The Source of Water for Nevada's Ash Meadows Springs

Lisa L. Stillings
U.S. Geological Survey, MS-176
University of Nevada Reno
Reno, NV 89557
stilling@usgs.gov

Ash Meadows National Wildlife Refuge is a true oasis in Nevada's Amargosa Desert, where the 22 in/yr (0.55 m/yr) of evapotranspiration outpaces the average rainfall of 4.3 in/yr (0.11 m/yr; Laczniak et al., 2001). Given a climate of this aridity, it is amazing that the springs at Ash Meadows (Fig. 1) deliver a combined water discharge of 24.9 cu ft/sec (0.704 cu m/sec; Laczniak et al., 2001). This flow is greater than in some surface streams in Nevada, and more than discharge at the other springs visited on the 2010 NANFA extended field trip (Table 1). The obvious questions were asked at the NANFA convention: "How can there be so much water flowing from these springs?" and "Where does it come from?" The first attempt to resolve these questions was by Loeltz (1960) where he determined the topographic drainage area of the springs was only about 50 square miles, none of the drainage area was very mountainous, and precipitation in this area was insufficient to account for the discharge at the springs.

Concept of Interbasin Flow

The state of Nevada lies entirely within the Great Basin geographic province, which is characterized by mountain ranges trending north to northeast and intervening valleys (Fig. 2). The valleys, which are also called basins, are filled with sediments shed from the surrounding

Fig 1.
Point of Rocks Spring at Ash Meadows National Wildlife Refuge, Nevada.
From http://www.americansouthwest.net/nevada/ash_meadows/ashmeadows.html, accessed April, 2011.

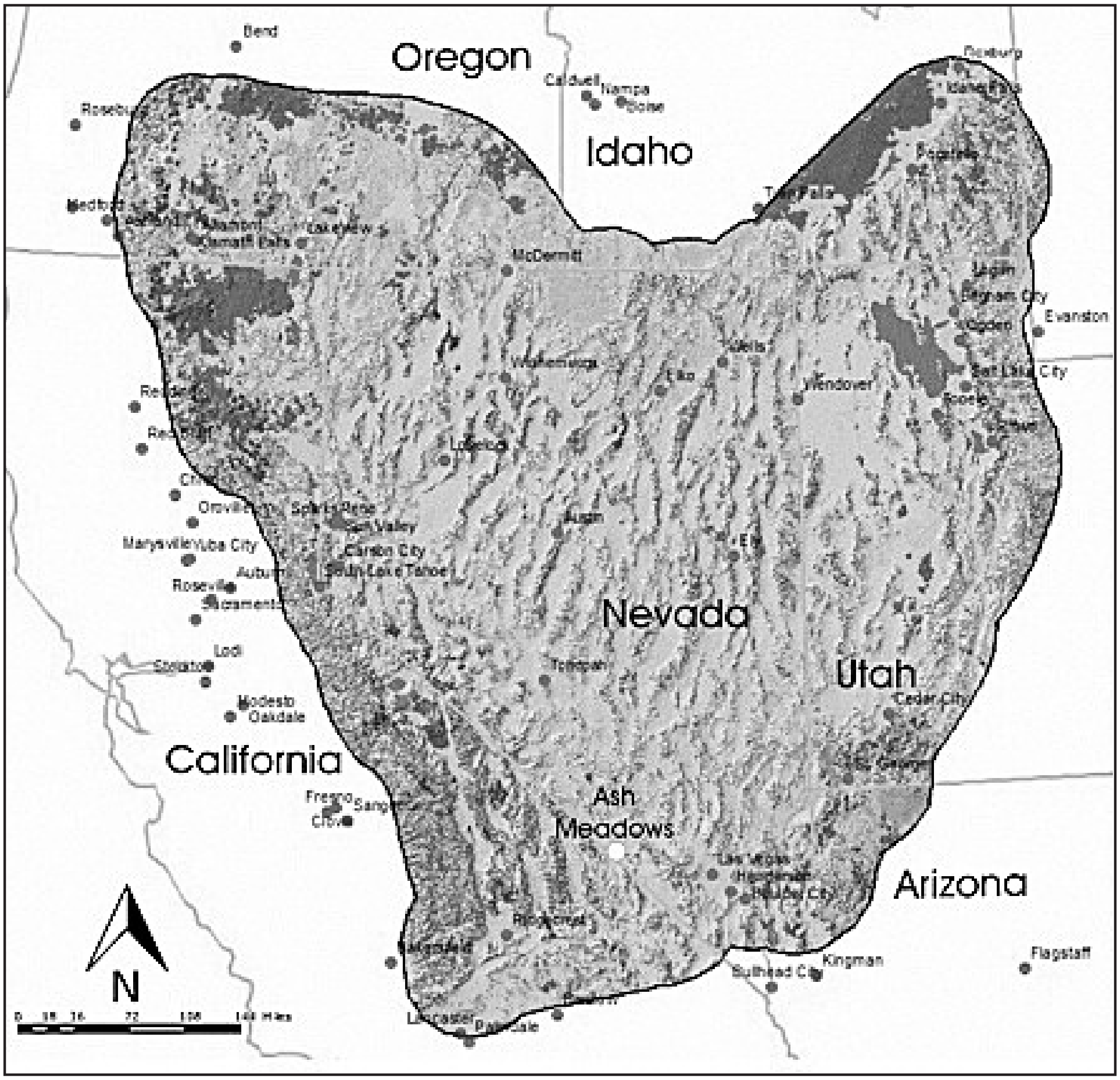

Fig. 2.
A shaded relief, geologic map of the Great Basin, showing north-south trending mountain ranges and intervening valleys. Lithology is depicted by color, where purple indicates Tertiary volcanic rock, yellow is young alluvium, green is sedimentary rock, brown is clastic rock, and blue is carbonate rock. Dark blue indicates lakes. This is an interactive map available from the Nevada Bureau of Mines and Geology, http://gisweb.unr.edu/GBCGE_Geologic/, accessed April, 2011.

mountains. The bedrock floor of most basins lies at great depth under a very thick layer of sediments. Groundwater is found within the basin-fill sediments, and also (potentially) within the deep bedrock. Boreholes drilled within the basins are rarely deep enough to penetrate to the floor, thus hydraulic properties of the bedrock are not well known.

Groundwater flow between basins of the Great Basin (Fig. 2) is a conceptual idea which has been discussed and tested by many studies over the past 100 years. It was first suggested by Mendenhall (1909), who was interested in locating springs in the southwestern Great Basin for use by mining prospectors and railroads. The concept was first quantified by Maxey and Eakin (1949) who discovered a discrepancy between the volumes of groundwater recharge and discharge in some eastern Nevada basins. Their calculations suggested that several basins received more water than was discharged in springs and streams of the basin, and the only way to balance these volumes was for water to be transferred underground, from one basin to another.

Much of our current, conceptual model of interbasin flow has developed from studies initiated by the U.S. Department of Energy (DOE) to understand the potential transport of radioactive material in groundwater flowing from the Nevada Test Site and the Yucca Mountain Nuclear Waste Repository, northeast of Ash Meadows (Fig. 3; Fenelon et al 2010). The conceptual model describes a groundwater system with a component of shallow flow, in which

Spring	Location			Mean Annual Discharge		Period of Record
	Latitude	Longitude	datum	cu ft/sec	cu m/sec	
Rogers Spring	36º22'35.7"	-114º26'36.9"	NAD83	1.64	0.0464	1985-2010
Warm Springs nr Flume @ Moapa NWR[1]	36º42'41.1"	-114º42'31.7"	NAD27	7.47	0.212	2002-2010
Ash Springs	37º27'35.5"	-115º11'35.7"	NAD27	3.11	0.0881	2004-2010
Crystal Springs	37º31'54.7"	-115º14'00.4"	NAD27	1.36	0.0385	2001-2010
Hot Creek	38º22'46"	-115º09'06"	NAD83	14.3	0.405	2006-2010
Preston Big Spring	38º56'00"	-115º04'48"	NAD83	8.03	0.227	1983-2010

[1]NWR=National Wildlife Refuge

Table 1.
Discharge at Nevada springs, visited during the 2010 NANFA extended field trip. Data source = http://waterdata.usgs.gov/nv/nwis/

groundwater flows from recharge areas in the mountains to basins in the adjacent valleys, and a deeper flow component where water moves between basins through the deep bedrock aquifers that underlie the valleys (Prudic et al 1995). Interbasin flow is not believed to occur among all basins, but is dependent upon the hydraulic gradient (elevation + pressure head, divided by distance) and connectivity of the bedrock and basin-fill aquifers.

This topic can be controversial because it is counterintuitive to think that groundwater can flow between basins that are separated by seemingly imposing mountain ranges. It is easy to understand how basins can hold groundwater in their porous sediments, but can water travel through the root of a mountain range? Is the mountain range in permeable to groundwater flow? If there is a hydraulic connection between the basins, then the ranges might not be the roadblocks to flow that they appear to be.

Groundwater flow at Ash Meadows & Devils Hole

The major, regional consolidated-rock (bedrock) aquifer in the southern part of Nevada is a thick section (up to 8km!) of Paleozoic-aged carbonates, such as limestone, that underlies the basins (Winograd and Thordarson, 1975). The carbonates are characterized by large hydraulic conductivities (permitting water flow), which result from fractures, faults, and solution channels (Winograd and Thordarson, 1975; Belcher et al. 2009). These carbonates form the aquifer for the water that discharges from springs in Ash Meadows and at Furnace Creek in Death Valley (springs noted in Fig. 3 [page 16]; Belcher et al 2009). Water recharges the aquifer where the carbonates are exposed in mountain ranges (colored blue in Fig. 3), and it flows through the deep carbonate aquifer to Ash Meadows in the general directions indicated by the blue arrows in Fig. 4 (page 19). The thick green line (Figs. 3, 4) outlines the boundaries of the groundwater flow system that flows through Devil's Hole and discharges at springs in Ash Meadows, Death Valley, and elsewhere. If this model is accurate then water that discharges at Ash Meadows may have travelled 100 miles (161 km) or more underground, possibly as far away as central Nevada, passing through (or around) mountain ranges and interconnected basins.

Not all investigators accept this model of groundwater flow. One reason is that the presence of a continuous, carbonate aquifer at depth in the basins is difficult to document. A number of boreholes have been drilled into the basins (black dots, Fig 3), yet the basins are so deep that most did not reach bedrock (Sweetkind, 2010). However a few did penetrate to bedrock, which was identified as carbonate rock (e.g., the well marked UE-25p#1, and the wells in the northern part of the Amargosa Desert, Fig. 3). Another problem with the concept of a regional groundwater flow is that basins in southern Nevada are bounded by numerous faults (black lines, Fig. 3). These faults can act as conduits or barriers for groundwater flow, depending upon the physical characteristics of the fault-zone material and the orientation and properties of rock on either side of the faults (Sweetkind, 2010).

One group of authors who argue against the concept of a large-scale regional flow, with the boundaries and directions noted in Fig. 4, is Bushman et al. (2010). They argue that the carbonate rocks are too fractured to allow for continuous groundwater flow, and that the faults shown in Fig. 3 act as flow barriers, thus disallowing flow in the southwest direction shown in Fig. 4. Their objections serve to refine the model, however; they do not discredit it. In their study, Bushman et al. (2010) compared water chemistry among springs and wells from Oasis Valley, Yucca Mountain, Frenchman/Groom Lake, Amargosa Desert, Ash Meadows, and Spring Mountains (identified in Fig. 3). From the literature they found chemical analyses for 246 individual water samples, and they used statistical cluster analysis and geochemical modeling to identify 13 separate water types. After comparing the Na and Cl concentrations and hydrogen and oxygen isotope values in these clusters, they argued that most of the water that discharges at Ash Meadows comes from the Yucca Mountain area, and flows parallel to the north-south trending faults depicted in Fig. 3. Thus, rather than water travelling a long way through a deep, fractured carbonate aquifer, they argue for a closer source and a water flow that follows faults.

In summary, there is a general consensus that the water in the springs of Ash Meadows and Death Valley has travelled underground over large distances, before it emerges at the springs. Details such as the areal extent of the groundwater system, specific directions of groundwater flow, and the primary source (or sources) of water for Ash Meadows springs remain points of discussion and research. The groundwater flow boundaries, rock types, and fault locations in Figs. 3 & 4 are data included in a numerical model of groundwater flow constructed by the U.S. Geological Survey (Belcher and Sweetkind, 2010). This model simulates flow at the springs in Ash Meadows and Death Valley, but because it is a model it is merely a representation of reality. The model can continue to be refined as more specifics are learned regarding the primary source of water at Ash Meadows, the hydraulic properties of the carbonate aquifer, and the geologic faults present in the groundwater flow system. Regardless of the source of the water and the route that it takes to Ash Meadows, desert pupfish, other wildlife, and humans benefit immensely from this complex geologic plumbing system.

References

Belcher, Wayne R., Bedinger M.S., Back Jennifer T., and Sweetkind Donald S., 2009. Interbasin flow in the Great Basin with special reference to the southern Funeral Mountains and the source of Furnace Creek springs, Death Valley, California, U.S. Journal of Hydrology 369, 30-43.

Belcher, Wayne R., and Sweetkind, Donald S., eds., 2010. Death Valley Regional Groundwater Flow System, Nevada and California—Hydrologeologic Framework and Transient Groundwater Flow Model. U.S. Geological Survey Professional Paper 1711, 398 p, http://pubs.usgs.gov/pp/1711/, accessed April 2011.

Bushman, Michelle, Nelson, Stephen T., Tingey, David, and Eggett, Dennis, 2010. Regional groundwater flow in structurally-complex extended terranes: An evaluation of the sources of discharge at Ash Meadows, Nevada. Journal of Hydrology, 386, 118-129.

D'Agnese, F.A., Faunt, C.C, Turner, A.K., and Hill, M.C.,1997. Hydrogeologic evaluation and numerical simulation of the Death Valley regional ground-water flow system, Nevada, and California. U.S. Geological Survey Water-Resources Investigations Report 96–4300, 124p.

Fenelon, J.M., Sweetkind, D.S., and Laczniak, R.J., 2010, Groundwater flow systems at the Nevada Test Site, Nevada: A synthesis of potentiometric contours, hydrostragraphy, and geologic structures. U.S. Geological Survey Professional Paper 1771, 54p.

Laczniak, R.J., Cole, J.C., Sawyer, D.A., and Trudeau, D.A.,1996. Summary of hydrogeologic controls on groundwater flow at the Nevada Test Site, Nye County, Nevada. U.S. Geological Survey Water-Resources Investigations Report 96–4109, 59 p.

Laczniak, R.J., Smith, J. LaRue, Elliott, P.E., DeMeo, G.A., Chatigny, M.A., and Roemer, G.J., 2001. Ground-water discharge determined from estimates of evapotranspiration, Death Valley regional flow system, Nevada and California: U.S. Geological Survey Water-Resources Investigations Report 2001–4195, 51p.

Loeltz, O.J., 1960, Source of water issuing from springs in Ash Meadow Valley, Nye County, Nevada [abs.]. Geological Society of America Bull., v. 71, p. 1917-1918.

Maxey, G.B., and Eakin, T.E., 1949. Groundwater in White River Valley, White Pine, Nye, and Lincoln Counties, Nevada. Nevada State Engineer, Water Resources Bulletin, Number 8, 59p.

Mendenhall, W.C., 1909. Some desert watering places in southeastern California and southwestern Nevada. U.S. Geological Survey Water-Supply Paper 224, 86p.

Potter, C.J., Sweetkind, D.S., Dickerson, R.P. and Killgore, M.L., 2002. Hydrostructural map of the Death Valley ground-water basin, Nevada and California. U.S. Geological Survey Miscellaneous Field Studies Map MF–2372, scale 1:350,000, 2 pls. 12p.

Prudic, D.E., Harrill, J.R., and Burbey, T.J., 1995. Conceptual evaluation of regional ground-water flow in the carbonate-rock province of the Great Basin, Nevada, Utah, and adjacent States. U.S. Geological Survey Professional Paper 1409-D, 102p.

Sweetkind, Donald S., Belcher, Wayne R., Faunt, Claudia C., and Potter, Christopher J., 2010. Chapter B. Geology and Hydrogeology. in: Belcher, Wayne R., and Sweetkind, Donald S., eds., Death Valley Regional Groundwater Flow System, Nevada and California—Hydrologeologic Framework and Transient Groundwater Flow Model. U.S. Geological Survey Professional Paper 1711, pp. 19-94. http://pubs.usgs.gov/pp/1711/, accessed April 2011.

Wernicke, B.P., 1992, Cenozoic extensional tectonics of the U.S. Cordillera, in Burchfiel, B.C., Lipman, P.W., and Zoback, M.L., eds., The Cordilleran orogen—Conterminous U.S.: Geological Society of America, Geology of North America, v. G–3, p. 553–581.

Winograd, I.J., and Thordarson, William, 1975. Hydrogeologic and hydrochemical framework, south-central Great Basin, Nevada-California, with special reference to the Nevada Test Site: U.S. Geological Survey Professional Paper 712–C, 126p.

Workman, J.B., Menges, C.M., Page, W.R., Taylor, E.M., Ekren, E.B., Rowley, P.D., Dixon, G.L., Thompson, R.A., and Wright, L.A., 2002. Geologic map of the Death Valley ground-water model area, Nevada and California: U.S. Geological Survey Miscellaneous Field Studies Map MF–2381–A, scale 1:250,000, 26p.

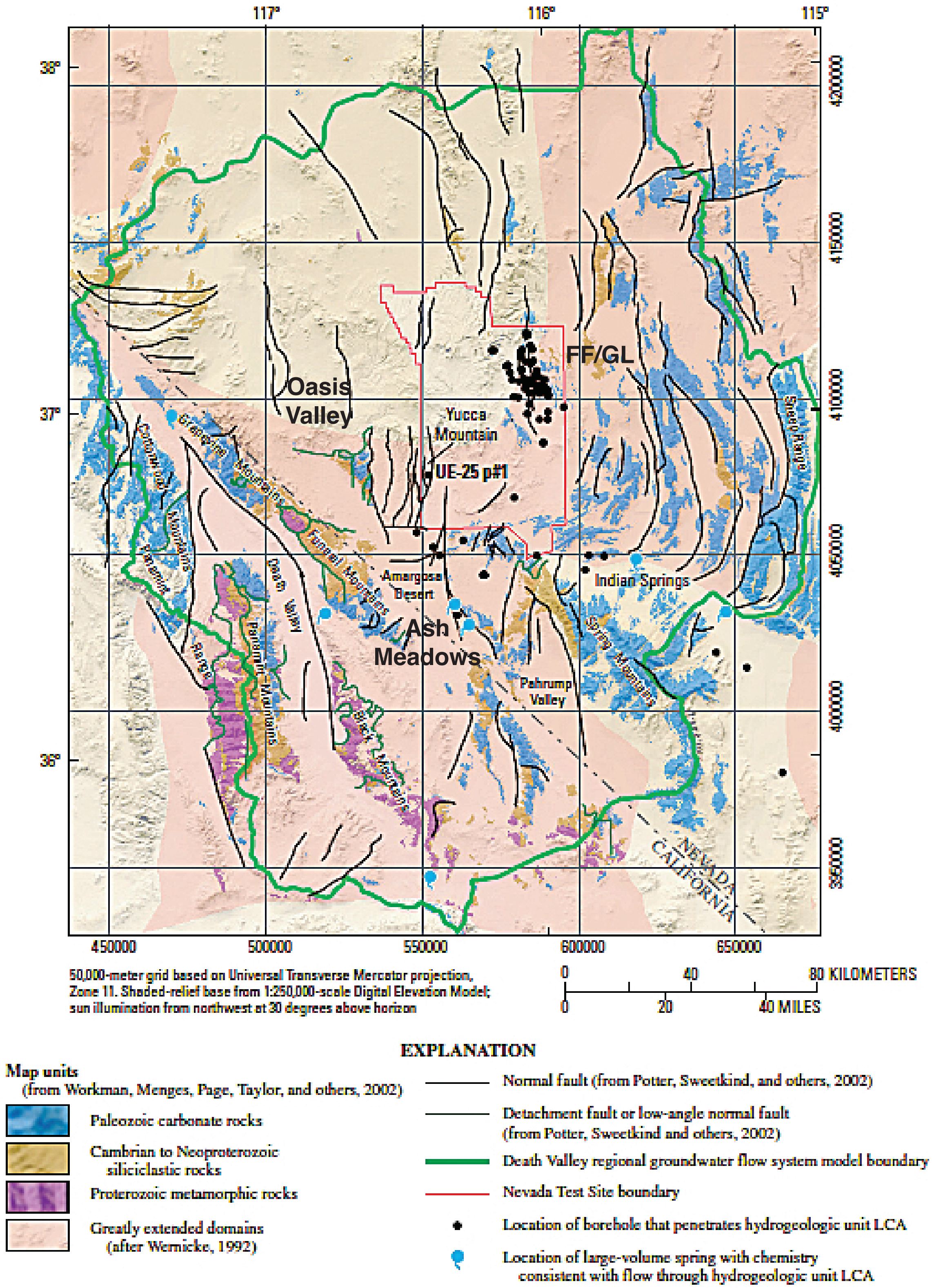

Fig 3.

Map of the southern portion of the Great Basin, with an outline of the groundwater flow system that contributes water to the Ash Meadows and Death Valley springs, adapted from Fig. B-36 in Sweetkind et al., 2010, http://pubs.usgs.gov/pp/1711/, accessed April 2011. PV = Pahranagat Valley, FF/GL = Frenchman Flat/Groom Lake, LCA = Lower Carbonate Rock Aquifer.

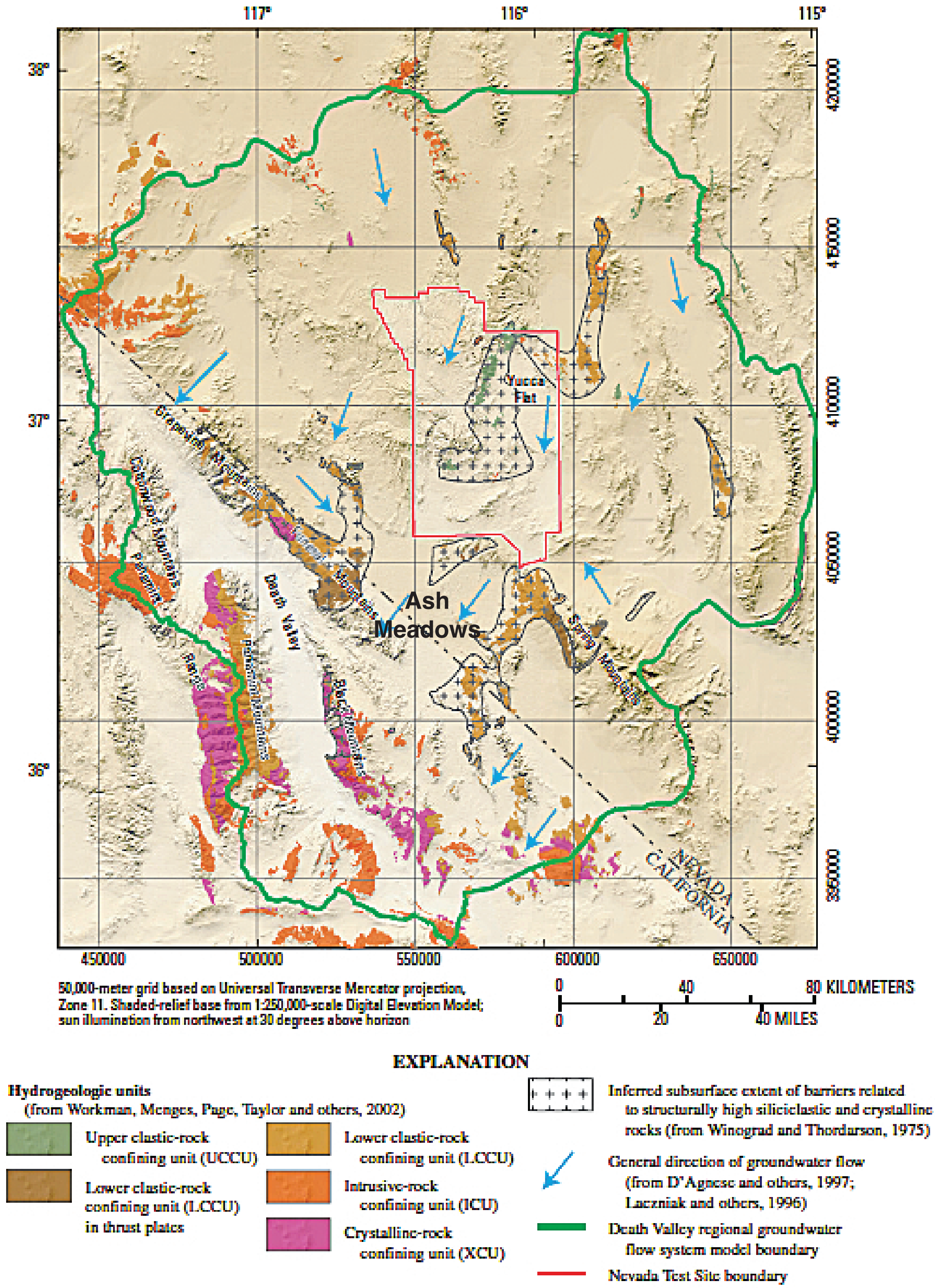

Fig 4.
General direction of groundwater flow within the Death Valley groundwater flow system, Fig. B-29 in Sweetkind et al., 2010, http://pubs.usgs.gov/pp/1711/, accessed April 2011. The hydrologic units depicted here represent rocks of low permeability, which create barriers to groundwater flow.