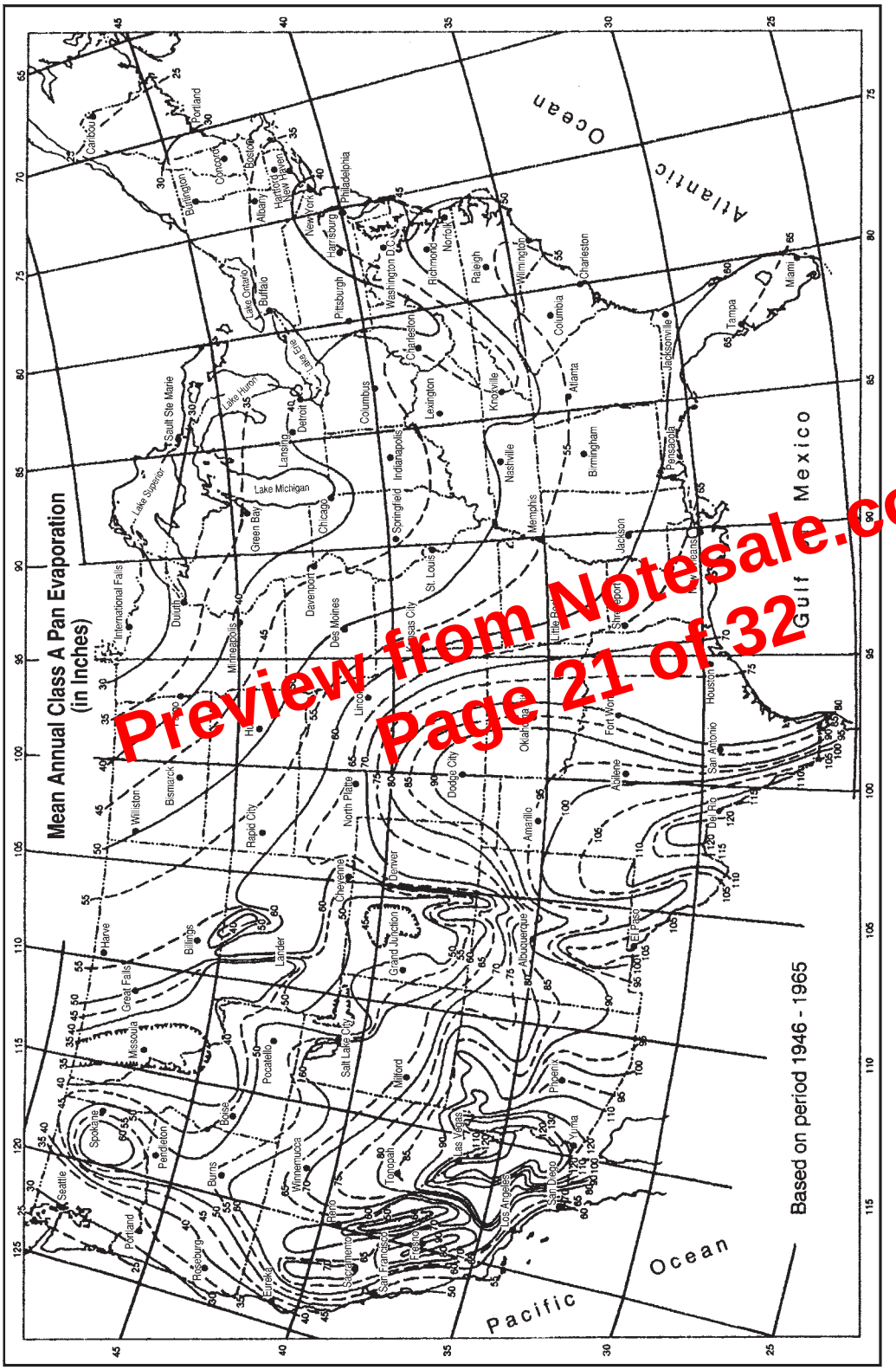

Fig. 7. Annual evaporation data for the contiguous United States.

Table 7
Analytical Data of Composite Settled Lagoon Sludge*, Lenox Water Treatment Plant, Lenox, Massachusetts

Parameter	Sludge data	US EPA limits for land application
pH, unit	6.9	None
Total suspended solids, mg/L**	30,425	None
Volatile suspended solids, mg/L**	3420	None
Fixed suspended solids, mg/L	27,005	None
Cadmium, mg/kg dry sludge	<0.14	16
Chromium, mg/kg dry sludge	54	140
Lead, mg/kg dry sludge	25	500
Copper, mg/kg dry sludge	64	850
Nickel, mg/kg dry sludge	80	82
Zinc, mg/kg dry sludge	14	1740
Aluminum, mg/kg dry sludge	30,500	None
Iron, mg/kg dry sludge	NA	None
Mercury, mg/kg dry sludge	BD	5

Adapted from Krofta and Wang (30,31) and Wang (41,42).
*The settled lagoon sludge was accumulated in the period from May 21 to Nov. 21, 1982.
**Total suspended solids and volatile suspended solids are average values of eight sludge samples.
NA = Not available.
BD = Below detection limit of AA.

sludge-testing period. It can be seen that the plant's chemical consumption was much lower than that of a comparable conventional water purification plant. However, the sludge production rate was estimated to be 150.8 dry lb/d/MGD, as shown in Table 5.

An engineer's rule of thumb for sludge production rate of a comparable conventional water purification plant is usually set at 75 dry lb/d/MGD. It is believed that the low sludge production rate of a conventional plant is caused by discharge of filter backwash wastewater, without recycle. Thus, the sludges in the discharged wastewater are not included in sludge quantity estimation (30,31,44):

It is understandable that the potable water flotation plant recycles its backwash wastewater for reuse, and in turn, has higher sludge production rate (150.8 instead of 75 dry lb/d/MGD) because almost all sludges are captured by dissolved air flotation. Table 5 further confirms the plant's sludge flow rate is about 0.7% of influent flow rate. The raw sludge concentration of TSS is about 2600 mg/L.

(b) Sludge Evaporation Performance: The data documented in Table 7 are for sludge handling and disposal (30,31,41,42). For freewheeling automatic operation without an operator's attention, the average sludge flow and sludge concentration (TSS) were 3.63 gpm and 2600 mg/L, respectively. By manual operation, with the operator's attention on June 29, 1982, the sludge concentration was as high as 15,800 mg/L, and the sludge flow was as low as 0.3 gpm. The floated sludge was discharged into a sludge lagoon with a built-in slow sand filter for disposal. The analytical data in Table 5 are for the settled lagoon sludge accumulated in the period from May 21 to November 21, 1982. It can be seen that the settled lagoon sludge with a consistency of about 3% meets the US Environmental Protection Agency limits for land application. The lagoon sludge contained mainly inorganic fixed suspended solids (27,005 mg/L),

Table 8
Sludge Evaporation and Monitoring at Lenox Water Treatment Plant

Date	Lagoon flow (gpm)	Lagoon and filter effluent		
		Turbidity (NTU)	TSS (mg/L)	Color (unit)
11/04/82	3.8–4.0	1.4	–	4
11/07/82	5.4–6.0	2.6	2.4	5
11/08/82	3.0–5.6	1.8	0.9	5
11/09/82	4.0–5.3	2.7	–	5
11/20/82	5.0–6.2	3.0	3.9	6

Adapted from Krofta and Wang (30,31). Fresh raw alum sludge (non-dewatered) was discharged directly into the sludge lagoon; 1 gpm = 1 gallon per minute = 3.785 liters per minute.

or, more specifically, the non-toxic aluminum (30,500 mg/kg dry sludge). All heavy metal contents were extremely low. The lagoon overflow passed though a slow sand filter, and eventually reached a small creek. The November 1982 lagoon operational data in Table 8 show that the slow sand filter effluent was as clean as reservoir raw water. When there is a water shortage, the lagoon filter effluent can be pumped back to the Lower Root Reservoir for reuse, so every drop of water can be conserved.

A Discharge Permit for discharging the lagoon effluent from the Lenox Water Treatment Plant to a nearby stream has been granted by the Commonwealth of Massachusetts Department of Environmental Quality. All dewatered alum sludge from the Lenox Water Treatment Plant is disposed to the town's Wastewater Treatment Plant.

The following paragraphs introduce the physical structures of the sludge evaporation lagoon system.

The Lenox plant's sludge evaporation lagoon consisting of a sludge lagoon and a slow sand filter was designed for holding and thickening of an average sludge flow of 3.63 gpm.

The lagoon's inlet and outlet are located at opposite ends. Its size is approx 31 ft W × 47.5 ft L at the top and 18.75 ft W × 42.5 ft L at the bottom, with a side slope of 1 1/2 to 1. Its depth is about 6 ft. The lagoon effluent is discharged to the slow sand filter via a spillway on a dividing concrete wall between the lagoon and the filter. The lagoon overflow rate and weir overflow rate are less than 500 gpd/ft^2 and less than 2000 gpd/ft, respectively.

The slow sand filter has a dimension of approx 34 ft L × 20 ft W, and is packed with 2 ft of coarse sand (0.5–0.7 mm effective size), 3 in. of small-diameter gravel under the sand, and 9 in. of graded gravel under the small diameter gravel. Its loading rate is equal to or less than 15 gpd/ft^2. The slow sand filter further polishes the lagoon effluent. The filter effluent is as clean as the reservoir raw water.

The entire sludge evaporation lagoon system has been constructed so as to provide for cleaning without interference with normal operation.

The lowest elevation of the sludge evaporation lagoon has been kept above ground water level to avoid being overflowed with ground water.

A similar but more improved evaporation lagoon system has been used at Feura Bush Filtration Plant of the City of Albany, New York, USA. The City of Albany's evaporation lagoon system involves the use of natural evaporation, freezing, thawing, and sedimentation processes for treatment of combined filter backwash water and sedimentation waste sludge.

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Appendix: Steam Tables (45)

Temperature (°F)	Pressure (psia)	ΔH_v (BTU/lb)	H_v (BTU/lb)
100	0.95[1]	1036.98	1105.02
230	20.781	958.81	1157.12
240	24.968[2]	952.27	1160.70

[1]0.95 psia corresponds to a T_L of 100°F, with ΔH_v = 1037 BTU/lb.
[2]10 psig corresponds to 24.696 psia. Interpolation yields a T_S of 239.4°F and 952.6 BTU/lb. 8 psig corresponds to 22.696 psia. Interpolation yields a T_L of 235°F.