leaving a longer west-facing slope, possibly indicating the direction of the glacial movement.

Fig. 1. Topographical sketch (overlay) of a portion of the "KL" Avenue Landfill area showing the different elevations caused by excavation by bulldozers during landfill operations.
Scale: 1"=100' (Abrams, 1971)

Legend

Sample Plot

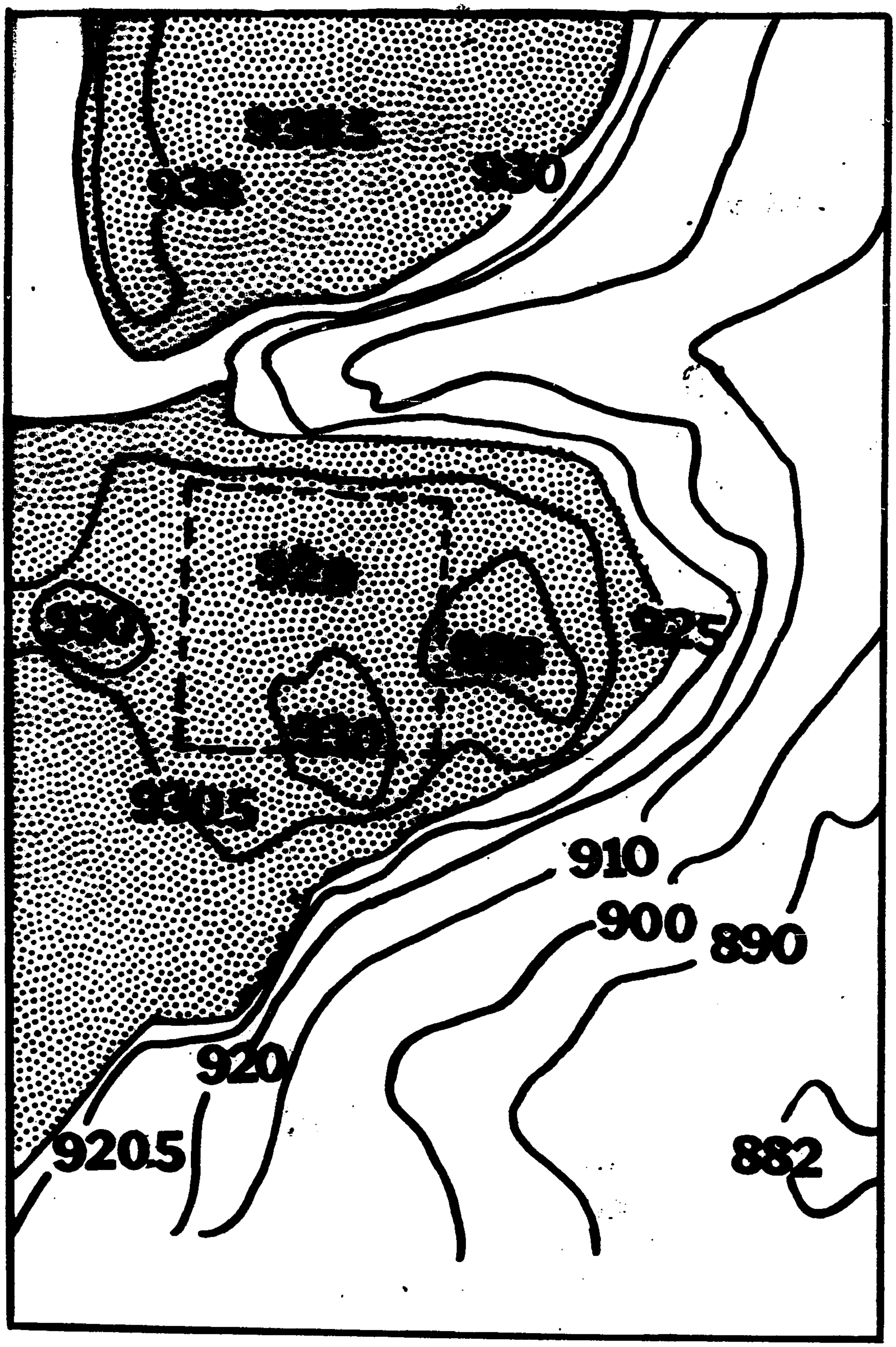
Topographical elevation

Area covered by landfill

Fig. 2. Topographical sketch of a portion of the "KL" Avenue Landfill area showing the elevations prior to landfill operations.
Scale: 1"=100' (Abrams, 1964)

Legend

Topographical elevations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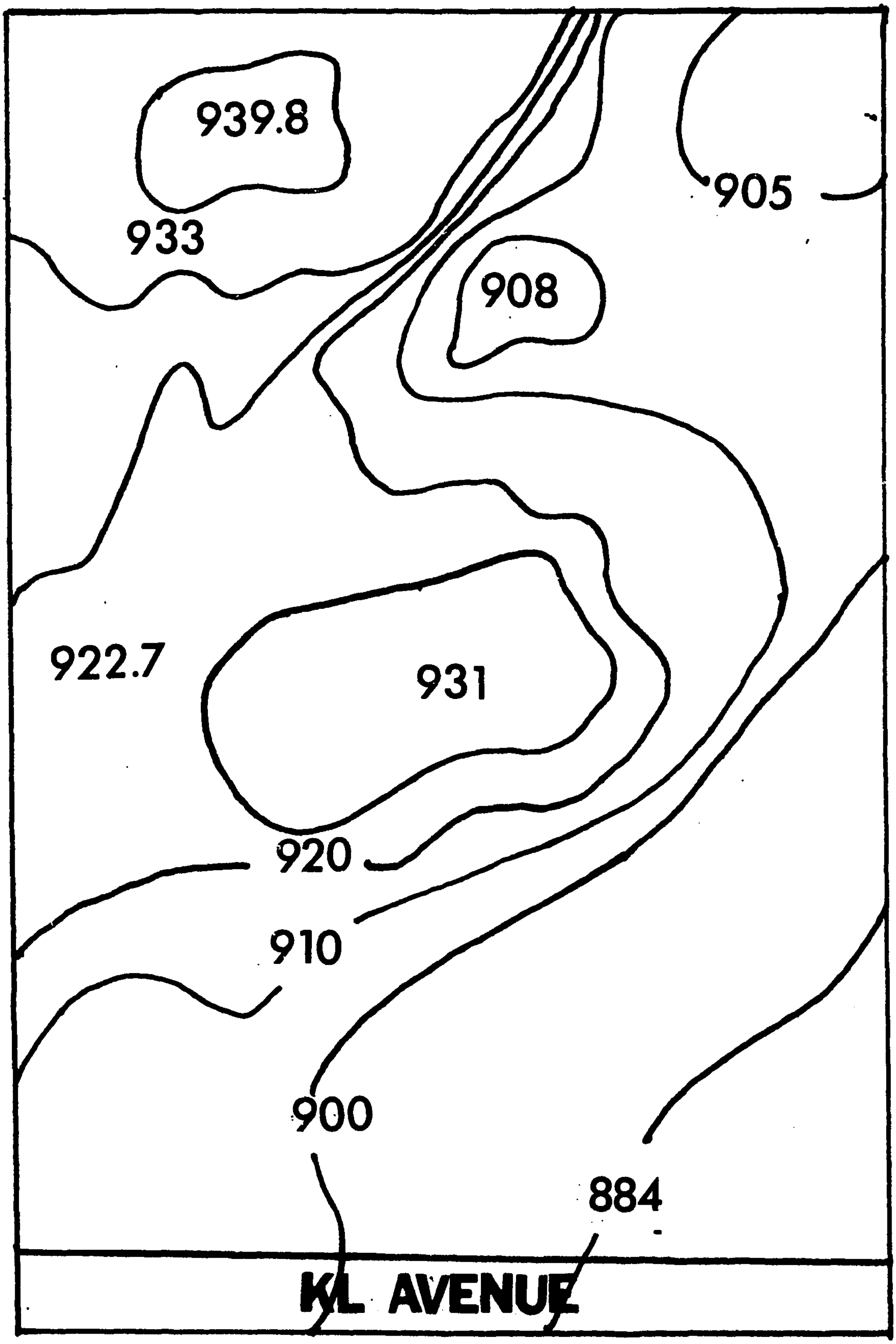
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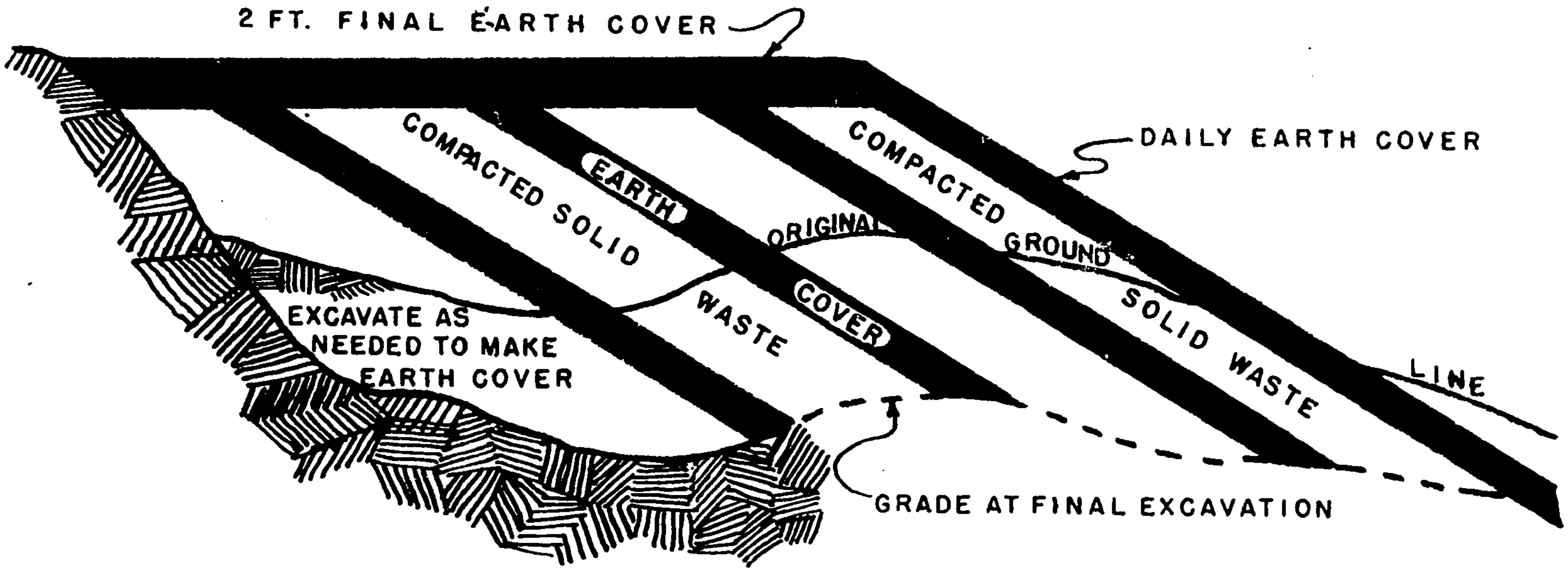


Fig. 3. A diagram of the "Area Ramp Method" used in the "KL" Avenue Landfill operation. An excavation is done prior to the beginning of the operation. Refuse is dumped and then covered daily by dirt from the original excavation, supplemented by dirt from near-by hills. (Wilkins and Wheaton Engineering Co., 1971)

The hills are generally flat on top, forming irregularly-shaped plateaus with shallow, diffuse drainage crevices meandering down the slope to deeper, larger ravines which are interwoven in the valleys between the small hills.

Soil

The soil, developed under natural conditions of physiography and climate, is a dark, grayish, sandy loam belonging to the Oshtemo series. The surface soil is 12-14 inches thick. The subsoil is a dark, yellowish-brown, sandy loam about 20 inches thick. The underlying material is yellowish-brown, with thin, dark, brown loamy sand lenses and chunks. Characteristically, the soil has relatively slow runoff and low available water capacity with rapid permeability.

After excavation and landfill operations, the soil is mixed so as to completely rearrange the podzol (Soil Conservation Service, 1972).

3-Year-Old Landfill

General Description of Field

The 3-year-old landfill is located between Cork St. and Interstate 94 on the south side of the City of Kalamazoo, Michigan and is a 100-acre tract situated in the southwest quarter of Section 36, T 2 S, R 10 W of Kalamazoo Township, Kalamazoo County. The apex angle of the triangle points due north and borders on

Cork Street, while the 800 and 900 yard radii are bordered by the Pennsylvania Central Railroad tracks with a 600 yard base running parallel to Interstate 94. The area is part of a glacial outwash plain lying at an elevation between 829 and 858 feet. The sample plot is located in the southeast portion of the tract at an elevation of 853 feet (Fig. 4).

History

Originally, the area was flat with several swales in the northeast portion dropping down to elevations of 829 feet. The general topography was caused largely by glacial waters during the Wisconsin retreat (Martin and Straight, 1956; Straw, 1971). The area is bordered by several stands of *Acer* sp. woods with *Salix* sp. and *Rhus typhina* seedlings and saplings on its borders. *Acer* may have been one of the major genera covering the area prior to clearing (Kenoyer, 1934). A diagram of the area, (Fig. 5), was taken from a 1964 photograph (Abrams, 1964) showing the general topography of the area prior to landfill operations.

Swine were grazed on the field as far back as 1910, and were allowed to graze over open garbage in the 1940's and 1950's until a high mortality rate in the herd was caused by toxic substances intermixing with the garbage (VerMeulen, 1971).

In 1960, the City of Kalamazoo purchased the area and began using it for sanitary landfill purposes, employing the "Trench Method." First a trench was excavated by a bulldozer, usually to a depth of ten feet. The solid wastes were then dumped into the trench and covered by excavating a trench adjacent to it (Ehlers, 1965) (Fig. 6). Landfill operations ceased on May 11, 1968, when Kalamazoo County assumed the responsibility for solid waste disposal and landfill operations were moved to "KL" Avenue. The Cork Street Landfill was abandoned except for periodic use during "Clean-Up Week" in the City of Kalamazoo, and then only certain bulky items were dumped and left in the still apparent swales (VerMeulen, 1971).

Physiography

The present topography of the field is the result of repeated excavation by bulldozers. An over-lay, taken from a 1968 aerial photograph (Abrams, 1964) depicts the present topography of the area (Fig. 4).

A flat, irregular-shaped plateau extends for 400 yards along the base of the triangle and 350 yards north from the base. The plateau is generally flat with several shallow swales on the northeastern portion of the landfill area. The entire perimeter of the area is marked by seedlings and gradual inclines which are part of drainage ravines.

Soil

The soil, developed under natural conditions of physiography and climate, is of the Chelsea series. The surface is divided into two parts. The top layer is 4-5 inches thick and is very dark, gray loamy sand. The second layer is a yellowish-brown,

Fig. 4. Topographical sketch (overlay) of a portion of the Cork Street Landfill area showing the different elevations caused by excavations by bulldozers during landfill operations.
Scale: 1"=100' (Abrams, 1968)

Legend

Sample Plot

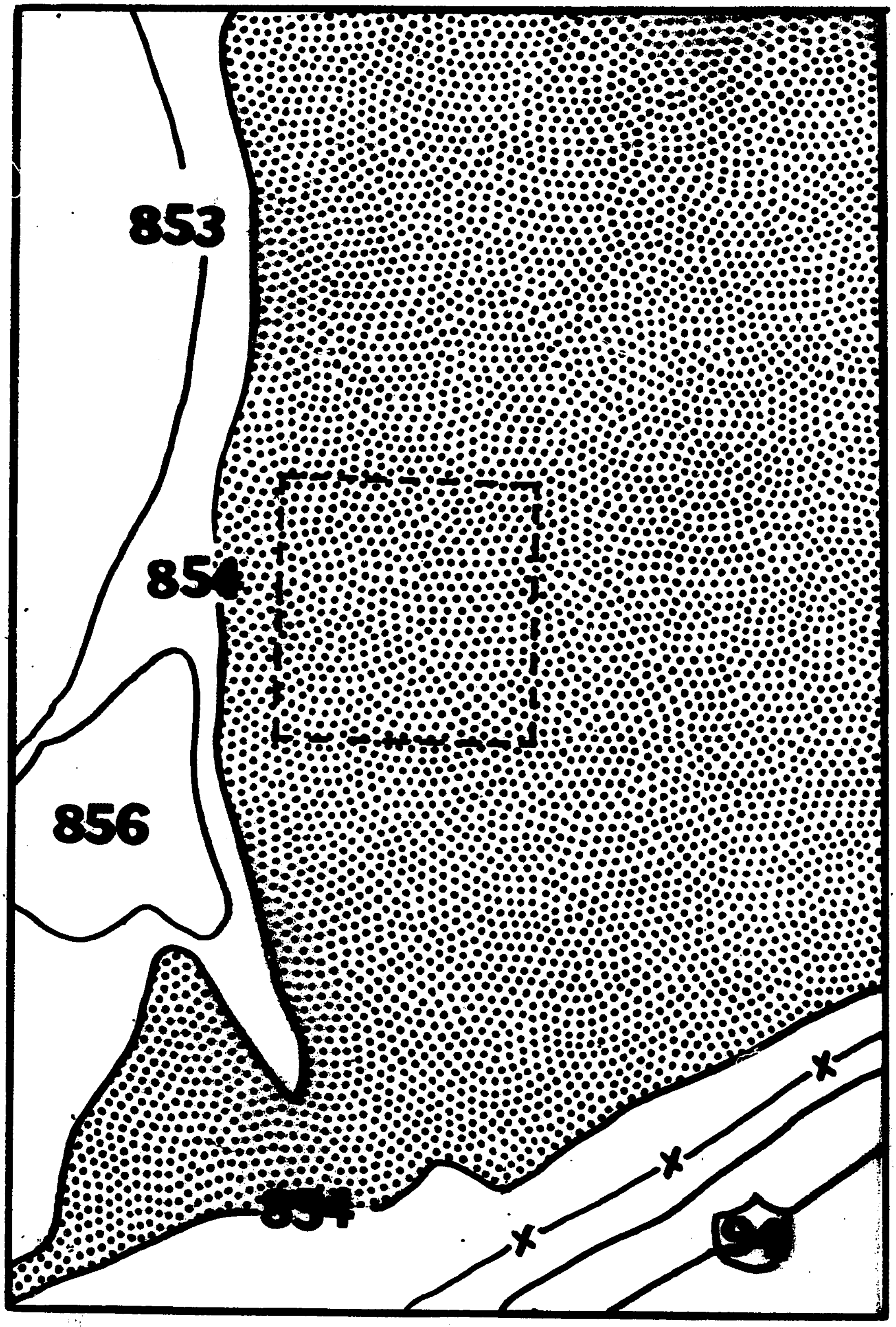
Topographical elevations

Area covered by landfill

Fig. 5. Topographical sketch of a portion of the Cork Street Landfill area showing the different elevations prior to landfill operations.
Scale: 1"=100' (Abrams, 1964)

Legend

Topographical elevations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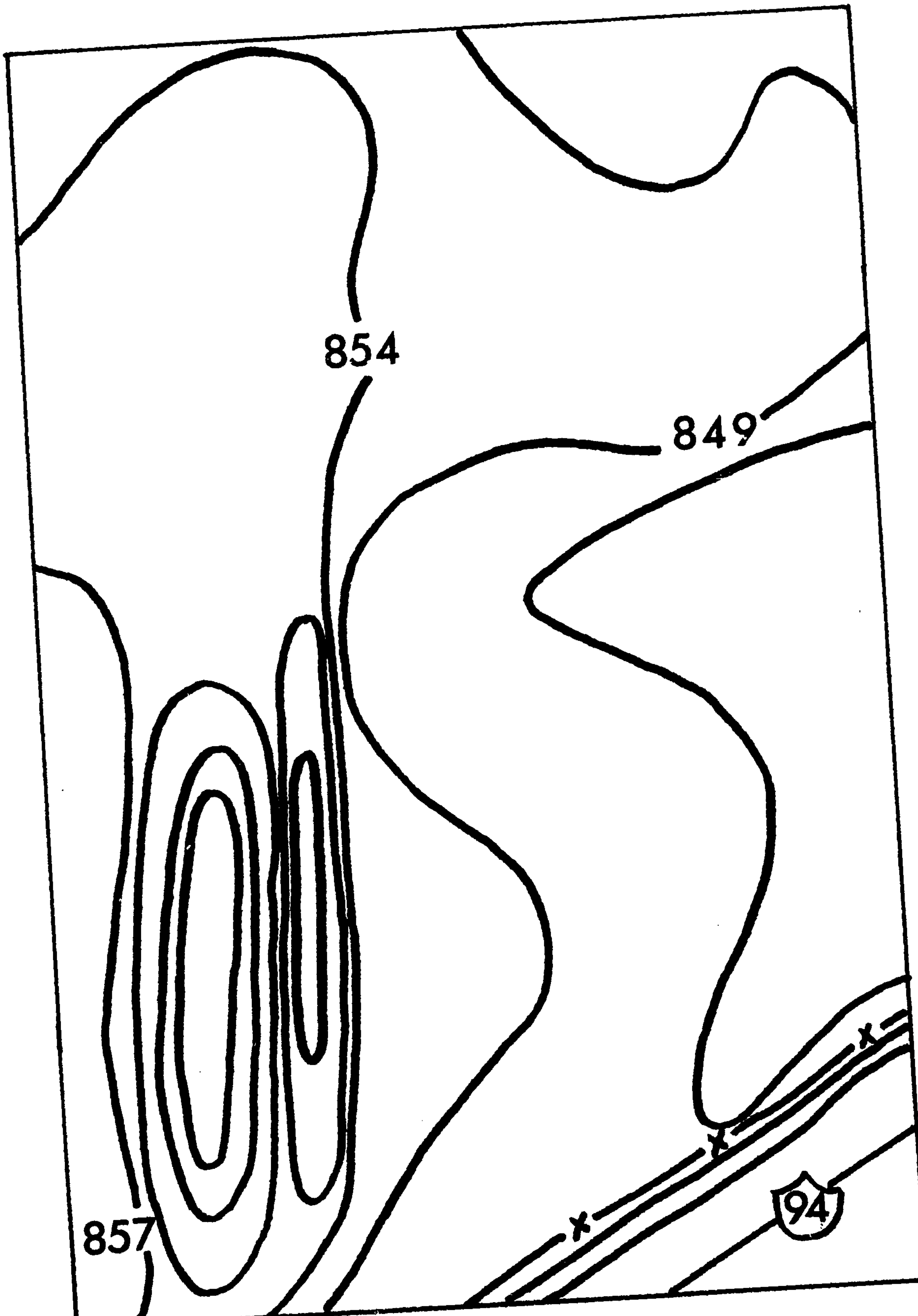
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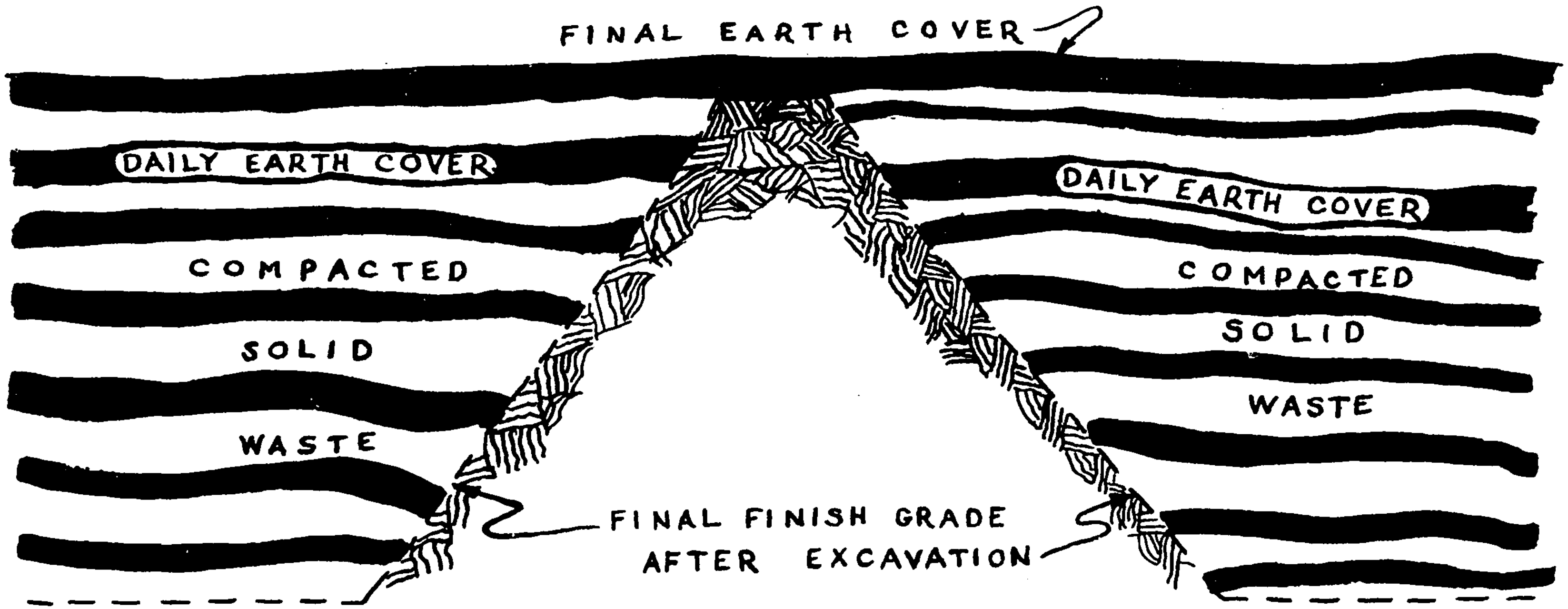


Fig. 6 A diagram of the "Trench Method" used in the Cork Street Landfill operation. The trench is excavated prior to beginning operation and then excavated progressively as work proceeds, using the dirt from each excavation as cover. (Ehlers, 1965)

loamy sand about 5 inches thick. The subsoil is yellowish-brown, loamy sand with lenses and chunks. The Chelsea soil has medium to rapid runoff and a low available water capacity with very rapid permeability.

After excavation and landfill operations, the soil is mixed so as to completely rearrange the podzol (Soil Conservation Service, 1972).

10-Year-Old Landfill

General Description of Field

The 10-year-old landfill is located one mile east of the City of Kalamazoo, Michigan and is a four and one-half acre tract situated in the southeast quarter of Section 13, T 2 S, R 9 W of Kalamazoo Township, Kalamazoo County. The tract lies approximately 400 feet south of a farmhouse, and is lengthwise parallel to Nazareth Road. The tract lies on a large glacial outwash plain at an elevation between 818.5 and 820 feet on one of the highest points along the old shoreline of a kettlehole lake, which is presently approximately 800 yards to the northeast. The field is 180 yards long and 100 yards wide, with its long axis pointing due north. The sample plot lies in the northwest portion of the tract at an elevation of 820 feet. The denuded plot lies in the southwest portion of the tract (Fig. 7).

History

Originally, the area was a series of small hills which were probably kames. The general topography of the area was largely due to the effects of glacial waters during the Wisconsin retreat (Martin and Straight, 1956; Straw, 1971). The field is bordered on the east side by a Quercus (Oak)-Acer (Maple)-Carya (Hickory) forest which evidently covered the field prior to clearing, which most likely was done in the latter half of the past century (Kenoyer, 1934).

The area, owing to its topography, was generally used for pasture purposes. A diagram of the area taken from a 1956 aerial photograph (Abrams, 1956) shows the general topography of the area prior to landfill operations (Fig. 8).

In 1959, the area was purchased by the City of Kalamazoo to be used for sanitary landfill purposes. The solid wastes were dumped over the edge of the shoreline and then covered by dirt which was excavated from near-by hills (Fig. 9). In 1961, the area was abandoned and dumping was prohibited. Since then, the area has been used by different companies under special permission only (VerMeulen, 1971).

Physiography

The present features of the field are the effects of excavation by bulldozers. A flat plateau extends for 400 feet along the top of the incline. An over-lay taken from a 1964 aerial photograph (Abrams, 1964) depicts the topography after excavation

Fig. 7. Topographical sketch (overlay) of a portion of the Nazareth Landfill area showing the different elevations caused by excavation by bulldozers during landfill operations.
Scale: 1"=100' (Abrams, 1964)

Legend

Sample Plot

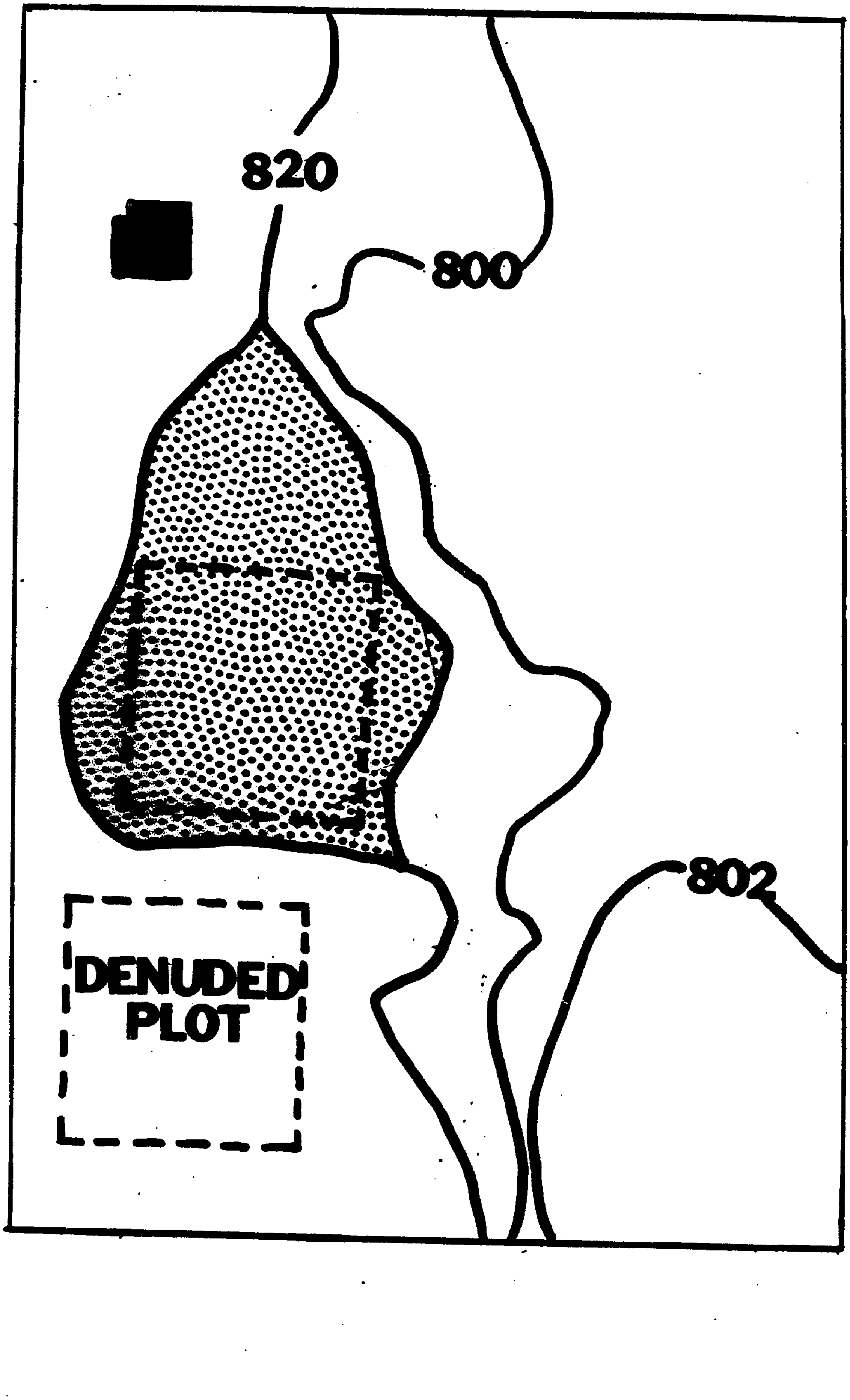
Topographical elevations

Area covered by landfill

Fig. 8. Topographical sketch of a portion of the Nazareth Landfill area showing the different elevations prior to landfill operations.
Scale: 1"=100' (Abrams, 1956)

Legend

Topographical elevations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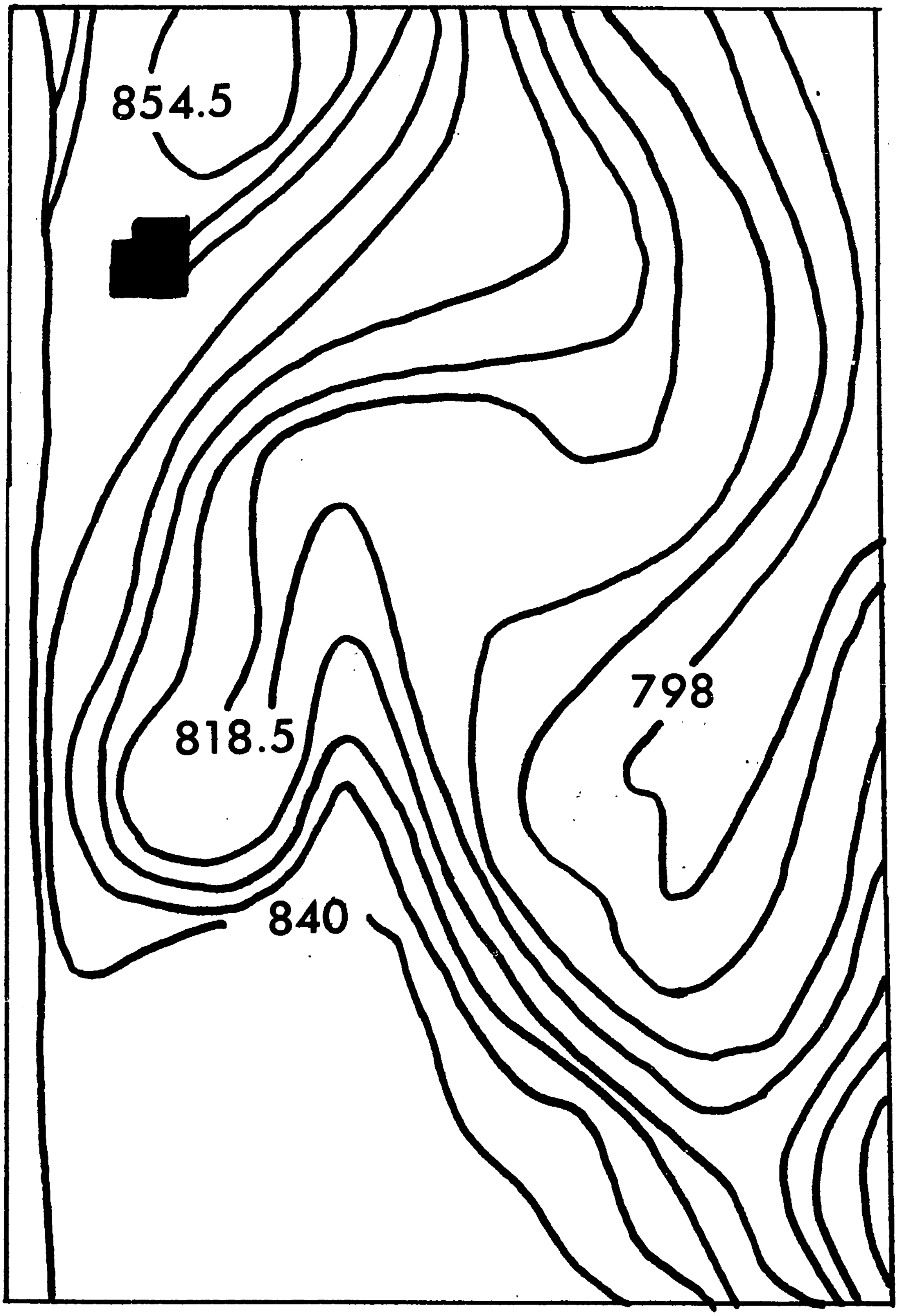
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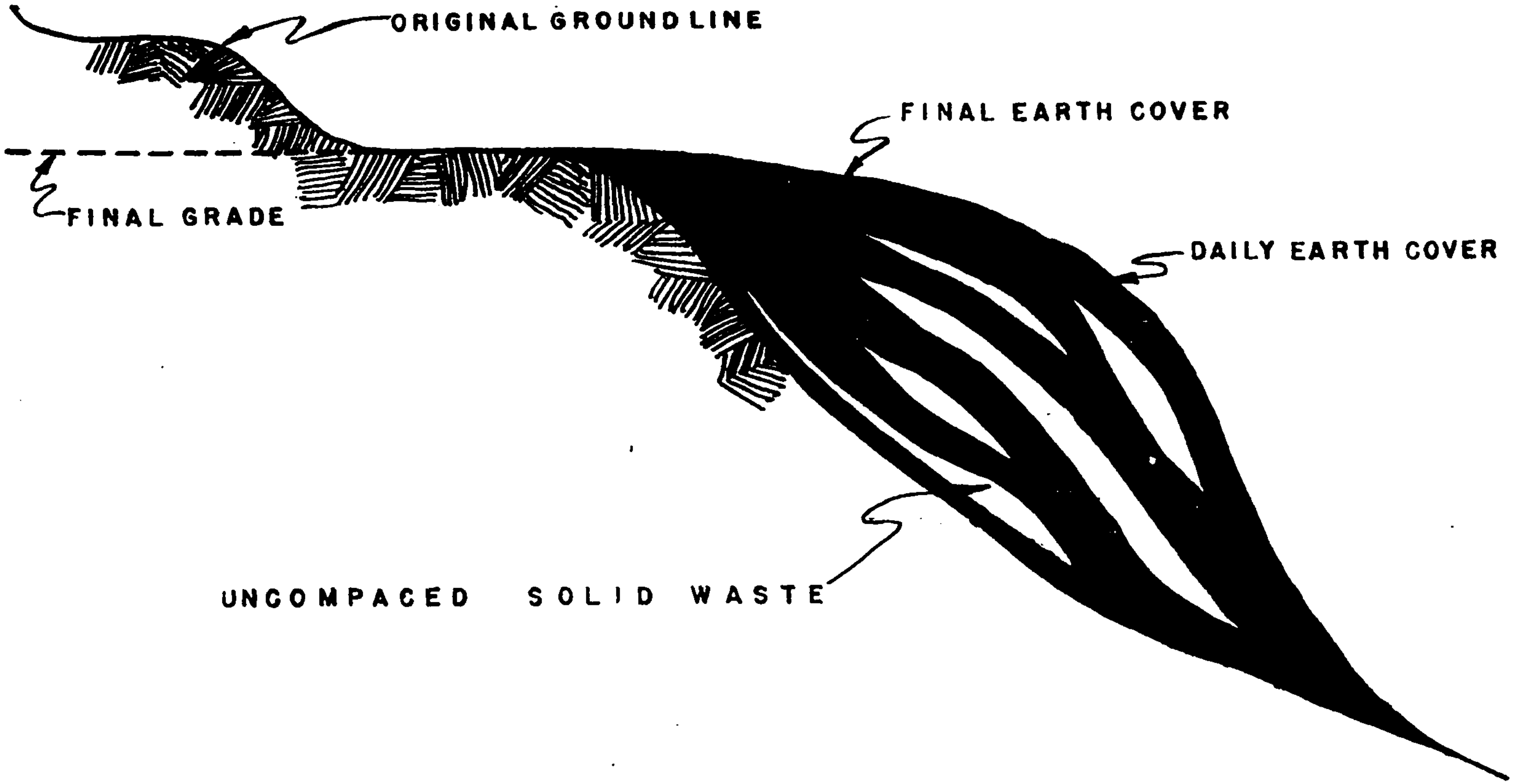


Fig. 9 A diagram of the "Area Fill Method" used in the Nazareth Landfill operation where dirt is brought in or excavated from other close-by locations to bring a deep depression to grade. Scale: 1" = 100' (Ehlers, 1965)

was done during landfill operations (Fig. 7).

The field is bordered on the south by several small hills, many of which have been excavated. Along the northeast perimeter is a steep incline that drops between 25 and 30 feet at an incline approximately 35 degrees to another plateau, supporting a *Quercus* (Oak)-*Acer* (Maple)-*Carya* (Hickory) forest. The field itself is relatively flat with several areas of erosion, clearly marking the drainage pattern of the area.

Soil

The soil, developed under natural conditions of physiography and climate, is a very dark, grayish-brown sandy loam of the Kalamazoo series. The surface soil is 8-10 inches thick. The subsoil is a dark, reddish-brown clay loam becoming more sandy with depth. The underlying material is brown, stratified gravel and sand. Characteristically, the soil has relatively slow runoff with a moderate available water capacity. Permeability is moderate in the upper parts.

After excavation and landfill operations, the soil is mixed so as to completely rearrange the podzol (Soil Conservation Service, 1972).

Climate

Weather data for the Kalamazoo area show that the highest temperature ever recorded was 109·F, on July 13, 1936, and the lowest was -25·F, on February 10, 1885. Temperatures reach the

100·F mark in about 1 summer out of 3. Days on which temperatures reach 90·F, or above, average 25 per year. At the other extreme, temperatures fall to zero or below on an average of 4 times during the winter. The average dates of the last freezing temperature in the spring and the first in the fall are May 9 and October 9. Lake Michigan greatly affects the weather at Kalamazoo, as the prevailing westerly winds are warmed in the winter and cooled in the summer while passing over the lake.

The average annual precipitation in the area is about 35 inches. Precipitation received during the growing season (April-September) averages 57 percent of the annual total. The rainfall is heaviest in May, which has an average of about 3.8 inches. The driest month of the year is February, in which the average is about 2 inches.

Snowfall averages about 55 inches, and 7 months of the average year have measurable amounts. January has the most snow, averaging 14.3 inches. Kalamazoo is on the eastern edge of the so-called snow belt, which is induced by moisture and warmth picked up by the prevailing westerlies while crossing Lake Michigan. Consequently, the average annual snowfall at Kalamazoo is 10-15 inches greater than in the central and eastern sections of southern Michigan (Eichmeier, 1963).

METHOD

The following criteria were used in selecting the landfill areas to be studied: (1) Proximity to Kalamazoo; (2) relatively flat topography to avoid micro-environments yielding unusual species distribution; (3) the surface covering a base of solid waste material; (4) the landfill merely abandoned and left barren with no further human disturbance; (5) the landfills of different ages from time of abandonment to time of study.

Three landfills were studied extensively and several others were examined but not sampled. The three that met the above criteria were chosen for quantitative studies. A 10-year-old, denuded area adjacent to the 10-year-old landfill was also studied for comparison since it was denuded during the landfill operation. Some of the surface soil from the denuded plot was used to fill the landfill (VerMeulen, 1971).

The 1-year-old landfill was abandoned in May of 1970 and was sampled in October of 1971. The 3-year-old landfill was abandoned in May of 1968 and was sampled in October of 1971. The 10-year-old landfill was abandoned in June of 1961 and was sampled in September of 1971.

In the spring of 1971, permanent sample plots, 50-meters-square, were placed at each landfill and the denuded plot and marked by metal stakes. At the 10-year-old landfill and the adjacent, denuded area, the sample plots were systematically placed because the size of the area prohibited random placement. The sample plots at the other two landfills were randomly selected by the use of a grid. The area was divided into plots, 50-meters-square. The coordinates for the northwest corner of each sample plot were recorded on separate sheets of paper and then drawn from a hat.

In the fall of 1971, separate, randomly-placed quadrats of 0.1-meter-square, 0.25-meter-square and 1-meter-square were examined in each sample plot. Each quadrat was randomly placed by the use of coordinates and a random numbers table. This avoided such contaminating variables as (1) lack of independence in contigious quadrats which tends to exaggerate the number of species and (2) the clumping of species together by summing randomly-placed quadrats, tending to eliminate the effect of contigious distribution (Kershaw, 1960, 1961, 1963; Greig-Smith, 1964; Hurlbert, 1969). The 1-meter-square and 0.25-meter-square quadrats were delimited by an aluminum frame, and the 0.1-meter-square quadrats were delimited by a plastic frame comprised of four metric rulers. Cover estimates were determined by the use of the 0.1-meter-square quadrats for the larger, two quadrat sizes and by measurement for the 0.1-meter-square quadrats.

The number of quadrats necessary for adequate sampling was determined by two methods; (1) a Species-area curve (Cain, 1938; Evans and Cain, 1952; Quarterman, 1957), and (2) summing the densities of consecutive pairs of quadrats, calculating the means, and plotting against the number of observations. As oscillations in the means decrease, the adequacy of sampling increases (Greig-Smith, 1964).

Fifty, 1-meter-square, randomly-placed quadrats were used in determining an Importance Index (Curtis and McIntosh, 1950; Kershaw, 1964) or DFD Index (Quarterman, 1957). For each species in each landfill and the denuded plot, frequency, density (number of stems of each species per unit area), and dominance or percent of total cover (estimate) were determined. A summary figure (Importance Index) was obtained for each species by adding relative frequency, relative density and relative dominance. Tables and figures were based on the raw data for frequency, density and dominance, plus the calculated Importance Index.

Interspecific association was studied using three different-sized quadrats to assess the effect of pattern size. Greig-Smith (1964) states that if species in a community exhibit pattern, this would indicate a control by specific influencing factors. The study of interspecific association between species would provide evidence of any grouping of species or competitive relationships from a like response. Hurlbert (1969) purports the use and calculation of data from several different quadrat sizes for the most satisfactory measure of association. Fifty quadrats, each 1-meter-square, 100 quadrats, each 0.25-meter-square, and 200 quadrats, each 0.1-meter-square were chosen for use in detecting association. Association will be least ambigious when based on presence-absence data (Hurlbert, 1969). The data were tested to see if the species occurred together more or less frequently than would be expected on the basis of chance, by the use of the Chi-square Test calculated from a 2 X 2 contingency table (Pielou, 1964; Greig-Smith, 1964; Hurlbert, 1969).

Stems of all vascular plants were counted in all three quadrat sizes. The results were then compared with the random expectations as indicated by a Poisson Series having the same mean. Aggregation was studied, using the Variance : mean ratio Test (Greig-Smith, 1964) also known as the coefficient of dispersion (Blackman, 1942), or the relative variance (Clapman, 1948) and the X^2 Test of Goodness of Fit (Greig-Smith, 1964).

The most common type of non-randomness is the occurrence of excessive numbers of empty quadrats and of those with higher numbers of individuals, owing either to exclusion of the species from part of the area by unfavorable environmental factors or by the presence of competing species or to aggregation brought about by inefficient propagule dispersal or by vegetative propagation. The Variance : mean ratio Test is normally sensitive to this type of discrepancy. Either the X^2 Test of Goodness of Fit or the Variance : mean ratio Test may detect evident non-randomness when the other fails to do so. This has been demonstrated both for artificial "communities" of discs with known pattern and for woody plants in forests (Greig-Smith, 1964).

The Variance : mean ratio Test makes use of the equality of the mean and the variance of the Poisson distribution. If the ratio of the variance to the mean is less than one, a tendency towards a uniform distribution is indicated. The difference can be compared with its standard error by means of the t test. The X^2 Test of Goodness of Fit makes use of the Poisson series with the observed mean calculated and observed number of quadrats containing 0, 1, 2, etc. individuals compared with random expectations by the X^2 test. In statistical tests, probability values of .001 were considered to indicate significant difference.

Soil samples were taken from each of the 50, 1-meter-square plots in each of the three landfills and the denuded plot. Available water was determined using the Gravitric-oven Drying Method (Black, 1965). Each sample was taken at a depth of three inches and placed in 75cc metal cans with tight-fitting lids which were secured immediately after samples were taken. The samples were later placed in a convection oven with their lids off for a period of 24 hours at 110°C. The samples were then re-weighed and put back in the oven for six hours and again re-weighed to determine any difference in weight. Water content was obtained by dividing the difference between wet and dry masses by the weight of the dry mass to obtain the ratio of the mass of water to the mass of the dry soil. By multiplying this number by 100, the percentage of water in the sample was determined on a dry mass (dry weight) basis. Soil pH was determined by the use of a LaMotte Soil Kit using Bromoethyl green and Phenol red chemical tests.

Gleason and Cronquist (1963) was used as a source for all scientific names for plants, while Hanes and Hanes (1947) was used for all common names for plants.

RESULTS

Floristic Composition

1-Year-Old Plot

Examination of 50, 1-meter-square quadrats in the 1-year sample plot showed the presence of 43 species. Trifolium pratense (Red clover), Ambrosia artemisiifolia (Ragweed), Poa pratense (Kentucky bluegrass), and Phleum pratense (Timothy) had the highest Importance Index values respectively (Table 1). Importance was also shown by Digitaria sanguinalis (Crab grass), Plantago lanceolata (English Plantian), Centaurea maculosa (Knapweed), and Chenopodium album (Lamb's quarters), respectively.

Two species, Trifolium pratense and Ambrosia artemisiifolia, had frequencies greater than 30 percent. Four species, Trifolium pratense, Poa compressa (Canada bluegrass), Phleum pratense and Digitaria sanguinalis had densities greater than 5 stems per 1-meter-square. Five species had densities greater than 2 stems per 1-meter-square: Ambrosia artemisiifolia, Bromus inermis, Panicum capillare (Witch grass), Berteroa incana and Melilotus officinalis (Yellow sweet clover). Trifolium pratense had the highest dominance or percent cover followed by Ambrosia artemisiifolia and Digitaria sanguinalis.

Species	1 Year Plot				3 Year Plot				10 Year Plot				Denuded Plot			
	Freq.	Den.	Dom.	II	Freq.	Den.	Dom.	II	Freq.	Den.	Dom.	II	Freq.	Den.	Dom.	II
Achillea millefolium									2	.02	.50	.44	4	.22	1.4	1.01
Agropyron repens					40	41.34	1165	96.85								
Agrostis sp.	14	1.18	18	.60												
Amaranthus graecizans					8	.56	5.80	3.63								
Ambrosia artemisiifolia	78	4.18	463	6.80	8	.42	7.80	3.08	12	.28	9.60	12.10	2	.06	2.4	.76
Asclepias syriaca	6	.08	7	.40	4	.40	.05	1.13	2	.02	.20	.42	2	.02	.3	.39
Aster pilosus	26	.90	114	1.80	70	12.70	96	54.89	28	1.26	11.60	12.50	10	.30	9.2	3.41
Barbarea vulgaris					2	.10	.30	.65								
Berteroa incana	32	2.68	47	2.90												
Bromus inermis	4	.26	4	.20												
Bromus secalinus					22	3.40	7.80	14.55								
Cenchrus longispinus									6	.08	.65	.43				
Centaurea maculosa	30	1.10	134	2.15	6	.66	1.24	4.51	56	6.15	73.80	65.00	94	19.64	96	70.12
Chenopodium album	22	1.08	142	1.98	26	2.06	38.80	15.42	8	.36	1.00	2.50	6	.80	.7	1.17
Chrysanthemum leucanthemum	14	.84	19.5	.81	4	.42	3.20	2.03	1	.12	.60	.73	4	.10	2.2	.81
Cichorium intybus					4	.10	.40	1.18								
Circium vulgare	.4	.04	3.5	1.66												
Convolvulus arvensis					4	.04	.50	1.12								

Table 1. Frequency (Freq.), density per 1-meter-square quadrat (Den.), dominance per 1-meter-square quadrat or percent cover (Dom.), and Importance Index (II), of species found in 50, 1-meter-square quadrats taken from sample plots on three landfills of various ages and a 10-year-old, denuded plot.

Species	1 Year Plot				3 Year Plot				10 Year Plot				Denuded Plot			
	Freq.	Den.	Dom.	II	Freq	Den.	Dom.	II	Freq.	Den.	Dom.	II	Freq.	Den.	Dom.	II
Conyza ramosissima	22	.88	3.80	2.46	14	3.14	13.80	8.25	18	1.74	4.00	6.60				
Cycloloma atriplicifolium									8	.22	1.40	.96				
Datura stramonium													4	.20	1.80	1.07
Daucus carota	26	1.66	14.50	9.14	2	.22	1.40	1.49	4	.12	.60	1.00	6	.12	1.00	1.25
Desmodium paniculatum													2	.08	1.20	.57
Digitaria sanguinalis	18	5.52	9.40	14.36												
Euphorbia glyptosperma									4	.14	.40	1.00				
Festuca elatior									6	.72	.70	2.00				
Hieracium sp.	6	.26	1.10	1.45					4	.32	.40	.93				
Hypericum perforatum	8	.16	1.60	1.65	4	.36	1.50	1.67	8	.20	1.10	2.13	4	.22	1.00	.95
Lepidium campestre	28	.42	21.10	8.48	6	.32	1.00	2.04	4	.20	1.20	1.55				
Lepidium virginicum	10	.50	2.90	2.79					2	.08	.60	.63				
Lychnis alba	10	.16	5.00	2.52												
Malva neglecta	6	.08	2.40	1.38					2	.40	.20	.47				
Malva rotundifolia	4	.10	1.50	.97												
Medicago lupulina													10	.32	3.70	2.49
Melilotus alba	16	1.66	14.60	7.59	18	2.12	20.90	10.49	12	1.02	9.40	8.36	20	.96	16.40	6.69
Melilotus officinalis	20	2.06	19.60	7.13	12	1.22	11.00	6.28	50	3.20	30.60	29	64	2.72	58.60	22.37

Table 1--continued

Species	1 Year Plot				3 Year Plot				10 Year Plot				Denuded Plot			
	Freq.	Den.	Dom.	II	Freq.	Den.	Dom.	II	Freq.	Den.	Dom.	II	Freq.	Den.	Dom.	II
Oxalis corniculata	6	.10	1.00	1.16	6	.12	2.20	2.01								
Oxybaphus hirsutus													4	.08	.40	1.39
Panicum capillare	34	2.82	11.00	11.43	30	2.62	7.50	10.74	24	1.26	.41	8.46	14	.64	1.35	2.94
Phleum pratense	44	5.28	24.20	19.30	18	3.36	26.60	13.70	30	4.56	11.60	20.40	30	2.44	6.35	7.74
Physalis heterophylla													2	.08	.60	.47
Phytolacca americana					2	.02	1.40	.75								
Plantago lanceolata	44	.98	24.40	12.07	14	.64	6.60	5.36	2	.02	.20	.15	2	.06	1.00	.53
Plantago rugelii	8	.18	2.50	1.84					10	.16	.85	2.23				
Poa compressa	14	1.60	4.60	5.10	10	6.60	17.60	13.16	4	1.60	1.80	4.93	84	33.00	.93	125.78
Poa pratense	30	6.94	2.08	19.52	12	2.84	1.87	6.34	4	82	.80	32.40	6	3.00	.80	3.94
Polygonum aviculare	10	.30	4.60	2.09	2	.08	.80	.72	18	.52	5.85	5.53				
Polygonum persicaria					4	.26	6.40	2.37								
Portulaca oleracea					16	.88	8.20	6.42								
Potentilla recta	28	1.64	7.60	7.98	2	.02	.60	.75	10	.30	2.40	3.23	52	8.96	49.90	21.88
Rumex crispus					10	.41	3.90	3.65								
Saponaria officinalis	12	.36	1.90	2.59					2	.10	.20	.35				
Solidago canadensis					6	.18	3.40	2.28	8	.20	1.20	2.23	10	.16	1.40	1.84
Solidago graminifolia									12	.22	1.88	3.17	4	.12	1.50	.98
Taraxacum officinale					20	1.10	14.60	8.76					2	.02	.80	.37

Table 1--continued

Species	1 Year Plot				3 Year Plot				10 Year Plot				Denuded Plot			
	Freq.	Den.	Dom.	II	Freq.	Den.	Dom.	II	Freq.	Den.	Dom.	II	Freq.	Den.	Dom.	II
Trifolium pratense	68	1.18	704	52.76	4	.20	1.90	1.55					6	.10	1.40	2.81
Trifolium hybridum													4	.02	.40	.72
Trifolium repens					6	.18	6.00	3.06	16	.98	2.80	6.01	18	1.16	8.42	5.09
Verbascum thapsis	8	.08	5.50	.28	2	.02	.02	.55	8	.08	1.60	2.13	4	.02	.40	.72
Trees & Shrubs																
Rhus typhina													6	.06	.22	1.42
Salix sp.					2	.60	1.10	3.03								
Populus tremuloides									2	.02	.02					

Table 1--continued

3-Year-Old Plot

A total of thirty-six species were found in 50, 1-meter-square quadrats in the three year sample plot with Agropyron repens (Quack grass) and Aster pilosus being the major dominants according to their Importance Index values (Table 1). Subdominance was shown by Chenopodium album, Poa compressa, Panicum capillare and Melilotus alba. Aster pilosus and Agropyron repens both had frequencies greater than 20 percent. Density was greatest in Agropyron repens averaging over 40 stems per 1-meter-square. Aster pilosus was next, averaging over 12 stems per 1-meter-square, followed by Poa compressa and Phleum pratense, both averaging over 5 stems per 1-meter-square. Agropyron repens had the highest average dominance or percent cover, covering over 40 percent of the total area, followed by Aster pilosus and Chenopodium album.

10-Year-Old Plot

In the 10-year-old sample plot, the 50, 1-meter-square quadrats contained 38 species with Centaurea maculosa having the highest Importance Index value, followed by Melilotus officinalis, Poa pratense, Aster pilosus, Phleum pratense and Ambrosia artemisiifolia respectively (Table 1). A frequency of over 48 percent was shown by Centaurea maculosa, followed by Melilotus officinalis, 25 percent; Phleum pratense, 15 percent; Poa pratense and Aster pilosus, 14 percent; and Ambrosia artemisiifolia, 12 percent. Density was shown to be greatest in Centaurea maculosa and Poa pratense, both with averages of over 6 stems per 1-meter-square. Melilotus officinalis and Phleum pratense both showed averages greater than 3 stems per 1-meter-square. Dominance or percent cover was greatest in Centaurea maculosa and Melilotus officinalis.

10-Year-Old Denuded Plot

In the 10-year-old denuded plot, of the 34 species present, Poa compressa was the major dominant species with an Importance Index of 70.12 (Table 1). Subdominance was shown by Potentilla recta (Cinquefoil) and Melilotus officinalis. The highest frequency was shown by Centaurea maculosa, 94 percent; then Poa compressa, 84 percent; Melilotus officinalis, 64 percent; and Potentilla recta, 52 percent.

Density was greatest in Poa compressa, averaging over 33 stems per 1-meter-square. Centaurea maculosa was next highest with an average of 19.6 stems per 1-meter-square, followed by Potentilla recta averaging 89.1 stems per 1-meter-square. Centaurea maculosa and Poa compressa both indicated a dominance or percent cover above 93 percent, followed successively by Melilotus officinalis and Potentilla recta.

Adequacy of Sampling

In determining the number of 1-meter-square quadrats necessary for adequate sampling, the 3-year landfill showed the need for the most number of quadrats. Both methods of determination indicated the need for fifty quadrats in the 3-year landfill;

Fig. 10. Adequacy of Sampling. (a) The mean of the first 2, 4, 6 ...50, observations of 1-meter-square quadrats, calculated and plotted against the number of observations. As the oscillation decreases, the adequacy increases (Greig-Smith, 1964). (b) Species-area curve indicating the number of 1-meter-square quadrats necessary to sample the vegetation adequately. Vertical line indicates point on curve at which a 10 percent increase in sample area gives a 10 percent increase in the total number of species.

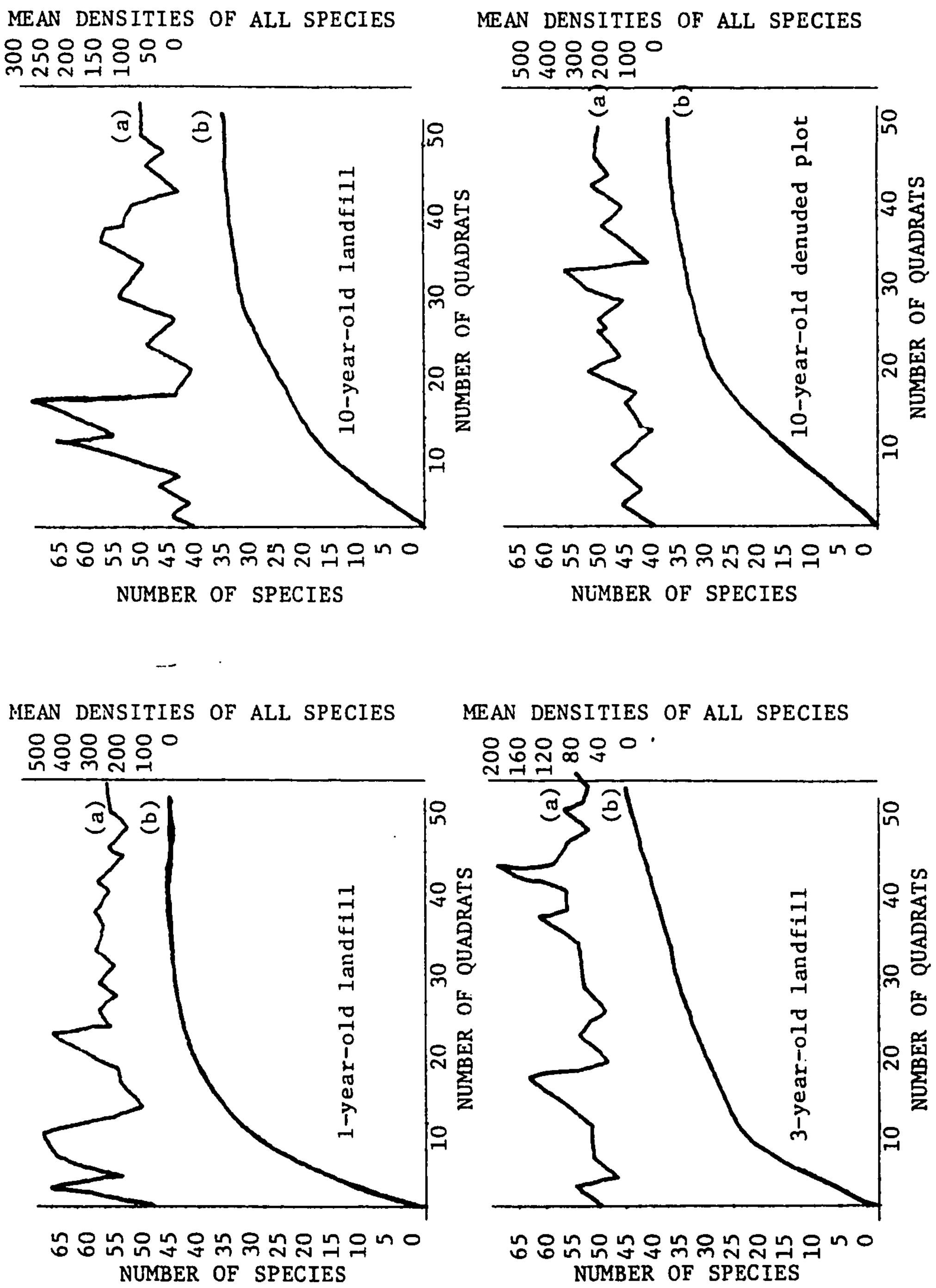
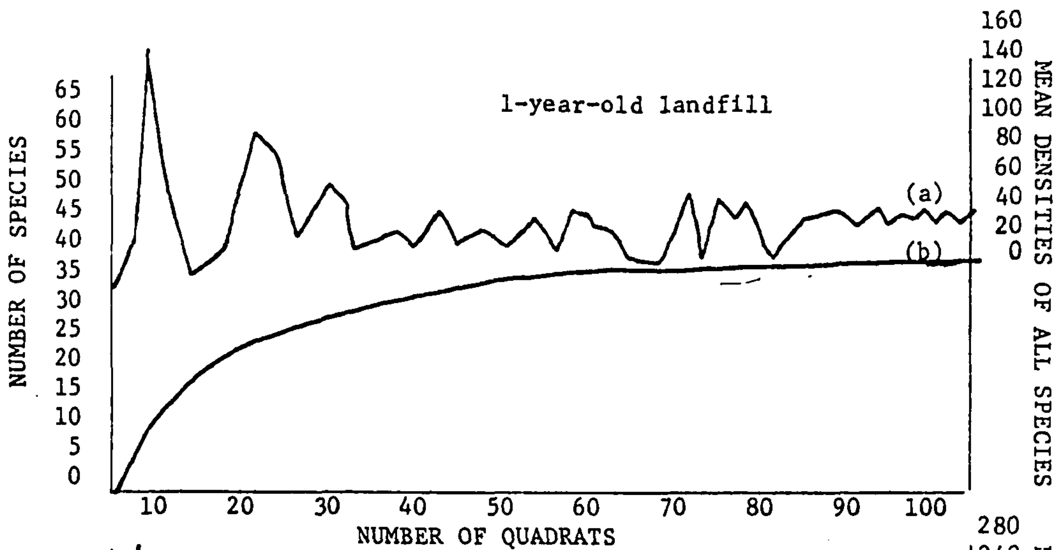
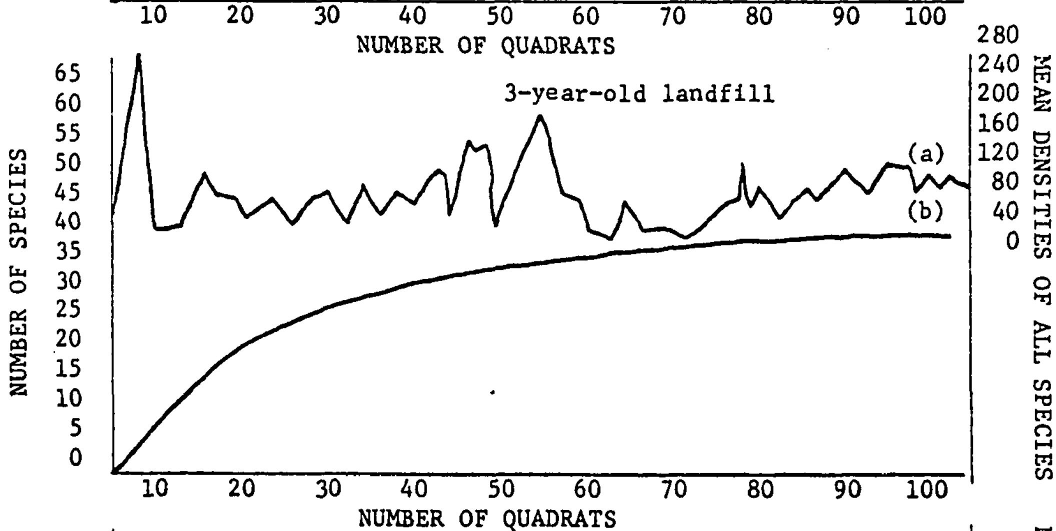

MEAN DENSITIES OF ALL SPECIES
NUMBER OF SPECIES
NUMBER OF QUADRATS
10-year-old landfill
10-year-old denuded plot
1-year-old landfill
3-year-old landfill
(a)
(b)

Fig. 11. Adequacy of Sampling. (a) The mean of the first 2, 4, 6... 100 observations of .25-meter-square quadrats, calculated and plotted against the number of observations. As the oscillation decreases, the adequacy increases (Greig-Smith, 1964). (b) Species-area curve indicating the number of .25-meter-square quadrats necessary to sample the vegetation adequately. Vertical line indicates point on curve at which a 10 percent increase in sample area gives a 10 percent increase in the total number of species.


1-year-old landfill
NUMBER OF SPECIES
65
60
55
50
45
40
35
30
25
20
15
10
5
0
10 20 30 40 50 60 70 80 90 100
NUMBER OF QUADRATS
160
140
120
100
80
60
40
20
0
MEAN DENSITIES OF ALL SPECIES
(a)
(b)


3-year-old landfill
NUMBER OF SPECIES
65
60
55
50
45
40
35
30
25
20
15
10
5
0
10 20 30 40 50 60 70 80 90 100
NUMBER OF QUADRATS
280
240
200
160
120
80
40
0
MEAN DENSITIES OF ALL SPECIES
(a)
(b)

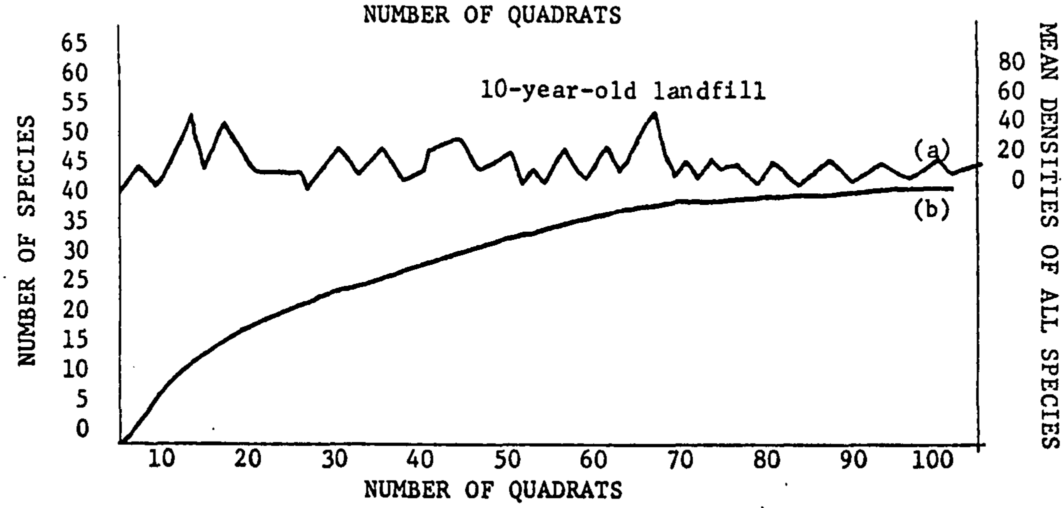
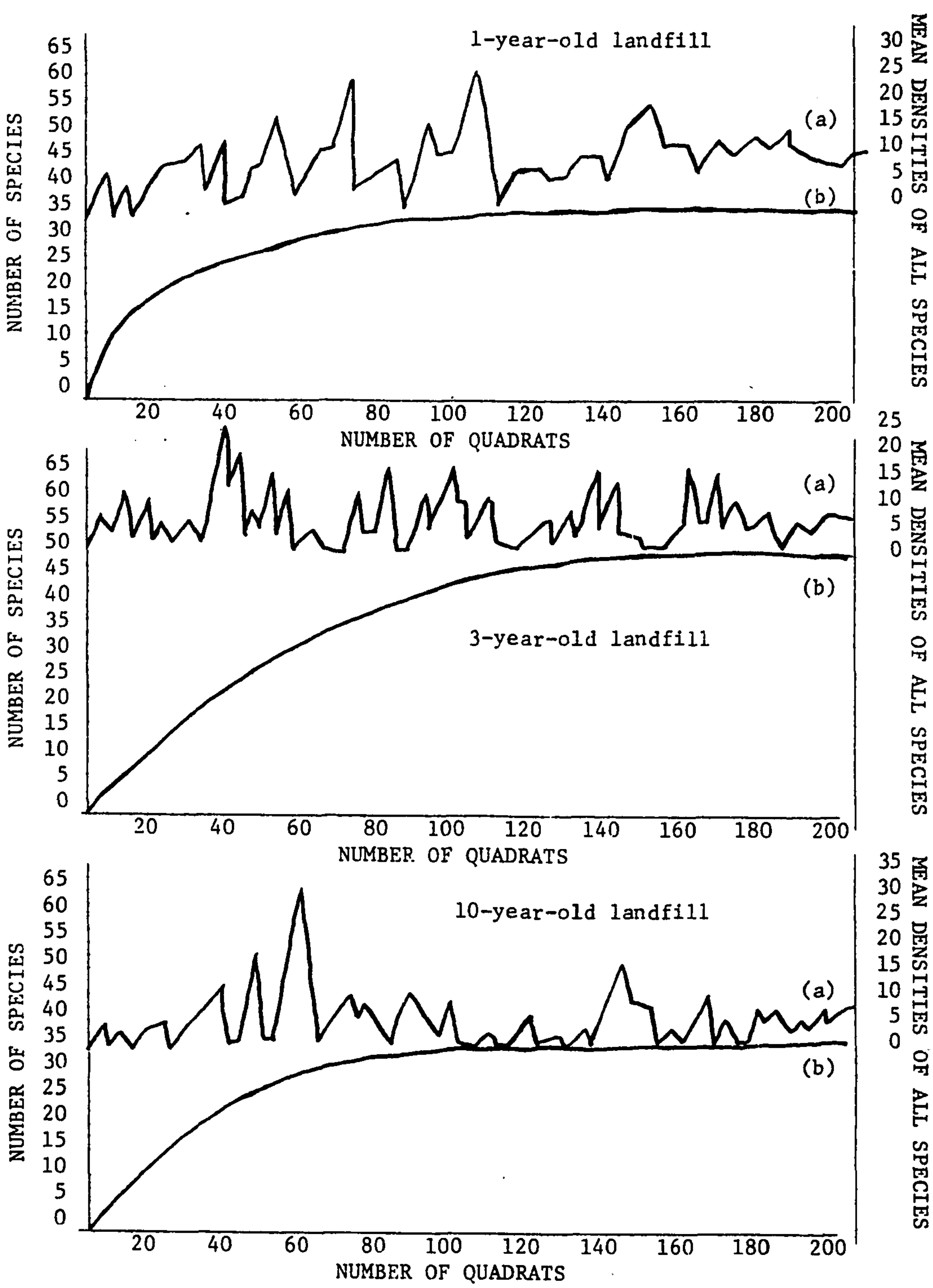

10-year-old landfill
NUMBER OF SPECIES
65
60
55
50
45
40
35
30
25
20
15
10
5
0
10 20 30 40 50 60 70 80 90 100
NUMBER OF QUADRATS
80
60
40
20
0
MEAN DENSITIES OF ALL SPECIES
(a)
(b)

Fig. 12. Adequacy of Sampling. (a) The mean of the first 2, 4, 6... 200 observations of .1-meter-square quadrats, calculated and plotted against the number of observations. As the oscillation decreases, the adequacy increases (Greig-Smith, 1964). (b) Species-area curve indicating the number of .1-meter-square quadrats necessary to sample the vegetation adequately. Vertical line indicates point on curve at which a 10 percent increase in sample area gives a 10 percent increase in the total number of species.


1-year-old landfill
NUMBER OF SPECIES
65
60
55
50
45
40
35
30
25
20
15
10
5
0
MEAN DENSITIES OF ALL SPECIES
30
25
20
15
10
5
0
(a)
(b)
20
40
60
80
100
120
140
160
180
200
NUMBER OF QUADRATS
3-year-old landfill
NUMBER OF SPECIES
MEAN DENSITIES OF ALL SPECIES
25
20
15
10
5
0
(a)
(b)
NUMBER OF QUADRATS
10-year-old landfill
NUMBER OF SPECIES
MEAN DENSITIES OF ALL SPECIES
35
30
25
20
15
10
5
0
(a)
(b)
NUMBER OF QUADRATS

therefore all other sample plots will be adequately sampled using fifty quadra' · (Fig. 10).

Both methods of determination for the 3-year landfill indicated that 100, 0.25-meter-square quadrats would adequately sample the vegetation. Both the 1-year and 10-year sample plots indicated a need for fewer quadrats; therefore, both could be adequately sampled using 100 quadrats (Fig. 11).

In determining the number of 0.1-meter-square quadrats necessary for adequate sampling, the 3-year landfill showed the need for the most number of quadrats. Both methods of determination indicated the need for 200 quadrats in the 3-year landfill; therefore all other sample plots will be adequately sampled using 200 quadrats (Fig. 12).

Pattern

Aggregation was exhibited in most of the species that were well enough represented to test. Fourteen species were tested from the 1-meter-square quadrats in all four sample plots separately. *Melilotus alba*, in the 1-year landfill sample plot and *Phleum pratense*, in the 3-year landfill sample plot indicated random distribution, while the rest were significantly aggregated (Table 2). The indication for random distribution for these two species was verified by the use of the X^2 Test of Goodness of Fit (Greig-Smith, 1964) indicating that both species fit with the Poisson distribution (Table 5). Seven other tests indicated possible random distribution; however, none of them fit the

Table 2. Variance, mean, variance/mean, *t* value and probabilities of fit to the Poisson distribution of herbacious plants on three different-aged, abandoned, sanitary landfills and a 10-year-old, abandoned, denuded plot. Calculations are based on 50, one-meter-square quadrats. Standard error .202. *t* values marked by an asterisk (*) are significant at the .001 level.

Species	Plot Age	Variance	Mean	Variance/Mean	t	Species	Plot Age	Variance	Mean	Variance/Mean	t
	1	232.34	4.18	55.58	270.20*		1	2.99	1.66	1.81	4.00*
Ambrosia	3	.06	.42	.1371	4.30*	*Melilotus*	3	16.18	2.12	7.63	32.82*
artemisiifolia	10	.04	.28	.142	6.06*	*alba*	10	.78	1.02	.77	1.19
	DP	.03	.06	.54	2.77		DP	.30	.96	.31	3.41*
	1	2.45	.90	2.72	8.51*		1	138.09	2.06	67.03	326.88*
Aster	3	1728.00	12.70	136.00	673.65*	*Melilotus*	3	1.00	1.22	.82	.94
pilosus	10	5.19	1.26	4.12	15.44*	*officinalis*	10	173.63	3.20	54.26	263.66*
	DP	2.32	.30	7.73	33.31*		DP	130.35	2.72	47.92	232.27*
	1	4.32	1.10	3.93	14.50*		1	148.84	5.28	28.18	138.01*
Centaurea	3	.01	.66	.02	4.90*	*Phleum*	3	1.22	3.36	.37	3.11
maculosa	10	10.33	6.15	1.67	3.32*	*pratense*	10	81.56	4.56	17.88	83.55*
	DP	68.56	19.64	1.30	3.90*		DP	33.24	2.44	13.62	62.47*
	1	10.55	1.08	9.77	48.37*		1				
Chenopodium	3	14.03	2.06	6.81	33.71*	*Poa*	3	8.00	6.60	1.21	1.04
album	10	.04	.36	.12	.58	*compressa*	10	.21	1.60	.13	4.30*
	DP						DP	36.60	33.00	1.10	5.44*
	1	.01	.16	.05	4.70*		1	201.72	6.94	29.07	138.96*
Hypericum	3	.23	.36	.65	1.73	*Poa*	3	5.39	2.84	1.89	4.45*
perforatum	10	.05	.20	.29	3.50*	*pratense*	10	111.75	8.20	13.62	62.47*
	DP	.00	.22	.02	4.90*		DP	100.00	3.00	33.33	160.04*
	1	73.07	2.18	33.52	160.90*		1	18.76	1.64	11.43	51.63*
Lepidium	3	.02	.32	.06	4.70*	*Potentilla*	3				
campestre	10	.02	.22	.02	4.26*	*recta*	10	.00	.30	.01	4.90*
	DP						DP	676.14	8.96	75.46	368.61*
	1	46.88	2.82	16.62	77.33*		1	1.27	1.18	1.07	.35
Panicum	3	7.80	2.62	2.98	9.80*	*Trifolium*	3	.03	.20	.15	4.25*
capillare	10	11.58	1.26	9.20	40.59*	*pratense*	10				
	DP	.37	.64	.58	2.07		DP				

Table 3. Variance, mean, variance/mean, *t* value and probabilities of fit to the Poisson distribution of herbacious plants on three, different-aged, abandoned, sanitary landfills. Calculations are based on 100, 0.25-meter-square quadrats. Standard error .1421. *t* values marked by an asterisk (*) are significant at the .001 level.

Species	Plot Age	Variance	Mean	Variance/Mean	t	Species	Plot Age	Variance	Mean	Variance/Mean	t
	1	10.11	1.90	40.73	279.59*		1	2.07	.53	3.89	20.33*
Ambrosia	3	14.20	2.54	10.00	63.33*	Melilotus	3	1.02	.34	3.01	14.14*
artemisiifolia	10	2.79	.08	1.78	5.46*	alba	10	.66	.35	1.88	6.19*
	1						1				
Aster	3	72.10	1.71	42.16	289.65*	Melilotus	3	.32	.46	2.00	5.20*
pilosus	10	.54	.35	1.54	3.80*	officinalis	10	.71	.41	1.74	7.03*
	1	.16	.17	.97	.28		1	78.44	1.97	39.97	274.24*
Centaurea	3	.15	.14	1.08	.56	Phleum	3	8.92	1.12	2.97	49.04*
maculosa	10	3.84	.93	4.13	22.03*	pratense	10	.45	.58	.77	1.69
	1	2.04	.52	3.93	20.61*		1				
Chenopodium	3	1.67	.45	3.67	18.79*	Poa	3	139.60	3.57	39.11	268.19*
album	10	.05	.22	.22	5.56*	compressa	10				
							1				
Hypericum						Poa	3	12.65	1.10	11.50	73.89*
perforatum						pratense	10				
	1	6.33	.81	7.85	48.20*		1				
Lepidium	3	2.18	.43	5.09	28.78*	Potentilla	3	1.96	.49	3.99	21.04*
campestre	10	.36	.13	2.90	13.37*	recta	10	1.41	.68	2.08	7.60*
	1	.31	.18	1.72	4.36*						
Panicum	3	174.42	2.42	72.00	499.64*	Trifolium					
capillare	10	4.09	.82	4.99	28.08*	pratense					

Table 4. Variance, mean, variance/mean, _t_ values and probabilities of fit to the Poisson distribution of herbacious plants on three, different-aged, abandoned, sanitary landfills. Calculations are based on 200, 0.1-meter-square quadrats. Standard error .1003. _t_ values marked by an asterisk (*) are significant at the .001 level.

Species	Plot Age	Variance	Mean	Variance/Mean	t	Species	Plot Age	Variance	Mean	Variance/Mean	t
Ambrosia artemisiifolia	1	5.00	.26	18.45	173.97*	Lepidium campestre	1	5.44	.27	20.17	191.13*
	3	1.72	.11	15.63	145.86*		3				
	10						10				
Aster pilosus	1					Poa compressa	1				
	3	1.02	.33	.31	6.98*		3				
	10						10	28.80	.62	46.58	454.43*
Chenopodium album	1										
	3	.09	.16	.55	4.58*						
	10										
Panicum capillare	1	3.21	.22	14.50	135.59*						
	3	.01	.22	.02	9.77*						
	10										
Phleum pratense	1	14.70	.19	77.42	761.91*						
	3	1.61	.24	6.71	56.92*						
	10										
Poa pratense	1	27.80	2.10	13.23	121.93*						
	3										
	10										

Table 5. Observed number of individuals compared with random expectations by the X^2 test of goodness of fit to the Poisson series of distribution using 50, 1-meter-square quadrats. Asterisk (*) indicates significance at the .001 level.

Species	Plot Age	X^2
Ambrosia artemisiifolia	10 YR DP	48.26
Chenopodium album	10 YR DP	14.81
Hypericum perforatum	3 YR	47.56
Panicum capillare	10 YR DP	43.06
Melilotus officinalis	3 YR	79.16
Melilotus alba	10 YR	8.36*
Phleum pratense	3 YR	11.20*
Poa compressa	1 YR	76.32
Trifolium pratense	1 YR	56.07

Table 6. Observed number of individuals compared with random expectations by the X^2 test of goodness of fit to the Poisson series of distribution using 100, .25-meter-square quadrats.

Species	Plot Age	X^2
Centaurea maculosa	1 YR	325.17
Centaurea maculosa	3 YR	86.28
Phleum pratense	10 YR	120.83

Poisson distribution.

There were two species at the 0.25-meter-square quadrat level that showed possible random distribution by use of the Variance : mean ratio Test (Table 3). These were Centaurea maculosa and Phleum pratense. Both were shown to be aggregated by use of the X^2 Test of Goodness of Fit (Table 6). Both were therefore considered aggregated. All other species showed significant aggregation to both tests.

Eight species were tested at the smallest scale, 0.1-meter-square. All were shown to be significantly aggregated (Table 4).

There were eight species that occurred in all three landfill plots at all three scales or quadrat sizes. Aggregation appeared to be the same for all three scales.

Ambrosia artemisiifolia and Phleum pratense appeared to reduce aggregation as a function of sample plot and age for all three scales. Chenopodium album, Centaurea maculosa, and Lepidium campestre indicated a similar trend. Melilotus alba indicated a reduction in aggregation as a function of sample plot and age within the 0.25-meter-square quadrat size.

Interspecific Association

Interspecific association was studied in each sample plot for all species which occurred in at least five quadrats. Three different quadrat sizes were used in all four sample plots. The quadrats used were 50, 1-meter-square quadrats; 100, 0.25-meter-square quadrats; and 200, 0.1-meter-square quadrats. To test if the species occurred together in quadrats by chance, Chi-square was calculated from a 2 X 2 contingency table (Greig-Smith, 1964). Unadjusted values and those values using the Yates' correction for continuity were both calculated (Simpson, Roe, and Lewontin, 1960). Of the 1140 tests run, there appeared to be no associations of any significance in any of the sample plots.

Comparison: 10-Year-Old Landfill and Denuded Plot

A standard t Test (Greig-Smith, 1964) was run on ten species which were represented in the 10-year-old landfill sample plot and the 10-year-old denuded plot to determine if there were any significant difference in their densities. There appeared to be no significant difference (Table 7).

Table 7. *t* test values computed from the densities of all species well-enough represented in both the 10-year-old landfill and the 10 -year-old denuded plot. Asterisk (*) indicates significance at .08 level.

Species	t
Ambrosia artemisiifolia	.275*
Potentilla recta	.094
Phleum pratense	.0559
Melilotus alba	.0163
Melilotus officinalis	.0316
Aster pilosus	.0979
Panicum capillare	.0507
Centaurea maculosa	.037
Poa compressa	.036
Poa pratense	.0464

Table 8. Average soil moisture and soil pH values taken from a depth of 3" below the surface in each 1-meter-square quadrat in each of the three landfill sample plots and the denuded field sample plot.

Sample Plot	Soil Moist.	pH
1-year-old landfill	.25 grams/cc	6.9
3-year-old landfill	.13 grams/cc	7.1
10-year-old landfill	.17 grams/cc	7.0
10-year-old denuded plot	.15 grams/cc	7.0

DISCUSSION

Quantitative Analysis

Floristic Composition

The vegetation of any abandoned field undergoes changes in composition (secondary succession) as a function of time. This results from modification of the physical environment by the plant community. That is, succession is community-controlled even though the physical environment determines the pattern, rate of change, and often sets the limits of how far it can go (Odum, 1971). Different species have different tolerance limits and different requirements from the environment. Only those species which can tolerate extreme environmental and competitive stresses are capable of invading and maintaining themselves within a newly abandoned area. These types of plants are called "pioneer species" (Wodehouse, 1971).

In all of the landfills examined in this study, many herbacious pioneer species were dominant regardless of the age of the landfill; the only difference being the relative importance of these species rather than the species composition.

The importance of pioneer species in the rate of secondary succession in abandoned areas, particularly *Ambrosia artemisiifolia*, *Aster pilosus*, *Chenopodium album*, *Panicum capillare*, *Phleum pratense*, *Melilotus alba*, *Melilotus officinalis*, *Poa pratense* and *Poa compressa* has been domonstrated in several studies from all over the country, including Michigan (Evans and Cain, 1952; Davis and Cantlon, 1969), Illinois (Bazzaz, 1969), Tennessee (Quarterman, 1957), Wisconsin (Thompson, 1943; Curtis, 1959), the Piedmont of New Jersey and North Carolina (Oosting, 1942; Keever, 1950; Bard, 1952), and Iowa (Warner and Aikman, 1942). The rate of secondary succession of the three landfills appeared to be slower in comparison with several of the above studies.

Normally, Ambrosia artemisiifolia decreases in dominance between one and three years and should show very few traces thereafter. Bazzaz (1969), Thompson (1943), Curtis (1959), and Quarterman (1957) indicated that its presence after the first three to five years was usually only in eroded areas. As is true with most pioneer species, Ambrosia artemisiifolia is unable to maintain a foothold because it accumulates topsoil, is shaded out, or its growth is retarded due to alleopathic substances, enabling more stable perennial competitors to overtake it (Wodehouse, 1971); however, Ambrosia artemisiifolia was still present and relatively large in size in one of the landfill areas after ten years. This may be due to high amounts of soil erosion, sterility of the sandy soil and the presence of gravel and large rocks, possibly increasing erosion and the spacing of some individuals and the restricting of others (Fig. 13).

Bazzaz (1969) and Quarterman (1957) indicated that Aster pilosus was absent in abandoned areas after 10 years or showed a sharp decrease in cover and frequency. This species is an annual

Fig. 13 *Ambrosia artemisiifolia*, *Centaurea maculosa* and *Melilotus* spp. (10 year-old landfill) are predominant on this area. *Ambrosia artemisiifolia* is still relatively large in size.

and its seeds germinate and grow slowly, hindering its competitive abilities in relation to the perennials and other fast germinating annuals such as Ambrosia artemisiifolia, Phleum pratense and Chenopodium album (King, 1966; Wodehouse, 1971; Bazzaz, 1969). Aster pilosus was well scattered and small in the 1-year landfill. It reached its peak in the 3-year landfill, and then gradually decreased and was less abundant in the 10-year landfill.

Chenopodium album was present in the 1-year landfill as several large, mature plants.. It appeared to reach its peak in the 3-year landfill with mature plants greater than five feet tall (Fig. 14). Chenopodium album was very scattered in the 10-year landfill, but still present as considerably-smaller, mature plants. This may be a function of available water and nitrates in the soil (King, 1966). Quarterman (1957) indicated that Chenopodium was absent after two years.

Panicum capillare appeared to be at its peak in the 1 and 3-year landfills, and decreased in the 10-year landfill. Bazzaz (1969) in his study on secondary succession in old fields, showed Panicum capillare only in the 1-year-old field. Panicum capillare is a hardy pioneer species due to its root system (King, 1966), however, it may not be a good competitor because of its size and need for radiation. With other plants of much greater size developing as a function of time, it could not compete for sunlight.

Centaurea maculosa was present in the 1-year landfill as several small, mature plants. The 10-year landfill contained an

Fig. 14 Chenopodium album (3 year-old landfill) mature plants are greater than five feet tall.

abundance of Centaurea maculosa of varied heights, reaching to 2.5 feet tall (Fig. 15). Of all other species present, Centaurea maculosa had the highest relative dominance in any area.

Phleum pratense was abundant on all three landfills, particularly the 1 and 10-year landfills. This may be due to its high pollen emission and relatively large seeds. This allows ample food reserve and wide dissemination, especially in areas with open space. The 3-year landfill had a greater amount of cover than the other two, possibly restricting emigration of Phleum pratense.

Melilotus alba and Melilotus officinalis were present on all three landfill plots. They appeared as small, spindly plants in the 1-year landfill, and large, bushy plants in the 10-year landfill. Harper (1960) and Caruso (1963) in their field studies, related the spindly appearance of the first year seedlings to competition for light.

Poa pratense, a perennial grass, was present along the edge of the 1-year landfill with little representation in the central portions, thus indicating that it was invading the area. It was of greater importance in the 10-year landfill and was more evenly distributed. Poa compressa, another perennial grass, appeared on all three landfill areas; however, it indicated a peak in the 3-year landfill. Caruso (1963) and Evans and Dahl (1955) in their field studies, indicated that Poa pratense required more available water than did Poa compressa.

Fig. 15 Centaurea maculosa, and Melilotus spp. (10 year-old landfill) are predominant in this area. Centaurea maculosa varies in size up to two and one half feet tall.

Bazzaz (1969) and Quarterman (1957) reported the presence of Rhus seedlings of several different species in abandoned areas after three to four years. Rhus typhina and Populus tremuloides seedlings were present only on the 10-year landfill and denuded plot. Thompson (1943) in his study in Wisconsin, indicated that Rhus came in sometime before twelve years.

Thus, the rate of succession on the three landfills appeared to be slower in relation to other studies on abandoned fields, as indicated by an abundance of Ambrosia artemisiifolia, Aster pilosus and Panicum capillare and an absence of tree and shrub seedlings after three or four years.

To reiterate, succession is a function of the environment, vegetation and climate of the area. Factors that would definitely have an effect on the succession of these particular areas are: (1) the relative sterility of the sandy soil, allowing only those plants capable of living in areas of low nutrition to survive. This would also affect the size of the individuals. (2) The porosity of sandy soil would allow rapid leaching, possibly creating a moisture stress which would restrict an even greater number of species as well as the growth of those present. (3) The presence of gravel and rocks of considerable size which would deter plant growth, especially native perennials, by spacing the vegetation. This would allow those pioneer species to develop to larger sizes due to the lack of competition. Rocks also enhance soil erosion by consistently washing away humus substances from the surface.

(4) The depodzolization of the soil by excavation rearranges the biota and mineral elements such that repodzolization will be severly retarded. (5) An excessive amount of heat is generated by chemical changes in the decomposition of the solid waste. Soil temperatures may reach 150-160·F, well above temperatures needed to kill seeds present in the soil (Ehlers, 1965). This means that the seeds must come from a near-by source and not from within the soil.

Cold weather and a short growing season could be factors that would retard successional rates, at least in the North. Davis and Cantlon (1969) showed that secondary succession on an abandoned area approximately 5 miles from Kalamazoo went from cropland to old-field grassy vegetation in two years. Therefore, climate in this study, is not a major deterrent to the successional rate.

Aggregation

Aggregation or spatial pattern of species has been studied by several authors using randomly-placed quadrats and testing for fit to the Poisson distribution. Blackman (1935, 1942), in examining various grasslands, has found some species to have random distribution. Ashby (1948) has shown most species to be aggregated. According to Ashby, in large areas where there is uniformity of soil and micro-climate, the species tend to be non-random. He also notes that smaller areas, appearing uniformly distributed, are likewise non-random. Curtis (1959) shows extreme aggregation of prairie species in Wisconsin. Most of the species tested on all three landfills in this study indicated a significant amount of aggregation with the probability at the .001 level (Tables 2,3, and 4), thus conforming with the results of these authors.

Kershaw (1964) states that the spread of vegetation by vegetative reproduction and heavy seeds are the two most likely factors that cause aggregation, according to most authors. Two species studied, Poa pratense and Poa compressa, vegetatively reproduce by rhizomes. Both showed significant aggregation.

Phleum pratense, a grass producing relatively large seeds, showed aggregation in all test quadrats in all three landfills except the 0.25-meter-square plot in the 3-year landfill where it was randomly distributed. King (1966) discussed the size and abundance of the seeds of Phleum pratense and stated that its viability and competitive nature were due to its large, abundant seeds. This would tend to clump or aggregate the species, as was shown on all but one scale.

For a total examination of pattern within an area, a more detailed study of the physical factors as well as biotic factors that affect the area is needed. Physical and biotic factors will vary from point to point between and within communities. Those plants most susceptible to these factors will show greater aggregation (Greig-Smith, 1964). The aggregation of these factors may be even greater on sanitary landfills where different chemicals and substances produced from the landfill operation have an effect on the soil atmosphere or the soil itself.

The production of allelopathic substances in a number of plant species which repress growth of other species has been studied (Moral and Cates, 1971; Kershaw, 1964; Curtis, 1959; Greig-Smith, 1964). A better understanding of these substances and their effects on the other species may lead to a better understanding of aggregation of species.

Interspecific Association

Interspecific association between species and environmental factors are important aspects of the organization of communities. The factors controlling and determining pattern are likely to affect many species rather than just one. If two, co-occurring species are affected similarly by the same environmental factors, they will produce a positive association. Differing responses of two or more species to the environment produce negative association.

The lack of any statistical significance between species indicates that the species are independent in their placement. A Chi-square Test indicated that there was no interspecific association of statistical significance with the probability at the .001 level in the three landfills studied. The lack of any significant associations is unusual in relation to Caruso's study (1963) done on a similar, abandoned area in Michigan. Caruso found associations between Melilotus alba, Melilotus officinalis, Poa pratense, Poa *compressa* and *Potentilla recta*. To understand why there were no associations, a more comprehensive investigation of the physical and biotic environments is needed.

Comparison of the Vegetation on the 10-Year-Old Landfill and the 10-Year-Old Denuded Plot

A comparison between the 10-year-old landfill and the 10-year-old, denuded plot was done to determine any significant difference in the vegetation of the two areas. A *t* test was calculated on the densities of those individual species well-enough represented in both areas. The results indicated that there were no significant differences with the probability at the .001 level in the number of stems of the different species in the two areas, thus indicating that both areas were similar in species density.

Though the densities of the individuals were similar, there were differences in the sizes of the individual plants in the two plots. *Ambrosia artemisiifolia* was considerably larger on the landfill. This may be important, as *Ambrosia artemisiifolia* grows largest in areas of high erosion and low competition, both characteristics of the early stages of succession (Keever, 1950). This was also true of *Chenopodium album*, which was larger in the 10-year-old landfill. If the size of the plant species is an important factor in determining the rate of succession, the 10-year-old landfill would appear to be succeeding at a slower rate than the denuded plot.

The cover of perennials may also indicate a difference in the rate of succession. Perennials are usually characteristic of the later stages of succession due to their greater need for available water and nutrients (Keever, 1950; Caruso, 1963; Piemeisel, 1954). Poa compressa, a perennial, covered considerably more area in the denuded plot than in the landfill. Poa pratense, a better competitor (Caruso, 1963) covered more area in the 10-year-old landfill than in the denuded plot; however, the greatest cover of perennials occurred in the denuded plot. This also inferred a slower rate of succession in the landfill.

To delineate the factors that are important in the rate of succession, more information is needed dealing with competition, environmental and physical variables and properties of species present. From the variables considered here, the rate of succession between the landfill and the denuded plot appears to be very similar; however, of the two, the landfill appears to be succeeding at a slower rate.

Social and Clinical Ramifications

Many pioneer plants that invade and survive on abandoned sanitary landfill areas are considered allergenic. Allergenic properties are the following: (1) the plant must be numerous and widely distributed; (2) each plant must produce a great number of pollen grains to "pollute" the air; (3) the pollen must contain an excitant of allergenic symptoms; (4) pollen must be anemophlous and sufficiently bouyant to be carried a considerable distance (National Academy of Science, 1968). Those plants with definite allergenic properties that were found on the sanitary landfills studied are listed in Table 9.

As discussed in one of the previous sections, the secondary succession of these landfills located on the peripheries of cities appeared to be slower than in old fields. Slower succession allows several allergenic species to survive for a longer period of time. Therefore, the presence of these allergenic species on landfill areas may have a definite effect on the number and severity of allergy cases within an adjacent city.

Newmark (1970) states that atmospheric pollen must be considered an important and pernicious air pollutant. Successful control programs cannot be instituted without full understanding of the ecological factors. In the planning and developing of sanitary landfills on the peripheral areas of cities, several important meteorological, ecological and clinical considerations should be made.

Meteorologists have discovered that urbanization is causing definite meteorological changes within and surrounding cities (Landsberg, 1970). An urban complex acts as a heat resevoir, producing positive pertubations on the thermal field. This pertubation is called the "Urban Heat Island" (Mitchell and Murray, 1961; Lowery, 1967; Clarke, 1969; Landsberg, 1970). Differential heating between urban complexes and the peripheral, foliated

Table 9. Plants producing pollen and known to cause allergenic reactions, found on the three landfills studied on the periphery of Kalamazoo, Michigan (Extracted from a more complete list published by the National Academy of Sciences, 1968).

Poa pratense (Kentucky bluegrass)
Poa compressa (Canada bluegrass)
Festuca sp.
Chenopodium album (Lambs' quarter)
Trifolium pratense (Red clover)
Trifolium repens (White clover)
Rumex crispus (Curly dock)
Plantago lanceolata (English plantian)
Ambrosia artemisiifolia (Common ragweed)
Phleum pratense (Timothy)
Plantago rugelli
Bromus sp. (some species)

environs produce the heat island. The same differential heating produces the heat island circulation and the intensity of the circulation is dependent on the amplitude and scale of the heat differential (Vulovick, 1972). Diurnal variation in the temperature difference between the city and the suburbs indicates that the heat island effect is most intense at night and least intense during the day (Vulovick, 1972). The differential heating distribution produces a weak, two-cell circulation system with low-level, horizontal convergence, upward vertical motion, and upper-level, horizontal divergence over the city. The circulation continues with a low-level horizontal divergence, downward vertical motion and upper-level horizontal divergence over the suburbs when there is no mean wind. A schematic circulation system of this type is shown in Fig. 16. The net effect of the heat island circulation is high horizontal air turbulances during the night, declining in the early morning and high vertical turbulances occurring in the early afternoon. This can result in a reduction of vertical transports of air pollutants during large mean winds (Vulovick, 1972), increased precipitation, and an increased number of small-scale eddies within the city (Landsberg, 1970).

What does this have to do with abandoned landfills and the presence of allergenic species? Considering the factors that determine pollen concentration along with the heat island effect, the heat island effect appears to have a definite effect on the concentration of pollen within an urban area.

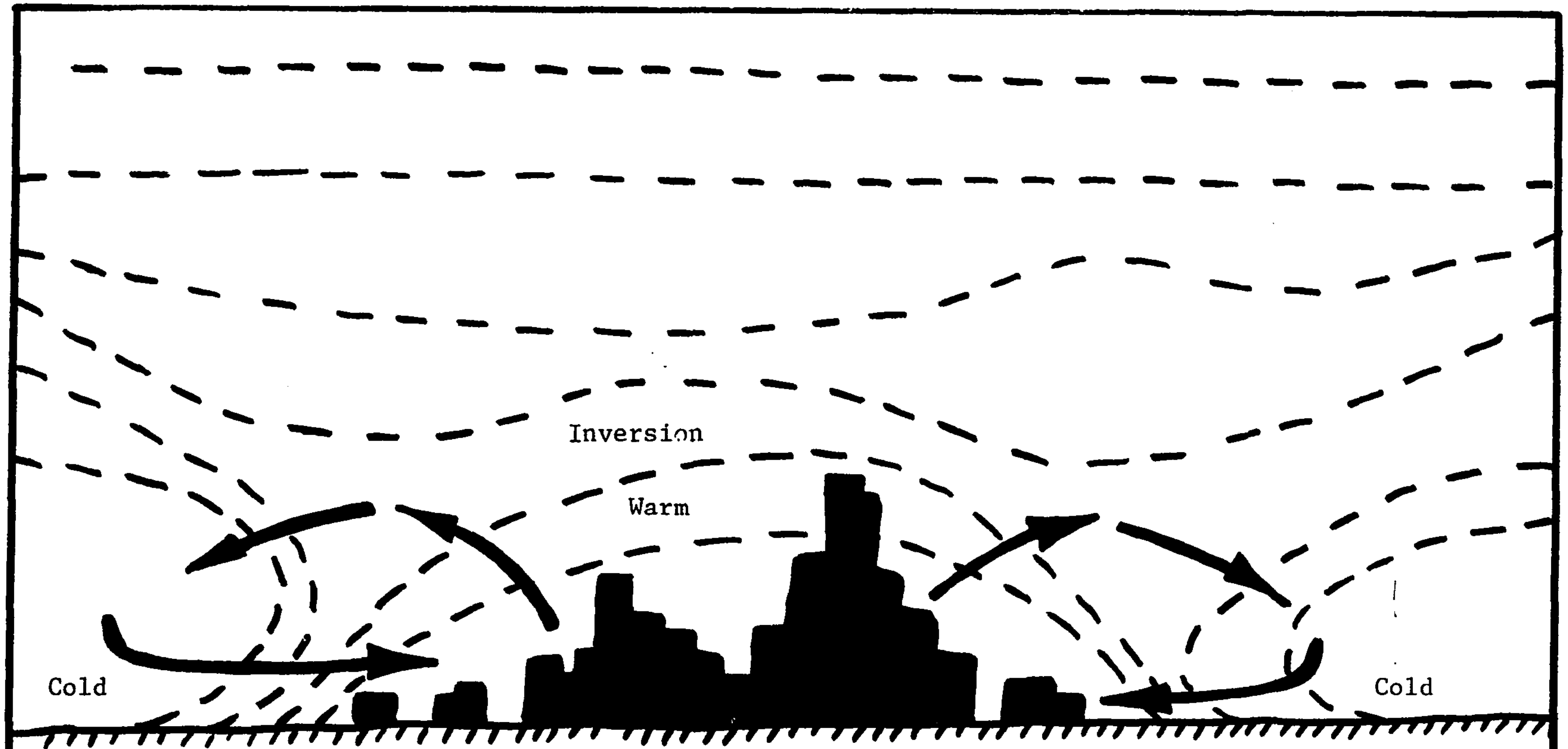


Fig. 16. Idealized scheme of nocturnal atmospheric circulation above a city in clear, calm weather. The diagram shows the heat island and the radiative ground inversions in the rural areas, a situation that causes a "country breeze" with an upper return current. (Dashed lines) Isotherms; (arrows) wind; Z, vertical coordinate (Landsberg, 1970).

Factors determining pollen concentration are: type of air mass, duration of air mass, frontal passage, air trajectory, wind-speed turbulance, relative humidity, and precipitation (Raynor and Hayes, 1970). The actual transfer of pollen from plant surfaces to the atmosphere is governed by wind speed and turbulence (Ogden, Hayes and Raynor, 1969). The peripheral areas of cities are those areas of high air turbulence owing to the heat island effect. Country breezes move from the country to the heat source (the city). With them, high concentrations of pollen will be carried. It should be realized that most pollen that becomes airborne returns to the earth near its source, and local sources of pollen are capable of increasing the background pollen concentration by several magnitudes in downstream regions (Raynor, Ogden and Hayes, 1968). The country breezes can only aid in the transfer and concentration of pollen in urban areas.

Pollen emissions are of highest magnitude just prior to sunrise, reaching a peak a few hours later (Holmes and Bassett, 1963; Ogden, Hayes and Raynor, 1969). This coincides with the highest low-horizontal country breezes blowing in the direction of the city. This will concentrate the pollen within the city especially if there are prevailing winds or if an inversion develops (Vulovick, 1972).

Emission of pollen most typically begins when moist, stable, night air gives way to unstable and drier air shortly after sunrise (Ogden, Hayes and Raynor, 1969). The heat island has greatest air turbulence at night during high horizontal circulation, while the countrysides should have a relatively stable lower-level. As morning approaches, condensation occurs, low-level turbulance begins and gradually increases the drying of vegetation on the lower level. This not only aids in the transporting of pollen within the low-level, horizontal air mass towards the city, but synergizes the emission of pollen.

Once the pollen is in the city, the eddies produced as a function of the differential heating and movement etc., help suspend the pollen for an even longer period of time.

The heat island effect causes increased precipitation. Rain normally aids in the removing of pollen from the air, but pollen emissions have been observed with humidity near 100% when the air is unstable and wind speeds are 0.5 miles per hour. Realizing that Ambrosia artemisiifolia accounts for more hayfever than all other species combined (Wodehouse, 1971), and that the drier months of the year are when ragweed emits its pollen, rain can hardly be considered a preventive measure.

Beyond the immediate, clinical impact of the heat island and adjacent allergenic plant communities, a possible, future ramification is involved. Ragweed is significantly related to the severity of symptoms of respiratory allergy. People exposed to ragweed for prolonged periods may develop a sensitivity to it. The severity of the symptoms varies according to the kind of disease and allergenic sensitivity. It is particularly noticeable among patients with allergenic rhinitis. It has also been shown that patients who were not allergic to ragweed showed symptoms during the hayfever season (Brown and Johannes, 1968). A case of hayfever followed by asthma occurred after prolonged exposure to ragweed pollen in a soldier who had previously lived in an area of low pollen concentration. Previously he had not had hay fever or any other allergic symptoms (Rosen, 1946).

Dr. W.W. Payne, of the University of Illinois, while doing his graduate work on ragweed, developed pollenosis after prolonged exposure to its pollen (Payne, 1972). This type of information indicates that if cities are progressively increasing in pollen concentrations, especially that of ragweed, more people may develop a sensitivity to it, creating an even greater problem to solve in the future.

Several people have emphasized the problem of "noxious," allergenic weeds as a major municipal interest.

> "Any city of importance should consider this problem a social need and take appropriate measures toward its solution by destroying the weeds within its limits. Moreover, a city is not likely to obtain the best results unless its campaign against weeds is developed outside the boundaries and made a more complete project, embracing the whole metropolitan area." (Groulx, 1954)

In 1954, Montreal began to solve the problem by passing legislation forcing people to destroy noxious weeds on their own private property. Booklets, posters, radio talks, exhibits, and special campaigns were used to help in the eradication (Groulx, 1954). New York City launched a campaign called "Operation Ragweed" with an annual expense that exceeded $85,000 in 1955 (Waltzer and Siegel, 1956).

Both Montreal and New York indicated a decrease in the total amount of pollen; however, neither city controlled the pollen concentration to any real degree. Both cities indicated the need for eradication of pollen sources both within and around the perimeter of the city. Because pollen-bearing pioneer species are becoming more abundant due to the increasing number of open areas, the incidence and eradication of these species is becoming an ever increasing problem. It seems ironic that cities are spending money to eradicate ragweed and other allergenic species while promoting and sustaining its growth in areas such as landfills that can even enhance its effects.

Ecological Alternatives

In the past, many people have looked upon land as a commodity to be traded in the market place, subject to supply and demand. In the process, much of our natural resources have been misused and destroyed. Odum (1969) states that most of our failure can be traced to the short-sighted action that considered only the benefits to a part of a system, rather than to the whole, or to a lack of understanding of the entire chain of events that must follow any large-scale manipulation of the landscape. In other words, anything we add to our environment must be considered in relation to the dynamic state of all its present components. Since the environment is our living space as well as our food supply and materials depot, its capabilities are as vitally important in the long run as its exploitation or its capacity to yield consumer products. It becomes apparent that we must have both protected and productive landscape, hopefully in reasonable balance.

Sanitary landfills are necessary and are severely compromising our natural landscape. The important consideration in the use of these landfills is that the vegetation is of a non-allergenic nature such that it will not augment the already present clinical problems. This can be accomplished in several ways.

If the land is needed for productive purposes, several alternatives are available that will not only help restore the landscape, but possibly create new sources of revenue. Landfill areas in conjunction with sewage treatment plants should be able to provide areas of high biomass yields. Kardose (1969) indicates that sewage effluent is high in phosphorus and nitrates which are key elements in maintaining abundant crop production. He showed an increased yield in corn, spruce and red pine as a function of irrigating with sewage effluent. This serves a dual purpose: (1) a place for depositing the solid waste, and (2) stabilization of the surface of these denuded areas with proper vegetational management. With this method, the areas could be used for growing crops, sod farms, nurseries or for growing tree seedlings to be used for stabilizing other denuded areas. This not only recycles waste products and essential resources, but with proper management, it can stabilize land, act as a commercial source of revenue, or an economic buffer for resource management programs. Sludge, dredged from river basins is another source of high nutrient material that is often wasted. This would serve the same purpose as the sewage.

Protected areas can also be established if proper range management techniques are employed and if the developmental stages or trends for a particular area are understood. Ecosystems undergo development because the biotic components are capable of modifying and controlling the physical environment to varying degrees at each stage of development. Vegetational development on landfills begins with anemophilous pioneer plants that are health hazards to adjacent urban communities. Man can solve this problem and still enhance the development of secondary succession by simulating a seral stage that is more advanced such that pioneer species will not be able to germinate or compete.

Piemeisel (1954) conceived and developed the idea of "replacement control," which employs an indirect ecological means of getting rid of pests by changing the vegetation. Replacement control makes use of the natural processes in secondary succession by the replacement of weeds with a more desirable cover of grasses and perennials. By the use of this method, one can speed up the rate of succession, by by-passing the primary sere conducive to undesirable pioneer species.

When dealing with replacement control in sanitary landfills, several considerations in its management should be made. Open-space areas such as landfills, will contain within the soil, many seeds from the vegetation of the surrounding area. These seeds will probably be the first to germinate due to lack of competition within the landfill. Chemical reactions taking place in the landfill soil may be helpful in eliminating these seeds. The chemical reactions produce temperatures upwards of 150°F. Temperatures above 100°F impede germination, and possibly kill those seeds present (U.S. Dept. of Agriculture, 1957). By monitoring the soil temperature, one could know when to plant desirable seeds before undesirable seeds could be transferred to the area by natural means. Higher temperatures can also promote germination such that if the soil were cool enough (45-80°F) to seed, the added warmth within the landfill may help to speed up the germination.

Another consideration is determining which species are non-allergenic, pioneer species that are more competitive than pioneer, allergenic species, and will still enhance secondary succession. Most species that germinate before allergenic, pioneer species will outcompete them (Payne, 1972). Therefore, a fast germinating species should eliminate a majority of undesirable, pioneer plants. Several grasses produce pollen in such small amounts that they are not considered to be hazardous (Wodehouse, 1971). Several perennial grasses are not only strong competitors, but build up humus relatively fast (Caruso, 1963). Poa pratense is one common perennial that produces humus as it grows and spreads (Caruso, 1963). Poa compressa is more drought resistant than Poa pratense, however it does not build up humus as fast (Evans and Dahl, 1955). Both are rhizominous which give them a definite competitive advantage. Melilotus spp. (Sweet clover) are leguminous, nitrogen-fixing perennials that are strong, pioneer competitors as evidenced by their abundance on the 10-year-landfill in this study (Table 1). The main drawback to these perennials is that they are slow germinators (Piemeisel, 1954).

By planting relatively fast-germinating, non-allergenic annuals along with several strong-competing perennials, such as Poa pratense and Melilotus spp., the growth of most weeds should be deterred. This will facilitate the growth of the perennials while the fast germinating annuals are out-competing the noxious weeds. Little monitoring will be needed as long as ample water is available.

The monitoring of the surface temperature, along with the seeding of the annuals and perennials, should be done simultaneously with the covering and completion of a particular landfill operation. This will inhibit any undesirable, pioneer species from germinating and developing a seed source.

A fast-germinating, annual grass that was used by Piemeisel (1954) in the replacement of weeds to eliminate leafhopper outbreaks was Bromus tectorum (Downy chess). Bromus tectorum is not considered as a hazardous allergenic species. It is also a winter annual, germinating before the onset of warm weather conditions, conducive for the germination of most other weeds.

Grazing on these areas should be somewhat restricted as overgrazing will allow bare paths to arise and this will facilitate the introduction of pioneer plants to the area (Piemeisel, 1954). With proper management and little capital outlay, these areas can be established and controlled. This type of management will enhance secondary succession up to the point of the perennial stage. Tree seedlings would further enhance secondary succession on the area.

Pine and spruce tree seedlings are inexpensive and conducive to secondary succession. In natural, secondary succession, pine trees are usually the predecessors of hardwoods. By planting pine and spruce seedlings along the inner perimeter of trees surrounding the area, or just on the edge of the area, the ecotone would increase. This would enhance the rate of secondary succession and would provide new wildlife habitats (Fig. 17). Entire tree stands could be developed.

Landfill areas can even be maintained as open meadows with proper management. Neiring (1958) in managing areas under power lines, indicated that the invasion of tree seedlings can be inhibited by the use of low shrub cover such as *Vaccinium* spp. (Low bush blueberry) or *Gaylussacia baccata* (Huckleberry). Other taller shrubs such as *Myrica pennsylvanica* (Bayberry) and *Vaccinium corymbosum* (Highbush blueberry) can also be used (Fig. 18). The planting of these species may have to be done after the soil has begun to podzolize due to the needs of the species. This type of environment would not only create a habitat and food source for

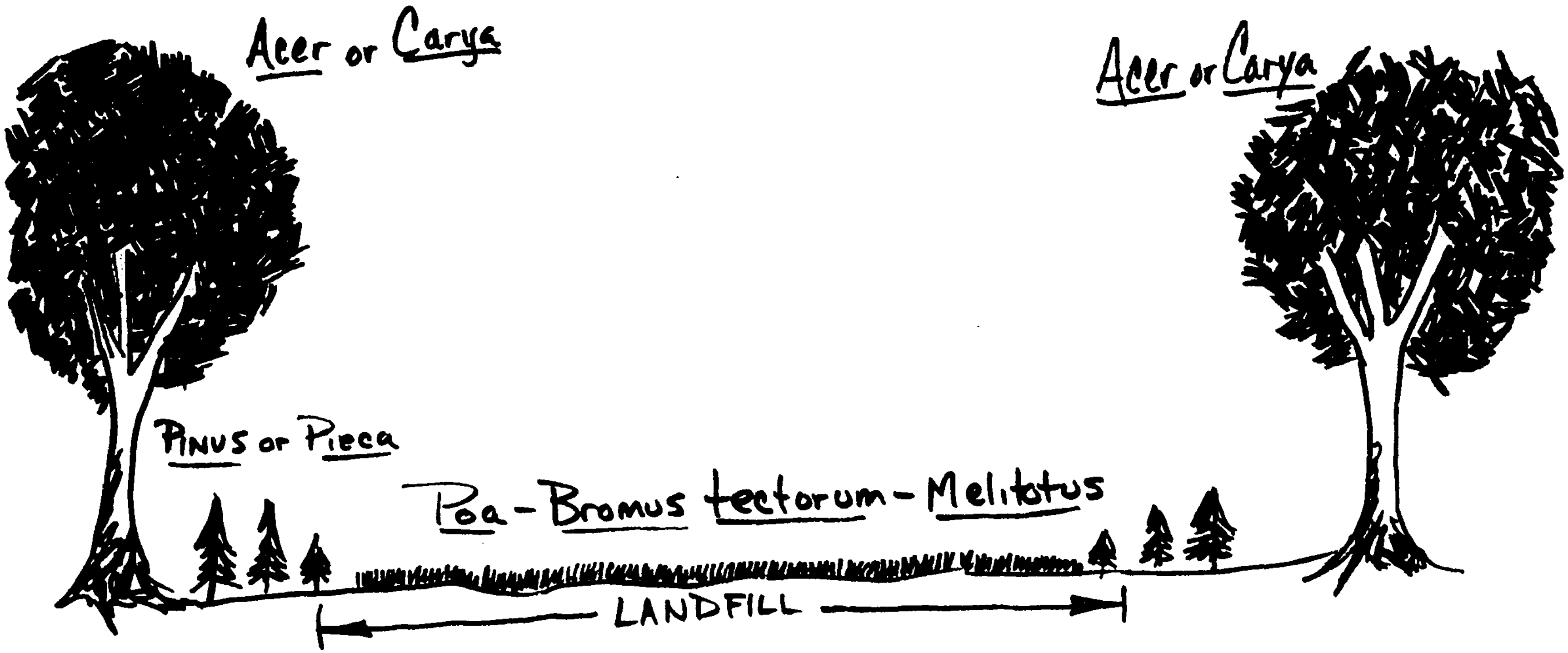


Fig. 17. Controlled vegetation of a landfill area using "Replacement Control." Pinus (pine) and Picea (spruce) seedlings planted on the inner perimeter of the adjacent woods with Poa-Bromus tectorum-Melilotus spp. herbacious covering the open area.

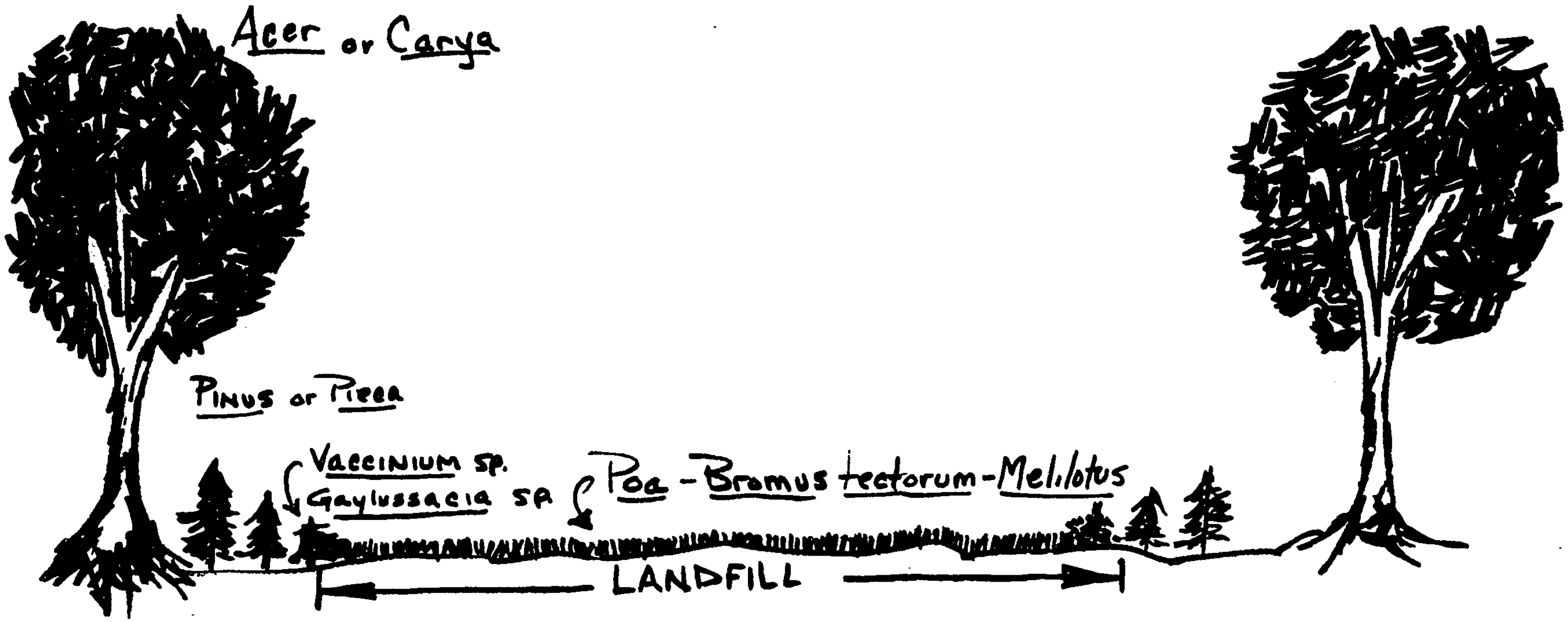


Fig. 18. Controlled vegetation of a landfill area using "Replacement Control." Pinus (pine) and Picea (spruce) seedlings planted on the inner perimeter of the adjacent woods with Vaccinium sp. (blueberry) and Gaylussacia spp. (huckleberry) woody shrubs inside the perimeter of the conifers. This will help maintain the Poa-Bromus tectorum-Melilotus spp. meadow.

wildlife, but could be used for recreation and for environmental teaching. At minimum, it would enhance the aesthetics around our cities and would aid in the balance between productive and protected landscape.

Sanitary landfills and their immediate and future ramifications are only a few problems to consider in the realm of landscape management. The major roles of the environmental scientist are (1) striving to understand ecosystems by striving to understand its components and (2) producing sound theory on which to base land management strategy. The environmental scientist's greatest challenge is to elicit sound management strategy for those portions of the landscape that must be developed for the multi-purposes of man.

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