

Table 1-1. Water quality concentrations of TDS, sulfate and barium of some outfalls and downstream sampling locations of oil and gas facilities in the Bighorn, Platte and Powder River basins.

Basin	Associated Oil/Gas Facility	General Location	Drainage or Outfall	Avg - TDS	Max- TDS	Avg - Sulfate	Max- Sulfate	Barium	Data source
Platte (Wind) River	S. Casper Creek field	North Platte and tributaries	Poison spider & Oregon Trail	3,153	3,450	1,561	1,746		Gene R. George & Assoc. 2005 (2002-2004 data)
Bighorn	Hamilton Dome field	Cottonwood Creek	Cottonwood B, WY0000680, WY0000175	4,011	7,320	1,640	3,270		SWWRC et al. 2002 (2002 data)
Bighorn	Oregon Basin oil field	Dry Creek	Maverick Springs	1,161		492			M. Blakesly, pers. comm
			Chatterton	1,204		511			
			Circle Ridge	703		80			
			Byron Battery #2 Injection			1,815			
			Garland Unit Battery	2,900		1,450			
			Battery #1 South Outfall	4,475	4,600	2,080	2,180		
			Battery #2 North Outfall	5,345	5,390	2,735	2,950		
			Battery #3-5 South Outfall	4,530	4,530	1,870	1,870		
			Battery #1 North	5,100		3,085			
			Pitchfork	2,065		772			
			Steamboat Butte - North	3,838		1,690			
			Steamboat Butte - South	1,297		532			
Powder River	Fidelity facilities	Downstream locations	Tongue River	1,508					R. Edds, pers. comm.
			Wrench Ranch	1,054					
			Lake de Smet	830					

Basin	Associated Oil/Gas Facility	General Location	Drainage or Outfall	Avg - TDS	Max- TDS	Avg - Sulfate	Max- Sulfate	Barium	Data source
Powder River	Anadarko facilities	Outfall	Alpha Pod #2	2,400		<10		1.7	J. Cline, pers. comm.
		Outfall	County Line Alpha Pod	3,000				1.9	
		Outfall	Delta/Epsilon Skew Inlet IMR	2,800	3,500	ND	ND	3.8	
		Outfall	County Line Beta Pod #1	2,708		64			
Powder River	Lance operations	Powder River	Powder River water compositions typical of Lance CBNG operations	2,500		4		1.6	D. Stephens, pers. comm.
Powder River	Salt Creek fields	Salt Creek	Salt Creek at main discharge area	3,995	4,580	1,132	1,680		RETEC 2004
		Salt Creek	Salt Creek downstream of discharges	3,876	4,610	1,235	1,700		
		Powder River	Powder River downstream of discharges	2,202	3,640	920	1,340		
Petition Proposed effluent limits:				2,000		500		0.2	

Notes:

all results in mg/l

Data reflects samples collected between 2002 and 2006.

ND = non-detect

Table 1-2. Wildlife species recorded in the Cottonwood Creek area near the confluence of the Bighorn River.

Mallard duck
Blue-winged teal
Canada goose
Great blue heron
Sandhill Crane
Wilson's phalarope
Spotted Sandpiper
Killdeer
Mountain Plover
Gray partridge
Chukar
Sage grouse
Ring-necked pheasant
Mourning dove
Northern harrier
Red-tailed hawk
Golden eagle
Bald eagle
Prairie falcon
Merlin
American kestrel
Great horned owl
Borrowing owl
Yellow-billed cuckoo
Belted kingfisher
Common nighthawk
Western kingbird
Cassin's kingbird
Horned lark
Black-billed magpie
Western meadowlark
Brewer's blackbird
Pine siskin
Vesper sparrow
Savannah sparrow
Grasshopper sparrow
Lark sparrow
Song sparrow

Table 1-2. Wildlife species recorded in the Cottonwood Creek area near the confluence of the Bighorn River.

Lark bunting
Cliff swallow
Sage thrasher
Rock wren
American robin
Mountain bluebird
Masked shrew
Western small-footed myotis
Desert cottontail
Least chipmunk
Wyoming ground squirrel
Montane vole
Long-tailed vole
Coyote
Red fox
Long-tailed weasel
Badger
Bobcat
Mountain lion
Moose
Mule deer
White-tailed deer
Pronghorn antelope

Notes:

Reproduced from SWWRC et al. 2002.

Table 1-3. Wildlife species recorded in the Loch Katrine wetland complex.

Canada goose	<i>Branta canadensis</i>
Redhead	<i>Aythya americana</i>
lesser scaup	<i>A. affinis</i>
mallard	<i>Anas platyrhynchos</i>
pintail	<i>A. acuta</i>
gadwall	<i>A. strepera</i>
American wigeon	<i>A. americana</i>
northern shoveler	<i>A. clypeata</i>
greenwinged teal	<i>A. crecca</i>
blue-winged teal	<i>A. discors</i>
cinnamon teal	<i>A. cyanoptera</i>
carled grebe	<i>Podiceps nigricollis</i>
American coot	<i>Fulica americana</i>
black-necked stilt	<i>Himantopus mexicanus</i>
American avocet	<i>Recurvirostra americana</i>
sandhill crane	<i>Grus canadensis</i>
white-faced ibis	<i>Plegadis chihi</i>
long-billed curlew	<i>Numenius americanus</i>
killdeer	<i>Charadrius vociferus</i>
black tern	<i>Chlidonias niger</i>
Wilson's phalarope	<i>Phalaropus tricolor</i>

Table 1-4. Birds and mammals surveyed in the South Casper Creek field near Poison Spider Creek.

Mallard
Gadwall
Wigeon
Ruddy Duck
Virginia Rail
Sora
American Coot
Killdeer
Baird's Sandpiper
California Gull
Turkey Vulture
Golden Eagle
Northern Harrier
Greater Sage Grouse
Mourning Dove
Western Kingbird
Say's Phoebe
Western Flycatcher
Horned Lark
Unknown Swallow
Black-billed Magpie
House Wren
Gray Catbird
Sage Thrasher
European Starling
Wilson's Warbler
Common Yellowthroat
Brewer's Sparrow
Chipping Sparrow 1
Savannah Sparrow
Vesper Sparrow
Unknown Sparrow
Lark Bunting
Western Meadowlark
Brewer's Blackbird
Northern Oriole

Table 1-5. Exposure parameters for each indicator receptor.

Receptor class	Species	IR _{water} (L-day)	IR _{food} (kg wet-day)	BW (kg wet wt)
Rodent	rat	0.046 EPA 1988	0.028 US EPA 1988	0.35 US EPA 1988
Ruminant-juvenile	growing steer	29.5 Winchester and Morris 1956	6.24 NAS 2000	300 NAS 2000
Passarine bird	mallard	0.064 US EPA 1993	0.251 US EPA 1993	1.13 US EPA 1993
Ruminant-adult	adult steer	34.8 Winchester and Morris 1956	7.76 Winchester and Morris 1956	800 NAS 2000

Notes:

IR_{water} = ingestion rate of water

IR_{food} = ingestion rate of food

BW = body weight

Table 1-6. Ingestion rate equations.

Equation	Species	Reference
$IR_{\text{water}} = 0.059(BW)^{0.67}$	for birds (L-day)	Calder and Braun 1983
$IR_{\text{water}} = 0.10(BW)^{0.7377}$	for laboratory mammals (L-day)	US EPA 1988
$IR_{\text{food}} = 0.648(BW)^{0.651}$	for birds (g-day)	Nagy 1987
$IR_{\text{food}} = 0.056(BW)^{0.6611}$	for laboratory mammals (kg-day)	US EPA 1988

Notes:

IR_{water} = ingestion rate of water

IR_{food} = ingestion rate of food

BW = body weight

Table 1-7. Barium toxicity study database and selected studies to derive water quality concentrations

Constituent	Receptor type	Reference	Chemical Form Administered	Organism	Route of Administration	Endpoints	Study Duration	NOAEL (mg/kg/d)	LOAEL (mg/kg/d)
Barium	bird	Johnson et al. (1960)	BaOH2	chicken (chicks)	oral in diet	mortality	4 weeks	208	417
Barium	bird	Taucins et al. (1969)	BaCl2 and BaCO3	chicken	oral in diet	weight gain, mortality		N/A	10.05
Barium	mammal (rat)	Borzelleca et al. (1988)	BaCl2	rats	gavage	growth, reproduction	10 days	138	198
Barium	mammal (rat)	Dietz et al. (1992)	BaCl2	rats	oral in water	growth, reproduction, development, mortality	92 days	61.1	121
Barium	mammal (rat)	McCauley et al. (1985)	BaCl2	rats	oral in water	absorption	16 to 46 weeks	N/A	N/A
Barium	mammal (rat)	Perry et al. (1983)	BaCl2	rats	oral in water	growth, hypertension	16 months	13.2	N/A
Barium	mammal (rat)	Schroeder and Mitchener (1975)	BaCl2	rats	oral in water	growth	lifetime	0.25	N/A
Barium	mammal (rat)	Tardiff et al. (1980)	BaCl2	rats	oral in water	adrenal weights	90 days	45.7	N/A

Notes:

Bolded text indicates studies selected to derive recommended water quality benchmarks for barium, sulfate and TDS.

Table 1-9. Sulfate toxicity study database and selected studies to derive water quality concentrations.

Constituent	Receptor type	Reference	Chemical Form Administered	Organism	Route of Administration	Endpoints	Study Duration	NOAEL (mg/kg/d)	LOAEL (mg/kg/d)
Sulfate	bird	Adams et al. (1975) (exp 1)	Na2SO4, MgSO4	chicken (hens)	oral in water	water/food intake, reproduction, mortality		101.2	404.9
Sulfate	bird	Adams et al. (1975) (exp 2)	Na2SO4, MgSO4	chicken (hens)	oral in water	water/food intake, reproduction, mortality		303.7	1619.2
Sulfate	bird	Harter and Baker (1978)	Na2SO4, KSO4	chicken	oral in diet	growth	28 days	N/A	288.3
Sulfate	bird	Katz and Baker (1975)	KSO4	chicken	oral in diet	feed efficiency, growth rate	7 weeks	1.1	N/A
Sulfate	bird	Krista et al. (1961)	Na2SO4	chicken	oral in water	egg production, intake rate		1196.0	1214.4
Sulfate	bird	Leach et al. (1960)	L-methionine	chicken	oral in diet	feed efficiency, growth rate	8 days	N/A	81.9
Sulfate	bird	Sasse and Baker (1974)	L-methionine	chicken	oral in diet	growth	8 days	N/A	81.9
Sulfate	mammal (livestock)	Digesti and Weeth (1976)	Na2SO4	growing cattle	oral in water	food/water intake, weight gain	90 days	245.8	N/A
Sulfate	mammal (livestock)	Embry et al. (1959) (exp 1)	Na2SO4	growing cattle	oral in water	food/water intake, weight gain	84 days	489.2	698.9
Sulfate	mammal (livestock)	Embry et al. (1959) (exp 2)	Na2SO4	growing cattle	oral in water	food/water intake, weight gain	112 days	604.7	N/A
Sulfate	mammal (livestock)	Grout et al. (2006) (exp 1)	Na2SO4	growing cattle	oral in water	water intake	11 days	421.9	N/A
Sulfate	mammal (livestock)	Grout et al. (2006) (exp 2)	MgSO4	growing cattle	oral in water	water intake	11 days	270.1	170.3
Sulfate	mammal (livestock)	Johnson and Patterson (2004)	natural water sources	growing cattle	oral in water	food/water intake, weight gain (feedlot)	112 days	N/A	251.4
Sulfate	mammal (livestock)	Johnson and Patterson (2004) (exp 1)	natural water sources	growing cattle	oral in water	food/water intake, weight gain	63 days	570.7	N/A
Sulfate	mammal (livestock)	Johnson and Patterson (2004) (exp 2)	natural water sources	growing cattle	oral in water	food/water intake, weight gain (open range)	112 days	360.4	N/A
Sulfate	mammal (livestock)	Loneragan et al (2001)	natural or treated water sources.	adult steers	oral in water	water intake, growth, feed efficiency	112 days	N/A	N/A
Sulfate	mammal (livestock)	Patterson et al. (2002)	natural/well water sources	adult steers	oral in water	food/water intake, weight gain, PEM	84 days	55.7	380.6
Sulfate	mammal (livestock)	Patterson et al. (2003)		growing cattle	oral in water	food/water intake, weight gain	3 months	N/A	N/A
Sulfate	mammal (livestock)	Patterson et al. (2004)	Na2SO4	adult cows	oral in water	water intake, weight gain, reproductive impacts	84 days	47.7	326.8
Sulfate	mammal (livestock)	Ward and Patterson (2004)	Na2SO4	adult cows	oral in water	water intake, weight gain, reproductive impacts	84 days	47.7	351.8
Sulfate	mammal (livestock)	Weeth and Caps (1972)	Na2SO4	growing cattle	oral in water	water intake, growth, feed efficiency	30 days	365.8	N/A
Sulfate	mammal (livestock)	Weeth and Hunter (1971)	Na2SO4	growing cattle	oral in water	food/water intake, weight gain	30 days	11.0	343.5
Sulfate	mammal (livestock)	Zimmerman et al. (2003)	MgSO4	cattle	oral in water	water intake, behavior	unknown	N/A	N/A
Sulfate	mammal (rat)	Brown and Gamatero (1970)	Na2SO4	rats	oral in diet	feed efficiency, growth rate	28 days	18.08	N/A
Sulfate	mammal (rat)	Cohen et al. (1958)	DL-methionine	rats	oral in diet	growth	72 days	N/A	412.8
Sulfate	mammal (rat)	Daniel and Waisman (1969)	L-methionine	rats	oral in diet	growth	24 days	172	516
Sulfate	mammal (rat)	Smith (1973)	methionine and CaSO4	rats	oral in diet	sulfate metabolism	7 days	16	N/A
Sulfate	mammal (rat)	Weeth and Hunter (1971)	Na2SO4	rats	oral in water	growth	unknown	668.0	N/A

Notes:

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Table 1-11. TDS toxicity study database and selected studies to derive water quality concentrations.

Constituent	Receptor type	Reference	Chemical Form Administered	Organism	Route of Administration	Endpoints	Study Duration	NOAEL (mg/kg/d)	LOAEL (mg/kg/d)
TDS	bird	Belnave and Scott (1986) (exp 1)	NaCl	chicken (hens)	oral in water	food intake, reproduction		N/A	37.4
TDS	bird	Belnave and Yolowitz (1987)	NaCl	chicken (hens)	oral in water	eggshell quality	5 weeks	N/A	111.2
TDS	bird	Belnave et al. (1989)	NaCl	chicken (hens)	oral in water	egg production, food/water intake	5 weeks	20.0	104.1
TDS	bird	Heller (1933)	NaCl	chicken (hens)	oral in water	egg production, growth	10 weeks	304.6	456.8
TDS	bird	Heller (1933)	MgSO4	chicken (hens)	oral in water	egg production, growth	10 weeks	456.8	N/A
TDS	bird	Heller (1933)	CaCl	chicken (hens)	oral in water	egg production, growth	10 weeks	N/A	456.8
TDS	bird	Kare and Biely (1948)	NaCl	chicken (chicks)	oral in food & water	feed efficiency, weight gain, mortality	29 days	7073.0	N/A
TDS	bird	Krista et al. (1961) (exp 1)	NaCl (municipal water)	chicken (chicks)	oral in water	food/water intake, growth	4 weeks	598.8	1047.9
TDS	bird	Krista et al. (1961) (exp 2)	NaCl (municipal water)	chicken (hens)	oral in water	food/water intake, growth	16 weeks	598.8	1497.0
TDS	bird	Krista et al. (1961) (exp 3)	NaCl (municipal water)	ducklings	oral in water	food/water intake, growth	21 days	269.2	384.6
TDS	bird	Scrivner (1946)	NaCl	1-day old turkey	oral in water	mortality	2 weeks	116.7	350.0
TDS	bird	Selye (1943)	NaCl	chicken (chicks)	oral in water	mortality, nephrosclerosis	20 days	727.3	2181.8
TDS	bird	Yolowitz et al. (1990)	NaCl	chicken (hens)	oral in water	egg production, defects, food/water intake	7 - 8 weeks	N/A	131.2
TDS	mammal (livestock)	Bahman et al. (1993)	brackish water well, total TDS measured.	dairy cows	oral in water	milk production, growth	196 days	613.2	N/A
TDS	mammal (livestock)	Ballantyne (1957)	NaCl	growing & adult cattle	oral in water	mortality	not reported	84.6	N/A
TDS	mammal (livestock)	Ballantyne (1957)	NaSO4	growing & adult cattle	oral in water	mortality	not reported	169.2	N/A
TDS	mammal (livestock)	Ballantyne (1957)	MgSO4	growing & adult cattle	oral in water	mortality	not reported	169.2	N/A
TDS	mammal (livestock)	Blosser and Soni (1956)	"Dissolved solids @ 105C"	dairy cows	oral in water	milk production	6 weeks	23.1	N/A
TDS	mammal (livestock)	Challis et al. (1987)	well water (NaCl measured)	dairy cows	oral in water	milk production		51.5	386.1
TDS	mammal (livestock)	Embry et al. (1959)	NaCl	growing cattle	oral in water	food/water intake, growth	112 days	790.8	1129.7
TDS	mammal (livestock)	Frens (1946)	NaCl	dairy cows	oral in water	milk production		937.5	N/A
TDS	mammal (livestock)	Heller (1933)	NaCl	dairy cows and steers	oral in water	milk production, reproduction, weight gain	21 weeks	1833.9	N/A
TDS	mammal (livestock)	Jaster et al. (1978)	NaCl	dairy cows	oral in water	milk production	28 days	23.6	611.1
TDS	mammal (livestock)	Johnson et al. (1959)	CaCO3 (water source from settling pit)	growing cattle	oral in water	rumen pH, microbial activity	16 weeks	202.3	N/A
TDS	mammal (livestock)	Lassiter and Cook (1963)	NaHCO3	growing cattle (yearlings)	oral in water	food/water intake, digestibility	21 days	398.9	N/A
TDS	mammal (livestock)	Patterson et al. (2003)	NaCl	growing cattle	oral in water	food/water intake, weight gain	3 months	N/A	N/A
TDS	mammal (livestock)	Ramsey (1924)	NaCl	cattle	oral in water	water intake, weight gain, survival	3 mo - 2 yrs	747.8	N/A
TDS	mammal (livestock)	Ray (1989)	CaCl, NaSO4, NaHCO3, NaCl (all added together).	growing cattle	oral in water	food/water intake, efficiency of growth	112 days	189.7	875.3
TDS	mammal (livestock)	Robertson et al. (1996)	sulfate-dominated	steers	oral in water	food/water intake, digestibility	43 days	87	N/A
TDS	mammal (livestock)	Solomon et al. (1995)	natural water sources	dairy cows	oral in water	milk production, water intake	4 months	2.8	63.4
TDS	mammal (livestock)	Spafford (1941)	NaCl	cattle	oral in water	water intake, survival	unknown	619.9	804.8
TDS	mammal (livestock)	Weeth (1962)	MgSO4 added to a TDS of 245	growing cattle	oral in water	food/water intake, growth	4 months	73.3	N/A
TDS	mammal (livestock)	Weeth and Haverland (1961) (exp 1)	NaCl	growing cattle	oral in water	food/water intake, growth	30 days	14.6	2136.6

Table 1-11. TDS toxicity study database and selected studies to derive water quality concentrations.

Constituent	Receptor type	Reference	Chemical Form Administered	Organism	Route of Administration	Endpoints	Study Duration	NOAEL (mg/kg/d)	LOAEL (mg/kg/d)
TDS	mammal (livestock)	Weeth and Haverland (1961) (exp 2)	NaCl	growing cattle	oral in water	food/water intake, growth	30 days	912.8	809.3
TDS	mammal (livestock)	Weeth and Hunter (1971)	NaCl	growing cattle	oral in water	growth	30 days	725.7	N/A
TDS	mammal (livestock)	Weeth et al. (1960)	NaCl	growing cattle	oral in water	food/water intake, growth	30 days	1675.5	1932.4
TDS	mammal (rat)	Embry et al. (1959) (exp 1)	NaCl	rats	oral in water	water intake, growth	112 days	1540.9	N/A
TDS	mammal (rat)	Embry et al. (1959) (exp 2)	MgCl	rats	oral in water	water intake, growth	112 days	627.2	940.7
TDS	mammal (rat)	Embry et al. (1959) (exp 3)	MgSO4	rats	oral in water	water intake, growth	112 days	N/A	790.2

Notes:

Bolded text indicates studies selected to derive recommended water quality benchmarks for barium, sulfate and TDS.