Lecture 16

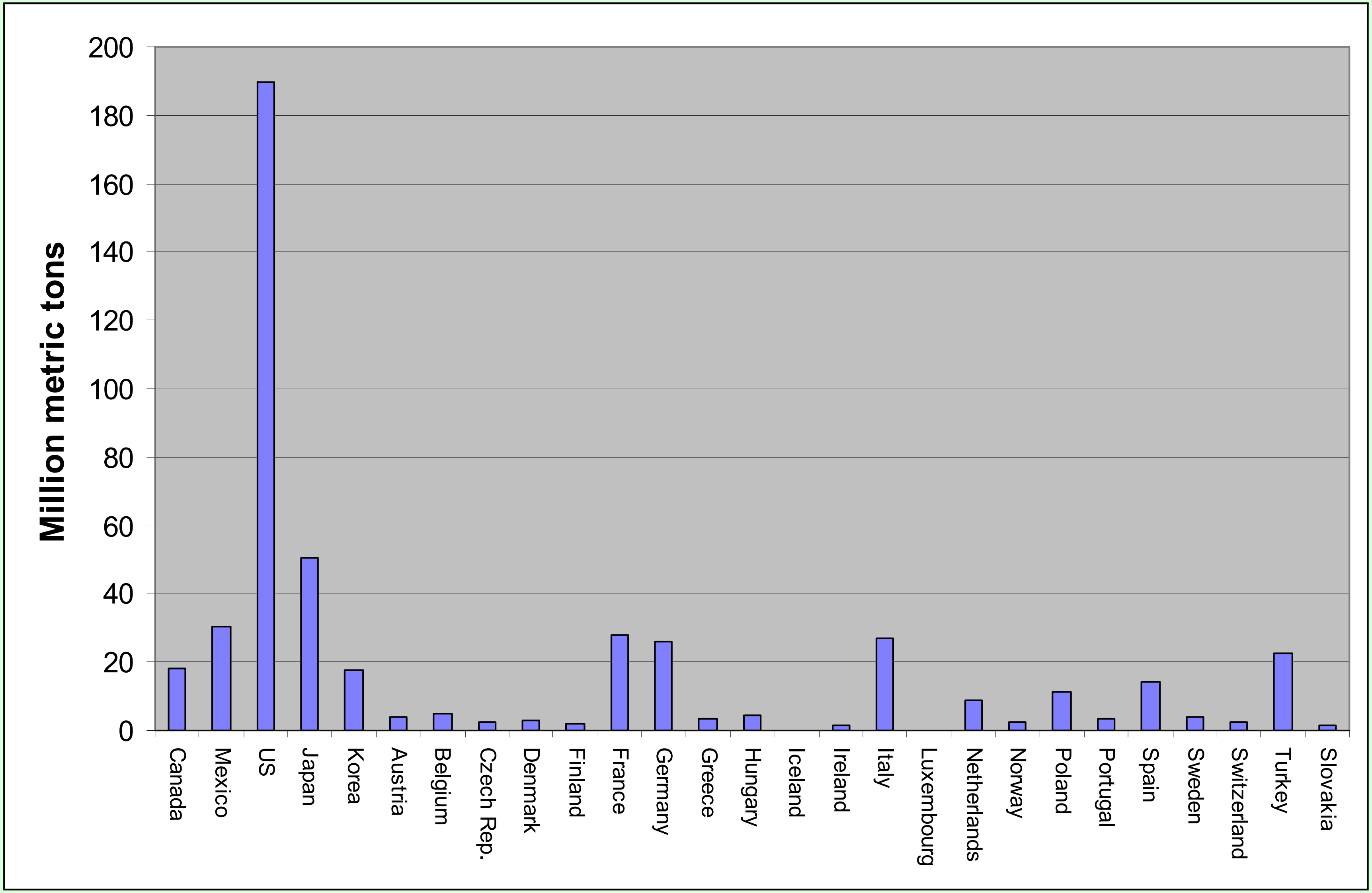
Introduction to waste disposal

Municipal Solid Waste Disposal

See image at the Web site of South Carolina Department of Health and Environmental Control, Division of Mining and Solid Waste Management. http://www.scdhec.net/lwm/html/plan.html.

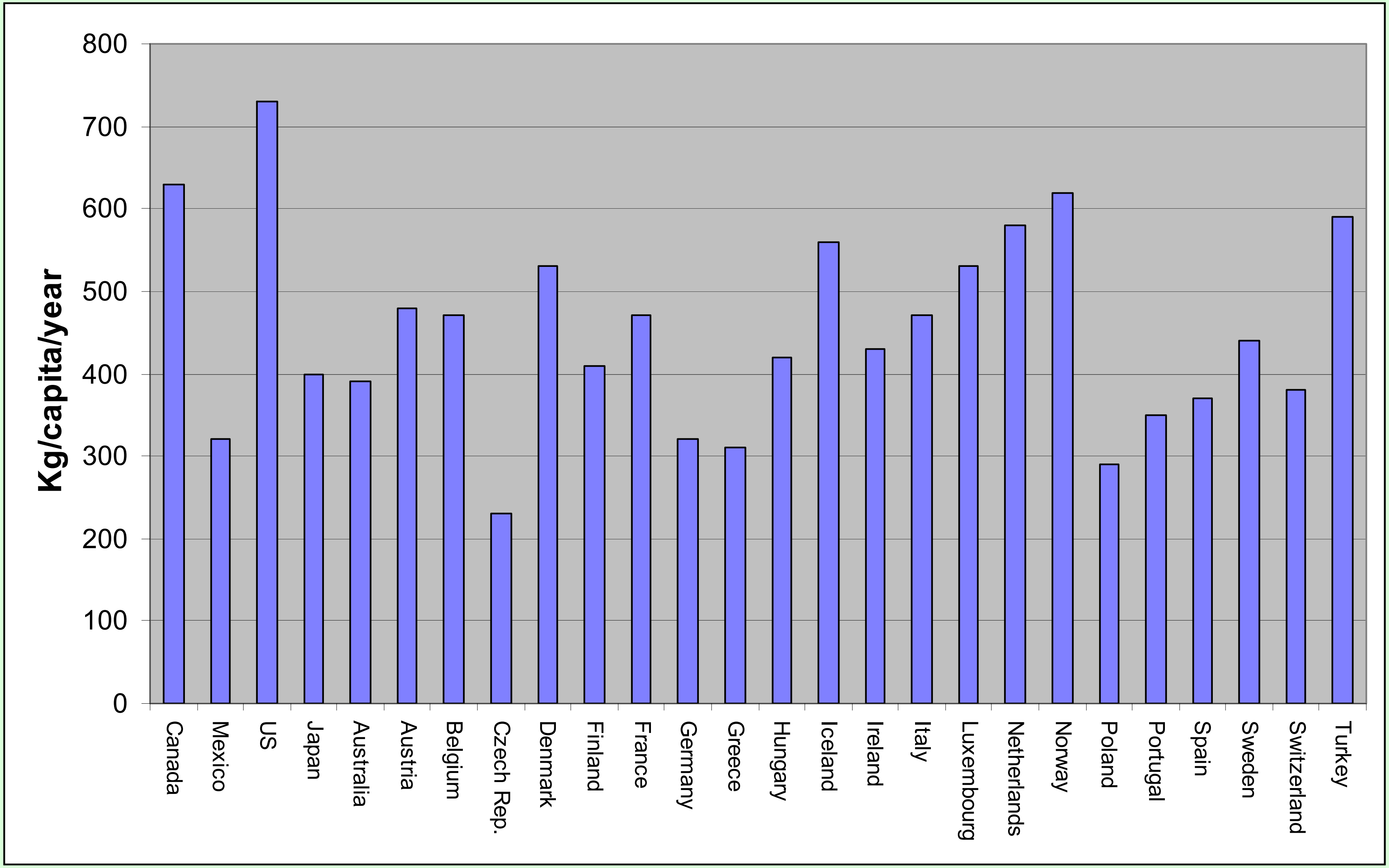
Accessed May 13, 2004.

Municipal solid waste generation - 1995



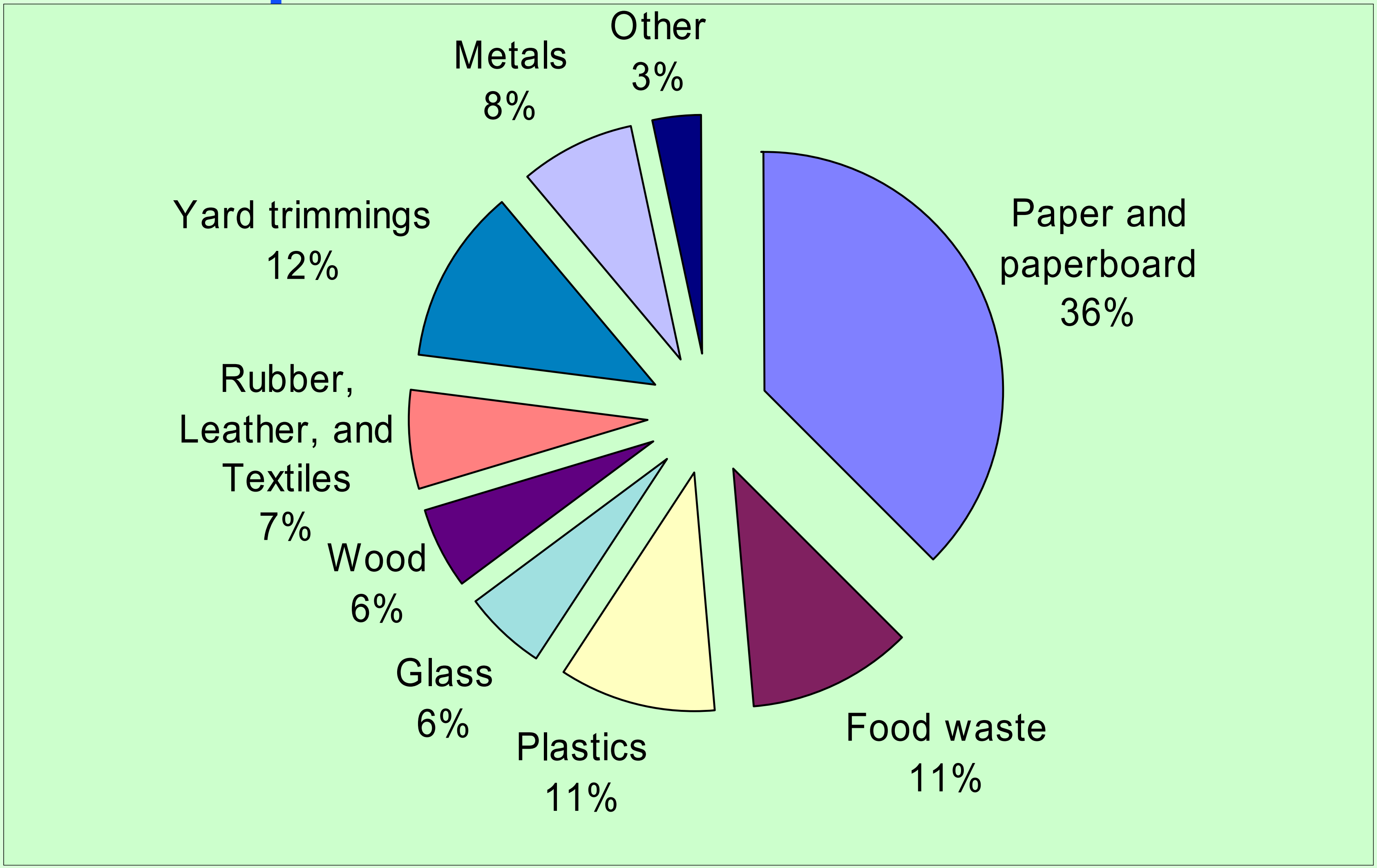
Source for charts: OECD Environmental Data, Compendium 1997. Organisation for Economic Co-operation and Development, Paris. 1997.

Per capita MSW generation - 1995



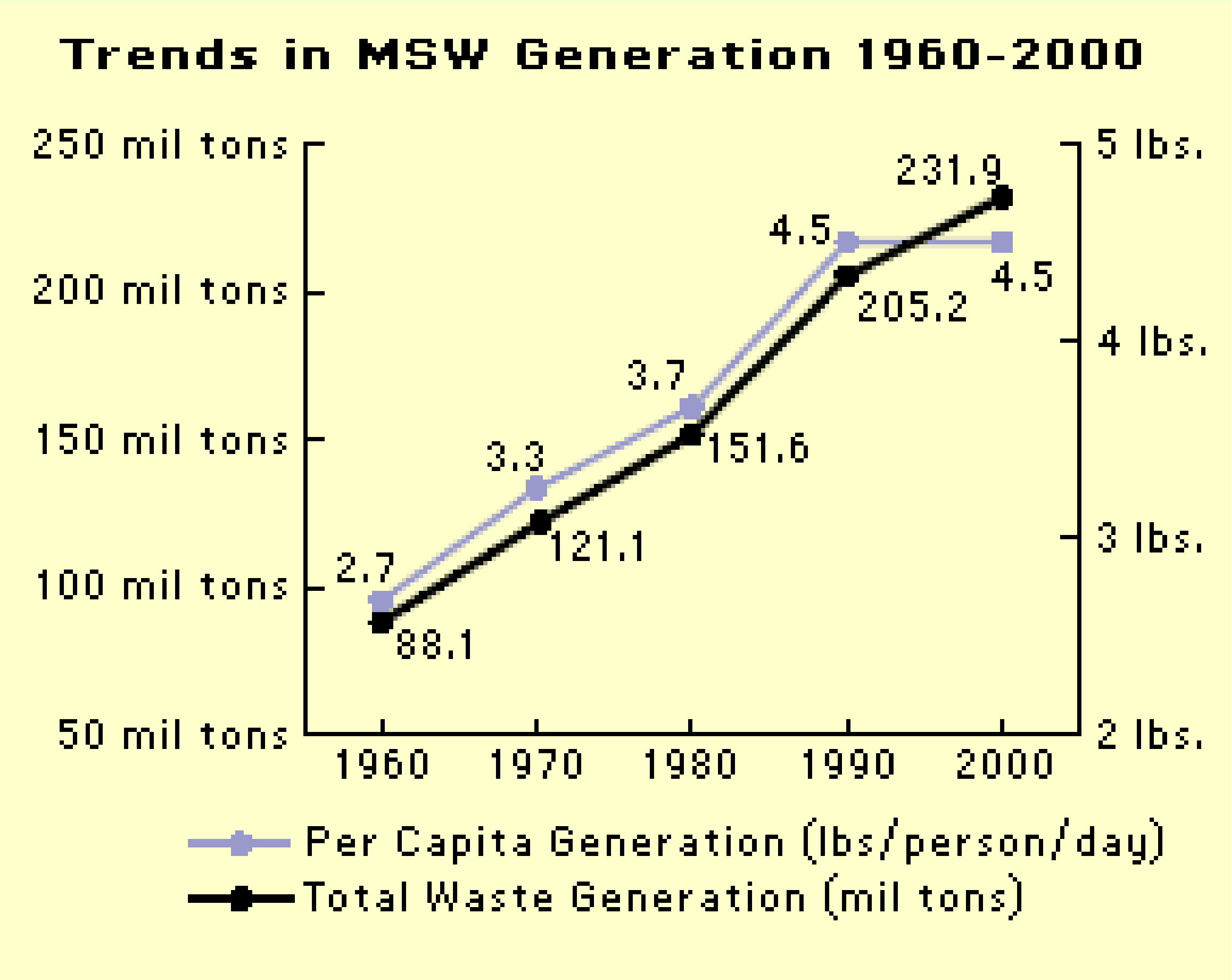
Source for charts: OECD Environmental Data, Compendium 1997. Organisation for Economic Co-operation and Development, Paris. 1997.

Composition of U.S. MSW - 2000



Source: U.S. EPA, 2003. Municipal Solid Waste (MSW). http://www.epa.gov/epaoswer/non-hw/muncpl/facts.htm. February 11, 2003. Accessed: April 6, 2003.
See also: U.S. EPA, 2002 Municipal Solid Waste in The United States: 2000 Facts and Figures. Report No. EPA530-R-02-001. Office of Solid Waste and Emergency Response, U.S. EPA, Washington, D.C. June 2002. http://www.epa.gov/epaoswer/non-hw/muncpl/report-00/report-00.pdf

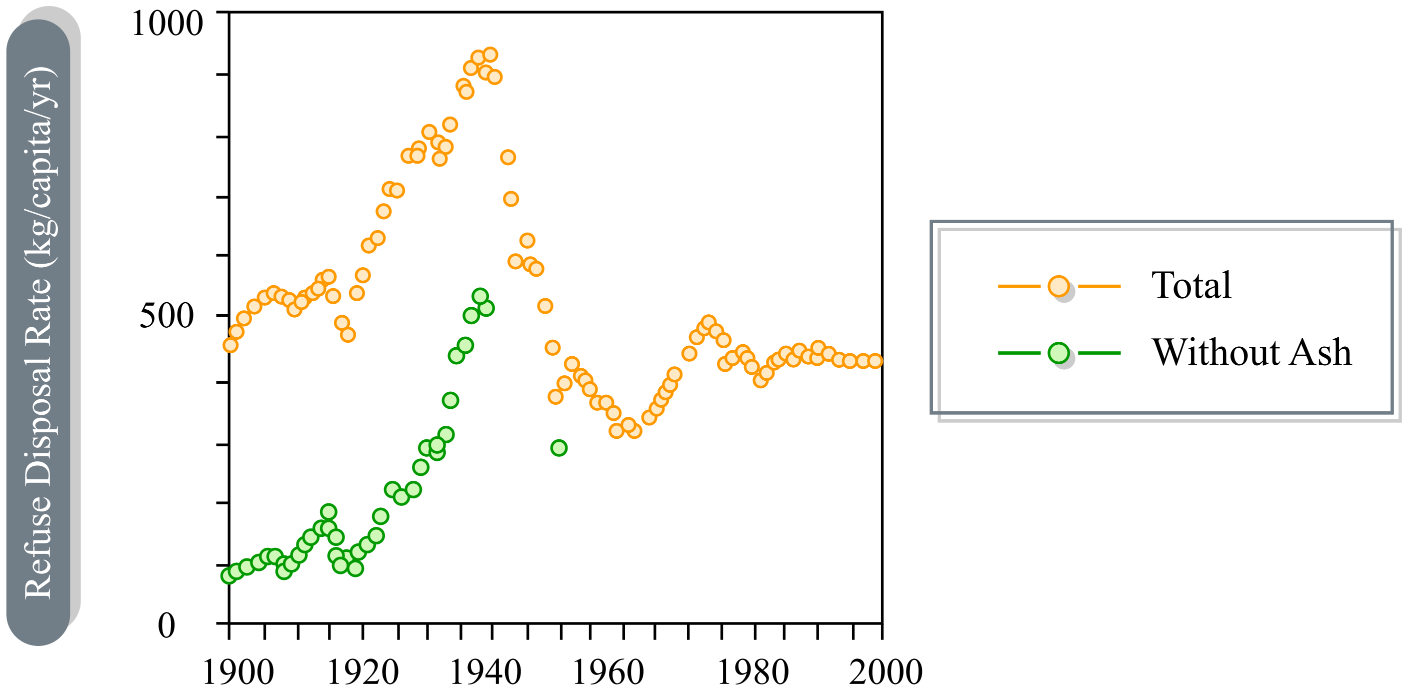
MSW generation rates in U.S. over time



Source: U.S. EPA, 2003. Municipal Solid Waste (MSW). http://www.epa.gov/epaoswer/non-hw/muncpl/facts.htm. February 11, 2003. Accessed: April 6, 2003.

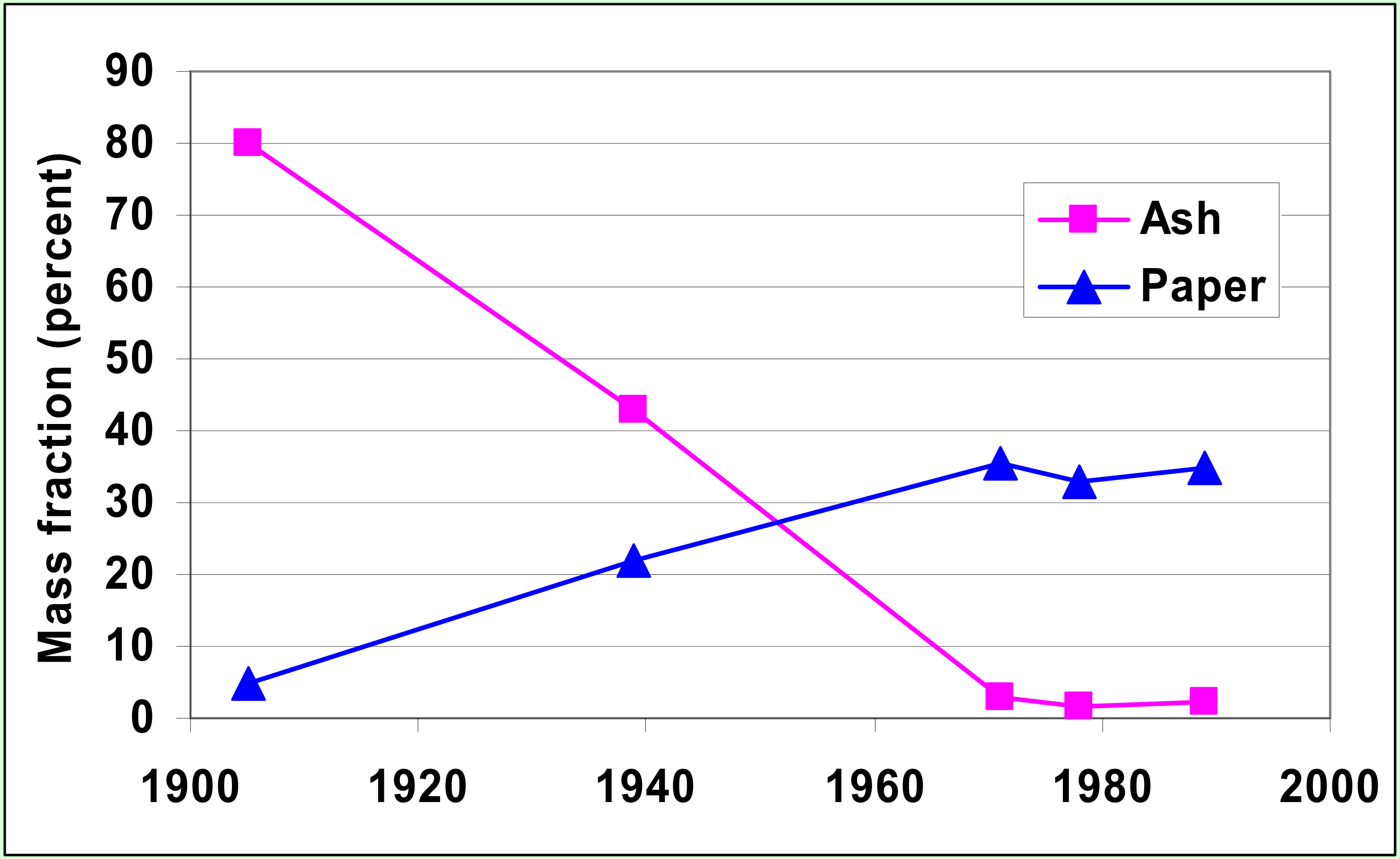
See image at Web site of New York City Department of Planning, Fresh Kills: Landfill to Landscape, Fresh Kills Map Viewer. http://www.nyc.gov/html/dcp/html/fkl/ada/index.html. Accessed May 13, 2004.

Refuse generation rates in NYC



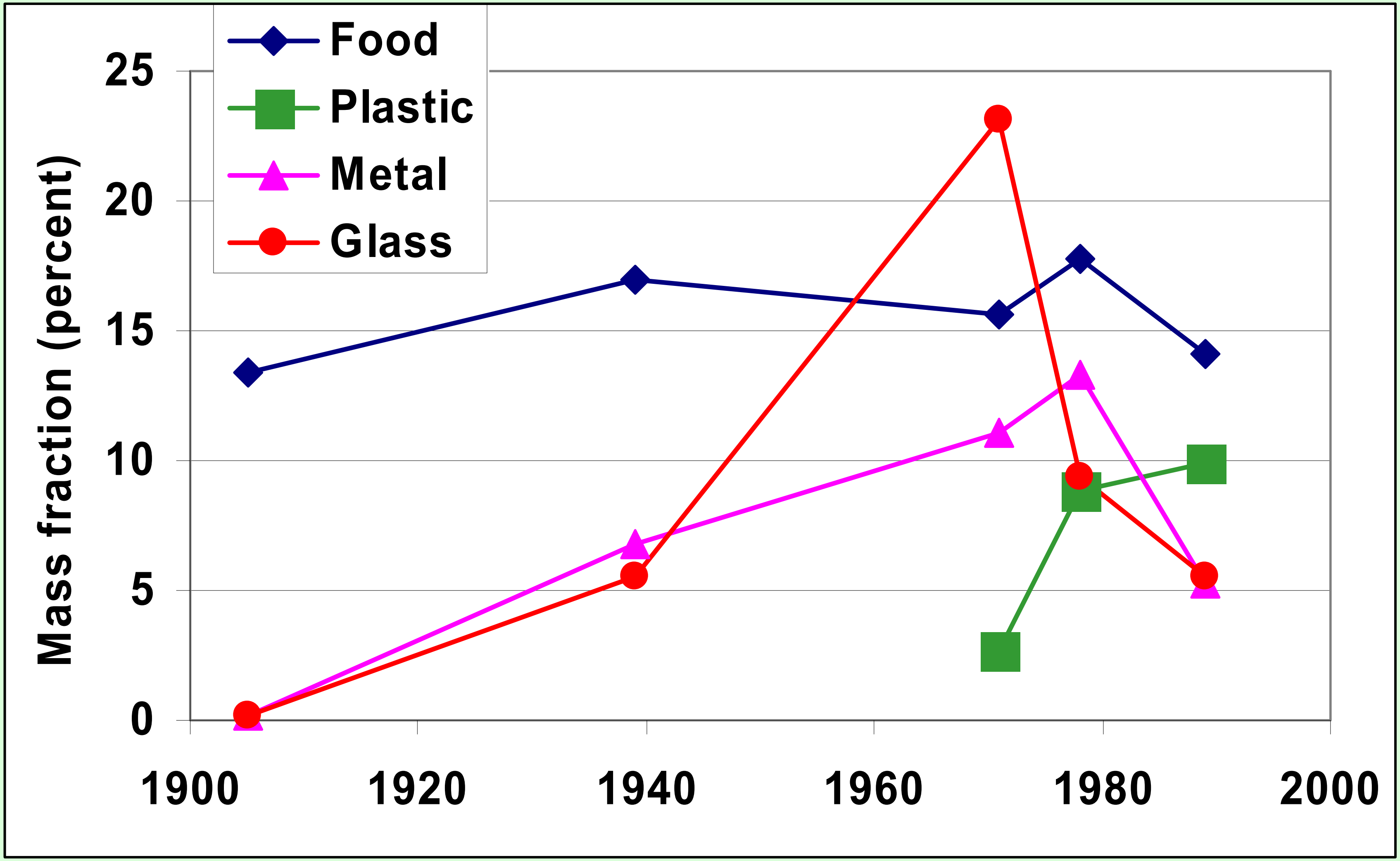
Adapted from: Walsh, D. C. "Urban Residential Refuse Composition and Generation Rates for the 20th Century." *Environmental Science & Technology* 36, no. 22 (October 2002): 4936.

Changes in MSW composition



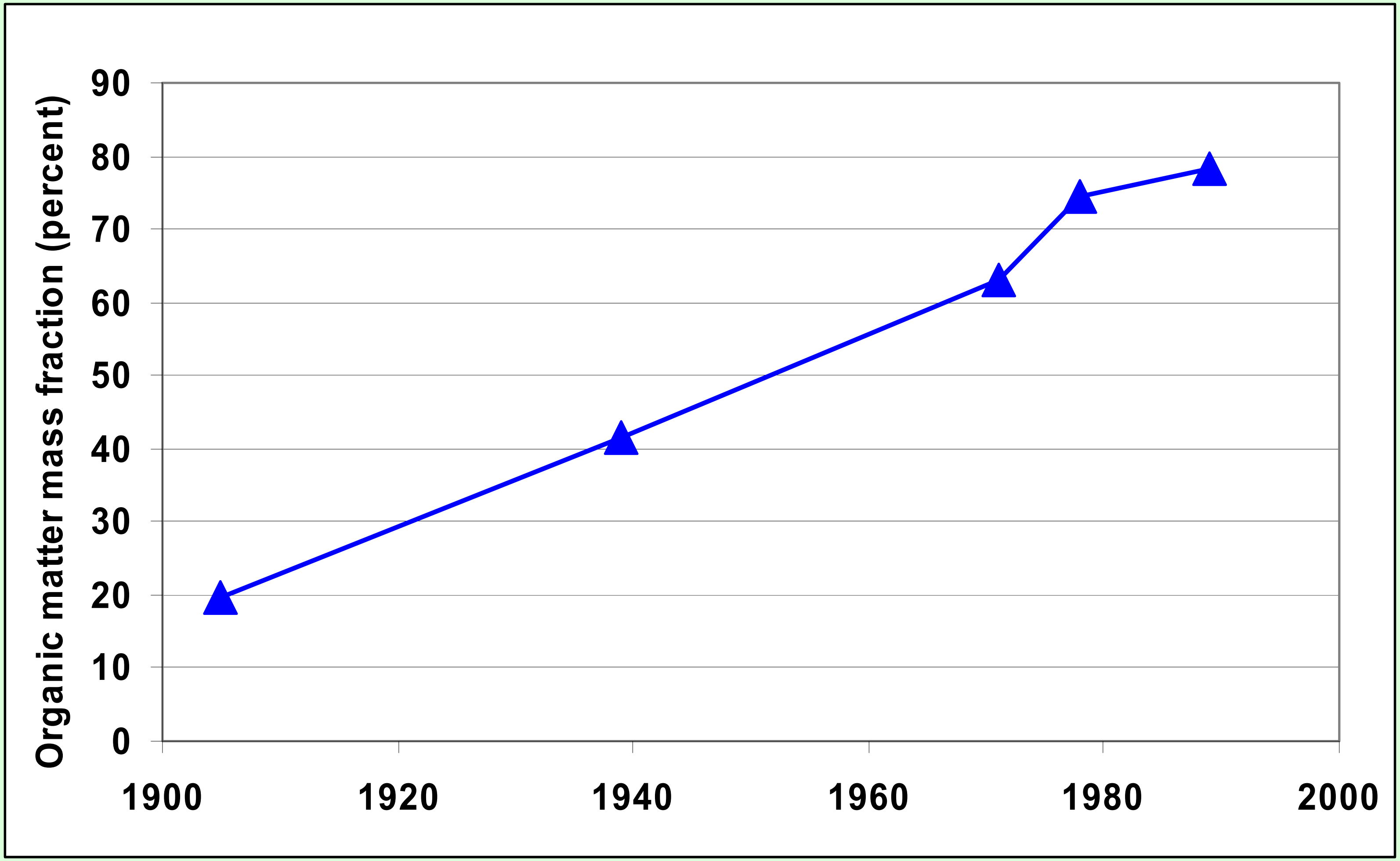
Source of data: Walsh, D. C., 2002. Urban Residential Refuse Composition and Generation Rates for the 20th Century. *Environmental Science & Technology.* Vol. 36, No. 22, Pg. 4936. October 2002.

Changes in MSW composition



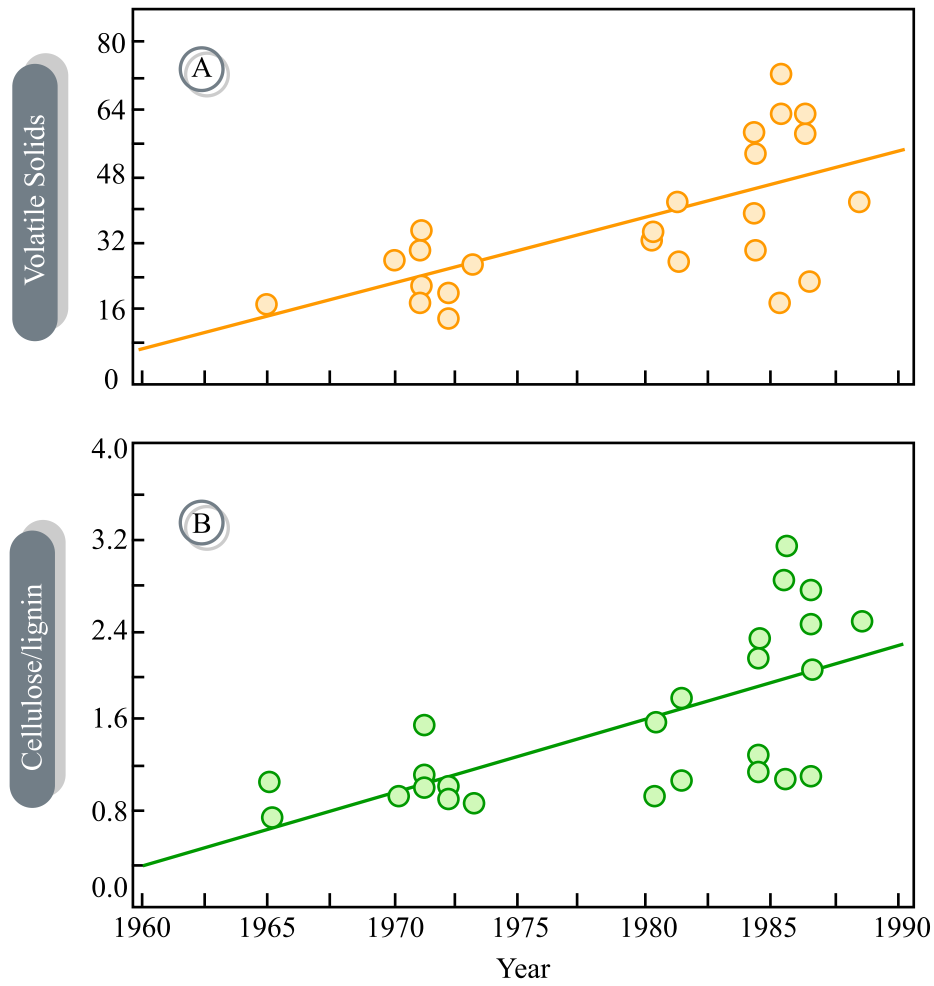
Source of data: Walsh, D. C., 2002. Urban Residential Refuse Composition and Generation Rates for the 20th Century. *Environmental Science & Technology.* Vol. 36, No. 22, Pg. 4936. October 2002.

Changes in MSW organic content



Source of data: Walsh, D. C., 2002. Urban Residential Refuse Composition and Generation Rates for the 20th Century. *Environmental Science & Technology.* Vol. 36, No. 22, Pg. 4936. October 2002.

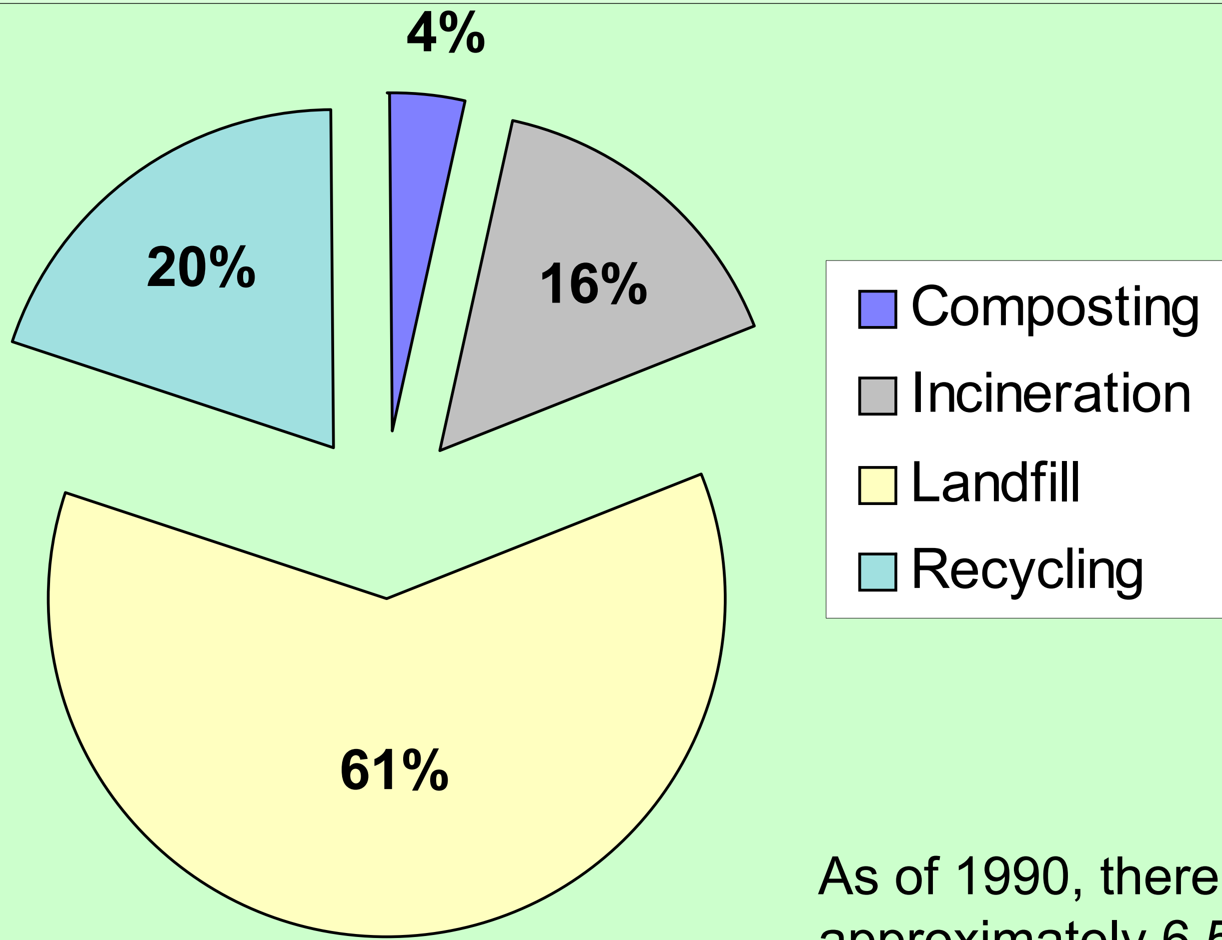
Landfill Age and Waste Content



The variation in volatile solids (a) and cellulose-to-lignin ratio (b) in samples of different age recovered from the Fresh Kills Landfill.

Adapted from: Suflita, J. M., C. P. Gerba, R. K. Ham, A. C. Palmisano and J. A. R. W. L. Rathje. "The World's Largest Landfill." *Environmental Science & Technology* 26, no. 8 (1992): 1486.

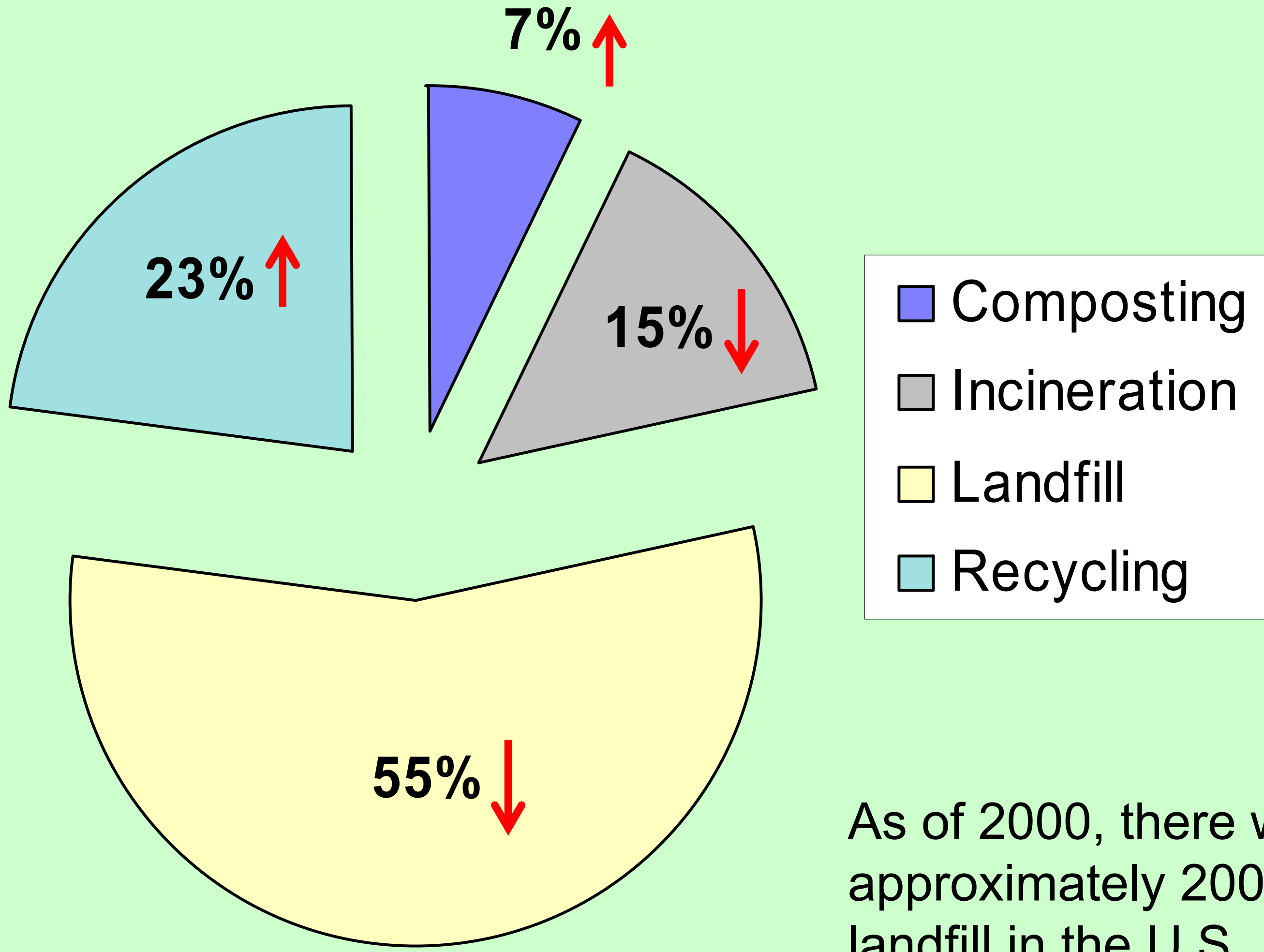
U.S. MSW Disposal - 1994



As of 1990, there were approximately 6,500 landfill in the U.S.

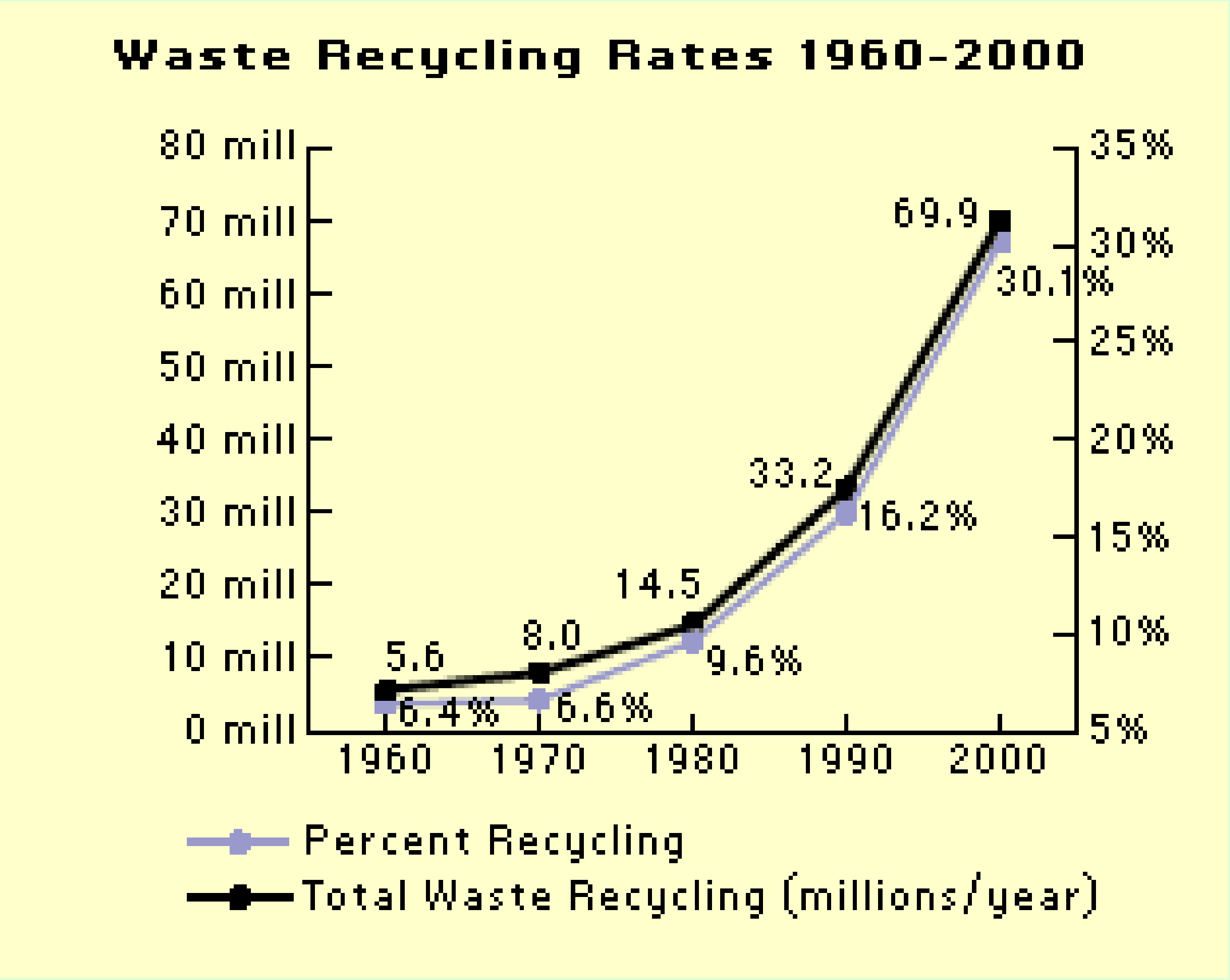
Sources: Franklin Associates, Ltd., 1998. Characterization of Municipal Solid Waste in the United States: 1997 Update. Report No. EPA 530-R-98-007. Office of Solid Waste, U.S. Environmental Protection Agency, Washington, D.C.
U.S. EPA, 2000. Environmental Fact Sheet, Municipal Solid Waste Generation, Recycling and Disposal in the United States: Facts and Figures for 1998. Report No. EPA530-F-00-024, Office of Solid Waste, U.S. Environmental Protection Agency, Washington, D.C.

U.S. MSW Disposal - 2000



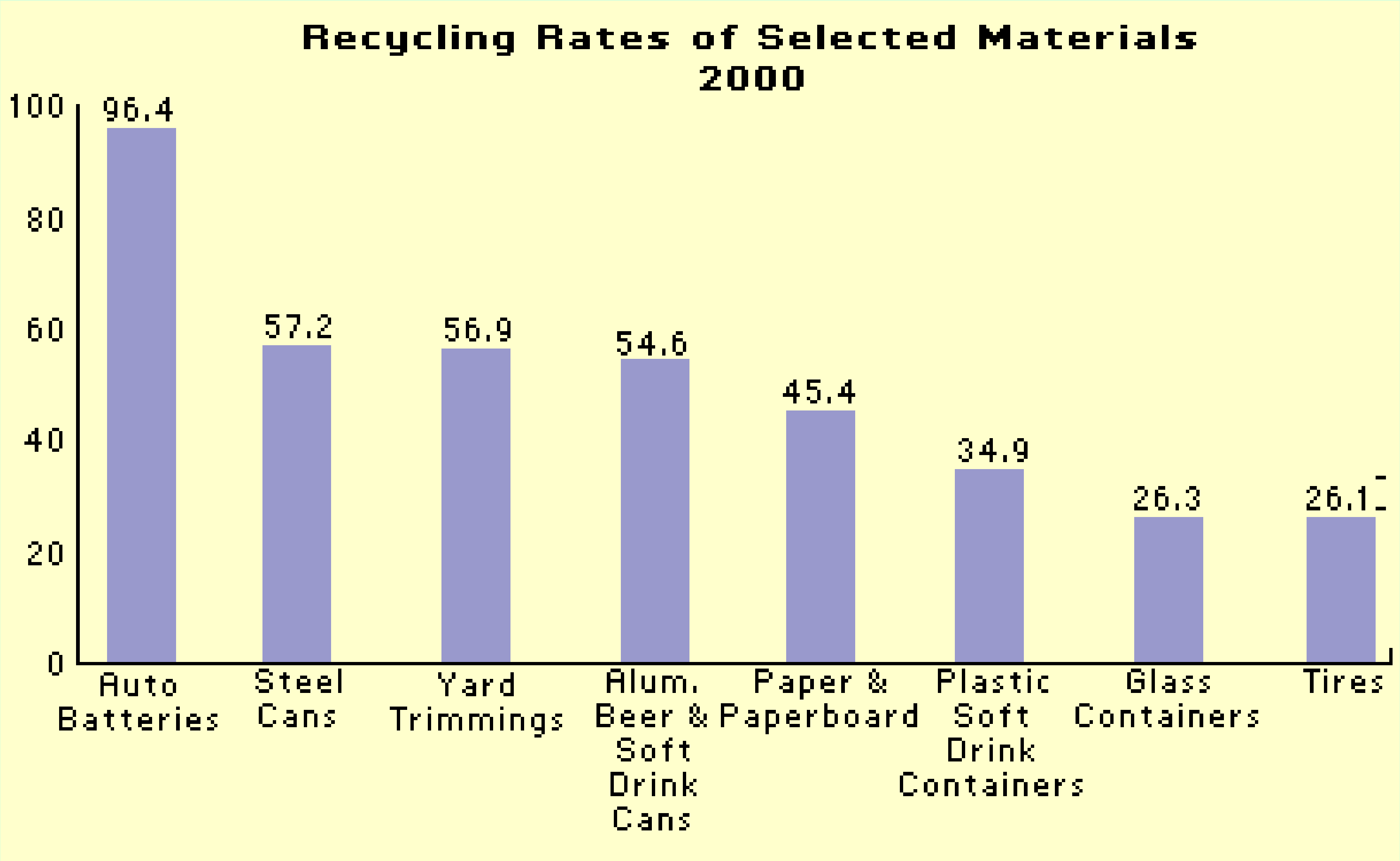
As of 2000, there were approximately 2000 landfill in the U.S.

U.S. Recycling Rates



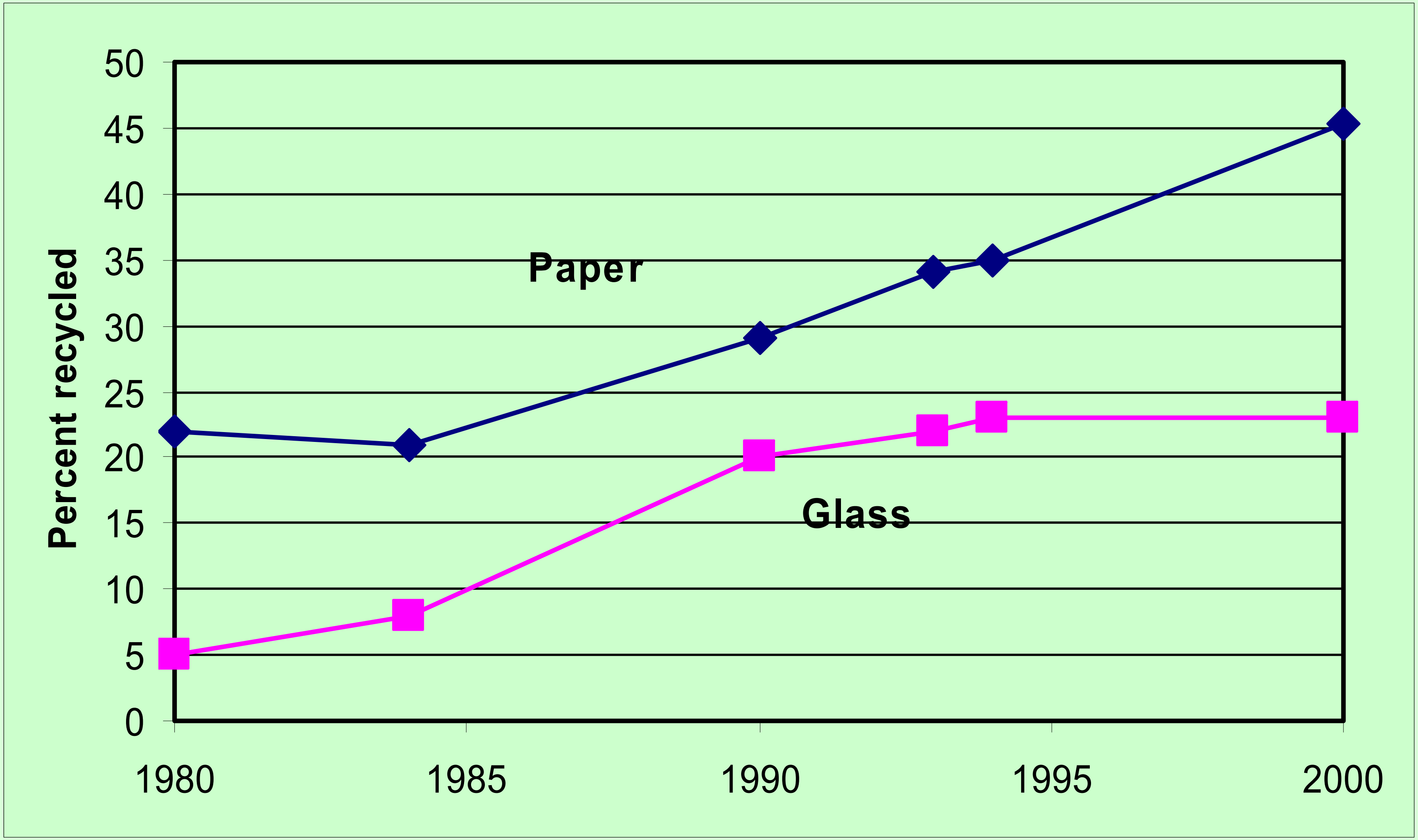
Source: U.S. EPA, 2003. Municipal Solid Waste (MSW). http://www.epa.gov/epaoswer/non-hw/muncpl/facts.htm. February 11, 2003. Accessed: April 6, 2003.

U.S. Recycling Rates



Source: U.S. EPA, 2003. Municipal Solid Waste (MSW). http://www.epa.gov/epaoswer/non-hw/muncpl/facts.htm. February 11, 2003. Accessed: April 6, 2003.

U.S. Recycling Rates



MSW Leachate

Typical Chemical Concentrations in Young Landfill Leachate

Parameter	Leachate Concentration (mg/L)	Typical Sewage Concentration (mg/L)	Typical Groundwater Concentration (mg/L)
COD	20,000-40,000	350	20
BOD_5	10,000-20,000	250	0
TOC	9,000-15,000	100	5
Volatile fatty acids (as acetic)	9,000-25,000	50	0
NH_3-N	1,000-2,000	15	0
Org-N	500-1,000	10	0
NO_3-N	0	0	5

Adapted from: McBean, E. A., F. A. Rovers, and G. J. Farquhar. *Solid Waste Landfill Engineering and Design*. Englewood Cliffs, New Jersey: Prentice Hall PTR, 1995.

Construction and demolition waste leachate

Comparisons of the Field Test Cell Leachate with Full-scale C&D Waste Landfill Leachate and Laboratory-scale Leachate

Parameters	Field Cell Average	C&D Landfill Leachate[a]	MSW Leachate[b]
pH	6.90	6.45-7.60 (6.95)	6.00
Alkalinity (mg as $CaCO_3$/L)	530	38.2-6,520 (970)	3,000
NPOC (mg/L)	21.1	19.0-1,900 (310)	6,000
TDS (mg/L)	2,120	990-3,530 (2,260)	10,000
Chloride (mg/L)	12.8	52.7-262 (158)	500
Sulfate (mg/L)	880	11.7-1,700 (254)	300
Potassium (mg/L)	24.4	0.24-618 (100)	300
Sodium (mg/L)	42.8	11.0-1,290 (160)	500
Calcium (mg/L)	470	90-600 (270)	1,000
Magnesium (mg/L)	53.8	15-280 (120)	250
Arsenic (μg/L)	41.4	1.4-24.6 (12.3)	1,000-10,000[c]
Chromium (μg/L)	17.8	--------------	1,000-10,000[c]
Manganese (μg/L)	420	20-76,000 (8,700)	______
Lead (μg/L)	4.5	4.9-1,180 (8.8)	1,000-10,000[c]
Iron (μg/L)	1,650	50-275,000 (36,000)	60,000

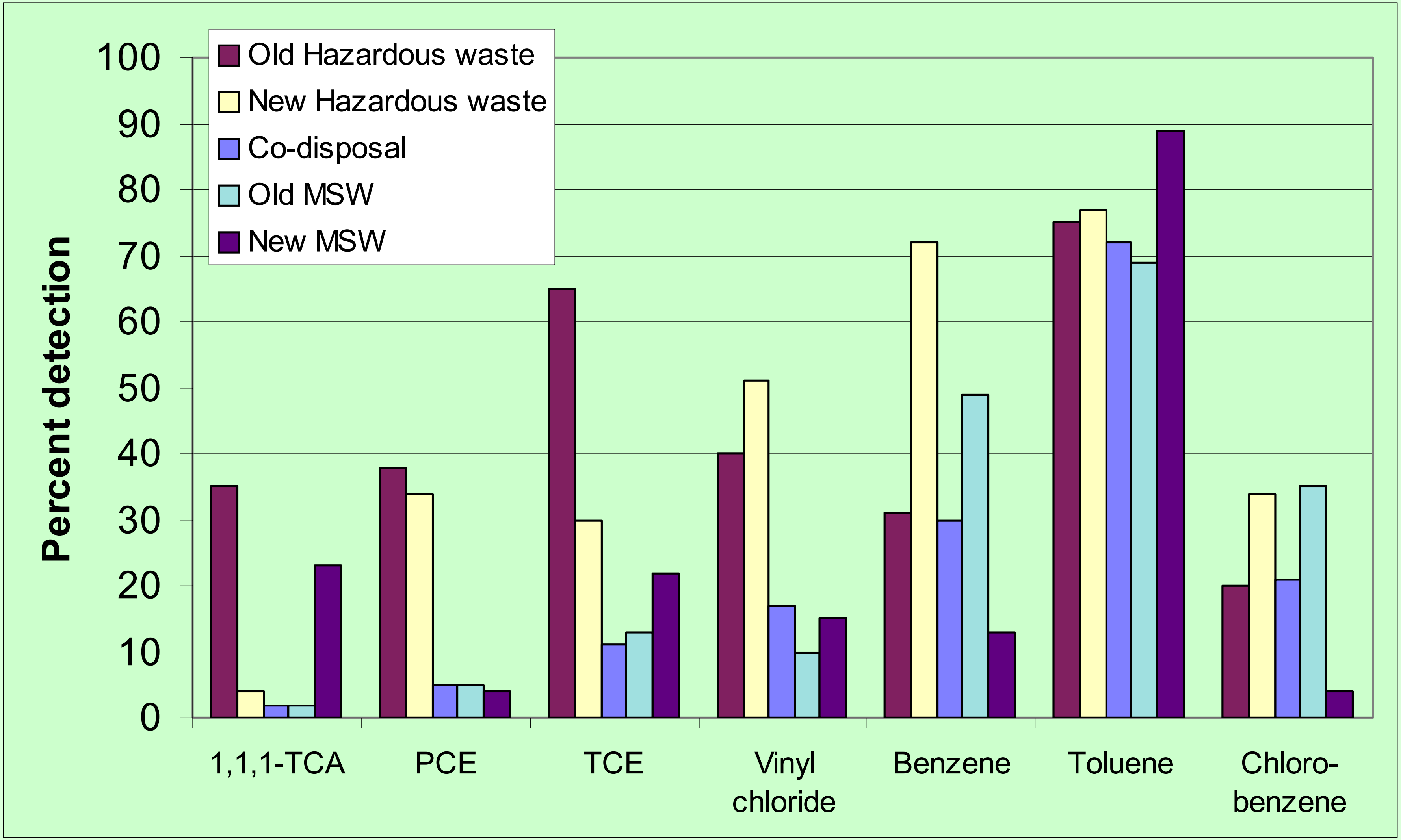
[a]Concentration ranges from literature review of C&D landfill leachate (Melendez 1996). Values in parentheses indicates average concentration in each parameter.

[b]Typical concentrations for MSW landfill leachate (Tchobanoglous et al. 1993).

[c]Typical concentration ranges (Farquhar 1989).

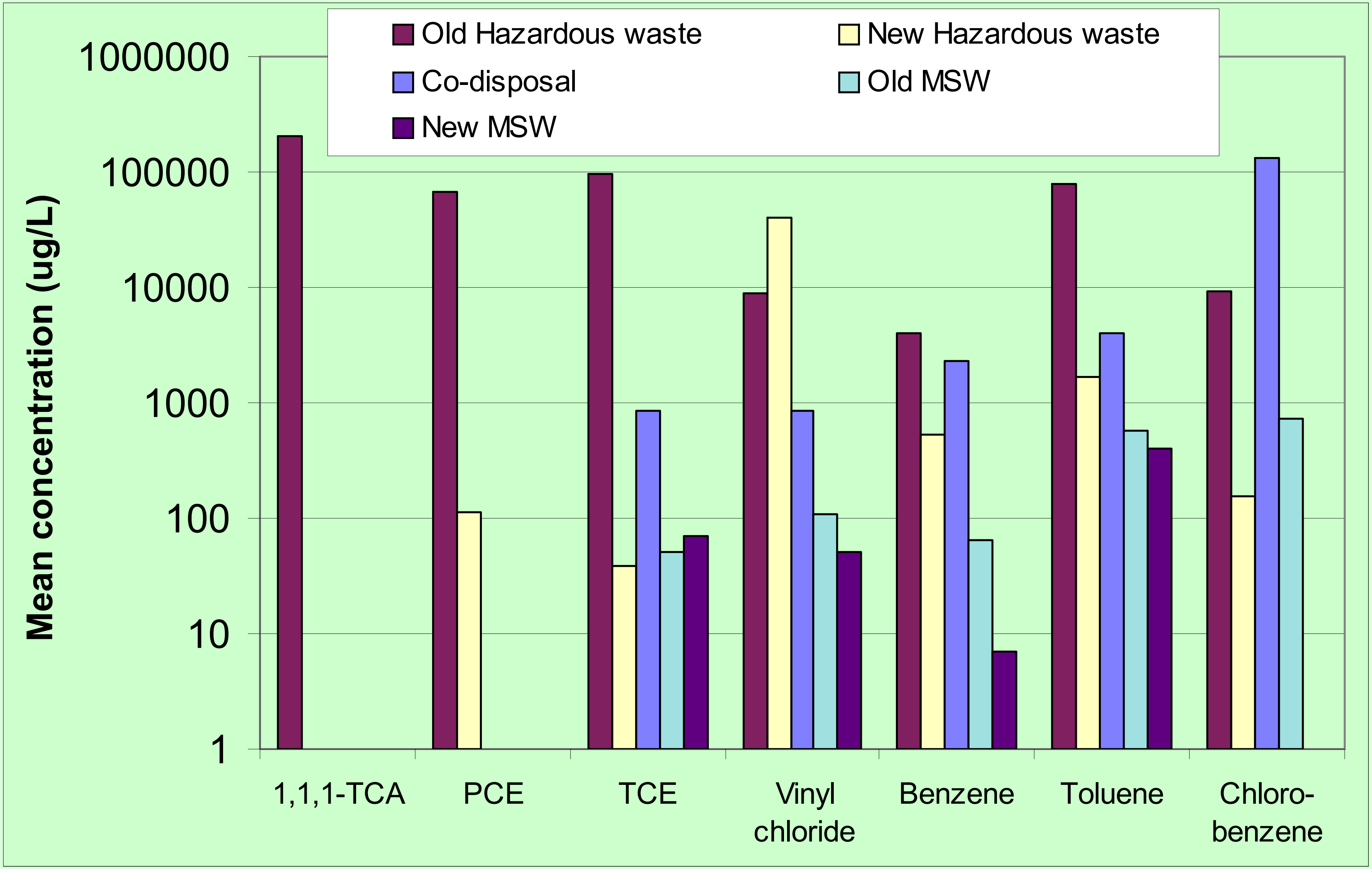
Adapted from: Weber, W. J., Y. C. Jang, G. T. Timothy, and S. Laux. "Leachate from Land Disposed Residential Construction Waste." *Journal of Environmental Engineering, ASCE* 128, no. 3 (March 2002): 237-245.

Leachate Quality - Organics



Data from: Gibbons, R. D., D. G. Dolan, H. May, K. O'Leary, and R. O'Hara, 1999. Statistical Comparison of Leachate from Hazardous, Codisposal, and Municipal Solid Waste Landfills. *Ground Water Monitoring and Remediation.* Vol. 19, No. 4, Pg. 57-72. Fall 1999.

Leachate Quality - Organics



Data from: Gibbons, R. D., D. G. Dolan, H. May, K. O'Leary, and R. O'Hara, 1999. Statistical Comparison of Leachate from Hazardous, Codisposal, and Municipal Solid Waste Landfills. *Ground Water Monitoring and Remediation.* Vol. 19, No. 4, Pg. 57-72. Fall 1999.

History of landfill

- Original landfills were open dumps on land surface
- Organized waste collection in U.S. cities during 1800s
  - Approximately half U.S. cities has waste collection around 1900
  - Increased to 100% by 1930s
- Sanitary landfill concept started around 1900
  - Sanitary landfill = burying waste in soil
- Practice improvements in 1930s
- Cut-and-cover method universal by 1948
- Liquid industrial wastes accepted in 1950s

Two basic landfill concepts

1. Natural attenuation landfill ("bioreactor")

   Natural processes expected to eliminate or reduce contaminants

   Historical landfill practice in U.S.

2. Containment landfill ("dry tomb")

   Barrier systems to contain waste and leachate

   All landfills leak – goal is to minimize and/or delay releases

Historical perspective on waste disposal

From: Webb, W. C., Limitations in the Use of Sanitary Landfill as a Method of Solid Trash Disposal. Proceedings of the Ninth Industrial Waste Conference, Purdue University, May 1954.

A sanitary landfill should not be adopted by an industry for the disposal of trash unless:

1. The nature of the material to be disposed of is such that disposal by this method is economical, desirable environmentally, and does not eliminate materials which should be salvaged.

…

5. The landfill operation will not pollute either surface or subsurface water supply because of the location chosen.

Historical incidents

1945 – Liquid waste disposal by pesticide manufacturer shuts down 11 public supply wells in Los Angeles

1950s – Contamination of private wells by organic chemicals from Rocky Mountain Arsenal, Colorado

1950s – Numerous papers in AWWA Journal and various reports describe link between waste disposal and ground-water contamination

1972 – 46 organic chemicals found in New Orleans water supply

1972-75 – Development of GC/MS for water analysis

Late 1970s-1980s – Numerous discoveries of ground-water contamination at public and private water-supply wells

Sources: Colten, C. E., and P. N. Skinner, 1996. *The Road to Love Canal: Managing Industrial Waste before EPA*. University of Texas Press, Austin, Texas.
Pankow, J. F., S. Feenstra, J. A. Cherry, and M.C. Ryan, 1996. Dense Chlorinated Solvents in Groundwater: Background and History of the Problem. In: Pankow, J. F., and J. A. Cherry, editors. *Dense chlorinated solvents and other DNAPLS in groundwater.* Waterloo Press, Portland, Oregon.

Love Canal

Source: U.S. Environmental Protection Agency, Cleanup News, Fall 1999, http://www.epa.gov/compliance/resources/newsletters/cleanup/cleanup3.pdf. Accessed May 13, 2004.

In 1942, Hooker Chemicals and Plastics Corporation (now Occidental Chemical) purchased the site of the Love Canal. Between 1942 and 1953 Hooker Chemical disposed of about 22,000 tons of mixed chemical wastes into the Love Canal. Shortly after Hooker ceased use of the site, the land was sold to the Niagara Falls School Board for a price of $1.00. In 1955, the 99th Street Elementary School was constructed on the Love Canal property and opened its doors to students. Subsequent development of the area would see hundreds of families take up residence in the suburban, blue-collar neighborhood of the Love Canal.

Unusually heavy rain and snowfalls in 1975 and 1976 provided high ground-water levels in the Love Canal area. Portions of the Hooker landfill subsided, 55-gallon drums surfaced, ponds and other surface water area became contaminated, basements began to ooze an oily residue, and noxious chemical odors permeated the area. Physical evidence of chemical corrosion of sump pumps and infiltration of basement cinder-block walls was apparent. Subsequent studies by the Agency for Toxic Substances and Disease Registry would reveal a laundry list of 418 chemical records for air, water, and soil samples in and around the Love Canal area.

In April of 1978 the New York Department of Health Commissioner, Robert Whalen, declared the Love Canal area a threat to human health and ordered the fencing of the area near the actual old landfill site. In August, the Health Commissioner declared a health emergency at the Love Canal, closed the 99th Street School, and recommended temporary evacuation of pregnant women and young children from the first two rings of houses around the site. Within a week, Governor Hugh Carey announced the intended purchase of all "Ring 1" houses (later expanded to 238 houses in Rings 1 and 2). President Jimmy Carter simultaneously announced the allocation of federal funds and ordered the Federal Disaster Assistance Agency to assist the City of Niagara Falls to remedy the Love Canal site.

Science and Engineering Library: University at Buffalo, April 2, 2002. Love Canal @ 20. Science and Engineering Library: University at Buffalo. Buffalo, NY. http://ublib.buffalo.edu/libraries/units/sel/exhibits/lovecanal.html. Accessed March 11, 2003

Love Canal timeline

1942 –	Hooker Chemicals and Plastics Corporation purchases site
1942-1953 –	Hooker disposes of about 22,000 tons of mixed chemical wastes into canal.
1953 –	Hooker sells site to the Niagara Falls School Board for a price of $1.00
1955 –	99th Street Elementary School constructed on site
1955-1960s –	Residential neighborhood developed around Canal Area
1975-76 –	Unusually heavy rain and snowfalls in 1975 and 1976 raise water table Portions of landfill subside, 55-gallon drums surface, ponds and other surface water area became contaminated, basements begin to ooze oily residue, and noxious chemical odors permeate the area.
April 1978 –	New York Department of Health declares Love Canal a threat to human health, landfill site fenced
Aug. 1978 –	NYDOH declared a health emergency at the Love Canal, closed the 99th Street School, and commenced purchasing homes with emergency Federal funds

Source: Science and Engineering Library: University at Buffalo, April 2, 2002. Love Canal @ 20. Science and Engineering Library: University at Buffalo. Buffalo, NY. http://ublib.buffalo.edu/libraries/units/sel/exhibits/lovecanal.html. Accessed March 11, 2003.

See image at Web site of The Love Canal Dump. ATOMCC News: The Hazardous Waste Website, www.iprimus.ca/~spinc/atomcc/dump.htm. Accessed May 13, 2004.

This fenced in area holds the 20,000 tons of chemical waste dumped by Hooker Chemical Co. starting in the 1920s. After the school board bought the land, two roads were constructed across the canal and homes built on either side. A school was built as well, on the edge of the canal. Seen below is how it looked after the school and the first wave of residents' homes were demolished.

McCormack, Jeff, June 8, 2001. The Love Canal Dump. ATOMCC News: The Hazardous Waste Website. www.iprimus.ca/~spinc/ atomcc/dump.htm. Accessed December 20, 2002.

U.S. Environmental Protection Agency, August 1, 2002. Superfund 20th Anniversary Report: Continuing the Promise of Earth Day. U.S. Environmental Protection Agency. Washington, D.C. http://www.epa.gov/superfund/action/20years/ch1pg4.htm. Accessed March 11, 2003.

Hazardous waste disposal

Governed by RCRA (Resource Conservation and Recovery Act of 1976)

Provides "cradle to grave" tracking and management of hazardous waste

Defines and governs TSD (treatment, storage, and disposal) facilities

Defines ten methods of waste management (in Subparts I through R of 40 CFR Part 265)

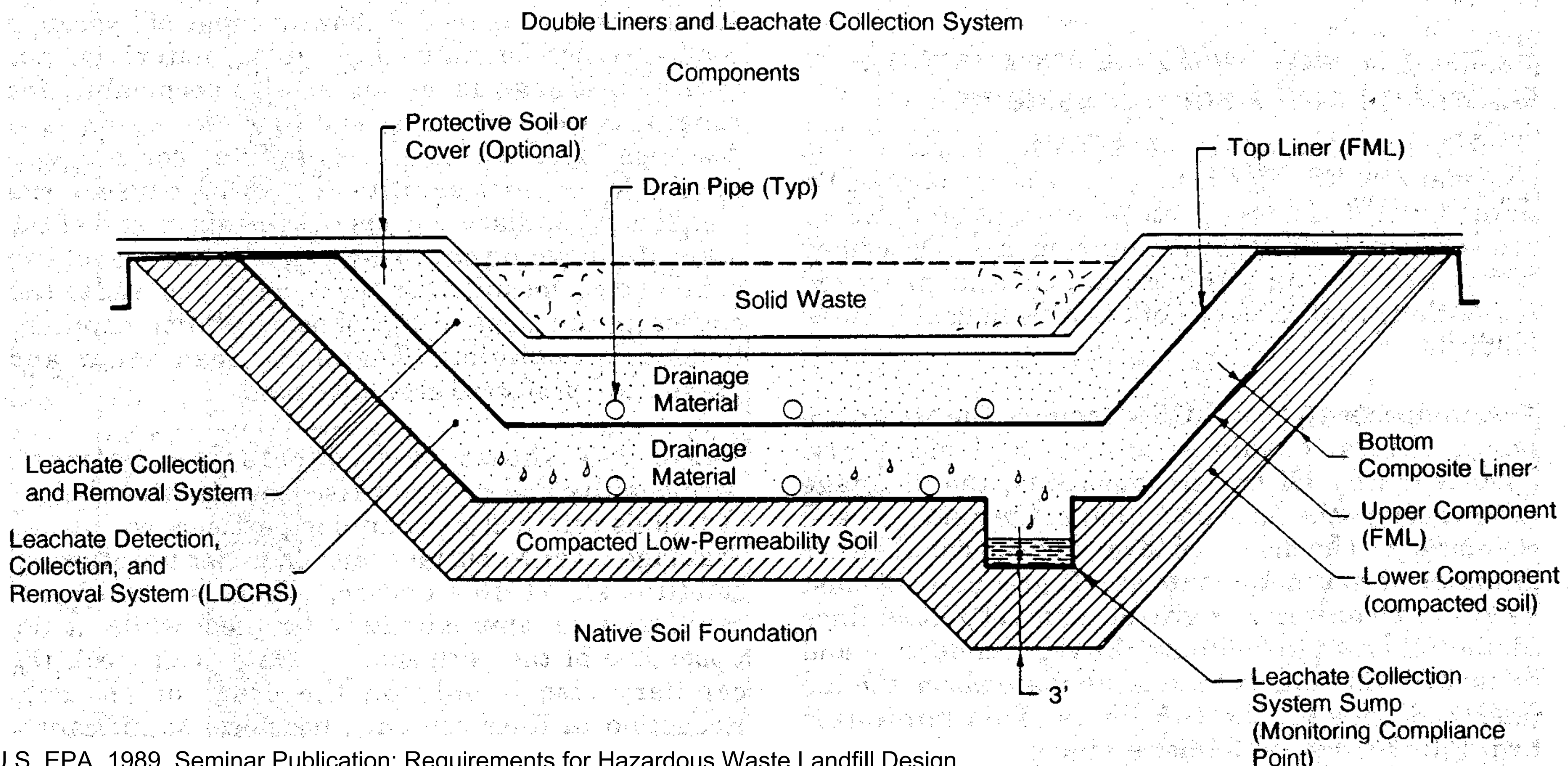
RCRA TSD methods

I. Containers
J. Tanks
K. Surface impoundments
L. Waste piles
M. Land treatment
N. Landfills
O. Incinerators
P. Thermal treatment
Q. Chemical, physical, and biological treatment
R. Underground injection

RCRA land-disposal regulations ("land ban")

- Requires more control than just containment
- Waste must be treated by "best demonstrated available technology" (BDAT) before disposal
  - Must eliminate or reduce toxicity of organics
  - Stabilize or immobilize metals
- Applies to soil containing hazardous waste as well as waste

Hazardous Waste Landfill



U.S. EPA, 1989. Seminar Publication: Requirements for Hazardous Waste Landfill Design, Construction, and Closure. Report Number EPA/625/4-89/022. Center for Environmental Research Information, U.S. Environmental Protection Agency, Cincinnati, Ohio. August 1989.

Medical Waste

1987-88 – New York and New Jersey beach closures due to washed-up medical wastes

November 1988 – Medical Waste Tracking Act (MWTA) added medical waste to RCRA

US medical waste statistics:

~450,000 tons waste/year

~375,000 generators (mostly hospitals)

Source: Orosz, Matthew, 2003. Medical Waste Management. Term paper for Course 1.34. MIT, Cambridge, Massachusetts. May 2003.

Types of medical waste

Regulated waste per MWTA:

1. Cultures and stocks
2. Pathological wastes
3. Human blood and blood products
4. Used sharps
5. Animal waste
6. Isolation waste
7. Unused sharps

Source: Orosz, Matthew, 2003. Medical Waste Management. Term paper for Course 1.34. MIT, Cambridge, Massachusetts. May 2003.

Medical waste disposal

Favored treatment option is incineration

Required for "Red Bag" (potentially infectious) waste

Used for most waste for extra safety and "aesthetics" (incinerated waste is not recognizable as medical waste)

Source: Orosz, Matthew, 2003. Medical Waste Management. Term paper for Course 1.34. MIT, Cambridge, Massachusetts. May 2003.

Per EPA web site, over 90% of medical waste is incinerated.

U.S. EPA, 2003. Medical Wastes, Frequently Asked Questions. http://www.epa.gov/epaoswer/other/medical/mwfaqs.htm. October 29, 2003. Accessed April 4, 2004.

Medical waste package treatment unit

See images at the following Web sites:
Sanitec West, Inc., Photo Gallery.
http://www.sanitecwest.com/

Valenti, M., 2000. Rx for medical waste. Mechanical Engineering Magazine. Vol. 122, No. 9. September 2000.
http://www.memagazine.org/backissues/sept00/features/rx/rx.html.

Accessed May 13, 2004.

Radioactive waste (defined by origin)

High-level waste – spent nuclear fuel

Transuranic waste – defense-related waste

Uranium mill tailings

Low-level waste

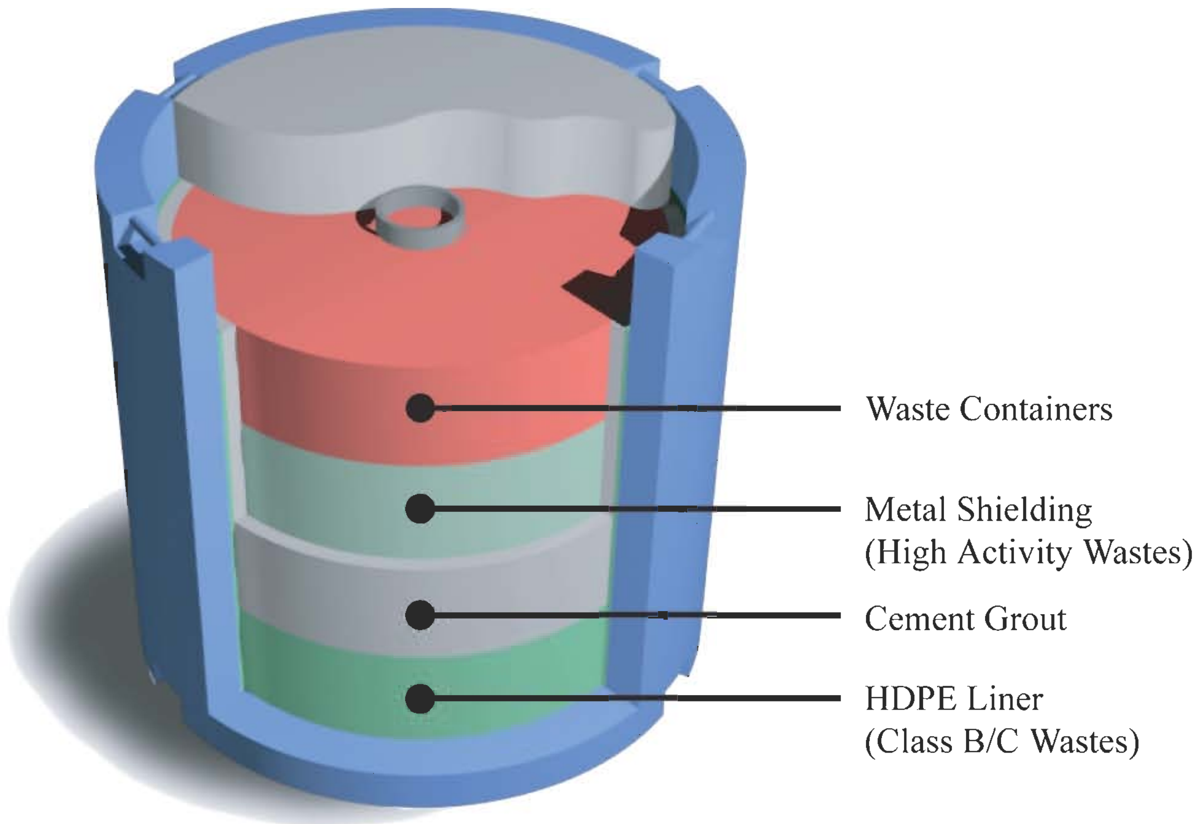
Natural occurring radioactive materials (NORM) and accelerator-produced radioactive waste

Mixed waste – radioactive and hazardous

Source: U.S. EPA, 1994. Radioactive Waste Disposal; An Environmental Perspective. Report Number EPA 402-K-94-001. Air and Radiation, U.S. Environmental Protection Agency, Washington, D.C. August 1994.

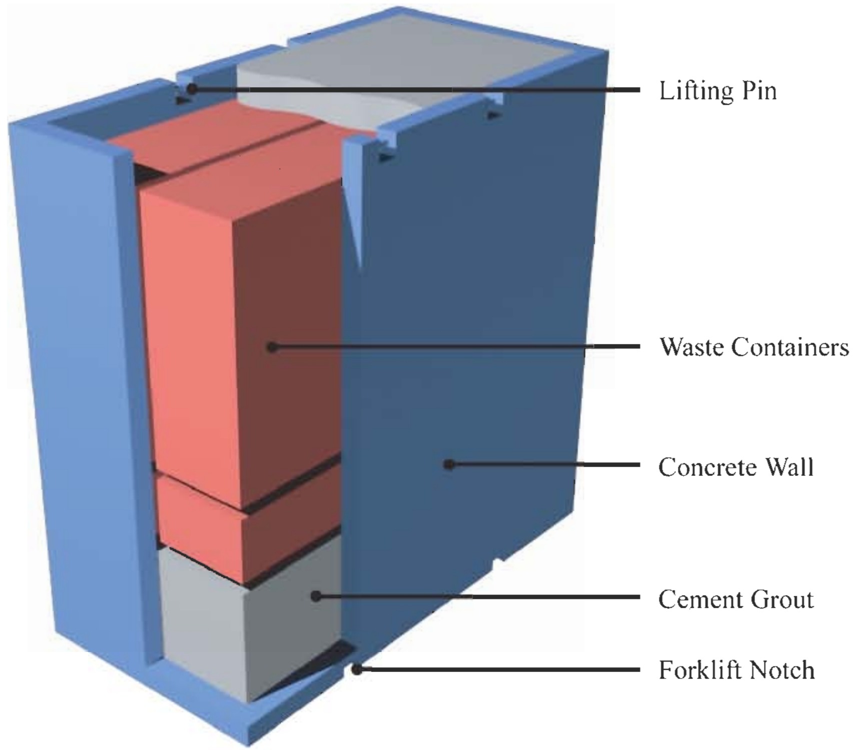
Low-Level Radioactive Waste Disposal

See image at the Web site of Chem-Nuclear Systems, Disposal Services.
http://www.chemnuclear.com/disposal.html
Accessed May 13, 2004.



CONCRETE WASTE OVERPACK (CYLINDRICAL)

Image adapted from: Chem-Nuclear, 1991. Illinois Low-Level Radioactive Waste Disposal Facility, License Application to Illinois Department of Nuclear Safety, Executive Summary. Chem-Nuclear Systems, Inc. Springfield, Illinois.



CONCRETE WASTE OVERPACK (RECTANGULAR)

Image adapted from: Chem-Nuclear, 1991. Illinois Low-Level Radioactive Waste Disposal Facility, License Application to Illinois Department of Nuclear Safety, Executive Summary. Chem-Nuclear Systems, Inc. Springfield, Illinois.

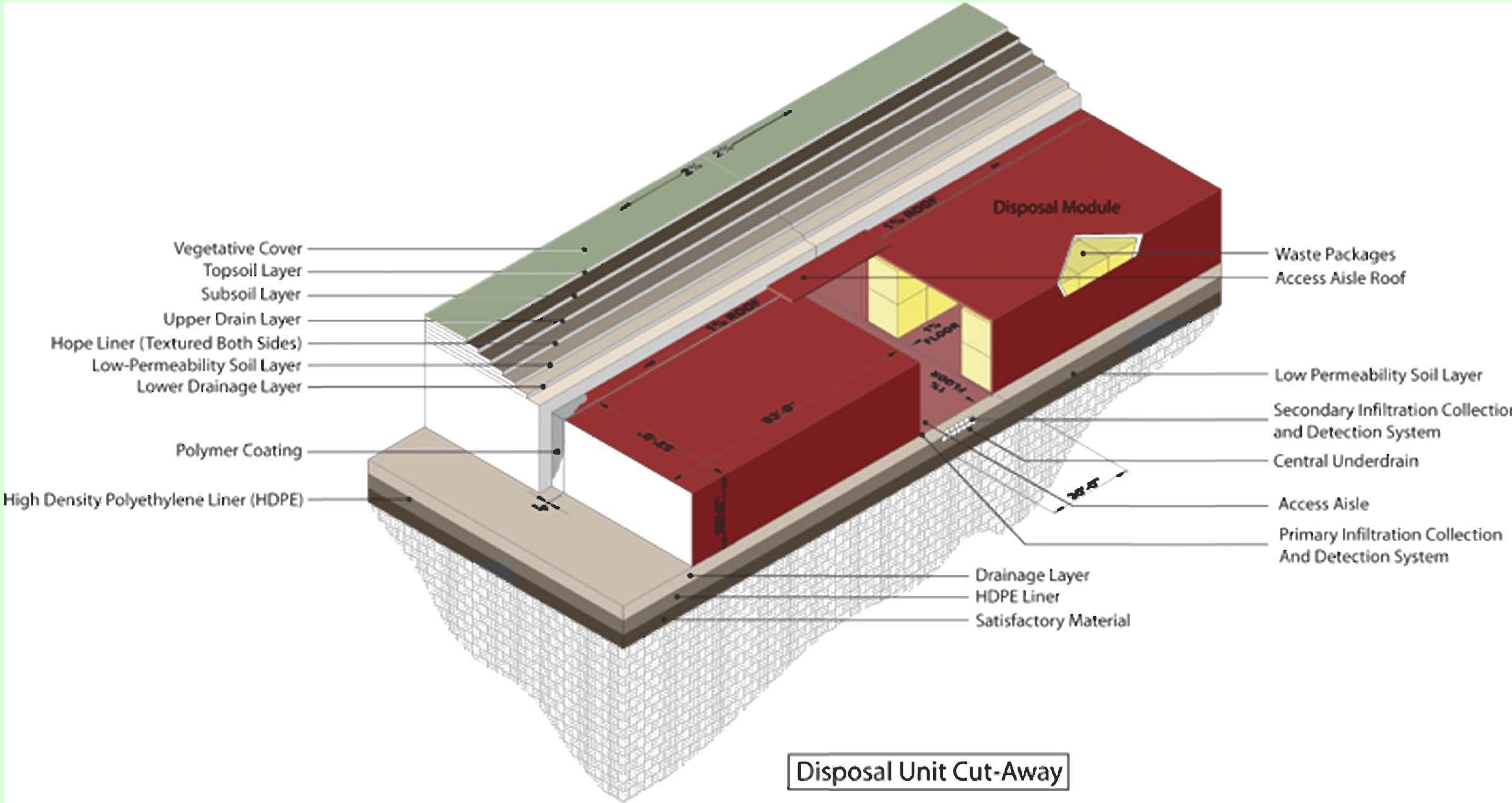
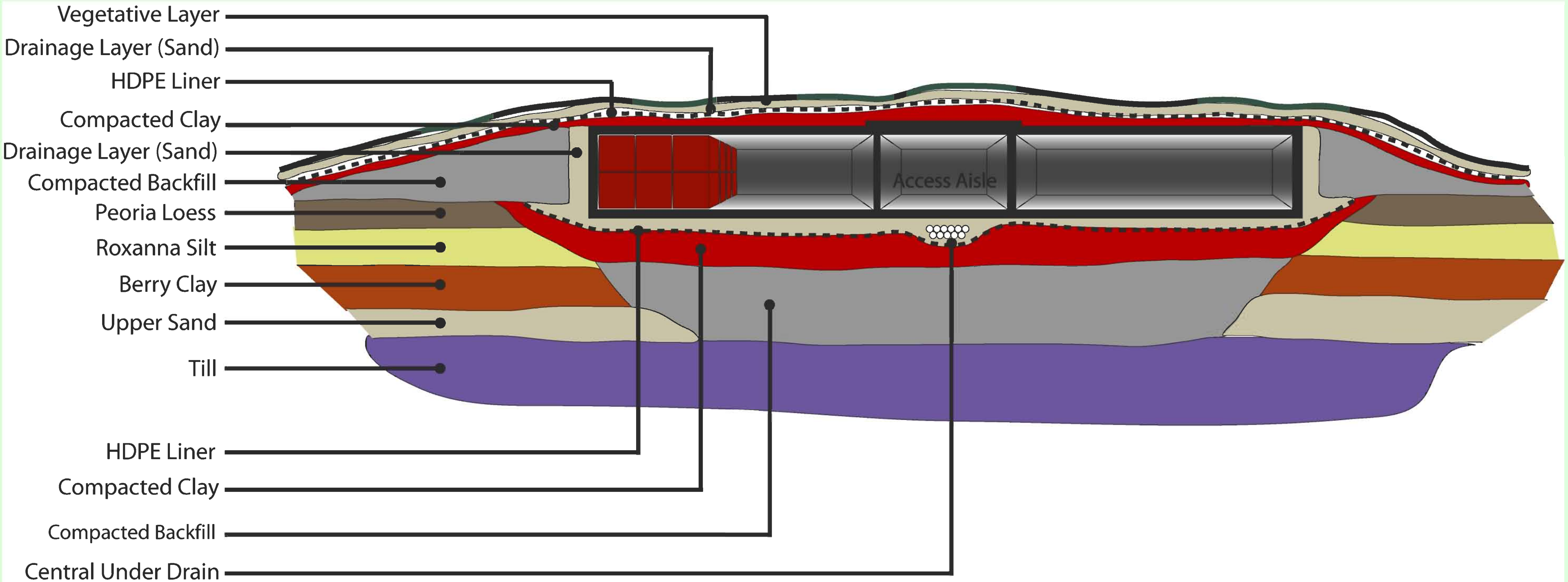


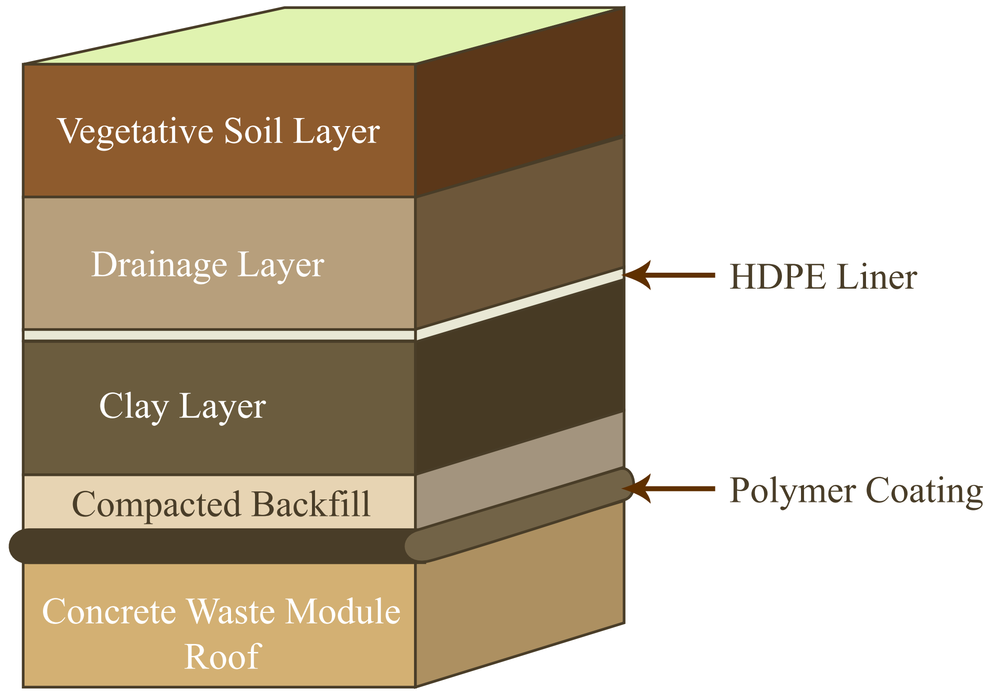
Image adapted from: Chem-Nuclear, 1991. Illinois Low-Level Radioactive Waste Disposal Facility, License Application to Illinois Department of Nuclear Safety, Executive Summary. Chem-Nuclear Systems, Inc. Springfield, Illinois.



Disposal Unit Cut-Away

Image adapted from: Chem-Nuclear, 1991. Illinois Low-Level Radioactive Waste Disposal Facility, License Application to Illinois Department of Nuclear Safety, Executive Summary. Chem-Nuclear Systems, Inc. Springfield, Illinois.

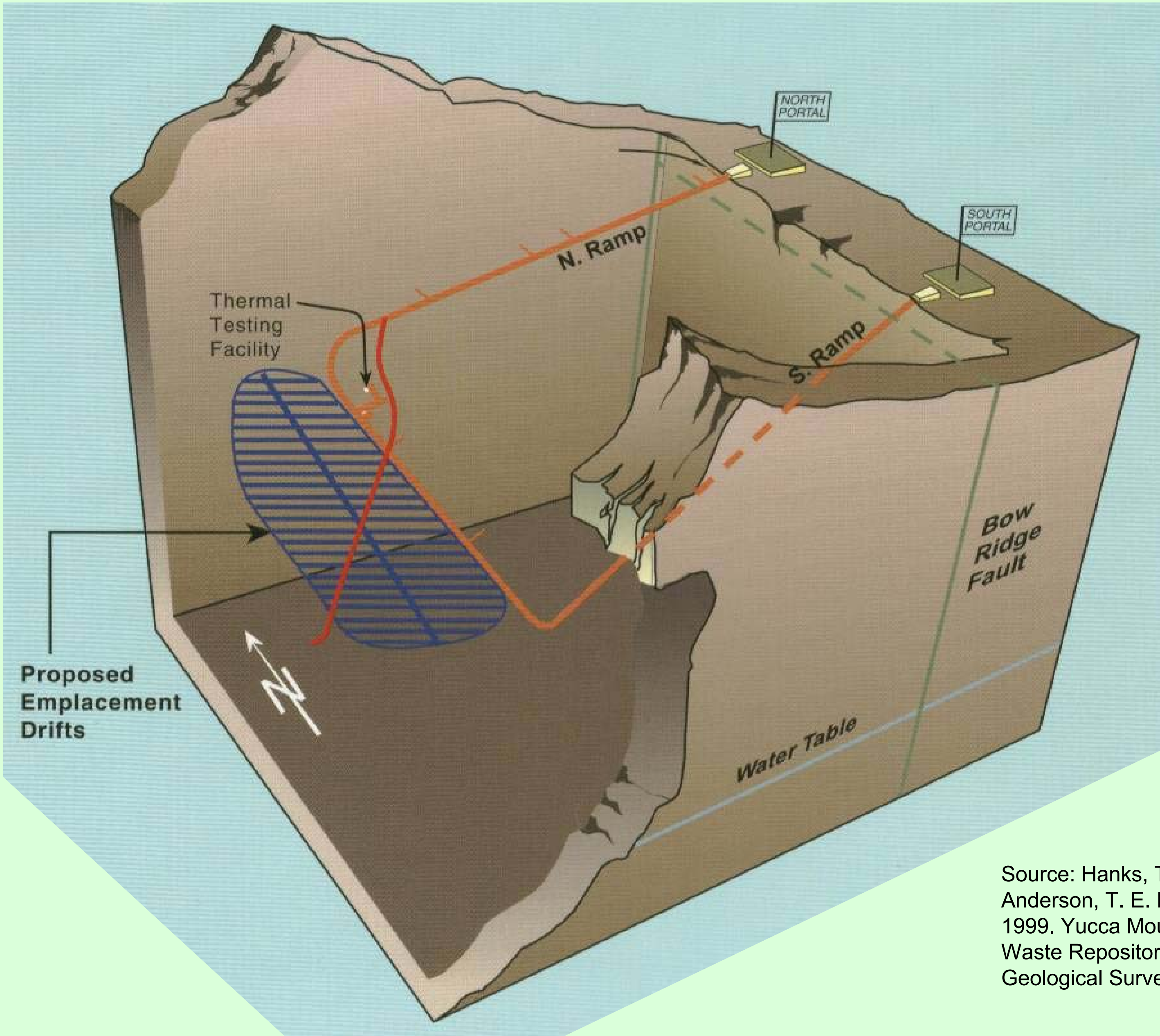
Multiple Layer Engineered Earthen Cap



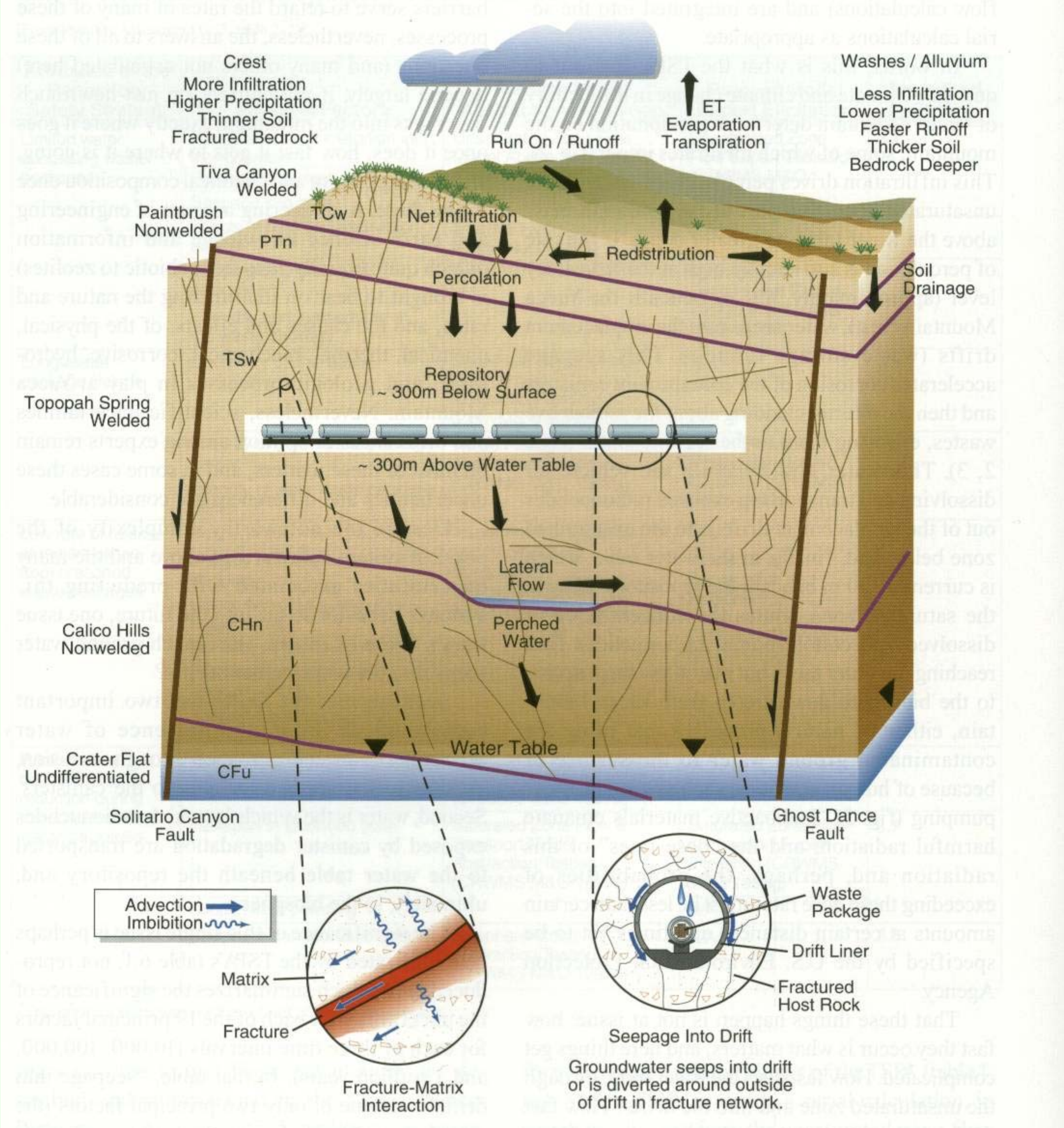
Adapted from: Chem-Nuclear. Illinois Low-Level Radioactive Waste Disposal Facility, License Application to Illinois Department of Nuclear Safety. Executive Summary. Chem-Nuclear Systems, Inc. Springfield, Illinois, 1991.

Source: Hanks, T. C., I. J. Winograd, R. E. Anderson, T. E. Reilly, and E. P. Weeks, 1999. Yucca Mountain as a Radioactive-Waste Repository. Circular 1184. U.S. Geological Survey, Denver, Colorado.

Yucca Mountain Repository – high-level waste



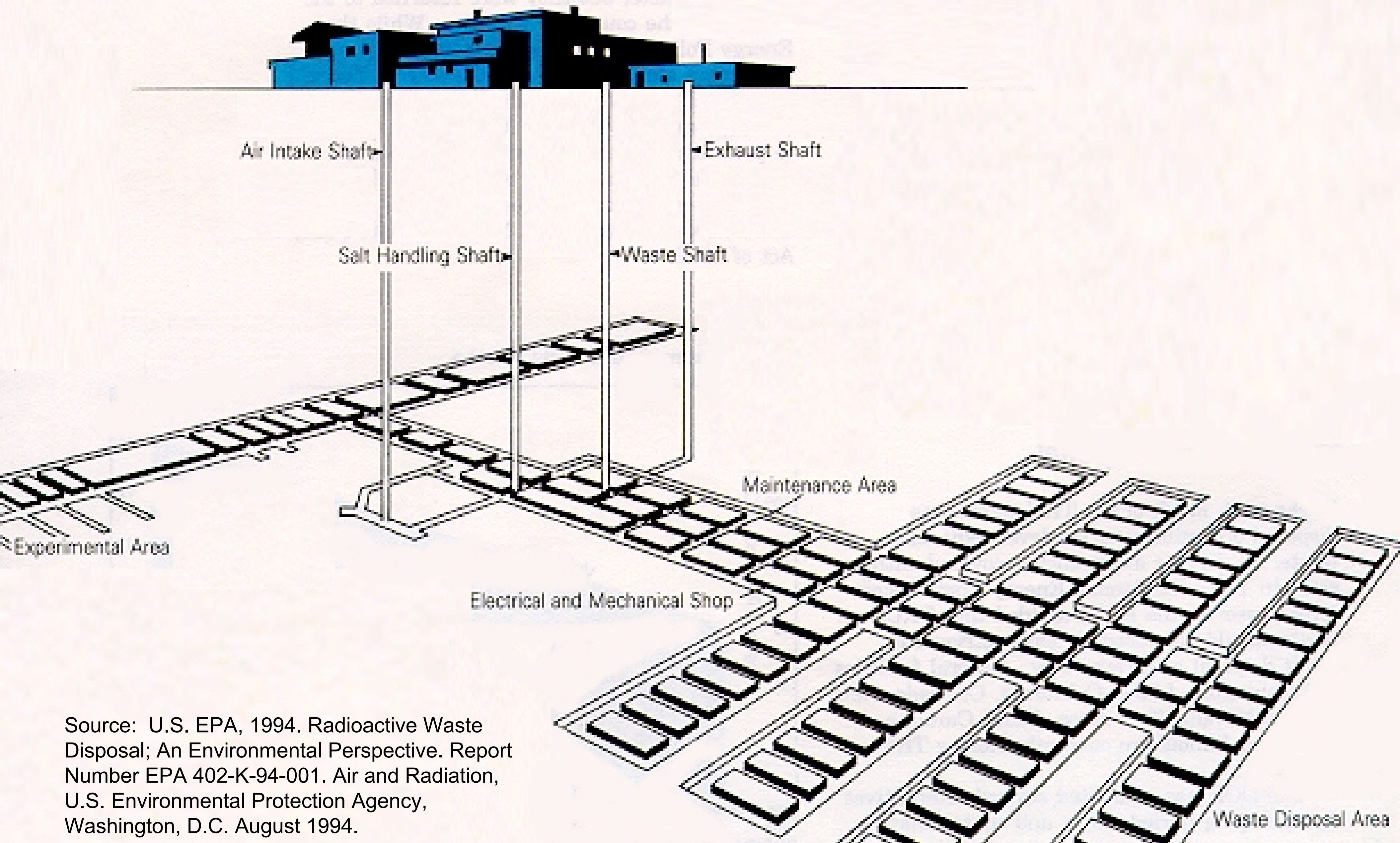
Source: Hanks, T. C., I. J. Winograd, R. E. Anderson, T. E. Reilly, and E. P. Weeks, 1999. Yucca Mountain as a Radioactive-Waste Repository. Circular 1184. U.S. Geological Survey, Denver, Colorado.



Source: Hanks, T. C., I. J. Winograd, R. E. Anderson, T. E. Reilly, and E. P. Weeks, 1999. Yucca Mountain as a Radioactive-Waste Repository. Circular 1184. U.S. Geological Survey, Denver, Colorado.

Waste Isolation Pilot Plant (WIPP) – Transuranic waste

See image in Jensen, R. C., 1999. Salted Away. *Environmental Protection*. Vol. 10, No. 9, Pg. 40-45. September 1999.



Source: U.S. EPA, 1994. Radioactive Waste Disposal; An Environmental Perspective. Report Number EPA 402-K-94-001. Air and Radiation, U.S. Environmental Protection Agency, Washington, D.C. August 1994.

Landfill siting

Landfill siting is very difficult process:

- Most zoning regulations prohibit landfills
- Considerable public opposition
  - NIMBY syndrome: Not In My Back Yard

Considerations in landfill siting

Proximity to waste generators

Geotechnical soundness

Compatibility with surrounding land uses

Environmental suitability

Relevant issues for landfill siting

Land use

- Allowed by zoning
- Government controls on land
- Compatibility with neighboring uses
- Proximity to parks, open space, recreational areas, etc.
- Community acceptance

Environmental

- Soil types and conditions
- Proximity to water bodies and wetlands
- Geological hazards
- Hydrogeology and hydrology
- Aquifers and drinking water wells
- Endangered species
- Unique habitats

Relevant issues for landfill siting

Transportation / economic

- Proximity to major roads
- Load limits on roads
- Compatibility with truck traffic
- Proximity to generators
- Operating and construction costs
- Land prices
- Eventual reuse opportunities

Other

- Proximity to airports (bird problems)
- Archeological or historic sites
- Loss of prime farmland
- Consistency with state solid-waste management plan
- Waste minimization requirements (reduction, reuse, recycling)

Permits for new solid waste facility

State permits:

- Solid waste facility permit
- Environmental impact assessment
- Wetlands permit
- Wastewater discharge permit (?)

Local permits:

- Zoning permits (regular and special use)
- Wetlands permits