THE HISTORIC
SEEDSKADEE ECOSYSTEM

GEOLOGY AND GEOMORPHOLOGY

Seedskadee NWR is within the Green River Structural Basin, one of the largest Rocky Mountain Intermountain basins (Mason and Miller 2005). Physical boundaries of the basin are the Gros Ventre and Wind River Ranges to the north, the Rock Springs uplift to the east, the east-west trending Uinta Mountains to the south, and the east thrust front of the Wyoming Range-Overthrust Belt to the west (Dover and M'Gonigle 1993). Precambrian rocks underlie the Green River Structural Basin at about 26,000 feet below the surface; the intervening sedimentary rock consequently is variably thick between surface and Precambrian rock (Blackstone 1993). Bedrock geology of Seedskadee NWR is comprised of alluvium and colluviums within the Green River floodplain and Bridger Formation sedimentary rock under upland terraces (Fig. 2). A small amount of the upper and lower parts of the refuge are underlain by Green River Formation rocks. The Precambrian history of Wyoming is poorly understood, but was one of seven Achaean provinces that form the North American craton. During the Middle Proterozoic Era, Wyoming had widespread magmatisim (Snoke 1993); no Precambrian rocks are exposed in Sweetwater County. The Precambrian basement rocks had low relief during the early to middle Paleozoic Era, which created only a thin accumulation of sedimentary rocks. The Green River Structural Basin probably had depositional and structural conditions in the Paleozoic Era that were relatively stable and constant (Krueger 1960). In the Late Paleozoic Era, sediments in the region were deposited by shallow seas and changes in sea level or tectonic activity periodically left some areas above

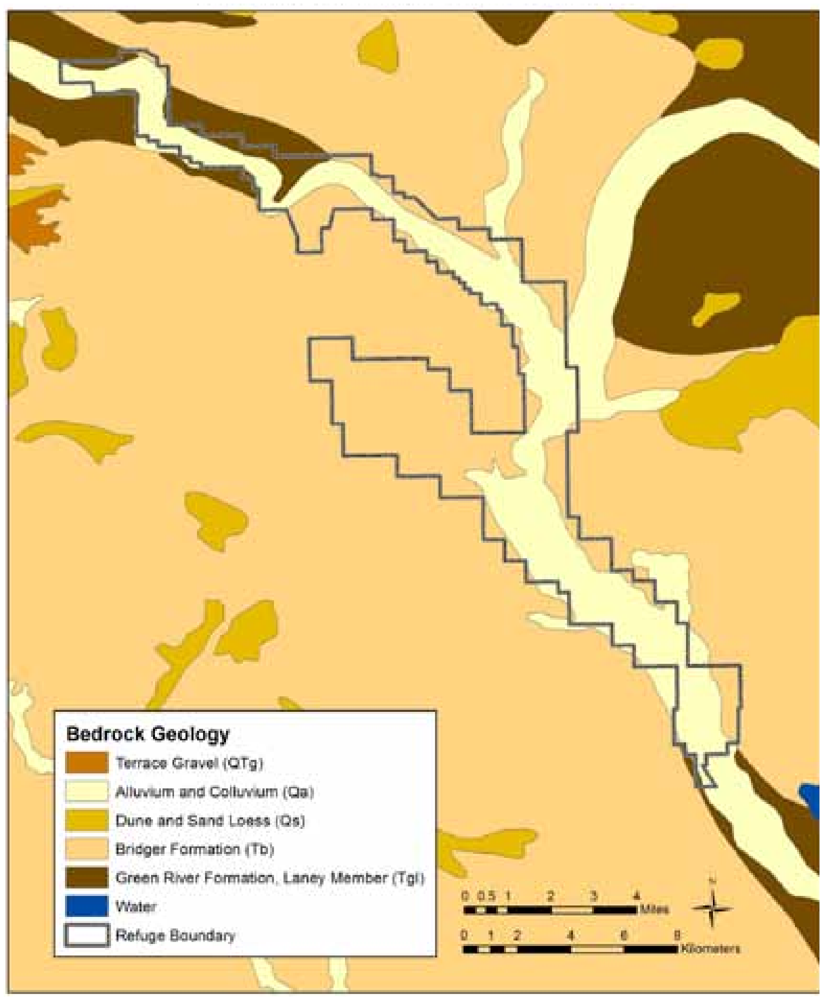

Figure 2. Bedrock geology at Seedskadee National Wildlife Refuge (from Love and Christianson 1985).

sea level, which caused erosion and unconformities in land surfaces.

In the Mesozoic Era, southwestern Wyoming was marked by marine sediments and relatively stable conditions until the Late Cretaceous Period (Krueger 1960). In the Triassic Period, land emergence again caused erosion and unconformity and periodic emergence of land during the Jurassic Period caused deposition of non-marine Nugget Sandstone and Morrison Formation. The Cretaceous Period in Wyoming was dominated by an epicontinental sea and erosion of sediments west of the sea resulted in thick accumulation of sediments in the marine basin. The Late Cretaceous Period was marked by tectonic activity and the Sevier orogeny created a fold and thrust belt west of the present day Sweetwater County, while the Laramide orogeny deformed most of the rest of Wyoming. The ancestral Green River was formed by the Laramide Orogeny (Krueger 1960, Welder and McGreevy 1966). The most notable geological development in the Seedskadee region in the Tertiary Period was the formation of Lake Gosiute during the middle Eocene Epoch. At its maximum extent, this lake covered all of Sweetwater County and sediments deposited in the lake are known as the Green River Formation (Bradley 1964). This formation is a fine-grained calcareous sedimentary rock embedded in thick sandy mudstone that filled the large inter-montane basin. The mudstone that composes the Green River Formation is divided into the Watasch and Bridger Formations above and below the Green River Formation, respectively. Lake Gosiute subsided throughout much of the Eocene Epoch and allowed for deposition of the thick fluvial sediments encompassing the lake deposits; these contain quantities of subbitumious low sulfur coal, oil, natural gas, and soda ash (trona) (Lowham et al. 1985, Roehler 1993).

The formation of Lake Gosiute may have been caused by a reversal of drainage when the east flowing streams of the Paleocene and early Eocene Epochs changed direction in response to the westward tilting of the Wyoming foreland (Love et al. 1963). Filling of the lake basin with sediment led to the extinction of the lake in the middle Eocene (Hansen 1986). Few Tertiary rocks from the Lake Gosiute period occur in Sweetwater County. After Lake Gosiute disappeared, fluvial sediments and tephra were deposited in the region; regional uplifts occurred in two pulses between the late Oligocene and late Pleistocene Epochs (Flanagan and Montagne 1993). In the late Miocene, large river systems including the Green River began to develop and erode older sediments from the basin. This fluvial development initiated the degradation regime in Wyoming that continues to today and was the beginning of the modern drainage system of the region.

During the Quaternary Period, headward erosion of the Green River drainage continued to remove sediments from the old Lake Gosiute basin and other uplift areas and moved the sediments, through fluvial transport, to the Gulf of California (Veatch 1907). This headward erosion continues to today, except that sediments currently are captured in Fontenelle Reservoir and other downstream reservoirs. Quaternary sand dunes are found in most areas of Sweetwater County including the Seedskadee NWR area (Love and Christiansen 1985). Some of these dune fields have been intermittently active for the last 20,000 years and record climatic fluctuations associated with the stades and interstades of continental glaciations (Gibbons et al. 1990). A few Pleistocene playa lakes and other lacustrine deposits occur in the north-central part of the Green River Structural Basin.

The current surficial geology of the refuge contains the active Holocene Green River channel and floodplain, the structural terrace of the Bridger Formation, relict alluvium of tributary channels, and alluvial fans (Fig. 3). The Green River floodplain at Seedskadee NWR is about one to one and half miles wide. This surficial geomorphology, dominated by the Holocene Green River floodplain, reflects Quaternary movement and sinuous migration of the Green River and the erosion of upland terraces adjacent to the floodplain.

SOILS

Contemporary USDA soil maps for Seedskadee NWR (and most of southwest Wyoming) are not available. Gross-scale maps prepared for the refuge in 1957 (Soil Conservation Service 1957) indicate a heterogeneous distribution of soil types with moderately deep sandy and loam soils that are strongly alkaline near the Green River in floodplains and on natural levees; deep clayey, alkali soils on alluvial fans; intermingled gravel and shallow loam soils on recent terraces; moderately deep clay saline-alkali and shallow gravelly soils on upland terraces; and moderately deep sandy soils on remnant terraces and upland benches (Fig. 4).

TOPOGRAPHY

LIDAR elevation surveys were conducted for the refuge region during summer 2010 (Fig. 5). Generally elevations range from 6,182 to 6,398 feet above mean sea level (amsl) and slope from north to south in the Green River floodplain corridor. Elevations commonly rise 200-300 feet from floodplain bottoms to adjacent terraces and uplands. The Little Dry Creek Valley slopes into the Green River floodplain on the west side of the refuge and the Big Sandy River floodplain merges with the Green River on the east side. The floodplain topography contains numerous relict scour and deposition surfaces created by historic fluvial dynamics of the Green River including abandoned channels, oxbows, high water floodflow channels, natural levees, point bar deposits, and floodplain depressions (Fig. 6). Elevations within each river bend area of the wetland units range from about 10-20 feet with the exception of Pal, which is almost a 35 foot range (Table 1). Relatively subtle topographic changes of 1-3 feet commonly occur from the bottom of old meander scrolls or “swales” to adjacent depositional floodplain “ridges.”

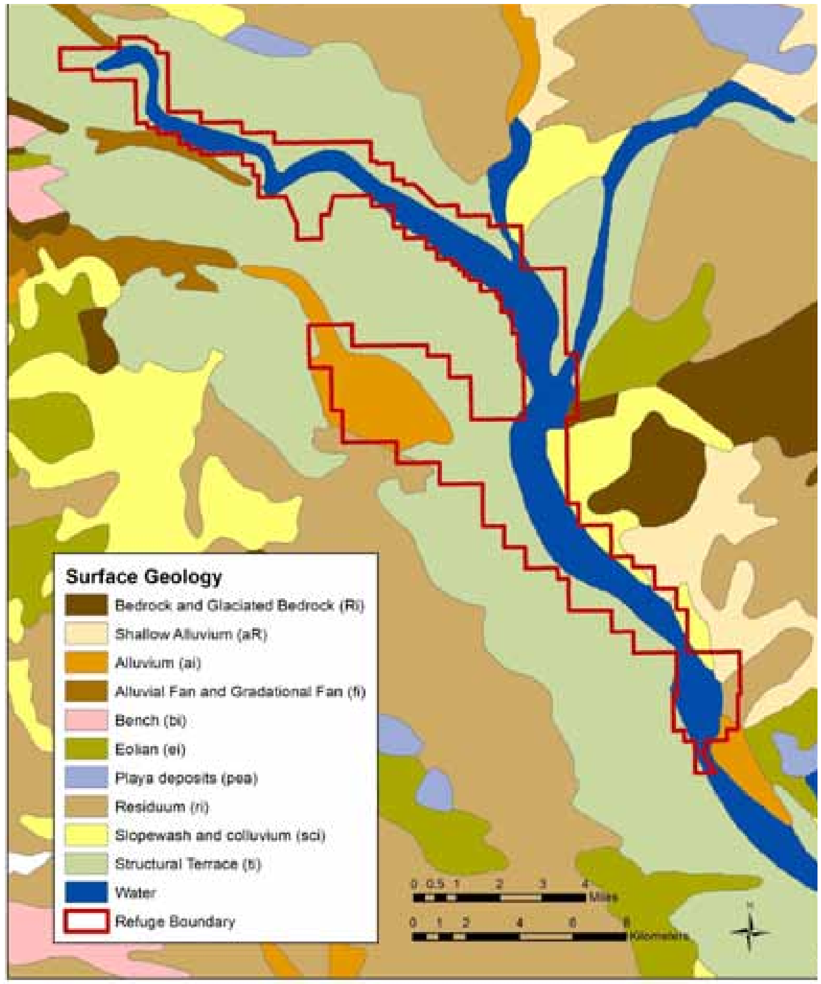

Figure 3. Surficial geomorphic surfaces at Seedskadee National Wildlife Refuge (from Case et al. 1998).

CLIMATE AND HYDROLOGY

The climate of the Seedskadee NWR region of southwestern Wyoming (in Sweetwater County) is broadly classified as desert and steppe (Mason and Miller 2005) The region has warm summers but cold winters and has a short 103-day annual frost-free period (Fig. 7a). Total annual precipitation at Green River, Wyoming averages 6.48 inches but is highly variable among years ranging from 3.82 inches in 1974 to 14.08 inches in 1947 (Fig. 8). Maximum rainfall occurs from May to July with a secondary increase in rainfall in September (Fig. 7b). Large peak pulses of annual precipitation > 11 inches have occurred 11 times since 1913 while extremely dry years with < 5 inches of precipitation have occurred 5 times during that period of record at Green River. Evapotranspiration is high in the Seedskadee NWR region, and often exceeds annual precipitation by 3-5 times.

The Green River and its major tributaries, especially the Big Sandy River, historically were the primary sources of surface water at Seedskadee NWR. Hydrology in the northern part of Seedskadee NWR is influenced mainly by Green River and headwater tributary flows, while the southern part of the refuge also is influenced by flows derived from the confluence of the Green and Big Sandy Rivers. River and stream flow characteristics in the Green River Basin are influenced by the diverse physiography and climate of southwestern Wyoming. The Green River at Seedskadee is a sand-cobble bed system with a meandering sinuosity of 1.56 and an average channel gradient rate-of-fall of 0.9 m/km (Glass 2002). Moderate to large flows in the Green River are the result of runoff from snowmelt, mostly from the Wind River Mountain Range, where the Green River originates.

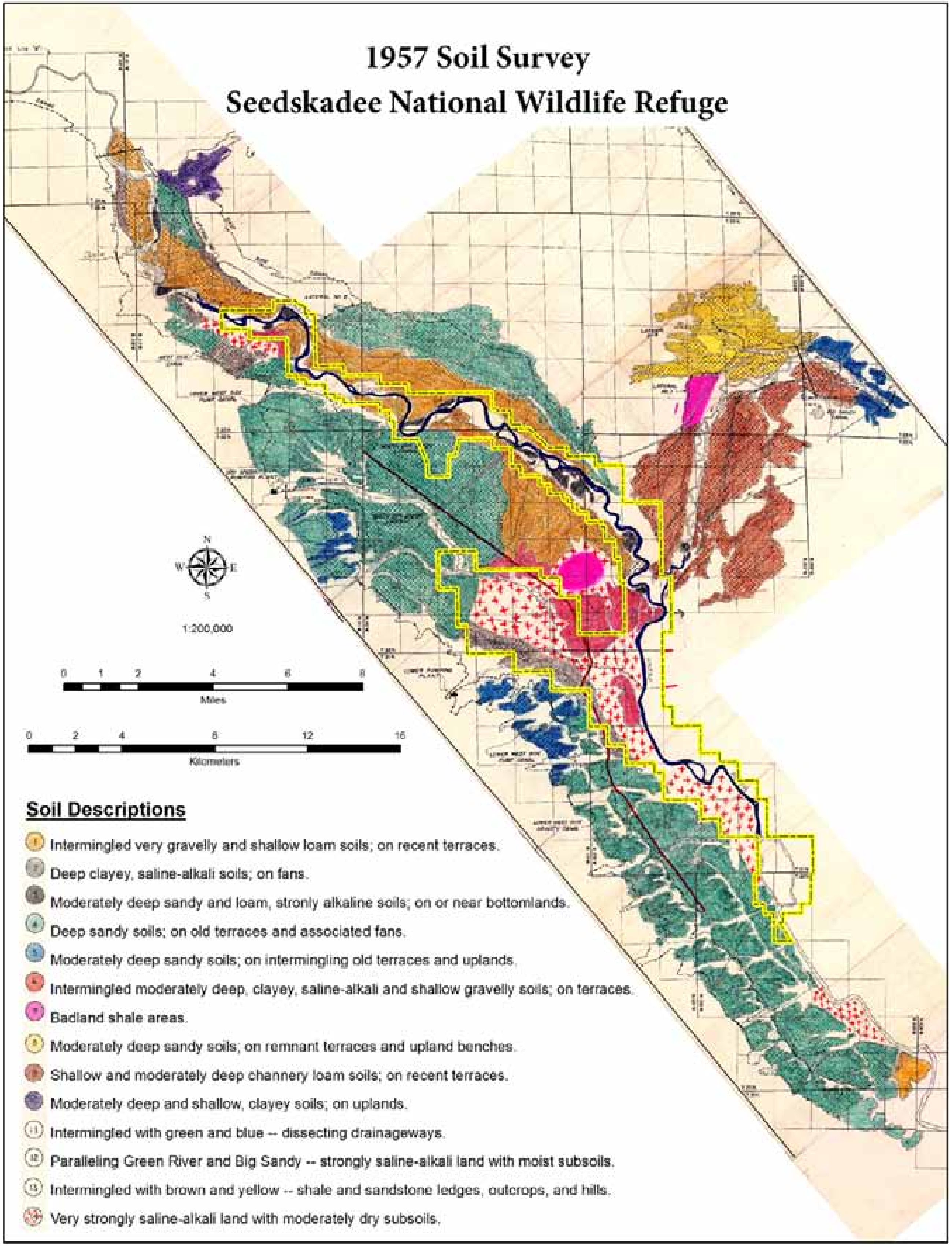

Figure 4. Soil descriptions in the vicinity of Seedskadee National Wildlife Refuge (from Soil Conservation Service 1957).

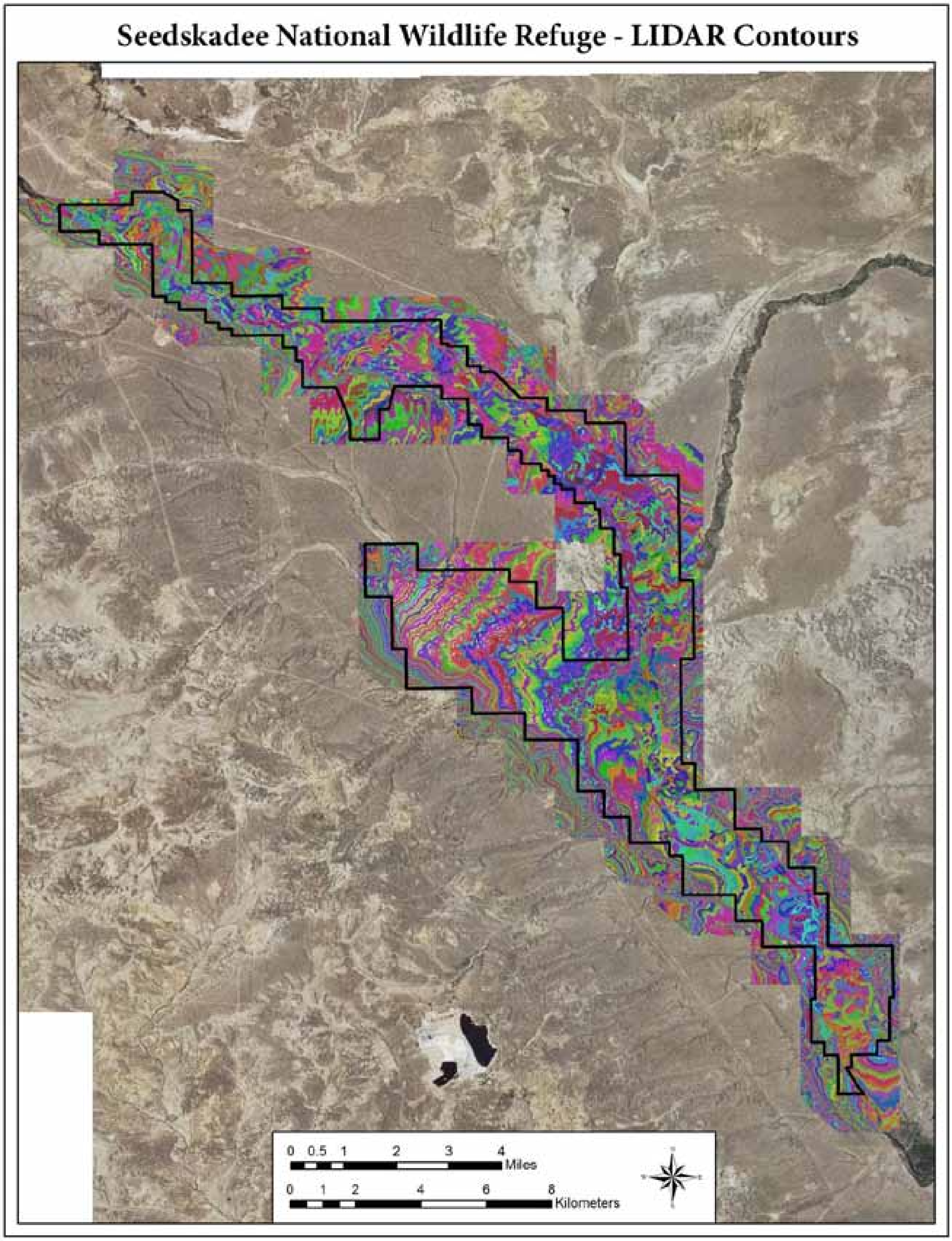

Figure 5. LIDAR topographic contours (one foot) on Seedskadee National Wildlife Refuge, 2010.

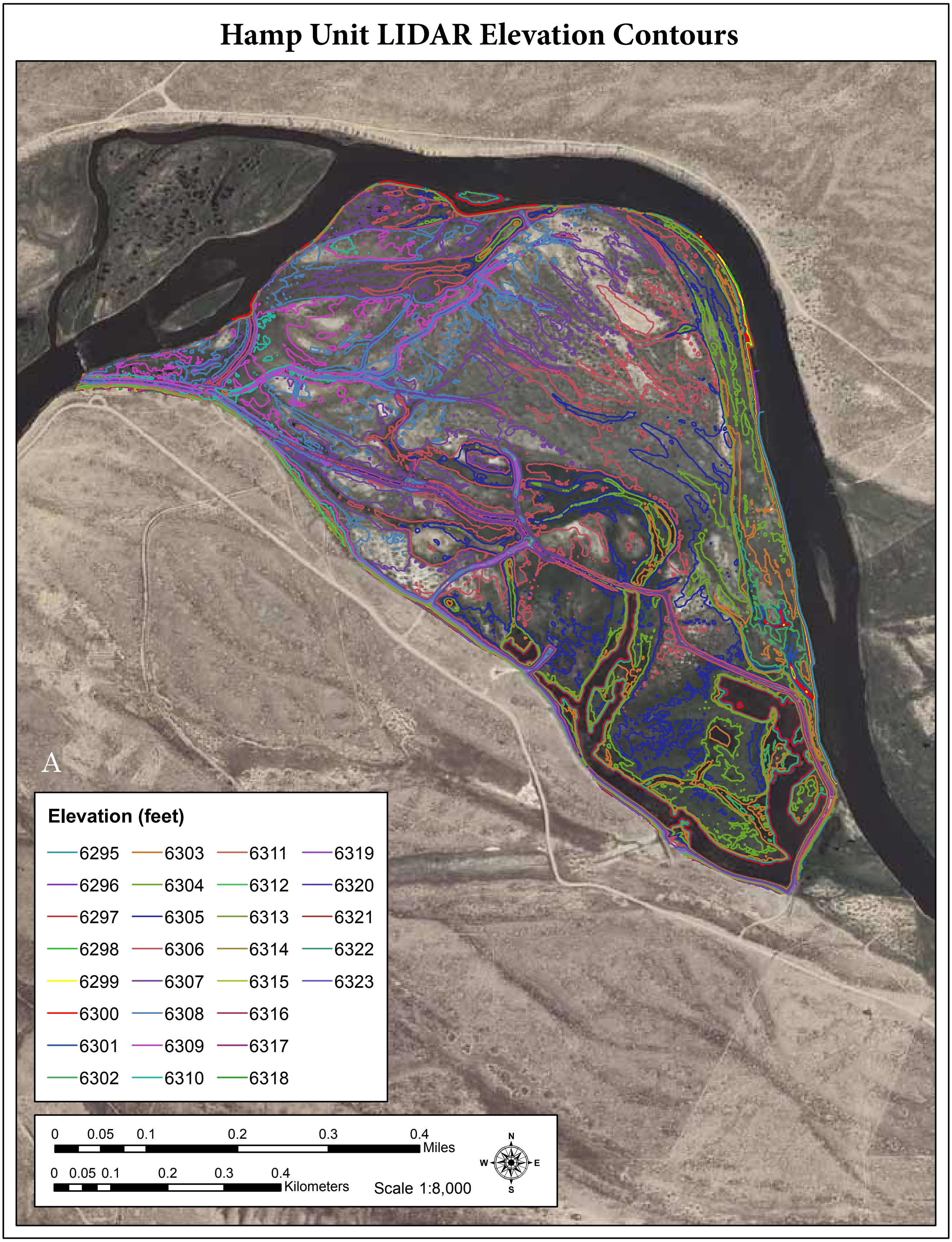

Figure 6. LIDAR topographic contours (one foot) for: a) Hamp, b) Hawley, c) Lower Hawley, d) Pal, e) Sagebrush, f) Cottonwood, and g) Dunkle wetland units on Seedskadee National Wildlife Refuge.

Hawley Unit LIDAR Elevation Contours

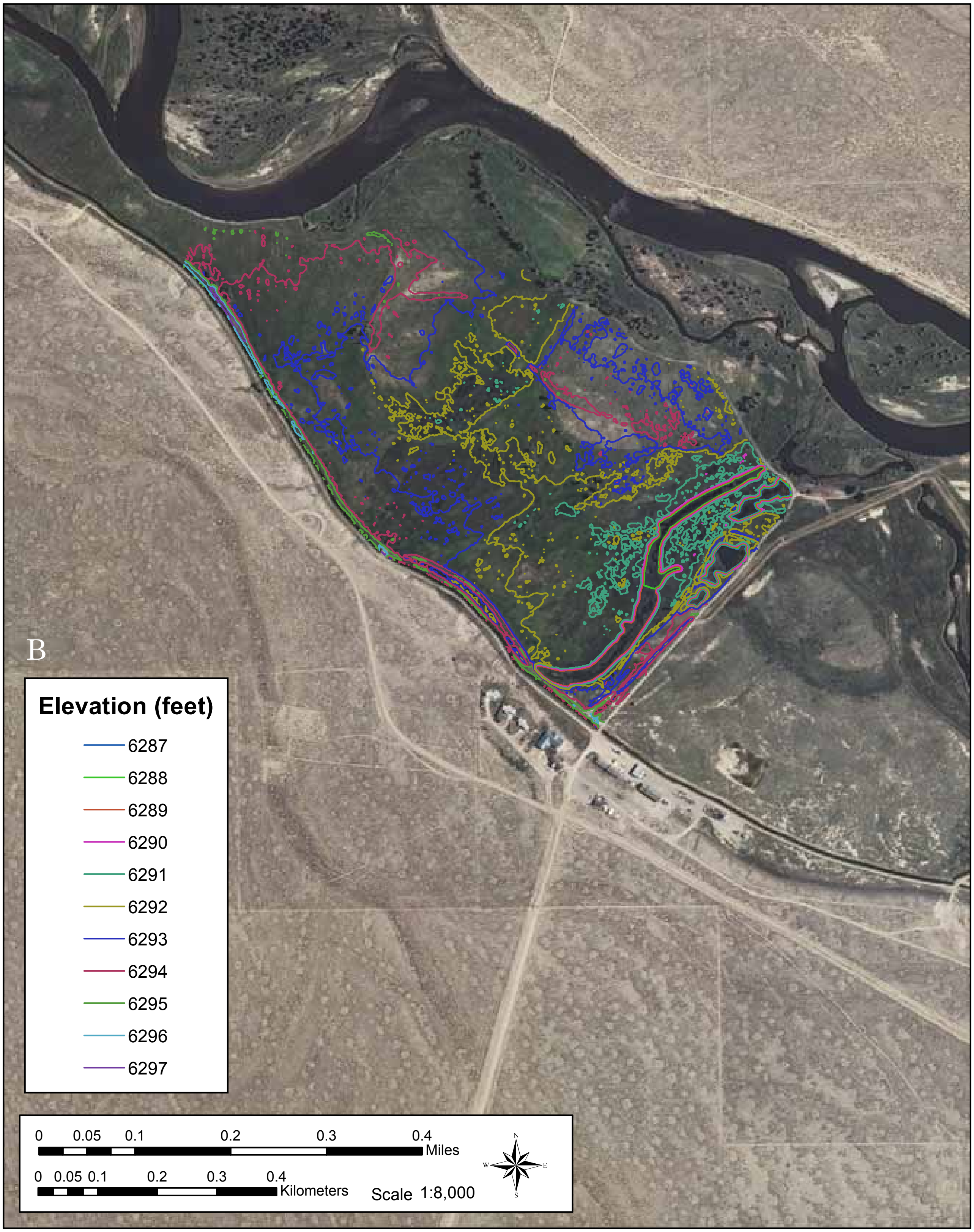

Figure 6, cont'd. LIDAR topographic contours (one foot) for: a) Hamp, b) Hawley, c) Lower Hawley, d) Pal, e) Sagebrush, f) Cottonwood, and g) Dunkle wetland units on Seedskadee National Wildlife Refuge.

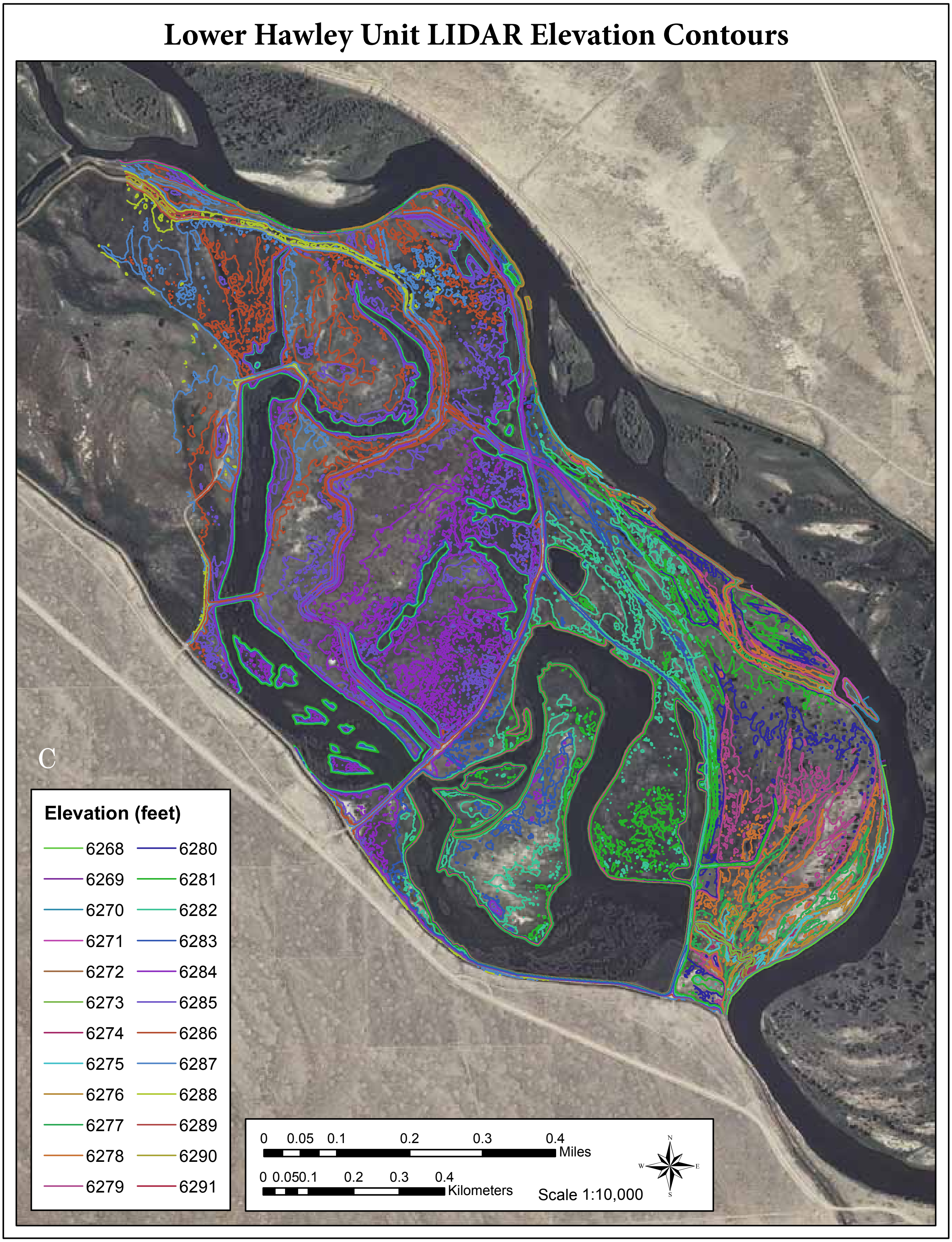

Figure 6, cont'd. LIDAR topographic contours (one foot) for: a) Hamp, b) Hawley, c) Lower Hawley, d) Pal, e) Sagebrush, f) Cottonwood, and g) Dunkle wetland units on Seedskadee National Wildlife Refuge.

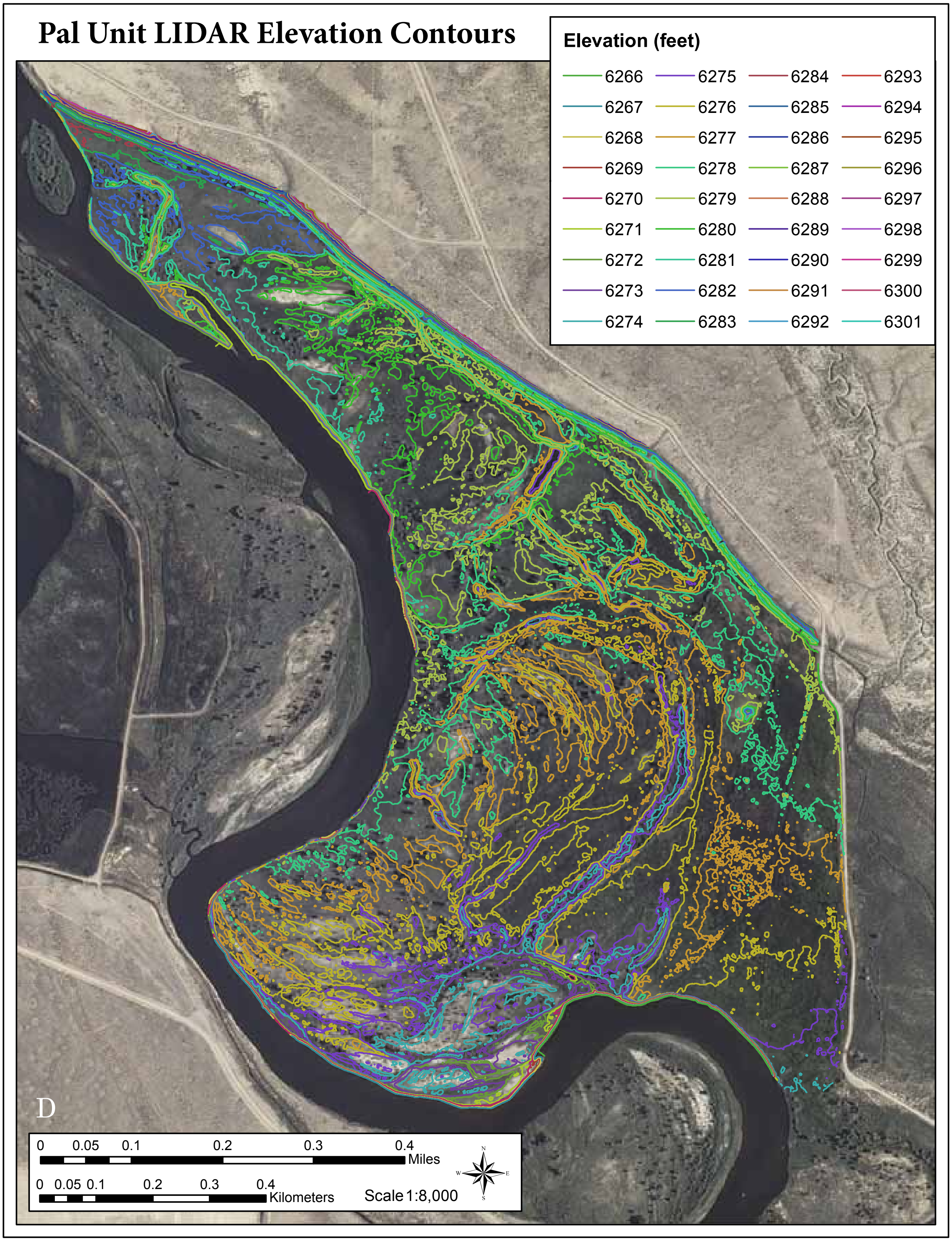

Figure 6, cont'd. LIDAR topographic contours (one foot) for: a) Hamp, b) Hawley, c) Lower Hawley, d) Pal, e) Sagebrush, f) Cottonwood, and g) Dunkle wetland units on Seedskadee National Wildlife Refuge.

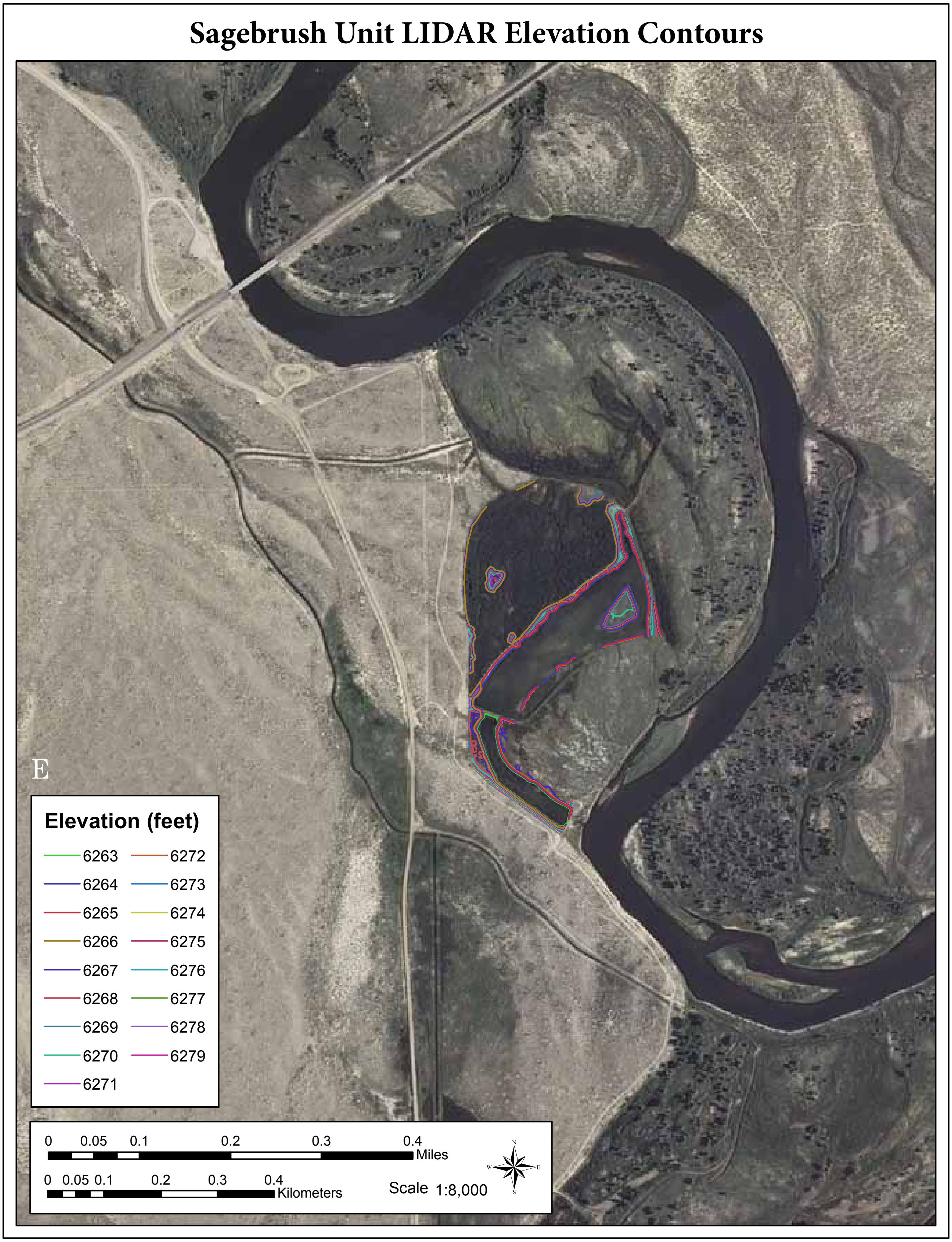

Figure 6, cont'd. LIDAR topographic contours (one foot) for: a) Hamp, b) Hawley, c) Lower Hawley, d) Pal, e) Sagebrush, f) Cottonwood, and g) Dunkle wetland units on Seedskadee National Wildlife Refuge.

Cottonwood Unit LIDAR Elevation Contours

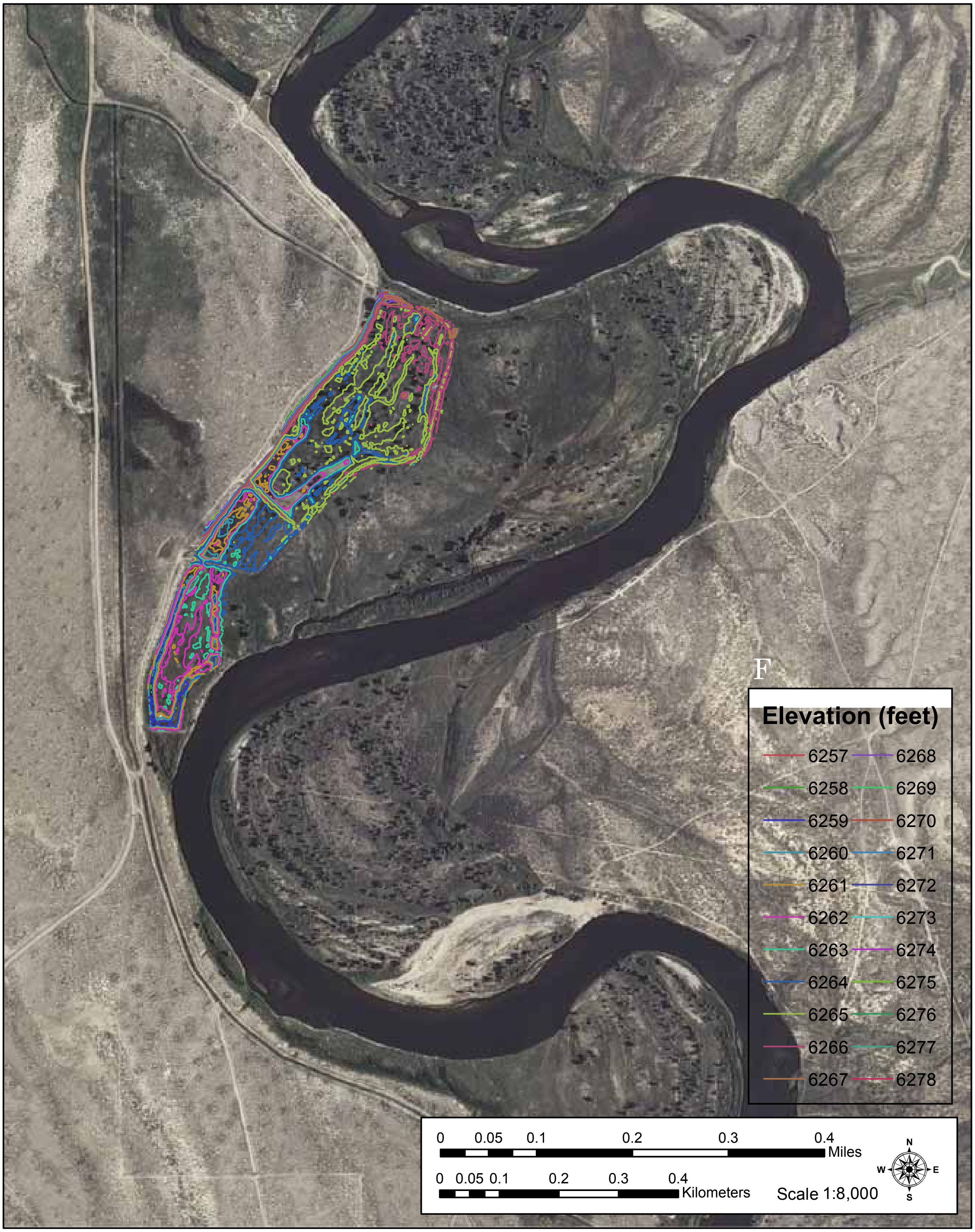

Figure 6, cont'd. LIDAR topographic contours (one foot) for: a) Hamp, b) Hawley, c) Lower Hawley, d) Pal, e) Sagebrush, f) Cottonwood, and g) Dunkle wetland units on Seedskadee National Wildlife Refuge.

Dunkle Unit LIDAR Elevation Contours

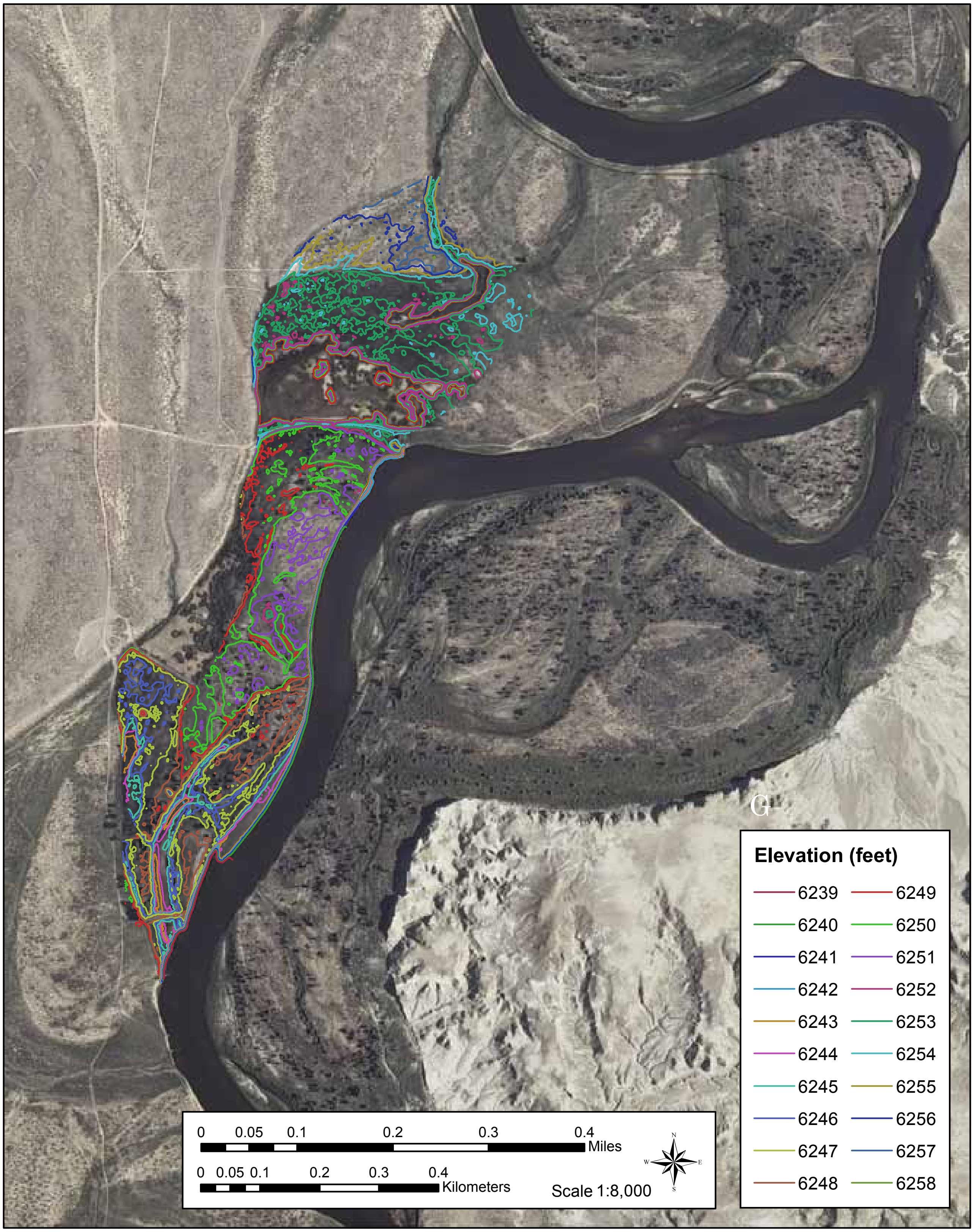

Figure 6, cont'd. LIDAR topographic contours (one foot) for: a) Hamp, b) Hawley, c) Lower Hawley, d) Pal, e) Sagebrush, f) Cottonwood, and g) Dunkle wetland units on Seedskadee National Wildlife Refuge.

Table 1. Upstream and downstream elevations for wetland units on Seedskadee National Wildlife Refuge, determined from LIDAR flown during 2010.

River Bend (near wetland unit)	Elevation (feet)	
	Low	High
Hamp	6295	6323
Hawley	6287	6297
Lower Hawley	6268	6291
Pal	6266	6301
Sagebrush	6263	6279
Cottonwood	6257	6278
Dunkle	6239	6258

The best information on historical (pre-Fontenelle Reservoir) flows of the Green River near Seedskadee NWR come from three U.S. Geological Survey (USGS) stream gauge monitoring stations located upstream near Fontenelle, Wyoming (USGS #09209500) from1947-1965 and downstream (USGS #09216500 and #09217000) near Green River, Wyoming from 1896 to 1939 and 1953-63, respectively (Peterson 1988, Mason and Miller 2005). River discharge measurements at the Fontenelle gauge station (USGS #09209500) are equivalent to published river level and discharge readings near La Barge, Wyoming (USGS #09209400) after March 1965, when the Fontenelle station was discontinued. Mean annual Green River flows upstream of Seedskadee at station # 9209500 from 1947 to 1965 averaged 1,570 cfs with a peak mean monthly discharge of 5,650 cfs in June (Table 2, Fig. 9). The range in daily flows for this station prior to Fontenelle Reservoir was a maximum flow of 13,300 cfs in June 1956 and a minimum flow of 200 cfs in December 1962. Peak annual flows > 10,000 cfs (a level of some backwater flooding in the Seedskadee Floodplain – see below) occurred in 9 of 19 years (47%) from 1947 to 1965 (Fig. 10). During this time flows > 8,490 cfs for at least 7 consecutive days occurred at a 50% yearly occurrence (i.e., on average every 2 years); flows > 10,600 cfs for at least 7 consecutive days occurred at a 20% yearly occurrence (i.e., on average every 5 years); and flows > 11,600 cfs for at least 7 consecutive days occurred at a 10% yearly occurrence (i.e., on average every 10 years) (Table 3). These data indicate that Green River flows capable of causing substantial flooding of the Seedskadee NWR floodplain was a common event.

Downstream at station #09216500 the mean annual flow of the Green River from 1896 to 1939 was 1,849 cfs with a mean peak monthly discharge of 6,921 cfs in June. This station and time period had a range in daily flow from 22,200 cfs in June 1918 and a low of < 100 cfs in 1935 (Table 4, Fig. 11). Peak flows at this station exceeded 10,000 cfs in 25 of 36 (69%) years with data during this period and flows > 15,000 cfs were exceeded 15,000 cfs in 9 of 36 (25%). At station #0921700 prior to construction of Fontenelle Reservoir, the mean annual discharge was 1,552 cfs, the peak mean monthly discharge was 5,466 cfs in June, and daily discharges ranged from 14,800 cfs in 1956 to a low of 170 cfs in 1955 (Table 5, Fig. 12). Green River flows at this station were > 10,000 cfs in 6 of 13 (46%) of the years from 1952 to 1963. Flows of 8,530; 11,300; and 12,700 cfs for at least 7 consecutive days occurred on average 50%, 20%, and 10% of the years, respectively (Table 6). The relative increase in Green River flow from Fontenelle to Green River, Wyoming reflects the entry of the Big Sandy River to the Green River below Eden, Wyoming where the mean annual inflow is 72.5 cfs and the mean peak monthly discharge is 145 cfs in June (Table 7).

Typically the Green River discharge at Seedskadee NWR historically began to gradually rise starting in April, peaked in early June, and gradually fell to low sustained levels from August through February or March. Both the average rising and falling limb of the annual hydrograph/discharge curve is about 1-2 cm/day, although individual years and events can cause rapid decline or rise of river levels. During the oldest period of record, 1896-1939, mean annual runoff from the Green River at Green River, Wyoming (USGS #09216500) was 1,339,000 acre-feet, with 30.8% of that occurring in June (Table 4). Average mean monthly discharge in June was 6,921cfs with a 90 percentile of 11,460 cfs. Prior to Fontenelle Reservoir, annual Green River runoff at Green River, Wyoming (USGS #09217000) during 1952-63 was 1,125,000 acre-feet and ca. 60% of the mean annual runoff occurred in May, June, and July (Table 5). Runoff from the Big Sandy River at Gasson Bridge near Eden, Wyoming (USGS #09216050) from 1973 to 2002 averaged only 52,540 acre-feet and peak runoff occurs slightly earlier than in the Green River, with about 22% of mean annual runoff occurring in March and April and only 37% occurring from May to July (Table 7).

Mean annual and yearly peak discharge of the Green River near Green River, Wyoming has varied widely among years, dating to 1895, especially

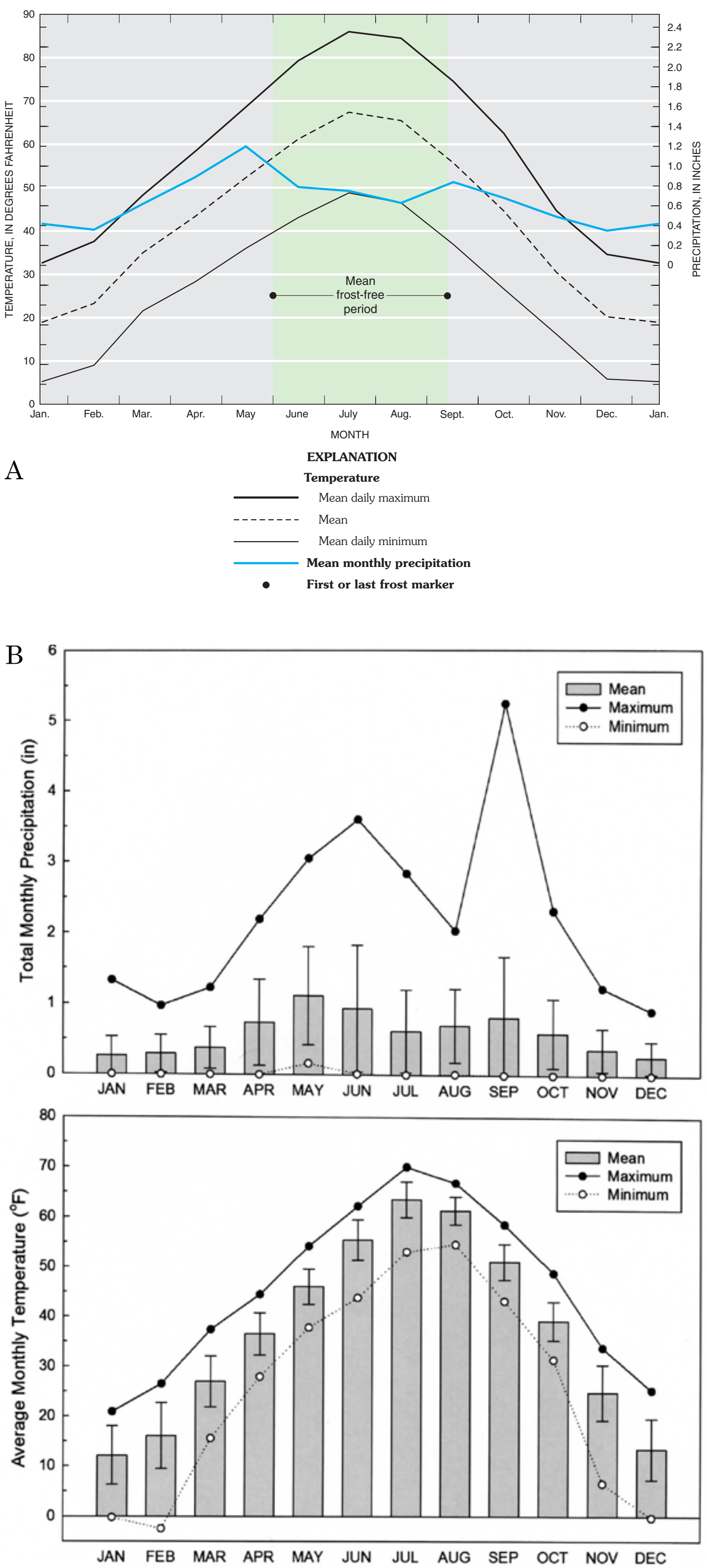

Figure 7. Mean a) daily precipitation and b) monthly precipitation and temperature for the Seedskadee National Wildlife Refuge region (compiled from Western Regional Climate Center, Fontenelle Station data, http://www.wrcc.dri.edu).

prior to construction of Flaming Gorge and Fontenelle Dam (Figs. 10-12, Tables 2-7). Historically, a discharge of > 10,000 cfs occurred in about 50% of all years and discharges of at least 15,000 cfs occurred in about every 4-5 years. Flood events of > 20,000 cfs were rare at locations north of Seedskadee, but occurred in 3 of 36 years at Green River, Wyoming from 1898 to 1922 (Fig. 11). Annual peak flooding discharges of >10,000 cfs probably were of relatively short duration in most years historically as suggested by percentage of time a discharge of > 10,000 cfs historically occurred for consecutive days (Tables 3, 6). For example 7 days of consecutive flooding > 10,000 cfs occurred only 20% of years at both Fontenelle and Green River for the period of records (pre-Fontenelle Reservoir) for these stations. Nonetheless, even a short duration flood would have inundated depressions, and surface water would have been recharged and been held in deeper depressions not directly connected to the river channel.

No long-term gauge station for the Green River is present on Seedskadee NWR proper. Consequently, the stage-discharge relationship for river discharge vs. elevation of flooding on the refuge lands is unknown. The official "flood stage", when significant overbank flooding occurs at Green River, Wyoming is 15,000 cfs; the National Weather Service issues flood warnings, with some predicted backwater flooding of low sloughs and floodplain depressions, at 12,700 cfs. Observations by refuge personnel (Carl Millegan, personal communication) indicate that a discharge of about 8,000 to10,000 cfs below Fontenelle Reservoir causes water from the Green River to enter low elevation "cuts" or "swales" in some floodplain bottoms on Seedskadee NWR. In June 2011, a discharge of ca. 8,700 cfs below Fontenelle Dam caused water to back from the Green River into old river channels, sloughs, and low elevation swales on parts of Seedskadee NWR. Further, aerial photographs indicate widespread flooding of Seedskadee floodplains in September 1965 when a river discharge of about 16,800 cfs occurred (Fig. 13). These 1965 photographs

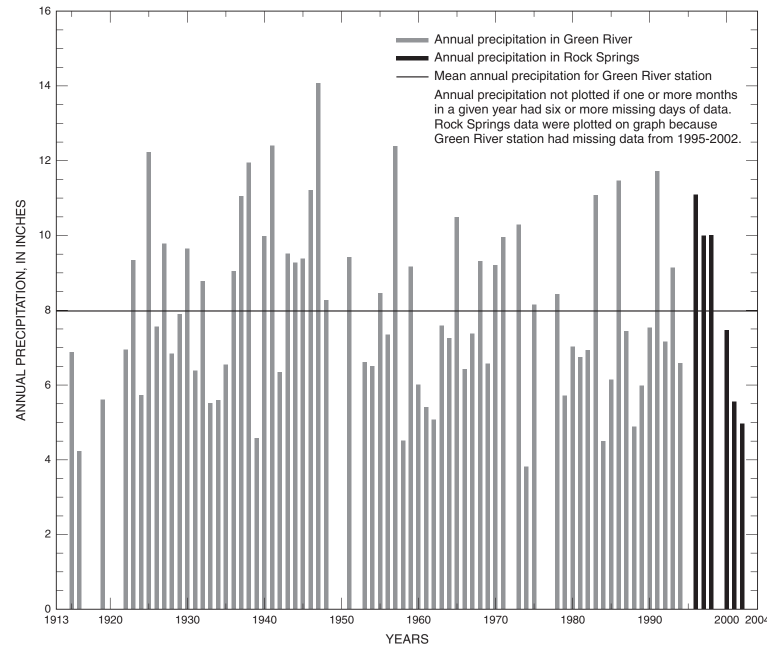

Figure 8. Total annual precipitation for Green River and Rock Springs, Wyoming 1913 to 2004 (from Mason and Miller 2005).

are important because they occurred prior to most levee and water-control infrastructure developments on Seedskadee NWR. Past observation by refuge personnel also indicate that discharges of about 500 cfs in the Big Sandy River causes initial backwater flooding and discharges of 2-3,000 cfs cause widespread flooding of the Big Sandy River floodplain. Estimates of bankfull flow of the Green River at select sites on Seedskadee in the early 2000s, using Manning's equation for discharge calculations, ranged from 237 to 1,524 m^3/second, which is equivalent to 8,368 to 29,131 cfs (Glass 2002). This variation in bankfull measurements reflects the large topographic heterogeneity along the Green River at Seedskadee NWR (see Figs. 5,6), but also indicates that discharge levels of > 8,000 cfs are capable of producing some backwater flooding into floodplain swales and depressions. Further, these data suggest extreme flood flows of 20,000 cfs are capable of flooding most areas in the contemporary Green River floodplain.

Rough estimates of the stage-discharge relationship of the Green River immediately below Fontenelle Reservoir (Fig. 14) suggest that river stage height rises about 5.6 inches per 1000 cfs increase, at least up to about 14,000 cfs total (Auble et al. 1997). This equates to about a one foot rise in water level per 2,142 cfs increase in discharge. At higher discharges, the curve flattens and becomes non-linear as surface area of channels and flows into floodplains increases. Consequently, relative increases in flooded area in Green River floodplains relative to larger increases in river discharge are unknown. Nonetheless, at the levels of historic first flooding into Seedskadee NWR floodplains, it seems reasonable to suggest that after initial entry of backwater into the floodplain, the elevation increments of additional flooding are in the range of one foot increase in flood water height and inundation per 2,000 cfs increase in discharge up to about 14,000 cfs and then the relationship flattens to about one foot increase in water levels per 3,000+ cfs increase in discharge, thereafter. This assumption seems at least partly supported by the fact that the current distribution of cottonwood in the Green River floodplain below Fontenelle Dam, most of which became established in the mid-late 1800s presumably with flood flows of ca. 20,000 cfs (Glass 2002, Fig. 11) are 3-8 feet above base flows of 2,000 cfs in the Green River (Auble and Scott 1998). Further, current cottonwood stands BD 92 and BD 94 near the old Lombard Ferry location on Seedskadee NWR are at

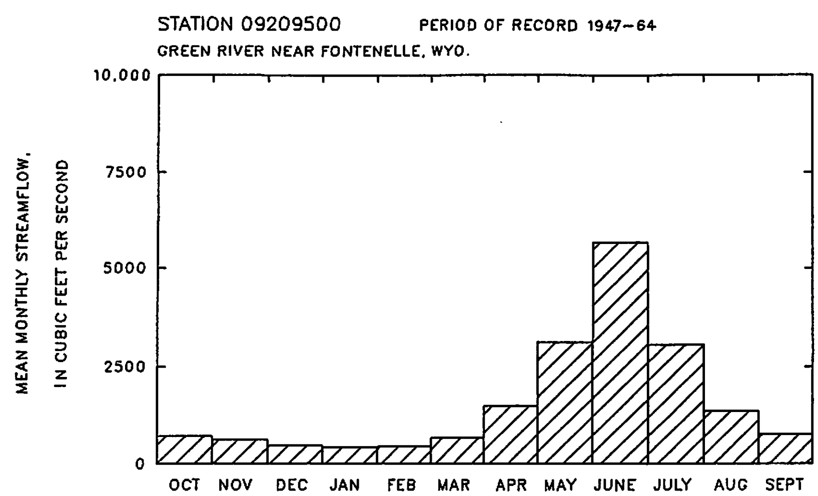

Figure 9. Mean monthly streamflow (cfs) for the Green River at Fontenelle, Wyoming, USGS gauge station #09209500, 1947-1964 (from Peterson 1988).

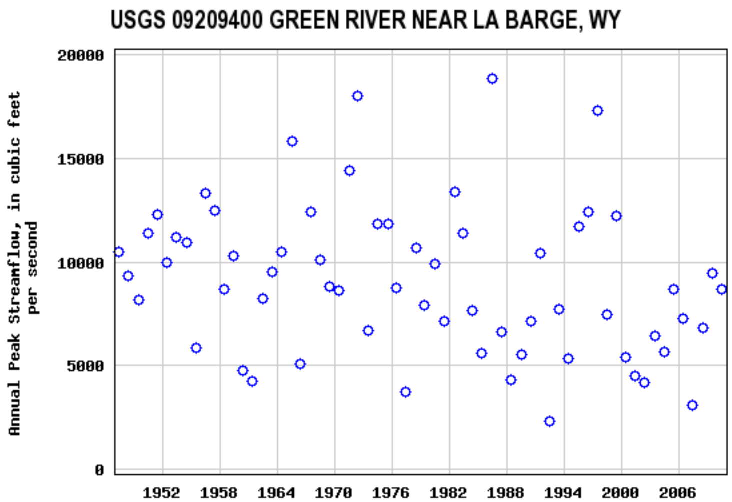

Figure 10. Peak streamflow for the Green River near LaBarge, Wyoming 1947-2010 (from http://waterdata.usgs.gov/nwis/peak).

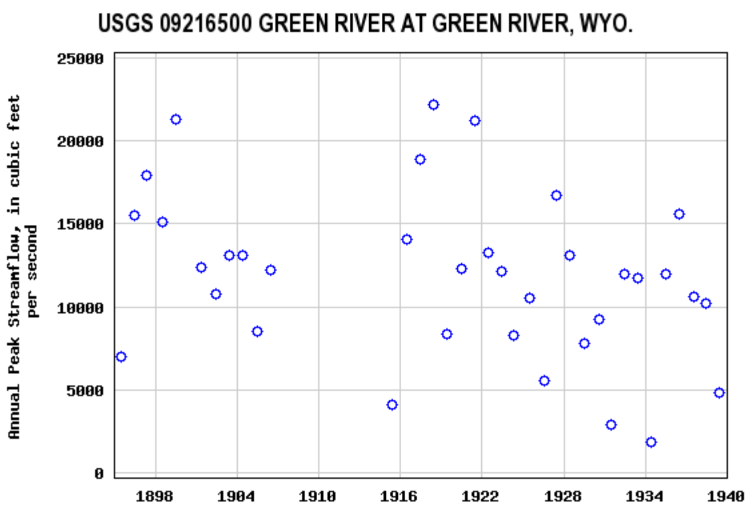

Figure 11. Peak streamflow for the Green River near Green River, Wyoming 1895-1940 (from http://waterdata.usgs.gov/nwis/peak).

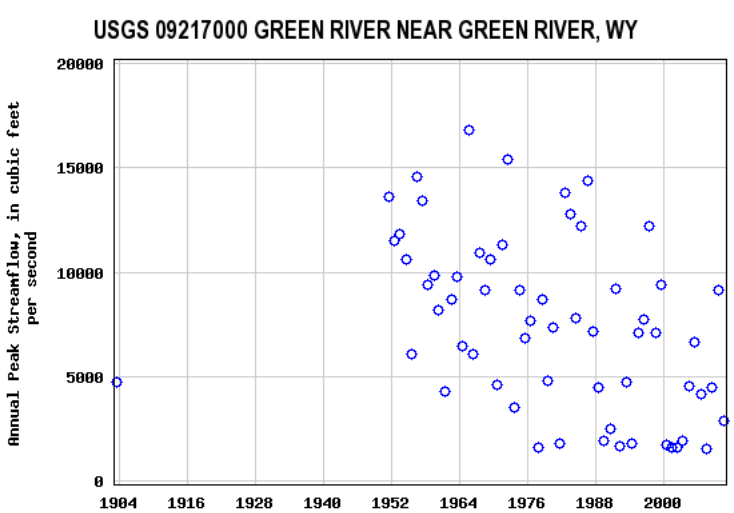

Figure 12. Peak streamflow for the Green River near Green River, Wyoming 1952-2010 (from http://waterdata.usgs.gov/nwis/peak).

elevations 6,276 and 6,268 feet amsl, which are about 6-7 feet above the low elevation entry point of floodplain swales off the Green River channel where floodwaters first enter the floodplain (Fig. 15).

We modeled the potential area flooded by different levels of Green River discharge for the floodplain bends that contain constructed wetland impoundments on Seedskadee NWR prior to major infrastructure developments on the refuge (Fig. 16). These seven areas were chosen because they have been highly modified by levees, water diversions, and water-control structures and management questions exist about restoration potential. Flood models were completed using visual estimates of the distribution of historical flooding and hydraulic analysis with HEC-RAS (Brunner 2010). HEC-RAS models of potential area flooded included the entire reach of the Green River within the boundary of Seedskadee NWR (Fig. 17).

Visually estimated flood distribution models were based on the following assumptions:

1. The current low elevation contour lines in abandoned channels, high flow channels, and seasonally connected sloughs in Seedskadee NWR floodplains (e.g., Fig. 6) represent the point of first inundation by Green River flows of 8,000 to 10,000 cfs. This assumption seems confirmed by observations of river backwater locations during June 2011 when river discharge was about 8,700 cfs.

2. Stage-discharge relationships at Seedskadee are a one foot rise in flood water level per 2,000 cfs increase in discharge up to 14,000 cfs and then one foot flood water rise per 3,000 cfs increase in discharge up to 20,000 cfs. This assumption is based on Fig. 14, the above discussion of cottonwood locations, and observed inundated

area in September 1965 when the Green River discharge was about 16,800 cfs and no water-control infrastructure was present.

3. By determining the elevation (from LIDAR maps) of surface water during the 1965 flood (Fig. 13) then elevation contours correlated with increased flows to 20,000 cfs (one foot elevation rise/3,000 cfs increase from assumption #2 above), 14,000 cfs (one foot elevation decline/3,000 cfs decrease), 12,000 cfs (one foot elevation decline/2,000 cfs decrease), and 10,000 cfs (one foot elevation decline/2,000 cfs decrease) can be mapped.

4. The LIDAR surveys flown in 2010 adequately represent topographic conditions (excepting current water-control levees and other infrastructure) present before the 1970s.

5. The area of flood inundation mapped for each unit only applies to that location because this method does not account for the slope of the Green River.

Hydraulic analysis with HEC-RAS was based on the following methods and assumptions:

1. The analysis is limited to the steady flow water surface profile computations, which computes water surface elevation for a constant flow rate at all points in the river. Multiple flow rates were analyzed, however only one flow rate was analyzed in each model run, rather than changing the flow rate at different points along the river.

2. The computational procedure is based on the solution of the one-dimensional energy equation. This procedure calculates energy losses using Manning's equation and contraction/expansion. Manning's equation is dependent on: 1) the cross-sectional shape of the river, 2) the surface roughness of the river channel, and 3) the slope of the water surface.

3. The cross-sectional area of the floodplain can be accurately modeled only for the areas that were above water at the time the LIDAR survey was flown. LIDAR does not penetrate water so the cross-sectional area of the river beneath the water surface was estimated by modifying the LIDAR data in ArcMap. This was accomplished by first identifying the edge of the water. The line defining the edge of the water was then offset toward the middle of the river by a distance of 3 m (9.8 feet) horizontally on both sides of the river. All LIDAR points between this offset line and the water edge were lowered 0.3 m (1 foot). Next, the line defining the edge of the water was offset towards the middle of the river by 5 m (16.4 feet) horizontally on both sides of the river. All

Table 2. Monthly and annual stream flow of the Green River, 1947-64 for USGS gauge station #09209500 near Fontenelle, Wyoming (from Peterson 1988).

Month	Maximum (ft^3/s)	Minimum (ft^3/s)	Mean (ft^3/s)	Standard deviation (ft^3/s)	Coefficient of variation	Percent of annual runoff
October	1040	476	715	188	0.26	3.80
November	1010	389	628	176	0.28	3.30
December	723	281	480	130	0.27	2.50
January	622	275	424	103	0.24	2.20
February	726	320	461	122	0.26	2.40
March	1230	428	674	197	0.29	3.60
April	3160	777	1510	724	0.48	8.00
May	5290	1040	3130	1470	0.47	16.60
June	8760	2690	5650	1770	0.31	30.00
July	6060	751	3060	1620	0.53	16.20
August	3010	579	1370	627	0.46	7.30
September	1310	467	768	270	0.35	4.10
Annual	2420	791	1570	472	0.30	100.00

Table 3. Magnitude and probability of annual high flow based for the Green River near Fontenelle, Wyoming 1947-64 (USGS gauge station #09209500) (from Peterson 1988).

Period (consecutive days)	Discharge, in ft^3/s, for indicated recurrence interval, in years, and exceedance probability, in percent					
	2 - 50%	5 - 20%	10 - 10%	25 - 4%	50 - 2%	100 - 1%
1	9600	11700	12600	13300	--	--
3	9270	11400	12300	13100	--	--
7	8490	10600	11600	12500	--	--
15	7410	9230	10100	10900	--	--
30	6110	7840	8750	9700	--	--
60	4930	6400	7100	7780	--	--
90	4020	5340	6010	6680	--	--

Table 4. Monthly and annual streamflow of the Green River, 1896-1939 for USGS gauge station #09216500 near Green River, Wyoming (from Mason and Miller 2005).

Month or annual	Water year			Streamflow, in cubic feet per second				Coefficient of variation (unitless)	Percentiles, in cubic feet per second					Mean runoff	
	Begin	End	Total	Maximum	Minimum	Mean	Standard deviation		10th	25th	50th	75th	90th	Acre-feet	Percent of annual
10	1896	1939	35	1,505	314	770	323	0.42	374	534	724	937	1,243	47,360	3.54
11	1896	1939	35	1,330	265	624	215	.34	387	473	608	755	849	37,130	2.77
12	1896	1939	35	700	260	461	121	.26	296	375	475	550	608	28,360	2.12
1	1896	1939	35	650	250	384	96.4	.25	271	302	360	450	500	23,580	1.76
2	1896	1939	35	700	250	408	101	.25	300	350	400	440	530	22,880	1.71
3	1896	1939	35	1,973	300	805	413	.51	444	531	656	938	1,440	49,480	3.69
4	1896	1939	35	2,924	376	1,778	675	.38	984	1,265	1,801	2,321	2,655	105,800	7.90
5	1896	1939	35	9,774	1,058	3,685	1,901	.52	1,396	2,418	3,394	4,575	6,217	226,600	16.9
6	1896	1939	35	13,430	846	6,921	3,277	.47	2,840	4,967	6,827	8,972	11,460	411,900	30.8
7	1896	1939	35	14,540	430	3,804	2,622	.69	1,661	2,517	3,460	4,449	5,379	233,900	17.5
8	1896	1939	35	5,169	476	1,589	872	.55	725	1,121	1,417	1,929	2,205	97,680	7.29
9	1896	1939	35	2,061	258	918	414	.45	471	635	890	1,223	1,311	54,650	4.08
ANNUAL	1896	1939	35	3,458	528	1,849	608	.33	1,140	1,456	1,859	2,230	2,459	1,339,000	100

Table 5. Monthly and annual streamflow of the Green River prior to construction of Fontenelle Reservoir 1952-1963 (from Mason and Miller 2005).

Month or annual	Water year			Streamflow, in cubic feet per second				Coefficient of variation (unitless)	Percentiles, in cubic feet per second					Mean runoff	
	Begin	End	Total	Maximum	Minimum	Mean	Standard deviation		10th	25th	50th	75th	90th	Acre-feet	Percent of annual
10	1952	1963	12	1,310	531	726	239	0.33	538	565	662	724	1,053	44,660	3.97
11	1952	1963	12	845	457	630	134	.21	475	525	602	732	804	37,460	3.33
12	1952	1963	12	703	288	476	118	.25	389	418	438	524	661	29,270	2.60
1	1952	1963	12	670	287	450	121	.27	319	356	432	526	600	27,690	2.46
2	1952	1963	12	868	324	546	192	.35	348	386	494	680	837	30,610	2.72
3	1952	1963	12	1,475	482	878	297	.34	556	707	811	999	1,252	53,990	4.80
4	1952	1963	12	3,416	842	1,693	893	.53	870	1,176	1,351	1,920	3,147	100,800	8.96
5	1952	1963	12	5,665	978	2,940	1,776	.60	1,092	1,262	2,467	4,615	5,004	180,800	16.1
6	1952	1963	12	9,322	2,718	5,466	1,987	.36	3,003	4,057	5,537	6,478	7,878	325,200	28.9
7	1952	1963	12	6,184	757	2,770	1,535	.55	1,115	1,732	2,547	3,535	4,066	170,300	15.2
8	1952	1963	12	1,795	575	1,273	415	.33	642	1,041	1,339	1,605	1,686	78,260	6.96
9	1952	1963	12	1,300	462	764	245	.32	583	635	676	826	1,117	45,480	4.04
ANNUAL	1952	1963	12	2,218	799	1,552	474	.31	986	1,250	1,514	2,015	2,156	1,125,000	100

LIDAR points between these offset lines were lowered a distance of 1 m.

4. The water surface across a cross-section of the river was assumed to be constant. The effects of hydraulic features such as levees and bridges were not modeled because the output of the HEC-RAS model was similar to historical flooding events.

5. The surface roughness of the river channel, also known as Manning's Value, varies greatly along a river reach and with different stages of flow. For example, channels with heavy vegetation have more surface roughness than a channel lined with short grass. The roughness of a channel can also vary through the year as vegetation type and height changes. For this modeling effort, Manning's value for the channel was set at 0.039. Manning's value for the floodplain was set to 0.05.

6. Water surface profile results created by HEC-RAS were processed to visualize inundation boundaries (Ackerman 2009).

Further explanation of the HEC-RAS model methods used in this report, and an example of analyses for the Lower Hawley Unit is provided in Appendix A to illustrate the uses of the procedure and its limitations.

The modeled distribution of flood inundation was similar between the visual and HEC-RAS methods in areas where water-control infrastructure developments were limited (e.g., Fig. 16d). Results for the two methods varied the most in areas where extensive dike construction has occurred and/or in areas that were flooded when the LIDAR was flown (e.g., Fig. 16c). These potential flood inundation maps can be improved in the future if: 1) more information becomes available about stage-discharge relationships along the Green River below Fontenelle Reservoir, 2) the cross-sectional profiles of the Green River and other areas flooded when the LIDAR was flown are surveyed and mapped, 3) surface roughness is measured during flood events, and 4) future flood events of different levels > 10,000 cfs occur and area flooded can be mapped. HEC-RAS models also could be improved by modeling the effects of hydraulic features such as levees, bridges, and varied and split flows in the river.

Despite some limitations, the potential flood inundation maps suggest interesting patterns of flood frequency based on location in the floodplain, past river migration routes and resulting topography, and river stage. Typically, floodwaters tend to enter floodplain bottoms in the Upper Green River from the downstream end of point bars (e.g., Fig. 16d, see also Fig. 18), inundate old river channel corridors and swales first and most extensively, and then floodwaters gradually shallowly flood higher swales and terraces. At higher discharge levels (usually > 14,000 cfs) river water then begins to overtop upstream river bend areas and natural levees and connect flood waters with downstream backwaters (see e.g., Fig. 16e).

While most of the surface water hydrology of the Seedskadee NWR region is driven by annual snowmelt runoff into the Green River, groundwater discharge from aquifers also contributes small amounts of surface water to the ecosystem. All major streams in the Green River Structural Basin, including the Green River and Big Sandy River are gaining streams that receive some groundwater discharge into the drainages that support base flows (Fig. 19). Groundwater in the Green River Basin occurs within both unconsolidated alluvial deposits and in the deeper bedrock formations and has a wide range of variability in quality and quantity. Groundwater originates, or is recharged, when rainfall, snowmelt, streamflow, and now in some areas, irrigation water infiltrates into geological materials. Over time the groundwater travels through the subsurface and returns to the surface as discharge. Between the points of recharge and discharge, groundwater flow in the Green River Basin can be very complex (WWC Engineering et al. 2010). Because groundwater is returning to the surface as springs or seeps, it creates "gains" to the perennial Green and Big Sandy rivers.

Table 6. Magnitude and probability of annual high flow based for the Green River near Green River, Wyoming 1952-63 (USGS gauge station #09217000) (from Peterson 1988).

	Discharge, i ft^3/s, fo indicated recurrenc interval, in years, and exceedanc probability, in percent					
Period (consecutive days)	2 - 50%	5 - 20%	10 - 10%	25 - 4%	50 - 2%	100 - 1%
1	9310	12300	13800	--	--	--
3	9090	12100	13500	--	--	--
7	8530	11300	12700	--	--	--
15	7360	9820	11200	--	--	--
30	5870	7950	9150	--	--	--
60	4610	6270	7150	--	--	--
90	3780	5220	6000	--	--	--

Table 7. Monthly and annual streamflow of the Big Sandy River 1972-2000 for USGS gauge station #09216050 near Eden, Wyoming (from Mason and Miller 2005).

Month or annual	Water year			Streamflow, in cubic feet per second				Coefficient of variation (unitless)	Percentiles, in cubic feet per second					Mean runoff	
	Begin	End	Total	Maximum	Minimum	Mean	Standard deviation		10th	25th	50th	75th	90th	Acre-feet	Percent of annual
10	1973	2002	30	102	25.8	60.7	16.5	0.27	43.0	52.0	60.7	70.1	83.8	3,730	7.10
11	1973	2002	30	149	27.0	53.3	21.6	.40	34.9	41.9	51.0	58.5	67.1	3,172	6.04
12	1973	2002	30	60.4	12.3	37.7	11.6	.31	23.4	30.9	38.2	45.0	51.4	2,318	4.41
1	1973	2002	30	55.5	10.6	30.6	9.16	.30	19.4	24.0	30.4	36.4	40.5	1,880	3.58
2	1973	2002	30	74.0	13.2	33.2	12.2	.37	21.3	25.1	32.6	38.2	43.4	1,859	3.54
3	1973	2002	30	393	32.7	84.2	72.8	.86	39.4	43.3	62.4	88.8	117	5,176	9.85
4	1973	2002	30	462	28.3	109	93.5	.86	44.8	51.9	75.2	140	184	6,464	12.3
5	1972	2002	31	208	19.8	76.0	49.3	.65	28.8	42.7	56.9	95.9	151	4,671	8.89
6	1972	2002	31	627	25.0	145	156	1.08	33.4	51.6	81.1	152	447	8,605	16.4
7	1972	2002	31	340	21.8	104	74.9	.72	36.4	59.6	89.1	116	204	6,420	12.2
8	1972	2002	31	119	23.0	77.7	26.3	.34	39.4	58.4	80.6	96.3	103	4,779	9.10
9	1972	2002	31	100	20.7	71.0	21.7	.31	42.2	53.9	75.8	88.8	95.1	4,222	8.04
ANNUAL	1973	2002	30	140	24.6	72.5	32.7	.45	35.0	47.8	65.2	90.6	117	52,540	100

Figure 13a

Hamp Unit - September 10, 1965

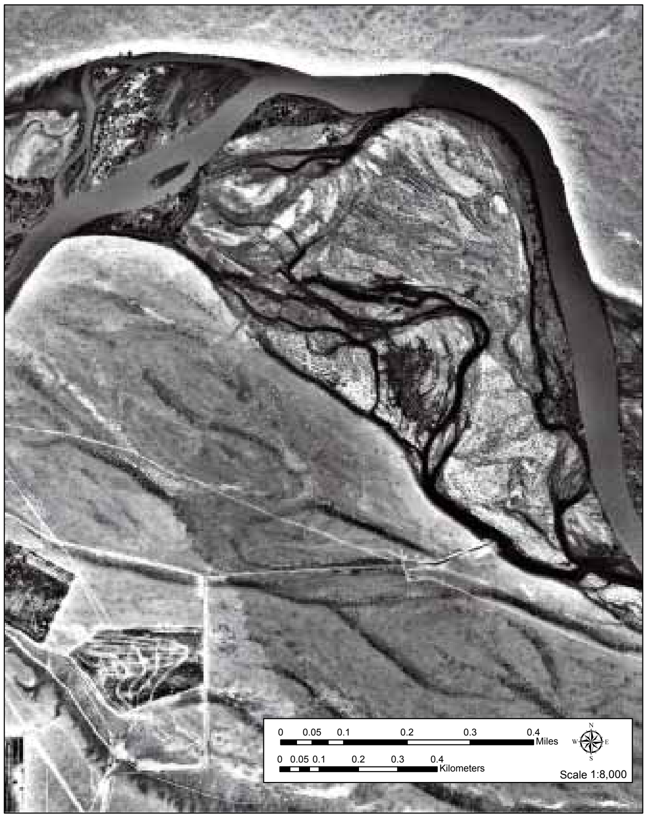

Figure 13b

Hawley Unit - September 10, 1965

Figure 13c

Lower Hawley Unit

Figure 13d

Pal Unit - September 10, 1965

Figure 13. Aerial photographs of select Seedskadee NWR floodplain areas showing the extent of flooding during a flood event of 16,800 cfs in September 1965.

Sagebrush Unit - September 10, 1965

Cottonwood Unit - September 10, 1965

Dunkle Unit - September 10, 1965

Figure 13, cont'd. Aerial photographs of select Seedskadee NWR floodplain areas showing the extent of flooding during a flood event of 16,800 cfs in September 1965.

Consequently, these river streamflow records include varying amounts of groundwater discharge. In general, shallow groundwater flow (< 500 feet below the ground surface) follows subsurface geologic stratigraphy and is discharged to river drainages.

Four major regional deep aquifers are present in the Green River Basin and include the Cenozoic, Mesozoic, Paleozoic, and Precambrian systems. The Cenozoic aquifer is the youngest and includes unconsolidated gravel and sand alluvial deposits, tertiary sedimentary rocks such as sandstone, conglomerate, and conglomeratic sandstone, and coal beds. This system includes Quaternary-age sands and gravels associated with major river courses. The primary Quaternary aquifer at Seedskadee is from saturated alluvium and colluviums deposits that range in thickness up to 50 feet deep. At Seedskadee NWR, the depth to groundwater is highly correlated with discharge and stage of the Green River (Scott et al. 2008). Wells in alluvial aquifers yield < 10 gal/min, but in clean sand and gravel along streams wells can produce up to several hundred gal/min. The Tertiary and overlying Quaternary aquifers make

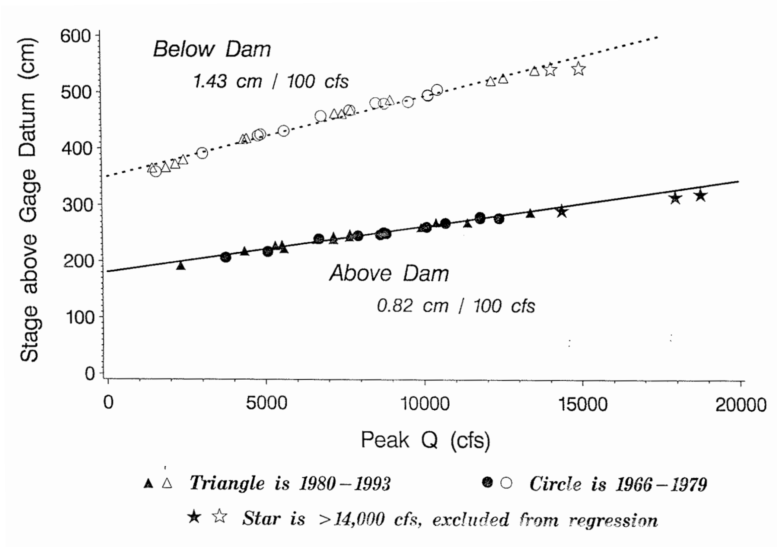

Figure 14. Stage-discharge relationships for the Green River near Fontenelle Reservoir (from Auble et al. 1997).

up 83% of the surficial geology of the Green River Basin and are the most abundant shallow aquifers in Sweetwater County; the Bridger and Green River Formations contain this aquifer. The older and deeper Mesozoic and Paleozoic aquifers are within water-bearing sandstone, conglomerate, and carbonate beds separated by confining shale units. The Precambrian system is comprised of old crystalline crustal rocks forming the deepest bedrock beneath the Basin and is only exposed at or near the surface in the cores of mountain uplifts at the rim of the Green River Basin.

Concentrations of dissolved constituents are low in the Green River because most flow in the river and its tributaries are derived from mountain snowmelt and because water runs across relatively resistant geological units, basin vegetative cover captures and uses water before it infiltrates deeper soil strata, and the relatively large annual runoff dilutes discharge concentrations (Mason and Miller 2005). Concentrations of dissolved constituents, suspended solids, and bacteria are higher in the smaller Big Sandy River system than in the Green River. Concentrations of dissolved solids in alluvial aquifers that contribute to base flows of the Green River also are relatively small. Groundwater quality tends to deteriorate with increasing distance from recharge areas and with increasing depths below the ground surface. Concentrations of dissolved solids are higher where groundwater discharges occur from the underlying Green River and Bridger Formations. Groundwater from depths of greater than a few thousand feet have total dissolved solid concentrations that make water moderately saline. In some areas, shallow groundwater discharge also is moderately saline.

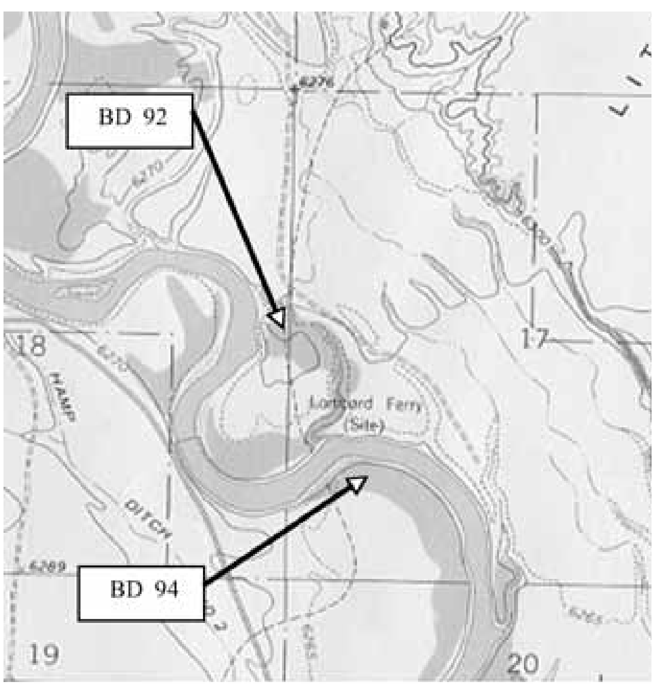

Figure 15. Location of two cottonwood stands on Seedskadee National Wildlife Refuge (from Glass 2002).

HISTORICAL PLANT AND ANIMAL COMMUNITIES

Seedskadee NWR contains relatively narrow (up to about 1.5 miles wide) floodplains along the Green and Big Sandy Rivers embedded within a sagebrush-dominated upland steppe landscape. The Green River is a sand-based sinuous channel system that has frequently meandered across the narrow floodplain. Historical channel movements created a heterogeneous topography (Fig. 6), that supported distinct vegetation communities, in abandoned channels, small oxbows, high flow braided scour channels, natural levee depositions, point bar meander scrolls, and other depressions (Fig. 20). The Green River Valley was visited by many early explorers, fur trappers, and pioneers, many of which recorded at least some vegetation features of the region (Nuttall 1834, Townsend 1839, Fremont 1845, Johnson and Winter 1846, Young 1899, Hafen and Hafen 1845). Common plant and

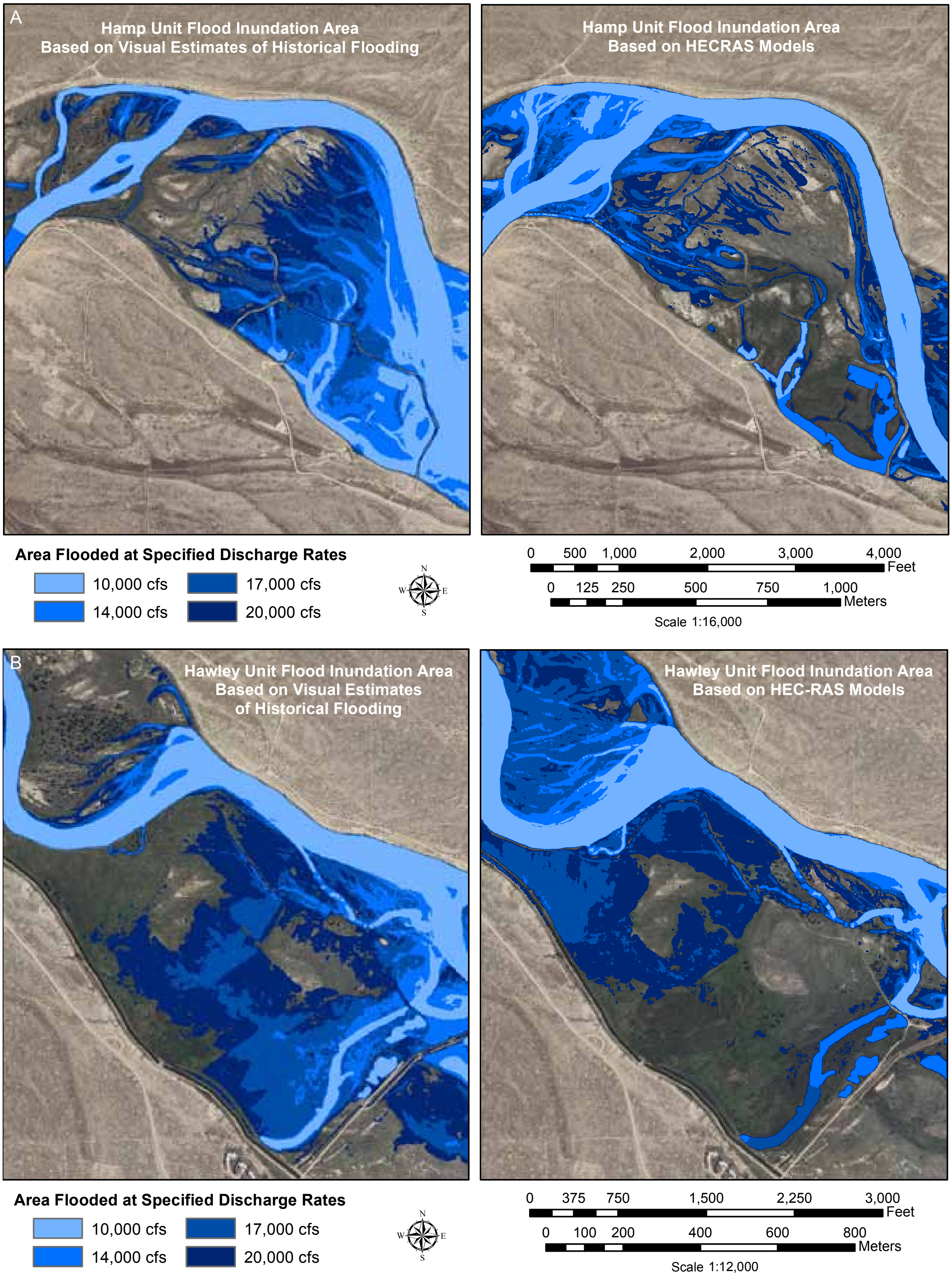

Figure 16. Estimated area potentially inundated for: a) Hamp, b) Hawley, c) Lower Hawley, d) Pal, e) Sagebrush, f) Cottonwood, and g) Dunkle wetland units on Seedskadee National Wildlife Refuge at Green River discharges of 10,000, 14,000, 17,000 and 20,000 cfs based on visual estimates of historical flooding and HEC-RAS hydraulic models (see text for explanation of methods).

Figure 16, cont'd.

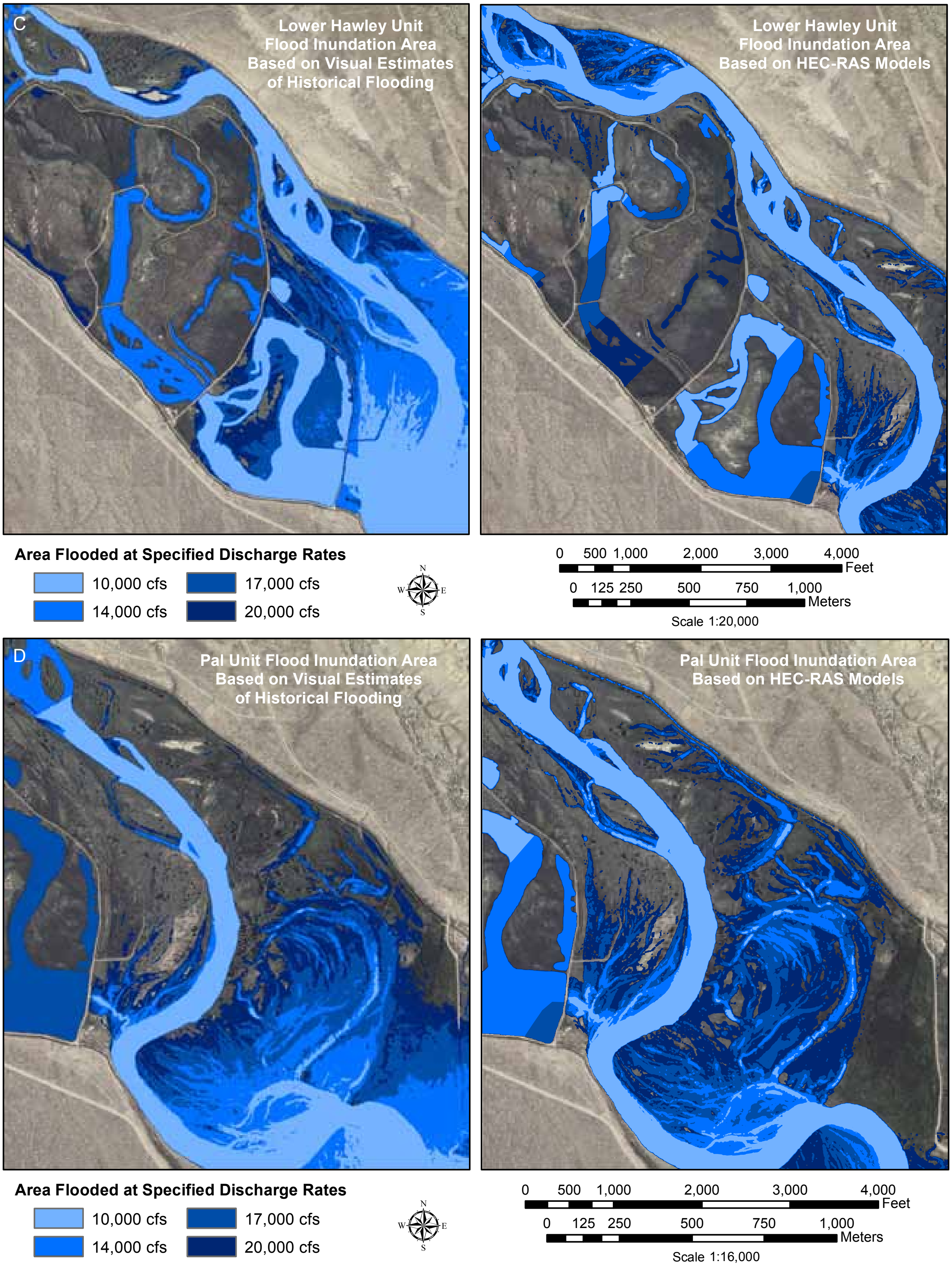

Figure 16. Estimated area potentially inundated for: a) Hamp, b) Hawley, c) Lower Hawley, d) Pal, e) Sagebrush, f) Cottonwood, and g) Dunkle wetland units on Seedskadee National Wildlife Refuge at Green River discharges of 10,000, 14,000, 17,000 and 20,000 cfs based on visual estimates of historical flooding and HEC-RAS hydraulic models (see text for explanation of methods).

Figure 16, cont'd.

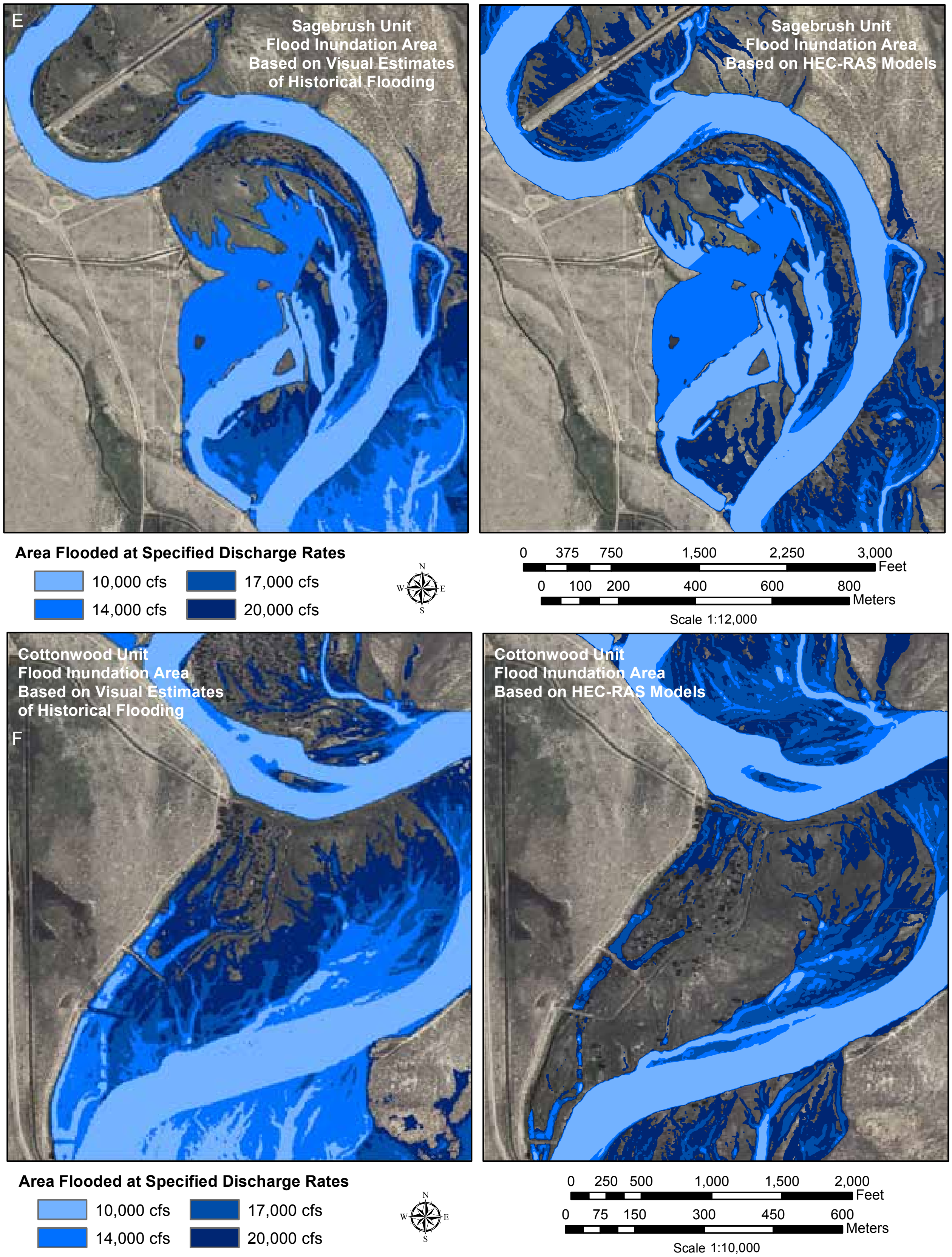

Figure 16. Estimated area potentially inundated for: a) Hamp, b) Hawley, c) Lower Hawley, d) Pal, e) Sagebrush, f) Cottonwood, and g) Dunkle wetland units on Seedskadee National Wildlife Refuge at Green River discharges of 10,000, 14,000, 17,000 and 20,000 cfs based on visual estimates of historical flooding and HEC-RAS hydraulic models (see text for explanation of methods).

Figure 16, cont'd.

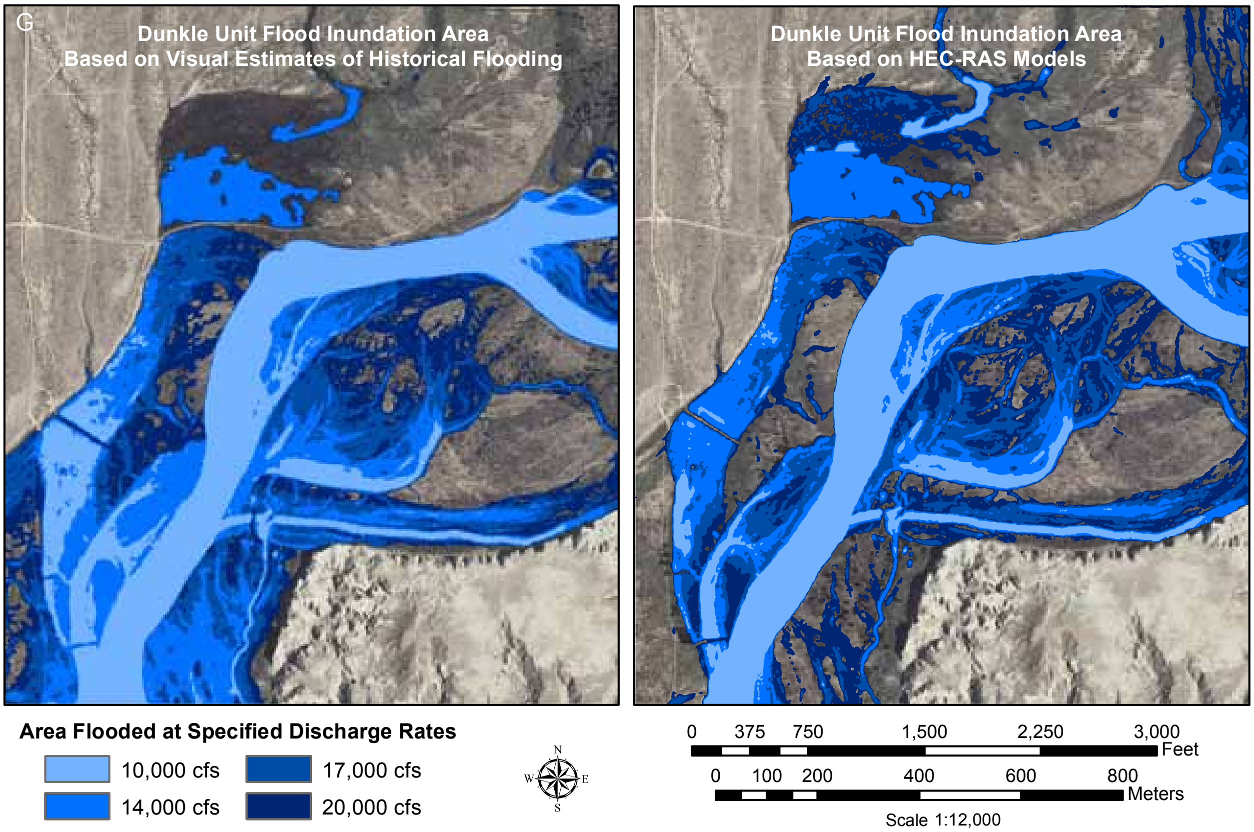

Figure 16. Estimated area potentially inundated for: a) Hamp, b) Hawley, c) Lower Hawley, d) Pal, e) Sagebrush, f) Cottonwood, and g) Dunkle wetland units on Seedskadee National Wildlife Refuge at Green River discharges of 10,000, 14,000, 17,000 and 20,000 cfs based on visual estimates of historical flooding and HEC-RAS hydraulic models (see text for explanation of methods).

animal species expected to occur in the various Seedskadee NWR habitats/communities are presented in Appendices B and C.

Areas adjacent to the Green River channel historically contained linear bands of riparian woodland dominated by cottonwood and willow. The historical extent of this riparian woodland is not entirely known, but apparently extended throughout the length of the Green River and Big Sandy River in the vicinity of the refuge as can be seen on the 1965 aerial photographs (Fig. 13). Early explorers commented on corridors and "groves" of trees that probably were dominated by narrowleaf cottonwood, (*Populus angustifolia*) (e.g., see notes in Dorn 1986). Howard Stansbury (1852) an army topographer, crossed the Green River in September 1850 and wrote: "The water was about 3 feet deep at the deepest point. The bottom was about a mile wide and covered with willow thickets and grass and clumps of narrowleaf cottonwood." An early painting of the Green River near Rock Springs, Wyoming by George Caleb Bingham in 1845 also shows a narrow corridor of cottonwood trees along the river bank (Dolin 2010). Tree-ring data indicate that most remnant cottonwood at Seedskadee appear to have been established in the mid-late 1800s (Glass 2002). In addition to narrowleaf cottonwood, riparian woodlands at Seedskadee NWR include coyote willow (*Salix exigua*) and water birch (*Betula occidentalis*) (Appendix B). The mixed shrub and grass understory including Wood's rose (*Rosa woodsii*), gooseberries (*Ribes oxyacanthoides*), basin big sagebrush (*Artemisia tridentata*), red-osier dogwood (*Cornus sericea*), and silver buffaloberry (*Sheperdia argentea*).

The relatively narrow riparian forest corridors at Seedskadee apparently were historically (and currently) present on newly deposited and scoured sand-silt and gravelly soils on natural levee deposits and channel edges/bars (Hansen 1994, Crowl and Goeking 2002). These deposits are most prominent on the inside point bar bends of the Green River channel (Fig. 18). Soils in these areas are well drained, but saturated, for much of the year and usually have some surface flooding each year (Youngblood et al.

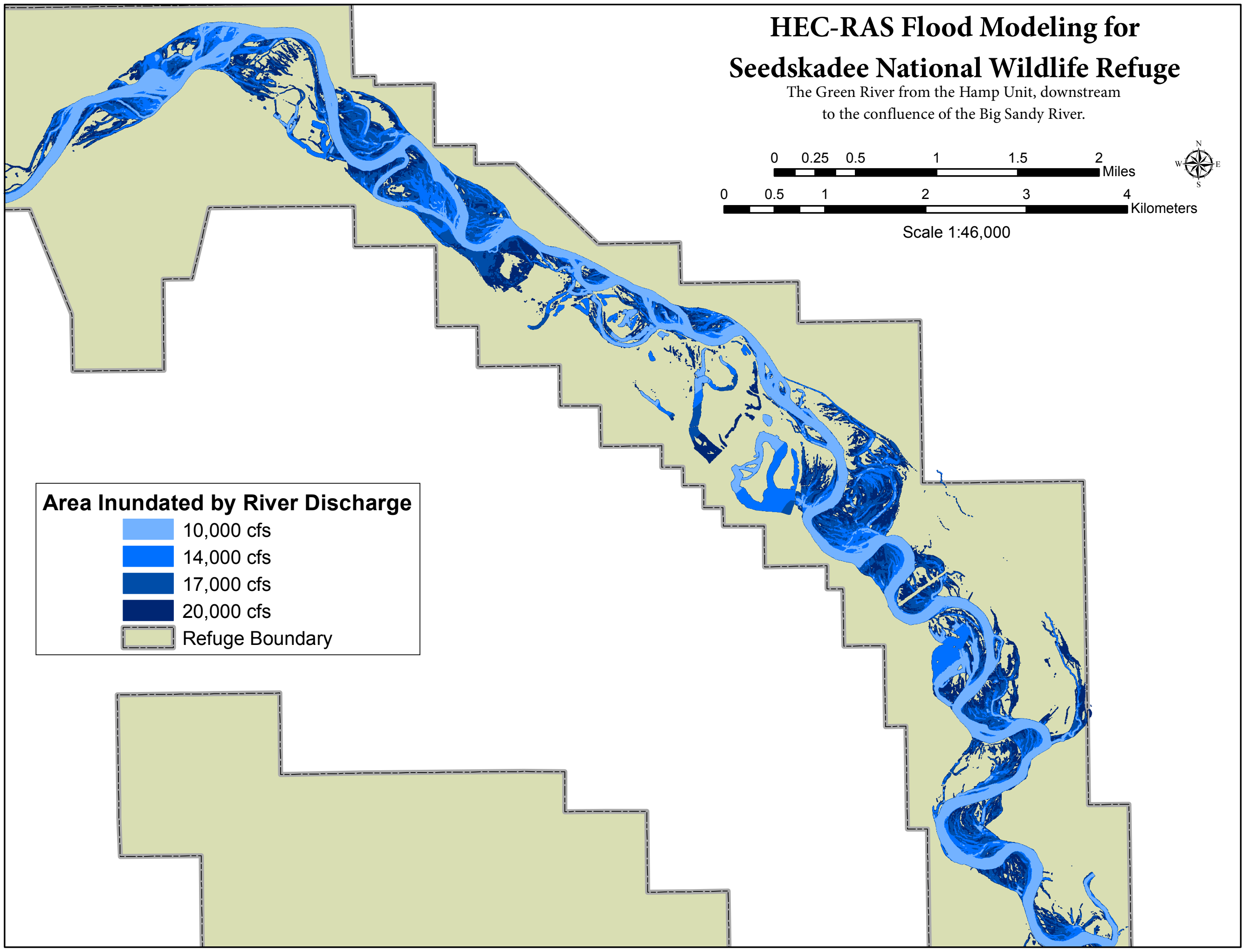

Figure 17. HEC-RAS flood inundation models for Seedskadee National Wildlife Refuge.

1985, Rood and Mahoney 1990, Braatne et al. 1996). Stansbury (1852) noted in 1850 that the Green River " .. streambed here appeared to have been completely filled by the spring rains, overflowing the low grounds and carrying down immense quantities of soil, which has been deposited below, upon the broad flats of Green River." Riparian communities comprise < 1% of the total land area in Wyoming, but have high biomass and diversity of plants and animals and are essential habitats for many species such as Neotropical migrant songbirds (Nicholoff 2003). About 80% of native animal species in Wyoming are dependent on riparian areas for some aspect of their life history (Olson and Gerhart 1982). During high flow events, coarse sediments are deposited on point bar surfaces on inside bends of river channels, and concurrent scouring of channel banks on outside bend areas occurs and exposes underlying sand and gravels (e.g., Heitmeyer and Fredrickson 2005). This periodic changing and exposure of sediments provides new substrates that allow cottonwood seeds to set and germinate. Regular flooding and high water levels in river channels also replenishes, raises, and sustains groundwater levels required by cottonwood seedlings to survive (Cooper et al. 1999, Auble et al. 1997, Auble and Scott 1998, Glass 2002). New sediments also provide ideal soil surfaces for germination of shrubs and some perennial forbs, grasses, and herbaceous plants.

Meander scrolls, high flow channels, and depressions in the Green River floodplain historically contained wetland vegetation ranging from wet grassland in ephemerally flooded areas, sedge-rush and "moist-soil" wetland herbaceous communities in seasonally flooded areas, and small areas of persistent emergent vegetation in deeper depressions where surface water ponded for much of the spring and summer in most years (see e.g., Cronquist et al. 1972).

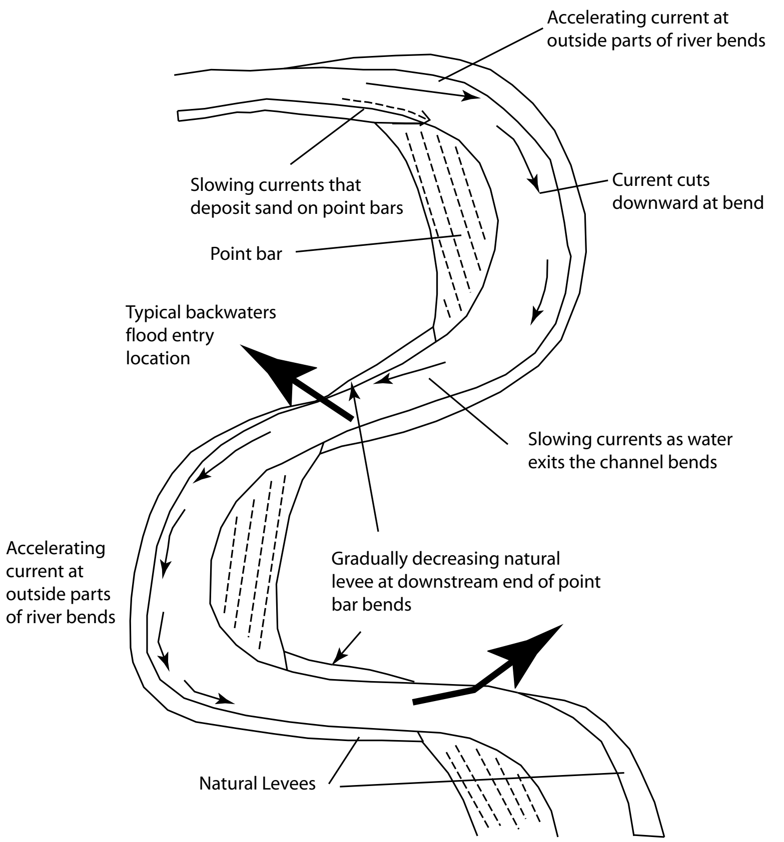

Figure 18. Schematic of typical geomorphic surfaces, river flows, flood entry location and cottonwood stands on the Green River (modified from Heitmeyer and Fredrickson 2005).

These wetland areas typically have clay or silt-clay veneer soils over varied alluvial deposits. Annual and inter-annual flooding of these wetlands was mostly driven by annually rising water levels of the Green River in spring and early summer that caused at least some backwater and overbank flooding of floodplain depressions. As previously described, Green River discharges of about 8,000 to 10,000 cfs occurred in most years and provided at least brief inundation of low elevation swales and depressions from river backwaters (see Fig. 16). Larger flood events that flooded more extensive areas of the floodplain also were relatively common in spring and recharged deeper depressions and shallowly inundated higher floodplain areas. LIDAR topography maps (Figs. 5,6) suggest that relatively few large depressions occurred in the Green River floodplain at Seedskadee NWR. Depressions that existed were mainly relict channels cutoff to form narrow "oxbows." These deeper water areas likely had more permanent water regimes that were recharged regularly by Green River flood water. As temperatures rose and high evapotranspiration rates occurred during summer, the deeper depressions dried on the edges, and perhaps completely dried in low precipitation/flood event years. The semi-permanent water regimes caused by this annual drying dynamic provided habitats for submergent aquatic plants such as coontail (*Ceratophyllum demersum*), naiads (*Najas* sp.), pondweeds (*Potamogeton* sp.), and algae (van der Valk 1989, Hansen et al. 1995, Appendix B). Seasonally flooded margins of floodplain depressions and deeper swales contain mostly non-persistent wetland plants such as arrowhead (*Sagittaria latifolia*), sedges (*Carex* sp.), and rushes (*Juncus* sp.).

Ephemerally flooded areas in the Green River floodplain were inundated for short periods in spring and early summer from onsite precipitation, runoff from adjacent uplands, and flood events. Flooding of these areas was predominantly a "sheetwater flow" type where shallow water flowed across floodplain "flats" and did not originate from a more confined drainage or water flow path. This ephemeral flooding supported wet meadow vegetation species that are tolerant to moist soils such as grasses, sedges, rushes, and some forbs (e.g., Cronquist et al. 1972). Wet meadows at Seedskadee were less extensive than in some other western Intermountain river valleys (e.g., Heitmeyer et al. 2010b), because of the higher river rate-of-fall gradient, narrow floodplain corridor, marked topography caused by frequent river meanders and high flow channels, and relatively abrupt rise in elevation on the edges of the floodplain. Consequently, wet meadow habitats often were relatively narrow bands of slightly higher elevation grass/sedge/rush communities between meander scrolls, swales, and depressions. Seasonal drying and saline soils caused many meadow areas to be at least slightly to moderately saline. Common species in these meadows included western wheat grass (*Pascopyrun smithii*), saltgrass (*Distichlis spicata*), basin wildrye (*Leymus cinereus*), alkali sacaton (*Sporobolus airoides*), and alkali cordgrass (*Spartina gracilis*) (Appendix B).

Upland areas at Seedskadee and the surrounding area in southwest Wyoming and eastern Idaho, including higher elevation edges of the floodplain and terraces, historically were dominated by

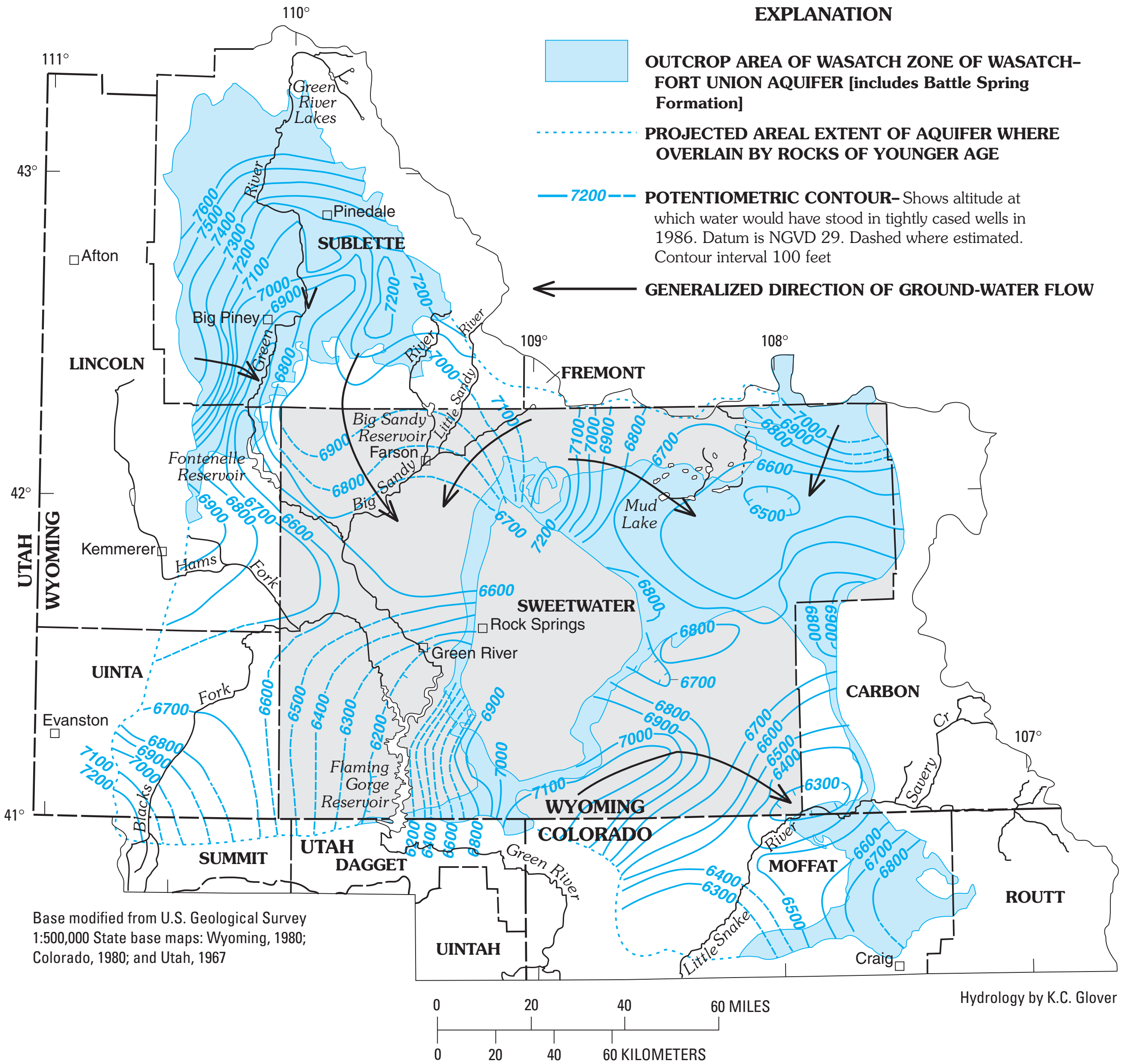

Figure 19. Potentiometric surface and inferred groundwater flow paths for the Wasatch Zone of the Wasatch-Fort Union aquifer, Sweetwater County, Wyoming, 1986 (from Naftz 1996).

sagebrush steppe communities (Cronquist et al. 1972, Hironaka et al. 1983, West 1988, Thompson and Pastor 1995). Soils under this community typically are sandy loams and depth of soil moisture sets limits of specific plant distribution. Big sagebrush (*Artemisia tridentata*) currently is the dominant plant species in sage-steppe communities, but may have been co-dominant with several perennial bunchgrass species under Presettlement conditions (West 1988). The sagebrush steppe community is the largest of the North American semi-desert vegetation types and its floristic diversity is moderate. Shrub layers are typically 0.5-1.0 meter high and cover from 10-80% of a site depending on the site and its succession status. Herbaceous forms are hemicryptophyte (Daubenmire 1970), although the presence of therophytes has increased markedly with disturbance (West 1983). Perennial grasses associated with this community include basin wildrye, wheat grasses, and *Stipa* sp. Pristine sagebrush steppe evolved with

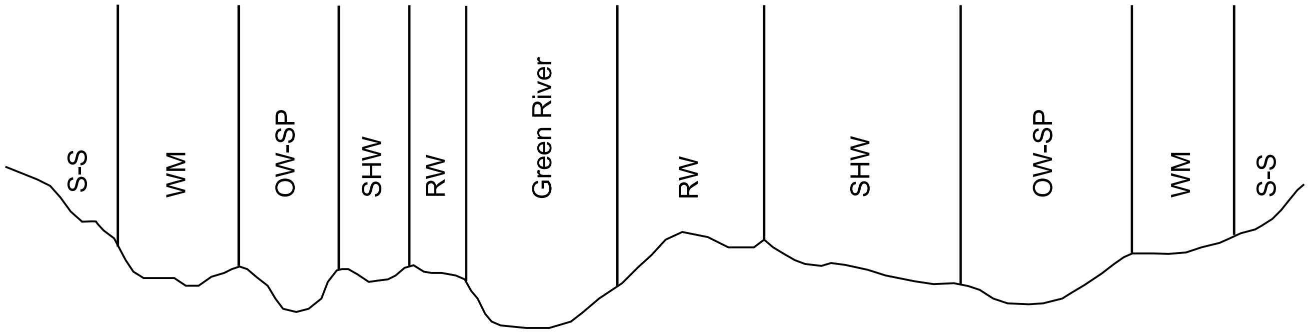

Figure 20. Cross-section of vegetation communities on Seedskadee National Wildlife Refuge.

Table 8. Hydrogeomorphic (HGM) matrix of historical distribution of major vegetation communities/habitat types on Seedskadee National Wildlife Refuge in relationship to geomorphic surface, soils, and hydrological regime. Relationships were determined from land cover maps prepared for the Government Land Office survey notes taken in the early 1800s, historic maps and photographs, U.S. Department of Agriculture soil maps, surficial geomorphology maps (Case et al. 1998), climate and hydrology data for the Green River floodplain; and various naturalist/botanical accounts and literature.

Habitat Type	Geomorphic Surface	Soil type	Flood Frequency[a]
Riverine	Active river channel	Gravel, sand	P
Riparian woodland cottonwood	Natural levee, Point bar ridges	Sandy, silt	A-SFE
Seasonal short emergent wetland vegetation	Floodplain swales	silt loam	A-SF
Open-water persistent tall emergent wetland	Deeper floodplain depressions	silt clay	A-PSMF
Wet meadow grassland	Higher floodplain flats	silt loam, some saline soils	I-TF
Mesic Uplands	Alluvial fans, High floodplain flats	sandy silt loam	R
Dry Uplands Sagebrush steppe	Alluvial fans, Upland terraces	well-drained sandy loam	R

[a] P = Permanently flooded
A-SFE = annually flooded for seasonal periods with extended soil saturation;
A-PSMF = annually flooded with permanent or semipermanent water regimes;
A-SF = annually flooded with short duration seasonal flooding in most years;
I-TP = intermittently temporarily flooded, flooding may not occur every year;
R = rarely if ever flooded, but with seasonal surface sheetflow runoff or groundwater infiltration.

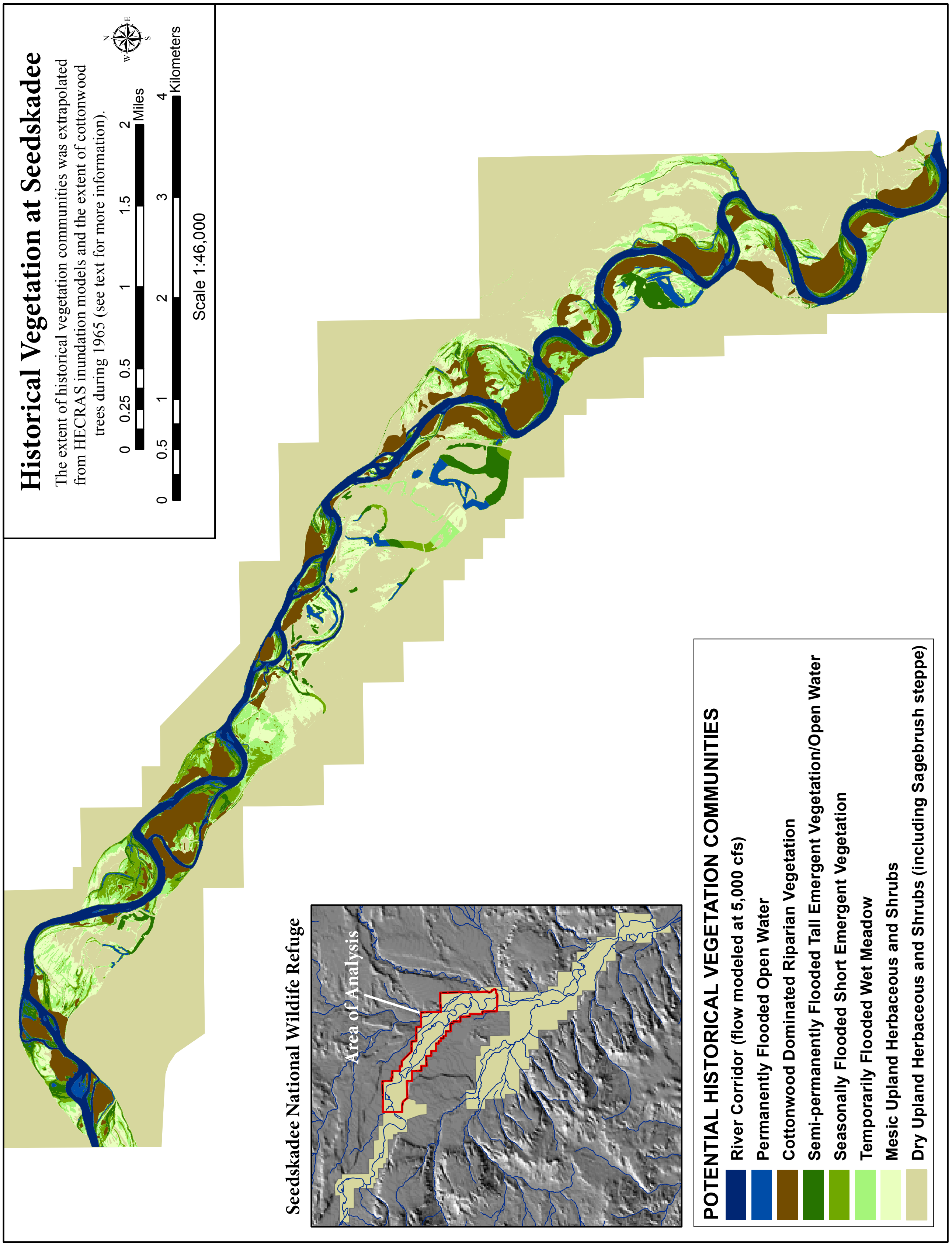

Figure 21. Map of potential historic distribution and types of vegetation communities on Seedskadee National Wildlife Refuge modeled from information in Table 8, HEC-RAS flood inundation maps (Fig. 17), and historical extent of cottonwood seen on old aerial photographs.

large browsers such as antelope, mule deer, and bison (Martin 1970). Fires historically were relatively infrequent in sagebrush steppe communities (Young et al. 1977, West 1988). Presettlement sagebrush steppe was only weakly stable; brush foliage has chemical defenses against herbivory, whereas grasses were highly palatable and native bunchgrasses have high mortality when grazed heavily in spring (Stoddart 1946). They also rarely produce good seed crops (Young et al. 1977). Consequently, heavy grazing from cattle and sheep has greatly altered most native sagebrush steppe areas, including those at Seedskadee NWR, and changes have been further exacerbated by introduction of aggressive annual grasses and weeds such as cheatgrass (*Bromus tectorum*).

A hydrogeomorphic matrix of relationships of the above major plant communities to geomorphic surface, soils, topography, and hydrology was developed to map the potential distribution of Presettlement communities at Seedskadee NWR (Table 8). Historical vegetation communities were estimated based on the extent of cottonwood trees shown in 1965 photographs, HEC-RAS inundation maps, and the flood frequency of varied discharge events (Fig. 21). Generally, communities are arrayed as "bands" or "zones" from the Green River to the uplands on the edges of the floodplain and were strongly related to topography and hydrology. The edges of the Green River channel, including low elevation natural levees and inside river bend point bars contained riparian woodlands. Relict river meander channels, swales, and depressions included relatively small areas of persistent tall emergent vegetation and open water with submerged aquatic vegetation in deeper areas that were semipermanently flooded and sedge-rush communities in seasonally flooded sites. Intervening, slightly higher elevation areas in floodplains contained wet meadow communities that were temporarily flooded by sheetwater flows. Flooding in these areas may be intermittent and not occur every year. Because the Green River is a gaining system influenced by groundwater, an area of mesic grassland/shrubland likely occurred between wet meadow and drier upland habitats. Higher elevation edges of the floodplain, alluvial fans, and upland terraces were dominated by sagebrush steppe communities.

Diverse animal communities historically were present in the various habitat types at Seedskadee NWR. Riparian woodland was used by large numbers animal species including Neotropical migrant birds such as rufous hummingbird, Wilson's warbler, yellow warbler and Bullock's oriole. This habitat also provides important resources to many birds of prey, herons, and mammals including moose, mule deer, beaver, porcupine, and bats (Appendix C). Many reptiles, especially lizards and snakes, also are present in this habitat. Wetland habitats present in the Green River floodplain attracted diverse waterbirds in the otherwise dry sagebrush steppe environment of southwestern Wyoming. Some species such as trumpeter swan, ruddy duck, and cinnamon teal nested and raised broods near the more permanently flooded wetlands, at least during wet years when the Green River had higher flood flow discharges. Other waterbirds used the site mainly during migration, especially in spring; these included American avocets, long-billed dowitcher, several sandpiper species, white-faced ibis, pied-billed grebes, sora, marsh wrens, and yellow-headed blackbirds. Mammals and amphibians also frequented wetland areas. Sagebrush uplands are used by pronghorn, mule deer, greater sage grouse, small mammals, sage sparrow, sage thrasher, Brewer's sparrow, ferruginous hawk, and pygmy rabbit. Several native fish species historically were present in the Green River in the Seedskadee NWR region including cutthroat trout, Colorado pikeminnow, razorback sucker, Utah chub, roundtail chub, humpback chub, bonytail chub, and Bonneville redside shiner (Appendix C). These fish species used both channel and backwater aquatic habitats and periodic flooding of floodplains provides sites for foraging adults and entrainment of larval and juvenile fishes (Wintzer 2008).

Adonia Henry