Assessment of the Potential for Carbon Dioxide Sequestration with Enhanced Oil Recovery in Nevada

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Abstract

This report follows the preliminary assessment of the potential for carbon dioxide sequestration in geological settings in Nevada (Price and others, 2005) by compiling data on the 15 oil fields that have had historical production. Critical factors in assessing the potential for enhanced oil recovery as a means of carbon dioxide sequestration in Nevada include depth, temperature, and cumulative production. Most Nevada oil reservoirs are considerably hotter than ideal conditions for maintaining a dense CO_2 phase underground. Furthermore, none of the Nevada oil fields is large enough to accommodate all the CO_2 from a large coal-fired power plant. The cumulative volume of oil and associated water production from all Nevada oil fields is about two orders of magnitude less than what would be needed to sequester a significant amount of CO_2 from a power plant. Therefore, there is not much potential in Nevada for CO_2 sequestration through enhanced oil recovery.

Introduction

In recent years, the prospect of using carbon dioxide (CO_2) injection as an enhanced oil recovery (EOR) technique has gathered much interest, not only as a way of improving oil recovery, but also as a method of sequestering CO_2 generated by coal-burning power plants. In a typical oil field, less than 15 percent of the oil present in the reservoir is recovered during the primary recovery phase, when the initial natural pressure of the reservoir or gravity helps drive oil into the wellbore, where it is generally pumped to the surface. Secondary recovery techniques may extend the oil field's productive life and increase recovery to 20 to 40 percent by injection of water or gas to displace oil and drive it to a production wellbore. With much of the easily produced oil already recovered from U.S. oil fields, some producers have attempted tertiary or EOR techniques that offer the possibility of converting up to 60 percent or more of the reservoir's original oil reserves to production.

Gas injection is the most commonly used EOR technique, accounting for nearly 50 percent of EOR production in the United States. Large volumes of gas such as CO_2, natural gas, or nitrogen are injected into a mature oil reservoir, where the gas pushes additional oil to a production wellbore. The gas also dissolves in the oil, lowering its viscosity and improving its flow rate. CO_2 injection has been used successfully to enhance oil recovery throughout the Permian Basin of West Texas and eastern New Mexico, and is now being pursued to a limited extent in many other states.

In 2003, the State of California, in collaboration with the U.S. Department of Energy and the States of Alaska, Arizona, Oregon, and Washington, asked the State of Nevada to join the West Coast Regional Carbon Sequestration Partnership (WESTCARB) and participate in a regional analysis of CO_2 sequestration potential, through both terrestrial and geological approaches. The terrestrial approaches involve growing more biomass (particularly trees), and the geological options include proven technologies, such as using CO_2 in EOR and disposal of CO_2 in saline aquifers. Some unconventional approaches are also being evaluated. The Nevada Bureau of Mines and Geology (NBMG) reported its findings from a preliminary assessment of the potential for geological sequestration in Nevada (Price and others, 2005). This report follows up with detailed information on Nevada oil fields.

Data Compiled

To aid in the evaluation of Nevada oil fields as potential targets for CO_2 EOR, we researched available literature on 15 commercially productive oilfields in Nevada for information pertinent to the suitability of these oil fields for sequestration of CO_2. Nevada's commercially productive oil fields are Bacon Flat, Currant, Duckwater Creek, Eagle Springs, Ghost Ranch, Grant Canyon, Kate Spring, Sand Dune, Sans Spring, and Trap Spring in Railroad Valley, Nye County; Blackburn, North Willow Creek, Three Bar, and Tomera Ranch in Pine Valley, Eureka County; and Deadman Creek in Toano Draw, Elko County. Their locations and relative approximate sizes are shown in Figure 1. Additional fields have been explored and identified within Nevada, but as yet, none of these has had significant commercial production of petroleum, so they were not included in this compilation. Nearly all Nevada oil production has come from fields in Railroad Valley (89.27%) and Pine Valley (10.73%; Davis, 2007).

Because Nevada's 15 commercially producing oil fields are either one-reservoir fields or consist of communicating reservoirs, the field and reservoir level data are essentially the same and are combined on a single data spreadsheet for the 15 oil fields, shown here as Table 1. The data presented in Table 1 are included in a geographic information system (GIS) coverage which accompanies the electronic version of this open-file report. Table 2 is an annotated list of the data field labels and a description of the data contained in each of the fields on Table 1. Field locations in Table 1 and on Figure 1 are based on the point locations of the discovery wells for each field as shown on the petroleum data map of Garside and Hess (2007). The oil field GIS coverage was generated in a shape file format, in UTM zone 11 projection, North American Datum (NAD) 1927. This is the same projection and NAD as the UTM coordinates listed in Table 1. The GIS coverage that accompanies the map of Garside and Hess (2007), available at http://www.nbmg.unr.edu/dox/zip/m162d.zip, includes locations of all oil and gas exploration and production wells in the state.

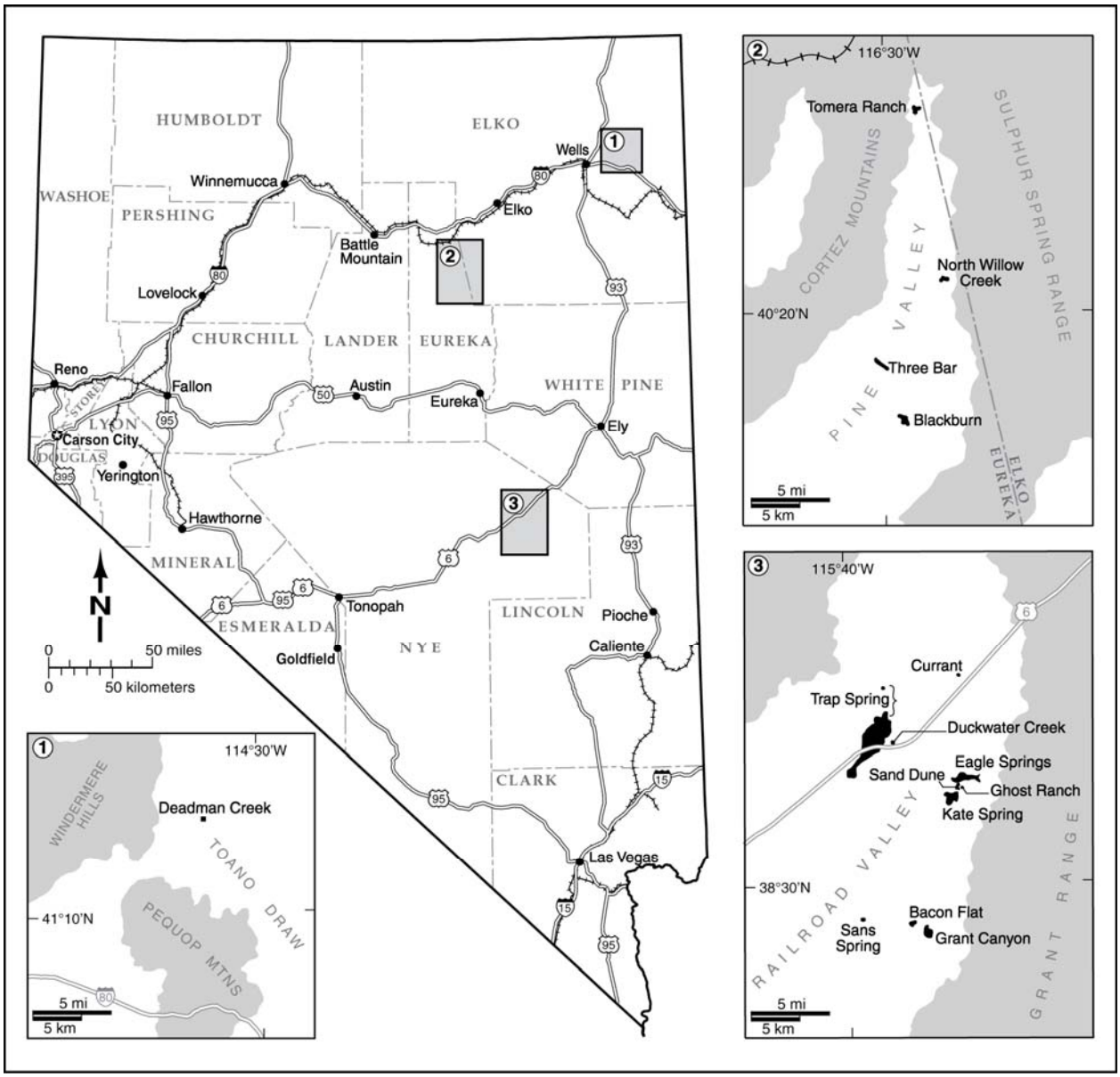

Figure 1. Location and relative sizes of oil fields from which production has been recorded in Nevada.

Table 1. Data compiled for each commercially productive oil field in Nevada. See Table 2 for descriptions of the data fields.

Oil field name	Discovery well name	NV permit number	Discovery well API number	Location	County
OILFIELDNA	DISCO_WELL	PERMIT	API	LOCATION	COUNTY
Eagle Springs	Eagle Springs Unit No. 1-35	4	27-023-05011	Railroad Valley	Nye
Kate Spring	Kate Spring No. 1	436	27-023-05365	Railroad Valley	Nye
Trap Spring	Trap Spring No. 1	180	27-023-05220	Railroad Valley	Nye
Currant	Currant No. 1	241	27-023-05265	Railroad Valley	Nye
Bacon Flat	Bacon Flat No. 1	316	27-023-05305	Railroad Valley	Nye
Blackburn	Blackburn No. 3	324	27-011-05210	Pine Valley	Eureka
Grant Canyon	Grant Canyon No. 1	353	27-023-05318	Railroad Valley	Nye
Tomera Ranch	Foreland-Southern Pacific Land Co. No. 1-5	492	27-011-05235	Pine Valley	Eureka
North Willow Creek	Foreland-Southern Pacific Land Co. No. 1-27	503	27-011-05239	Pine Valley	Eureka
Three Bar	Three Bar Federal No. 25-A	556	27-011-05246	Pine Valley	Eureka
Duckwater Creek	Duckwater Creek No. 19-11	542	27-023-05413	Railroad Valley	Nye
Sans Spring	Federal No. 5-14	635	27-023-05466	Railroad Valley	Nye
Ghost Ranch	Ghost Ranch Springs No. 58-35	789	27-023-05544	Railroad Valley	Nye
Deadman Creek	Deadman Creek No. 44-13 (formerly SP No. 3-13)	342	27-007-05228	Toano Draw	Elko
Sand Dune	Sand Dune Federal No. 88-35	816	27-023-05561	Railroad Valley	Nye

Table 1 (continued).

Oil field name	Township	Range	Sections	Quarter section	Depth to top of field
OILFIELDNA	T	R	S	QTRSEC	DEPTHTOTOP
Eagle Springs	9N	57E	35	SE/4 NE/4 NW/4	5780 feet (1,762 meter)
Kate Spring	08N	57E	2	NW/SW	4450 feet (1,356 meters)
Trap Spring	9N	56E	27	SE/SE	3210 feet (978 meters)
Currant	10N	57E	26	SW/SE	6850 feet (2088 meters)
Bacon Flat	07N	57E	17	C/SW	4960 feet (1512 meters)
Blackburn	27N	52E	8	C NE/4 SW/4 SW/4	5776 feet (1761 meters)
Grant Canyon	07N	57E	21	C E/2 SW/4 NW/4 Sec. 21, T 7N, R 57E	4374 feet (1333 meters)
Tomera Ranch	30N 31N	52E 53E	5; 33	SE/NE/NE	1150 feet (351 meters)
North Willow Creek	29N	52E	27	NW/SE	6290 feet (1917 meters)
Three Bar	28N	51E	25	C NE/4	5720 feet (1743 meters)
Duckwater Creek	09N	057E	19	NW/NW	5680 feet (1731 meters)
Sans Spring	07N	056E	14	SW/NW	5640 feet (1710 meters)
Ghost Ranch	08N, 09N	057E, 057E	02; 34, 35	NE/NW 02; SE/SW 35	4350 feet (1326 meters)
Deadman Creek	39N	65E	13	SE/SE	8165 feet (2489 meters)
Sand Dune	09N	057E	35	SE/SE/SE	5970 feet (1820 meters)

Table 1 (continued).

Oil field name	Depth of producing zone in discovery well	Average depth of production zone in all producing wells	Average depth of production zone in all producing wells (meters)	Cumulative production through 2006 (barrels)
OILFIELDNA	PRODDEPTH	AVDEPTHPRO		CUMPROD2006
Eagle Springs	5,780-7,360 feet	6508 feet	1984	5,218,259
Kate Spring	4450-4820 feet	4598 feet	1401	2,256,573
Trap Spring	3210-4950 feet	4005 feet	1221	13,753,356
Currant	6850-7080 feet	7059 feet	2152	1,523
Bacon Flat	4960-5350 feet	5163 feet	1574	997,509
Blackburn	5776-7140 feet	6902 feet	2104	5,183,966
Grant Canyon	4374-4426 feet	3979 feet	1213	20,938,790
Tomera Ranch	1150-1950 feet	1670 feet	509	36,472
North Willow Creek	6290-6470 feet	6093 feet	1857	50,529
Three Bar	5720-7070 feet	5448 feet	1661	23,837
Duckwater Creek	5680-5830 feet	5755 feet	1754	18,310
Sans Spring	5640-5770 feet	5766 feet	1757	265,457
Ghost Ranch	4350-4620 feet	4474 feet	1364	502,023
Deadman Creek	8165-8850 feet	8508 feet	2593	367
Sand Dune	5970-6200 feet	6178 feet	1883	116,626

Table 1 (continued).

Oil field name	Zone status (currently producing, shut-in, or abandoned wells) 2006 data	Number of producing wells (2006)	Number of inactive wells (2006)	Depth to base of fresh water
OILFIELDNA	ZONESTATUS06	NUMPRODWEL	NUMINACTWE	DEPTHFRESH
Eagle Springs	15 producers, 6 shut-in, 1 injection	15	5	not known
Kate Spring	4 producers, 2 shut-in	4	2	not known
Trap Spring	33 producers, 10 shut-in, 1 P&A	33	11	not known
Currant	1 past producer, now shut-in	0	1	not known
Bacon Flat	1 active producer, 2 shut-in	1	2	not known
Blackburn	5 producers, 2 shut-in	5	2	not known
Grant Canyon	2 producers, 4 shut-in	2	4	not known
Tomera Ranch	2 shut-in, 1 P&A, 1 injection	2	1	not known
North Willow Creek	1 producer, 1 shut-in, 1 P&A	1	2	not known
Three Bar	2 shut-in, 1 P&A	2	1	not known
Duckwater Creek	1 producer	1	0	not known
Sans Spring	1 producer, 2 shut-in, 1 abandon	1	3	not known
Ghost Ranch	4 producers; 1 shut-in	4	1	not known
Deadman Creek	1 P&A	0	1	not known
Sand Dune	1 producer	1	0	not known

Table 1 (continued).

Oil field name	Host rost age/formation/rock type	Average thickness of reservoir rock units in producing wells
OILFIELDNA	HOSTROCK	AVEUNITTHI
Eagle Springs	Oligocene Garrett Ranch Group; Eocene Sheep Pass Formation lacustrine carbonates; Pennsylvanian Ely Limestone carbonate (minor production)	1500 feet
Kate Spring	Neogene Horse Camp Formation breccia and Devonian Guilmette Formation (carbonate, dolomite)	413 feet of Pennsylvanian carbonate breccia; 560 feet of Devonian dolomite & limestone
Trap Spring	Oligocene Tuff of Pritchards Station, ash flow tuff (ignimbrite)	2490 feet
Currant	Eocene Sheep Pass Formation calcareous shale and shaly limestone	439 feet
Bacon Flat	Devonian Guilmette Formation carbonate, dolomite; possibly also Sheep Pass Fm	73 feet
Blackburn	Devonian Telegraph Canyon Formation dolostone; Mississippian Chainman Shale and Dale Canyon Formation shale, sandstone & siltstone; Oligocene Indian Well Formation tuff and tuffaceous sandstone	1275 feet
Grant Canyon	Devonian Simonson and Guilmette Formation vuggy brecciated dolomite	448 feet
Tomera Ranch	Oligocene Indian Well Formation chert and tuffaceous sandstone	189 feet
North Willow Creek	Mississippian Chainman Shale	604 feet
Three Bar	Miocene Humboldt Formation sandstone and volcanic rock; Oligocene Indian Well Formation, and Cretaceous Newark Formation sandstone and carbonate	6000 feet
Duckwater Creek	Oligocene Garrett Ranch Group volcaniclastic rocks and ignimbrites	3125 feet
Sans Spring	Oligocene Garrett Ranch Group volcaniclastic rocks and ignimbrites	933 feet
Ghost Ranch	Late Tertiary landslide breccia blocks of Devonian Guilmette Formation limestone and dolomite	265 feet
Deadman Creek	Miocene Humboldt Formation	685 feet
Sand Dune	Permian and Pennsylvanian limestones	465 feet

Table 1 (continued).

Oil field name	Field area (from literature)	Porosity	Permeability
OILFIELDNA	FIELDAREA	POROSITY	PERMEABILI
Eagle Springs	640 acres	volcanics - 13.5%; Sheep Pass - 16%	volcanics - 10 md; Sheep Pass - 4 md
Kate Spring	Tertiary - 60 acres, Devonian - 200 acres	average 10-12%, up to 17 % in Devonian rock	2000-4100 md possible
Trap Spring	2440 acres	overall, <3%, but 5-15 % matrix porosity in isolated vesicles	highly variable
Currant	40 acres	5.80%	up to 24.6 md
Bacon Flat	80 acres	< 4 %	very high- interconnected fractures, vugs & caverns
Blackburn	400 acres	8%	high - open fractures
Grant Canyon	320-400 acres	< 4 %	very high- interconnected fractures, vugs & caverns
Tomera Ranch	80 acres	up to 24 % but average 6-15 %	<2 md
North Willow Creek	<120 acres	15 - 26% in discovery hole	.05 - 78 md in discovery hole (7.35 md)
Three Bar	<120 acres	unknown	unknown
Duckwater Creek	~40 acres	< 2%	highly variable
Sans Spring	160 acres	18%	1688 md
Ghost Ranch	1500 acres	huge	huge permeabilities
Deadman Creek	~40 acres	unknown	unknown
Sand Dune	~40 acres	10%	0.39 - 1.3 md

Table 1 (continued).

Oil field name	Initial pressure	Initial temperature	Formation water salinity
OILFIELDNA	INITPRE	INITIALTEM	FMSALINITY
Eagle Springs	3000 psi at 6400 feet	200° F (93°C) at 6400 feet	24,298 ppm Cl; 7476-27,912 ppm TDS in oil field waters of 6 wells
Kate Spring	unknown	150° F (66°C)	TDS 239 ppm; 914-2,952 ppm TDS in oil field waters of 5 wells
Trap Spring	1645 psi at 1000 feet	100°-120° F (38-49 °C)	3000-6000 ppm TDS; 2633-3378 ppm TDS in oil field waters of 3 wells
Currant	2944 psig	194° F (90°C)	2264 mg/l TDS
Bacon Flat	2273 psig	250° F (121°C)	4380 ppm TDS; 4662-4943 ppm TDS in oil field waters of 3 wells
Blackburn	3233 psig at 7196 feet	250° F (121°C)	1984-3684 ppm TDS in oil field waters of 3 wells.
Grant Canyon	1,885 psig at 4,400 feet; 1,735 psig at 4,000 feet	239° F (115°C)	4382-4487 ppm TDS in oil field waters of 5 wells
Tomera Ranch	unknown	120° F (49°C)	543-580 mg/l TDS
North Willow Creek	2,798.5 psi	180°-185° F (82-85°C)	7000 ppm to 9000 ppm salt water chlorides in re-entry well
Three Bar	unknown	unknown	530-939 ppm chlorides
Duckwater Creek	unknown	140° F, (60°C) estimated	10,200 ppm TDS
Sans Spring	2410 psig	200° F (93°C)	10,000-17,000 ppm TDS
Ghost Ranch	2179 psig	unknown	TDS concentration 17,500 to 21,000 mg/L.
Deadman Creek	unknown	154° F (68°C)	11,260 to 52,917 ppm TDS
Sand Dune	2866 psig	149° F (65°C)	unknown

Table 1 (continued).

Oil field name	Seal type	Seal thickness	Trap type
OILFIELDNA	SEALTYPE	SEALTHICK	TRAPTYPE
Eagle Springs	Indurated valley fill (Horse Camp Formation) and altered basal volcaniclastic-rich valley fill sediments	169-2680 feet	paleotopographic & stratigraphic, structural-stratigraphic; erosional unconformity pinch-outs
Kate Spring	Indurated clay-rich Tertiary valley fill above unconformity	4371-4738 feet	structural/unconformity; clay-richvalley fill trap
Trap Spring	Alluvial valley fill, argillized clay-rich non-welded tuff layer, unfractured clays, and devitrified ash	271-4854 feet	fault block, structural-stratigraphic
Currant	altered basal volcaniclastic-rich valley-fill sediments; Tertiary volcanic rocks	2995 feet	structural-stratigraphic
Bacon Flat	altered Tertiary basal volcaniclastic-rich valley fill sediments	153-5355 feet	structural; structural-stratigraphic; valley fill trap
Blackburn	pre-Tertiary unconformity; altered Tertiary basal volcaniclastic-rich valley fill sediments	1200-2768 feet	structural
Grant Canyon	altered Tertiary basal volcaniclastic-rich valley fill sediments	910-4020 feet	structural; structural-stratigraphic; valley fill trap
Tomera Ranch	valley fill clays	800-1850 feet	structural fault block; structural-stratigraphic
North Willow Creek	range-bounding fault of the Pinon Range and Devonian Woodruff Fm.	1500 -3000 feet	structural fault block
Three Bar	Tertiary valley fill and volcanic rocks	3000-5000 feet	probably structural
Duckwater Creek	Tertiary valley fill and volcanic rocks	5500 feet	structural - fault block
Sans Spring	Tertiary valley fill and volcanic rocks	5000 feet	fault-bounded structure; structural-stratigraphic
Ghost Ranch	altered basal volcaniclastic-rich valley fill sediments	unknown	Structural high with four-way closure
Deadman Creek	Ash member, Humboldt Formation	2365 feet	unknown
Sand Dune	Tertiary valley fill and volcanic rocks	5900 feet	unknown

Table 1 (continued).

Oil field name	Stimulation (history of secondary and tertiary recovery efforts)	Logs available (discovery hole)
OILFIELDNA	STIMULATIO	LOGS
Eagle Springs	2,000 gallon (7,571 liter) mud acid wash	Lithologic 0 - 10,358 feet; IES 1,018 - 10,358 feet; GR/N 30 - 10,358 feet; ML 1,500 - 10,354 feet; DM 3,460 - 8,205 feet; Section Gauge 1,016 - 10,356 feet.
Kate Spring	Worked over after 1521 BO produced; plugged original perfs; perforated and acidized 4500-1625 feet (1372-1410m)	FIL 4,864-7,495 feet; DM 4,864-7,495 feet; DLL/ML 4,864-7,487 feet; BHCS 4,864-7,497 feet; CBL 3,490-4,814 feet; Directional 4,864-7,495 feet; CN/FDC 4,864-7,495 feet; GR 3,400-7,495 feet; lithologic 60-7500 feet.
Trap Spring	A few attempts to acidize or fracture have been mostly unsuccessful.	Lithologic 1,000 - 6,137 feet; DIL 1,008 - 5,982 feet; CNL/FDC 1,008 - 5,990 feet; BHCS 1,008 - 5,970 feet; FIL 4,000 - 5,600 feet
Currant	none	Lithologic 60-7,800 feet, 6,720-7,115 feet; FIL 2,200-7,790 feet; DIL 427-7,789 feet; GR 6,800-7,118 feet; BHCS 429-7,791 feet; CNL/FDC 428-7,793 feet; DM 436-7,793 feet
Bacon Flat	acidized with 1000 gallons (3,785 liters) 15 % HCl	Lithologic 515-5,441 feet; DI 519-5,451 feet; BHCS 519-5,433 feet; CNL/FDC 3,404-5,439 feet; DM 612-5,450 feet; Dip log 3,414-5,419 feet; CBL 3,350-5,394 feet
Blackburn	Devonian - none, Mississippian & Oligocene - sand/oil fracture treatment	Lithologic 80-7,950 feet; FDL 4,800-7,867 feet; CBL 5,200-7,900 feet; TS 58-7,909 feet; Cal 1,548-5,550 feet; CNL/FDC/DI 95-7,954 feet; BHCS 95-7,943 feet; FIL/GR 4,800-7,956 feet; DM 1,608-7,956 feet; DLL 5,800-7,523 feet
Grant Canyon	none	Lithologic 400 - 4,040 feet; DLL/ML 392 - 3,949 feet; BHCS 392 - 3,957 feet; DI 3,931 - 4,297 feet; LSS 3,931 - 4,300 feet; FIL 3,931 - 4,300 feet; CNL/FDC 392 - 4,300 feet; DM 3,931 - 4,300 feet; Temp/press/gradient 3,900 - 4,150 feet
Tomera Ranch	none	Lithologic 1007 - 5786 feet; DLL 980 - 5774 feet; FDC/N 1018 - 5772 feet; BHCS 988 - 5755 feet; DM 1000 - 5570 feet; DM/computed 1000 - 5570 feet; CBL 1000 - 4567 feet
North Willow Creek	none	CBL 4200 - 6393 feet; FDC/N 980 - 7672 feet; BHCS 950 - 7666 feet; ML 5600 - 7662 feet; DLL 950 - 7650 feet; DM 980 - 7672 feet; Perf. Rec. 6200 - 6393 feet; lithologic 0 - 7678 feet
Three Bar	unknown	Lithologic 57-7217 feet; GR 950-7217 feet; DI 950-7213 feet; DM 950-7216 feet; EM 950-7201 feet; FDC/N 950-7217 feet; S 950-7203 feet; CBL 750-7213 feet
Duckwater Creek	none	DI/GR, 716-5754; BHCS/GR, 716-5750; DM, 3737-5754
Sans Spring	none	lithologic 900-8,463 feet ; CBL-5,000-6,087; DM 4,000-8,459 feet; DI 4,000-8,460 feet; BHCS 4,000-8,462 feet; FDC/N 4,000-8,464 feet; Drift survey 4,000-8,459 feet; Water Flow 5,690-5,910 feet
Ghost Ranch	unknown	lithologic log 515 feet-4570 feet; BHCS/GR 512 feet-4530 feet; Directional Plot 512 feet-4580 feet; DLL 512 feet-4562 feet; FDL/N 3550 feet-4530 feet
Deadman Creek	unknown	Lithologic 90 - 10,930 feet; DM 916 - 10,918 feet; CBL 7,818 - 8,745 feet; BHCS 897 - 10,926 feet; DI 898 - 10,926 feet; FIL 1,500 - 10,923 feet; FDC/N 898-8,638; DM 898 - 8,639 feet; DL 898 - 10,923 feet; GR 898-8,607 feet
Sand Dune	unknown	Lithologic log 642 feet-6411 feet; BHCSGR 642 feet-6366 feet; Directional 636 feet-6400 feet; DMGRCal 3000 feet-6400 feet; IESGR 642 feet-6398 feet; MLGRCal 2400 feet-6407 feet; NGRCal 2400 feet-6407 feet

Table 1 (continued).

Oil field name	Location of logs	Samples available (discovery hole)	Reservoir fluid (oil, gas, water)
OILFIELDNA	LOGLOC	SAMPLES	RESFLUID
Eagle Springs	NBMG & U. S. Geological Survey Core Research Center, Well Reports, Data on cuttings and core available online at: http://geology.cr.usgs.gov/crc/data/NV/	Cuttings 140 - 10,345 feet; Core 4,710 - 9,960 feet.	oil, gas, water
Kate Spring	NBMG & U. S. Geological Survey Core Research Center, Well Reports, Data on cuttings and core available online at: http://geology.cr.usgs.gov/crc/data/NV/	Cuttings 60 - 7,500 feet	oil, water, gas
Trap Spring	NBMG & U. S. Geological Survey Core Research Center, Well Reports, Data on cuttings and core available online at: http://geology.cr.usgs.gov/crc/data/NV/	Cuttings 1,800 - 6,100 feet; Core 4,375 - 4,444 feet	oil, water
Currant	NBMG & U. S. Geological Survey Core Research Center, Well Reports, Data on cuttings and core available online at: http://geology.cr.usgs.gov/crc/data/NV/	Cuttings 430-7,800 feet	oil
Bacon Flat	NBMG & U. S. Geological Survey Core Research Center, Well Reports, Data on cuttings and core available online at: http://geology.cr.usgs.gov/crc/data/NV/	Cuttings 520-5,450 feet	oil, water
Blackburn	NBMG & U. S. Geological Survey Core Research Center, Well Reports, Data on cuttings and core available online at: http://geology.cr.usgs.gov/crc/data/NV/	Cuttings 1,600 - 7,930 feet	oil, water
Grant Canyon	NBMG & U. S. Geological Survey Core Research Center, Well Reports, Data on cuttings and core available online at: http://geology.cr.usgs.gov/crc/data/NV/	Cuttings 390 - 4,040 feet	oil, water
Tomera Ranch	NBMG & U. S. Geological Survey Core Research Center, Well Reports, Data on cuttings and core available online at: http://geology.cr.usgs.gov/crc/data/NV/	Cuttings 900 - 5786 feet	oil, gas, water
North Willow Creek	NBMG & U. S. Geological Survey Core Research Center, Well Reports, Data on cuttings and core available online at: http://geology.cr.usgs.gov/crc/data/NV/	Cuttings 3000 - 7678 feet	oil, water (none initially), some gas initially
Three Bar	NBMG & U. S. Geological Survey Core Research Center, Well Reports, Data on cuttings and core available online at: http://geology.cr.usgs.gov/crc/data/NV/	Cuttings 57 - 7,217 feet	oil, water
Duckwater Creek	NBMG & U. S. Geological Survey Core Research Center, Well Reports, Data on cuttings and core available online at: http://geology.cr.usgs.gov/crc/data/NV/	Cuttings 718-5835 feet	oil, water
Sans Spring	NBMG & U. S. Geological Survey Core Research Center, Well Reports, Data on cuttings and core available online at: http://geology.cr.usgs.gov/crc/data/NV/	Cuttings 900-8,463 feet	oil, water
Ghost Ranch	NBMG & U. S. Geological Survey Core Research Center, Well Reports, Data on cuttings and core available online at: http://geology.cr.usgs.gov/crc/data/NV/	Cuttings: 500 feet - 4570 feet	oil, small amount of gas, (no) water
Deadman Creek	NBMG & U. S. Geological Survey Core Research Center, Well Reports, Data on cuttings and core available online at: http://geology.cr.usgs.gov/crc/data/NV/	Cuttings 0 - 10,930 feet. Core analysis is available at NBMG for 9440-9475 feet.	oil, gas, water
Sand Dune	NBMG & U. S. Geological Survey Core Research Center, Well Reports, Data on cuttings and core available online at: http://geology.cr.usgs.gov/crc/data/NV/	Cuttings: 642-6411 feet	oil, water

Table 1 (continued).

Fracture intensity	Main reference, number 1	Main reference, number 2	Main reference, numbers 3+
FRACINTENS	REF1	REF2	REF3
fractured	Bortz (1994a and b)	Bortz and Murray (1979)	Nevada Petroleum Society (1989)
fractured carbonate	Herring (1994a and b)	Nevada Petroleum Society (1989)	
unknown	French (1994b and c)	French and Freeman (1979)	Duey (1979)
unknown	Duey (1994a and b)		
high concentration of interconnected fractures, vugs, and caverns	Johnson and Schalla (1994a)	Hulen and others (1994)	Johnson (1994); MCCutcheon and Zogg (1994)
strong	Flanigan (1994)		
intense; high concentration of interconnected fractures, vugs, and caverns	Johnson and Schalla (1994b)	Hulen and others (1994)	Read and Zogg (1988); Johnson (1994); McCutcheon and Zogg (1994)
strong	Hansen and others (1994a)	Ransom (1994b)	
unknown	Hansen and others (1994b)	Ransom (1994a)	
fractured limestone	Schalla and Grabb (1994)		
unknown	French (1994a)	French and Kozlowski (1994)	Hess and others (2004)
unknown	Grabb (1994a and b)	Hess and others (2004)	
intense fracturing of dolomite	Montgomery and others (1999)	Hansen and Schaftenaar (2005)	
unknown	Frerichs and Pekarek (1994)	Hess and others (2004)	
unknown	Nevadd Bureau of Mines and Geology oil well files		

Table 1 (continued).

Oil field name	Current operator	Approximate UTM northing	Approximate UTM easting	Cumulative water production through 2006 (barrels)
OILFIELDNA	OPERATOR	APROX_UTMN	APROX_UTME	H2OCUMPROD
Eagle Springs	Meritage Energy Company	4273342	627676	5,121,534
Kate Spring	Western General Incorporated	4270858	627193	6,255,046
Trap Spring	Apache Incorporated	4273931	617249	32,908,982
Currant	Makoil, Inc.	4283509	627560	0
Bacon Flat	Equitable Res. Energy Co., Balcron Oil Div.	4257863	622670	729,680
Blackburn	Amoco Production Co.	4453568	573279	33,116,941
Grant Canyon	Makoil, Inc.	4256785	624173	4,856,303
Tomera Ranch	Foreland Corp.	4485300	574050	498,612
North Willow Creek	Deerfield Production Corporation	4468420	576920	3,210
Three Bar	The Gary-Williams Company	4459310	571050	5,958
Duckwater Creek	Makoil, Inc.	4276600	620800	66,225
Sans Spring	Double D Nevada, LLC	4258450	617700	3,716,058
Ghost Ranch	Eagle Springs Production LLC	4272120	627980	2,619,324
Deadman Creek	Foreland Corp.	4570112	703709	0
Sand Dune	Meritage Energy Company	4272050	627800	298,659

Table 2. Data field labels and description of the data contained in each of the fields on Table 1 and in the accompanying GIS coverage of Nevada's commercially producing oil fields.

OILFIELDNA	Name of the oil field
DISCO_WELL	Name of the discovery well for the oil field
PERMIT	Nevada permit number for the discovery well for the oil field
API	API number of the discovery well for the oil field
LOCATION	General location of the oil field
COUNTY	County in which the oil field is located
T	Township in which the oil field is located
R	Range in which the oil field is located
S	Section(s) in which the oil field is located
QTRSEC	Quarter section in which the discovery well for the oil field is located
DEPTHTOTOP	Depth to top of the oilfield in the discovery well for the oil field
PRODDEPTH	Range of depth of the producing zone in the discovery well for the oil field
AVDEPTHPRO	Average depth of the production zone in all producing wells for the oil field
CUMPROD2006	Cumulative production of the oil field through 2006 (in barrels)
ZONESTATUS06	Zone status of all wells in the oil field as of the end of 2006: currently producing, shut-in, or abandoned (P&A)
NUMPRODWEL	Number of producing wells in the oil field at the end of 2006
NUMINACTWE	Number of inactive wells in the oil field at the end of 2006
DEPTHFRESH	Depth to base of fresh water in oil field wells (not known)
HOSTROCK	Host rock (reservoir) ages, name of formations, and rock types for oil fields
AVEUNITTHI	Average thickness of reservoir rock units in producing wells for each field (this may not be the average potential thickness of reservoir rocks in the surrounding area.)
FIELDAREA	Field area as reported in or inferred from literature. A minimum value of 40 acres was used for small fields with no area reported.
POROSITY	Porosity of reservoir rocks
PERMEABILI	Permeability of reservoir rocks
INITPRE	Initial pressure at TD in discovery well
INITIALTEM	Initial temperature at TD in discovery well
FMSALINITY	Formation water salinity
SEALTYPE	Type of seal for reservoir
SEALTHICK	Seal thickness if known or thickness of formation that acts as the seal to the reservoir
TRAPTYPE	Type of trap; structural, stratigraphic, lithologic, other
STIMULATIO	Stimulation, history of secondary and tertiary recovery efforts
LOGS	Logs available for the discovery hole in each oil field
SAMPLES	Samples available for discovery hole in each oil field
LOGLOC	Location of logs and samples for discovery hole and other producing wells of the oil field
RESFLUID	Reservoir fluid (oil, gas, water)
FRACINTENS	Intensity or presence of fracturing of reservoir rock
REF1	Main reference, number 1
REF2	Main reference, number 2
REF3	Main reference, numbers 3+
OPERATOR	Current or most recent operator for the oilfield
APROX_UTMN	Approximate UTM northing of the discovery well for the oilfield
APROX_UTME	Approximate UTM easting of the discovery well for the oilfield
H2OCUMPROD	Cumulative water production of the oil field through 2006

Sources of data for Table 1 include well, core, sample, and log repositories of the Nevada Bureau of Mines and Geology and the U.S. Geological Survey. The Nevada Bureau of Mines and Geology Information Office archives the most complete records and samples. Companies drilling oil and gas wells are required by Nevada state law to give the state copies of logs and two sets of cuttings for each oil and gas well drilled. The logs and sample sets are kept confidential for six months. The Information Office is also the repository for other well cuttings (from geothermal and some other wells) and core. All cuttings, core, and well logs described in the accompanying database of producing Nevada oil fields are housed at NBMG and available for examination. The collection is electronically indexed and may be examined during NBMG business hours. There are also logs for 115 Nevada oil and gas exploration wells available from the USGS as part of the Basin and Range Carbonate Aquifer System Study. They are available online at http://nevada.usgs.gov/barcass/geo_logs/nye_county.htm

Discussion

Critical factors in assessing the potential for enhanced oil recovery as a means of CO_2 sequestration in Nevada include depth of oil production (with a minimum depth of 800 m, so that the CO_2 stays in a liquid state under hydrostatic pressure), temperature (so that the density of CO_2 is preferably greater than 0.6 g/cm^3), volume of pore space available (as estimated from the resource potential or, for fields with declining production, cumulative production), permeability of the oil reservoir, and thickness of the seal that kept the oil in place. These factors, along with others, are listed in Table 1. With one exception (the Tomera Ranch field in Pine Valley), the Nevada oil fields meet the minimum depth criterion. Most fields, however, are so hot that densities of the CO_2 would likely to be less than 0.6 g/cm^3 within the reservoirs (Figure 2). Exceptions, where CO_2 may be denser, include two insignificant producers (Duckwater Creek in Railroad Valley and Deadman Creek in Toano Draw) and one major producer (Trap Spring field in Railroad Valley).

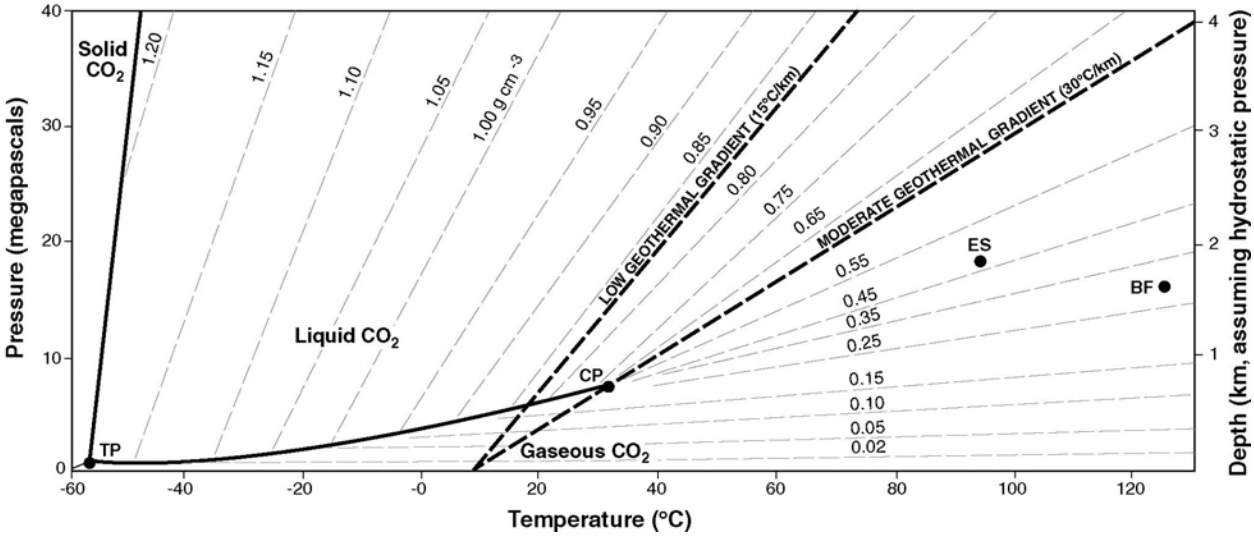

Figure 2. Phase relations, with lines of equal density, for CO_2 (modified from Roedder, 1984). TP = triple point (-56.6°C, 0.5 megapascals), at which solid, liquid, and gaseous CO_2 coexist. CP = critical point (31.0°C, 7.38 megapascals), above which the distinction between gas and liquid cannot be made with increasing pressure or temperature. ES = bottom-hole temperature (93°C at 1,830 m) in the Eagle Springs oil field (Shevenell and Garside, 2005, and http://www.nbmg.unr.edu/geothermal/gthome.htm). BF = reservoir temperature (120-130°C at about 1,625 m) in the Bacon Flat-Grant Canyon oil fields (Hulen and others, 1994).

Davis (2007) provided the most recent update on Nevada oil production. Nevada's total oil production in 2006 was 425,705 barrels (0.023% of total U.S. production), from nine fields located in Railroad Valley, Nye County, and from two fields in Pine Valley, Eureka County. Nevada's four other past-producer oil fields were shut in throughout 2006. Nevada ranked 26 out of the 31 oil producing states in the country in 2006 oil production. Nevada's 67 productive oil wells yielded between 3 and 166 barrels of oil and up to 2,503 barrels of water per day. Nevada's cumulative oil production from 1954 through 2006 from all commercial oil fields totaled just less than 50 million barrels, and annual production has steadily declined since 1992 (Figure 3). Cumulative production for each oil field during this time period is shown in Table 1, and cumulative production for each field is shown in Figure 4. Each of the major Nevada oil fields – ones that have produced over 1 million barrels (Grant Canyon, Trap Spring, Eagle Spring, and Kate Spring in Railroad Valley and Blackburn in Pine Valley) – experienced substantial declines in production since peaking in the 1990s or earlier (Figure 5). For more detailed information on Nevada's petroleum resources, please refer to Garside and Hess (2007); their petroleum data map shows current and past oil production and exploration wells in Nevada, as well as "seeps" or surface shows of oil, gas or solid bitumen.

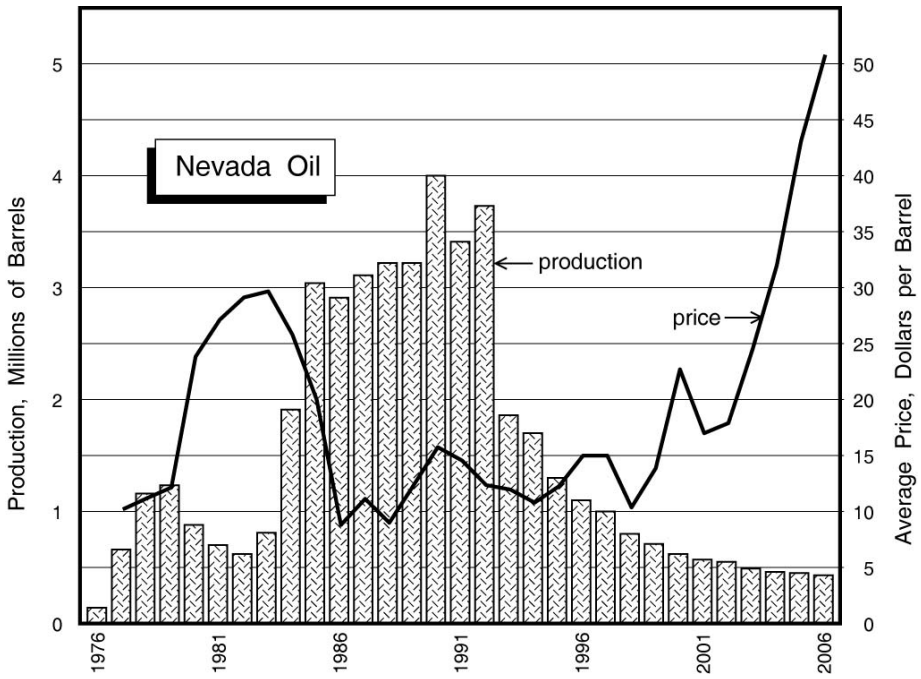

Figure 3. Production and price history for Nevada oil, 1976-2006 (from Price and Meeuwig, 2007).

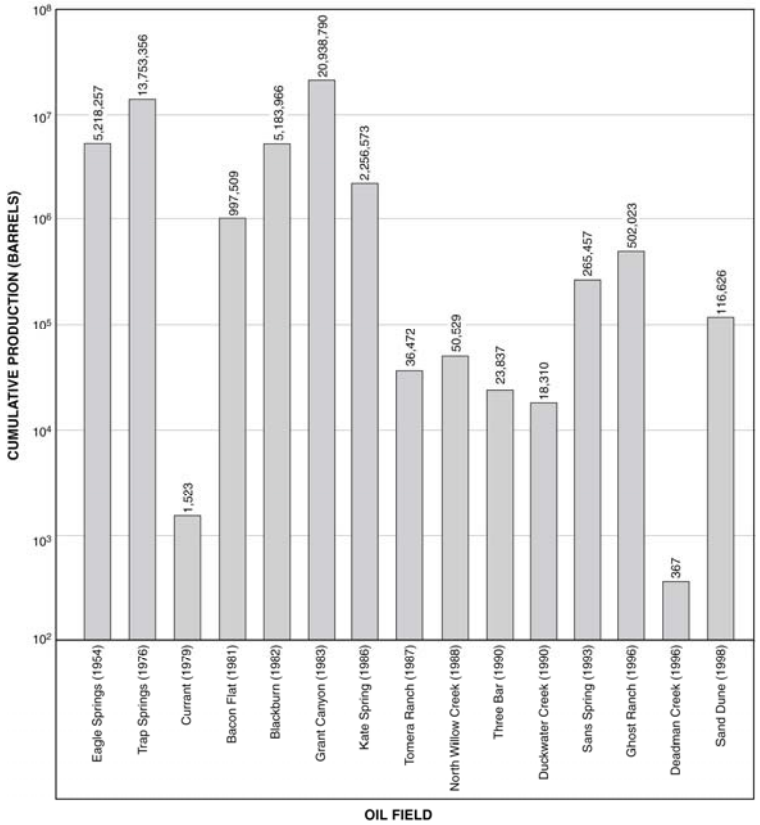

Figure 4. Cumulative Nevada oil production, through 2006, by field, with year of discovery in parentheses.

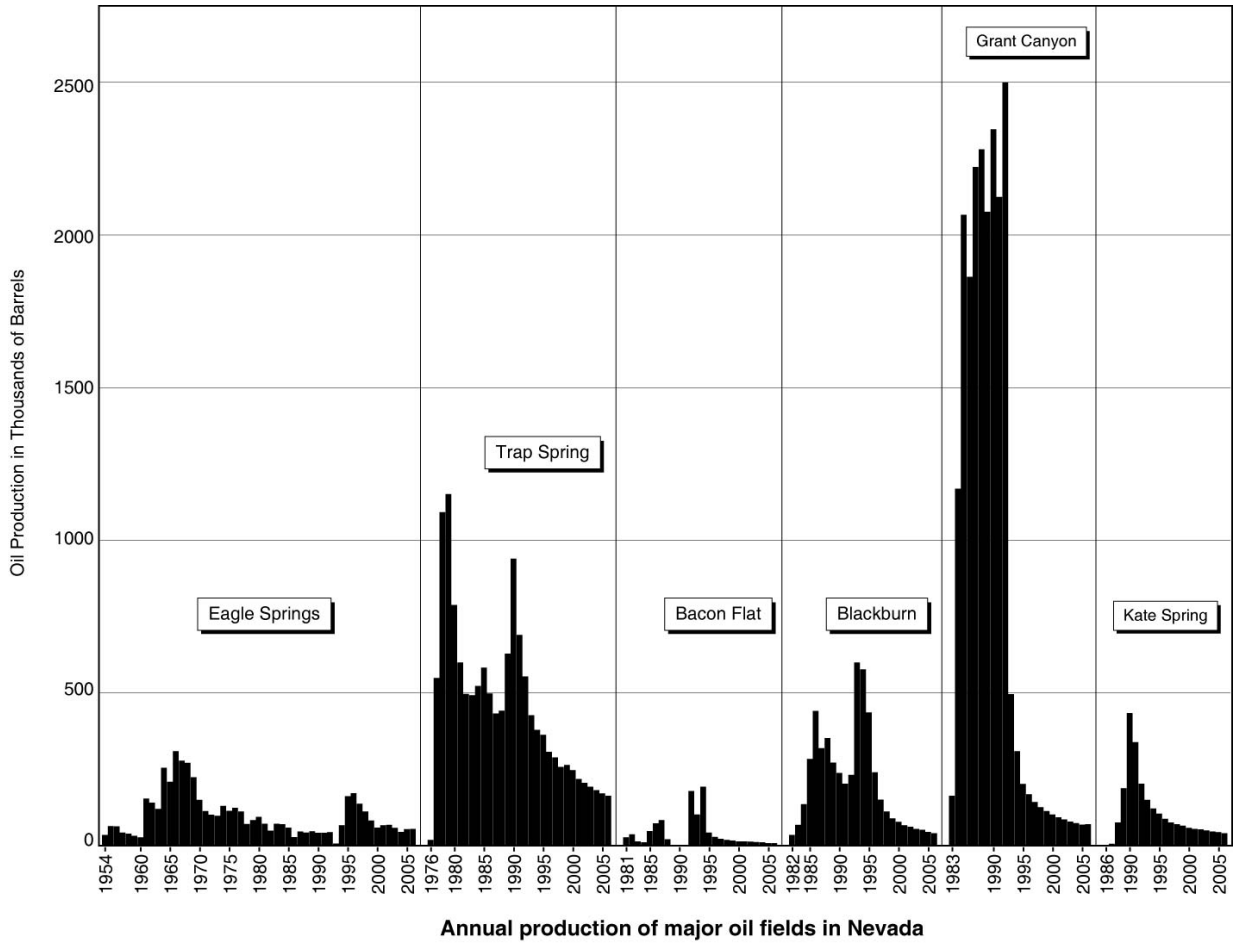

Figure 5. Production histories of Nevada's largest oil fields (from Davis, 2007).

Price and others (2005) concluded that there does not appear to be much potential in Nevada for CO_2 sequestration through enhanced oil recovery, in part because the oil fields in Nevada tend not to have much associated natural gas, implying that gas originally associated with the fields has escaped. Injected CO_2 would likely leak to the surface as well. In addition, the oil fields in Nevada are small relative to fields in many other parts of the United States, and most Nevada fields are considerably hotter than ideal conditions for maintaining a dense CO_2 phase underground. A large coal-fired power plant that burned 250 million tons of carbon over its lifetime would generate 0.916 gigaton of CO_2, which would occupy a volume of 7.7 billion barrels at a CO_2 density of 0.75 g/cm^3 (typical of areas with low geothermal gradients) or 19 billion barrels at a density of 0.30 g/cm^3. The lower density of CO_2 is applicable for the largest oil fields in Nevada, which are hot (Figure 2; 120 to 130°C at 1,625 m in the Bacon Flat-Grant Canyon oil fields; Hulen and others, 1994). Cumulative oil production from Nevada, through 2006, is slightly less than 50 million barrels, and cumulative water production has been approximately 90 million barrels. The cumulative volume of oil and water production from all Nevada oil fields, approximately 140 million barrels, is about two orders of magnitude less than what would be needed to sequester a significant amount of CO_2 from a power plant. Therefore the conclusion still stands: there is not much potential in Nevada for CO_2 sequestration through enhanced oil recovery.

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