CHAPTER 17

PROTECTION OF THE HYDROLOGIC BALANCE

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CHAPTER 17

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CHAPTER 17

PROTECTION OF THE HYDROLOGIC BALANCE

Introduction

In order to minimize the impact of mining on the hydrologic balance within the leasehold and prevent material damage to the hydrologic balance in the region adjacent to the leasehold: (1) mining, reclamation and monitoring plans and data reporting should be consistent with the significance findings of the Probable Hydrologic Consequences analysis; and (2) local and regional water uses, including alluvial valley floor farming, and water rights should be identified and defined. The following discussion will address the two principal topics referenced above. The mining, reclamation and monitoring plans and data reporting are discussed in the context of how they relate to ground- and surface-water protection and monitoring. Where possible in this first section, reference has been made to those chapters which contain details regarding mining and reclamation plans and practices. The second principal topic describes existing water uses, the current status of water rights in the Little Colorado River Basin, past and present alluvial valley floor practices and the significance of alluvial valley floors to the postmining land use.

Ground-Water Protection

Ground-Water Quality. The impact of acid and toxic spoil material on the Wepo and alluvial aquifers was found to be of minimal significance. Because of the high neutralization potential in the spoil, the only changes anticipated in the ground water quality would be elevated TDS levels as a result of dissolution of additional salts. This reaction would occur regardless of what material was placed in the wet portions of the pits. Thus, the Hydrologic Reclamation Plan (Chapter 18) does not include special handling of overburden and parting for purposes of ground-water protection.

Bore holes, shafts, wells and auger holes will be cased and/or sealed to prevent the mixing of ground waters of significantly different quality and to ensure the safety of people, livestock, fish, wildlife and machinery. Monitoring wells within the permit area are cased and sealed at the time-of-drilling as shown on Figure 1 and described in the Wepo and alluvial well installations, completion and development section of Chapter 16, Hydrologic Monitoring Program. All monitoring wells, following the approval of the

Regulatory Authority, shall be properly abandoned according to the procedures described in the Wepo and alluvial well abandonment section of Chapter 16. Should mining intercept any monitoring wells, the wells will be sealed in advance with bentonite or cement from the bottom of the well to an elevation just above the bottom of the mining pit.

Temporary and permanent sealing of drill holes and borings is discussed in the temporary sealing of drill holes and permanent sealing of drill holes sections of Chapter 4, Geology. Should drill holes extending to greater depths than the mining pits be mined through, no additional sealing beyond what is described in Chapter 4 well be necessary to comply with the requirements of 30 CFR 816.13. Drill holes and exploration borings are only 4 5/8" in diameter and will remain adequately sealed following blasting. As such, they pose no safety hazard while mining is conducted around and over them. No pits are proposed to be left as impoundments, thus all truncated borings will be covered with significant amounts of spoil during reclamation of the mined areas. Therefore, concerns regarding protection of the hydrologic balance, acid or toxic drainage and safety will have been addressed.

Ground-Water Quantity. Recharge to the Wepo aquifer and potential spoil aquifers occurs by two processes, vertical infiltration of rainfall or snowmelt recharge and the horizontal inflow of groundwater into the spoil from the adjacent Wepo aquifer where the Wepo aquifer is saturated to heights above the bottom of the spoil. The significance of mining on these two processes will be discussed separately. The impact of spoil replacement on Wepo ground-water flow (horizontal) was found to be of long duration but of little significance (Chapter 18). Replacement of spoil material on the leasehold is principally accomplished using draglines and dozers. Studies by Rahn (1976) and VanVoast and Hedges (1975) indicate regardless of how the spoil material is replaced in the wet portions of pits, greater porosities and horizontal hydraulic conductivities will be achieved because of increased void volumes between the original stratified material and its rearranged state following replacement. Van Voast and Hedges demonstrated measurably increased hydraulic conductivities by aquifer tests in the spoil. Though PWCC has only two wet pits (N7 and N2) which have been reclaimed, aquifer tests in spoil wells (176, 177 and 209) completed in these reclaimed areas yielded hydraulic conductivities equal to or greater than those obtained in undisturbed portions of the Wepo aquifer. The mean weighted hydraulic conductivity value for the Wepo aquifer tests run on the PWCC leasehold is 0.12 ft/day; whereas, the hydraulic conductivities for the 3 spoil aquifer tests range from 2-14 ft/day. Resaturation of the spoil in the pits which intercepted the Wepo aquifer may take a few years to several years. This is not controlled so much by the spoil horizontal

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permeability as it is by the horizontal hydraulic conductivities of the adjacent, undisturbed portions of the Wepo aquifer.

The impact of the replaced spoil on infiltration recharge to the Wepo aquifer was also found to have no significance (Chapter 18). This statement is made for several reasons. Depths to ground water in this area are measurable. The average depth to ground water in the Wepo wells on the leasehold is approximately 95 feet. Typical pit depths are from 150 to 180 feet. Spoil wells 176 and 177 indicate only the bottom 20 to 30 feet of the southern portion of the N7 pit is saturated. These represent considerable depths infiltrating recharge must travel to reach the zones of saturation. This portion of Arizona is a recharge deficit area which means annual evaporation exceeds annual precipitation. Aquifer tests measuring vertical hydraulic conductivities as compared to horizontal hydraulic conductivities consistently demonstrate horizontal hydraulic conductivities are at least one order of magnitude or more higher. Summarizing, the potential for recharge to infiltrate to the aforementioned depths in the typical leasehold soils/bedrock and in the replaced spoil is extremely low. Recharge in the Wepo formation predominantly occurs at the outcrops and in the areas where the Wepo strata have been burned and are highly fractured.

Several infiltration tests were performed on the spoil material utilizing sprinkler-type infiltrometers which simulate terminal rain drop velocities. The infiltrometer was constructed and tested at the Water Resources Research Center at the University of Arizona. In the Black Mesa tests, water was applied at a rate of 6.35 cm/hr per hour for a one-hour period. An infiltration curve representing an average of all the infiltration curves is shown in Figure 1. Infiltration rates ranged from over 6 cm/hr for the first .1 of an hour to less than 0.13 cm/hr at the end of the one-hour tests (Berkas, 1978). Table 1, taken from the ASCE Manual of Engineering Practice No. 28, shows that the replaced spoil material would fall into the low infiltration rate category. Though the spoil showed low infiltration rates, many of the soils and the bedrock comprising the Wepo formation also show low infiltration potential. The foregoing discussion shows the principal process by which spoil will recharge is from lateral inflow from surrounding portions of the undisturbed Wepo aquifer and undisturbed burn areas.

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Ground-Water Monitoring

Since 1980, Peabody has installed an extensive network of 98 wells to monitor the shallow and deep aquifers beneath the leasehold. Monitoring instrumentation, parameters monitored and monitoring frequencies are described in detail in Chapter 16. The ground-water

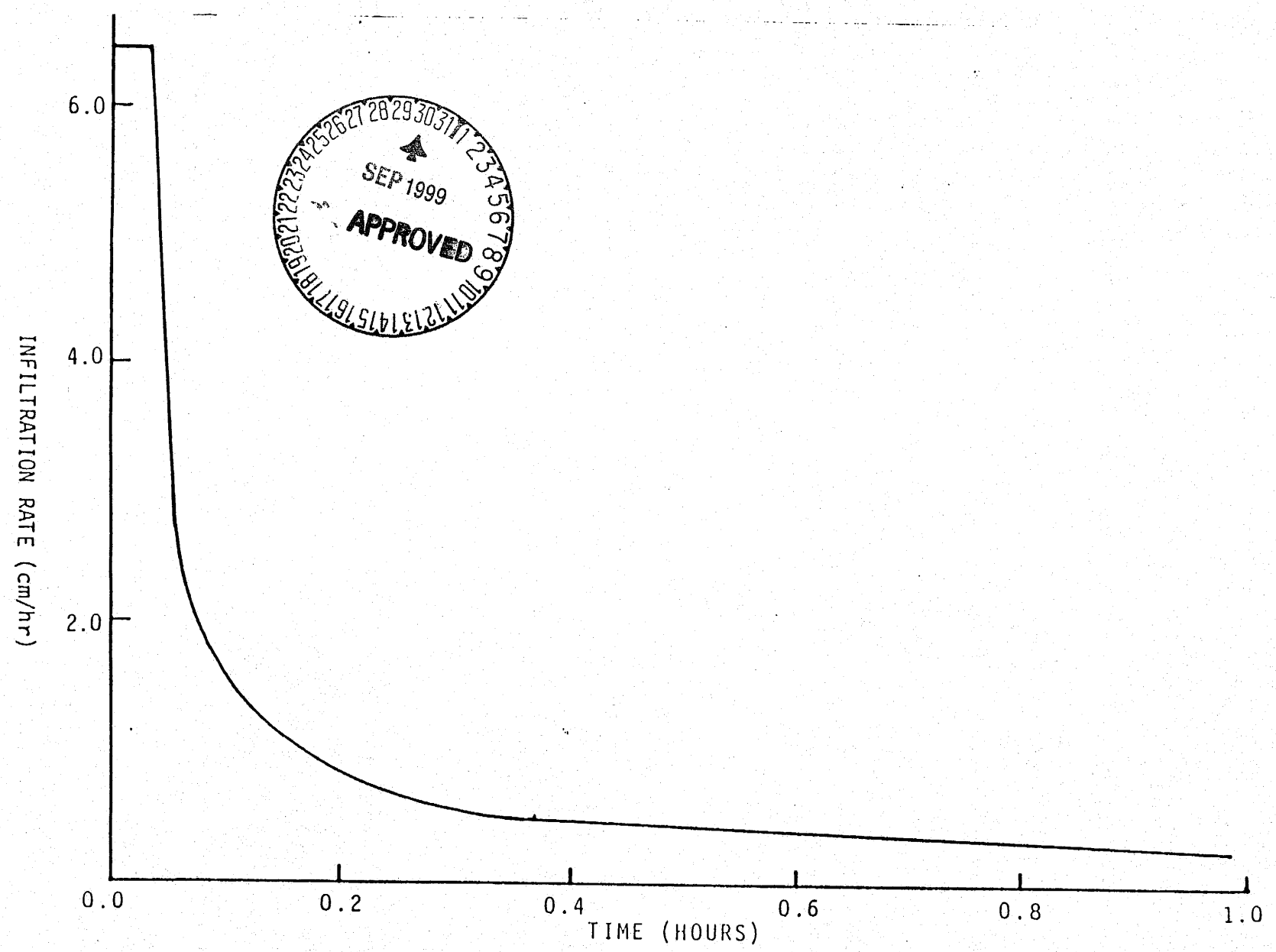

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FIGURE 1 AVERAGE INFILTRATION CURVE FOR REPLACED SPOIL MATERIAL

TABLE 1

Classification Scheme for Infiltration Rates

At the End of One Hour

Infiltration Class	Infiltration Rate (cm/hr)
High	1.27 - 2.54
Intermediate	0.25 - 1.27
Low	0.03 - 0.25

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monitoring plan employed to monitor the extent and magnitude of any mining impacts is discussed in detail in Chapter 19. The mining operation is being conducted to minimize disturbances to the ground water portion of the hydrologic balance within the permit area and prevent material damage to the ground water portion of the hydrologic balance outside the permit area (see Chapter 18, Probable Hydrologic Consequences). The shallow Wepo and alluvial aquifer water quantity and quality is marginally suitable to unsuitable for use as livestock water. The Navajo aquifer water is suitable for both domestic and livestock purposes and is being provided. An evaluation of the effects of Peabody’s pumping of the N-aquifer indicate hundreds of feet of available water remain above the production zones in local and regional Navajo wells. The local wells and springs removed by mining have been replaced by the water impounded in dams and permanent impoundments, and the two public water stands (drinking quality water from the N-aquifer). Seasonal variations in water levels and chemical concentrations have been adequately defined. The ground-water monitoring program as installed will identify the extent and magnitude of any measurable mining impacts.

Reporting of ground-water data from 1980 through 1984 was done on an annual basis (see annual Hydrological Data Reports). Data reporting in 1985 was done on a quarterly basis. Peabody shall report future ground water data according to the reporting frequencies specified in Chapter 16, Hydrological Monitoring Program.

The ground-water monitors will be maintained for the life of the mining operation or until such time as OSM may agree that they are no longer necessary. All off-lease ground water monitoring sites shall be reclaimed in accordance with the Reclamation Plan. The reclamation liability for the ground water monitoring sites (including the off-lease sites) is included in Chapter 24, Bonding.

Surface-Water Protection

Surface-Water Quality. The impact of runoff from disturbed and reclaimed areas on stream water chemistry and sediment loads was found to be of minimal signficance (see Chapter 18, Probable Hydrologic Consequences). Based on water quality analyses from permanent internal impoundments (PII's) in non-topsoiled pre-law areas, runoff water quality is not signficantly different from streamflow water chemistry. The potential for acid and toxic runoff from reclaimed areas is negligible because: (1) the spoil material has a high neutralization potential; (2) a post-reclamation sampling program (see Chapter 22) is designed to locate any acid or toxic zones at the surface of the regraded spoil material;

(3) the plant growth medium reconstruction plan (Chapter 22) provides for burial of any toxic materials identified in the graded spoil sampling program; (4) sediment yields predicted from reclaimed areas using SEDIMOT II (see Chapter 18) and EASI (see Chapter 19) are minimal compared to typical stream loads and in-channel erosion; (5) all disturbed areas drain to a series of sediment ponds and dams which are designed to contain at least the 10-year, 24-hour runoff plus an additional volume of sediment; and (6) channel diversions are designed for areas where channel flow could contact spoil material. The design criteria and construction of diversions, sediment ponds, PII's, energy dissipators and dams as they relate to the protection of the hydrologic balance are discussed in detail in Chapter 6, Facilities.

Discharges from sediment ponds and dams bordering disturbed areas will be in compliance with applicable Federal and State water quality laws and regulations. All discharges, monitoring of discharges and reporting of effluent concentrations will be in compliance with the requirements of NPDES Permit No. NN-0022179 (Chapter 16, Attachment 3).

Surface-Water Quantity. The impact of dams, diversions, sediment ponds, PII's and reclaimed areas on streamflows and downstream users was found to be minimal in Chapter 18, Probable Hydrologic Consequences.

Flow and sediment yield changes following release of bond for select reclaimed areas in the Coal Mine Wash watershed were simulated using SEDIMOT II and presented in Chapter 15, Hydrologic Description (pages 132-156). Changes in the flow characteristics when these two mining areas were included in the runoff analysis were not determined to be significant. Though no MSHA sized or other PI’s (permanent impoundments) are contained in the N1 and N2 mining areas, there are several PII’s (permanent internal impoundments) and as such, it is believed this analysis is indicative of the magnitude of the flow changes when all temporary impoundments in other mining areas are removed prior to release from bond.

Stream buffer zones in a proximity to surface mining areas that are not approved for any disturbance will be marked (refer to Drawing Nos. 85360, 85210 and 85640). Where mining must necessarily be close to existing channels, approved diversions are designed and constructed to convey flows with a minimal effect on suspended solids concentrations, channel gradients, and natural flow velocities. Disturbances will not occur in stream buffer zones unless specifically approved by OSM before the disturbances occur, except

those associated with routine groundwater and stream monitoring site maintenance as required by 30 CFR 816.41c.(4) and e.(4).

Surface-Water Monitoring

Since 1980, Peabody has installed a network of 14 stream monitoring stations at the up and downstream portions of all washes and 22 reclaimed area surface-water monitors which contain a variety of automated samplers and recorders as well as instantaneous samplers and recorders. Current monitoring instrumentation, parameters monitored and monitoring frequencies are described in detail in Chapter 16. This surface-water monitoring plan is discussed in detail in Chapter 19. The mining operation is being conducted to minimize disturbances to the surface water portion of the hydrologic balance within the permit area and prevent material damage to the surface water portion of the hydrologic balance outside the permit area (see Chapter 18, Probable Hydrologic Consequences). Combined impounded drainage areas of the total Moenkopi and Dinnebito watershed areas as of June 2008 amount to less than three percent. The nature of the flows, the terrace heights and the stream-water quality are such that streamflows are not suitable to support the existing and postmining land use. The quality of water in permanent internal impoundments and temporary sediment ponds and dams indicate such structures are supportive of the postmining land use. Finally, seasonal variations in surface-water parameters have been adequately defined (Chapter 15, pages 76-79 and Table 29). Fluctuations in flows, sediment yields, and channel geometries can best be described over a period of years. The surface-water monitoring program as installed will identify the extent and magnitude of any measurable mining impacts.

Reporting of surface-water data from 1980 through 1984 was done on an annual basis (see annual Hydrological Data Reports). Starting in 1985, surface water hydrologic monitoring data was reported on a quarterly basis. Peabody shall report future surface water data according to the reporting frequencies specified in Chapter 16, Hydrological Monitoring Program. The monitoring frequency at any surface water site dictates what data shall be included in each quarterly report. Clearly 30 CFR 816.41e(3), subparts i and ii demonstrates the regulatory authority did not envision quarterly monitoring for all parameters and all surface water monitoring sites ad infinitum. As such, changes to the surface water monitoring frequencies and parameters will be a continually evolving process through bond release.

The surface-water monitors will be maintained until bond release or until such time as OSM may agree they are no longer necessary as allowed for in 30 CFR 816.41e(3) and subparts

(3)i and (3)ii. All surface water monitoring sites shall be reclaimed in accordance with the Reclamation Plan. The reclamation liability for the surface water monitoring sites (including the off-lease sites) is included in Chapter 24, Bonding.

Water Rights and Alternative Water Supplies

The State of Arizona is proceeding with the adjudication of water rights in the Little Colorado River Basin, which includes Black Mesa. This adjudication is still in the process of being finalized. Once the adjudication is final, it is believed Peabody’s water use will be a prescribed use based on the allotments to each Tribe. Peabody's use of water on Black Mesa for the mining operations is authorized in the three mining lease agreements (Lease Nos. 14-20-0603-8580, 14-20-0603-9910 and 14-20-0450-5743) with the Tribes. The mining lease agreements clearly state that Peabody may use that amount of water necessary for its mining operations, including the transportation by slurry pipeline of coal mined from the lease areas.

Since surface- and ground-water appropriations on the reservation were not filed with the State of Arizona prior to the present adjudication process, water use data collected by the USGS between 1950 and 1961 was emphasized along with any supplemental data supplied by the Tribes to document water use within and in the region around the Peabody leasehold. Figure 2 shows all wells and springs completed in the Wepo, Toreva and D-aquifer system within and around the Peabody leasehold that have USGS, BIA, Tribal and Peabody field identification numbers.

Pre-existing Wells and Springs

Table 2 lists available information regarding coordinates, well completions, aquifers penetrated by wells, aquifer characteristics and yield and water quality for the 40 wells shown on Figure 2. The outline of the leasehold has been included on Figure 2 to show the relationship of these pre-existing shallow private wells and springs to the mining operation.

Twenty local wells have been identified, or are professed to exist within the Peabody leasehold or within an approximate 2 mile distance of the Peabody leasehold (Figure 2 and Drawing 85322). Those which have been located in the field, have established BIA or Tribal ID numbers or are known to have been removed by mining are shown on Figure 2 (17 wells, 16 of which agree with Drawing 85322). Drawing 85322 includes 4 wells which are not shown on Figure 2 because they could never be found in the field. They have either

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TABLE 2

Aquifer, Well Completion, Water Yield and Water Quality Data for all Local Dug Wells and Private Wepo Toreva, Dakota and Morrison Formation Wells Completed Within or Adjacent to the Leasehold (Davis et al. 1963, McGavock et al. 1966, Navajo Nation, 1999 and PWCC, 1999)

Well Number	Location Coordinates* Northing	Easting	Well Depth (Ft)	Perforation Zone (Ft)	Aquifer Thickness (Ft) Aquifer	Static Water Level (Ft)	Rate (GPM)	Draw-Down (Ft)	Duration (Hrs)	Water Quality
4M-28	-98868.0	33599.9	19	Well Developed From Spring	-, Alluvium	13.5	-	-	-	Good
4M-33	-76202.0	83189.1	20	Rock Cribbed	-, Wepo	15	-	-	-	-
4M-34	-67918.0	79162.1	15	Rock Cribbed	-, Alluvium	10.7	-	-	-	-
4M-58	-95991.0	17837.3	9	Masonry Cribbed	-, Wepo	7.1	-	-	-	-
4M-61	-78273.0	-30256.0	13	Masonry Cribbed	-, Toreva	10.2	-	-	-	Good
4K-349	-94956.0	-10121.0	7.5	Cribbed	-, Landslide and Talus	6	-	-	-	Good
4K-380	-65458.7	43760.7	950	525-950	650, Wepo 300, Toreva	520	14	31	1.5	Good
4K-389	-30713.7	80281.8	417	370-403	397, Wepo	356	6	-	1	Fair
4T-405	-62368.0	22956.4	436	375-436	434, Wepo	335	4	100	1	Good
4M-52	-93833.0	172841.0	9.5	Rock Cribbed	-,Alluvium	6.8	0.8	-	-	Fair
8A-PHS-10	-172.7	34901.2	-	Rock Cribbed	-,Alluvium	11.0	-	-	-	Fair
8A-PHS-15	-9038.6	22370.5	-	-	-,Wepo	-	-	-	-	-

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TABLE 2 (Cont.)

Aquifer, Well Completion, Water Yield and Water Quality Data for all Local Dug Wells and Private Wepo Toreva, Dakota and Morrison Formation Wells Completed Within or Adjacent to the Leasehold (Davis et al. 1963, McGavock et al. 1966, Navajo Nation, 1999 and PWCC, 1999)

Well Number	Location Coordinates* Northing	Easting	Well Depth (Ft)	Perforation Zone (Ft)	Aquifer Thickness (Ft) Aquifer	Static Water Level (Ft)	Rate (GPM)	Draw-Down (Ft)	Duration (Hrs)	Water Quality
Mission Well	-94841.0	34405.3	350	-	350, Wepo	-	-	-	-	-
2T-503	-63890.3	-35459.7	730	430-730	355, Toreva	359	11	90	1	Fair
4K-382	-72897.7	127686.2	191	70-191	121, Toreva	36	27	23	1	Good
4T-396	-90934.6	43649.7	500	200-336	488, Wepo	254	2	246	1	Good
4T-403	-47753.2	31550.0	510	395-510	68, Toreva	283	13	100	1.5	Good
4T-404	-36902.3	56248.9	540	480-540	220, Toreva	450	15	90	1	Fair
4T-406	-87822.0	29227.8	716	-	503, Wepo 211, Toreva	492	13	40	1	Good
4T-500	-73404.3	165573.4	205	Open Hole	145, Wepo	60	-	-	-	Fair
4T-510	-89778.0	55115.4	452	260-450	248, Toreva	281	27	140	1	Good
4T-511	-93832.6	15031.9	645	300-645	363, Toreva	308	16	205	1.2	Good
4T-512	-62017.5	57109.2	600	-	78, Wepo 328, Toreva	-	-	-	-	Good
4T-516	-91256.0	167097.0	-	-	-, Dakota	1050	-	-	-	-
4M-190	-49164.0	36246.2	15	Rock Cribbed	-, Alluvium	7	-	-	-	-
4M-27	-103120.0	48097.0	8	Masonry Cribbed	-, Alluvium	3.9	-	-	-	Good
Sagebrush Well	-52624.0	31669.2	13.5	Rock Cribbed	-, Alluvium	8.3	-	-	-	Fair
Grapevine Well	-44794.0	13101.7	-	Masonry Cribbed	-, Alluvium	-	-	-	-	-

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TABLE 2 (Cont.)

Aquifer, Well Completion, Water Yield and Water Quality Data for all Local Dug Wells and Private Wepo Toreva, Dakota and Morrison Formation Wells Completed Within or Adjacent to the Leasehold (Davis et al. 1963, McGavock et al. 1966, Navajo Nation, 1999 and PWCC, 1999)

Well Number	Location Coordinates* Northing	Easting	Well Depth (Ft)	Perforation Zone (Ft)	Aquifer Thickness (Ft) Aquifer	Static Water Level (Ft)	Rate (GPM)	Draw-Down (Ft)	Duration (Hrs)	Water Quality
4T-514	-92038.3	165235.6	430	-	416, Toreva	81	2	349	1.5	Fair
8T-504	-21737.0	66552.6	500	270-450	278, Toreva	218	30	125	.75	Fair-Good
8T-506	-7513.4	26416.0	552	70-552	376, Wepo	34	60	222	3	Fair
					174, Toreva					
4K-387	-91389.0	-19671.0	945	854-914	50, Dakota	450	6	495	2	Fair
					35, Cow Springs					
4K-407	-94937.0	103549.0	603	493-580	113, Dakota	445	20	70	-	Fair
4T-399	-65557.0	149056.0	1172	998-1172	202, Morrison	787	18	15	1	Fair
4T-402	-30479.0	44751.9	1300	Open Hole	95, Dakota	922	10	65	1.5	Fair
4T-503	-100710.0	80542.8	833	710-833	40, Dakota	490	10	110	1.75	Fair
					88, Cow Springs					
4T-504	-103990.0	127849.0	1125	975-1125	130, Morrison	999	6	90	.7	Fair
4T-508	-72750.0	-10121.0	1000	880-1000	80, Dakota	450	20	55	.8	Fair
					45, Cow Springs					
W00236110-D.24	-61795.0	78280.7	-	-	-, Wepo	-	-	-	-	-
Reed Well	-21135.9	46682.8	-	-	-, Alluvium	-	-	-	-	-

* Coordinates shown are based on PWCC's coordinate system

been abandoned or never existed. The following text includes a discussion of all 20 wells referenced above.

The eleven local wells on Drawing 85322 that have BIA field numbers are 4T-403, 4T-402, 4T-404, 8T-504, 8T-506, 4K-389, 4T-512, 4K-380, 4T-405, 4M-34 and 4M-190. Of these eleven wells, six are professed to be partly or wholly completed in the Wepo formation. Wells 8T-506, 4T-512 and 4K-380 were completed in both the Wepo and Toreva and most probably derived their yields from the Toreva aquifer. Wells 4K-389 and 4T-405 are reported as being completed in the Wepo aquifer only; however, their completion depths (417 and 436 feet) and perforation zones (370-403 feet and 375-436 feet, respectively) suggest that they may be partially open to the upper Toreva sandstone, especially considering the high degree of intertonguing between the two units. The Wepo formation ranges in thickness from 0 to approximately 350 feet across the Peabody leasehold. Wells 4M-34 and 4M-190 appear to be dug wells in the Wepo and/or alluvium. Other local wells with BIA field numbers that are located on or near the leasehold are 4T-403, 4T-404, and 8T-504. These wells are completed in the Toreva aquifer only. Well 4T-402, located between the east and west leasehold tracts, is completed in the Dakota aquifer.

Well 8T-506 is the only well reported as partly or largely completed in the Wepo aquifer that is located on the Peabody leasehold. The well (windmill) was dismantled prior to 1979 and abandoned in advance of mining. The status of the off-lease local wells completed in the Wepo aquifer is unknown, but it is assumed they are still operable.

Five other local wells that do not have BIA field numbers have been identified on or within 1 mile of the Peabody leasehold. These wells are: 1) Sagebrush Well, located in the alluvium on Yucca Flat Wash; 2) Reed Well, located in the alluvium near the mouth of Reed Valley Wash; 3) 8A-PHS-10 located in the alluvium along Coal Mine Wash near monitoring well #42; 4) 8APHS-15 presumed to be completed in the Wepo and/or Toreva and located along Coal Mine Wash north of the N-5 pit; and 5) Grapevine Well located in the alluvium on Moenkopi Wash approximately 1 mile SW of the leasehold boundary. To the best of Peabody's knowledge, most of these wells appear not to be in use. A majority of the wells probably had low yields, fair to poor water quality, collapsed, or required extensive maintenance and repair in the well bore or with the windmill portion of the wells.

In addition to the wells mentioned above, four other local wells are professed as being located on the leasehold (see Drawing 85322). These wells are: 1) WLKRPETRF Well,

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located east of the confluence of Yellow Water Canyon and Coal Mine Wash; 2) Well DM-19, presumably located southeast of WLKRPETRF Well; 3) Well DM-10, presumably located in Red Peak Wash above the J-7 pond; and 4) Well DM-11, presumably located in Red Peak Wash below Well DM-10 and flooded by the J-7 pond. Peabody has conducted extensive searches to find these undocumented wells. Excepting WLKRPETRF Well, nothing has been found to indicate these wells exist or existed at or in the vicinity of their presumed locations, and no completion information is available. WLKRPETRF Well was an oil exploration boring which has been abandoned. If any of the other 3 wells existed, they have been abandoned or removed, most probably due to low yields or poor water quality, flood flows, collapse, or would have required extensive renovation to provide a viable water supply.

Wells 8T-506 and 4T-403 were removed in advance of the mining operations in the N-6 and J-7 mining areas, respectively. Well 4T-404 will also have to be removed as mining advances in the J-19 mining area. Peabody will replace these three wells following completion of mining or at such time during mining that PWCC and the Tribes can reach agreement as to suitable replacement locations. These wells will be replaced in the same aquifers as they were completed in or in aquifers of at least the same quality and yield. The replacement wells will be located as proximate to their original locations as is feasible given the currently proposed mining disturbance. In the interim, Peabody is providing these local residents an alternative water supply in the form of standpipes located near the N-6 and N-14 mining areas. The water is of drinking water quality (N-aquifer water) and is available on a 24-hour basis.

Figure 2 shows all springs located within and around the Peabody leasehold that have USGS ID's, BIA ID's, Tribal names or PWCC ID's. Table 3 lists available information regarding coordinates, sources, yields and water quality for the 49 springs shown on Figure 2. Those springs shown on Figure 2 that occur within or immediately adjacent to the Peabody leasehold are shown on Drawing 85322. Since two of these springs are duplicates: Peabody spring site NSPG140 corresponds to spring DM-20; and Peabody spring site NSPG91 corresponds to spring 8A-144, there are actually 23 spring sites shown on Drawing 85322.

Extensive surveys of the water resources within and immediately surrounding the leasehold indicates that several of the springs located on Figure 2 and/or Drawing 85322 do not presently exist, occur only as damp spots, or are indistinguishable in baseflow reaches. This is not surprising as springs are very sensitive to climatic and ground water level fluctuations. Twelve persistent, flowing and sampleable springs presently exist on or just outside the leasehold. These springs include Peabody site numbers NSPG22, NSPG61,

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TABLE 3

Locations, Source, Yields and Water Quality for All Springs Existing Within or Adjacent to the Leasehold
Davis et al. 1963, Navajo Nation, 1999 and PWCC, 1999

Spring Number	Location Coordinates* Northing	Easting	Stratigraphic Unit Aquifer	Yield GPM	Water Quality
8A-119	-1684.1	2932.9	Toreva	-	Good
2A-50	-46057.0	-31982.0	Wepo	-	-
2A-52	-57217.0	-37275.0	Wepo	-	-
2A-54	-60439.0	-42567.0	Toreva	-	-
2A-7	-64696.0	-63507.0	Wepo	-	-
2A-8	-71369.4	-60400.8	Wepo	-	-
2A-55	-74590.9	-52116.8	Alluvium	-	-
2A-56	-94150.5	-52922.2	Toreva	3	Fair
2A-58	-69900.0	-30796.5	Alluvium	-	-
2A-59	-68377.9	-19325.8	Alluvium	-	-
2A-60	-62855.2	-12192.4	Alluvium	-	-
2A-61	-59288.5	-7129.9	Alluvium	-	-
S00236110-D.28	-31753.7	83181.1	Wepo		-
S00136110-E.38	8571.8	69264.5	Wepo	-	-
DM-6	-39438.5	73070.8	Wepo	-	Poor
Hogan Gulch Spg.	-5227.5	58090.3	Wepo	<0.1	Poor
Goat Spring #2	-5705.3	53074.3	Wepo	<0.1	Poor
4M-50	-90740.2	168422.6	Alluvium/Toreva	0.4	Fair

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TABLE 3 (Cont.)

Locations, Source, Yields and Water Quality for All Springs Existing Within or Adjacent to the Leasehold
Davis et al. 1963, Navajo Nation, 1999 and PWCC, 1999

Spring Number	Location Coordinates* Northing	Easting	Stratigraphic Unit Aquifer	Yield GPM	Water Quality
4M-60	-79193.2	-17600.0	Toreva	2	Good
4M-207	-91159.0	23820.2	Wepo	Dry	-
4M-26	-91389.1	47751.8	Wepo	-	-
4M-22	-93000.0	67311.3	Wepo	-	-
4M-23	-83220.1	89517.2	Wepo	Dry	-
4M-31	-66191.8	52123.9	Alluvium	Damp	-
4M-190A	-49163.6	36246.2	Wepo	2	Fair
4M-191	-41454.8	30148.2	Wepo	2	Fair
2A-45	-46977.5	9783.3	Alluvium	-	-
2A-47	-52040.0	3685.4	Alluvium	-	-
2A-44	-26152.4	15191.0	Wepo	-	-
8A-147	-24081.3	41078.6	Wepo	0.5	Bad
8A-149A	-19018.9	49362.6	Wepo	-	-
4K-348	-100312.9	170189.8	Toreva	0.1	Fair
4M-28A	-98856.4	33600.1	Wepo	3.0	Fair
NSPG91	-573.8	34078.2	Wepo	1.6-2.1	Fair
NSPG92	-33620.1	31946.8	Wepo	0-4.2	Poor
NSPG111	-5137.0	53970.4	Wepo	<0.1	Poor
NSPG140	7023.2	18215.9	Wepo	<0.1	Poor
NSPG147	-37980.9	26086.6	Wepo	0.6	Poor

TABLE 3 (Cont.)

Locations, Source, Yields and Water Quality for All Springs Existing
Within or Adjacent to the Leasehold
Davis et al. 1963, Navajo Nation, 1999 and PWCC, 1999

Spring Number	Location Coordinates* Northing	Easting	Stratigraphic Unit Aquifer	Yield GPM	Water Quality
8A-153	-14416.6	54655.2	Wepo	1.0	-
4M-9	-80357.6	121442.9	Toreva	6.0	Fair
8A-139	4452.5	24855.7	Wepo	1.0	Bad
8A-140	-1070.1	20598.6	Alluvium	-	Bad
8A-143	-3026.1	29688.0	Wepo	1.0	Fair
8A-145	1231.0	37051.6	Wepo	1.0	-
8M-141	-6592.8	24740.6	Alluvium	2.0	-
Forest Lake Spg.	-61873.1	77544.8	-	-	-
Pine Spring	25876.6	45901.5	Wepo	-	-
Great Spring	-33129.6	26933.2	Wepo	-	-
Sand Spring	-50446.8	21412.2	Wepo	-	Good

* Coordinates shown are based on PWCC's coordinate system

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NSPG91, NSPG92, NSPG111, NSPG140, NSPG147 ("Benally Spring"), NSPG149 ("Sand Spring"), NSPG151, NSPG162, Goat Spring #2 and Hogan Gulch Spring. One additional spring, Peabody Site NSPG97, was monitored until it was destroyed by mining at the N-14 coal resource area.

In the pit inflow and probable hydrologic consequences discussion in Chapter 18, it was concluded that no significant impacts in the form of significant diminution of local wells and springs would result from mining interception of portions of the Wepo aquifer. Drawdown resulting from pit pumpage has been minimal to date other than in the immediate area of the pits. Drawdown proximate to most current Wepo monitoring wells were only on the order of five feet or less. Only one spring (NSPG97) has been interrupted by mining and an alternative water supply in the form of impounded water around the N-14 mining area or the N-14 public water standpipe has been provided to mitigate this impact.

Pre-existing Ponds

Twenty-five pre-existing surface water structures have been documented or are purported to occur on or near the Black Mesa leasehold (see Drawing 85322). Peabody has conducted extensive field surveys and thorough reviews of the appropriate aerial photographs and topographic maps in an attempt to locate and describe these structures. This work was initiated in 1980 and intermittent field surveys have been continued. The kinds of structures found, viability for intended uses, and plans for protection and mitigation are discussed below.

Nine structures identified on Drawing 85322 could not be found or verified through field surveys and review of aerial photographs. These nine (DM-2, DM-8, DM-15, DM-16, 4M-107, 4M-118, 3855-2, 3855-3 and unnamed pond in Yellow Water Canyon Wash) have been noted and plotted as undocumented structures. As such, no protection or mitigation plan for these undocumented structures is proposed.

Two structures (DM-4 and 4M-38) shown on Drawing 85322 appear to be water spreader/erosion control structures with no ability to impound water. Structure DM-4 is completely silted in and non-functional. There is no protection or mitigation plan proposed for these structures.

Two structures (DM-3 and DM-5) shown on Drawing 85322 have breached embankments, appear to have been in this condition for some time and are not capable of impounding water. There is no protection or mitigation plan proposed for these structures.

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The remaining 12 surface water structures on Drawing 85322 (DM-1, DM-7, DM-9, DM-12, DM-13, DM-14, 4M-113, 3755-2, 3855-1, two unnamed ponds near windmill 8T-504 and an unnamed pond near Great Spring) presently exist and are reasonably functional or have been documented to have existed. All structures, excepting DM-1, DM-7 and DM-9, exist in areas where there will be no direct mining impacts to the physical structures themselves. In a few cases, very minor portions of the watersheds draining to these structures will be disturbed by mining. Additionally, no measurable mining impacts to the shallow ground water system are projected in Chapter 18 Probable Hydrologic Consequences in the vicinity of the 3 structures (unnamed ponds near Great Spring and windmill 8T-504 and structure DM-12) which may receive some ground water feed. Thus, no special protection or mitigation will be required other than for DM-1, DM-7 and DM-9. DM-1 will be removed by the Reed Valley Wash channel realignment, DM-9 will have a significant portion of its watershed truncated by mining, and DM-7 has been removed during the construction of temporary impoundment KP pond.

No special protection of the three structures that will, or have been impacted, by mining and associated activities is feasible. The loss of past and existing water supplies provided by these structures due to mining will be mitigated during the mining interval by existing sediment ponds. Several sediment ponds, possessing superior embankments and potential for impounding water, exist near the pre-existing structures. Mitigation for the loss of DM-1, DM-7, and DM-9 after mining will be accomplished by retaining permanent impoundments located in close proximity to the original structures in the postmining landscape. Postmining mitigation for these three structures is fully discussed in Chapter 18 (Removal of Pre-existing Surface Water Structures).

Peabody N-aquifer pumpage has been shown in Chapter 18 (Impact of Peabody Wellfield Pumpage on Regional Water Levels and Stream and Spring Flows) to have a minimal impact on the total available N-aquifer well water heights at the various Tribal communities within the portion of the N-aquifer influenced by the PWCC wellfield pumpage. Simulated drawdown in the N-aquifer from Peabody and community pumping has been performed using a 3-D numerical flow model (Chapter 18, PHC). Comparisons of these simulations indicate hundreds of feet of available water columns will remain above the top of the N-aquifer or production zones in local and regional community wells. Recent published reviews of annual USGS monitoring reports (e.g. Macy and Brown, 2011) and Peabody’s annual Hydrologic Data Reports indicate material damage to the N Aquifer hydrologic balance outside of PWCC’s permit area has not occurred (e.g., OSM, 2010). Thus the quantity and

quality of the N-aquifer water being used by local and regional water users is being protected.

Peabody is providing drinking quality water at two locations on the leasehold (see Chapter 19, Water Rights and Alternative Water Supplies). This water is supplied from the N-aquifer and is available on a 24-hour basis.

Following surface coal mining and reclamation activities, Peabody will seal and properly abandon all monitoring wells in the alluvial and Wepo aquifers and remove the surface installations and instrumentation. Sealing and abandonment procedures are described in Chapter 16. The final disposition of the Navajo Formation wells will be determined after consultation with the Tribes; however, they will be considered temporary structures unless approved by the regulatory authority as an element of the postmining land use plan. All wells will be properly cased, sealed and protected to prevent water quality contamination and to ensure the safety of people, livestock, fish and wildlife and machinery.

Alluvial Valley Floors

Introduction. The mining leases are drained by four main washes, all of which, including some of the larger tributaries to these washes, have alluvial material in and adjacent to the stream channels. Based on OSM's definition for intermittent channels, all tributaries and washes above the confluence of Coal Mine Wash with Moenkopi Wash whose watershed areas are greater than one square mile are intermittent. Below the confluence of Coal Mine and Moenkopi Wash for an approximate 2 mile distance, the channel of Moenkopi Wash intersects the water table and exhibits baseflow for extended periods of each year. This reach of Moenkopi Wash meets the hydrologic definition of intermittent as well as OSM's definition for intermittent which is based solely on watershed area regardless of the location of the water table relative to the channel bottom.

The precipitation events on the Black Mesa are cellular in nature and tend to be quite intense when they do occur. Downstream portions of the washes may flow while upstream reaches are dry. The same holds true for the major tributaries.

Related Studies. During 1980, Peabody Coal Company conducted studies to determine the presence of alluvial valley floors and define their characteristics and limits. The studies focused on: (1) the geomorphic mapping of the alluvium; (2) the surface- and ground-water quantity, quality and availability; and (3) vegetation and soils studies in the alluvial areas. A consultant and geologist with the Museum of Northern Arizona

border area. Mapping identified the contacts between and areal extent of alluvium, fan deposits and colluvium. The mapping was done using current color aerial photographs.

Soil and vegetation studies in the alluvial areas were performed during 1980 by Espey, Huston and Associates, Inc. (EHA), as part of their baseline studies for the Black Mesa leasehold. Their studies focused on evidence of flood irrigation, farming, and vegetation that would support or disprove classification of these alluvial areas as alluvial valley floors. The EHA work was superceded by the Intermountain Soils study performed in 1985 and referenced later in this discussion.

Peabody also surveyed vegetation in alluvial areas for background information in 1980. The surface- and ground-water hydrology of the alluvium and alluvial aquifer system has and continues to be studied by Peabody personnel as part of the ongoing hydrologic monitoring program. Other than the hydrology monitoring and the aforementioned consulting and PWCC studies, no other studies specific to AVF's have been performed on the leasehold. The results of all the studies are summarized in the following Section (Study Results and Discussions) and the 1985 IMS study results are presented in Attachment 1.

The only comprehensive land survey which has been completed in the vicinity of Peabody's leasehold was published in 1964. In that year, the Branch of Land Operations, Bureau of Indian Affairs, published soils and range inventories for the 1882 Executive Order Area. The survey maps showed the location of cultivated lands as well as range land.

In February, 1979, the Bureau of Indian Affairs, Flagstaff Administrative Office, published a sociocultural assessment of the livestock reduction program in the Navajo-Hopi Joint Use Area. The report was prepared by staff of the Northern Arizona University. The study provides insight as to the importance of rainfall on farming in the area.

Finally, during 1985, Intermountain Soils, Inc. performed a survey of phreatophytes and subirrigation on the Black Mesa leasehold and surrounding area (see Attachment 1). Study objectives included: (1) the location and observation of existing farming practices; (2) determination of irrigation or dryland farming; (3) characterization of irrigation practices; (4) documentation of evidence of any current or past subirrigated cultivation; and (5) characterization of natural vegetation communities in or near major drainages, including alluvial terraces, emphasizing occurrences and distributions of phreatophytes.

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Study Results and Discussions.

Geomorphic Mapping. Analysis of the mapping reveals that portions of the material mapped as alluvium do not extend very far onto the first terraces. The greatest continuous amounts of alluvium are between the channel meanders and along Dinnebito Wash. Most of the significant tributaries to the main washes consist of fan deposits. Colluvium comprises most of the material extending from the bordering bedrock units to the alluvium and fan deposits.

The mapping results suggest that the alluvium is not extensive along the principal washes and their tributaries. Dinnebito Wash has the largest amount of alluvium and a quite wide valley for the small degree of meandering it presently exhibits. It is probable that Dinnebito Wash is a remnant part of the ancient San Juan drainage network. The other washes exhibiting substantial alluvium and saturated alluvial cross sectional areas are Reed Valley and lower Coal Mine Washes and Moenkopi Wash, especially in the two-mile zone just downstream from the leasehold (see Attachment 13, Chapter 15). In summary, the alluvium constitutes only small, narrow stretches of land adjacent to the washes. Most of the headwater reaches of all washes and the lesser side tributaries contain little to no alluvial water.

Domestic Farming. In Peabody's 1980 survey, the few existing farm plots were found to be limited primarily to meandering sections of the washes. These locations were chosen to take advantage of the limited availability of cultivatable soils and minimum slopes. The flatter slopes on the terraces allow for greater infiltration and less runoff during the erratic rainfall events experienced on Black Mesa. The potential for farming based strictly on the availability of alluvial material would be limited to thin strips of land adjacent to the channels and isolated meanders.

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During 1980, Peabody personnel measured the actual areas of each farm plot (corn and squash fields) and determined that there were 138 acres (see Table 4) out of the 64,858 acres (.2 percent) within the leasehold that were cultivated in some fashion. This is well below the 60 acres out of 1,000 acres suggested by Senator Melcher in 1977 as a criterion for the negligible impact exemption (123 Cong. Rec. §8144, dail. ed. May 20, 1977).

The BIA inventory published in 1964 encompassed 1,822,208 acres of reservation land. The inventory showed 1,815,930 acres to be range land and 6,278 acres or .34 percent of the

TABLE 4

Agricultural Plot Area Survey

Plot Number	Area
1	182,756 ft^2
2	122,675 ft^2
3	82,944 ft^2
4	240,590 ft^2
5	137,270 ft^2
6	99,698 ft^2
7	131,225 ft^2
8	375,463 ft^2
9	96,877 ft^2
10	77,841 ft^2
11	152,686 ft^2
12	54,056 ft^2
13	22,500 ft^2
14	1,297,891 ft^2
15	82,944 ft^2
16	96,410 ft^2
17	301,401 ft^2
18	103,041 ft^2
19	207,253 ft^2
20	437,582 ft^2
21	124,256 ft^2
22	156,222 ft^2
23	122,150 ft^2
24	97,344 ft^2
25	90,450 ft^2
26	67,340 ft^2
27	143,452 ft^2
28	29,756 ft^2
29	29,498 ft^2
30	42,539 ft^2
31	105,462 ft^2

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Total: 5,311,572 ft^2 = 138 Acres

Revised 12/01/88

study area to be cultivated. This figure is consistent with the .2 percent of Peabody's leasehold which showed evidence of cultivation during or before the field survey conducted in the spring of 1980.

The authors of the 1979 BIA report found that agriculture throughout the entire Executive Order Area was not significant enough to be a study element in assessing the social-cultural impacts of the livestock reduction program addressed in that report. Rainfall was determined to be very important in farming success or attempts in the area. The following statement was made on Page 73, "The number of households who farm also fluctuates periodically with good and bad years of rainfall. One respondent, for example, said that "members of the household did not farm in 1977 because there was not enough rain".

Soil and vegetation studies in alluvial areas on the Black Mesa leasehold performed by EHA in 1980 found very few farm plots, and those that existed were very small. These plots were entirely dependent on rainfall infiltration and were used to support only single or small numbers of families.

Hydrology and Flood Irrigation. The Peabody survey conducted in 1980 found no evidence of past or present flood irrigation. The BIA mapped all structures including dikes and diversions. No structures supporting flood irrigation were identified in the Black Mesa area. Further, EHA found no evidence of flood irrigation. The latest survey, (Attachment [illegible]), conducted by Intermountain Soils, Inc. during 1985, corroborates the conclusions reached in the previous studies. The report states "No evidence of past or present flood irrigated cultivation has been discovered within the Black Mesa lease area".

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A discussion of hydrologic characteristics that precludes the use of flood irrigation in the alluvial areas on the Black Mesa leasehold follows. Storm events causing significant runoff on the Black Mesa are very infrequent. This factor alone would preclude flood irrigation without the use of large retention ponds and some means of pumping water from them. Only two storms of any significance occurred during the summer and fall of 1980 and 1985. During the period from 1/1/81 to 1/1/85, 1,000 cfs or greater flows occurred only 15 times at the fourteen stream monitoring sites. This equates to approximately one 1,000 cfs flow per station per every four years. Peak flows ranged from 1,160 to 4,350 cfs and peak stage heights from approximately 10.0 to 8.0 feet at Sites 34 and 25, respectively. These flow stage heights are 30 and 15 percent of the terrace heights above Sites 34 and 25, respectively. Most of the first terraces above the principal washes on Black Mesa are

at elevations of at least 15 to 20 feet above the channel bottoms. Typical first terrace heights in comparison to peak flow stage heights would preclude economical flood irrigation practices. An additional problem would be the high TSS concentrations in the storm runoff. Sediment load monitoring from 1980 through 1985 at Stations 15, 16, 18, 35 and 50 indicates that sediment loads of approximately 100,000 tons/day are not uncommon. Sediment loads as high as 2,700,000 have been documented.

A portion of the alluvial aquifers are saturated and they remain so throughout the year. With the network of 46 alluvial wells, water level changes in response to daily evapotranspiration, storm runoff events and long dry spells have been monitored. Five-year hydrographs for alluvial wells in each wash and major tributary are presented in Attachment 12, Chapter 15. Typically, monitoring wells show gradual water level declines in the spring and late fall and water level shallowing during the summer monsoon period and during the wet winters. Recharge is from the Wepo aquifer and runoff or snowmelt seepage through the channel beds. Alluvial aquifer discharges are caused by a combination of ground-water throughflow and evapotranspiration.

Depths to water below the channel beds are reasonably shallow; however, as one moves away from the channel and onto the first terraces, water level depths increase markedly due to the abrupt changes in land elevation (see Attachment 13, Chapter 15). Of the alluvial wells that are continuously monitored, four (Nos. 33, 83, 84 and 95) show distinct diurnal fluctuations of approximately .1 foot during the summer and early fall. This type of pattern is indicative of evapotranspiration effects. This does establish the fact that some phreatophytes exist and are supported by natural subirrigation; however, it will be pointed out later in this discussion that their abundance and extent is quite limited and highly dependent on depth to water table. The alluvial ground water quality is fair to poor. According to Davis and DeWiest (1966), the average total dissolved solids, sodium and sulfate concentrations of 6016, 511 and 3321 mg/l respectively (see Chapter 15) would give the alluvial water an irrigation water classification of poor. Tables 5 and 6 have been included to document the poor water quality of the alluvial ground water. Table 5 was prepared in 1976 by M.K. Botz and Dick Pedersen of the Water Quality Bureau, Montana Department of Health and Environmental Sciences, Helena, Montana. This table shows those concentrations of chemical constituents that are not known to cause adverse environmental effects for the uses specified. Table 6 is a compilation for the period 1980 through 1985 of those chemical parameters, determined from monitoring of alluvial ground water and streamflow water quality, whose average concentrations exceed the recommended concentrations for various water uses in Table 5.

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Table 5 Water Quality Criteria

Concentration Listed Known Not To Cause Adverse Effects Unless Specified

ELEMENTS	Public H2O Supply	Stock Usage	Irrigation Long Term	Freshwater Aquatic Life Affect	Freshwater Aquatic Life No Affect	US Avg. Conc.	Montana Average	Montana Range
Aluminum	1 - 5	5	1	0.07	0.005	0.074	0.2	<.1-2.8
Antimony				3.5				
Arsenic	0.05	0.2	0.1	1.1	1	0.043	0.025	<.001-.09
Barium	1		1	12	5		<0.1	<.1-.4
Beryllium			0.1	0.15	0.011	0.0002	<0.005	<.005-.01
Boron	5	5	0.75	5000	2000	0.101	0.1	<.1-13
Bromine				10	1			
Cadmium	0.01	0.05	0.01	0.0005	0.0004	0.0095	0.006	<.002-.055
Calcium		1000				57.1	65.3	15-216
Cerium				0.14				
Chlorine	2		3	0.03	0.002			
Chromium	0.05	1	0.1	1.2	0.05	0.0097	<0.02	<.02-.02
Cobalt		1	0.05	10	1	0.001	<0.03	<.03-.03
Copper	1	0.5	0.1	0.025	0.02	0.0138	0.01	<.01-.23
Gold				0.4				
Iodine						0.046		
Iron	0.3		5	0.2		0.044	<0.05	<.05-.29
Lanthanum				0.15				
Lead	0.05	0.1	5	0.1	0.03	0.023	<0.05	<.05-.07
Lithium	5		0.075					
Magnesium	30 - 125	500	24	300		14.3	17	<1-175
Manganese	0.05	10	0.2	2.2	1	0.029	<0.01	<.01-.1
Mercury	0.002	0.01		0.008	0.00005			
Molybdenum			0.01	70		0.068	0.03	<.001-.299
Nickel	1		0.2	5		0.019	<0.02	<.02-.03
Oxygen	>= 4						10.2	7.4-22
Palladium				7				
Potassium	340			50		4.3	3.1	<.1-13
Radium						5.00E-11		
Rubidium				14				
Selenium	0.01	0.05	0.02	2		0.000016	0.004	<.002-.014
Silver	0.05		0.05	0.003		0.0026	<0.05	
Sodium		2000		500		55.1	40.6	1-530
Strontium						0.22	0.2	<.1-1
Sulfur				10				
Thallium					0.05			
Thorium				0.4				
Tin			40	6	1.2			
Titanium			12	2				
Tungsten				110				
Uranium	0.5 - 1.0			2.8				
Vanadium		0.1	0.1	4.8		0.04	0.018	<.001-.16
Zinc	5	25	2	0.01	0.003		0.03	<.01-.17
Zirconium				14		0.052		

All values in mg/l unless indicated

COMPOUNDS	Public H2O Supply	Stock Usage	Irrigation Long Term	Freshwater Aquatic Life Affect	Freshwater Aquatic Life No Affect	US Avg. Conc	Montana Average	Montana Range
Acidity		170						
Alkalinity		170					134	57-300
Ammonia	0.5			0.11	0.02			
Carbonate	20						0.11	0-13
Bicarbonate	150		172			90	158	61-500
Carbon Dioxide								1.2-13
Chloride	250	1500	100			9	10.9	<.5-74
Cyanide	0.01		0.2	0.05	0.005			
Fluoride	1.4-2.4	1	1	2.3	1.5		0.43	<.05-2.4
Hardness	150		70				191	63-1260
MBAS	0.5					<0.1		<.01-17
Nitrate N	10	100				0.9	0.1	<.01-.69
Nitrite N	1	10					<0.01	<.01-.02
Oil & Grease	0	30		0.39				
Phenol	0.001	1000	50	0.079				<.001-8.4
Phosphate	50		60		0.01	0.087	0.013	<.001-.05
PCB				0.00001	0.000002			
RSC			1.25					
Silica	50		10-50.				8	1.0-32
SAR			8				1.2	.1-7.4
Sulfate	250	500	200			32	130	<10-1254
Sulfide	0.2			0.017	0.002			
PHYSICAL								
Color (units)	75						7	<5-45
Conductance (umho/cm)			750				531	128-2269
pH	5.0-9.0		4.5-9.0		6.5-8.5		8.1	6.7-9.4
TSS					25			
TDS	500	2860	500				330	82-2361
Temperature							9.5	0-27
Turbidity	1-5.						325	7.5-22000
%Gas Saturation					110%			

TSS=Total Suspended Solids; TDS=Total Dissolved Solids; MBAS=Methylene Blue Active Substance; PCB=Polychlorinated Biphenyls; RSC=Residual Sodium Carbonate; SAR=Sodium Adsorption Ratio

Table 5 Water Quality Criteria (cont.)

The following references were used by Botz and Pederson, 1976 in developing the water quality criteria summarized in Table 5.

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14. PCB in Water: A bibliography, Vol. 2 (1975). U S Dept. of the Interior. Office of Water Research and Technology.
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TABLE 6

Chemical Parameters in the Alluvial Ground Water and Streamflows
Which Would Render the Water Quality Classification Poor to Unsuitable
for Livestock and Irrigation Water Use

ALLUVIAL WELLS

Well No.	Stock	Irrigation
13	Alk., V	Alk., Cond., Mn, V, Mo, SO_4, TDS
17	Alk., V	Alk., Cond., Mn, V, Mo, SO_4, TDS
19	Alk., V	Alk., Cond., V, Mo, SO_4, TDS
23	Alk., V	Alk., Cond., Mn, V, Mo, SO_4, TDS
27	Alk., V	Alk., Cond., Mn, V, Mo, SO_4, TDS
29	Alk., V, SO_4	Alk., Cond., V, Mo, SO_4, TDS
32	Alk., V	Alk., Cond., Mn, V, Mo, SO_4, TDS
68	Alk., V	Alk., Cond., Mn, V, Mo, SO_4 TDS
69	Alk., V	Alk., Cond., V, Mo, SO_4, TDS
70	Alk., V, SO_4, TDS	Alk., Cond., Mn, V, Mo, SO_4, TDS
71	Alk., Pb, V, TDS	Alk, Cond., V, Mo, SO_4, TDS
72	Alk., Pb, V, SO_4, TDS	Alk., Cond., Mn, V, Mo, SO_4, TDS
73	Alk., V, SO_4, TDS	Alk., Cond., Mn, V, Mo, SO_4, TDS
74	Alk., V, TDS	Alk., Cond., Mn, V, Mo, So_4, TDS
75	Alk., Pb, V	Alk., Cond., Mn, V, Mo, SO_4, TDS
76	Alk, V	Alk., Cond., V, Mo, SO_4, TDS

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TABLE 6 (Cont.)

Chemical Parameters in the Alluvial Ground Water and Streamflows Which Would Render the Water Quality Classification Poor to Unsuitable for Livestock and Irrigation Water Use

ALLUVIAL WELLS

Well No.	Stock	Irrigation
77	Alk., Pb, V	Alk., Cond., Mn, V, Mo, SO_4, TDS
79	Alk., V	Alk., Cond., V, Mo, SO_4, TDS
80	Alk., V	Alk., Cd, Cond, Mn, V, Mo, SO_4, TDS
81	Alk., V	Alk., Cond., Mn, V, Mo, SO_4, TDS
82	Alk., V, SO_4	Alk., Cond., V, Mo, SO_4, TDS
83	Alk., Pb, V	Alk., Cond., V, Mo, SO_4, TDS
84	Alk., Pb, V	Alk., Cond., V, Mo, SO_4, TDS
87	Alk., V	Alk., Cond., Mn, V, Mo, SO_4, TDS
88	Alk., V	Alk., Cond., Mn, V, Mo, SO_4, TDS
89	Alk., V	Alk., Cond., Mn, V, Mo, SO_4, TDS
93	Alk., Pb, V	Alk., Cond., Mn, V, Mo, SO_4, TDS
94	Alk., Pb, V	Alk., Cond., V, Mo, SO_4, TDS
95	Alk., Pb, V	Alk., Cond., Mn, V, Mo, SO_4, TDS
96	Alk., V	Alk., Cond., Mn, V, Mo, SO_4, TDS
98	V, SO_4, TDS	Alk., B, Cond., Mn, V, Mo, Ni, SO_4, TDS
99	V, SO_4, TDS	Cond., V, Mo, SO_4, TDS
100	Alk., V, SO_4, TDS	Alk., Cond., Mn, V, Mo, SO_4, TDS

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TABLE 6 (Cont.)

Chemical Parameters in the Alluvial Ground Water and Streamflows
Which Would Render the Water Quality Classification Poor to Unsuitable
for Livestock and Irrigation Water Use

ALLUVIAL WELLS

Well No.	Stock	Irrigation
101	Alk., Pb, V, SO_4, TDS	Alk., Cond., Mn, V, Mo, SO_4, TDS
102	Alk., V	Alk., Cond., Mn, V, Mo, SO_4, TDS
103	Alk., V	Alk., Cond., V, Mo, SO_4, TDS
104	Alk., V	Alk., Cond., Mn, V, Mo, SO_4, TDS
105	Alk., V	Alk., Cond., Mn, V, Mo, SO_4, TDS
106	Alk., V	Alk., Cond., Mn, V, Mo, SO_4, TDS
107	Alk., Pb, V, SO_4, TDS	Alk., Cond., Mn, V, SO_4, TDS
108	Alk., V	Alk, Cond., Mn, V, Mo, SO_4, TDS
109	Alk., V	Alk, Cond., Mn, V, Mo, SO_4, TDS

STREAMFLOWS

Stream Station No.		
14	V	Mn, V, Mo, SO_4, TDS
	Alk., V	Alk., Cond., Mn, V, Mo, SO_4, TDS
25	Alk., V	Alk., Cond., Mn, V, Mo, SO_4, TDS
26	Alk., V	Alk., Cond., Mn, V, Mo, SO_4, TDS
85	V	Mn, V, Mo
155	V	Cond., V, Mo

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TABLE 6 (Cont.)

Chemical Parameters in the Alluvial Ground Water and Streamflows Which Would Render the Water Quality Classification Poor to Unsuitable for Livestock and Irrigation Water Use

STREAMFLOWS

Stream Station No.	Stock	Irrigation
15	Alk., V	Alk., Cond., Mn, V, Mo, SO_4, TDS
16	V	Cond., Mn, V, Mo
34	Alk., V	Alk., Cond., V, Mo, SO_4, TDS
35	V	Cond., Mn, V, Mo, SO_4, TDS
37	Alk., V	Alk., Cond., V, Mo, SO_4, TDS
50	Alk., V	Alk., Cond., V, Mo, SO_4, TDS
78	V	Cond., V, Mo, SO_4, TDS
157		Mn, Mo

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Vegetation. Vegetation surveys performed by Espey, Huston and Associates (EHA) in 1980 determined the presence of the phreatophytes tamarisk, greasewood and salt cedar; however, these plants were primarily limited to areas along middle and lower Moenkopi and lower Coal Mine Wash. Where the phreatophytes were found, they tended to be grouped into clusters and extended away from the channels only some 30 to 40 feet. Their conclusion was that the phreatophytes were limited to the active floodplain zones adjacent to the washes where a thin soil veneer had formed over the coarser alluvial materials. They felt the limits of the phreatophytes away from the active channels also marked the limits of areas exhibiting subirrigation potential.

During 1985 Intermountain Soils, Inc., identified two natural vegetation types in the valley bottoms within the study areas (Attachment 1). They are a mixed shrub type and a riparian type dominated by salt cedar. Species classified in both types can be found in Tables 1 and 2 of Attachment 1.

The IMS, Inc. report found that three of the species that may occur as phreatophytes in the coal regions of the western U.S. (according to "Alluvial Valley Floor Identification and Study Guidelines", OSM, 1983) were found in either the riparian or mixed shrub vegetation types. However, IMS concluded that the presence of greasewood and four-wing saltbush on the alluvial terraces above the active drainages and flood-plains does not indicate phreatic conditions that would enhance subirrigation. The only true phreatic indicator on the leasehold is salt cedar and it was only found adjacent to the active channel waterlines (see Figure 3), not on the terraces.

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Average Annual Water Yields. A final concept to be discussed is average annual water yields. An average annual runoff map for the different regions of Arizona has been developed by the USGS. This map, showing isopleths of average annual runoff, is presented in the 1969 Arizona Bureau of Mines Bulletin 180, Mineral and Water Resources of Arizona (Figure 4).

For the Peabody leasehold, average annual runoff values range from .5" to 1.0". Using the data presented by Sellers and Hill (1977), the percentage of the average annual rainfall that occurs during the 5-month growing period in northeastern Arizona is 51%. Multiplying this percentage by the average annual yield values gives average 5-month yield values of .255" to .51". Assuming uniform runoff over the four principal washes draining the leasehold, average 5-month yields have been calculated and are presented in Table 7.

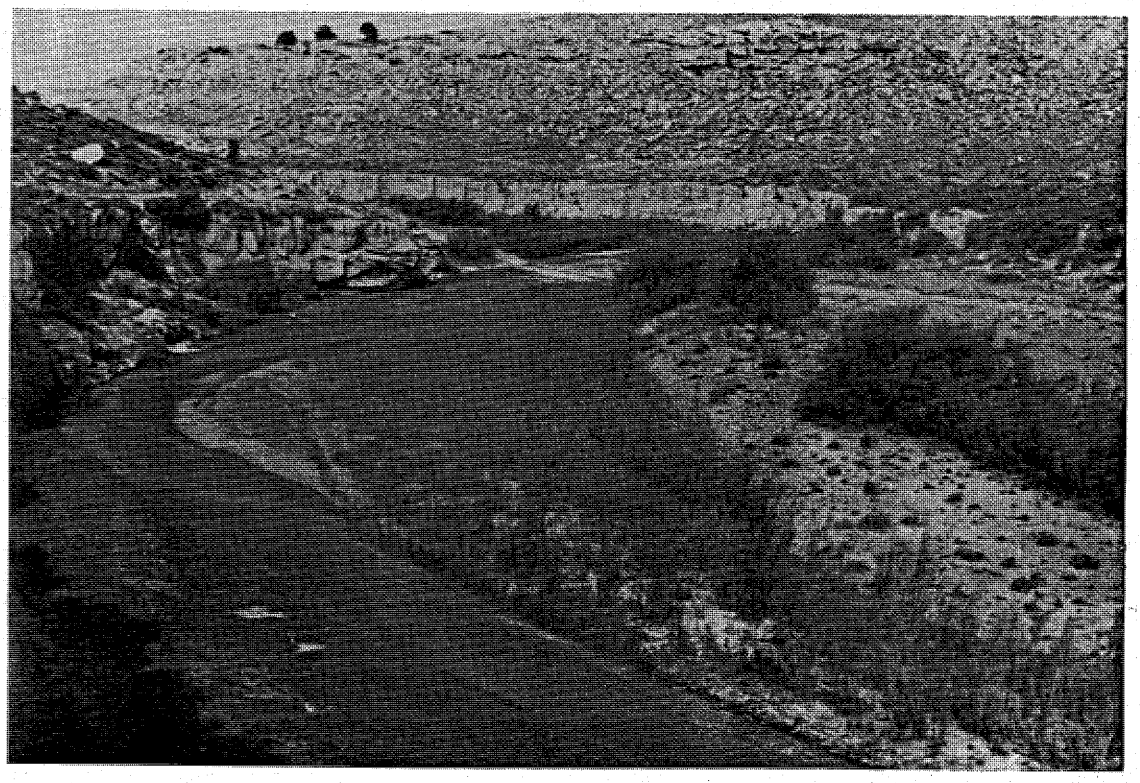

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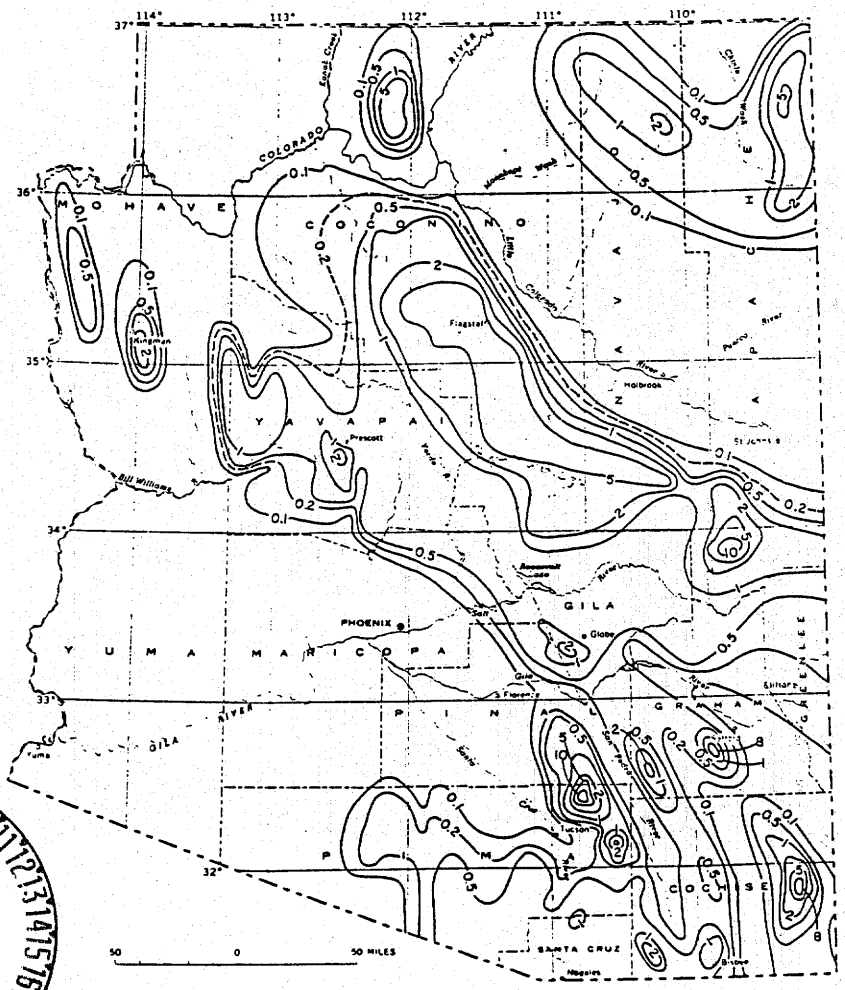
Figure 3

Typical Location of True Phreatophytes Adjacent
to the Active Channel Waterline



EXPLANATION

0.5

ISOPLETH OF AVERAGE ANNUAL RUNOFF, IN INCHES
DASHED WHERE INFERRED

FIGURE 4 —Average annual runoff in Arizona.

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TABLE 7

Five Month Water Yields for the Principal Washes on the Leasehold

Watershed	Drainage Area (Square Miles)	Average 5-Month Yield Range (Acre Feet)
Yellow Water Canyon Wash	41.7	567-1134
Coal Mine Wash	43.1	586-1172
Moenkopi Wash	121.0	1646-3291
Dinnebito Wash	34.8	473-947

Rough estimates of the total acreage on terraces and flood plains within the Peabody leasehold were made using the 1"=1000' scale alluvial deposits maps. The area estimates are shown in Table 8 below.

TABLE 8

Terrace and Floodplain Acreages on the Leasehold

Watershed	Terrace Acreage	Total Flood Plain Acreage
Yellow Water Canyon Wash	1240	1860
Coal Mine Wash	763	1745
Moenkopi Wash	1615	8160
Dinnebito Wash	1263	1894

A comparison of Table 7 and Table 8 indicates that there is insufficient runoff to meet the OSM minimum requirement of 2 acre-feet of water for each acre of land to be irrigated sometime during the period May 1 to September 15 for more than one-third of all years (refer to OSM Alluvial Valley Floor Guidelines, June, 1980).

Conclusion. Peabody has investigated the possibility of past or present flood irrigation within and adjacent to the Black Mesa leasehold. Results of these investigations yielded no evidence that flood irrigation is or has been practiced on the leasehold or in the immediate vicinity. Farm plots have been found, but rely solely on precipitation

infiltration for crop growth. The nature of precipitation patterns, surface-water occurrence and quality, ground-water quality and availablity, and deeply incised active channels precludes the use of either flood irrigation or subirrigation for cultivation. Vegetation studies have documented the existence of phreatophytes on the leasehold; however, true phreatophytes (salt cedar) are located only at the active channel waterlines and not on the terraces. This confirms that crops grown on the terraces are totally reliant on rainfall, not subirrigation. Finally, agricultural practices in alluvial areas on and adjacent to the leasehold are very limited and of little significance. Thus, it is concluded that alluvial valley floors, in the true sense of the definition (geomorphic and water availability criteria), do not exist on or immediately adjacent to the leasehold.

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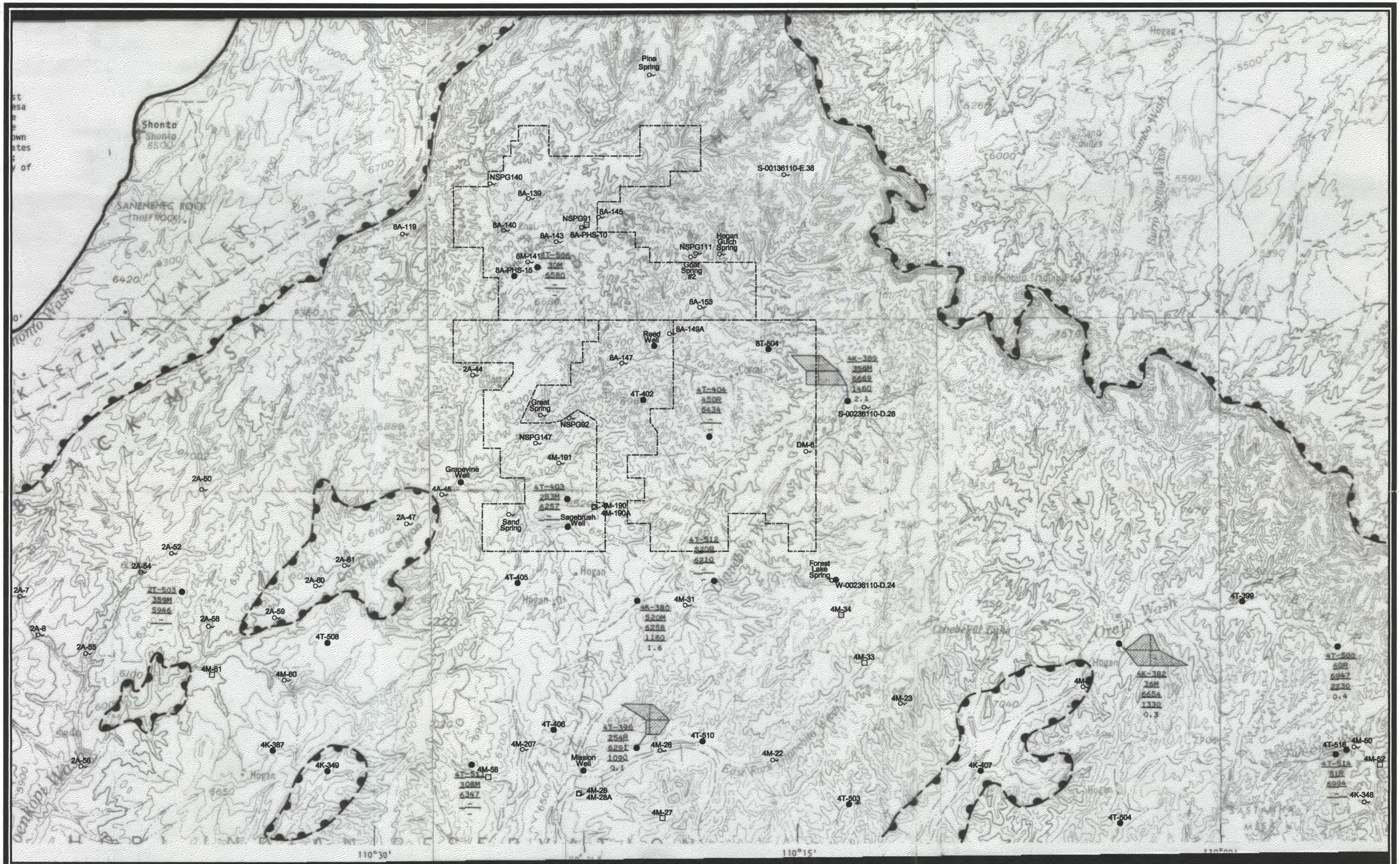

PEABODY WESTERN

1 0 1 2 Miles

Spring and Well Locations

- Dug Well
- Spring
- Dug Well developed from Spring
- Dakota, Toreva and/or Wepo Well
- Lease Line

Figure 2

PRIVATE WELLS AND SPRINGS COMPLETED IN THE SHALLOWER AQUIFERS WITHIN AND ADJACENT TO THE MINING LEASE (LEVINGS AND FARRAR, 1977, COOLEY ET AL, 1966, NAVAJO TRIBE, 1999)

Figure 2

Environmental Building, Black Mesa Complex
PO Box 625, Kayenta, Arizona 86033

Produced For:	Ted Smith	Map By:	J. Hamilton
Map Scale:	1:125,000	Contour Interval:	200 Feet (Supplemental Reserve 100 Feet)
Photo Date:		Photo Resolution:	N/A
c:\hamiltonprojects\wells99.apr		Plot Date:	Thursday June 10, 1999

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ATTACHMENT 1

Phreatophyte and Subirrigation Survey

of the

Black Mesa Lease Area

JAN 5 1989

ATTACHMENT 1

Phreatophyte and Subirrigation Survey

of the

Black Mesa Lease Area

INTERMOUNTAIN SOILS

PHREATOPHYTE AND SUBIRRIGATION SURVEY OF THE BLACK MESA LEASE AREA

PURPOSE AND METHODS

In June 1985, a field reconnaissance survey was conducted along the major drainages and associated terraces of the Black Mesa lease area. The objectives of the study were: 1) to locate and observe existing farming practices within the lease area and to determine whether farming is irrigated or dryland; 2) to characterize irrigation practices, if any; 3) to look for evidence of any current or past cultivation under flood irrigation; 4) to characterize the natural vegetation communities in or near major drainages, including alluvial terraces above major drainages, especially emphasizing occurrences and distributions of potentially phreatophytic plant species.

Major drainages were initially reconnoitered during which geomorphic features, farming practices, and presence of phreatophytes were noted. On the basis of these initial observations, locations were selected for more intensive investigation. At these locations, floodplains and alluvial terraces were traversed on foot, and observations pertaining to the objectives of the study were noted.

RESULTS AND DISCUSSION

Most of the valley bottoms observed in this survey are deeply dissected by their stream channels, with the first terrace five to more than 20 feet above the active channel. The active channel area consists of the ephemeral stream course and the current floodplain. Stability of the terrace banks is quite variable with some nearly perpendicular and others showing signs of slumping.

Several small cultivated dryland plots are scattered throughout the lease area, all of which are located on alluvial terraces adjacent to active drainage channels and floodplains. These plots are all family operated and non-commercial. The predominant crop is corn. No evidence of subirrigation on the terraces was found. No evidence of past or present flood irrigated cultivation has been discovered within the Black Mesa lease area.

Two natural vegetation types were identified in the valley bottoms. One is a riparian type, dominated by an overstory of salt cedar (*Tamarix pentandra*), and is generally confined to

the current floodplain. The other is a mixed shrub type characteristic of terraces above the drainage channel floodplains. Riparian vegetation occurs along the middle and lower Moenkopi and the lower Coal Mine Washes. A few small reaches of riparian vegetation were found in the middle and lower parts of Red Peak Valley and Yucca Flat Wash. Populations of riparian vegetation were also found in discontinuous areas in the middle and lower portion of Reed Valley. These areas are ten to 20 feet wide and range from only a few yards up to a half mile or more in length. Primarily found on recent alluvial deposits, these areas are generally oblong and encompass from one to five acres. A map showing locations of riparian vegetation within the Black Mesa lease area accompanies this report.

Species composition of these two vegetation types is shown in Tables 1 and 2. The salt cedar type is dominated by salt cedar and greasewood (*Sarcobatus vermicalatus*), accounting for 37 percent and 13 percent of the total vegetation cover, respectively. Forbs comprise 29 percent of the total vegetation cover and grasses 12 percent. In the mixed shrub type, shrubs comprise 51 percent of the total vegetation cover. The dominant species are big sagebrush (*Artemisia tridentata*) and four-wing saltbush (*Atriplex canescens*). Accounting for 38 percent of the total vegetation cover, grasses are relatively more abundant in the mixed shrub type in comparison to the salt cedar type.

The Office of Surface Mining has published a guideline on alluvial valley floors which lists plant species from the coal regions of the western United States which may occur as phreatophytes (OSM 1983). Three species from this list are found in the riparian and mixed shrub vegetation types described above. These are four-wing saltbush, greasewood and salt cedar. Four-wing saltbush and greasewood occur in both vegetation types; salt cedar occurs only in the salt cedar type. Greasewood and four-wing saltbrush can tolerate both arid and moist sites. Salt cedar is the only one of these three species which may be considered reliably indicative of the existence of a near-surface phreatic zone. In addition, the species composition of the salt cedar vegetation type further suggests that this type is a true riparian community, while the mixed shrub type is not. Grass species in the salt cedar vegetation type, such as salt muhly (*Muhlenbergia squarrosa*) and weeping alkali grass (*Puccinellia distans*), are indicative of high salinity and poor drainage. The mixed shrub type, on the other hand, has grass species such as sand dropseed (*Sporobolus cryptandrus*) and galleta (*Hilaria jamesii*) which require well drained soils. On the Black Mesa lease area, riparian vegetation is limited to sites along the bottoms of washes and on narrow sandbars. Typically, riparian expressions are found at the water line or where the water

table is relatively high. The salt cedar vegetation type is not found on terraces above active drainage channels. It is concluded from these observations that the occurrence of the shrub species greasewood and four-wing saltbush on the alluvial terraces above the active drainages and floodplains within the Black Mesa lease area is not indicative of phreatic conditions or subirrigation. Finally, there is no known past or present irrigated agricultural production anywhere within the lease area.

REFERENCE

U.S. Department of the Interior, Office of Surface Mining Reclamation and Enforcement. 1983. Alluvial valley floor identification and study guidelines. Washington, D.C.

Table 1. Species composition of the salt cedar vegetation type.

Scientific name	Common name	Percent composition
Grasses		
Agropyron smithii	Western wheatgrass	1
Bromus tectorum	Cheatgrass	3
Distichlis spicata ssp. *divaricata*	Desert saltgrass	2
Muhlenbergia squarrosa	Salt muhly	1
Puccinellia distans	Weeping alkali grass	1
Sitanion hystrix	Bottlebrush squirreltail	4
Forbs		
Ambrosia acanthicarpa	Annual burweed	2
Chaenactis stevioides	False yarrow	1
Cirsium vulgare	Thistle	2
Cryptantha crassisepala	Hairy cryptantha	T
Erigeron divergens	Spreading fleabane	T
Heterotheca villosa	Golden aster	3
Hymenopappus filifolius	Fineleafed hymenopappus	T
Lappula redowskii	Stickseed	3
Leucelene ericoides	Small aster	1
Marrubium vulgare	Common hoarhound	1
Mentzelia pumila	Evening star	1
Oenothera sp.	Evening primrose	1
Psilostrophe tagetina	Paperflower	2
Sphaeralcea coccinea	Scarlet globemallow	3
Senecio spartioides	Butterweed	3
Suaeda torreyana	Torrey seepweed	3
Other forb spp.		3
Shrubs		
Atriplex canescens	Four-wing saltbush	2
Chrysothamnus nauseosus	Rubber rabbitbrush	6
Lycium pallidum	Wolfberry	1
Sarcobatus vermiculatus	Greasewood	13
Tamarix pentandra	Salt cedar	37

Table 2. Species composition of the mixed shrub vegetation type.

Scientific name	Common name	Percent composition
Grasses		
Agropyron smithii	Western wheatgrass	6
Aristida fendleriana	Fendler threeawn	4
Bouteloua gracilis	Blue grama	6
Bromus tectorum	Cheatgrass	7
Distichlis spicata ssp. *divaricata*	Desert saltgrass	1
Hilaria jamesii	Galleta	4
Oryzopsis hymenoides	Indian ricegrass	1
Sitanion hystrix	Bottlebrush squirreltail	3
Sporobolus airoides	Alkali sacaton	2
Sporobolus cryptandrus	Sand dropseed	3
Stipa neomexicana	New Mexico feathergrass	1
Forbs		
Astragalus ceramicus	Painted milkvetch	2
Descurainia pinnata	Tansy mustard	2
Lappula redowskii	Stickseed	2
Oxytropsis lambertii	Lambert loco	1
Sphaeralcea coccinea	Scarlet globemallow	2
Sisymbrium altissimum	Tumbling hedge mustard	2
Shrubs		
Artemisia nova	Black sagebrush	3
Artemisia tridentata	Big sagebrush	11
Atriplex canescens	Four-wing saltbush	10
Atriplex confertifolia	Shadscale saltbush	2
Chrysothamnus nauseosus	Rubber rabbitbrush	4
Chrysothamnus vicidflorus	Douglas rabbitbrush	8
Gutierrezia sarothrae	Broom snakeweed	4
Senecio douglasii	Douglas groundsel	2
Sarcobatus vermiculatus	Greasewood	7