# IRRIGATION STUDY

VALLEY ELECTRIC ASSOCIATION, INC.
NEVADA 18, VALLEY
HIGHWAY 372
PAHRUMP, NEVADA 89041

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APRIL 19, 1988

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## EXECUTIVE SUMMARY

Irrigation on the VEA system is down sharply since 1981. This is probably due to increases in electric rates and decreases in alfalfa prices. While alfalfa prices could rise, this report assumes no sharp increases. It is doubtful electric rates will return to 1980 levels.

This report forecasts a slight decrease in Amargosa Valley. Amargosa Valley is hard to predict since the drop here has been so steep and considerable farmland is idle, available and could be put back into production. Also there is considerable pressure on landowners to pump to maintain water rights. However, the poor economic conditions continue and the environment in this area is less conducive to farming than the other areas.

In Fish Lake Valley, a stable farm economy is forecast. The agricultural economy is strong and productivity, production and investment have increased. However, even here a slight decrease could occur due to the economics.

In Pahrump, as the trend to convert farm acreage to residential subdivisions continues, irrigation is expected to continue to decline.

# Summary of Irrigation Study

**Method of Irrigation:** SPRINKLER **Area:** AMARGOSA VALLEY

| ITEM | 1987 | 1992 | 1997 | 2002 |
|---|---|---|---|---|
| 1. No. Pumps - All Fuels | 54 | 52 | 44 | 39 |
| 2. No. Pumps - Electric | 54 | 52 | 44 | 39 |
| 3. Total Acs. - All Fuels | 1,400 | 1,350 | 1,150 | 1,000 |
| 4. Total Acs. - Electric | 1,400 | 1,350 | 1,150 | 1,000 |
| 5. Avg. Acres/Pump | 25.9 | 26.0 | 26.1 | 25.6 |
| 6. Avg. Pump HP | 38.9 | 38.7 | 38.7 | 38.7 |
| 7. Avg. CPD HP | N/A | N/A | N/A | N/A |
| 8. Total Avg. HP | 38.9 | 38.7 | 38.7 | 38.7 |
| 9. Total HP - Electric | 2,099 | 2,012 | 1,702 | 1,509 |
| 10. Overall Plant Eff. % | 56 | 56 | 56 | 56 |
| 11. Motor Eff. % | 90 | 90 | 90 | 90 |
| 12. Pump Eff. - % | 62 | 62 | 62 | 62 |
| 13. Total Lift - Feet | 190 | 190 | 190 | 190 |
| 14. Sprinkler PSI | 10.8 | 10.8 | 10.8 | 10.8 |
| 15. Water Appl. Eff. - % | 60 | 60 | 60 | 60 |
| 16. GPM | 503 | 500 | 500 | 500 |
| 17. Effective GPM | 301.8 | 300 | 300 | 300 |
| 18. Ac. Ft. Pumped - AF | 7,756 | 7,479 | 6,371 | 5,540 |
| 19. Ac. Ft. Pumped - El. | 7,756 | 7,479 | 6,371 | 5,540 |
| 20. Ac. Ft. Pumped/Pump | 143.6 | 143.8 | 144.8 | 142.0 |
| 21. Ann. kWh/HP | 1,286 | 1,295 | 1,304 | 1,279 |
| 22. Ann. kWh/Pump | 50,025 | 50,117 | 50,465 | 49,497 |
| 23. Total MWH Sold | 2,699 | 2,606 | 2,219 | 1,930 |
| 24. Cost/kWh to Irrig. - ¢ | 4.223 | 4.223 | 4.223 | 4.223 |
| 25. Avg. Ann. Cost - Irrig. $ | 2,113 | 2,116 | 2,131 | 2,090 |
| 26. Diversity | 1.25 | 1.25 | 1.25 | 1.25 |

TABLE _ S

Summary of Irrigation Study

Method of Irrigation: SPRINKLER Area: FISH LAKE VALLEY

| ITEM | 19 87 | 19 92 | 19 97 | 2002 |
|---|---|---|---|---|
| 1. No. Pumps - All Fuels | 86 | 86 | 86 | 86 |
| 2. No. Pumps - Electric | 86 | 86 | 86 | 86 |
| 3. Total Acs. - All Fuels | 5,900 | 5,900 | 5,900 | 5,900 |
| 4. Total Acs. - Electric | 5,900 | 5,900 | 5,900 | 5,900 |
| 5. Avg. Acres/Pump | 68.6 | 68.6 | 68.6 | 68.6 |
| 6. Avg. Pump HP | 78.9 | 78.9 | 78.9 | 78.9 |
| 7. Avg. CPD HP | N/A | N/A | N/A | N/A |
| 8. Total Avg. HP | 78.9 | 78.9 | 78.9 | 78.9 |
| 9. Total HP - Electric | 6,781 | 6,794 | 6,794 | 6,794 |
| 10. Overall Plant Eff. % | 56 | 56 | 56 | 56 |
| 11. Motor Eff. % | 90 | 90 | 90 | 90 |
| 12. Pump Eff. - % | 62 | 62 | 62 | 62 |
| 13. Total Lift - Feet | 198 | 198 | 198 | 198 |
| 14. Sprinkler PSI | 27.3 | 27.3 | 27.3 | 27.3 |
| 15. Water Appl. Eff. - % | 60 | 60 | 60 | 60 |
| 16. GPM | 977 | 980 | 980 | 980 |
| 17. Effective GPM | 586.2 | 588 | 588 | 588 |
| 18. Ac. Ft. Pumped - AF all Fuels | 42,406 | 42,406 | 42,406 | 42,406 |
| 19. Ac. Ft. Pumped - El. | 42,406 | 42,406 | 42,406 | 42,406 |
| 20. Ac. Ft. Pumped/Pump | 493 | 493 | 493 | 493 |
| 21. Ann. kWh/HP | 2,272 | 2,265 | 2,265 | 2,265 |
| 22. Ann. kWh/Pump | 179,261 | 178,709 | 178,709 | 178,709 |
| 23. Total MWH Sold | 15,406 | 15,388 | 15,388 | 15,388 |
| 24. Cost/kWh to Irrig. - ¢ | 4.223 | 4.223 | 4.223 | 4.223 |
| 25. Avg. Ann. Cost - Irrig. $ | 7,570 | 7,547 | 7,547 | 7,547 |
| 26. Diversity | 1.25 | 1.25 | 1.25 | 1.25 |

25/20 =

**Diversity I[illegible]ation Load**

EA Designation: Nevada 18, Valley

Date: 2-12-88

| ITEM | Historical 1983 | 1984 | 1985 | 1986 | 1987 | Future 5th 1992 | 10th 1997 | 15th 2002 |
|---|---|---|---|---|---|---|---|---|
| **Irrigation Only** | | | | | | | | |
| 1. MWH - Sold | 4,345 | 4,882 | 4,805 | 4,101 | 4,516 | 23,390 | 23,034 | 20,890 |
| 2. Line Loss - % | 14.81 | 14.47 | 16.49 | 14.75 | 16.27 | 15.45 | 15.45 | 15.45 |
| 3. MWH Purchased | 6,087 | 5,708 | 5,754 | 4,810 | 5,394 | 27,664 | 26,060 | 24,708 |
| 4. Total HP | 13,023 | 12,971 | 12,891 | 11,724 | 11,785 | 11,199 | 10,451 | 9,887 |
| 5. KW Demand - Div. 1.00 | 10,794 | 10,752 | 10,685 | 9,718 | 9,769 | 9,283 | 8,663 | 8,195 |
| 6. Diversity | 1.24 | 1.30 | 1.29 | 1.37 | -1.25 | 1.25 | 1.25 | 1.25 |
| 7. KW Demand - Calculated | 8,693 | 8,242 | 8,268 | 7,095 | 7,815 | 7,426 | 6,930 | 6,556 |
| 8. Monthly Load Factor - % | .94 | .93 | .94 | .94 | .93 | .43 | 43 | 43 |
| 9. kWh/HP - Month | 333.63 | 376.36 | 372.73 | 349.76 | 383.24 | X | X | X |
| **System Less Irrigation** | | | | | | | | |
| 10. MWH - Sold | 5,730 | 6,592 | 6,013 | 5,962 | 6,390 | | | |
| 11. MWH - Purchased | 8,028 | 7,707 | 7,200 | 6,994 | 7,632 | | | |
| 12. kW Demand | 13,159 | 14,798 | 14,664 | 12,453 | 15,085 | | | |
| 13. Monthly Load Factor - % | .82 | .70 | .66 | .78 | .68 | | | |
| **Total System** | | | | | | | | |
| [illegible]4. MWH Purchased | 14,115 | 13,414 | 12,954 | 11,804 | 13,026 | | | |
| 1[illegible] kW Demand | 21,852 | 23,040 | 22,932 | 19,548 | 22,900 | | | |
| 16 Monthly Load Factor - % | .87 | .78 | .76 | .84 | .76 | | | |
| 17. Month of Demand | AUGUST | JULY | JULY | JUNE | AUGUST | | | |

Comments:

TABLE 3

## Summary of Irrigation Study

**Method of Irrigation:** SPRINKLER **Area:** PAHRUMP

| ITEM | 1987 | 1992 | 1997 | 2002 |
|---|---|---|---|---|
| 1. No. Pumps - All Fuels | 87 | 71 | 58 | 47 |
| 2. No. Pumps - Electric | 87 | 71 | 58 | 47 |
| 3. Total Acs. - All Fuels | 1,640 | 1,340 | 1,100 | 890 |
| 4. Total Acs. - Electric | 1,640 | 1,340 | 1,100 | 890 |
| 5. Avg. Acres/Pump | 18.9 | 18.9 | 19.0 | 18.9 |
| 6. Avg. Pump HP | 33.4 | 33.7 | 33.7 | 33.7 |
| 7. Avg. CPD HP | N/A | N/A | N/A | N/A |
| 8. Total Avg. HP | 33.4 | 33.7 | 33.7 | 33.7 |
| 9. Total HP - Electric | 2,904 | 2,393 | 1,955 | 1,584 |
| 10. Overall Plant Eff. % | 56 | 56 | 56 | 56 |
| 11. Motor Eff. % | 90 | 90 | 90 | 90 |
| 12. Pump Eff. - % | 62 | 62 | 62 | 62 |
| 13. Total Lift - Feet | 188 | 188 | 188 | 188 |
| 14. Sprinkler PSI | 12.6 | 12.6 | 12.6 | 12.6 |
| 15. Water Appl. Eff. - % | 45 | 45 | 45 | 45 |
| 16. GPM | 436 | 440 | 440 | 440 |
| 17. Effective GPM | 196.2 | 198 | 198 | 198 |
| 18. Ac. Ft. Pumped - AF | 19,178 | 15,651 | 12,830 | 10,360 |
| 19. Ac. Ft. Pumped - El. | 19,178 | 15,651 | 12,830 | 10,360 |
| 20. Ac. Ft. Pumped/Pump | 220 | 220 | 221 | 220 |
| 21. Ann. KWh/HP | 2,255 | 2,255 | 2,264 | 2,255 |
| 22. Ann. KWh/Pump | 75,317 | 75,994 | 76,297 | 75,994 |
| 23. Total MWH Sold | 6,551 | 5,396 | 4,426 | 3,572 |
| 24. Cost/kWh to Irrig. - ¢ | 4.223 | 4.223 | 4.223 | 4.223 |
| 25. Avg. Ann. Cost - Irrig. $ | 3,181 | 3,209 | 3,222 | 3,209 |
| 26. Diversity | 1.25 | 1.25 | 1.25 | 1.25 |

A. GENERAL DATA

VEA serves Nye and portions of Clark, Esmeralda and Mineral Counties in Nevada and portions of Inyo and Mono Counties in California. There are no foreseen changes in the service area.

VEA is governed by a four member Board of Directors who are popularly elected from four districts.

The VEA service area is generally west and northwest of Las Vegas. The main population center, Pahrump, is about 65 vehicular miles west of Las Vegas. Over 7,100 people inhabit Pahrump whose population is growing consistently at a rate close to 10% per year.

The service area generally parallels the Nevada - California state line and contains several valleys that have irrigated farmland.

VEA's service area consists of approximately 7,000 square miles of generally flat high desert with some mountainous areas. About 65% of the service area is federal land.

District 1 is the southernmost of the four districts. It consists primarily of Pahrump Valley, Sandy Valley and Mountain Springs plus a few very small, scattered communities. There is irrigation in Pahrump and Sandy Valley and they are combined in this report. Pahrump's growing season is over 200 days per year. The temperature extremes vary from 10 to 115 degrees Fahrenheit. Pahrump is nominally 2,600 feet above sea level.

Pahrump's population consists primarily of retirees, Nevada Test Site (NTS) workers, commuters to Las Vegas, people who work locally for a casino, a developer or a limited number of smaller local businesses and some farmers.

District 2 is the next district going north. It is composed of Amargosa Valley. Amargosa's growing season is slightly shorter but still in excess of 200 days. Amargosa is nominally 3,000 feet above sea level and is 35 miles northwest of Pahrump. Amargosa's temperature range is similar to Pahrump.

The largest employer for Amargosa residents is NTS and there are a few local farmers. A large number of people had worked at the American Borate Company (ABC) mine and processing plant prior to its closing in July 1986. Most of these people have moved away from the area.

District 3 is the next district north and it consists mainly of the town of Beatty and nearby areas. Since there is very little irrigation in this district and it is near Amargosa, its data is included in Amargosa's.

Development of various mining operations in the Beatty area could dramatically impact the load resulting in an increase as large as 80% or more.

District 4 is composed of Fish Lake Valley. Its economy is primarily agricultural although there are also two industrial loads.

Pahrump's soil is mostly a clay loam that takes water readily, has good water holding capacity but tends to compact.

Sandy Valley's soil is sandy and requires frequent watering.

Likewise Amargosa Valley's soil tends to be sandy, requiring frequent watering. It also tends to be highly alkaline which causes agricultural problems. High winds sometimes cause application problems.

FLV soil is generally a sandy loam or course soil which also requires frequent watering.

The VEA system load could be impacted by various major changes such as:

- Addition of large mining loads.
- Development of a nuclear waste depository.
- Termination or reduction of nuclear weapons testing.
- Reinstatement of MX missile program.

B. WATER RESOURCES

The State of Nevada issues water rights to various landowners, giving them the legal right to pump underground water. If water is not used during a five year period for a beneficial purpose then the rights are subject to revocation.

State law prohibits mining of water. This is generally interpreted to mean water can be pumped but only to the level of normal recharge. Another interpretation is water can be pumped as long as the water table does not drop.

The only water resource in Pahrump, Sandy Valley and Amargosa Valley is underground.

A large amount of farmland in Pahrump has been converted to subdivisions for residential use. As a result there has been a large drop in the amount of water used for farming. A smaller amount of water is being used for the new primarily residential use accounts and this use is increasing very slowly. As a result there is much less use of water overall. In the past, irrigators pumped far more water than the recharge. Now water use has dropped to just under the recharge level which has been estimated to be 19,000 acre feet of recharge annually.

Currently no new water rights are being issued in any area of Nevada. This is to conserve water and prevent the mining of water. Therefore, if an irrigator loses his water rights to a piece of land, the loss may be permanent and no further irrigation could take place legally on that land. This would sharply reduce the value of the land since nothing can be grown in this area without irrigation. As a result, some owners of farmland pump specifically to maintain their water rights.

In Amargosa Valley there has been little indication of depletion. Several free flowing springs exist in the Ash Meadows area. Some of these flow at the rate of several hundred gallons per minute.

Fish Lake Valley (FLV) has four streams which are fed from snowpack from the White Mountains to the immediate west of FLV. Many of these streams run year around. The rate of stream water flow varies from year to year and therefore cannot be depended upon for irrigation. Approximately 25 percent of acreage is irrigated from these streams although from year to year and throughout the season this may vary greatly.

FLV also has an underground aquifer which has maintained its level since depletion about equals recharge.

C. IRRIGATION DATA

Irrigation represents 24.0 percent of the VEA kwh consumption. FLV has the largest concentration of irrigation with 15.3 percent of the total system kwh consumption. Next is Pahrump with 6.0 percent. Amargosa Valley has 2.6 percent.

1981 was a peak for irrigation and there has been a relatively constant drop since then.

The last report in 1983 had forecasted a drop in total kilowatt-hour usage from the 1981 peak of 39,000 megawatthours to 36,000 megawatthours in 1987. The actual 1987 usage is only 23,000 megawatthours, 41 percent below the 1981 peak. In general various irrigation indicators have decreased much more since the 1981 peak than projected in the last report. Actually the 1982 drop reflected the start of a major new trend of decreasing irrigation.

In May 1981, VEA's electric rate for irrigation was increased 58.31 percent for usage of 2,700 kilowatt-hours per horsepower or less (see Appendix A). The reduced rate for usage above 2,700 kilowatt-hours per horsepower was deleted.

In April 1982, rates were increased by 13.91 percent for a total increase of 80.34 percent.

In January 1983, rates were again increased by 21.99 percent. The total increase over April 1981 then became 120 percent.

In August 1985, prices were reduced by 7.49 percent. At this point, rates were still over 103 percent above April 1981.

These rate increases were probably a major factor in the decline in irrigation in the VEA service area.

During this period, alfalfa prices also dropped from a three year, month by month moving average of $87.77 to $80.00. This decrease was probably also a major factor in the decline.

The projections in this study assume in general that present conditions will continue without any changes in electric rates, agricultural prices, etc.

As long as alfalfa prices continue to be low, economic conditions will be poor for most irrigators in VEA's service area. Some irrigators have gone bankrupt. However, in each case the land has been sold to a new owner and irrigation of the land has continued.

In Pahrump, it appears more and more farmland will gradually be subdivided for residential use. The population of Pahrump has been increasing at about a 10 percent per year rate. If this assumption is correct, there will probably continue to be a gradual decline in irrigation.

In Amargosa Valley, most of the decrease in irrigation has probably taken place. This was mainly due to the out migration caused by the closing of American Borate Company as well as the generally poor agricultural economy. There may continue to be a slight decline as projected. However, there could also be an increase since there are many acres which have been taken out of production and as a result may now lose water rights. In order to save the water rights and therefore also the value of this land, some of this land may be put back into irrigation. Some farmland (and residential subdivisions) have been taken out of service due to environmental considerations. A large area in Ash Meadows had been sold to a developer for subdivision into residential and commercial properties. Since then all development and farming in this area has been terminated due to environmental concerns.

In FLV, irrigation has been relatively constant with only a slight decrease. Since the local economy is primarily agricultural and is committed to this, one can assume only a slight decrease would occur at worse if current conditions continue. On the other hand, increases in production indicate underlying strength and stability in the agricultural economy (see Appendix D).

In this report, no irrigation growth is projected for several reasons:

- The increase in rates in 1981-1983 has not reversed and has made the economics of irrigated farming less favorable. The agricultural economy is depressed and farm commodity prices are low both from a historic viewpoint and in respect to the cost of farming (See Appendix B).

- The Co-op's historical data clearly show an era of decreasing irrigation and long term trends do not generally change abruptly.

- The State of Nevada has frozen the issuance of new water rights effectively restricting any irrigation growth.

Many of the Co-op's irrigation accounts could be described more accurately as "hobby farms" rather than "commercial enterprises". Many of these may irrigate a few acres of alfalfa for their personal use possibly for a horse or other animal. They also pump to irrigate their shade and wind break trees, personal garden and lawn and in certain circumstances to provide water for residential use.

There are also a number of accounts who use relatively little electricity and for all practical purposes may best be classified as idle.

Overall between 1982 and 1986, the number of active services has dropped 8.4 percent, the total horsepower 8.6 percent and the total kilowatt-hour sales 15.6 percent.

In particular, Amargosa Valley has dropped precipitously by 45.9 percent of total kwhr between 1982 and 1986. The other areas have dropped much more gradually.

There are irrigators irrigating to maintain water rights but who want to limit operating costs to as low a level as possible and they are not particularly concerned about a return on the sale of their crop.

VEA started a pump testing program in 1982. The data from this test is analyzed by computer and given to the irrigator without charge as a service of the Co-op. With the help of this information plus assistance from Co-op personnel, the irrigator can determine which pumping systems are inefficient and the replacement of which systems will be economically advantageous.

There is considerable evidence that increases in irrigation rates have resulted in decreases in usage. The fragile economic condition of some irrigators cannot support any additional costs whether from higher irrigation rates or due to some other reason. Any drop in alfalfa prices could also have a severe effect.

Several irrigation wells in Pahrump have been converted from farm use to residential water company use. They were reclassified by the Co-op from the irrigation rate to a commercial rate.

Two golf courses in Pahrump irrigate heavily and enjoy the irrigation rate.

At one time cotton was the primary crop in Pahrump. However, it is no longer grown here since it is no longer economically profitable.

The primary crop now is alfalfa throughout the VEA system. Much of it is cubed rather than baled to facilitate shipment to distant markets.

Farm products are transported to markets exclusively by truck. All areas have reasonably good paved conventional roads to facilitate this.

About 50 percent of Pahrump farms are flood irrigated. Most of the rest are irrigated by sprinklers from wheel lines or hand moved lines.

In Amargosa Valley, high and low pressure pivot systems and sprinklers mounted on wheel lines and hand moved lines are used. Frequent high wind conditions often cause problems with water application and soil erosion.

In FLV, about half of the acres are irrigated by pivots and half by wheel lines.

D. DIVERSITY

VEA has a summer non-coincidental peak due to electrical air conditioning (mostly of residences) and irrigation. The winter peak has increased to approach the summer peak due primarily to residential heating.

The large commercial irrigators mostly pump as continuously as possible, 24 hours per day, throughout the irrigation season providing a very good load factor of about 93 percent.

## E. CONVERSIONS

At this time, there are no known irrigation wells being powered by internal combustion engines. The economics very strongly favor using the Co-op's electric power at the very low $.04223 irrigation rate rather than the relatively expensive diesels or other generators. The diesels have the disadvantages of requiring a large capital outlay for the diesel, higher operating costs due to the diesel engine system and more need for labor to oversee and operate.

## F. RATES

The irrigation rate is shown on Schedule I in the Appendix. A special high usage rate was reinstated in 1987 on a season by season basis. This rate was only $.025 per kilowatt-hour for each kilowatt-hour over 2,700 kilowatt-hours per horsepower. This rate has been discontinued.

## G. POWER SUPPLY AVAILABILITY

Overall VEA is growing at about 6% per year mainly due to the 10% per year growth in Pahrump. Eventually this growth will cause VEA to acquire a new additional resource. This resource will be far more expensive than the existing resources. When this occurs, the higher cost of the new resource will probably be blended into the rate schedule. A reasonable projection might be for relatively stable rates for the next five years and then a gradual increase.

## H. LOAD MANAGEMENT

VEA now does not have a load management program other than educating consumers. The wholesale power supplier does not have a load management program either except for a Conservation and Renewable Energy Program. This program promotes conservation and includes VEA's well testing program. It is difficult to determine what impact this program has to save energy. Due to the poor economic plight of most irrigators, investments of new capital equipment have been very limited. Overall the VEA load factor has been gradually increasing.

## APPENDIX A

### HISTORICAL IRRIGATION RATES

| START DATE | 1ST 2700 WKHR ¢/KWHR | PERCENT INCREASE | OVER 2,700 KWHR ¢/KWHR | PERCENT INCREASE |
|---|---|---|---|---|
| NOVEMBER 1974 | 1.987 | - | 0.987 | - |
| AUGUST 1980 | 2.075 | 4.41 | 1.031 | 4.41 |
| MAY 1981 | 3.285 | 58.31 | 3.285 | 218.62 |
| APRIL 1982 | 3.742 | 13.91 | 3.742 | 13.91 |
| JANUARY 1983 | 4.565 | 21.99 | 4.565 | 21.99 |
| AUGUST 1985 | 4.223 | (- 7.49) | 4.223 | (- 7.49) |
| :IL 1987 | 4.223 | - | 2.5 | (- 40.80) |
| MARCH 1988 | 4.223 | - | 4.223 | 68.92 |

## APPENDIX B

## HISTORICAL ALFALFA PRICES

| YEAR | PRICE | 3 YEAR MONTH BY - MONTH MOVING AVERAGE |
|---|---|---|
| 1978 | 53.20 | - |
| 1979 | $73.00 | 74.77 |
| 1980 | 98.10 | 84.57 |
| 1981 | 82.60 | 88.43 |
| 1982 | 84.60 | 87.77 |
| 1983 | 96.10 | 87.80 |
| 1984 | 82.70 | 86.27 |
| 1985 | 80.00 | 80.00 |
| 1986 | 77.30 | - |
| 1987 | N/A | - |

# APPENDIX C

## CURRENT IRRIGATION RATE SCHEDULE

## SCHEDULE I
## IRRIGATION SERVICE

### AVAILABILITY

Available for service to irrigation pumps, subject to Seller's established rules and regulations.

### TYPE OF SERVICE

Three-phase or single phase, 60 hertz, at available secondary voltages.

### MONTHLY CHARGE

Energy charge:
All kilowatt-hours used, per kwh $0.04223

### DETERMINATION OF HORSEPOWER

The horsepower for billing purposes shall be the motor manufacturer's nameplate rating of horsepower output, except that if the Seller so elects it shall be determined by actual measurements of power input during a period of maximum normal use, less an allowance of ten percent of input for motor losses.

### MINIMUM ANNUAL CHARGE

The minimum annual charge for each installation shall be $15.00 per horsepower, but not less than $240.00 per year.

### POWER FACTOR ADJUSTMENT

The consumer agrees to maintain unity power factor as nearly as practicable. The horsepower for billing purposes will be adjusted for consumers with 50 hp or more to correct for average power factors lower than 85%, and may be so adjusted for consumers if and when the Seller deems necessary. Such adjustments will be made by increasing the horsepower 1% for each 1% by which the average power factor is less than 85% lagging.

### TERMS OF PAYMENT

All of the above rates are net, the gross rates being 10 percent higher. In the event the bill is not paid within 15 days from the date of the bill, the gross rates shall apply. Bills shall be rendered monthly during the irrigation season.

The minimum charge shall be due and payable in five equal monthly installments on the bills for the first five months of the irrigation season whether or not service is actually used.

SCHEDULE I (Continued)
IRRIGATION SERVICE

## IRRIGATION SEASON

The irrigation season starts on the meter reading date nearest to the first day of April each year and extends over a period of twelve months from that date.

## APPENDIX D

## ESMERALDA - COUNTY - ALFALFA YIELDS

| | ACRES | PRODUCTION | YIELDS TONS/ACRE |
|---|---|---|---|
| 1978 | 5,800 | 18,560 | 3.2 |
| 1979 | 5,200 | 18,200 | 3.5 |
| 1980 | 4,200 | 15,960 | 3.8 |
| 1981 | 5,500 | 20,900 | 3.8 |
| 1982 | 5,500 | 20,350 | 3.7 |
| 1983 | 5,000 | 20,000 | 4.0 |
| 1984 | 6,000 | 22,200 | 3.7 |
| 1985 | 6,000 | 24,600 | 4.1 |
| 1986 | 6,000 | 26,400 | 4.4 |

APPENDIX E

WATER RIGHTS

# Individual Water Rights Hearings in PV on Dec. 8-10

BY MILT BOZANIC

Hearings on whether 16 certificated water rights in Pahrump Valley should be forfeited by present owners because they haven't used them as required by state law during the past five years will be held in Pahrump Valley Dec. 8, 9, and 10. The hearing starts at 10 a.m. each day at the Community Center.

The hearings are part of the on-going efford by the state to regulate water use in Pahrump in order to insure long-term availability of water for a growing population.

Neither working farms nor subdivision development would be affected.

State law requires that a water right be put to beneficial use. Failure to use the water for such a use subjects the right to forefeiture. This law has held for many years but only in recent times has the Department of Conservation and Natural Resources made efforts to tighten its policies in Pahrump Valley.

Pahrump Valley in 1985 was pumping about 23,000 acre feet of water against a natural recharge of about 19,000. The pumpage has been declining since its peak use in 1968 or 48,000 acre feet. The goal is to reach an equilibruim where no more water is pumped than is recharged. The extra water comes from the vast reservoir below Pahrump Valley. The state wants to halt dipping into that reserve. A state low prohibits "water mining," although it has taken place extensively in other parts of the state.

Pahrump Valley has over 40,000 subdivied lots. State officials contend that if and when all thost lots are occupied, water should be available to the owners.

One person could hold dozens of different water rights. The loss of one right could not affect others.

Those facing water rights forfeiture to be heard on Dec. 8 include John William Ward, J hn and Marie Harrell, John O. Parko, Gerald and Virginia Allison, and Preferred Equities, which has three permits in jeopardy.

On Dec. 9, those facing forfeiture loss of a water right include: on one certificate—Lovee Miller, Wulfenstein Realty, and Ray and Irene Wulfenstein; Hollis Harris and Charles Barton; Andrew Dickman; and Rachelle Development and Katrina Development.

On Dec. 10, those to be heard include: the estate of Earl Burson; Clover Bruson, Gordon and Iva Chrisite; the Christies with several other; Zolin and Shirley Burson and several others.

The state last month advertised points in its present water policy in Pahrump Valley. Included are that applications for water "on the fan," that is, on the east side of Highway 160 in Pahrump Valley, will continue to be denied. Also, applications for new water rights will be denied except for small commercial uses. Applications for commercial use requiring water of 5000 gallons per day of less will be considered on the merit of the application.

These policies do not affect all the many water rights in good standing.

People losing water rights have the right to reapply for the right. Also, an effort is expected to be made by to get a two year grace period in which water right facing forfeiture could be put to beneficial use to meet state law.

Pahrump rancher - developer Tim Hafen said last month that at a meeting Sept. 18 with Roland Westegard, heading of the state Division of Conservation and Natural Resources, that there was a gentleman's agreement that a two year grace period would be granted. Hafen said about 20 people were present.

If that point is agreed to , then it's possible none of the water rights in jeopardy would be forfeited. Some have already asked for extensions.

# Lisle Lowe Nephew Abducted

The search continues for the 7-year-old nephew of an Amargosa resident who was abducted from Whiskey Pete's a little over a week ago.

The youngster. _Alexander Harris. large glasses.

When last seen, he was wearing a red fleece jacket with a black pattern, turquoise shirt, faded blue blue and white high-top tenn . shoes.

APPENDIX F

DATA SHEETS

**INSTRUCTIONS FOR TABLE I** - *1. Totals and averages should be computed from maximum number active installations using service during year. 2. Any installation producing revenue during year to be considered active. 3. Show average HP to nearest tenth (26.3). 4. To calculate five year average:*
*a. Item 6 - Five Year Total for Item 5 divided by Five Year Total for Item 2.*
*b. Item 7 - Five Year Total for Item 5 divided by Five Year Total for Item 3.*

**TABLE I - PAST IRRIGATION PUMP INSTALLATION OPERATING DATA** *(Most recent 5 years)*

| ITEM | 1983 | 1984 | 1985 | 1986 | 1987 | 5 YEAR TOTAL |
|---|---|---|---|---|---|---|
| 1. NUMBER IRRIGATION SERVICES (Active and Idle) | 291 | 314 | 312 | 309 | 309 | |
| 2. MAXIMUM NUMBER USING SERVICE (Active) | 250 | 244 | 238 | 239 | 227 | 1,198 |
| 3. TOTAL HORSEPOWER | 13,023 | 12,971 | 12,891 | 11,724 | 11,785 | 62,394 |
| 4. AVERAGE HORSEPOWER PER INSTALLATION | 52.09 | 53.16 | 54.16 | 49.05 | 51.92 | |
| 5. TOTAL KWH USED IRRIGATION | 26,824,503 | 26,420,204 | 26,877,493 | 24,979,576 | 22,730,565 | 127,832,341 |
| | | | | | | **5 YEAR AVERAGE** |
| 6. AVERAGE ANNUAL KWH INSTALLATION | 107,298 | 108,279 | 112,931 | 104,517 | 100,135 | 106,705 |
| 7. AVERAGE ANNUAL KWH/HP | 2,059 | 2,037 | 2,085 | 2,131 | 1,929 | 2,049 |
| 8. PERCENT IRRIGATION SALES LINE 5 TO TOTAL SYSTEM SALES | 28.7 | 25.9 | 26.2 | 26.7 | 24.0 | |

**TABLE II - PAST IRRIGATION LOAD BY SUBSTATION**

| SUBSTATION OR METERING POINT | 1983 | | | 1984 | | | 1985 | | | 1986 | | | 1987 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NO. OF PUMPS | AVG. HP | TOTAL HP | NO. OF PUMPS | AVG. HP | TOTAL HP | NO. OF PUMPS | AVG. HP | TOTAL HP | NO. OF PUMPS | AVG. HP | TOTAL HP | NO. OF PUMPS | AVG. HP | TOTAL HP |
| AMARGOSA VALLEY | 62 | 51.1 | 3168 | 62 | 52.5 | 3255 | 63 | 52.0 | 3275 | 56 | 38.8 | 2170 | 54 | 38.9 | 2099 |
| FISH LAKE VALLEY | 81 | 76.5 | 6199 | 85 | 75.8 | 6443 | 84 | 78.4 | 6589 | 81 | 80.8 | 6541 | 86 | 78.8 | 6781 |
| PAHRUMP | 107 | 34.2 | 3656 | 97 | 33.7 | 3273 | 91 | 33.3 | 3027 | 102 | 29.5 | 3013 | 87 | 33.4 | 2905 |
| TOTALS | 250 | 52.1 | 13,023 | 244 | 53.2 | 12,971 | 238 | 54.. | 12,891 | 239 | 49.1 | 11,724 | 227 | 51.9 | 1178 |

Date: 4/4/88

TABLE 1-A

Historical Irrigation Pump Operating Data

Method of Irrigation: SPRINKLER

Area: FISH LAKE VALLEY

| ITEM | 1983 | 1984 | 1985 | 1986 | 1987 | 5 Yr. Total |
|---|---|---|---|---|---|---|
| 1. Number of Meters | 81 | 85 | 84 | 81 | 86 | X |
| 2. Total Horsepower | 6,199 | 6,443 | 6,589 | 6,541 | 6,781 | 32,553 |
| 3. Average HP/Meter | 76.5 | 75.8 | 78.4 | 80.75 | 78.8 | X |
| 4. Annual kWh Sold - Irrig. | 14,010,806 | 15,084,415 | 15,362,896 | 14,978,454 | 14,538,124 | 73,974,695 |
| 5. Avg. Ann. kWh/Meter | 172,973 | 177,463 | 182,892 | 184,919 | 169,048 | 5 Yr. Avg. |
| 6. Avg. Ann. kWh/HP | 2,260 | 2,341 | 2,332 | 2,290 | 2,144 | 2,272 |

Avg. Ann. kWh/HP -Adjusted for 5 Yrs. = ______ 5 Yr. Composite divided by ______ ___ Yr. Composite X ______ Line 6 = ______

Method of Irrigation: SPRINKLER

Area: PAHRUMP

| ITEM | 1983 | 1984 | 1985 | 1986 | 1987 | 5 Yr. Total |
|---|---|---|---|---|---|---|
| 1. Number of Meters | 107 | 97 | 91 | 102 | 87 | X |
| 2. Total Horsepower | 3,656 | 3,273 | 3,027 | 3,013 | 2,905 | 15,874 |
| 3. Average HP/Meter | 34.2 | 33.7 | 33.3 | 29.5 | 33.4 | X |
| 4. Ann. kWh Sold - Irrig. | 8,370,855 | 6,990,749 | 7,477,073 | 7,225,976 | 5,731,832 | 35,796,485 |
| 5. Avg. Ann. kWh/Meter | 78,232 | 72,070 | 82,166 | 70,843 | 65,883 | 5 Yr. Avg. |
| 6. Avg. Ann. kWh/HP | 2,290 | 2,136 | 2,470 | 2,398 | 1,973 | 2,255 |

Avg. Ann. kWh/HP -Adjusted for 5 Yrs. = ______ 5 Yr. Composite divided by ______ ___ Yr. Composite X ______ Line 6 = ______

Date: 4/4/88

TAB. . 1-A

**Historical Irrigation Pump Operating Data**

Method of Irrigation: SPRINKLER    Area: AMARGOSA VALLEY

| ITEM | 1983 | 1984 | 1985 | 1986 | 1987 | 5 Yr. Total |
|---|---|---|---|---|---|---|
| 1. Number of Meters | 62 | 62 | 63 | 56 | 54 | X |
| 2. Total Horsepower | 3,168 | 3,255 | 3,275 | 2,170 | 2,099 | 13,967 |
| 3. Average HP/Meter | 51.1 | 52.5 | 52.0 | 38.8 | 38.9 | X |
| 4. Annual kWh Sold - Irrig. | 4,342,842 | 4,345,040 | 4,037,524 | 2,775,146 | 2,460,609 | 17,961,161 |
| 5. Avg. Ann. kWh/Meter | 70,046 | 70,081 | 64,088 | 49,556 | 45,567 | 5 Yr. Avg. |
| 6. Avg. Ann. kWh/HP | 1,371 | 1,335 | 1,233 | 1,279 | 1,172 | 1,286 |

Avg. Ann. kWh/HP -Adjusted for 5 Yrs. = ______ (5 Yr. Composite) divided by ______ (___ Yr. Composite) X ______ (Line 6) = ______

Method of Irrigation: ______    Area: ______

| ITEM | 19__ | 19__ | 19__ | 19__ | 19__ | ___ Yr. Total |
|---|---|---|---|---|---|---|
| 1. Number of Meters | | | | | | X |
| 2. Total Horsepower | | | | | | |
| 3. Average HP/Meter | | | | | | X |
| 4. Ann. kWh Sold - Irrig. | | | | | | |
| 5. Avg. Ann. kWh/Meter | | | | | | ___ Yr. Avg. |
| 6. Avg. Ann. kWh/HP | | | | | | |

Avg. Ann. kWh/HP -Adjusted for 5 Yrs. = ______ (5 Yr. Composite) divided by ______ (___ Yr. Composite) X ______ (Line 6) = ______

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USDA - REA

# DATA FOR IRRIGATION STUDY (Cont'd.)

BORROWER DESIGNATION: NEVADA 18, VALLEY

DATE: 4/4/88

## TABLE III-ESTIMATED IRRIGATION POWER REQUIREMENTS BY SUBSTATION AREA

| SUBSTATION OR METERING POINT | 5TH YEAR - 19 | | | 10TH YEAR - 1997 | | | 15TH YEAR - XX2002 | | |
|---|---|---|---|---|---|---|---|---|---|
| | NO. OF PUMPS | AVG. HP | TOTAL HP | NO. OF PUMPS | AVG. HP | TOTAL HP | NO. OF PUMPS | AVG. HP | TOTAL HP |
| FISH LAKE VALLEY | 86 | 79.0 | 6794 | 86 | 79.0 | 6794 | 86 | 79.0 | 6794 |
| PAHRUMP | 71 | 33.7 | 2393 | 58 | 33.7 | 1955 | 47 | 33.7 | 1584 |
| AMARGOSA VALLEY | 52 | 38.7 | 2012 | 44 | 38.7 | 1702 | 39 | 38.7 | 1509 |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| TOTAL SYSTEM | 209 | 53.58 | 11,199 | 188 | 55.59 | 10,451 | 172 | 57.48 | 9,887 |

| *ANNUAL KWH ESTIMATES | TOTAL |
|---|---|
| 1. 5 YEARS 19 ........ | |
| 2. 10 YEARS 19 ........ | |
| 3. 15 YEARS 19 ........ | |

*ANNUAL KWH REQUIREMENTS = TOTAL ACRE FEET (TABLE A) X TOTAL DYN. HD. (TABLE B) X 1.024 / EFFICIENCY

1/ HP X 746 / 1000 EFFICIENCY = KW DEMAND

2/ TOTAL ANN. IRRIGATION KWH = ANN. IRRIGATION LOAD FACTOR / TOTAL DEMAND X 8760

*Efficiency normally is between .87 and .95 for large motors. If efficiency is unknown, use .90. There may also be diversity between irrigation loads which must be considered.*

## TABLE IV-ESTIMATED IRRIGATION KWH USAGE, DEMAND AND LOAD FACTOR

| YEAR | ACTIVE NO. PUMPS | AVERAGE HP | TOTAL HP | TOTAL DEMAND 1/ | AVG. ANNUAL KWH/HP | AVG. ANNUAL KWH/INST. | TOTAL ANNUAL KWH | ANN. LOAD 2/ FACTOR | 
|---|---|---|---|---|---|---|---|---|
| 1. PRESENT 19 87 | 227 | 51.92 | 11,785 | 7,815 | 2,049 | 100,135 | 24,147,465* | 93** |
| 2. 5 YEARS 19 92 | 209 | 53.58 | 11,199 | 7,426 | 2,089 | 111,915 | 23,390,165 | 42.52 |
| 3. 10 YEARS 19 97 | 188 | 55.59 | 10,451 | 6,930 | 2,108 | 117,202 | 22,033,938 | 42.93 |
| 4. 15 YEARS XX 2002 | 172 | 57.48 | 9,887 | 6,556 | 2,113 | 121,455 | 20,890,341 | 43.02 |

COMMENTS

*Data is normalized based upon average for last five years.

**Peak month.

PAGE 3 OF 3 PAGES

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TABL'

**AVERAGE IRRIGATION REQUIREMENTS FOR CROPS GROWN IN THE AREA**

**thod of Irrigation:** SPRINKLER **Area:** AMARGOSA VALLEY **REA Designation:** NEVADA 18, VALLEY

| IRRIGATED CROP | MRO | MPO | NIR | Number of Acres 19 87 | 19 92 | 19 97 | 2002 |
|---|---|---|---|---|---|---|---|
| 1. ALFALFA | 60 | 4 | 56 | 1,400 | 1,250 | 1,050 | 900 |
| 2. TURF | 60 | 4 | 56 | - | 100 | 100 | 100 |
| 3. | | | | | | | |
| 4. | | | | | | | |
| 5. | | | | | | | |
| 6. | | | | | | | |
| 7. CNIR - Crops Only | | | | 56 | 56 | 56 | 56 |
| 8. Correction Factor | | | - 16.11 | | | | |
| 9. Total Acres | | | | 1,400 | 1,350 | 1,150 | 1,000 |
| 10. Composite Net Irrigation Requirements - inches | | | | 39.89 | 39.89 | 39.89 | 39.89 |
| 11. Water Application Efficiency - % - Projection | | | | 60 | 60 | 60 | 60 |
| 12. Composite Gross Irrigation Requirement - inches | | | | 66.48 | 66.48 | 66.48 | 66.48 |
| 13. Acre Feet pumped - Total | | | | 7,756 | 7,479 | 6,371 | 5,540 |
| 14. Acre Feet Pumped - Electric | | | | 7,756 | 7,479 | 6,371 | 5,540 |

TAB 1

## AVERAGE IRRIGATION REQUIREMENTS FOR CROPS GROWN IN THE AREA

Method of Irrigation: SPRINKLER Area: FISH LAKE VALLEY REA Designation: NEVADA 18, VALLEY

| IRRIGATED CROP | MRO | MPC | NIR | Number of Acres 1987 | 1992 | 1997 | 2002 |
|---|---|---|---|---|---|---|---|
| 1. ALFALFA | 50 | 4 | 46 | 5,500 | 5,500 | 5,500 | 5,500 |
| 2. SMALL GRAINS | 26 | 4 | 22 | 400 | 400 | 400 | 400 |
| 3. | | | | | | | |
| 4. | | | | | | | |
| 5. | | | | | | | |
| 6. | | | | | | | |
| 7. CNIR - Crops Only | | | | 44.37 | 44.37 | 44.37 | 44.37 |
| 8. Correction Factor | | | 7.38 | | | | |
| 9. Total Acres | | | | 5,900 | 5,900 | 5,900 | 5,900 |
| 10. Composite Net Irrigation Requirements - inches | | | | 51.75 | 51.75 | 51.75 | 51.75 |
| 11. Water Application Efficiency - % - Projection | | | | 60 | 60 | 60 | 60 |
| 12. Composite Gross Irrigation Requirement - inches | | | | 86.25 | 86.25 | 86.25 | 86.25 |
| 13. Acre Feet pumped - Total | | | | 42,406 | 42,406 | 42,406 | 42,406 |
| Acre Feet Pumped - Electric | | | | 42,406 | 42,406 | 42,406 | 42,406 |

TABLE

**AVERAGE IRRIGATION REQUIREMENTS FOR CROPS GROWN IN THE AREA**

Method of Irrigation: SPRINKLER  Area: PAHRUMP  REA Designation: NEVADA 18, VALLEY

| IRRIGATED CROP | MRC | MPC | NIR | Number of Acres 1987 | 1992 | 1997 | 2002 |
|---|---|---|---|---|---|---|---|
| 1. ALFALFA | 60 | 4 | 56 | 1,350 | 1,100 | 900 | 725 |
| 2. PASTURE | 57 | 4 | 53 | 250 | 200 | 160 | 125 |
| 3. PISTACHIOS | 44 | 4 | 40 | 40 | 40 | 40 | 40 |
| 4. Sod | | | | | | | |
| 5. | | | | | | | |
| 6. | | | | | | | |
| 7. CNIR - Crops Only | | | | 55.15 | 55.07 | 54.98 | 54.86 |
| 8. Correction Factor | | | 8.00 | | | | |
| 9. Total Acres | | | | 1,640 | 1,340 | 1,100 | 890 |
| 10. Composite Net Irrigation Requirements - inches | | | | 63.15 | 63.07 | 62.98 | 62.86 |
| 11. Water Application Efficiency - % - Projection | | | | 45 | 45 | 45 | 45 |
| 12. Composite Gross Irrigation Requirement - inches | | | | 140.33 | 140.16 | 139.96 | 139.69 |
| 13. Acre Feet pumped - Total | | | | 19,178 | 15,651 | 12,830 | 10,360 |
| 14. Acre Feet Pumped - Electric | | | | 19,178 | 15,651 | 12,830 | 10,360 |

TABLE 6 -

PRESENT IRRIGATI DATA PROJECTIONS

…od of Irrigation: SPRINKLER Area: AMARGOSA VALLEY REA Designation: NEVADA 18, VALLEY

| YEAR | Number of Pumps | | | Plant Efficiency - % | | | GPM | Avg. Ac. /Pump | AF Pumped /Pump |
|---|---|---|---|---|---|---|---|---|---|
| | All Pumps | El. Pumps | % Elec. | PE | ME | OPE | | | |
| …esent 19 87 | 54 | 54 | 100 | 62 | 90 | 56 | 503 | 25.93 | 143.63 |
| …h 19 92 | 52 | 52 | 100 | 62 | 90 | 56 | 500 | 25.96 | 143.83 |
| …th 19 97 | 44 | 44 | 100 | 62 | 90 | 56 | 500 | 26.14 | 144.80 |
| …th ~~19~~XX 2002 | 39 | 39 | 100 | 62 | 90 | 56 | 500 | 25.64 | 142.05 |

| YEAR | Average HP | | | Total HP | Hours | kWh/HP | Annual kWh Requirements | |
|---|---|---|---|---|---|---|---|---|
| | Pump | CCPD | Total | | | | THP x kWh/HP | AF Method |
| …esent 19 87 | 38.9 | - | 38.90 | 2099 | 1551 | 1286 | 2,699,314 | 2,694,655 |
| …h 19 92 | 38.69 | - | 38.6[illegible] | 2012 | 1502 | 1295 | 2,605,540 | 2,598,420 |
| …th 19 97 | 38.69 | - | 38.69 | 1702 | 1573 | 1304 | 2,219,408 | 2,213,466 |
| …th ~~19~~XX 2002 | 38.69 | - | 38.69 | 1509 | 1543 | 1279 | 1,930,011 | 1,924,754 |

| YEAR | Average Pumping Lift - Feet | | | | | Power Unit Energy Source | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pumping Level | Friction Loss | Sprinkler | | Total Lift | Diesel | Natural Gas | LP Gas | Gasoline |
| | | | PSI | Lift | | | | | |
| …sent 19 87 | 165 | - | 10.82 | 25 | 190 | NONE | NONE | NONE | NONE |
| …5 19 92 | 165 | - | 10.82 | 25 | 190 | NONE | NONE | NONE | NONE |
| 10th 19 97 | 165 | - | 10.82 | 25 | 190 | NONE | NONE | NONE | NONE |
| 15th ~~19~~XX 2002 | 165 | - | 10.82 | 25 | 190 | NONE | NONE | NONE | NONE |

…ents:

PRESENT IRRIGAT[illegible] DA[illegible] D PROJECTIONS

[illegible]thod of Irrigation: SPRINKLER Area: FISH LAK[illegible] VALLEY REA Designation: NEVADA 18, VA[illegible]

| YEAR | Number of Pumps | | | Plant Efficiency - % | | | GPM | Avg. Ac. /Pump | AF Pumped /Pump |
|---|---|---|---|---|---|---|---|---|---|
| | All Pumps | El. Pumps | % Elec. | PE | ME | OPE | | | |
| Present 1987 | 86 | 86 | 100 | 62 | 90 | 56 | 977 | 68.6 | 493 |
| 5th 1992 | 86 | 86 | 100 | 62 | 90 | 56 | 980 | 68.6 | 493 |
| 10th 1997 | 86 | 86 | 100 | 62 | 90 | 56 | 980 | 68.6 | 493 |
| 15th 2002 | 86 | 86 | 100 | 62 | 90 | 56 | 980 | 68.6 | 493 |

| YEAR | Average HP | | | Total HP | Hours | kWh/HP | Annual kWh Requirements | |
|---|---|---|---|---|---|---|---|---|
| | Pump | COPD | Total | | | | THP x kWh/HP | AF Method |
| Present 1987 | 78.9 | - | 78.9 | 6781 | 2741 | 2272 | 15,406,432 | 15,353,394 |
| 5th 1992 | 79.0 | - | 79.0 | 6794 | 2733 | 2265 | 15,388,410 | 15,353,394 |
| 10th 1997 | 79.0 | - | 79.0 | 6794 | 2733 | 2265 | 15,388,410 | 15,353,394 |
| 15th 2002 | 79.0 | - | 79.0 | 6794 | 2733 | 2265 | 15,388,410 | 15,353,394 |

| YEAR | Average Pumping Lift - Feet | | | | | Power Unit Energy Source | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pumping Level | Friction Loss | Sprinkler | | Total Lift | Diesel | Natural Gas | LP Gas | Gasoline |
| | | | PSI | Lift | | | | | |
| Present 1987 | 135 | - | 27.27 | 63.0 | 198 | NONE | NONE | NONE | NONE |
| [illegible]h 1992 | 135 | - | 27.27 | 63.0 | 198 | NONE | NONE | NONE | NONE |
| [illegible]th 1997 | 135 | - | 27.27 | 63.0 | 198 | NONE | NONE | NONE | NONE |
| 15th 2002 | 135 | - | 27.27 | 63.0 | 198 | NONE | NONE | NONE | NONE |

[illegible]mments:

## PRESENT IRRIGAT[illegible] DA[illegible] D PROJECTIONS

[illegible]thod of Irrigation: SPRINKLER Area: PAHRUMP REA Designation: NEVADA 18, VALLE[illegible]

| YEAR | Number of Pumps | | | Plant Efficiency - % | | | GPM | Avg. Ac. /Pump | AF Pumped /Pump |
|---|---|---|---|---|---|---|---|---|---|
| | All Pumps | El. Pumps | % Elec. | PE | ME | OPE | | | |
| Present 19 87 | 87 | 87 | 100 | 62 | 90 | 56 | 436 | 18.85 | 220 |
| 5th 19 92 | 71 | 71 | 100 | 62 | 90 | 56 | 440 | 18.87 | 220 |
| 10th 19 97 | 58 | 58 | 100 | 62 | 90 | 56 | 440 | 18.97 | 221 |
| 15th 19x 2002 | 47 | 47 | 100 | 62 | 90 | 56 | 440 | 18.94 | 220 |

| YEAR | Average HP | | | Total HP | Hours | kWh/HP | Annual kWh Requirements | |
|---|---|---|---|---|---|---|---|---|
| | Pump | CCPD | Total | | | | THP x kWh/HP | AF Method |
| Present 19 87 | 33.4 | - | 33.4 | 2905 | 2721 | 2255 | 6,550,775 | 6,592,848 |
| 5th 19 92 | 33.7 | - | 33.7 | 2393 | 2721 | 2255 | 5,396,215 | 5,380,365 |
| 10th 19 97 | 33.7 | - | 33.7 | 1955 | 2731 | 2264 | 4,426,120 | 4,410,587 |
| 15th 19x 2002 | 33.7 | - | 33.7 | 1584 | 2721 | 2255 | 3,571,920 | 3,561,472 |

| YEAR | Average Pumping Lift - Feet | | | | | Power Unit Energy Source | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pumping Level | Friction Loss | Sprinkler PSI | Sprinkler Lift | Total Lift | Diesel | Natural Gas | LP Gas | Gasoline |
| Present 19 87 | 159 | - | 12.55 | 29 | 188 | NONE | NONE | NONE | NONE |
| [illegible]h 19 92 | 159 | - | 12.55 | 29 | 188 | NONE | NONE | NONE | NONE |
| [illegible]th 19 97 | 159 | - | 12.55 | 29 | 188 | NONE | NONE | NONE | NONE |
| 15th 19x 2002 | 159 | - | 12.55 | 29 | 188 | NONE | NONE | NONE | NONE |

[illegible]ments:

**Diversity Ir[illegible]ion Load**

[illegible]A Designat[illegible] NEVADA 18, VALLEY

**Date:** 2-12-88

| ITEM | Historical 1983 | 1984 | 1985 | 1986 | 1987 | Future 5th 1992 | 10th 1997 | 15th 2002 |
|---|---|---|---|---|---|---|---|---|
| **Irrigation Only** | | | | | | | | |
| 1. MWH - Sold | 4,344,898 | 4,881,808 | 4,804,806 | 4,100,592 | 4,516,499 | 23,390,165 | 23,033,938 | 20,890,341 |
| 2. Line Loss - % | 14.81 | 14.47 | 16.49 | 14.75 | 16.27 | 15.45 | 15.45 | 15.45 |
| 3. MWH Purchased | 6,086,996 | 5,707,714 | 5,753,570 | 4,810,079 | 5,394,123 | 27,664,299 | 26,060,246 | 24,707,677 |
| 4. Total HP | 13,023 | 12,971 | 12,891 | 11,724 | 11,785 | 11,199 | 10,451 | 9,887 |
| 5. KW Demand - Div. 1.00 | 10,794 | 10,752 | 10,685 | 9,718 | 9,769 | 9,283 | 8,663 | 8,195 |
| 6. Diversity | 1.24 | 1.30 | 1.29 | 1.37 | 1.25 | 1.25 | 1.25 | 1.25 |
| 7. KW Demand - Calculated | 8,693 | 8,242 | 8,268 | 7,095 | 7,815 | 7,426 | 6,930 | 6,556 |
| 8. Monthly Load Factor - % | .94 | .93 | .94 | .94 | .93 | 42.52 | 42.93 | 43.02 |
| 9. kWh/HP - Month | 333.63 | 376.36 | 372.73 | 349.76 | 383.24 | X | X | X |
| **System Less Irrigation** | | | | | | | | |
| 10. MWH - Sold | 5,730,337 | 6,591,544 | 6,013,125 | 5,962,032 | 6,390,071 | | | |
| 11. MWH - Purchased | 8,027,931 | 7,706,704 | 7,200,485 | 6,993,586 | 7,631,758 | | | |
| 12. kW Demand | 13,159 | 14,798 | 14,664 | 12,453 | 15,085 | | | |
| 13. Monthly Load Factor - % | .82 | .70 | .66 | .78 | .68 | | | |
| **Total System** | | | | | | | | |
| 14. MWH Purchased | 14,114,927 | 13,414,418 | 12,954,055 | 11,803,665 | 13,025,881 | | | |
| 1[illegible] kW Demand | 21,852 | 23,040 | 22,932 | 19,548 | 22,900 | | | |
| 1[illegible] Monthly Load Factor - % | .87 | .78 | .76 | .84 | .76 | | | |
| 17. Month of Demand | AUGUST | JULY | JULY | JUNE | AUGUST | | | |

**Comments:**

# Interview Worksheet

Control No.
IW-

| Interviewee/Tele. No. | Company/Agency | Organization | Building/Room No. |
|---|---|---|---|
| Container I.D. : | Drawer/Shelf No.: ________ All See below | | Volume: |

Use and Purpose of the Documents

Value of the order or sequence (including index information)

Procedure governing activity ______________________

Applicable Requirements (if Any) ______________________

Are Documents Controlled (Describe, if Yes) ______________________

Retrieval requests or activity ____ /Day ____ /Week ____ /Month ____ /Year

Document Value

________ Permanent ________ Temporary ________ Non–Records

Retention Requirements ______________________

Transfer Instructions ______________________

☐ check if continued

| Analyst Name | Date | Organization/Dept. |
|---|---|---|
| | | |

# Record Series Inventory Worksheet

Control No.
IW-

| Point of Contact/Tele. No. | Company/Agency | Organization | Building/Room No. |
| --- | --- | --- | --- |
| Container I.D.: | Drawer/Shelf No.: ________ All See below | | Volume: |

**Container Type:**

- ____ Lateral
- ____ Vertical
- ____ Bookcase
- ____ Desk
- ____ Shelf
- ____ Pile
- ____ Box
- ____ Safe
- ____ Other (Describe) ____________________

Fire Resistent (Circle one) Yes No

____ # of Drawers/Shelves

**Paper Format:**

Size Legal Letter

Nonstandard ________

- ____ 3 ring binder
- ____ Computer Printouts
- ____ Spiral bound
- ____ Ledger
- ____ Cardex
- ____ Hanging file folders
- ____ Loose paper
- ____ Charts
- ____ Drawings
- ____ Maps
- ____ Photographs/film
- ____ Other (describe below)

**Media:**

- ____ Optical
- ____ Micrograph ____ Microfiche ____ Aperture cards
- ____ Magnetic ____ Floppy ____ 3.5 in. ____ 5.25 in. ____ 8 in.
- ____ 9-track (reel to reel)
- ____ Other (Describe below):

**Location Status** (check one minimum in each column):

- ____ Work station ____ Active
- ____ File Station ____ Inactive

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- ☐ Alphanumeric ☐ Chronological ☐ Subject ☐ None

**Program /Subprogram:**

**Epidemiological Impact:** ☐ Yes ☐ No ☐ Potential

**Restrictions on access or use (Describe, if yes):** ☐ No ☐ Yes ________

**Describe Documents**

☐ check if continued

| Analyst Name | Date | Organization/Dept. |
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| | | |

SLTR87-XXXX
July 1987

# WATER REQUIREMENTS

by

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**ABSTRACT**

Water requirements during the construction, emplacement, caretaker, and decommissioning phases for the proposed nuclear waste repository at Yucca Mountain, Nevada are identified and estimated. The estimates are based on information from available literature, information generated in previous project reports, and other relevant data based on the current state of repository design. Both surface and underground requirements are addressed. These estimates include average and peak demands for personnel consumption, ventilation, process water, and construction requirements. Water for fire protection requirements is considered as a separate reserve quantity and estimates are provided for each phase. The potential source of water to supply the proposed repository is identified.

Enclosure 4
8.3.1.9.2.2

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(continued)

# EXECUTIVE SUMMARY

This study identifies the quantity of water required during all phases of the repository: construction, emplacement, caretaker, and decommissioning. The one-stage, no consolidation option of waste handling facilities and vertical emplacement configuration are used as a basis.

Bases for estimating water requirements are compiled from available literature, information generated in previous project reports, or other relevant data. Estimates of water requirements are made based on the latest design information and assumptions derived from a review of the water requirements bases. Estimates of peak and average demands are tabulated for each phase and include water for personnel consumption, ventilation, process water, and construction requirements. The estimates are dominated by water required for subsurface ventilation mining, and dust control. The requirement for ventilation is considered very conservative since it is based on a worst case scenario. Water for fire protection requirements is considered as a separate reserve quantity and estimates are provided for each phase.

The Amargosa-Desert ground-water basin is identified as the source for repository water supply. Aquifers in this basin yield sufficient quantity and acceptable quality of water to supply the repository. The average water requirement over the life of the repository is 95 million gallons (292 acre-feet) per year and is less than 4 percent of the current consumption from the basin. The effect of this additional demand on the Amargosa-Desert basin is therefore expected to be negligible.

## 1.0 INTRODUCTION

The objective of this study is to identify the quantity of water required during all phases of the Nevada Nuclear Waste Storage Investigation repository construction and operations. The one-stage, no consolidation option waste handling facilities and vertical emplacement configuration are used as a basis for estimating water requirements for surface and underground facilities and are described.

Bases for estimating water requirements are compiled from available literature, information generated in previous project reports, or other relevant project documents. These include bases for personnel consumption, ventilation process water, construction requirements, and water for fire protection. Estimates are provided for each phase of the repository and tabulated for the construction, emplacement, caretaker, and decommissioning phases. The estimates are developed from the latest design information compiled in the bases and assumptions derived from a review of this information.

The potential source of water to satisfy the repository requirements is identified and the impact of repository usage on this supply is addressed.

## 2.0 SITE DESCRIPTION

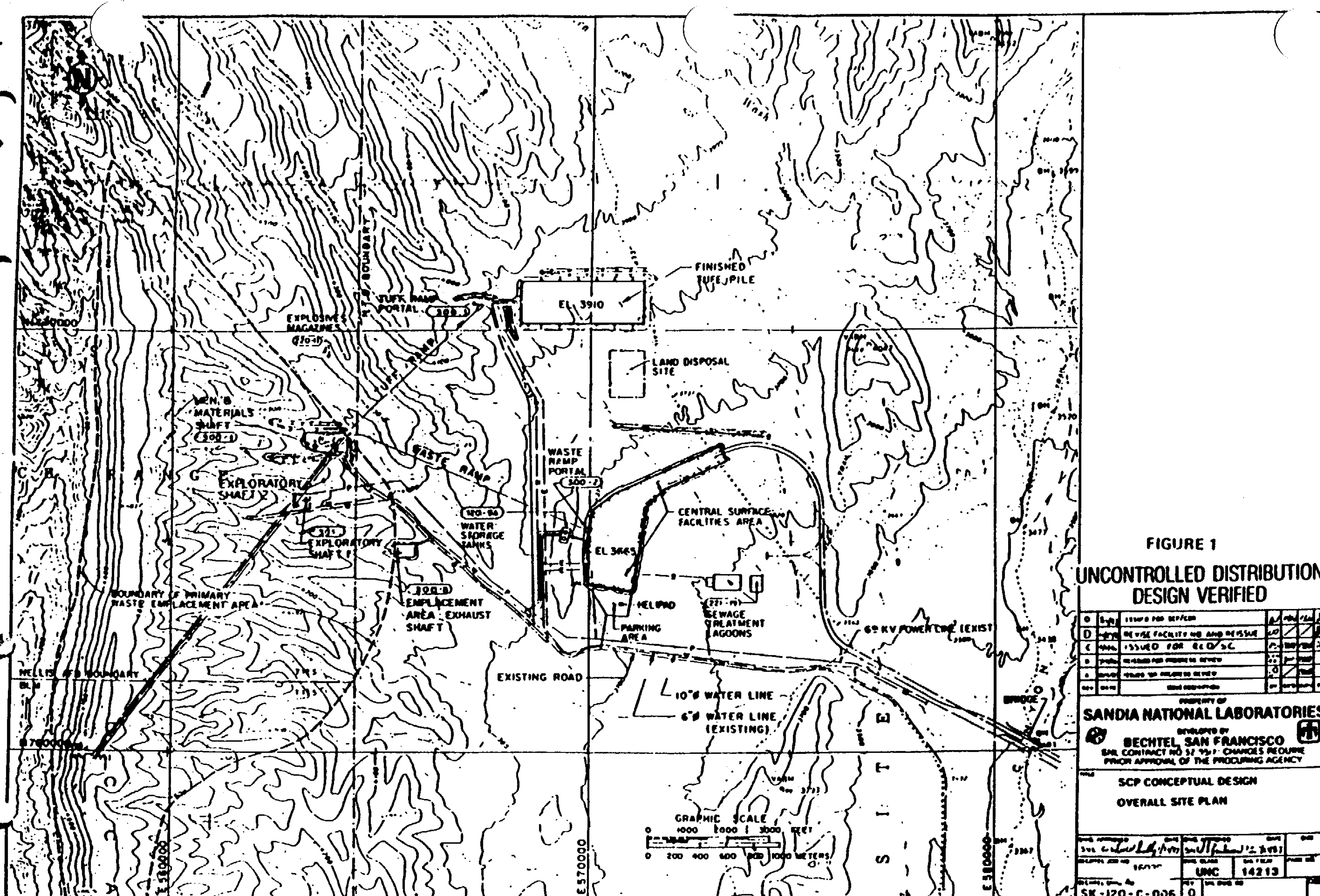
The reference repository configuration used in this study includes a single-stage waste handling building with no fuel consolidation at the repository and vertical emplacement of waste containers underground. The design concepts for this reference configuration are summarized in this section.

### 2.1 Site Location

The prospective repository site at Yucca Mountain is located on and immediately adjacent to the southwestern portion of the Nevada Test Site (NTS), which is in Nye County, Nevada. The site is about 85 miles (137 km) by air and 100 miles (161 km) by road from Las Vegas. The proposed repository is located on federal lands under the separate control of the DOE, the U.S. Air Force, and the Bureau of Land Management.

Proposed highway access to the repository site originates at U.S. Highway 95 approximately 0.5 mile (0.8 km) west of the city of Amargosa Valley and extends about 16 miles (26 km) northward to the site. A new railroad originates at Dike Siding about 11 miles (18 km) northeast of Las Vegas and extends about 98 miles (158 km) to the site. A helipad located near the parking area south of the surface facilities provides a means of rapid access and facilitates emergency medical service for the repository.

The repository surface and underground facilities are linked by a combination of shafts and ramps (Figure 1). The central surface facilities are located on gently sloping terrain at the eastern base of Yucca Mountain. The underground facilities are located below the ridgeline of the mountain. A ramp is provided for transporting waste from the central surface facilities to the underground emplacement area. Another ramp is provided for conveying

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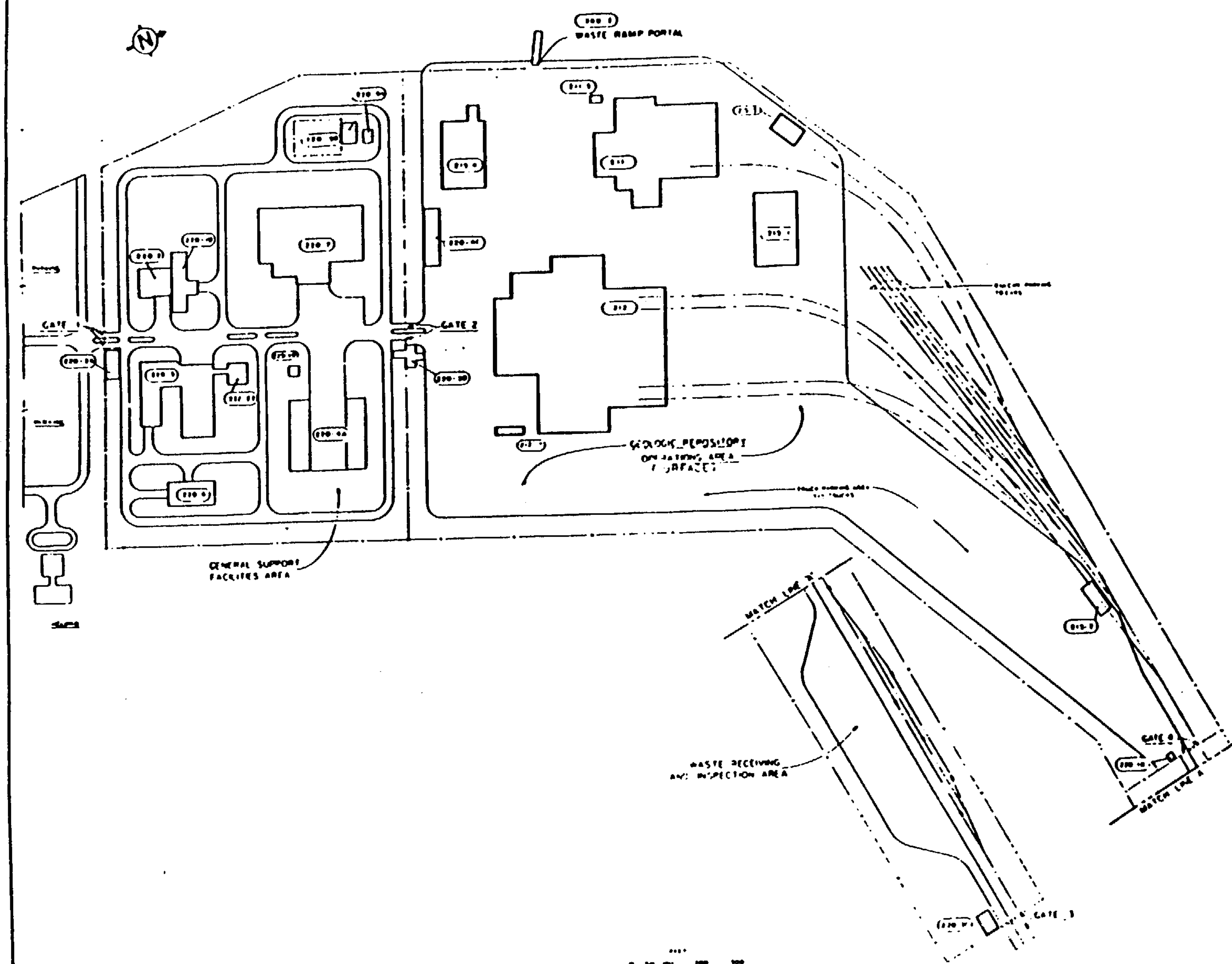
mined tuff to the surface. Four vertical shafts are located near the northeast boundary of the underground facilities for underground ventilation and access for personnel, materials, and equipment.

### 2.1.1 Surface Facilities Description

Facilities on the surface are located on the eastern slopes of Yucca Mountain, and include the central surface facilities area shown in Figure 2, men and materials shaft area, exploratory shaft area, emplacement exhaust shaft area, tuff ramp portal, and tuff pile.

The central surface facilities area is divided by security fencing into three distinct functional areas: the waste receiving and inspection area, the geologic repository operations area, and the general support facilities area. Incoming railroad and highway shipments of radioactive waste will enter the waste receiving and inspection area through the north access gate (gate 3); this area provides necessary railcar siding and truck parking. The geologic repository operations area includes all facilities in which radioactive materials are handled or stored. These facilities include the waste handling building, decontamination building, vehicle wash facility, performance confirmation building, waste operations area garage, health physics station, and waste treatment building. Parking is provided in this area for interim storage of waste shipments. Support buildings located in the general support facilities area include the security stations, administration building, food service facility, computer building, medical center, fire station, mockup building, shops, central warehouse, main substation and standby generator building, and motor pool and service station.




SURFACE FACILITIES

FIGURE 2

UNCONTROLLED DISTRIBUTION
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BECHTEL SAN FRANCISCO

SCP CONCEPTUAL DESIGN
CENTRAL SURFACE FACILITIES
PLOT PLAN

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Waste Handling Building. The major activities performed in the waste handling building (Figure 3) involve waste unloading, preparation, packaging, and interim storage. The building is designed to receive and process up to 3,000 metric tons of uranium (MTU) as spent fuel and 400 MTU of vitrified high level waste (HLW) annually. All spent fuel and HLW are processed through the waste handling building.

Receiving and shipping bays with airlocks are provided for vehicle entrance and exit and to unload casks from transport vehicles. A cask preparation area is provided adjacent to the receiving and shipping bays. Here, the cask inner lid surfaces are surveyed, inner cavity gases are sampled, and cask seal adapter installed (for mating to the hot cell).

Separate unloading hot cells are provided for spent fuel and vitrified HLW. Equipment is provided in each cask unloading hot cell to package the received waste in containers and to decontaminate the containers. Four below-grade transfer cars are provided to move filled waste containers either to a surface storage vault (for interim holdup) or to the waste transporter vehicle for transport to the underground facility for emplacement.

Empty casks are returned to the cask preparation area where attachments to flush the cask interior and two cask decontamination stations are provided to decontaminate the exterior of the casks, if necessary. Cask decontamination support equipment, including a 5,000-gallon flush water tank, flush water pump, and filter system, is located in an adjacent area of the WHB.

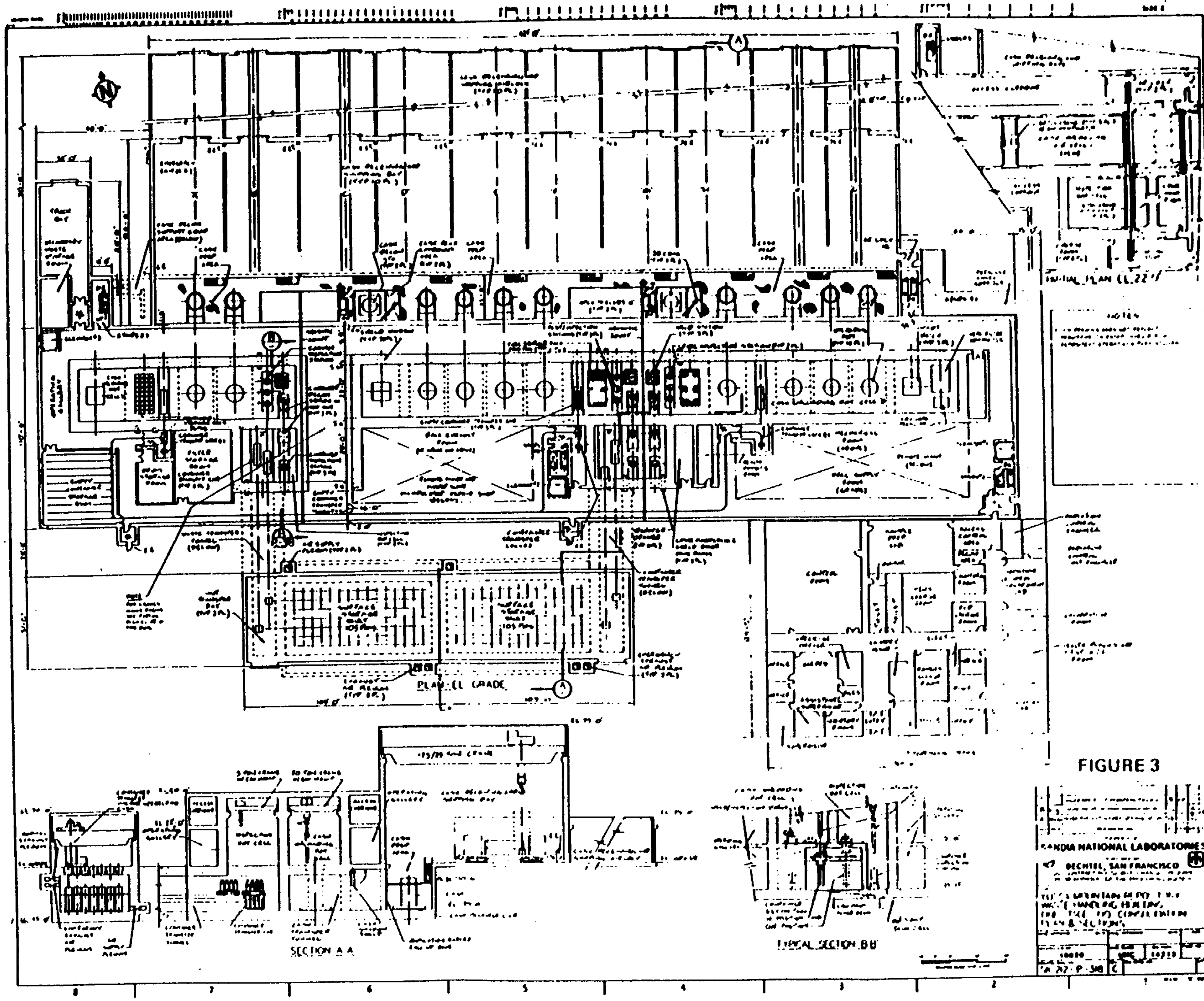


FIGURE 3

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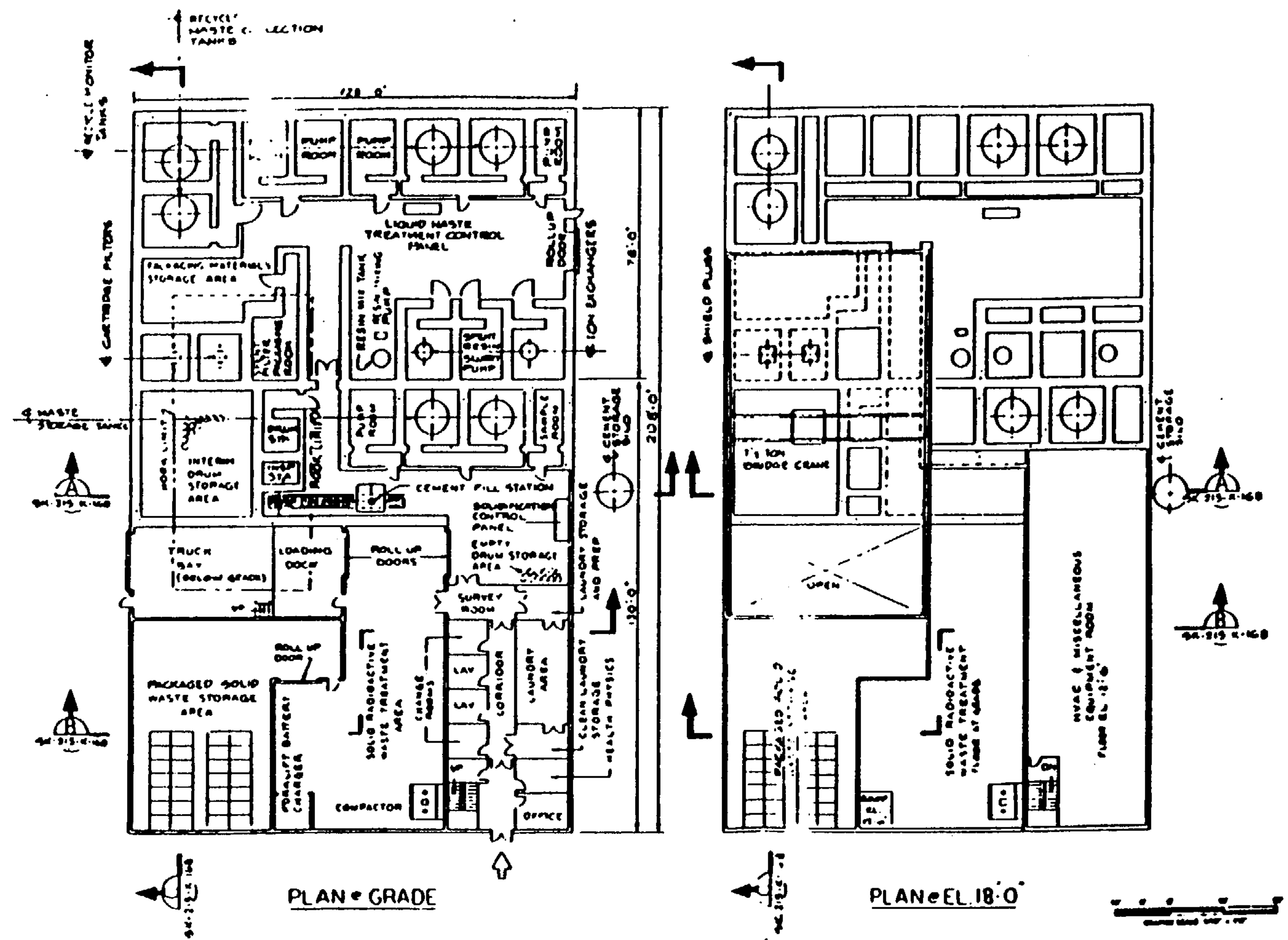
0 0 3 5 8 2 2 5 5

A personnel annex is located on the southeastern side of the waste handling building. The annex includes a control room, mechanical and electrical room, offices, laboratories, health physics, first aid, change rooms, and laundry.

<u>Decontamination Building</u>. The decontamination building provides the capability to receive, disassemble, decontaminate, and return to service any contaminated components or larger equipment, including casks and transport vehicles, in the unlikely event that they become contaminated. The building includes a bay for vehicle and cask decontaminations; a room to disassemble, decontaminate, and reassemble tools and other small components; an office area with health physics station; and a mechanical equipment room. Contact operation and contact maintenance are used because neither spent fuel nor HLW are unloaded from casks in this building. Decontamination equipment includes ultrasonic baths, electropolishers, chemical baths, and spray booths.

<u>Performance Confirmation Building</u>. Containers of spent fuel and HLW will be removed from the emplacement area as part of the repository performance confirmation program. Retrieved waste containers will be received, sampled, tested, and repackaged in the performance confirmation building for return and emplacement underground. The building is located in the geologic repository operations area near the portal of the waste handling ramp. Containers are handled in a reinforced-concrete, shielded hot cell equipped with remote handling equipment.

<u>Waste Treatment Building</u>. The waste treatment building (Figure 4) receives site generated radioactive wastes (both liquids and solids) and processes these wastes in preparation for disposal. The building includes areas for truck loading and unloading, offices, health physics, and treatment of wastes. Waste treatment includes processes for segregation of solid wastes into compactible and noncompactible waste, compaction of the relevant




NOTES

REFERENCE DRAWINGS

SK-215-K-168 WASTE TREATMENT BUILDING GENERAL ARRANGEMENT - SECTIONS

SK-215-K-165 LIQUID RADIOACTIVE WASTE PROCESS FLOW DIAGRAM

SK-215-K-166 SOLID RADIOACTIVE WASTE PROCESS FLOW DIAGRAM

FIGURE 4

UNCONTROLLED DISTRIBUTION
DESIGN VERIFIED

| | | |
|---|---|---|
| B | | ISSUED FOR REVIEW |
| A | | ISSUED FOR PROGRESS REVIEW |

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WASTE TREATMENT BUILDING
GENERAL ARRANGEMENT
PLAN

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waste, and packaging of the wastes for disposal. Liquid wastes are either processed to allow recycling to the repository facilities for reuse or solidified with cement in 55-gallon drums.

Laundry equipment, offices, and health physics spaces are included in the office and laundry area. The HVAC and miscellaneous equipment room provides space for the ventilation systems, compressed air system, electrical distribution panels, and related equipment.

Other Support Facilities. As indicated in Figure 2, security stations are provided at the south entrance to the geologic repository operations area (gate 2), at the personnel entrance to the repository (gate 1), and at gate 3 entering the receiving and inspection area. Also, a small building houses the health physics station located at the north entrance to the geologic repository operations area (gate 4).

A vehicle wash facility washes incoming waste shipments to remove snow and road dirt from the shipping cask and transport vehicle and from waste carriers after removal of the shipping cask. It is located just inside gate 4. The drive-through structure accommodates both trucks and railcars. Automatic washing equipment, similar to a carwash, is housed inside this facility.

The administration building is a two-story structure with office space and a training auditorium with seating for approximately 50 people. Laboratories and training rooms are also provided, with additional space for data analysis. The food service facility, adjoining the administration building to the south, includes kitchen, storage, serving, and dining facilities.

The computer center, connected to the administration building by an enclosed corridor to the north, houses computer hardware, tape storage, terminals, and offices.

The fire and medical facilities are located east of the administration building. The fire station includes firemen's quarters, locker and shower facilities, laundry room, and a lunch room. Space is also provided for a communications room, offices, and equipment storage. A high-bay area houses the fire fighting apparatus. Adjacent to the fire station is the medical building, which houses examination rooms, offices, a laundry room, and a waiting area. An enclosed garage with space for two ambulances is attached to this building.

The tuff pile and tuff-handling equipment are located 1 mile north of the central surface facilities complex near the tuff ramp portal. During the construction and waste emplacement phases, approximately 15 million tons of tuff will be excavated from the underground and piled on the surface, assuming that the vertical emplacement configuration is used and that the underground facility is not backfilled before closure. The tuff pile will be developed eastward to a maximum size of 3,000 by 1,000 by 120 ft.

For other repository support facilities not discussed here see Reference 1.

### 2.1.2 Shafts, Ramps, and Underground Facilities Description

Access to the underground portion of the repository consists of two ramps and four shafts. The waste ramp provides access for the waste transporter to the underground facilities, and is 6,548 feet long with an overall grade of 8.9 percent. During construction and waste emplacement operations, approximately 15 million tons of tuff rock will be excavated and piled on the surface. The design provides a ramp directly from the underground facility to transport the excavated tuff to the surface; the tuff ramp can also be used for returning backfill. The exploratory shaft, the men-and-materials shaft, the emplacement area exhaust shaft, and their related facilities are located 1 to 1.5 miles west of the central surface facilities area in the rugged terrain of Yucca Mountain. Access to these shafts is from the road located in Drill Hole Wash.

The exploratory shafts (ES-1 and ES-2) are located on a level embankment and are large enough to support underground investigations during the site characterization phase. During emplacement operations, the ES-1 is used for the emplacement area ventilation intake, and ES-2 is used as an air intake for the underground shops, offices, and decontamination area. The men-and-materials shaft provides access for personnel and materials, and serves as a ventilation intake for the underground development area. The development ventilation building and underground workers' change house are located near the men and materials shaft. The emplacement area exhaust shaft is used to exhaust air from the waste emplacement area.

The underground facilities are segregated into two main areas: the waste emplacement area where waste handling operations take place, and the development area where additional excavations are mined. This layout is shown in Figure 5. Three parallel main entry drifts extend southwest through the underground facility to provide access to the emplacement panels. The slopes of all drifts are less than 10 percent. A rock pillar separates the main drifts from the emplacement panels.

The repository accommodates a total of 62,000 MTU of spent fuel and 8,000 MTU of HLW. Approximately 30,000 containers of spent fuel and 15,000 containers of HLW will be emplaced underground.

The underground repository layout is divided into panel segments of equal widths and various lengths that conform to the boundary of the underground facility. The emplacement panels are 1,400 feet long. The emplacement boreholes for spent fuel and HLW are commingled within emplacement drifts, and an areal power density not to exceed 57 kW/acre determines the spacing between emplacement drifts.

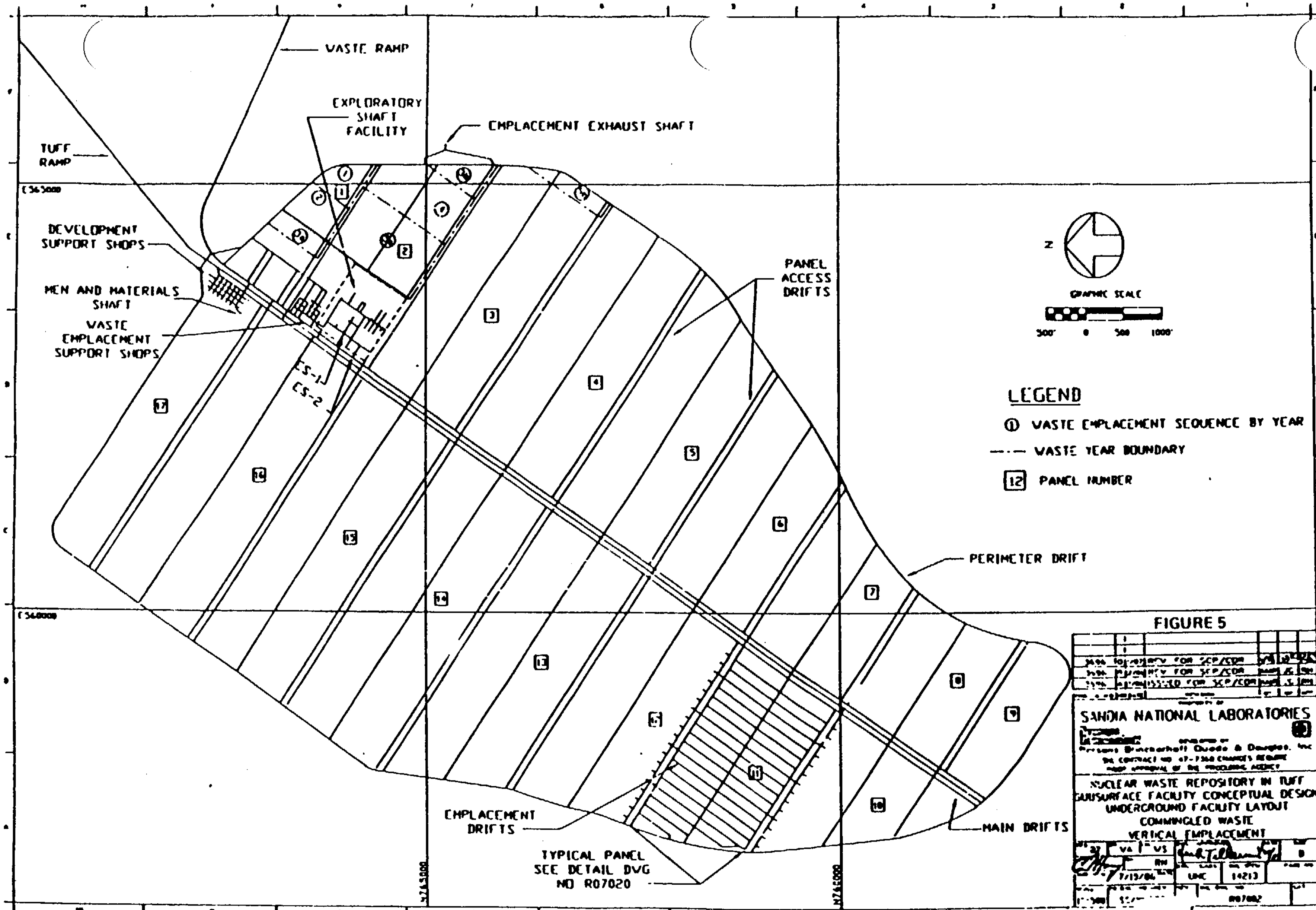

FIGURE 5

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Maintenance and repair shops are located in the development and emplacement areas near the base of the waste ramp. Underground service facilities are fully equipped so that all preventive maintenance and most repair functions can be performed in the underground excavations. Decontamination facilities are provided in this area for off-normal situations where equipment may become contaminated with radioactivity.

## 2.2 Potential Water Sources

The Environmental Assessment (EA) Report for the Yucca Mountain site (Reference 2) indicates that the tuffaceous aquifers underlying Yucca Mountain are part of the Alkali Flat-Furnace Creek Ranch ground-water basin. In general, water in these aquifers meets United States Environmental Protection Agency (EPA) secondary standards in major cations and anions and the primary standards for deleterious constituents. This water is acceptable for all purposes; domestic, stock, municipal supply, irrigation, or industrial use.

In 1979 the Nevada State engineer designated a large part of the Alkali Flat-Furnace Creek Ranch basin and a small part of the Ash Meadows basin to the east as the Amargosa Desert ground-water basin. The total sustained yield of aquifers in the Amargosa Desert basin has been estimated to be about 26,800 acre-feet per year. Current principal use, agricultural and domestic consumption, is 9,253 acre-feet per year. The main source of recharge is probably Pahute Mesa to the north and northwest of Yucca Mountain.

The regional effects of withdrawing ground water for a repository at Yucca Mountain are expected to be negligible. The water level in well J-13 on the Nevada Test Site has remained essentially constant after long periods of pumping between 1962 and 1980 (Reference 3). Withdrawal rates from well J-13 during pumping tests ranged from 300 to 700 gpm (18.9 to 44.0 liters per second) as reported in Reference 3. The large volume of water produced from this well along with the minor drawdown during pumping tests (Reference 4) suggests that the aquifers underlying Yucca Mountain can produce an abundant quantity of ground water for long periods of time without lowering the regional ground-water table. Preliminary water requirements for the repository reported in the EA estimate usage at 350 acre feet per year, an increase of less than 4 percent over current consumption.

## 3.0 BASES FOR DESIGN

The bases for water requirements have been determined from a review of existing NNWSI project information and findings of a literature search focused on water use and water requirements for public, commercial, industrial, mining, and construction water consumption.

### 3.1 Surface Facilities

To develop water requirements for surface facilities, bases are required for personnel consumption, ventilation, process water, surface dust control, construction requirements, and fire protection.

#### 3.1.1 Personnel Consumption

Water consumed by personnel at the proposed nuclear waste repository at Yucca Mountain, Nevada, includes drinking water and water for washing, showers, laundry, meals, and sewerage wastes.

For surface facilities operating personnel during emplacement, caretaker, and decommissioning phases, the working environment is similar to that in a commercial or office facility and personnel water consumption is also expected to be similar. Commercial water supply systems are estimated for capacities of 28 gallons per day (gpd) per person (Reference 5) and will be used as the basis for surface operating personnel during emplacement, caretaker, and decommissioning phases. Additionally, water used at the food service facility for surface personnel will be calculated at 3 gallons per meal served (Reference 6).

Operating personnel dedicated to development of underground facilities and emplacement of waste containers underground will most likely require showers at their end of shift, and thus, more water than their counterpart surface personnel. This requirement will result in a per capita daily demand of 50 gallons per day per person (Reference 7). This demand will also be used as a basis for construction personnel requirements for underground excavation activities.

For surface construction personnel, consumption of water is expected to be less than for operating personnel since permanent toilet and wash basin facilities will not be available during the construction period. The lack of facilities requires drinking and wash water to be provided on a daily batch type basis distributed from a central water outlet to the various work areas around the construction site. This batch type operation results in a relative constant volume of water being withdrawn each day, but also results in waste of any water not consumed. Historically for site construction forces, each person is assumed to consume 3 gallons per day for drinking and wash water (Reference 8). It is assumed that service of portable toilets including collection and disposal of sanitary wastes and recharge of chemical additives will be done by offsite vendors. No additional water requirements are provided for these sanitary portable toilets for construction personnel.

Laundry water requirements include water for laundry at the WHB, WTB, change house, fire station, and medical center. Laundry is assumed to be washed in 8-pound loads requiring 50 gallons per load (Reference 7). It is further assumed that each person requiring laundry use will generate 1 pound of soiled laundry each day resulting in a water requirement of 6.25 gallons for each person requiring laundry use.

### 3.1.2 Ventilation

For cooling ventilated air at surface facilities, two methods are employed: evaporative cooling and chilled water systems. For evaporative cooling systems, the initial water quantity to charge the system is small and negligible. Make up water for these systems is considered for evaporation and blow-down losses. Operational losses such as carryover and overflow are not considered. Design parameters, based on sea level conditions, assume outside air temperature at 102°F dry bulb/67°F wet bulb at 42 grains. An 80 percent saturation efficiency is assumed resulting in the evaporator leaving air temperature of 74°F dry bulb/67°F wet bulb at 88 grains. Evaporation and blow-down make up water is calculated at $7.91\text{x}10^{-5}$ gallons per minute (gpm) per cubic foot per minute (cfm) air flow. An air flow rate of 3 cfm/SF is assumed within the structures serviced by evaporative cooling.

Water required to fill the chilled water system for surface facilities is based on historical information from previous projects which indicates that approximately 0.127 gallons/SF of floor area is required.

### 3.1.3 Process Water

Process water for surface facilities includes water for the vehicle wash facility, decontamination and waste treatment, cleaning, and concrete during the emplacement, caretaker, and decommissioning phases of the project. Additionally, process water for the construction phase will include water for concrete, soil compaction, and dust control. Dust control water is also required during the decommissioning phase.

The vehicle wash facility washes incoming waste shipments to remove snow and road dirt from the shipping cask exterior and transport vehicle (railcar or truck trailer). A HEDL report (Reference 9) advocates use of a "total recovery" water reclamation system for the vehicle wash facility and estimates an upper limit of 200 gallons per transporter wash. This compares with the 330 gallons per car average value from Reference 4 for commercial car washes. Not all incoming shipments are expected to be washed and safety considerations would only require the capture of wash water radioactively contaminated. Therefore, assuming a "total recovery" water reclamation system may not be conservative for estimating water requirements. For these reasons a basis for vehicle wash facility water requirements is chosen as 330 gallons per transporter washed.

Process water used for decontamination and waste treatment has been evaluated extensively under the "Site Generated Waste Treatment and Disposal Study," (Reference 10). Total liquid radioactive waste is considered as the process make-up water requirement for the facility, neglecting any chemicals or additives that may be included in this estimate. This quantity includes water for decontamination, laboratory drains, spent resin slurrys, contaminated vehicle wash water and contaminated laundry wash water and is estimated at 51,800 gallons/year or approximately 210 gallons per day based on 250 working days per year.

Cleaning water for washing floors, windows, and other housekeeping chores, has been estimated based on office requirements (Reference 11). For general maintenance of 600,000 SF of office space, 355 gallons are required on a daily basis. When several maintenance activities occur simultaneously, a peak demand of 3,770 gpd to maintain 600,000 SF is required. This peak demand is expected to occur only twice each year.

During the construction phase, water is required for concrete, soil compaction, and dust control. Thirty-three gallons of batch water are normally required per cubic yard (cy) of typical structural concrete with 1-1/2 inch maximum aggregate size, 0.4 water/cement ratio, and 3 to 4 inch slump (Reference 12). This requirement will also be necessary during the emplacement phase for casting the precast borehole plugs. Soils compaction water is calculated assuming that all backfill will be compacted to 95 percent of the maximum dry density at the optimum moisture content of the soil. Index properties of the soils from Reference 13 were used to determine that 24 gallons of water per cubic yard of soil backfill are required. Water for dust control is normally required on construction projects to reduce nuisance airborne dust caused by vehicular traffic on the site. Historically this quantity is quite large, 600 gallons per day per acre (Reference 14). For the Tuff site 49,200 gallons per day over the 82 acre central surface facilities site is required.

Water for compaction and dust control at the tuff pile is included in the quantity for underground mining and dust control. The water for underground mining and dust control reported in Section 3.2.2 will sufficiently wet the mined tuff so that no additional water will be required at the surface.

### 3.1.4 Fire Protection Water

Department of Energy (DOE) Order 6430.1 (Reference 15) outlines general design criteria for fire protection and specifies that water supply requirements are to be determined in accordance with National Fire Protection Association (NFPA) Standard 13 (Reference 16). A minimum four-hour reserve for fire flow is to be provided. Additionally, NFPA Standard 14 (Reference 17) and NFPA Standard 231C (Reference 18) are used to insure that the most stringent applicable methods for fire protection water requirements are met and include both interior hose streams and sprinklers, plus outside hose streams.

Water for fire protection is required during off-normal situations only. Reserve capacities for fire protection water will be identified but are not included in the estimate for daily demand.

## 3.2 Underground Facilities

Water requirements bases for underground facilities are for ventilation, process water and dust control, and fire protection.

Personnel consumption for operating personnel dedicated to development of underground facilities and emplacement of waste containers underground has been discussed in Section 3.1.1.

### 3.2.1 Ventilation

Ventilation will be provided to the emplacement drift only until the emplacement process for that drift is completed. Ventilation will be re-established for periodic inspection, maintenance, performance confirmation purposes, or retrieval, until closure of the repository. Continuous ventilation of the ramp, access drifts, and service areas is planned until repository closure. Ventilation ductwork is provided throughout the underground repository to facilitate cooling the required emplacement drift(s) as necessary. Dampers and valves are provided to direct the ventilation supply only to areas where required. For design purposes, rock temperatures have been determined to be 120°F around the panel access drifts and 243°F around the emplacement drifts. The air is cooled by circulation through a heat exchanger that uses a chilled water spray. Underground ventilation, determined by PBQ&D (Reference 19), is designed to supply water-saturated air at 50°F to the emplacement drift(s) being cooled. Make up water required for evaporation and leakage losses is estimated an average to be 170 gpm. To fill this system 2.8 million gallons are required. These quantities are based on maximum airflow demands when the emplacement area is nearly fully developed and emplacement and inspection or maintenance are occurring simultaneously.

### 3.2.2 Process Water and Dust Control

Service water for underground mining activities are estimated at 270,000 gallons per day (Reference 19). Included in this total is water for rock drilling service to drill jumbos, roof bolters, reamer drills and pilot hole drills, plus water to service the tunnel boring machine and water for dust control at conveyor transfer points along the mined tuff disposal conveyors.

Additional water is required for underground grouting, concrete, and shotcrete operations, and mixing water for mortar, used for construction of concrete masonry unit (CMU) ventilation bulkheads. Grout water is required at 2 gallons per 60 pounds of grout (Reference 20). Water for concrete and shotcrete underground is required at 40 gallons per cubic yard (Reference 33). For shotcrete this is equivalent to 5 gallons per 100 pounds of shotcrete cement (Reference 21). Mixing for masonry mortar is assumed to be 10 gallons per 100 pounds of mortar cement.

### 3.2.3 Fire Protection Water

Combustible fuels, lubricants, and solvents are the main contributors to fires underground. Automatic systems of fire suppression are proposed at underground fueling areas and for mobile underground mining equipment. These systems, as described in Reference 22, use halon, dry chemicals and aqueous forming foams to suppress these fires.

No special storage and supply of water for fire protection is currently proposed for the underground facilities (Reference 23). The mine service water discussed in Section 3.2.2 is to be used as the fire protection supply. This supply is capable of yielding 2 hose streams at 80 psi nominal pressure. A deluge sprinkler system will be employed for fire protection at locations of conveyor drives within the underground development area and tuff ramp. The system will consist of 2 deluge valves, rated at 150 gpm each, at each conveyor drive. A preset control system will automatically shut off the fire protection deluge after a 20-minute flush period. The total quantity of water required for this system under a worse case scenario is 6,000 gallons and is assumed for all phases of repository construction and operation.

Water for fire protection of underground facilities is not investigated further in this study.

# 4.0 WATER REQUIREMENTS

## 4.1 Construction Phase

Construction of the proposed reference configuration repository at Yucca Mountain, Nevada, is expected to span a period of over 4-1/4 years. The schedule for the one-stage, no consolidation configuration shows construction beginning the last quarter of 1993 and completing on December 1, 1997, prior to the first emplacement of radioactive waste (Reference 24). These dates do not reflect the recent revision to the Department of Energy Mission Plan, proposing a 5-year delay in the opening date of the first repository.

Table 1 shows the water requirements for the construction phase of the repository. Included in this estimate are water for both surface and underground personnel consumption, water for both surface and underground dust control, water for mining operations, water for concrete, shotcrete, grout, masonry mortar, and compaction of backfill, and laundry water requirements for subsurface mining workers. During the construction phase, average requirements are estimated at 371,807 gpd and peak demand at 791,297 gpd.

Water for fire protection of surface facilities is not included in Table 1. This requirement is a separate reserve quantity stored onsite but not included in estimates of daily demand. Water required for fire protection of underground facilities is discussed in Section 3.2.3.

### 4.1.1 Personnel Consumption

The bases discussed in Section 3.1.1 are used along with staffing estimates to determine the water requirements for personnel consumption. No estimate of construction staffing is available for the one-stage, no consolidation repository configuration.

Table 1

Water Requirements

Constructions Phase

| ITEM | BASIS | POPULATION/QUANTITY AVERAGE | POPULATION/QUANTITY MAXIMUM | WATER REQUIREMENTS AVERAGE | WATER REQUIREMENTS PEAK |
|---|---|---|---|---|---|
| Personnel Consumption | | | | | |
| Surface | 3 gpd/person | 1,116 people (1) | 1,799 people (2) | 3,348 gpd | 5,397 gpd |
| Underground | 50 gpd/person | 203 people (3) | 272 people (4) | 10,150 gpd | 13,600 gpd |
| Laundry | 6.25 gpd/person | 203 people (3) | 272 people (4) | 1,269 gpd | 1,700 gpd |
| Process | | | | | |
| Concrete | 33 gal/cy | 106 cy/day (5) | 4,093 cy/day (6) | 3,498 gpd | 135,069 gpd |
| Soil Compaction | 24 gal/cy | 1,424 cy/day (7) | 13,146 cy/day (8) | 34,176 gpd | 315,504 gpd |
| Dust Control | 600 gpd/acre | 82 acres | 82 acres | 49,200 gpd | 49,200 gpd |
| Underground Mining & Dust Control | | | | 270,000 gpd (9) | 270,000 gpd (9) |
| Grout | 2 gal/60 lb grout | 22,600 lb/5 days (10) | 22,600 lb/day (11) | 151 gpd | 753 gpd |
| Shotcrete | 5 gal/100 lb shotcrete | 580 lb/5 days (10) | 580 lb/day (11) | 6 gpd | 29 gpd |
| Masonry Mortar | 10 gal/100 lb | 450 lb/5 days (10) | 450 lb/day(11) | 9 gpd | 45 gpd |
| TOTAL | | | | 371,807 gpd | 791,297 gpd |

1. From Reference 25, Table 5-1, Average of Subtotal Surface Repository Workers from 1993 through 1998 (772) + Average of Subsurface Support Services (158) + 20% contingency = 1,116 people.
2. From Reference 25, Table 5-1, Subtotal Surface Repository Workers from year 1996 (1,320) + Subsurface Support Services from year 1996 (179) + 20% contingency = 1,779 people.
3. From Reference 25, Table 5-1, Average of Subtotal Subsurface Repository Workers from 1993 through 1998 (327) - Average of Subsurface Support Services (158) + 20% contingency = 203 people.
4. From Reference 25, Table 5-1, Subtotal Subsurface Repository Workers from year 1996 (406) - Subsurface Support Services from year 1996 (179) + 20% contingency = 272 people.
5. From Reference 24, 1 Stage - No Consolidation Option Estimate total concrete quantity (113,108 cy) ÷ 4.25 year construction duration ÷ 250 working days/year = 106 cy/day.
6. Maximum placement is assumed to be WHB module basemat 200 LF x 110.5 LF X 5 ft. thick = 4,093 cy
7. From Reference 24, 1 Stage - No Consolidation Option Estimate total backfill quantity (1,513,345 cy) ÷ 4.25 year construction duration ÷ 250 working days/year = 1,424 cy/day.
8. From Reference 24, 1 Stage - No Consolidation Option Summary Level Construction Schedule and Estimate, Mass Engineering Backfill (333,430+900,000) = 1,232,430 cy ÷ 4.5 months duration x 12 months/yr ÷ 250 days/yr = 13,146 cy/day.
9. Reference 19.
10. From Reference 25, quantities provided by PBQ&D for 5 day period.
11. Assumed quantity from (10) above used in one day.

Therefore, construction phase staffing estimates are determined from the SCP/CDR estimate of repository workers for the vertical emplacement method (Reference 25), and are considered valid for the reference configuration.

The average number of surface construction workers is determined as the average of surface repository workers plus subsurface support services repository workers over the construction period, plus a 20 percent contingency. This yields an average population of 1,116 people and an average daily water requirement of 3,348 gpd based on a 3 gpd/person drinking water consumption basis for surface repository construction workers. Average underground water requirements are estimated at 10,150 gpd based on 50 gpd consumption for underground workers and an average population of 203 people. The average number of underground construction workers is determined as the average of subsurface repository workers over the construction period, plus a 20 percent contingency.

Peak values are determined in a similar manner using peak staffing estimates for the year 1996 plus a 20 percent contingency, and the same consumption bases. Peak construction staffing estimates are 1,799 people for surface and subsurface support services, and 272 people for underground construction workers. Water requirements for peak surface and underground construction personnel demand is 5,397 gpd and 13,600 gpd, respectively.

Underground construction workers are expected to be provided showers and towels at each shift change. Laundry services for washing towels will require 6.25 gpd/person which results in average and peak demands of 1,269 gpd and 1,700 gpd, respectively. As is normal in most underground mining operations, workers are responsible for laundering their personal work garments.

### 4.1.2 Surface Process Water

Surface construction process water for concrete, soils compaction, and dust control are developed using the bases discussed in section 3.1.3, quantities from the cost estimate for the repository option study (Reference 24), and from a review of the critical path construction schedule and drawings for the one-stage, no consolidation option.

The average concrete quantity placed each day has been derived from the estimate of 113,100 cy of total concrete and the 4-1/4 year overall construction duration yielding an average daily placement of 106 cy. Average water requirements for this placement rate is 3,498 gpd. A peak concrete placement rate is assumed as that required for placement of a WHB module basemat. This mat is 200 feet long by 110 feet 6 inches wide by 5 feet thick (Reference 26) requiring 4,093 cy of concrete. It is assumed that the concrete batch plant(s) will be capable of supplying this quantity of concrete in one day. Peak water requirements for this placement will then be 135,069 gpd.

Water for soils compaction is expected to be a substantial quantity since the site area is so large and site soils are in a relatively dry state. The average daily backfill quantity is 1,424 cy based on the estimated backfill quantity of over 1.5 million cy over the 4-1/4 year construction schedule. The peak daily backfill quantity is 13,146 cy based on the estimated backfill quantity for rough grading of over 1.2 million cy and the scheduled duration for this task of 4-1/2 months. The daily backfill rates result in average and peak water requirements of 34,176 gpd and 315,500 gpd, respectively.

Control of surface dust at construction sites is a constant problem caused by construction traffic on unpaved roads and graded areas. Scheduled periodic spraying of these traffic surfaces by water tanker trucks is common on all major construction projects and is expected to be required year round at the arid Yucca Mountain location. Historical information from other Bechtel construction jobs used as the basis over the 82-acre tuff site yields a daily requirement of 49,200 gpd.

Water for dust control and other uses to construct the access highway and railroad is not considered in this study. Water for these purposes is assumed to be supplied from sources other than those used for the repository.

### 4.1.3 Underground Process Water

Water requirements for underground mining and dust control have been established for the vertical emplacement option by PBQ&D (Reference 19) and discussed in Section 3.2.2.

Additional water for grout, shotcrete and masonry mortar is required for underground construction. Average 5-day consumption quantities have been estimated at 22,600 pounds (lbs) for grout, 580 lbs for shotcrete, and 450 lbs for masonry mortar (Reference 27). For construction use, grout, shotcrete, and masonry mortar will require mixing water in quantities of 151 gpd, 6 gpd, and 9 gpd, respectively. For peak flows it is assumed that the 5-day quantity is consumed in one day resulting in water requirements of 753 gpd for grout, 29 gpd for shotcrete, and 45 gpd for masonry mortar.

### 4.1.4 Fire Protection Water

Water requirements for fire protection of surface facilities during the construction period have been determined in accordance with DOE order 6430.1 and applicable NFPA standards as discussed in Section 3.1.4. Calculations to support Reference 28 determined that a flow of 1,500 gpm is required over a 4-hour duration, resulting in a worse case daily demand of 360,000 gpd. The calculations completed in 1984 are still valid for the reference configuration of the proposed repository.

## 4.2 Emplacement Phase

The emplacement phase, spanning a 25 year period of repository operations, begins when construction is complete and the WHB is ready for operation on December 1, 1997, and continues through the year 2022. Again, these dates do not reflect the recent revision to the DOE Mission Plan proposing a 5-year delay in the opening date of the first repository.

Table 2 shows the water requirements for the emplacement phase of the repository. Included in this estimate is water for surface and underground personnel consumption and meals; surface and underground ventilation water; process water for surface facilities including vehicle wash water, decontamination and waste treatment; process water for underground mining and dust control, grout, shotcrete, and masonry mortar; laundry water; and water for concrete shield plugs. During the emplacement phase, average demand is estimated at 603,437 gpd and peak demand is estimated at 623,635 gpd.

Water for fire protection of surface facilities is not included in Table 2. This requirement is a separate reserve quantity stored onsite but not included in estimates of daily demand. Water required for fire protection of underground facilities is discussed in Section 3.2.3.

### 4.2.1 Personnel Consumption

The bases discussed in Section 3.1.1 are used along with staffing estimates to determine the water requirements for personnel consumption. For the emplacement phase, the staffing estimate from the Reference Configuration Operations Plan (RCOP, Reference 1) provides surface and underground personnel for steady state repository operations and is used for peak values.

Table 2

Water Requirements

Emplacement Phase

| ITEM | BASIS | POPULATION/QUANTITY AVERAGE | POPULATION/QUANTITY MAXIMUM | WATER REQUIREMENTS AVERAGE | WATER REQUIREMENTS PEAK |
|---|---|---|---|---|---|
| Personnel Consumption | | | | | |
| Surface | 28 gpd/person | 1,062 people (1) | 1,090 people (2) | 29,736 gpd | 30,520 gpd |
| Underground | 50 gpd/person | 210 people (3) | 257 people (4) | 10,500 gpd | 12,850 gpd |
| Meals | 3 gpd/meal servd | 531 people (5) | 1,090 people (2) | 1,593 gpd | 3,270 gpd |
| Laundry | 6.25 gpd/person | 269 people (10) | 316 people (11) | 1,681 gpd | 1,975 gpd |
| Ventilation | | | | | |
| Surface | $2.373X10^{-4}$gpm/SF | 293,380SF (15) | 293,380SF (15) | 41,850 gpd (16) | 41,850 gpd (16) |
| Underground | | | | 244,800 gpd (6) | 244,800 gpd (6) |
| Process | | | | | |
| Housekeeping/cleaning | (17) | 552,560SF | 552,560SF | 327 gpd | 3,472 gpd |
| Vehicle wash | 330 gpd/wash | 2 washes/day (7) | 13 washes/day (8) | 660 gpd | 4,290 gpd |
| Decon/waste treatment | 210 gpd | - | - | 210 gpd (9) | 210 gpd (9) |
| Concrete | 40 gal/cy | 25 cy/day (12) | 125 cy/day (13) | 1,000 gpd | 5,000 gpd |
| Underground Mining & Dust Control | | | | 270,000 gpd (6) | 270,000 gpd (6) |
| Grout | | | | 151 gpd (14) | 753 gpd (14) |
| Shotcrete | 40 gal/cy | 23 cy/day (12) | 115 cy/day (13) | 920 gpd | 4,600 gpd |
| Masonry mortar | | | | 9 gpd (14) | 45 gpd (14) |
| TOTAL | | | | 603,437 gpd | 623,635 gpd |

1. From Reference 1 Appendix H Table 1, Surface personnel (223+402+52+231=908) ratio to Reference 25 Table 5-1, surface personnel years 2005-2016 (781+231 = 1,012) x Reference 25, Table 5-1, Average Surface Personnel years 1999 through 2022 (757+229=986) + 20% contingency = 1,062 people.
2. From Reference 1 Appendix H Table 1, Surface Personnel (908) + 20% contingency = 1,090 people.
3. From Reference 25 Table 5-1, Average of Subtotal Subsurface Repository Workers from 1999 through 2022 (404) - Average of Subsurface Support Services (229) = 175 + 20% contingency = 210 people.
4. From Reference 25 Table 5-1, Subtotal Subsurface Repository Workers from year 2004 (444) - Subsurface Support Services (230) = 214 + 20% contingency = 257 people.
5. Assume 50% of surface personnel eat at the food service facility.
6. Reference 19.
7. Assume 15% of shipments received each day are washed, 13 shipment are received daily per Reference 1 Table 5 (0.15 x 13 = 2).
8. Assume all shipments received each day are washed = 13.
9. From Reference 10, SK-215-K-169 Rev. 1, Total Liquid Radwaste = 51,800 gal/year and 250 working days/yr = 207 gpd say 210 gpd.
10. Assumed from Reference 1 Appendix H Staffing Estimate Bases, 16 WHB + 7 security + 10 medical + 13 fire protection + 3 WTB = 49 require laundry service + 20% contingency + 210 from (3) above = 269 people.
11. 49 from (10) above + 20% contingency + 257 from (4) above = 316 people.
12. From Reference 33.
13. Assumed 5 days of concrete (shotcrete) used in one day.
14. Same as construction phase.
15. Assumed 80% of floor area for WHB, WTB, Decontamination Bldg., Performance Confirmation Bldg., and Mock-up Facility are serviced by evaporative coolers.
16. Assume 10 hr/day requirement for evaporative cooling.
17. See Section 3.1.3.

Two hundred twenty-three people are dedicated to waste handling, 402 to balance of plant, and 283 to underground support, totalling 908 people. With a 20 percent contingency, this yields a peak surface personnel estimate of 1,090 people for the emplacement phase. Using the 28 gpd/person basis, peak surface personnel consumption results in a water requirement of 30,520 gpd. Peak underground personnel is estimated from Reference 25 for the year 2004, plus a 20 percent contingency yielding a peak underground personnel estimate of 257 people. The peak underground personnel water requirement is 12,850 gpd using on a 50 gpd/person consumption basis.

The RCOP does not contain detailed information to obtain average staffing estimates for the emplacement phase. To obtain an average staffing estimate for the 25-year emplacement period the average values from the SCP/CDR are factored by the ratio of peak RCOP to SCP/CDR surface personnel. This results in 885 surface personnel, plus a 20 percent contingency to yield an estimate of 1,062 people for average surface personnel during the emplacement phase. An average water demand of 29,736 gpd is required. Average underground personnel staffing is determined from the SCP/CDR and is 175 people plus a 20 percent contingency resulting in an estimate of 210 people and yielding an average water requirement of 10,500 gpd for underground personnel during the emplacement phase.

Additional water is required in the food service facility and is classified for this report as personnel consumption. It is assumed that no personnel dedicated to underground operations will use the food service facility. It is further assumed that 50 percent of the average surface personnel will eat meals at this facility yielding an average water requirement of 1,593 gpd. For peak flow, all the peak surface personnel are assumed to eat meals at this facility yielding a peak water requirement of 3,270 gpd.

Laundry facilities are provided for laundering:

- towels at each shift change for underground workers,
- soiled linens, protective clothing, and towels of emergency fire personnel,
- linens and medical garments from the emergency medical facility,
- towels and protective clothing for underground waste handling personnel, and
- towels and protective clothing for waste treatment equipment operators and contact handled solid waste transfer personnel.

Table 3 lists the personnel estimates for average and peak activities and result in average and peak flows for laundry services of 1,681 gpd and 1,975 gpd, respectively.

#### 4.2.2 Ventilation

Ventilation for surface facilities uses evaporative cooling methods with back up chilled water systems in the WHB, WTB, Decontamination Building, Performance Confirmation Building, and Mock-up Building. Approximately 80 percent of the floor area in these buildings, or over 293,000 SF of floor area is serviced by evaporative cooling and requires 41,850 gpd of make up water for evaporative losses and blow down. Glycol for freeze protection and rust inhibitors is added to the 65,000 gallons of water required to fill the chilled water systems used for back up to evaporative cooling and in the remaining facilities. These chillers are designed as closed systems and no make up water due to off-normal leakage or other losses is considered.

Cooling water for underground ventilation is a substantial quantity. PBQ&D has estimated that 2.8 million gallons are required to fill this evaporative cooling system and that 244,800 gpd are required for make up water due to evaporative losses and blow down.

Table 3

Emplacement Phase Personnel Requiring Laundry Facilities

| Facility | Personnel Average | Peak |
|---|---|---|
| Change House | 210 (1) | 257 (2) |
| WHB | 19 (3) | 19 (3) |
| WTB | 4 (3) | 4 (3) |
| Medical Building | 12 (3) | 12 (3) |
| Fire Station | 16 (3) | 16 (3) |
| Security | 8 (3) | 8 (3) |
| | 269 | 316 |

(1) From Reference 25 Average Subsurface Personnel for years 1999 through 2022 plus 20% contingency.

(2) From Reference 25 Peak Subsurface Personnel for year 2004 plus 20% contingency.

(3) From Reference 1 Appendix H Staffing Estimate Bases, plus 20% contingency.

No estimate has been made for peak flows for ventilation. Peak flows are expected to occur only during off-normal situations. At this time too little detail is available to satisfactorily quantify water required for these scenarics.

### 4.2.3 Surface Process Water

Process water for surface facilities includes water for the vehicle wash, water for decontamination and waste treatment, and water for precasting the concrete shield plugs. The bases from Section 3.1.3 are used with additional parameters discussed below.

For the vehicle wash facility, it is assumed that an average of 15 percent of the waste shipments received daily will be washed. Therefore, of the 13 shipments scheduled daily per Reference 1, two will be washed, yielding an average water requirement of 660 gpd. Peak demand will result from washing all 13 daily shipments, which yield a peak water requirement of 4,290 gpd.

Decontamination requirements during the waste handling operations and treatment of site-generated radioactive wastes are discussed in depth in SAND86-7136 (Reference 10). This study has estimated water requirements for normal operations of decontamination and waste treatment to be 51,800 gallons each year resulting in an average requirement of 210 gpd. Again, peak flows are expected to occur only during off-normal conditions and no attempt has been made to quantify these values.

Concrete is required during the emplacement phase to precast concrete shield plugs for emplacement boreholes. PBQ&D (Reference 29) has estimated that on average 85 cy of concrete will be required each day for this operation. However, currently it is anticipated that these shield plugs will be precast by offsite vendors and shipped to the site (Reference 33).

During the emplacement phase, it is estimated that over 550,000 SF of floor area must be maintained. Water requirements for housekeeping and cleaning will average 327 gpd based on an average of 250 working days each year. Peak flows to maintain this floor area occur when several housekeeping/cleaning activities occur simultaneously resulting in a water requirement of 3,472 gpd.

#### 4.2.4 Underground Process Water

Process water for underground operations is required only for underground development of the emplacement drifts and boreholes. Water requirements for grout and masonry mortar are the same as for the construction phase and discussed in Sections 3.2.2 and 4.1.3. Average quantities of concrete and shotcrete are estimated at 25 and 23 cubic yards per day (Reference 33), respectively, resulting in average water requirements of 1,000 gpd and 920 gpd. Peak requirements are based on 5-day quantities.

#### 4.2.5 Fire Protection Water

Water for fire protection of surface facilities during the emplacement phase is required at a flow rate of 2,500 gpm for a four hour duration. This results in a maximum daily requirement of 600,000 gpd. This requirement has been determined for the central warehouse building considering its size, location, exposure, and building usage. The NFPA Standard 231C governs water requirements for inside hose streams and sprinklers resulting in a 1,500 gpm flow. Additionally, two outside hose streams are assumed at 500 gpm each.

### 4.3 <u>Caretaker Phase</u>

The caretaker phase will begin upon completion of emplacement for all scheduled waste shipments. As presently scheduled, this phase will extend over a period of 25 years, from 2023 through 2047.

These dates do not reflect the recent revision to the DOE Mission Plan proposing a 5-year delay in the opening date of the first repository.

Table 4 shows the water requirements for the caretaker phase of repository operations. Included in this estimate is water for surface and underground personnel consumption and meals, surface and underground ventilation, decontamination and waste treatment, underground mining and dust control, housekeeping and cleaning, and laundry facilities. Average demand is estimated at 258,678 gpd and peak demand is estimated at 533,057 gpd for this phase.

Water for fire protection of surface facilities is not included in Table 4. This requirement is a separate reserve quantity stored onsite but not included in estimates of daily demand. Water required for fire protection of underground facilities is discussed in Section 3.2.3.

### 4.3.1 Personnel Consumption

Staffing estimates for the caretaker phase reflect the constant level of effort expected to be required during this period. Surface and underground personnel for this phase from Reference 25 are 163 and 25 people, respectively. No peak estimates of personnel are identified for the caretaker phase. Using the bases from Section 3.1.1 results in water requirements for this phase of 4,564 gpd for surface personnel consumption and 1,250 gpd for underground personnel consumption.

Water required at the food service facility is determined in a similar manner to that used for the emplacement phase described in Section 4.2.1. Average water requirements at the food service facility for the caretaker phase are 246 gpd and peak water requirements are 489 gpd.

## Table 4

**Water Requirements**

**Caretaker Phase**

| ITEM | BASIS | POPULATION/QUANTITY AVERAGE | POPULATION/QUANTITY MAXIMUM | WATER REQUIREMENTS AVERAGE | WATER REQUIREMENTS PEAK |
|---|---|---|---|---|---|
| Personnel Consumption | | | | | |
| Surface | 28 gpd/person | 163 people (1) | 163 people (1) | 4,564 gpd | 4,564 gpd |
| Underground | 50 gpd/person | 25 people (2) | 25 people (2) | 1,250 gpd | 1,250 gpd |
| Meals | 3 gpd/meal served | 82 people (3) | 163 people (1) | 246 gpd | 489 gpd |
| Laundry | 6.25 gpd/person | 61 people (10) | 61 people (6) | 381 gpd | 381 gpd |
| Ventilation | | | | | |
| Surface | 2.3/3X10$^{-4}$gpm/SF | 46,520SF (11) | 46,520SF (11) | 6,630 gpd (12) | 6,630 gpd (12) |
| Underground | | | | 244,800 gpd (4) | 244,800 gpd (4) |
| Process | | | | | |
| Housekeeping/cleaning | (13) | 243,980SF | 243,980SF | 144 gpd | 1,533 gpd |
| Underground Mining & Dust Control | | | | - (7) | 270,000 gpd (8) |
| Decon/waste treatment | 210 gpd for 9 containers/day | 1 containers/day (9) perf. confirmation | 9 container/day (10) | 23 gpd | 210 gpd |
| Concrete | 40 gal/cy | 9 cy/day (14) | 45 cy/day (15) | 360 gpd | 1,800 gpd |
| Shotcrete | 40 gal/cy | 7 cy/day (14) | 35 cy/day (15) | 280 gpd | 1,400 gpd |
| TOTAL | | | | 258,678 gpd | 533,057 gpd |

1. From Reference 25 Table 5-1, Average of Surface Repository Workers from 2023 through 2047 (77) + Average of Subsurface Support Services (59) + 20 % contingency = 163 people (no peak personnel identified for this phase).
2. From Reference 25 Table 5-1, Average of Subtotal Subsurface Repository Workers from 2023 through 2047 (80) - Average of Subsurface Support Services (59) + 20% contingency = 25 people.
3. Assume 50% of surface personnel eat at the food service facility.
4. Reference 19.
6. Assumed from Reference 1 Appendix H Staffing Estimate Bases, 7 security + 10 medical + 13 fire protection = 30 plus 20% contingency + 25 subsurface personnel from (2) above = 61 people.
7. Assume no subsurface mining operations during normal conditions.
8. Assume full subsurface mining operations during off normal conditions.
9. From Reference 10, 1 container per month is evaluated in the Performance Confirmation facility and assumed evaluated in 1 day.
10. Assumed 9 containers per day, which equals the WHB throughput during the emplacement phase.
11. Assumed 80% of floor area for the WTB and Performance Confirmation Bldg. are serviced by evaporative coolers.
12. Assume 10 hr/day requirement for evaporative cooling.
13. See Section 3.1.3.
14. From Reference 33.
15. Assumed 5 days of concrete (shotcrete) used in one day.

Laundry requirements for water are estimated at 381 gpd based on a complement of 61 people requiring laundry services who will be involved with the underground, security, and emergency response activities.

### 4.3.2 Ventilation Cooling

Not all surface facilities are required to be operational during the caretaker phase and water requirements reflect the reduced building areas for ventilation. During this phase the WHB, WTB, decontamination building, shops, mock-up building and central warehouse are likely to be placed in a standby mode and not require ventilation cooling. The evaporative cooling systems require 6,630 gpd to service the reduced complement of support facilities. Again, the chilled water systems do not require any make up water.

Cooling water for underground ventilation is assumed for the maximum condition to support performance confirmation. Water requirements are the same as during the emplacement phase for underground ventilation and equal to 244,800 gpd.

### 4.3.3 Surface Process Water

For the reduced level of effort during the caretaker phase, process water for surface facilities includes only decontamination and waste treatment water and housekeeping/cleaning water. Water for decontamination and waste treatment is needed for performance confirmation activities. For average flows, 23 gpd are required assuming that one container is evaluated each month and the evaluation is completed in the period of one day. For peak flows, the 210 gpd used during the emplacement phase is assumed.

During the caretaker phase, 243,980 SF of floor area must be maintained. For these tasks average flows of 144 gpd and peak flows of 1,533 gpd are required. Bases from Section 3.1.3 are used to determine these flows.

4.3.4 Underground Process Water

Process water for subsurface activities during caretaker operations is not expected during normal conditions. Some intermittent repair of access drifts, supports, and bulkheads may be required. Concrete and shotcrete quantities for this repair are estimated 9 and 7 cubic yards per day, respectively, (Reference 33), resulting in average water requirements of 360 gpd and 280 gpd. Peak requirements are based on 5-day quantities. Water requirements for underground mining and dust control during the emplacement phase will be assumed as peak flows during this caretaker period.

4.3.5 Fire Protection Water

The fire protection requirements during the caretaker phase are as stringent as those during the emplacement phase since all facilities may need to be reopened should retrieval of the waste be required. Fire flows and storage capacities for fire protection water are the same as the emplacement phase.

## 4.4 Decommissioning Phase

The decommissioning phase is scheduled to begin in 2048 and extend through 2058. During this 11-year period decontamination and demolition of surface facilities will be undertaken along with other necessary activities to restore the site to its natural state (Reference 1). The dates provided above do not reflect the recent revision to the DOE Mission Plan proposing a 5-year delay in the opening of the first repository.

Included in Table 5 are water requirements for surface and underground personnel consumption, ventilation cooling, and process water for surface and underground dust control, concrete and grout for underground sealing. During this phase average requirements are estimated at 154,435 gpd and peak requirements are estimated at 431,947 gpd.

Water for fire protection of surface facilities is not included in Table 5. This requirement is a separate reserve quantity stored onsite but not included in estimates of daily demand. Water for fire protection of underground facilities is discussed in Section 3.2.3.

### 4.4.1 Personnel Consumption

Personnel staffing estimates are available from Reference 25 for the decommissioning phase and are used for determining personnel water consumption. Average surface personnel are estimated at 184 people over a 10-year decommissioning period used for the SCP/CDR and includes a 20 percent contingency. Three hundred ninety-five are required for peak surface personnel during the year 2043. This estimate also includes a 20 percent contingency. Using the basis from Section 3.1.1 yields average and peak surface personnel water consumption of 5,152 gpd and 11,060 gpd, respectively.

Average underground personnel over the 10-year SCP/CDR decommissioning period is 83 people and includes a 20 percent contingency. Peak underground personnel are required in the year 2056 and are estimated at 102 people including a 20 percent contingency. Average and peak underground personnel water requirements are 4,150 gpd and 5,100 gpd, respectively.

### 4.4.2 Ventilation

It is expected that some site-generated waste treatment will still be required during this phase so ventilation for the WTB will still be required. The average water requirement for evaporative cooling is 3,510 gpd for the 24,680 SF of floor area in the WTB. Peak water requirements assume that some performance confirmation activities are ongoing and 6,630 gpd are needed for ventilation of the 46,520 SF of combined floor area.

Table 5

Water Requirements

Decommissioning Phase

| ITEM | BASIS | POPULATION/QUANTITY AVERAGE | POPULATION/QUANTITY MAXIMUM | WATER REQUIREMENTS AVERAGE | WATER REQUIREMENTS PEAK |
|---|---|---|---|---|---|
| Personnel Consumption | | | | | |
| Surface | 28 gpd/person | 184 people (1) | 395 people (1) | 5,152 gpd | 11,060 gpd |
| Underground | 50 gpd/person | 83 people (3) | 102 people (2) | 4,150 gpd | 5,100 gpd |
| Ventilation | | | | | |
| Surface | $2.373X10^{-4}$gpm/SF | 24,680SF (7) | 46,520SF (8) | 3,510 gpd (7) | 6,630 gpd (8) |
| Underground | | | | - | 244,800 gpd (9) |
| Process | | | | | |
| Surface Dust Control for Demolition | 600 gpd/acre | 82 acres | 82 acres | 49,200 gpd (10) | 49,200 gpd (10) |
| Surface Dust Control @ Tuff Pile | 158,533,000 gal (11) | 10 years | 10 years | 91,157 gpd (12) | 91,157 gpd (12) |
| Concrete | 40 gal/cy | 23 cy/day (13) | 400 cy/day (14) | 920 gpd | 13,200 gpd |
| Grout | 2 gal/60 lb grout | 10,368 lb/day (15) | 324,000 lbs/day (16) | 346 gpd | 10,800 gpd |
| TOTAL | | | | 154,435 gpd | 431,947 gpd |

1. From Reference 25 Table 5-1, Average of Surface Repository Workers from 2048 through 2057 (73) + Average of Subsurface Support Services (80) = 153 + 20% contingency = 184 people.
2. From Reference 25 Table 5-1, Subtotal Surface Repository Workers from 2049 (243) + Subsurface Support Services from year 2049 (86) = 329 + 20% contingency = 395 people.
3. From Reference 25 Table 5-1, Average of Subtotal Subsurface Repository Workers from 2048 through 2057 (149) - Average of Subsurface Support Services (80) + 20% contingency = 83 people.
4. From Reference 25 Table 5-1, Subtotal Subsurface Repository Workers from year 2056 (171) - Subsurface Support Services from year 2056 (86) + 20% contingency = 102 people.
5. Assume 50% of the average surface personnel eat at the food service facility.
6. Assume all of the peak surface personnel eat at the food service facility.
7. Assume 80% of WTB floor area is serviced by evaporative coolers requiring 10 hr/day operation.
8. Assumed same as Caretaker Phase.
9. Reference 19.
10. Assumed same as construction phase.
11. Reference 30.
12. 250 days per year for 10 years and 158,533,000 gallons = 79,267 gpd + 15% (Reference 31) = 91,157 gpd.
13. From Reference 33.
14. Assume maximum placement is approximately 400 cy/day.
15. From References 30 and 31, 1,600 cy over 2 years = 800 cy/yr = 3.2 cy/day and 60 lbs grout/0.5 cf = 10,368 lbs grout/day.
16. Assume 100 cy grout or 324,000 lbs grout/day maximum.

For the underground it is assumed that no ventilation is required on a normal basis. For peak conditions it is assumed that the underground ventilation requirement used for other phases is required (244,800 gpd).

4.4.3 Process Water

Process water during decommissioning includes dust control water for demolition of surface facilities and water for underground dust control, concrete and grout for backfilling the underground repository. These requirements are very difficult to estimate at this time.

As a rough estimate, the surface dust control water requirement is assumed equal to that used during the construction phase, 49,200 gpd. This value is assumed as an average requirement and no attempt has been made to estimate a peak value.

Water for underground dust control is expected to be required at the surface crushing plant to be located near the tuff ramp portal. Parsons, Brinckerhoff, Quade, and Douglas has estimated that 6 percent by weight of water should be added to the backfill material passing through the surface crushing plant resulting in 158,533,000 gallons required for dust control of underground backfill material during the SCP/CDR decommissioning phase (Reference 30). For a no consolidation configuration additional backfilling will be required resulting in approximately 91,157 gpd over the 11-year period. Again no attempt has been made to quantify peak demand for this process.

Providing seals of the shafts and ramps will require 15,700 cy of concrete and 1,600 cy of grout (Reference 30). These seals will be constructed over the last 2 to 3 years of the decommissioning period (Reference 31). The average water requirements for these items over a 3 year period are 920 gpd for concrete based on an average quantity of 23 cubic yards per day (Reference 33), and

346 gpd for grout. For peak values it is assumed that 400 cy of concrete and 100 cy of grout are placed underground in one day. This results in peak water requirements of 13,200 gpd for concrete and 10,800 gpd for grout during the decommissioning phase.

### 4.4.4 Fire Protection Water

Water requirements for fire protection of surface facilities have been determined to be the same as for the construction phase (see Section 4.1.4).

## 5.0 SUMMARY AND CONCLUSIONS

This study has estimated water requirements during the four phases of repository development and operations. Table 6 summarizes the average and peak demands for these four phases. A summary calculation shows that, over the life of the repository (65-1/4 years), the average water requirement exceeds 95 million gallons (292 acre-feet) per year. This overall average water requirement is well within the estimate reported in the EA (Reference 32).

The estimates are dominated by water required for underground ventilation cooling, mining, and dust control. These items contribute from 34 to 95 percent of the average or peak estimated water requirement for each phase. The influence of underground ventilation water is considered very conservative since the estimate provided is for a worst case scenario and requirements for continuous ventilation cooling may not be necessary.

The Amargosa Desert ground-water basin has been identified as containing the tuffaceous aquifers beneath Yucca Mountain to be utilized for the repository water supply. This supply is acceptable for all repository uses and meets necessary EPA primary standards for deleterious materials and secondary standards for major cations and anions. The yield of this supply has been estimated at over 24,000 acre-feet per year.

The average water requirement over the life of the repository will result in an increase of less than 4 percent over current consumption from the Amargosa Desert basin. This effect is considered negligible as pumping tests have shown that the aquifers beneath Yucca Mountain can produce an abundant quantity of ground water for long periods of time without lowering the regional ground water table.

Table 6

Summary of Repository Water Requirements

| Phase | Duration (yr) | Requirement (gpd) Average | Requirement (gpd) Peak |
|---|---|---|---|
| Construction | 4.25 | 371,807 | 791,297 |
| Emplacement | 25 | 603,437 | 623,635 |
| Caretaker | 25 | 258,678 | 533,057 |
| Decommissioning | 11 | 154,435 | 431,947 |

Average Water Requirements over the life of the repository.

| | | |
|---|---|---|
| (371,807 gpd)(250 days/yr)(4.25 yr duration) | = | 395,045,000 gallons |
| (603,437 gpd)(250 days/yr)(25 yr duration) | = | 3,771,481,250 gallons |
| (258,678 gpd)(250 days/yr)(25 yr duration) | = | 1,616,737,500 gallons |
| (154,435 gpd)(250 days/yr)(11 yr duration) | = | 424,696,250 gallons |
| | | 6,207,960,000 gallons |
| (6,207,960,000 gallons)/(65.25 yr duration) | = | 95,141,149 gallons/yr |
| | = | 292 acre feet/yr |

Fire water requirements for surface facilities for the four phases of the repository development and operations are shown in Table 7. The DOE design criteria and NFPA standards are used to determine these values insuring that the most stringent requirements for fire protection are met.

No special storage and supply of water for fire protection is currently proposed for the underground facilities. The mine service water is to be used as the fire protection supply. Automatic fire suppression systems are proposed at underground fueling areas and for mobile underground mining equipment. These systems use dry chemicals and aqueous forming foams to suppress fires. Deluge systems are proposed at conveyor dives in the underground development areas and tuff ramp.

## Table 7

**Summary of Surface Facilities Fire Protection Water Requirements (Reference 26)**

| Phase | Requirement: Flow (gpm) | Requirement: Storage (gallons) |
|---|---|---|
| Construction | 1,500 | 360,000 |
| Emplacement | 2,500 | 600,000 |
| Caretaker | 2,500 | 600,000 |
| Decommissioning | 1,500 | 360,000 |

## 6.0 ASSUMPTIONS

Some major assumptions used in the evaluation of repository water requirements are summarized below.

The water requirements estimates for each phase are based on the current state of repository design for one-stage, no-consolidation waste handling facilities and vertical emplacement of waste containers underground. Available design data were used when possible; otherwise, engineering judgment was used for estimating water requirements.

The referenced material used for developing the water requirements bases, found in the open literature, personal communications, and information generated in other project reports, is applicable and valid for the specific items as described in Section 3.0.

The SCP/CDR staffing estimates are applicable and valid for the construction, caretaker, and decommissioning phases. Bare values from Reference 25 are used for determining average and peak staffing. The 20 percent contingency is added to be consistent with the RCOP staffing (Reference 1) which also uses a 20 percent contingency.

During the construction phase portable toilets will be used for sanitary waste facilities. The sanitary waste will be collected and disposed of by offsite vendors, resulting in no additional water requirements.

Peak demand for concrete mixing water during the construction phase assumes a single placement for a WHB basemat module (4,093 cy). Concrete batch plant(s) are assumed capable of supplying the concrete for a placement of this magnitude.

Water required for dust control and construction of the access highway and railroad is assumed to be supplied from sources other than those used for the repository.

Ten gallons of mixing water are assumed required for each 100 pounds of cement for masonry mortar. Peak demand for grout, shotcrete, and masonry mortar mixing water are assumed to be a five-day total of average demand during the construction and emplacement phases.

Design parameters for evaporative cooling are based on sea level conditions and assume an outside air temperature of 102°F dry bulb/67°F wet bulb at 42 grains. An 80 percent saturation efficiency is assumed in the evaporator. Eighty percent of the floor area of the buildings using evaporative coolers is assumed to have an air flow rate of 3 cfm for calculating evaporation and blow-down make up water.

For the emplacement and caretaker phase it is assumed that no underground personnel use the food service facility. Average water requirements at the food service facility assume 50 percent of the average surface personnel take meals there. Peak water requirements at the food service facility assume all of the peak surface personnel take meals there.

At the vehicle wash facility during the emplacement phase, 15 percent of the incoming waste shipments are assumed to be washed on average. Peak requirements assume all incoming waste shipments are washed.

The peak demand for concrete mixing water during the emplacement phase is assumed to be a 5-day total of average demand.

During the caretaker phase underground ventilation requirements are assumed to be the same as for the emplacement phase. Underground mining and dust control water is assumed to not be required on a normal basis. The quantity used for construction and emplacement mining and underground dust control is used for peak requirements.

Performance confirmation operations during the caretaker phase are assumed to evaluate one container per day for average process water requirements. For peak requirements the quantity used during the emplacement phase is assumed.

During the caretaker phase the WHB, WTB, Decontamination building, shops, mock-up building, and central warehouse are expected to be mothballed.

During the decommissioning phase surface dust control requirements are assumed the same as the construction phase to return the site to its natural state.

Peak placement rates for grout and concrete are assumed to be 100 cy/day and 400 cy/day, respectively, during decommissioning.

For surface ventilation requirements the WTB is assumed to be the only facility required during decommissioning for average requirements. For peak demand performance confirmation ventilation is added.

No underground ventilation is required during normal decommissioning operations. For peak demand the emplacement phase underground ventilation requirements are assumed.

Water for underground mining and dust control will sufficiently wet the mined tuff so that no additional water is required at the surface tuff pile.

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# THE ECONOMIC VALUE OF WATER

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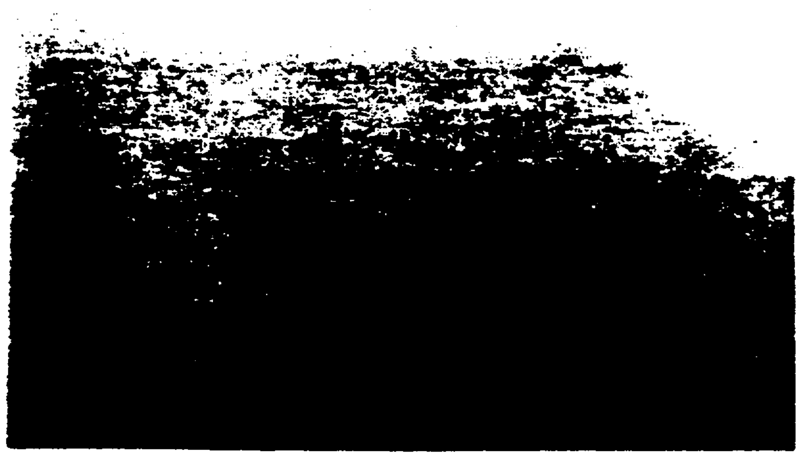



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