APPENDIX B:
HYDROLOGIC INFORMATION

B-1
Analysis of Locational Data

APPENDIX B-1: ANALYSIS OF LOCATIONAL DATA

ADWR used several early and recent lines of evidence to determine predevelopment flow conditions along major streams in the San Pedro River Watershed. To compare these lines of evidence, locations of water-related features were projected to a common reference datum and geographic coordinate system and plotted on a defined stream network. ArcGIS 9.3, a widely used Geographic Information System (GIS) computer program, facilitated the projection and plotting of the locational data.

Data Projections

ADWR analyzed the following types of locational data to determine predevelopment streamflows:

- Historic accounts that reference known geographic features[1]
- Hard copy maps
- Legal descriptions and cadastrals
- Latitude and longitude coordinates
- Aerial photographs
- Electronic maps.

To utilize historic accounts, ADWR first identified the geographic features on current 1:24,000-scale topographic (topo) maps. Digital versions of topo maps are available through the U.S. Geological Survey (USGS) and are referenced to the North American Datum of 1983 (NAD83). After identifying the geographic features, the locations of water-related features were delineated based on the historic accounts and then digitized. The resulting vector (point and line) data were recorded in ArcGIS using the Universal Transverse Mercator (UTM) coordinate system.

To utilize hard copy maps and aerial photographs, ADWR first scanned its copy of the images electronically. The resulting digital images were then rectified using the

[1] Some historic accounts, including court transcripts, refer to points of diversion that ADWR used to locate associated water-related features.

Georeferencing toolbar in ArcGIS. The digital images were overlain on topo maps and rectified by matching a minimum of three control points to known geographic features and coordinates. To complete the process, the rectified images were projected to NAD83 using a 1st order polynomial (affine) transformation algorithm and the raster (pixel) data stored in ArcGIS. At this stage, locations of water-related features were delineated and, like the historic accounts, digitized and associated points and lines stored as UTM coordinates.

Legal descriptions provided the location of many water-related features, particularly the points of diversion for irrigation ditches. In most cases, legal descriptions included a township, range, section and one or more quarter sections. Locations of some features were only known to their section or half section, while others were known down to their 160-acre (¼), 40-acre (¼,¼), or 10-acre (¼,¼,¼) sections. ADWR used SQL, a database programming language, to convert the legal descriptions into cadastrals, which provide the same locational information as legal descriptions but in a different format. A legal description specifies a location from its smallest known subdivision (10-acre quarter section, if known) to its largest (township and range). A cadastral specifies the same location from it largest to smallest subdivision.

ADWR maintains a database of UTM coordinates that locate the centerpoint of all cadastrals in Arizona. After conversion to cadastrals, legal descriptions were matched against this database and associated UTM coordinates recorded in ArcGIS. Locations originally provided as cadastrals were directly matched to the UTM database. ADWR used the Project Tool in ArcGIS to convert locations provided in latitude and longitude to UTM coordinates. Note that ADWR manually adjusted the location of some points plotted based on their UTM coordinates if narrative information provided a more exact location.

Recent maps used as evidence of predevelopment streamflows were typically prepared using GIS software and available electronically. ADWR brought these maps and associated line data directly into ArcGIS and, as necessary, changed the reference datum from NAD27 to NAD83.

Stream Network

ADWR used recent channel data to define the location of the San Pedro and Babocomari Rivers and Aravaipa Creek. AZGS (2009) mapped the extent of active channel deposits along the streams (unit Qycr) and generated GIS polygons of the unit. ADWR brought these polygons into ArcGIS, converted them to boundary lines, and clipped off any ends to create pairs of line. A centerline was then plotted through the mapped Qycr using the Collapse Duel Lines to Centerline Tool (ESRI, 2008). The center line defined the stream network in this study. AZGS did not map Qycr in a narrow bedrock canyon along the Babocomari River so, for this reach, ADWR used the stream location depicted on the current 1:24,000-scale topo map of the area.

Linear Referencing

After projection to NAD83 and using UTM coordinates, the location of water-related features were plotted on the stream network and analyzed using the Linear Referencing toolbox in ArcGIS. Linear referencing created a longitudinal profile for each stream and allowed the water-related features to be directly compared on the basis of stream miles. However, due to the accuracy of the locational data, not all of these features plotted exactly on the stream network. To adjust their location so that they would plot on the network and allow further analysis, the features were reprojected using search radii (for data points) and cluster tolerances (for lines) set at distances from 0.1 to 0.6 miles. Several iterations were needed before all of the features plotted exactly on the streams.

ADWR used the Make Route Event Layer Tool (ESRI, 2006a) to display the water-related features on maps of the stream network and the Locate Features along Routes Tool (ESRI, 2006b) to record the location of each feature in stream miles. The latter allowed the lines of evidence to be graphed and compared as shown in **Figures 3-21** through **3-23**.

B-2
Historic Irrigation Ditches and Ore Mills

Tables

TABLE B-2a. HISTORIC IRRIGATION DITCHES AND ORE MILLS IN THE SAN PEDRO RIVER WATERSHED

MAP KEY[1]	NAME	DATE[2]	STREAM	DATA SOURCE(S)
Ore Mills [3]				
a	Charleston	1880s	San Pedro River	Bufkin (19??), Tellman and Hadley (2006) and Tiller (1982)
b	Corbin	1878		
c	Gird			
d	Boston	1880s		GLO (1902)
e	Empire			GLO (1881)
f	Emery			Tellman and Hadley (2006)
g	Grand Central			
h	Contention			
i	Sunset or Head Center			
j	E. Clifford	Unknown		
k	Mammoth	1890		Benjamin (2002) and Peterson (1938)
l	Klondyke	mid-1890s(?)	Aravaipa Creek	Hadley and others (1991)
Irrigation Ditches [4]				
1	Hereford	1870s	San Pedro River	Bryan and others (1934)
2	W. C. Greene	1889		Hill (1889)
3	Unnamed	1903		GLO (1903)
4	Kirk	1887		NOA
5	Haviland/Quibiris	1892		
6	Woolery	1903		ASA and NOA
7	Levi Scranton	1888		Hill (1889)
8	Unnamed	1881		GLO (1881)
9	Randolph and Claflin	1889		Hill (1889)
10	Lindsey	1881		
11	Boquillas	1906		Bryan and others (1934) and NOA
12	Walk Williams	1880s		Hill (1889)
13	Noyes (Noyes and Christianson)	1879		Hill (1889) and NOA
14	H. C. Herrick	1879		Hill (1889)
15	Jacob Landis	1877		Grijalba (1889)
16	Hop Kee	1880s		Hill (1889)
17	Bertolomeo Avancino	1881		
18	Kemble	1879		
19	Curtis	1905		NOA
20	Richardson	1894	Babocomari River	ASA
21	E.B. Perrin	1912		
22	McLane	1906		ASA and NOA
23	Rock	1907		ASA
24	Smith	1897		ASA and NOA
25	Joerger	1906		NOA
26	Reuter	1907		ASA
27	W. C. Land	1884		Hill (1889)
28	Mr. Harris	1880s		
29	Unnamed	1906		NOA
30	Mason and Union	1880s	San Pedro River	Hill (1889)
31	St. David	1880		Walcott (1901)
32	Curtis	1900s		Bryan and others (1934)
33	Unnamed	1881		GLO (1881)
34	Unnamed	1881		
35	Ryan	1898		ASA
36	Benson	1908		NOA
37	Unnamed (Wiley?)	1879		
38	Etts	1899		Walcott (1901)
39	Horacitas	1870s		Grijalba (1889)
40	Acequia (Chisholm?)	1870s		GLO (1873) and Walcott (1901)
41	Acequia (Madrid?)	1873		GLO (1873) and Grijalba (1889)
42	Acequia (Gibson?)	1870s		GLO (1873), Grijalba (1889), and Walcott (1901)
43	Acequia	1874		GLO (1873)
44	Acequia	1873		
45	Acequia (McCormick, Mongomery, and/or Grijalba)	1873		GLO (1873) and Grijalba (1889)
46	Acequia	1873		GLO (1873)
47	Dunbar	1870s		Walcott (1901)
48	Lopez and Nigger George	1866		Grijalba (1889)
49	Unknown	1860s		
50	Archibald and DeLong	1870s		
51	Frederico	1866		
52	Grijalba	1873		
53	Allen/Diaz	1890s		NOA
54	Lopnaus	1870s		Bryan and others (1934), GLO (1873) and Walcott (1901)
55	Unnamed	1902		GLO (1902)
56	Redus or Sanchez	1900s		NOA and GLO (1902)
57	Aperdiser	1899		Walcott (1901)
58	Bohn	1899		
59	Blanchard	1899		
60	Unnamed	1879		GLO (1879)
61	Unnamed (Mexican?)	1870s		GLO (1879) and Walcott (1901)
62	Unnamed	1879		GLO (1879)
63	Unnamed (Frenchman?)	1870s		GLO (1879) and Walcott (1901)
64	Pantano	1899		Walcott (1901)
65	Acequia	1879		Bryan and others (1934) and GLO (1879)
66	Acequia	1879		
Irrigation Ditches [4]				
67	Soza	1899	San Pedro River	Walcott (1901)
68	Soza	1899		
69	Mange	1879		GLO (1879) and Walcott (1901)
70	Los Angeles	1899		Walcott (1901) and Wood (1997)
71	Warner	1899		Walcott (1901)
72	Patton	1899		Walcott (1901) and Wood (1997)
73	Bayless	1870s		GLO (1879) and Wood (1997)
74	Pearson	1888		ASA
75	Unnamed	1879		GLO (1879) and Wood (1997)
76	Unnamed	1885		ASA
77	Unnamed	1879		GLO (1879)
78	Bayless & Berkalew	1880		GLO (1880) and Walcott (1901)
79	Markham	1900s		Wood (1997)
80	Davis	1886		ASA and NOA
81	Bayless & Berkalew	1899		Walcott (1901)
82	Bayless & Berkalew	1899		
83	Z. Taylor	1888		ASA
84	Chrismon	1883		
85	John Bayles	1910		ASA and NOA
86	Bollen	1870s		Wood (1997)
87	Bollen	1902		
88	Bayless	1905		ASA
89	Charles Dyke	1888		
90	Unnamed	1893		NOA
91	Schoenholzer (also Noel)	1880s		
92	Schoenholzer	1887		
93	Unnamed (W. Johnson?)	1870s		GLO (1880)
94	Miley	1880s		NOA and Walcott (1901)
95	Acton-Clark	1880s		
96	Figueroa	1899		AZ Governor (1890) and Walcott (1901)
97	Brown	1880s		
98	Hines	1886		NOA
99	Cronley/Girard	1893		
100	Rhodes	1886		
101	Cronley	1880s		
102	Doll	1890		
103	Brown	1886		
104	Brown & Wills	1870s		GLO (1878) and Walcott (1901)
105	Putnam	1880		NOA
106	Putnam & Land	1899		Walcott (1901)
107	Cook	1883		AZ Governor (1890), NOA and Walcott (1901)
108	Pusch	1880s		
109	Ellsworth	1886		NOA
110	Dodson	1883		AZ Governor (1890), NOA and Walcott (1901)
111	Gibson	1884		NOA
112	Unnamed	1879		GLO (1878)
113	Wyrough	1883		NOA
114	Forey	1882		
115	Finch & Draper	1880s		AZ Governor (1890) and Walcott (1901)
116	Lytle (or Indian)	1870s		GLO (1878) and Walcott (1901)
117	Swingle	1889		Walcott (1901)
118	Swingle	1879		NOA and Walcott (1901)
119	Young	1879		
120	Scott & Cunningham	1899		Walcott (1901)
121	Young	1899		
122	Lopez	1909		NOA
123	Acequia	1878		GLO (1878)
124	Bates II	1884		NOA
125	Harrington/Acequia	1878		GLO (1878)
126	Lattin	1878		AZ Governor (1890), NOA and Walcott (1901)
127	Bates	1882		
128	Kendell	1892		NOA
129	Cunningham	1882		
130	Putnam	1884	Aravaipa Creek	
131	Gibson	1899		NOA and Walcott (1901)
132	Bunt	1893		NOA
133	Chamberlin	1903		
134	Voss	1878		
135	Land	1890		NOA and Walcott (1901)
136	Kielberg	1892		NOA
137	Doll II	1891		
138	Brandenberg	1899		
139	Kielberg II	1894		
140	Old Pat Cashing	1893		
141	Epigmenio Salazar	1867		ADWR (1991)
142	Pennsyl	1900		ASA
143	Wright	1870s	Babocomari River	Rodgers (1965)
144	Belamy	1875		

Notes:

[1] See Figures B-2a through B-2e for location of irrigation ditch diversions and ore mills; only major streams in the watershed were considered.

[2] Approximate date of first use, if known.

[3] Unknown to ADWR whether mills "a" through "j" were fed by the same dam on the San Pedro River or by multiple dams and diversions.

[4] Ditches identified by county records at the Arizona State Archives (ASA) and/or in Notices of Appropriation (NOAs) at ADWR may or may not have actually been constructed.

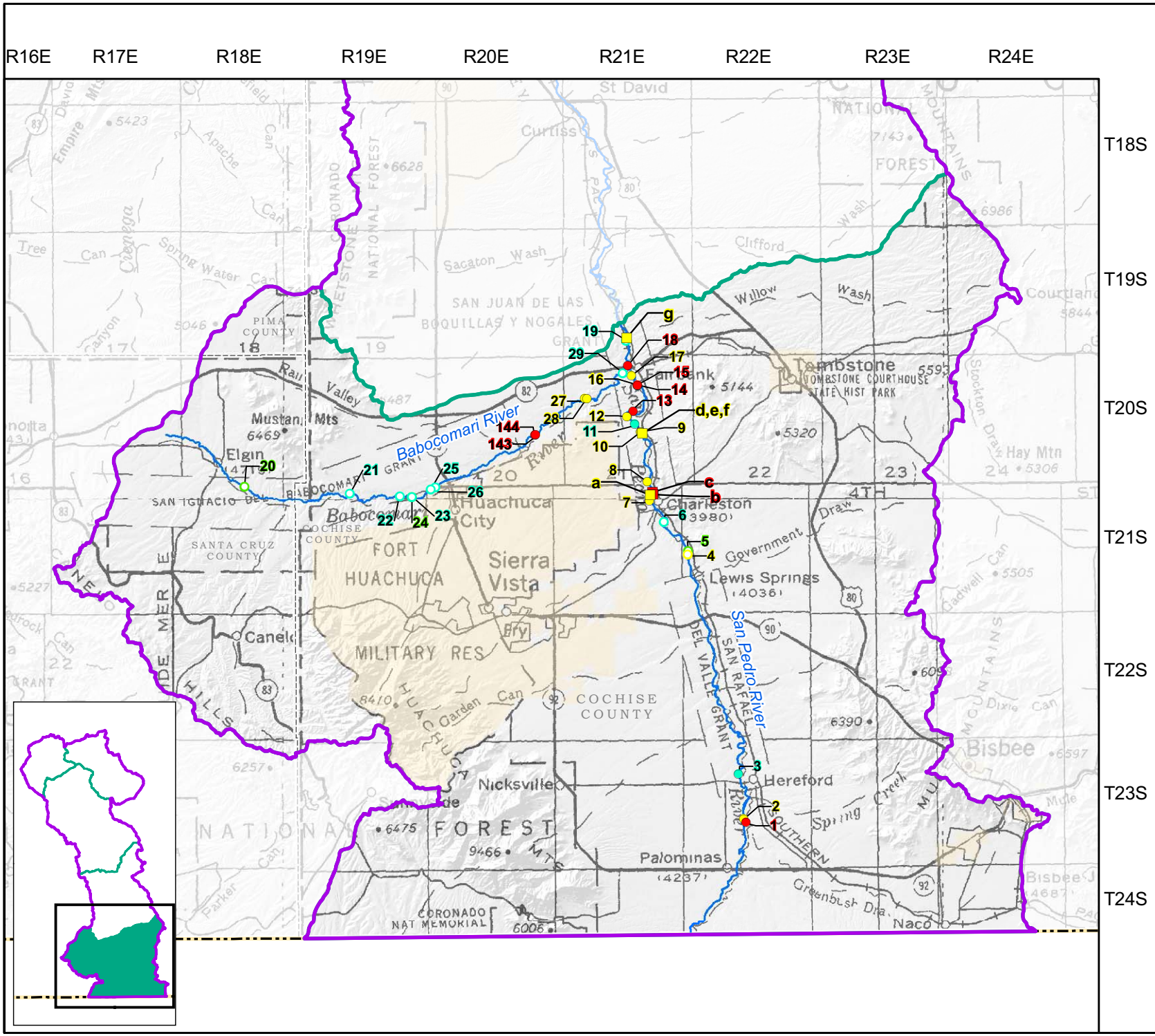
TABLE B-2b. IRRIGATION DIVERSIONS SURVEYED IN THE SAN PEDRO RIVER WATERSHED BY THE ARIZONA STATE WATER COMMISSIONER BETWEEN 1920 AND 1923

MAP KEY[1]	DIVERSION NAME/TYPE	SURVEY DATE	STREAM
1	Pump Plant (direct)	1921	San Pedro River
2	Ditch		
3	Ditch		
4	Boquillas Ditch		
5	Boquillas Ditch		
6	Curtis Ditch		
7	St. David Canal	1923	
8	Benson Canal		
9	Pump Plant (direct)	1921	
10	Apodaca Ditch		
11	Sanchez Ditch		
12	Vasquez Ditch		
13	Gamez Ditch		
14	Munguia Ditch		
15	Soza Ditch		
16	Bayless Ditch		
17	Vasquez Ditch		
18	Vasquez Ditch		
19	Amado Ditch	1920	
20	Acton Clark Ditch		
21	Smith Ditch #1		
22	Daily Ditch		
23	Smith Ditch #2		
24	Zapata Ditch		
25	San Pedro Ranch Ditch		
26	Buzan Ditch		
27	Pump Plant (direct)		
28	Stewart Ditch		
29	Pusch Ditch		
30	Pusch Ditch		
31	Pusch Ditch		
32	Ditch		
33	Ditch		
34	Brooks Ditch		
35	Finch Ditch #1		
36	Indian Ditch		
37	Ditch		
38	Finch Ditch #2		
39	Finch Ditch #3		
40	Bittick Ditch		
41	Drake Ditch		
42	Wilcox Ditch		
43	Reay Ditch		
44	Wilcox Ditch Heading		
45	Pump Plant (indirect)		
46	Pump Plant (direct)	1920	San Pedro River
47	Ditch	1921	
48	Ray Con Ditch		
49	Valdez Canal		
50	Upshaw Ditch		
51	Hardwick Ditch		
52	Whelan Ditch	1921	Aravaipa Creek
53	Kennedy Bros. Ditch		
54	Valenzuela Ditch		
55	Eureka Springs Cattle Co Ditch		
56	Roten Ditch		
57	Haby Ditch		
58	Ditch		
59	Ditch		
60	Ditch		
61	Ditch		
62	Trail Ditch #1		
63	Trail Ditch #2		
64	Ditch		
65	Trail Ditch #3		
66	Trail Ditch #4		
67	Salazar Ditch		
68	Trail Ditch #5		
69	Trail Ditch #6		
70	Trail Ditch #7		
71	Buzan Ditch		
72	Stewart Ditch		
73	Kielberg Ditch		
74	Brandenberg Ditch #1		
75	Brandenberg Ditch #2		
76	Brandenberg Ditch #3		
77	Zapata Ditch 1		
78	Zapata Ditch 2		
79	Zapata Ditch 3		
80	Row Ditch		
81	Baker Ditch		
82	Flannery Ditch		
83	Satathite Ditch		
84	Indian Ditch #1		
85	Indian Ditch #2		
86	Indian Ditch #3		
87	San Pedro Ranch Ditch		
88	Stewart Ditch		
89	Ditch		
90	Ditch		

Notes:

[1] See Figure B-2f for location of irrigation diversions; only the San Pedro River and Aravaipa Creek were surveyed.

Figures



Legend

Irrigation Ditch Diversions

- On or before 1869
- 1870 to 1879
- 1870 to 1879 (from NOA)
- 1880 to 1889
- 1880 to 1889 (from NOA)
- 1890 to 1899
- 1890 to 1899 (from NOA)
- On or after 1900
- On or after 1900 (from NOA)

Ore Mills

- 1870 to 1879
- 1880 to 1889
- 1890 to 1899
- Unknown

- San Pedro River Watershed
- Sierra Vista Subwatershed
- Major Stream
- County
- International Boundary

Notes:

(1) Data from Rogers (2007).

(2) Based on historic maps, county and court records, government reports, and Notices of Appropriation (NOAs).

(3) List of ditch and mill names presented in Table B-2a.

(4) Only major streams in watershed considered.

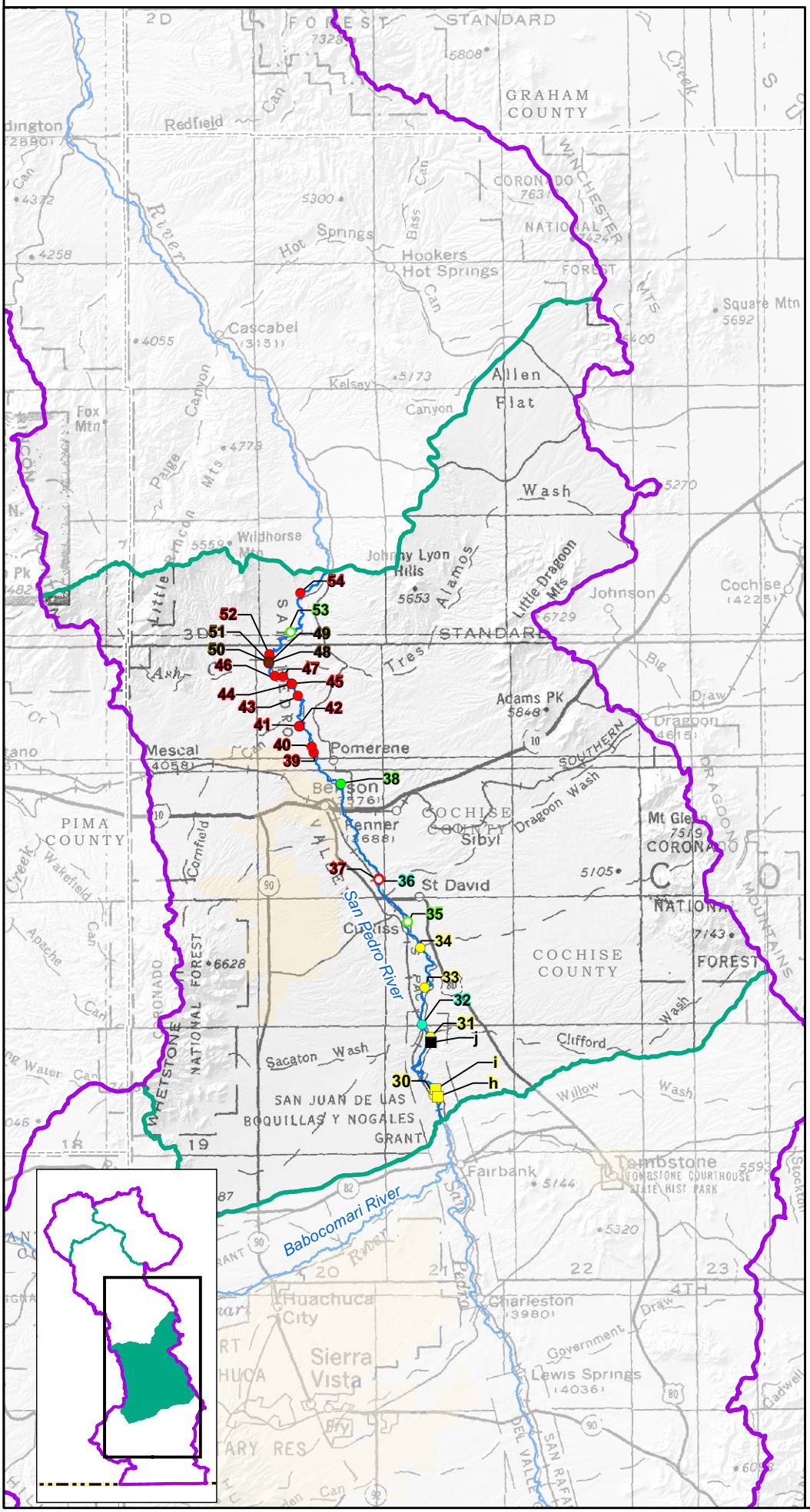
Basemap: 1:500K USGS Topo Arizona 1981

N

0 1 2 3 4 5 Miles

Figure B-2a
Historic Irrigation Ditch Diversions and Ore Mills Sierra Vista Subwatershed

Subflow Zone Delineation Report for the San Pedro River Watershed



Legend

Irrigation Ditch Diversions

- On or before 1869
- 1870 to 1879
- 1870 to 1879 (from NOA)
- 1880 to 1889
- 1880 to 1889 (from NOA)
- 1890 to 1899
- 1890 to 1899 (from NOA)
- On or after 1900
- On or after 1900 (from NOA)

Ore Mills

- 1870 to 1879
- 1880 to 1889
- 1890 to 1899
- Unknown
- San Pedro River Watershed
- Benson Subwatershed
- Major Stream
- County
- International Boundary

Notes:

(1) Data from Rogers (2007).

(2) Based on historic maps, county and court records, government reports, and Notices of Appropriation (NOAs).

(3) List of ditch and mill names presented in Table B-2a.

(4) Only major streams in watershed considered.

Basemap: 1:500K USGS Topo Arizona 1981

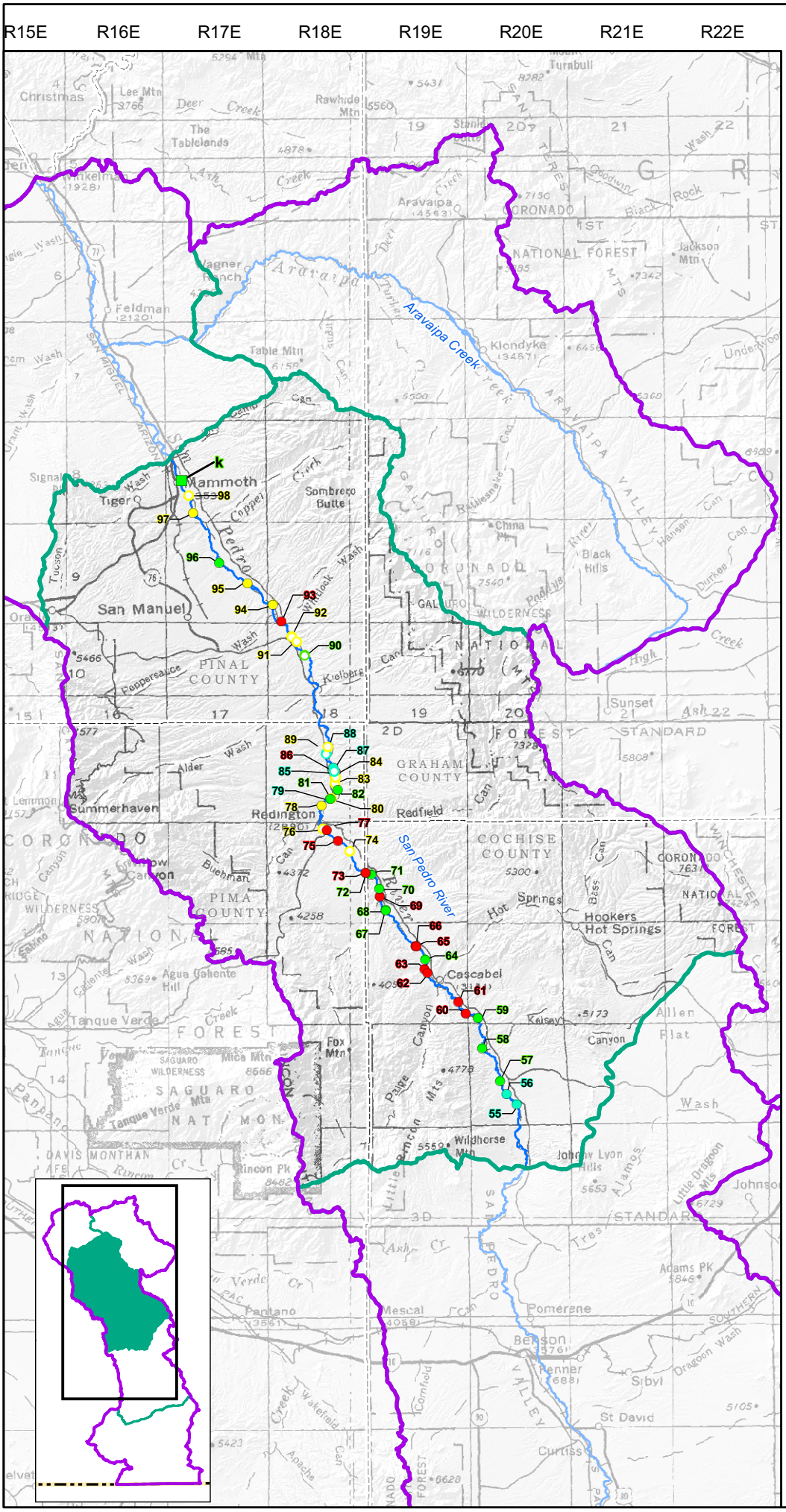
N

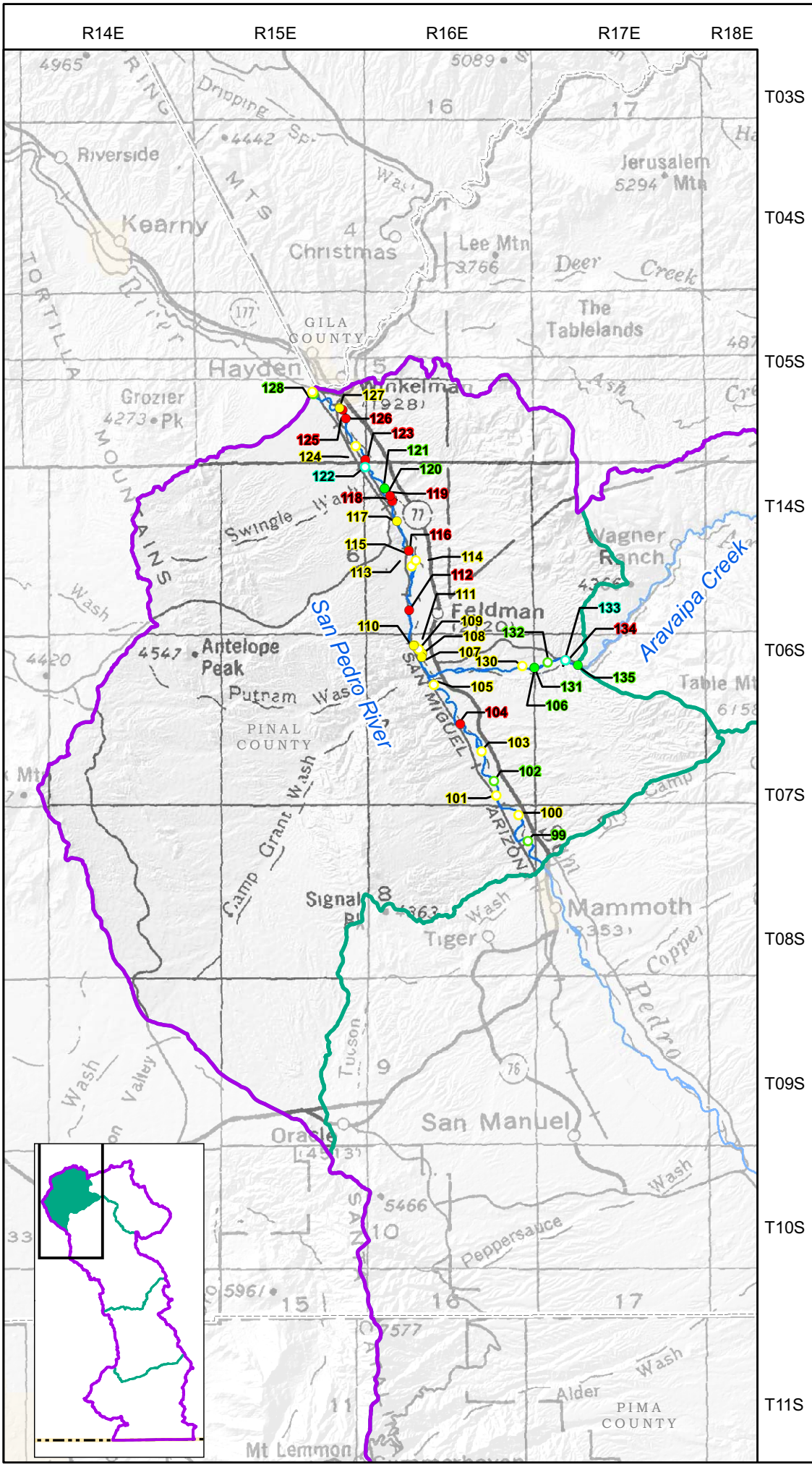
0 1 2 3 4 5 Miles

Figure B-2b
Historic Irrigation Ditch Diversions and Ore Mills
Benson Subwatershed

Subflow Zone Delineation Report for the San Pedro River Watershed

6/18/2009, \\adwrsas1-phx01.azwater.gov\gis-vns, u:\workspaces\statewideplanning\adjudications\projects\sanpedro\maps\subflow_report_figures\mxd\appendixb-2_historicditchmilldiversions\appb-2b_benson_historicditchmills.mxd


R15E
R16E
R17E
R18E
R19E
R20E
R21E
R22E
T04S
T05S
T06S
T07S
T08S
T09S
T10S
T11S
T12S
T13S
T14S
T15S
T16S
T17S
T18S
Mammoth
San Manuel
Redington
Redfield
Cascabel
Aravaipa Creek
San Pedro River
PINAL COUNTY
GRAHAM COUNTY
COCHISE COUNTY
PIMA COUNTY
Summerhaven
Hookers Hot Springs
Klondyke
Sombrero Butte
Tiger
Feldman
Aravaipa
Kelsey
Wildhorse Mtn
Pomerene
Benson
Sibyl
St David
Curtiss
Johnny Lyon Hills
Adams Pk
Rincon Pk
Mica Mtn
Fox Mtn
Table Mtn
Black Hills
Jackson Mtn
Turnbull
Christmas
Lee Mtn
Rawhide Mtn
The Tablelands
Agua Caliente Hill
Tanque Verde
Pantano
Mescal
Renner
Allen Flat
Johnson
Little Dragoon Mts
Little Rincon Mts
Paige Mts
Tanque Verde Mts
Alamos
Black Rock Wash
Dragoon Wash
Kielberg
Pappersauce
Buehman
Alder
Durkee Can
Hansen Can
Hot Springs
Kelsey Canyon
Allen Flat Wash
Ash Cr
Tres Alamos
Wakefield Can
Apache Can
Comfield
Pedro
Tucson
Arizona
Signal
Lemon
Sunset
Standard
Coronado
Galiuro
Wilderness
Saguaro
Nat Mon
Davis Monthan AFB
Coronado National Forest
Coronado Nat Forest
Chiricahua Nat Mon
Rincon Mts
Tortilla Mts
Galiuro Mts
Pinaleño Mts
Dragoon Mts
Rattlesnake Can
Podhue Can
Hot Springs Can
Bass Can
Black Rock Can
Kelsey Canyon
Paige Canyon
Tanque Verde Creek
Agua Caliente Wash
Pantano Wash
Mescal Can



Legend

Irrigation Ditch Diversions

- On or before 1869
- 1870 to 1879
- 1870 to 1879 (from NOA)
- 1880 to 1889
- 1880 to 1889 (from NOA)
- 1890 to 1899
- 1890 to 1899 (from NOA)
- On or after 1900
- On or after 1900 (from NOA)

Ore Mills

- 1870 to 1879
- 1880 to 1889
- 1890 to 1899
- Unknown

- San Pedro River Watershed
- Winkelman Subwatershed
- Major Stream
- County
- International Boundary

Notes:

(1) Data from Rogers (2007).

(2) Based on historic maps, county and court records, government reports, and Notices of Appropriation (NOAs).

(3) List of ditch and mill names presented in Table B-2a.

(4) Only major streams in watershed considered.

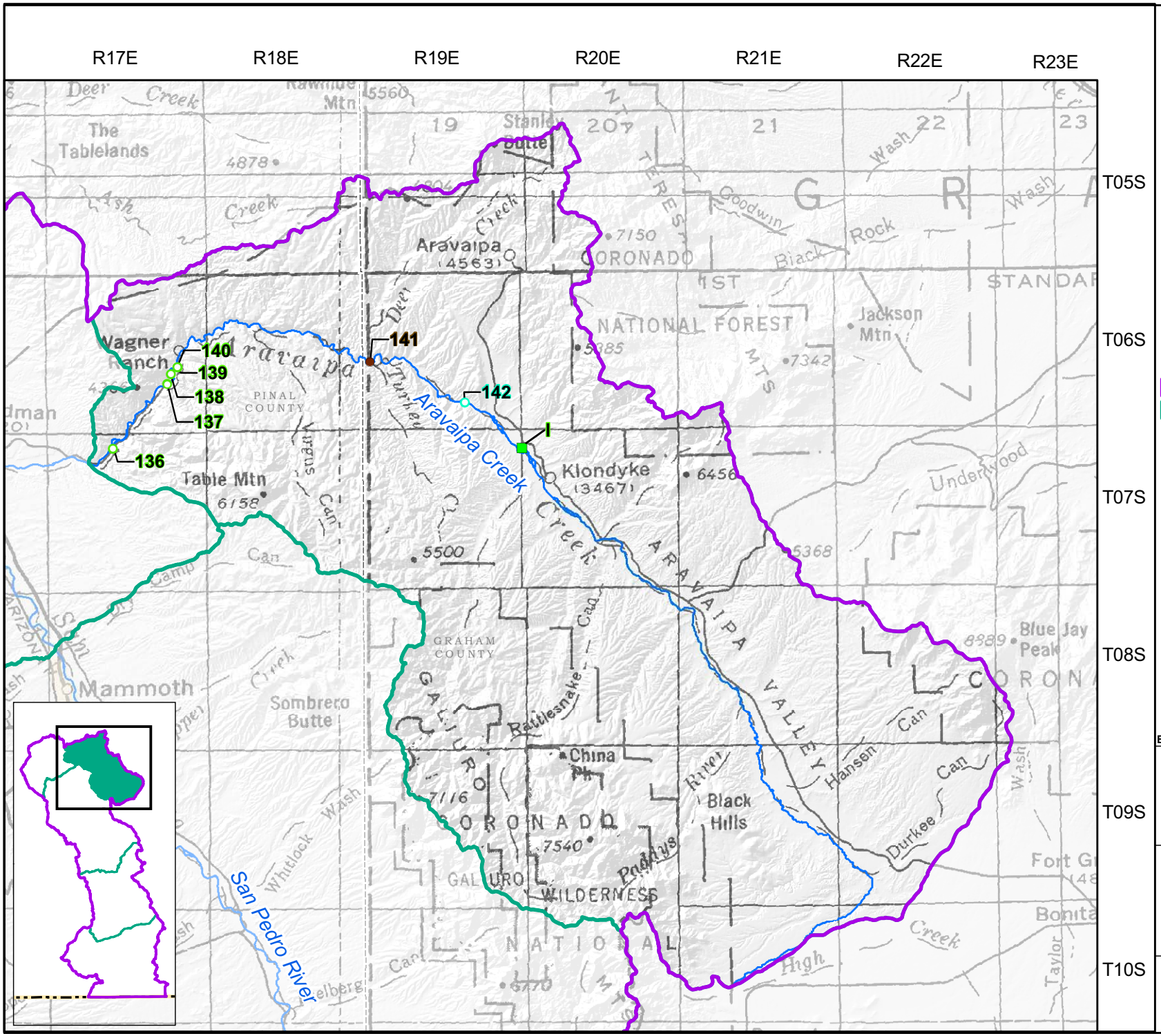
Basemap: 1:500K USGS Topo Arizona 1981

N

0 1 2 3 4 5 Miles

Figure B-2d
Historic Irrigation Ditch Diversions and Ore Mills Winkelman Subwatershed

Subflow Zone Delineation Report for the San Pedro River Watershed



Legend

Irrigation Ditch Diversions

- On or before 1869
- 1870 to 1879
- 1870 to 1879 (from NOA)
- 1880 to 1889
- 1880 to 1889 (from NOA)
- 1890 to 1899
- 1890 to 1899 (from NOA)
- On or after 1900
- On or after 1900 (from NOA)

Ore Mills

- 1870 to 1879
- 1880 to 1889
- 1890 to 1899
- Unknown

- San Pedro River Watershed
- Aravaipa Subwatershed
- Major Stream
- County
- International Boundary

Notes:

(1) Data from Rogers (2007).

(2) Based on historic maps, county and court records, government reports, and Notices of Appropriation (NOAs).

(3) List of ditch and mill names presented in Table B-2a.

(4) Only major streams in watershed considered.

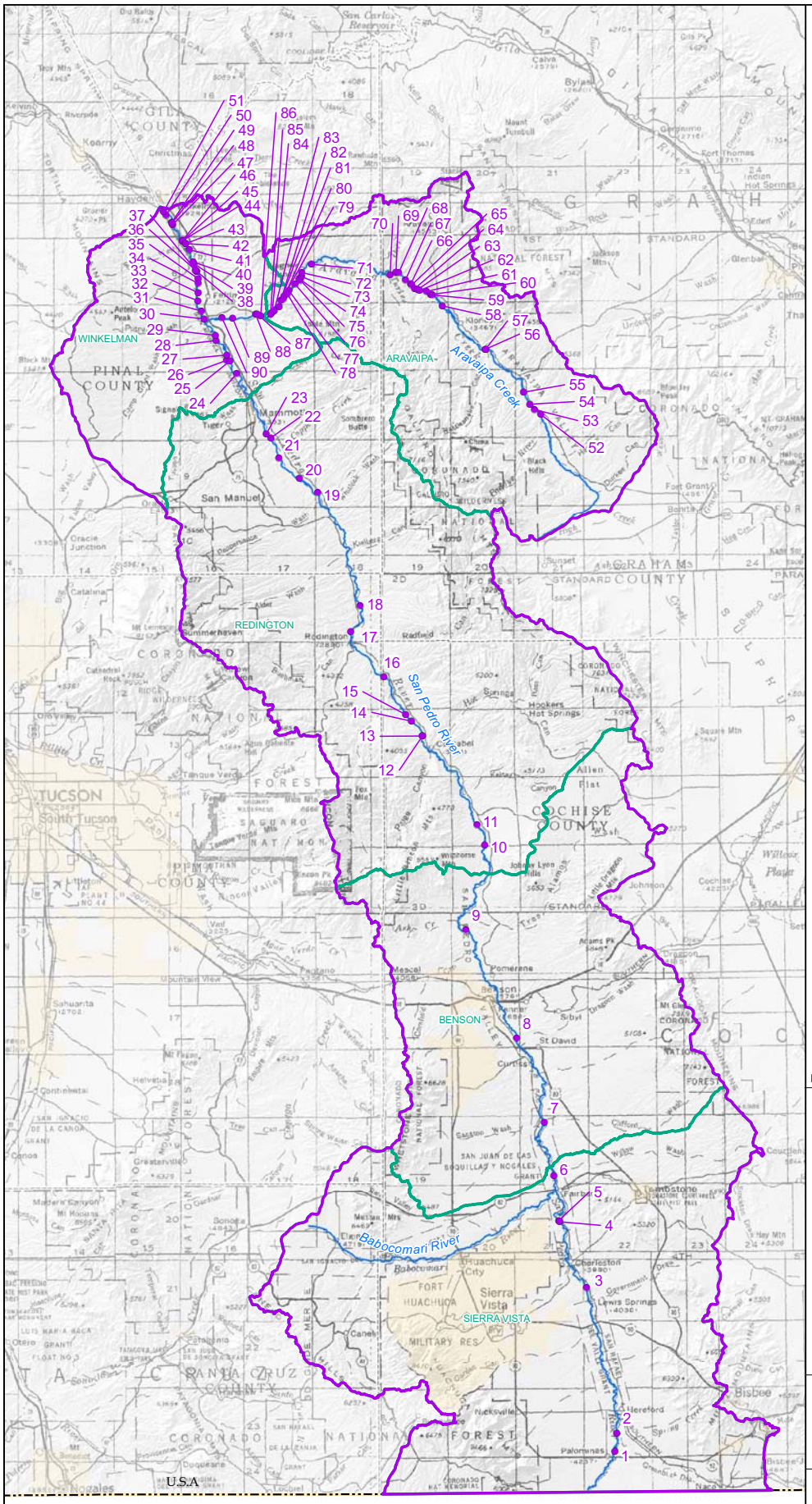
Basemap: 1:500K USGS Topo Arizona 1981

N

0 1 2 3 4 5 Miles

Figure B-2e
Historic Irrigation Ditch Diversions and Ore Mills Aravaipa Subwatershed

Subflow Zone Delineation Report for the San Pedro River Watershed



Legend

Irrigation Ditch Diversions

- Diversion Point

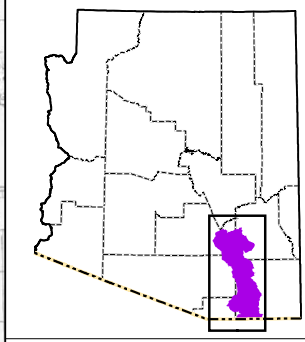
- San Pedro River Watershed
- San Pedro River Subwatershed
- Major Stream
- County
- International Boundary

Notes:

(1) The map key with a list of diversion names/types is presented in Table B-2b.

(2) Only the San Pedro River and Aravaipa Creek were surveyed.

Basemap: 1:500K USGS Topo Arizona 1981



N

ARIZONA DEPARTMENT OF WATER RESOURCES

0 5 10 15 Miles

Figure B-2f
Irrigation Diversions Surveyed by the Arizona State Water Commissioner Between 1920 and 1923

Subflow Zone Delineation Report for the San Pedro River Watershed

B-3
Annual Hydrographs

Text

APPENDIX B-3: ANNUAL HYDROGRAPHS

This portion of **Appendix B** presents annual hydrographs for the San Pedro and Babocomari Rivers and Aravaipa Creek based on records from stream gages with at least one year of daily flow measurements. Hydrographs were not developed for three gages with less than one year of record (USGS gages 9471040, 9471070, and 9471565) and for a gage on the San Pedro River at Winkelman Bridge. Schwalen (1922-1941) primarily collected daily *stage* measurements at the Winkelman Bridge gage, whose vertical datum changed periodically in response to flood events, and his semi-weekly flow measurements at the site were not collected at consistent intervals.

Figures B-3a through **B-3s** show the annual hydrographs that ADWR developed for 19 stream gages. The hydrographs were constructed by plotting the median of the daily mean discharge for each day of the calendar year, excluding leap days (February 29). All hydrographs are based on published USGS records with the exception of **Figures B-3b** and **B-3d** which are based on unpublished daily flow data from Schwalen. Gage locations are shown in **Figure 3-8**, and **Tables 3-2** and **3-5** summarize the streamflow records.

The period of the early 1940s was used by ADWR to distinguish early and recent streamflow records. Data collected during the early 1940s and before were grouped, and median daily mean discharge values calculated. The resulting hydrographs are labeled "early" and their corresponding years of record specified. Data collected since the early 1940s were similarly grouped and analyzed and the resulting hydrographs labeled "recent." If a gage has both early and recent streamflow records, two hydrographs appear in the figure and are labeled accordingly. Also specified on the figures is the "median annual streamflow frequency" which represents the percentage of days in the year when the median of the daily mean discharge measurements was greater than zero cubic feet per second. This frequency was a criteria used by ADWR to distinguish perennial, intermittent and ephemeral flow conditions.

Figures

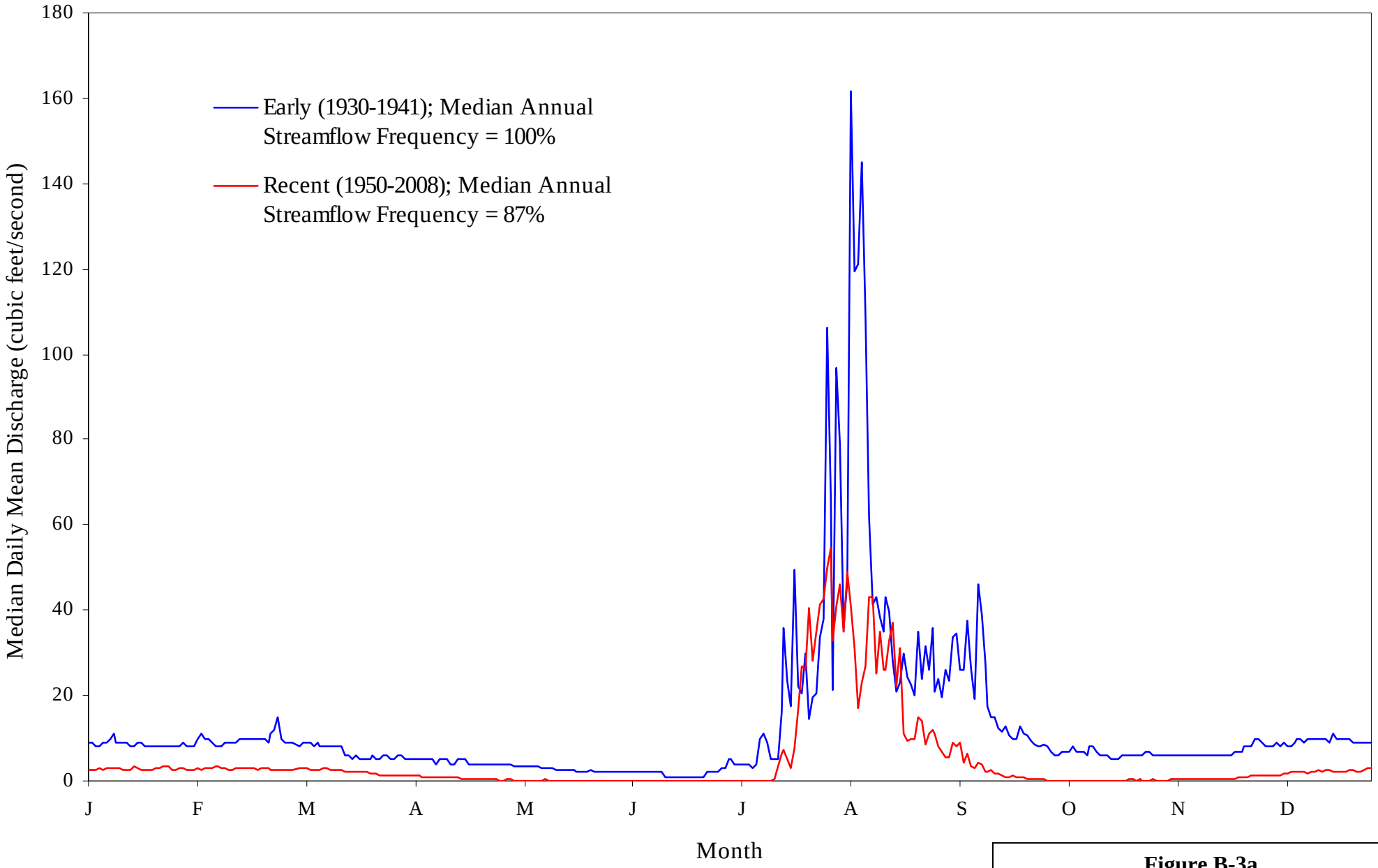


Figure B-3a
Annual Hydrographs for the San Pedro River at Palominas (USGS 9470500)

Subflow Zone Delineation Report for the San Pedro River Watershed

ARIZONA DEPARTMENT OF WATER RESOURCES ©

U:\WorkSpaces\StatewidePlanning\Adjudications\Projects\SanPedro\maps\Subflow_Report_Figures\PPT\AppB-3_AnnualHydrographs\FigB-3a_Hydrograph_SP_Palominas.ppt

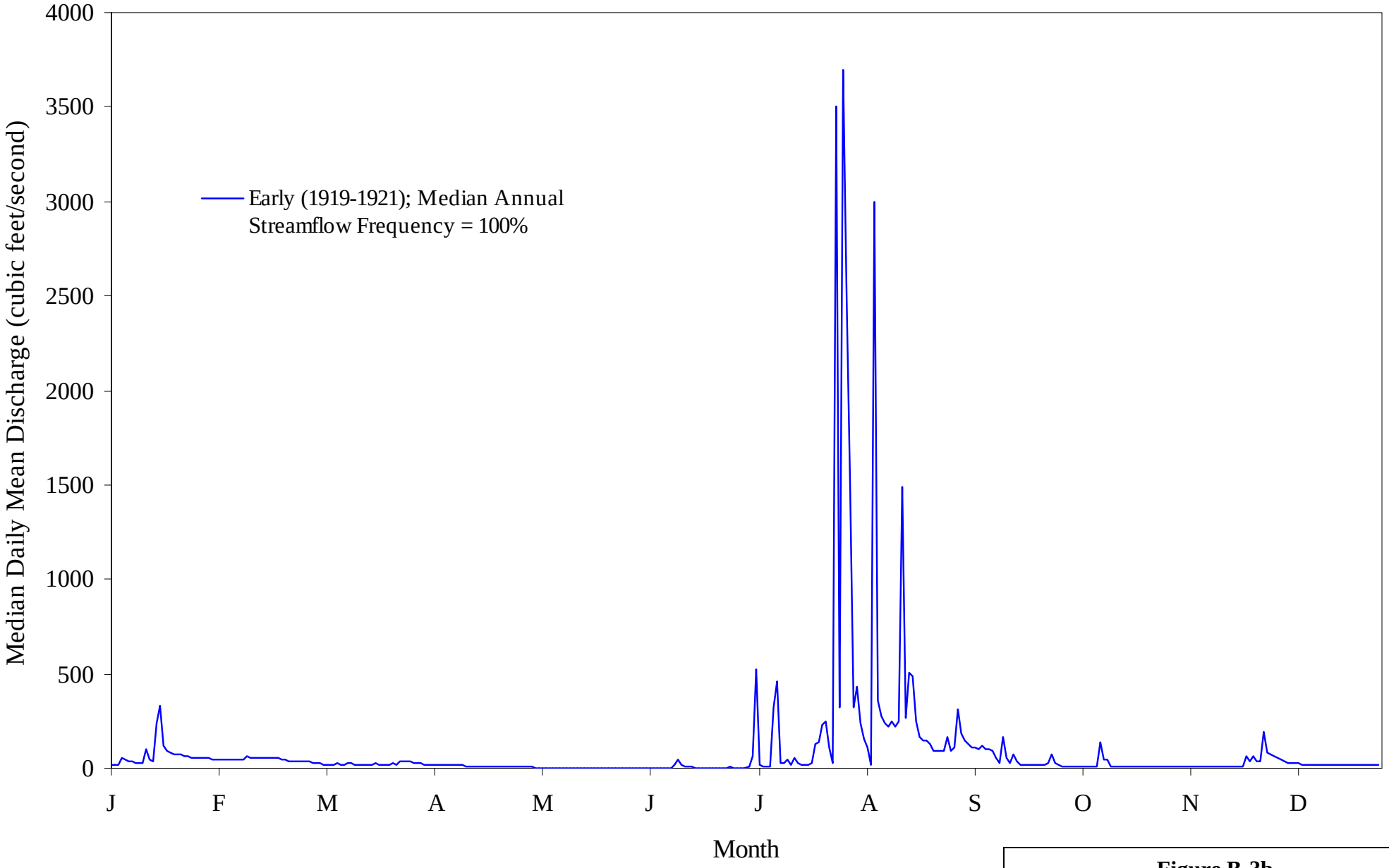


Figure B-3b
Annual Hydrograph for the San Pedro River at Hereford Bridge (Schwalen)

Subflow Zone Delineation Report for the San Pedro River Watershed

ARIZONA DEPARTMENT OF WATER RESOURCES ©

U:\WorkSpaces\StatewidePlanning\Adjudications\Projects\SanPedro\maps\Subflow_Report_Figures\PPT\AppB-3_AnnualHydrographs\FigB-3b_Hydrograph_SP_HerefordBridge.ppt

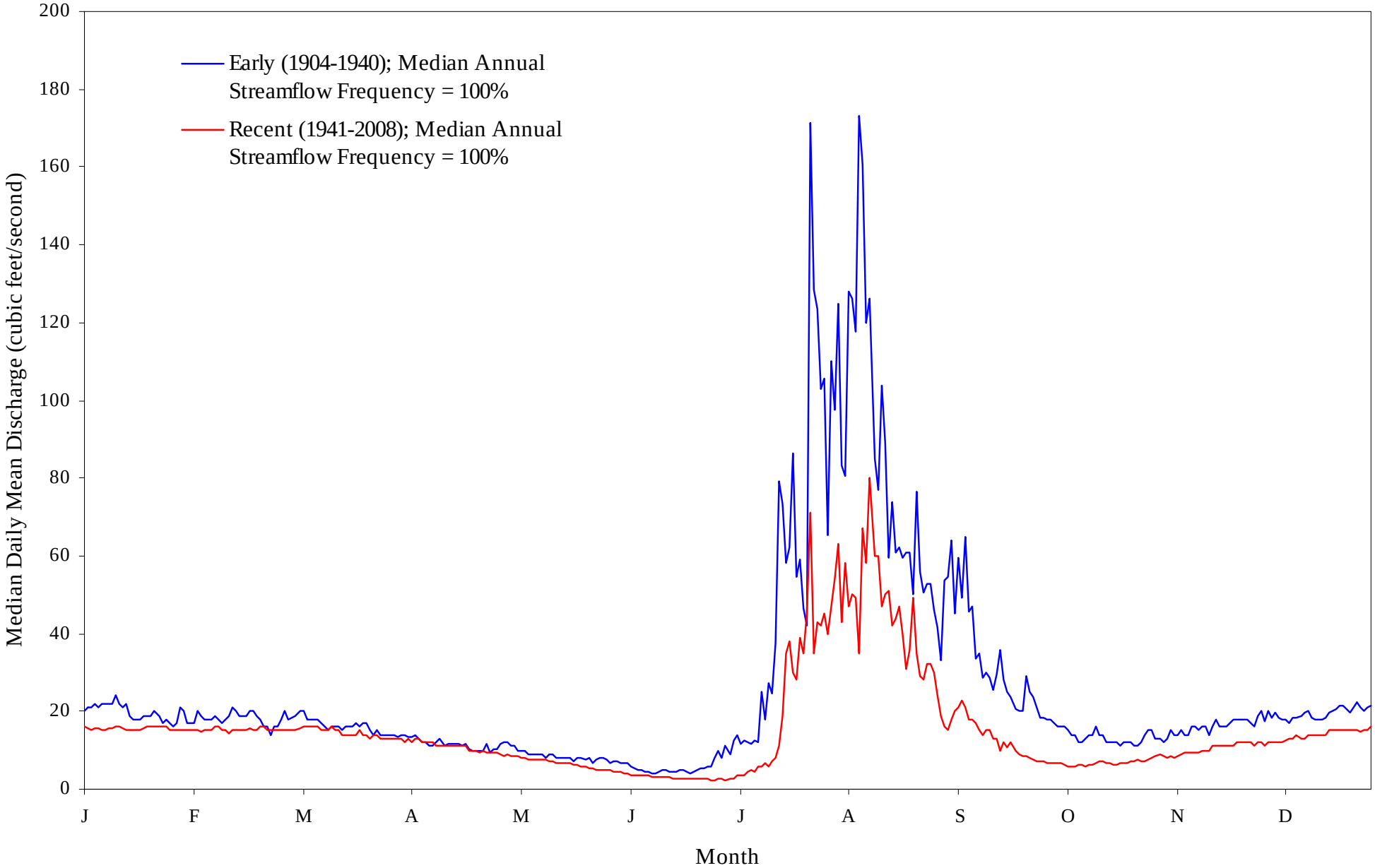


Figure B-3c
Annual Hydrographs for the San Pedro River at Charleston (USGS 9471000)

Subflow Zone Delineation Report for the San Pedro River Watershed

ARIZONA DEPARTMENT OF WATER RESOURCES ©

U:\WorkSpaces\StatewidePlanning\Adjudications\Projects\SanPedro\maps\Subflow_Report_Figures\PPT\AppB-3_AnnualHydrographs\FigB-3c_Hydrograph_SP_Charleston.ppt

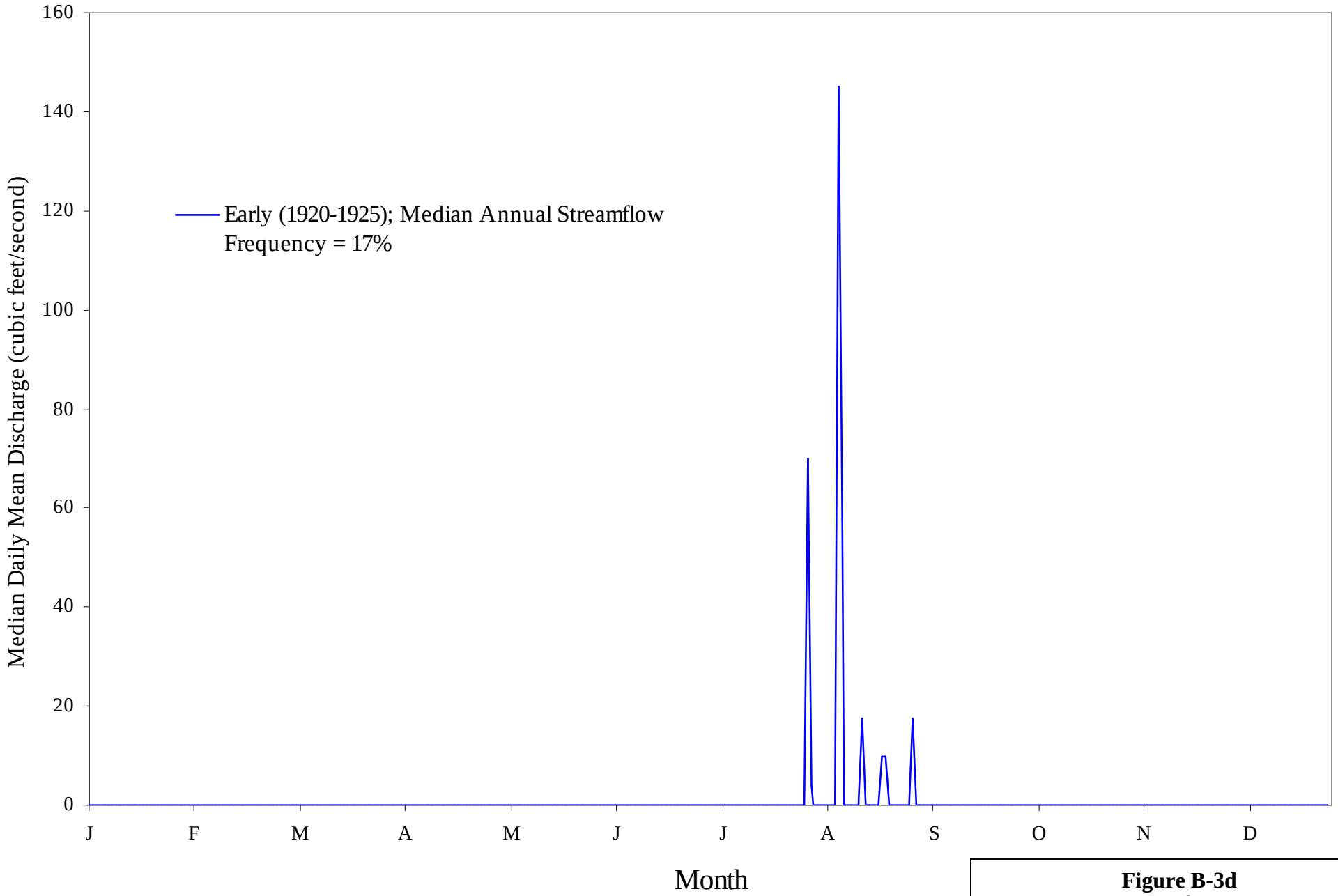


Figure B-3d
Annual Hydrograph for the Babocomari River at Huachuca Siding (Schwalen)

Subflow Zone Delineation Report for the San Pedro River Watershed

ARIZONA DEPARTMENT OF WATER RESOURCES ©

U:\WorkSpaces\StatewidePlanning\Adjudications\Projects\SanPedro\maps\Subflow_Report_Figures\PPT\FigB-3d_Hydrograph_Babo_Huachuca_Siding.ppt

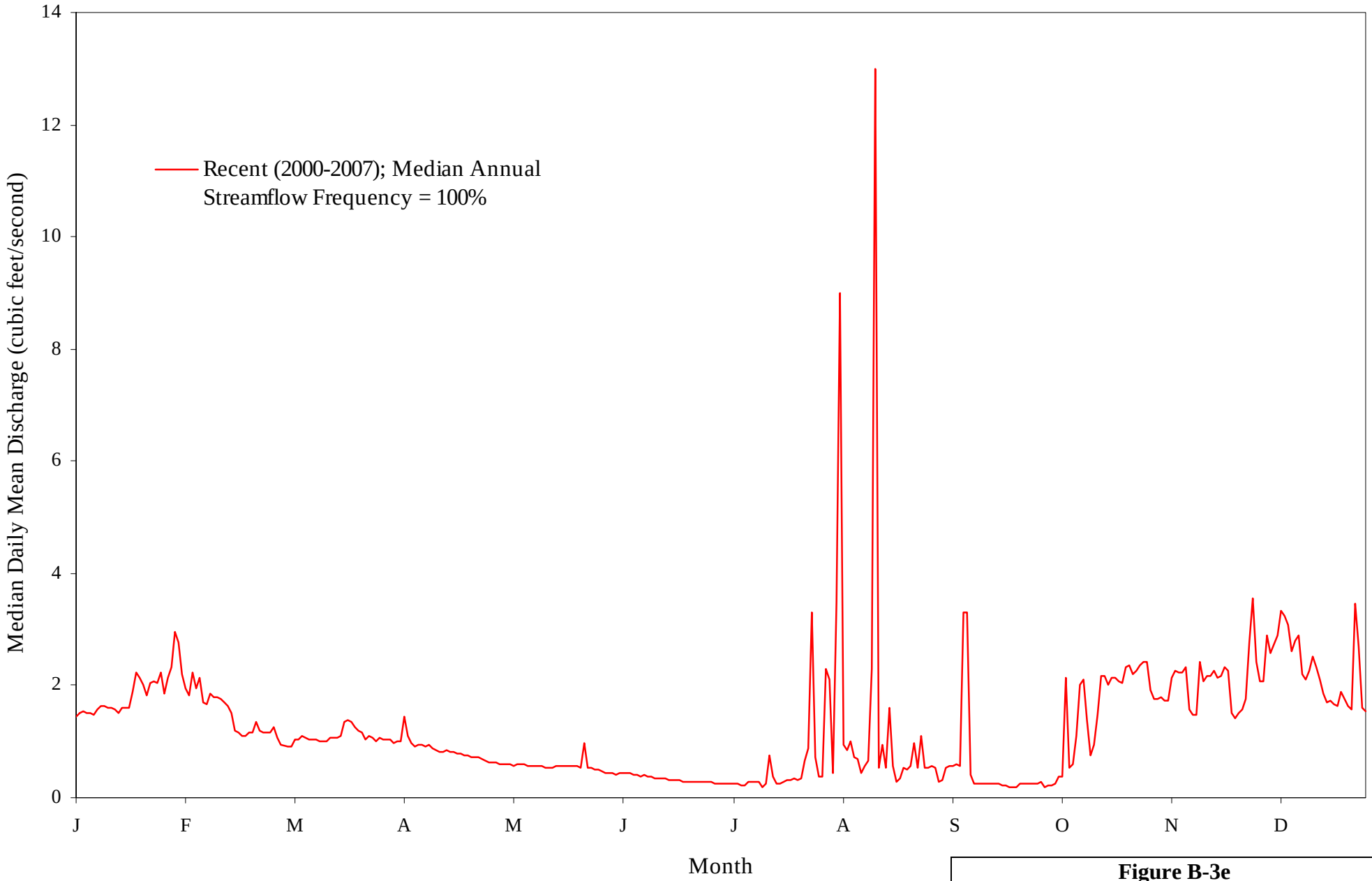


Figure B-3e
Annual Hydrograph for the Upper Babocomari River near Huachuca City (USGS 9471380)

Subflow Zone Delineation Report for the San Pedro River Watershed

ARIZONA DEPARTMENT OF WATER RESOURCES ©

U:\WorkSpaces\StatewidePlanning\Adjudications\Projects\SanPedro\maps\Subflow_Report_Figures\PPT\FigB-3e_Hydrograph_Babo_Huachuca_City.ppt

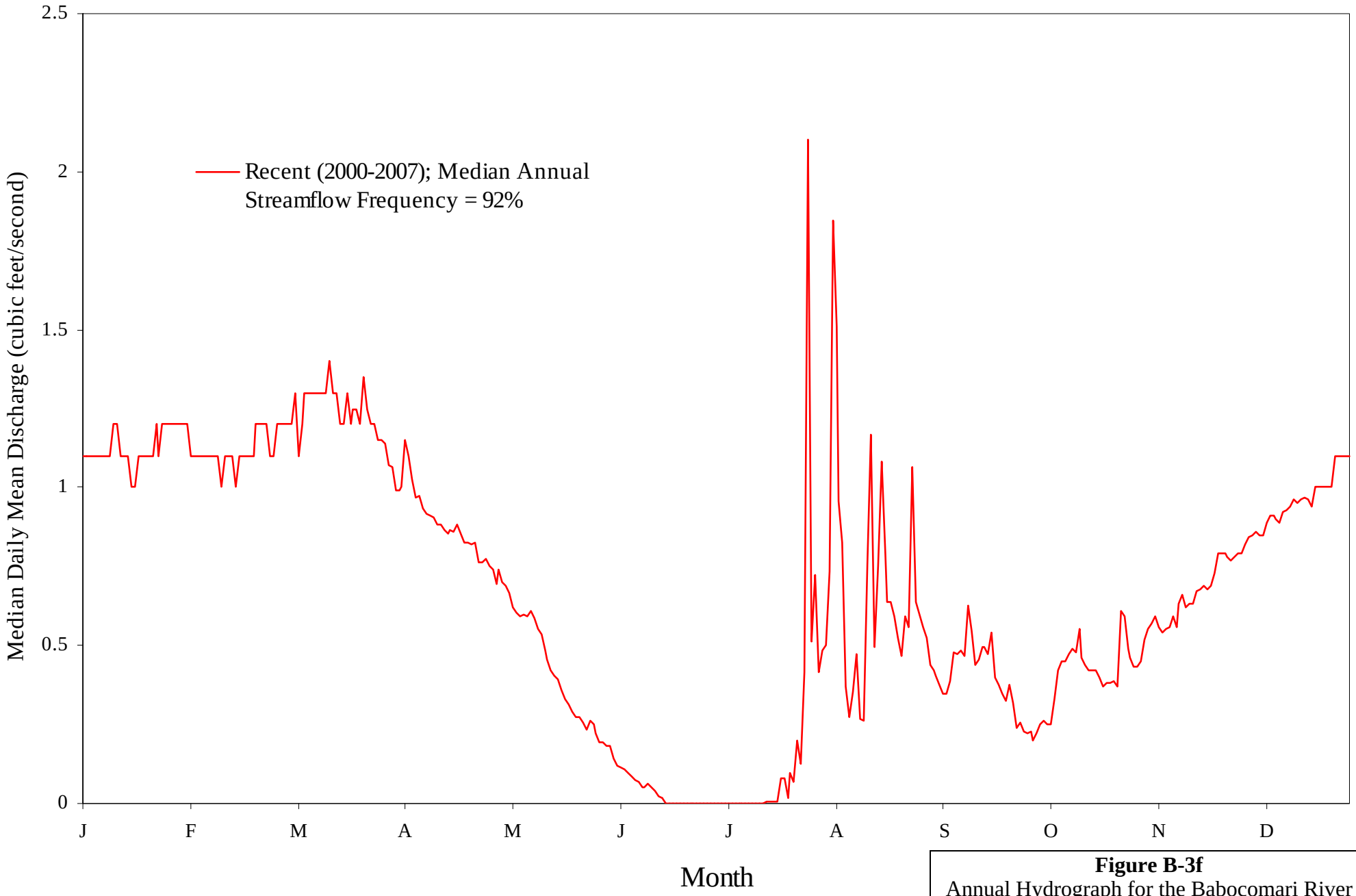


Figure B-3f
Annual Hydrograph for the Babocomari River near Tombstone (USGS 9471400)

Subflow Zone Delineation Report for the San Pedro River Watershed

ARIZONA DEPARTMENT OF WATER RESOURCES ©

U:\WorkSpaces\StatewidePlanning\Adjudications\Projects\SanPedro\maps\Subflow_Report_Figures\PPT\FigB-3f_Hydrograph_Babo_Tombstone.ppt

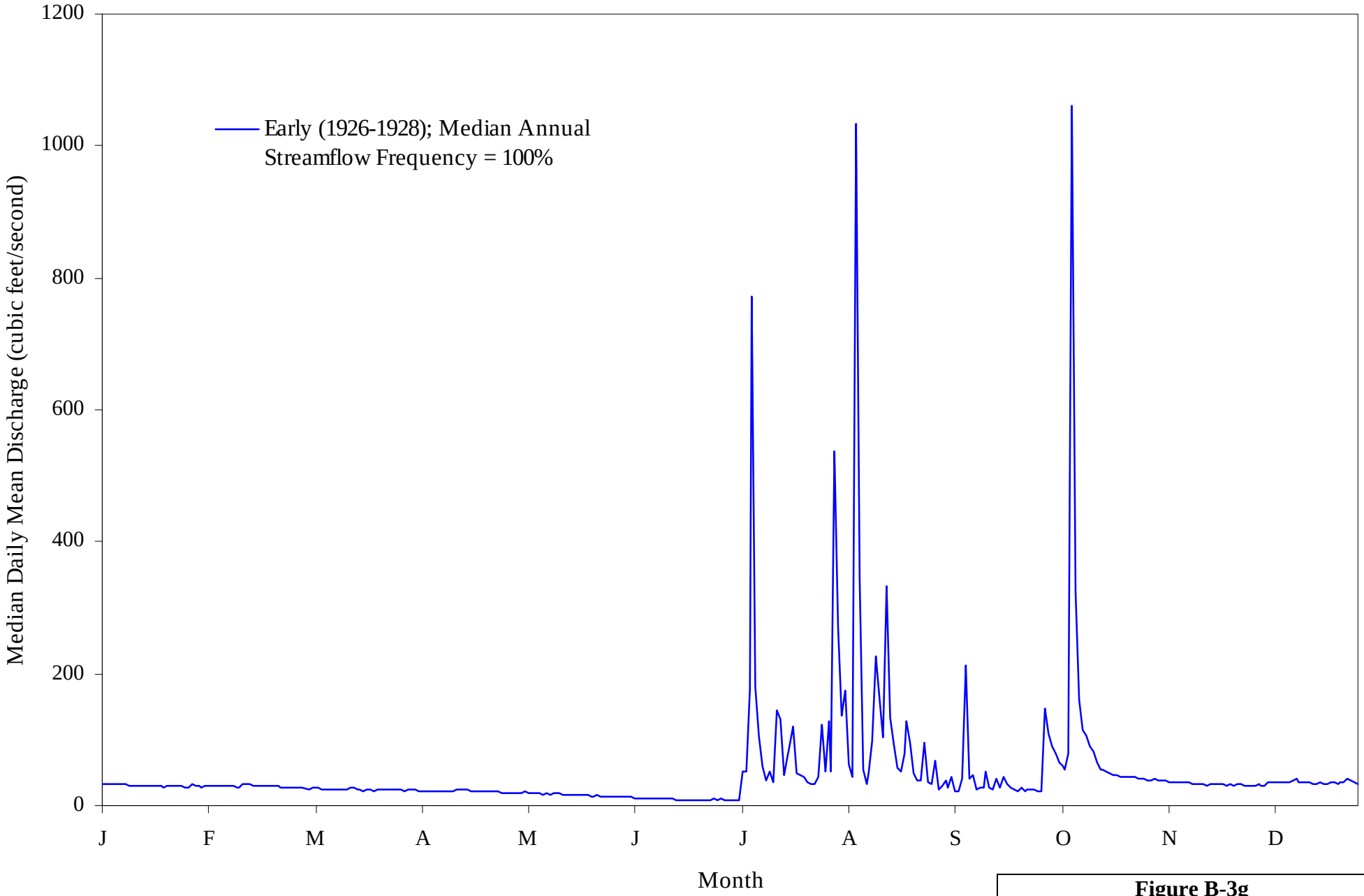


Figure B-3g
Annual Hydrograph for the San Pedro River at Fairbanks (USGS 9471500)

Subflow Zone Delineation Report for the San Pedro River Watershed

ARIZONA DEPARTMENT OF WATER RESOURCES ©

U:\WorkSpaces\StatewidePlanning\Adjudications\Projects\SanPedro\maps\Subflow_Report_Figures\PPT\FigB-3g_Hydrograph_SP_Fairbanks.ppt

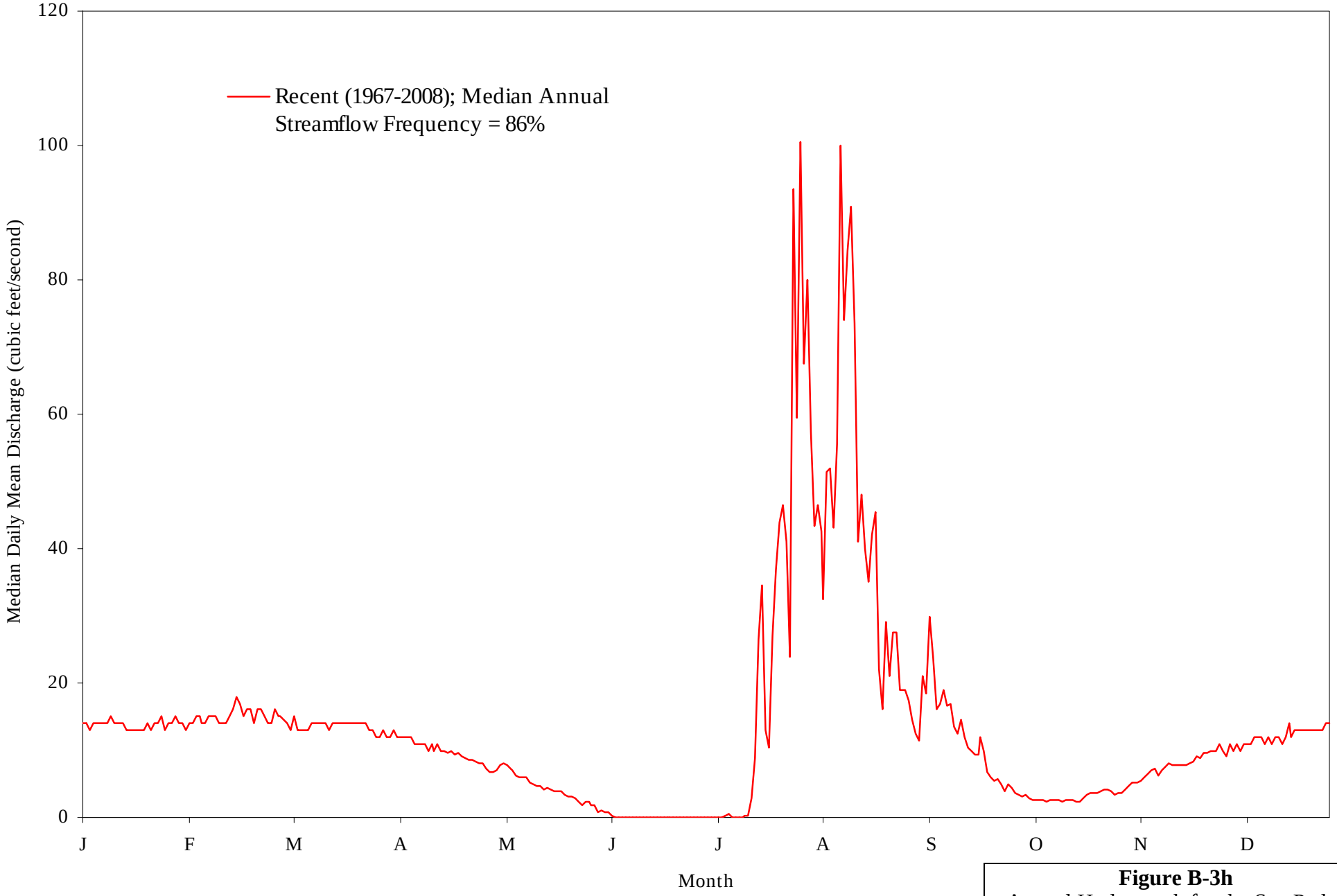


Figure B-3h
Annual Hydrograph for the San Pedro River near Tombstone (USGS 9471550)

Subflow Zone Delineation Report for the San Pedro River Watershed

ARIZONA DEPARTMENT OF WATER RESOURCES ©

U:\WorkSpaces\StatewidePlanning\Adjudications\Projects\SanPedro\maps\Subflow_Report_Figures\PPT\FigB-3h_Hydrograph_SP_Tombstone.ppt

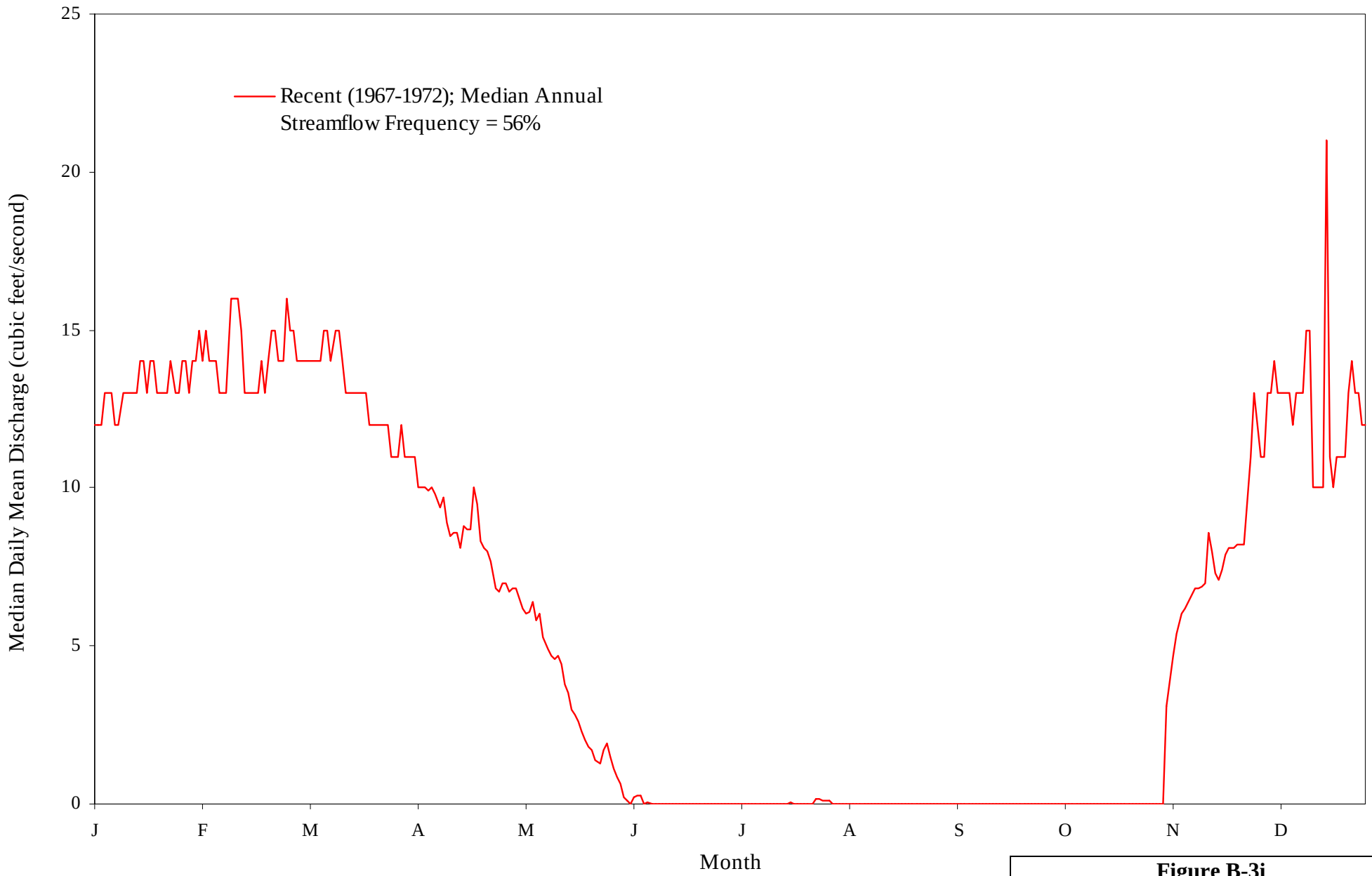


Figure B-3i
Annual Hydrograph for San Pedro River Diversions into the Saint David Ditch Near Saint David (USGS 9471560)

Subflow Zone Delineation Report for the San Pedro River Watershed

ARIZONA DEPARTMENT OF WATER RESOURCES ©

U:\WorkSpaces\StatewidePlanning\Adjudications\Projects\SanPedro\maps\Subflow_Report_Figures\PPT\FigB-3i_Hydrograph_SP_SaintDavidDitch.ppt

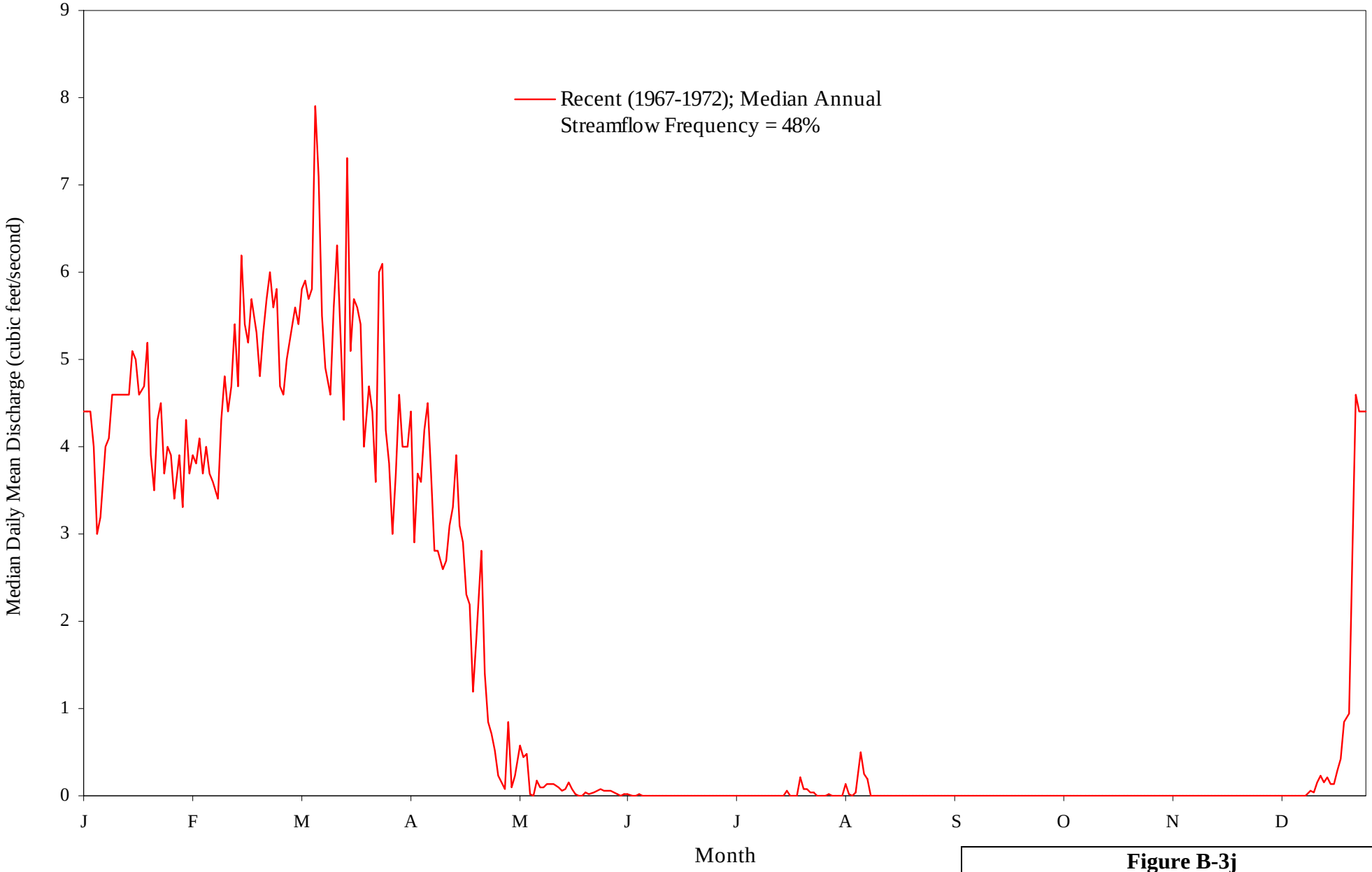


Figure B-3j
Annual Hydrograph for San Pedro River Diversions into the Pomerene Canal near Saint David (USGS 9471590)

Subflow Zone Delineation Report for the San Pedro River Watershed

ARIZONA DEPARTMENT OF WATER RESOURCES ©

U:\WorkSpaces\StatewidePlanning\Adjudications\Projects\SanPedro\maps\Subflow_Report_Figures\PPT\FigB-3j_Hydrograph_SP_PomereneCanel.ppt

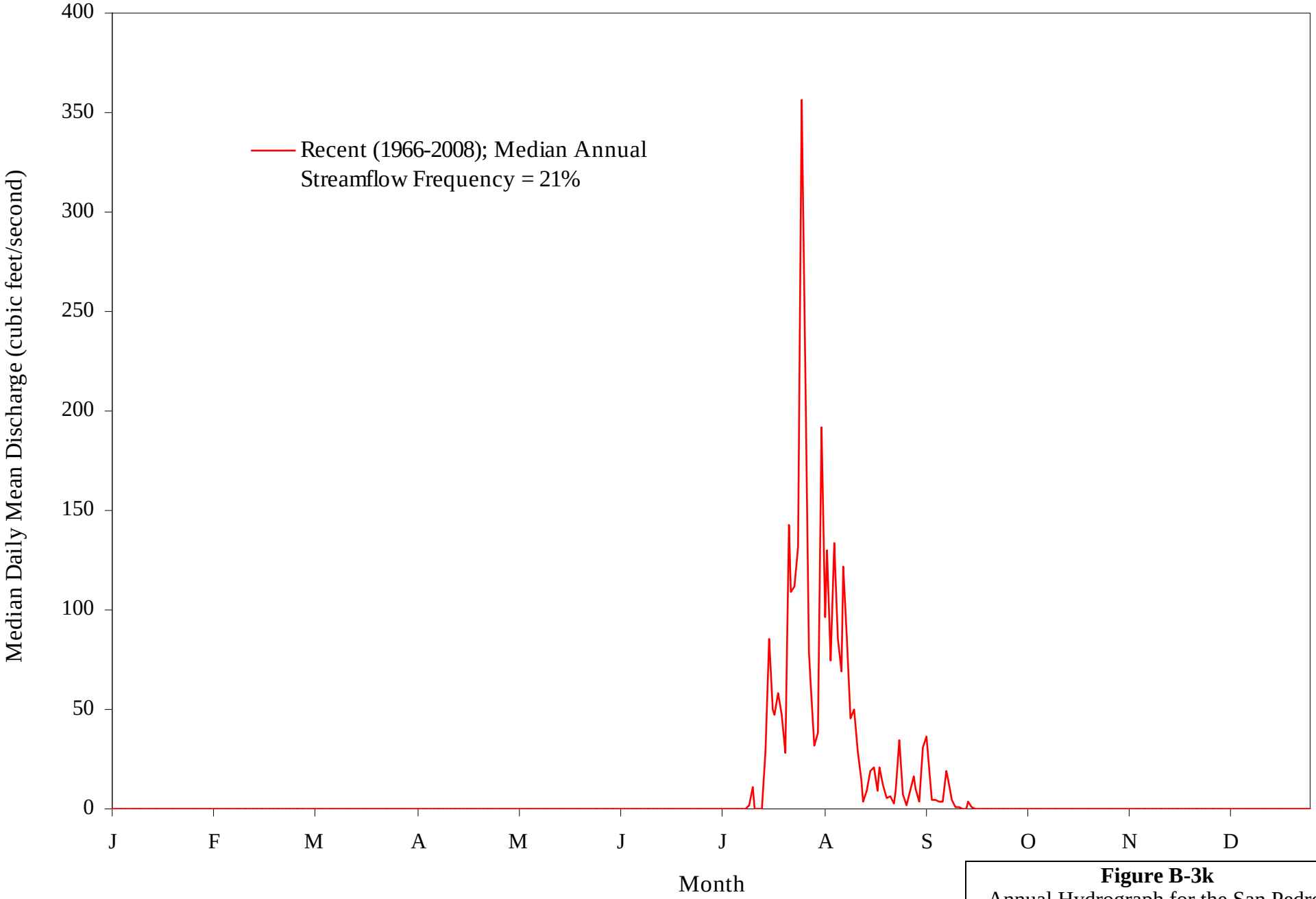


Figure B-3k
Annual Hydrograph for the San Pedro River near Benson (USGS 9471800)

Subflow Zone Delineation Report for the San Pedro River Watershed

ARIZONA DEPARTMENT OF WATER RESOURCES ©

U:\WorkSpaces\StatewidePlanning\Adjudications\Projects\SanPedro\maps\Subflow_Report_Figures\PPT\FigB-3k_Hydrograph_SP_Benson.ppt

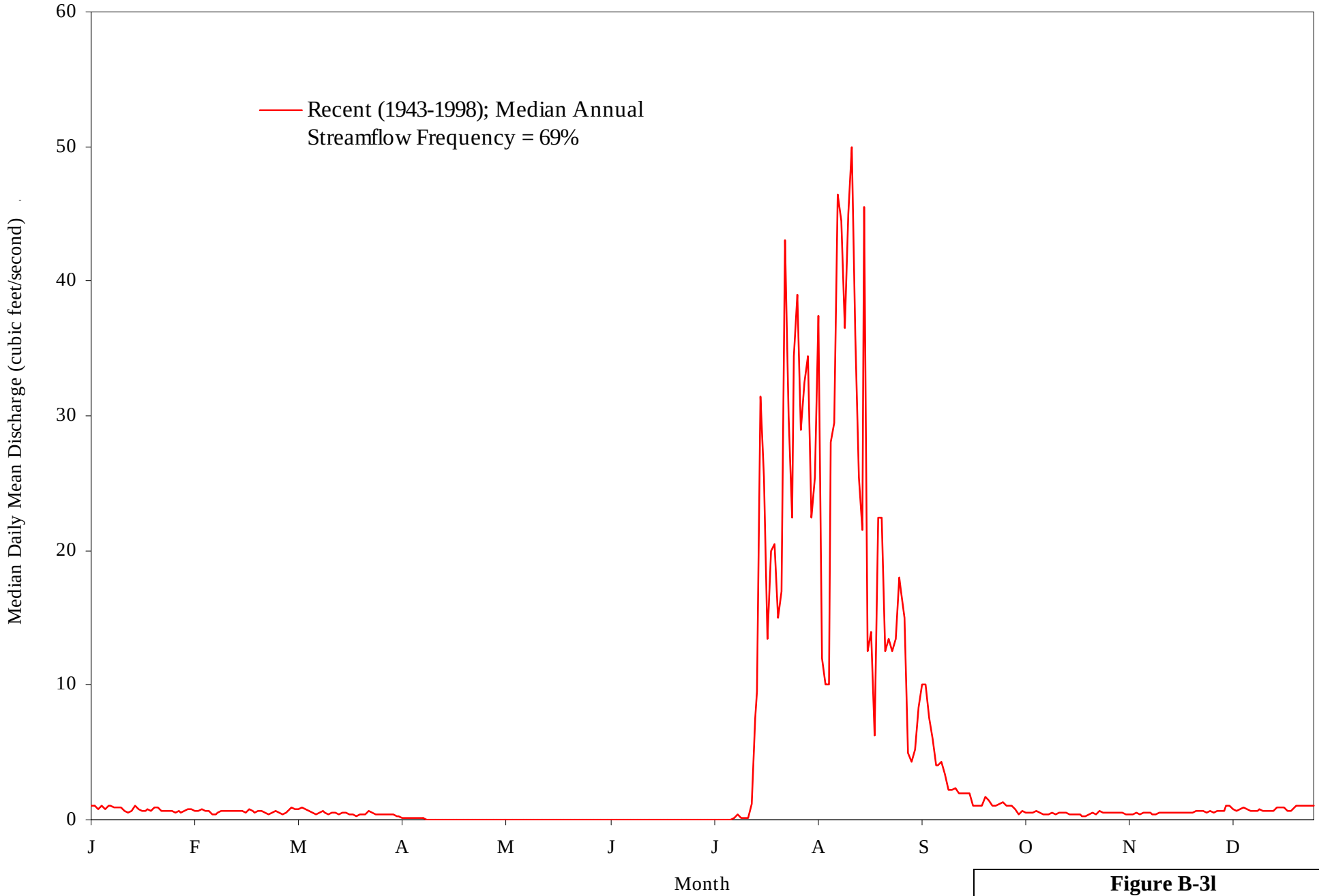


Figure B-3l

Annual Hydrograph for the San Pedro River near Redington (USGS 9472000)

Subflow Zone Delineation Report for the San Pedro River Watershed

ARIZONA DEPARTMENT OF WATER RESOURCES ©

U:\WorkSpaces\StatewidePlanning\Adjudications\Projects\SanPedro\maps\Subflow_Report_Figures\PPT\FigB-3l_Hydrograph_SP_Redington.ppt

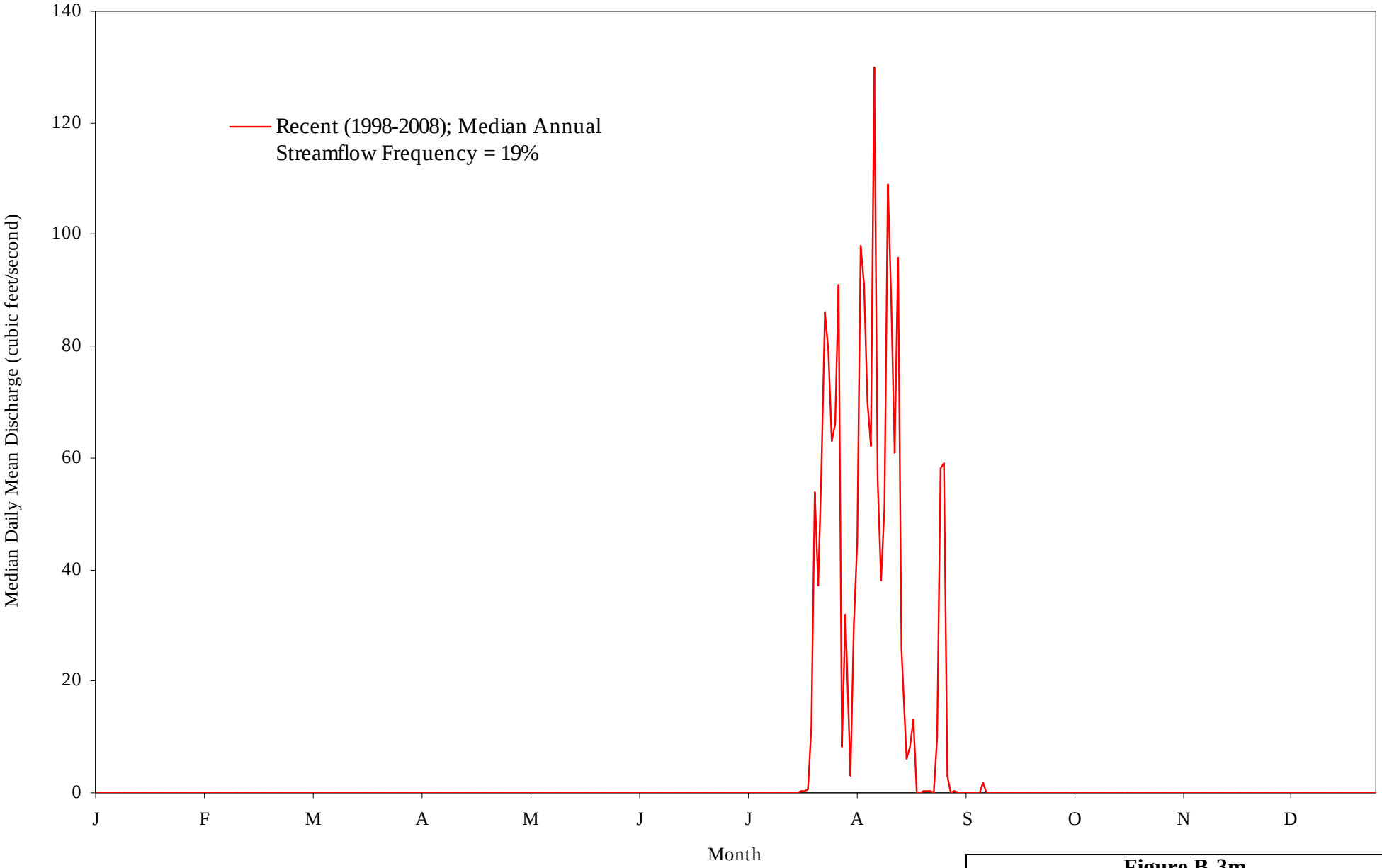


Figure B-3m
Annual Hydrograph for the San Pedro River at Redington Bridge (USGS 9472050)

Subflow Zone Delineation Report for the San Pedro River Watershed

ARIZONA DEPARTMENT OF WATER RESOURCES ©

U:\WorkSpaces\StatewidePlanning\Adjudications\Projects\SanPedro\maps\Subflow_Report_Figures\PPT\FigB-3m_Hydrograph_SP_RedingtonBridge.ppt

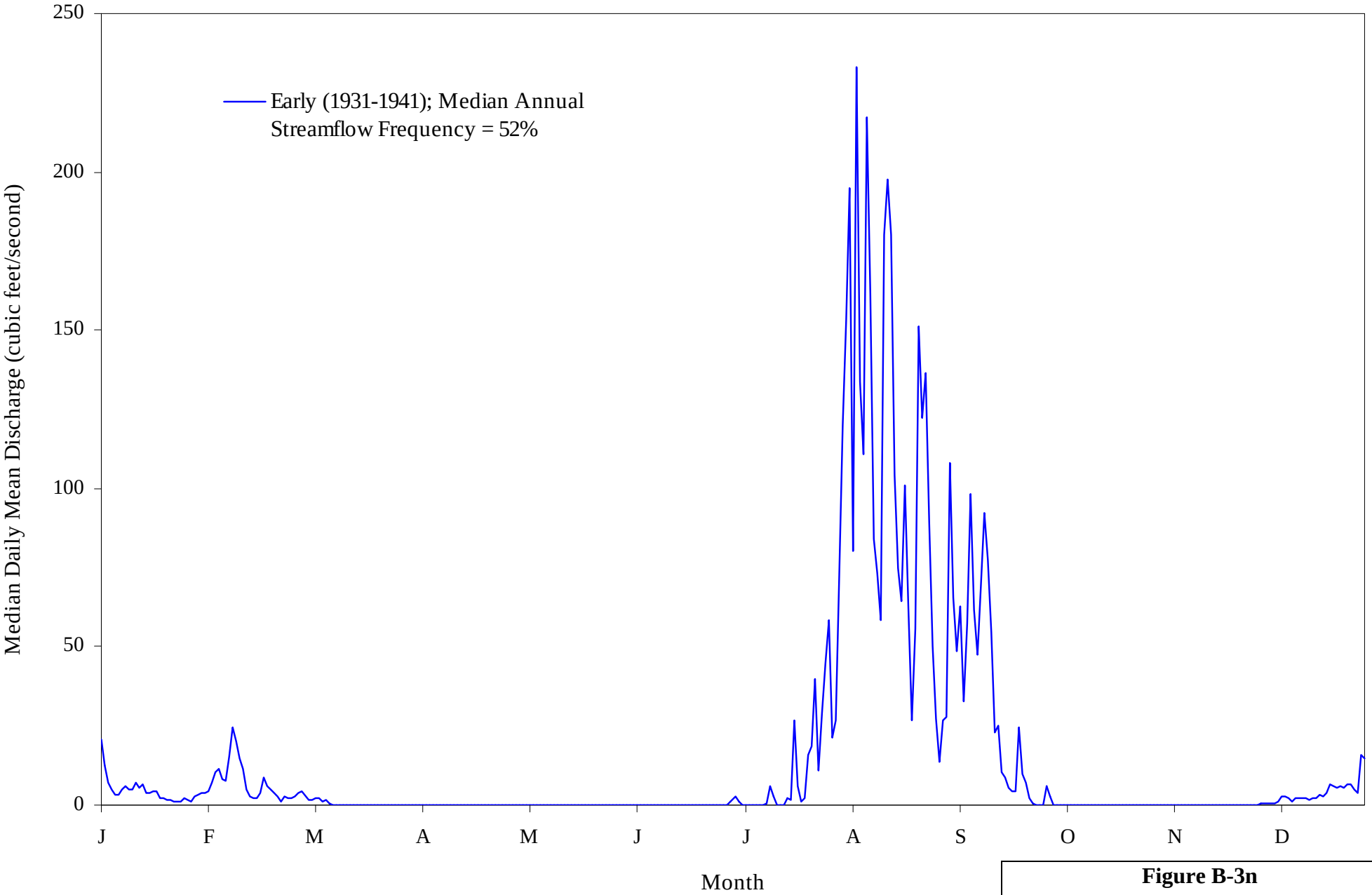


Figure B-3n
Annual Hydrograph for the San Pedro River near Mammoth (USGS 9472500)

Subflow Zone Delineation Report for the San Pedro River Watershed

ARIZONA DEPARTMENT OF WATER RESOURCES ©

U:\WorkSpaces\StatewidePlanning\Adjudications\Projects\SanPedro\maps\Subflow_Report_Figures\PPT\FigB-3n_Hydrograph_SP_Mammoth.ppt

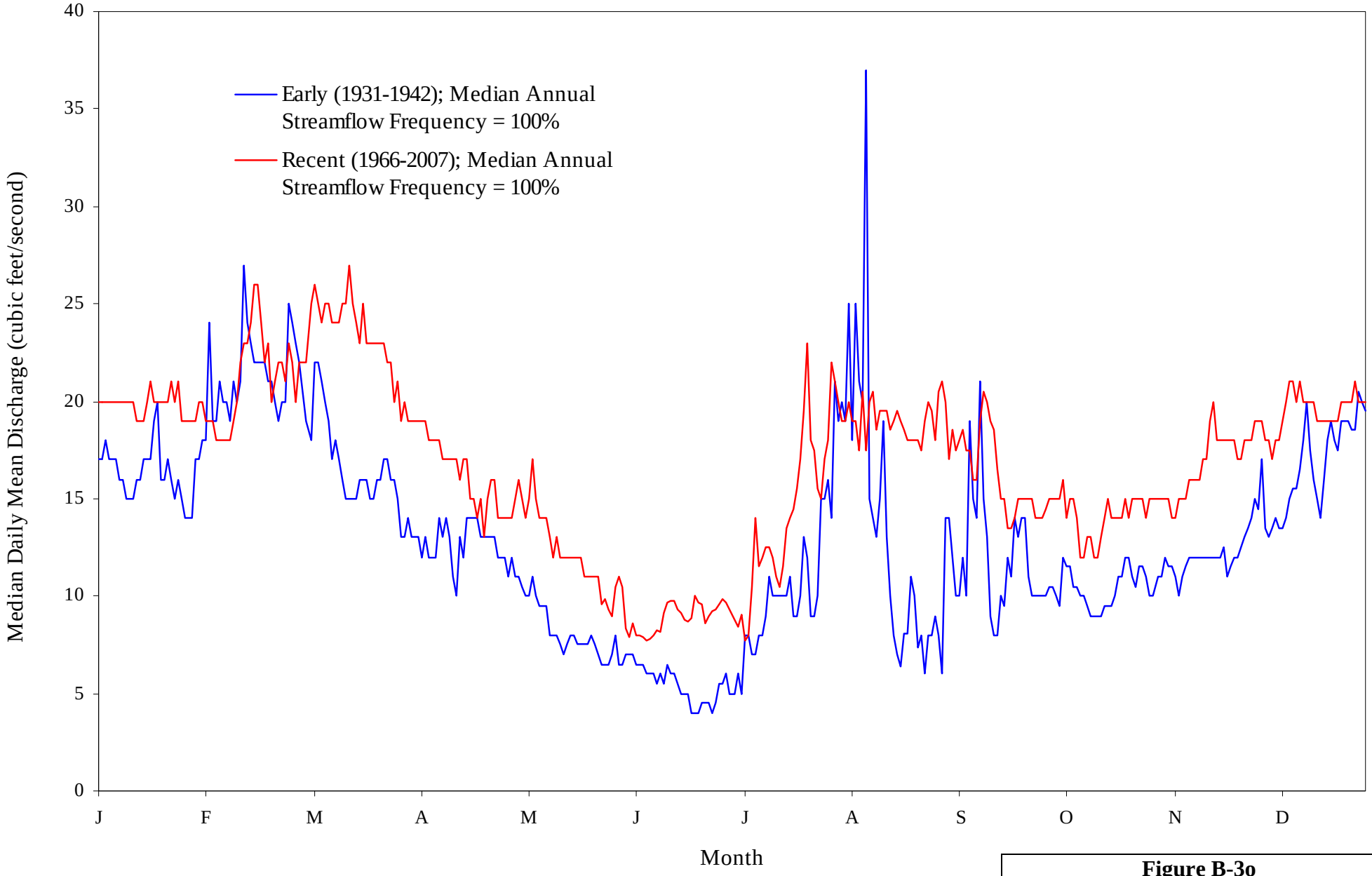


Figure B-3o

Annual Hydrographs for Aravaipa Creek near Mammoth (USGS 9473000)

Subflow Zone Delineation Report for the San Pedro River Watershed

ARIZONA DEPARTMENT OF WATER RESOURCES ©

U:\WorkSpaces\StatewidePlanning\Adjudications\Projects\SanPedro\maps\Subflow_Report_Figures\PPT\FigB-3o_Hydrograph_Aravaipa_Mammoth.ppt

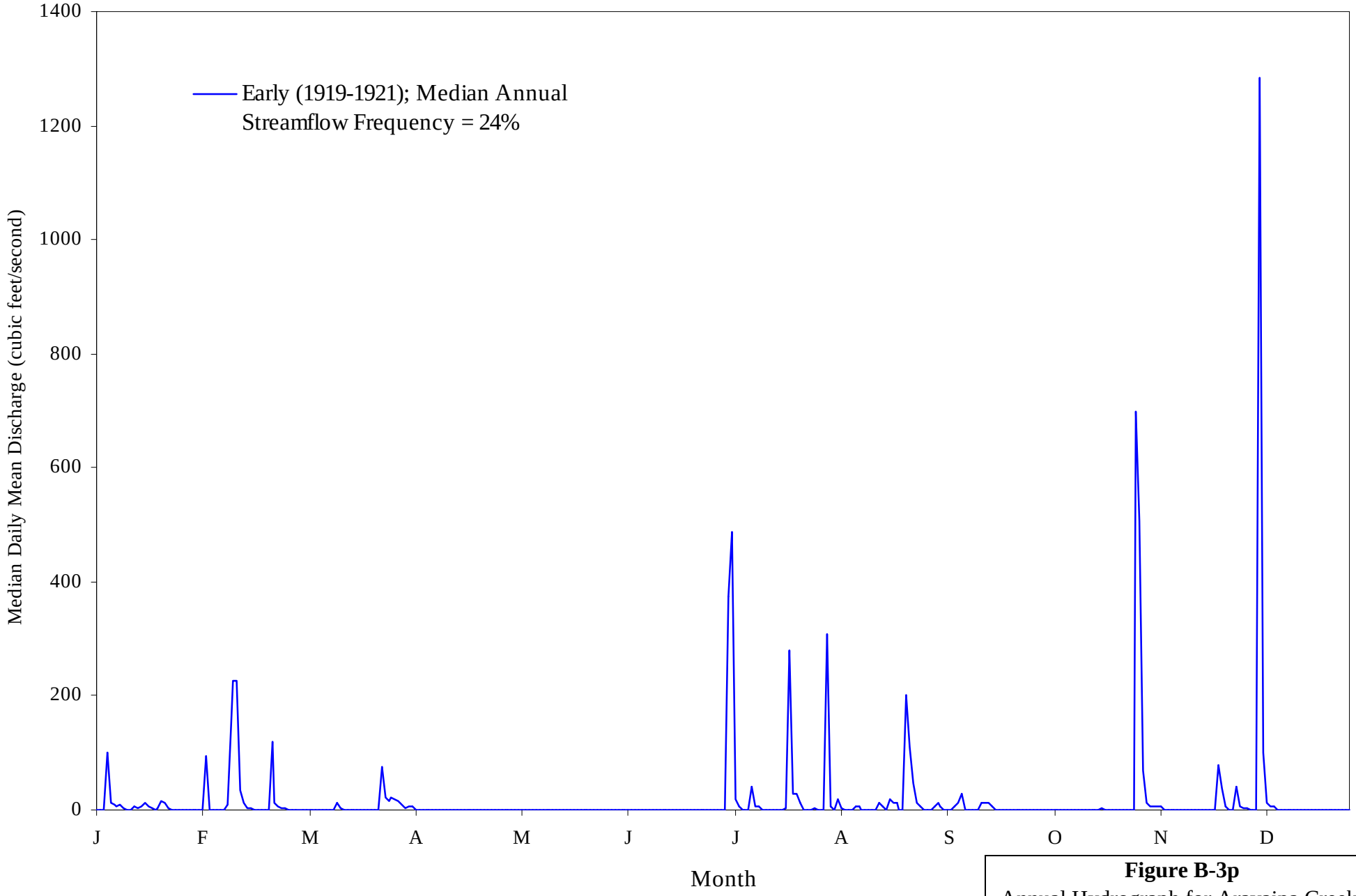


Figure B-3p
Annual Hydrograph for Aravaipa Creek near Fieldman (USGS 9473020)

Subflow Zone Delineation Report for the San Pedro River Watershed

ARIZONA DEPARTMENT OF WATER RESOURCES ©

U:\WorkSpaces\StatewidePlanning\Adjudications\Projects\SanPedro\maps\Subflow_Report_Figures\PPT\FigB-3p_Hydrograph_Aravaipa_Fieldman.ppt

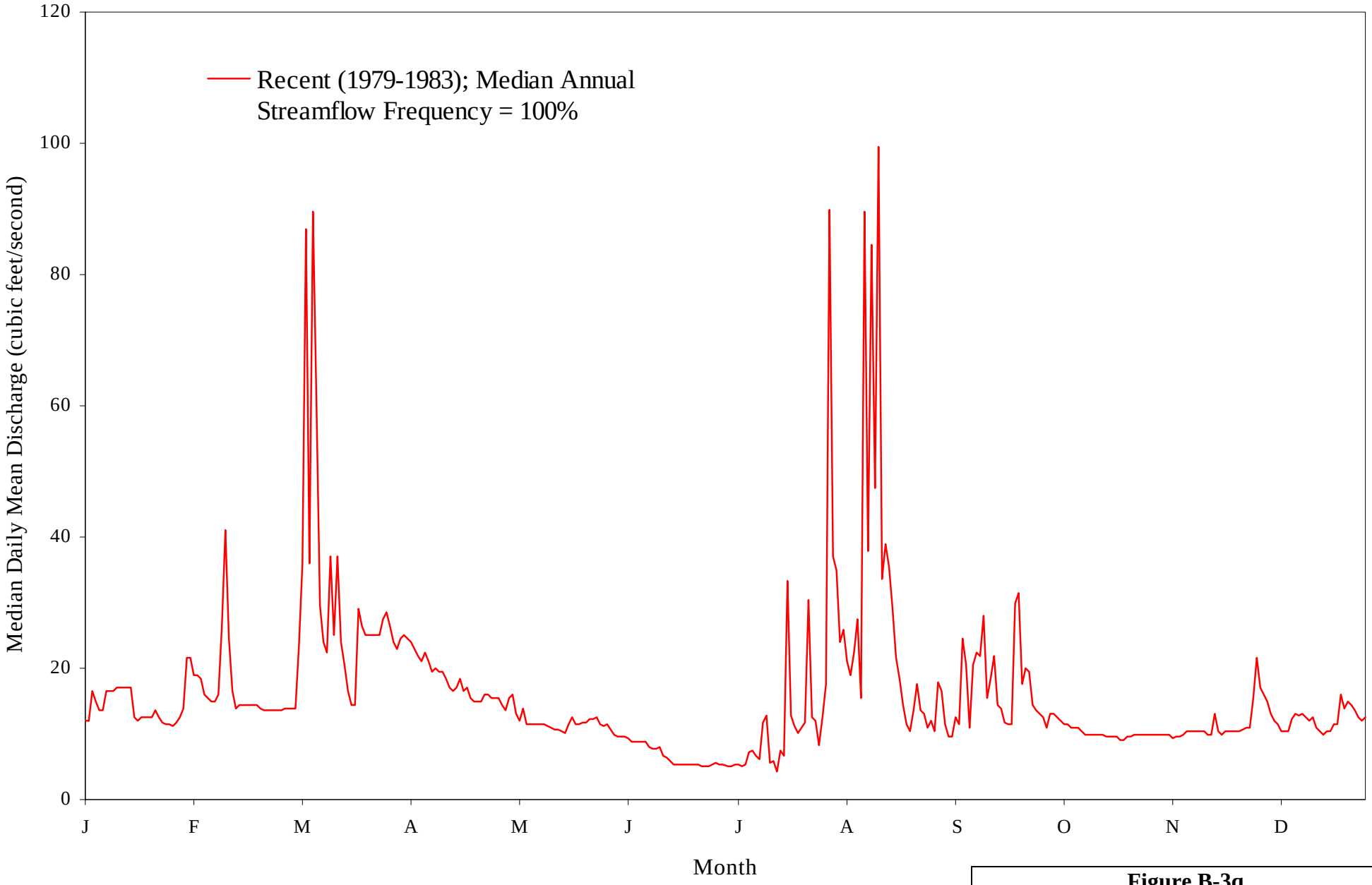


Figure B-3q

Annual Hydrograph for the San Pedro River Below Aravaipa Creek (USGS 9473100)

Subflow Zone Delineation Report for the San Pedro River Watershed

ARIZONA DEPARTMENT OF WATER RESOURCES ©

U:\WorkSpaces\StatewidePlanning\Adjudications\Projects\SanPedro\maps\Subflow_Report_Figures\PPT\FigB-3q_Hydrograph_SP_BelowAravaipa.ppt

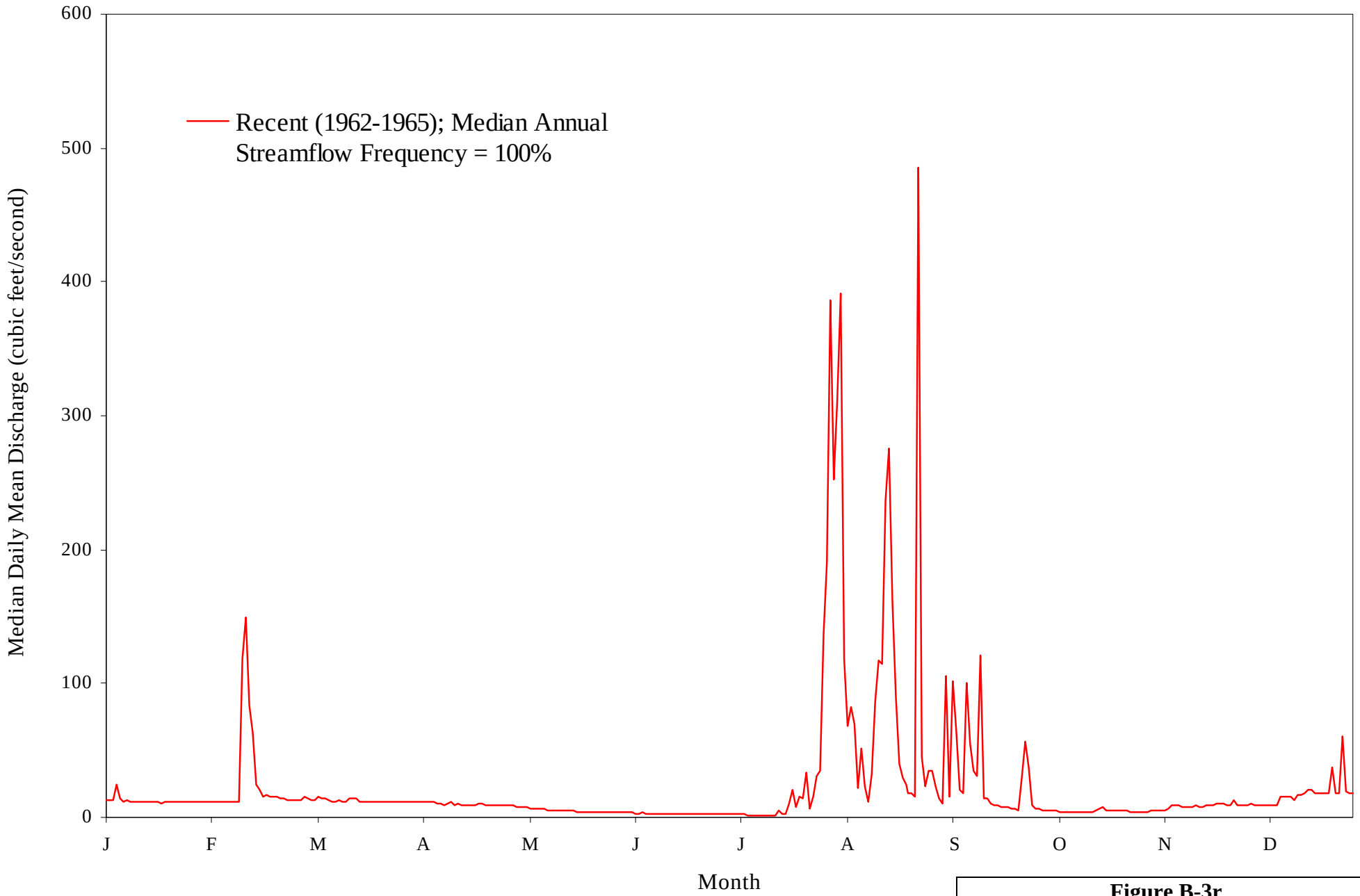


Figure B-3r

Annual Hydrograph for the San Pedro River Near Winkelman (USGS 9473400)

Subflow Zone Delineation Report for the San Pedro River Watershed

ARIZONA DEPARTMENT OF WATER RESOURCES ©

U:\WorkSpaces\StatewidePlanning\Adjudications\Projects\SanPedro\maps\Subflow_Report_Figures\PPT\FigB-3r_Hydrograph_SP_NearWinkelman.ppt

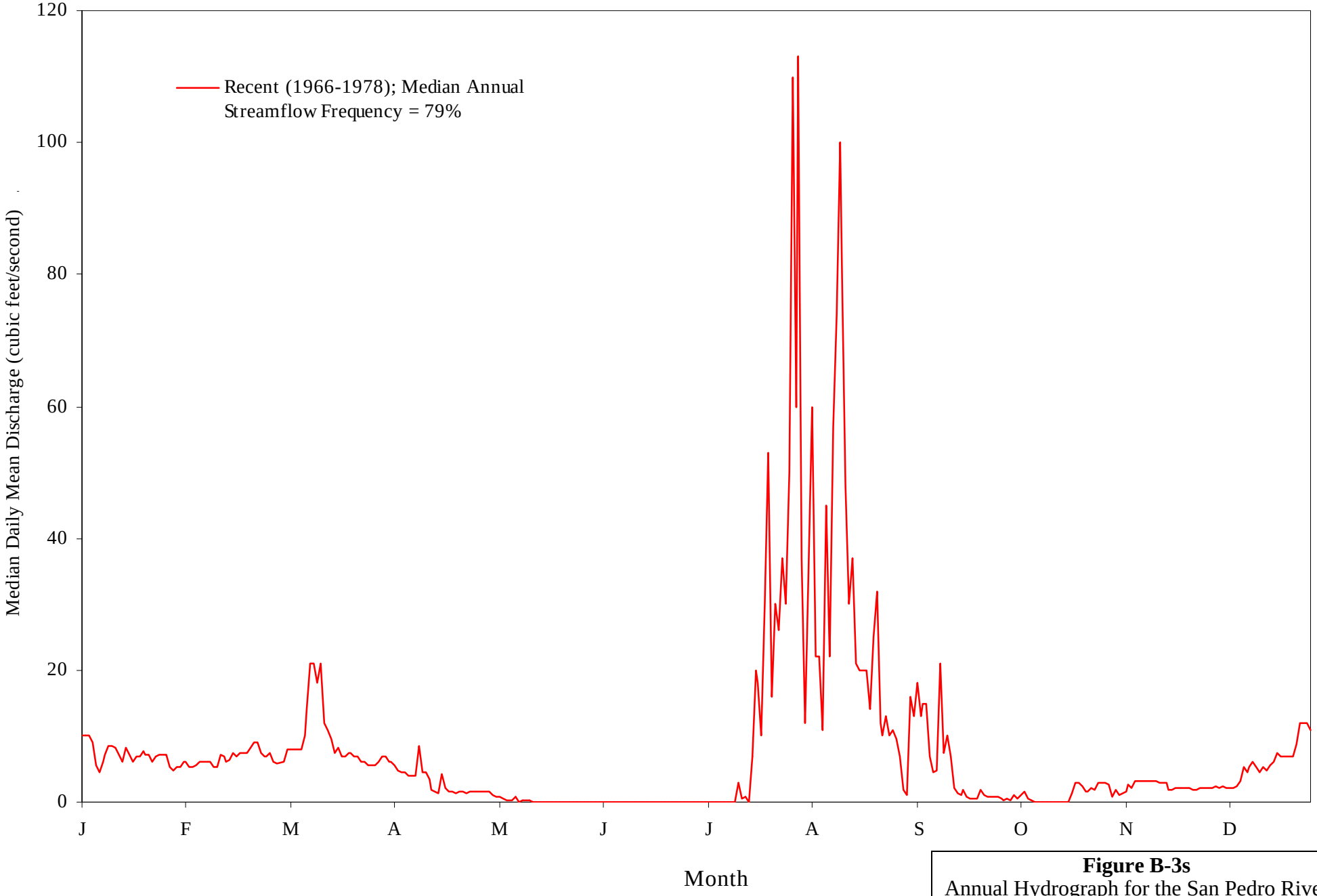


Figure B-3s
Annual Hydrograph for the San Pedro River at Winkelman (USGS 9473500)

Subflow Zone Delineation Report for the San Pedro River Watershed

ARIZONA DEPARTMENT OF WATER RESOURCES ©

U:\WorkSpaces\StatewidePlanning\Adjudications\Projects\SanPedro\maps\Subflow_Report_Figures\PPT\FigB-3s_Hydrograph_SP_AtWinkelman.ppt

B-4
Historic Winter Precipitation and Storm Runoff Analysis

Text

APPENDIX B-4: HISTORIC WINTER PRECIPITATION AND STORM RUNOFF ANALYSIS

BACKGROUND

ADWR used three lines of evidence that could be affected by historic winter precipitation and storm runoff to determine predevelopment streamflow conditions. These lines of evidence include:

- A seepage run conducted along the San Pedro River in March 1899 and reported by Walcott (1901);
- A seepage run conducted along the San Pedro River from March 16-22, 1921 and reported by Schwalen (1921); and
- Aerial photographs of the San Pedro River Watershed believed to have been taken between January and March (winter) 1935 by Fairchild Aerial Surveys Incorporated (Fairchild).

Sections 3.2.3 and **3.2.4** of the report further discuss the seepage runs and Fairchild photographs, respectively. This sub-appendix evaluates whether these lines of evidence likely reflect baseflow conditions.

DATA SOURCES

ADWR used three data sources to evaluate streamflow conditions at the time the seepage runs were conducted and the aerial photographs were flown. First, historic precipitation records were available from seven weather stations in the region. Whether storm runoff occurred during March 1899 and March 1921 and during the winter of 1935 was inferred from the extent, magnitude, and duration of precipitation at these stations. **Figure B-4a** shows the location of the early weather stations and **Table B-4a** lists their period of record. Daily precipitation measurements are graphed in **Figures B-4b** through **B-4d**.

The second data source used to evaluate the aerial photographs and one of the seepage runs was existing streamflow records. The location of nine early stream gages in the watershed is shown in **Figure B-4a,** and their periods of record are listed in **Table 3-2**. **Figure B-4c** shows streamflow hydrographs for two gages during 1921, and **Figure B-4d** shows streamflow hydrographs for three gages during 1935. Storm runoff can be readily distinguished from baseflow based on the shape of these hydrographs. Note that some gage data were not graphed either because no flows were measured during the period of interest or for other reasons described below. No streamflow data were available during 1899.

The third data source used by ADWR was the 1935 Fairchild photographs themselves. To assess whether the photographs were taken during baseflow conditions, ADWR further examined them for evidence of overbank (flood) flows along the major stream channels and visible flow in minor tributaries. **Figures B-4e** through **B-4h** are examples of the aerial photographs that show portions of the upper and lower San Pedro River, Babocomari River and Aravaipa Creek, respectively, and include ADWR's assessment of flow conditions.

REGRESSION ANALYSIS

In addition to the data sources described above, ADWR attempted to evaluate the seepage runs and aerial photographs by developing a series of logistic regression models based on the relationship between historic winter precipitation and observed storm runoff. Since streamflow records were either not available or relatively sparse when these lines of evidence were collected, the regression models would allow ADWR to fill in the period of record. More specifically, the models would allow the probability that storm runoff occurred at a stream gage to be predicted based on available precipitation measurements from one or more nearby weather stations. This type of regression analysis is further described by Collett (2003) and Helsel and Hirsch (2002).

ADWR developed regression models for five early stream gage stations in the watershed:

- San Pedro River at Palominas (USGS Gage 9470500);
- San Pedro River at Charleston (USGS Gage 9471000);
- San Pedro River near Mammoth (USGS Gage 9472500);
- San Pedro River at Winkelman Bridge (unnumbered); and
- Aravaipa Creek near Fieldman (USGS Gage 9473020).[1]

ADWR reviewed early (prior to 1942) flow records from each gage and, based on observed changes in flow and hydrograph shape, identified thresholds in daily streamflow which it believed indicated the occurrence of storm runoff. The various thresholds are described below.

At Palominas, where early streamflows in the San Pedro River were perennial, storm runoff appeared to occur when the daily flow increased by greater than or equal to 5 cubic feet per second (cfs) from the prior day. At Charleston, where early streamflows in the San Pedro River were also perennial, storm runoff appeared to occur when the daily flow increased by greater than or equal to 10 cfs from the prior day. Near Mammoth, where early streamflows in the San Pedro River were intermittent, storm runoff appeared to occur when the daily flow increased from 0 cfs or increased by 5 cfs from the prior day. At Winkelman Bridge, where early streamflows in the San Pedro River were perennial and stage was measured, storm runoff appeared to occur when river stage increased by greater than or equal to 0.3 feet from the prior day. And near Fieldman, where early streamflows in Aravaipa Creek were ephemeral, storm runoff appeared to occur when the daily flow increased from 0 cfs or increased by greater than or equal to 10 cfs from the prior day.

Using the above thresholds, existing streamflow records for the gaging stations were transformed into a *binary* record that indicated either the presence or absence of storm runoff. The binary records were then compared to precipitation data from the weather station nearest to each stream gage and to average precipitation data from

[1] ADWR also reviewed streamflow records for the Babocomari River near Huachuca Siding, but did not develop a regression model for this gage due to a lack of winter storm runoff during 1920-1922. In addition, due to the proximity of the Charleston and Fairbank (USGS 9471500) gages on the San Pedro River and the Fieldman and Mammoth (USGS 9473000) gages on Aravaipa Creek, the latter gages were not evaluated separately, and were considered to reflect flow conditions at the former. Also, the gage on the San Pedro River at Hereford Bridge was not evaluated due to its relatively short period of record and upstream flow regulation.

various combinations of weather stations in the region. To account for the potential time lag between precipitation events and storm runoff, the binary runoff record was compared to precipitation measurements taken the same day and total precipitation amounts from the previous 2, 3, 7, 10, 20, and 30 days.

ADWR selected the Gompertz distribution to model the relationship between precipitation and the occurrence of storm runoff since it provided the best fit among the highly skewed distributions used to represent the relatively rare occurrence of runoff events (less than 10% of observations). A final model that estimated storm runoff events from precipitation was then selected for each stream gage based on the model fit (highest Nagelkerke R^2 value).

Table B-4b summarizes the results from the regression analysis including the stream gages and their periods of record, the number of daily mean flow records (observations) tested, which precipitation data set(s) best predicted storm runoff (predictors), whether the regression models are statistically significant (p-value), model fit (R^2), and the percentage of runoff observations that were correctly predicted by the model. Unfortunately, the regression models did a poor job of predicting when storm runoff actually occurred, with only 4% to 36% of runoff events correctly predicted. Since the goal of the regression analysis was to fill in the period of record and determine whether storm runoff occurred at the gages when the lines of evidence were being collected, ADWR decided that the models were inadequate for their purpose and did not consider them further. A more complex rainfall-runoff model may provide better predictions, but was considered outside the scope of this report.

RESULTS

March 1899

Walcott (1901) did not report which day or days in March 1899 the seepage run along the San Pedro River was conducted. During this time, precipitation records are available from five regional weather stations – Benson, Bisbee, Cochise, Oracle, and Tombstone (**Figure B-4b**). An isolated storm was detected at the Oracle station on March 18 and a widespread storm was detected at all stations between March 26 and

March 29. Total precipitation measured at the stations in March 1899 was below their long-term average for that month (**Table B-4a**).

It is unlikely that storm runoff occurred in the San Pedro River Watershed during the first half of March 1899 as the only precipitation recorded occurred the prior month (on February 25) and was relatively minor (less than 0.25 inches). Any runoff from that storm would likely have ended within a few days. The isolated storm detected at Oracle on March 18 may have caused runoff for a few days along the lower San Pedro River. However, since this storm was not detected at any of the other regional weather stations, it is unlikely that it caused runoff along the upper and middle San Pedro River. The regional storm from March 26 to 29 produced modest precipitation (daily totals ranged from 0 to 0.31 inches) and potentially caused localized runoff across the watershed. Unfortunately, streamflow records were not available during March 1899 to confirm this.

March 1921

Schwalen (1921) reported that his seepage run along the San Pedro River was conducted from March 16 to March 22. During that time, precipitation records are available from six regional weather stations – Benson, Bisbee, Canelo, Cochise, Fairbank, and Tombstone (**Figure B-4c**). A widespread storm was detected at all of the weather stations between March 17 and March 20. Total precipitation measured at the stations during March 1921 was below their long-term average for that month (**Table B-4a**).

It is unlikely that storm runoff was occurring in the San Pedro River Watershed when the seepage run began on March 16 as the only substantial precipitation occurred over two weeks prior, between February 26 and 28. Any runoff from that storm would likely have ended within a few days. The regional storm from March 17 to 20 produced modest precipitation (daily totals typically ranged from 0 to 0.3 inches) and may have caused localized runoff during the seepage run. Storm runoff would have been most likely along the upper San Pedro River near the International Border since the greatest daily precipitation (about 0.5 inches) was measured during the storm at the Bisbee station. This is consistent with streamflow records collected at several gages during the seepage run.

Little or no runoff was generated from the March 1921 storm along the major tributaries to the San Pedro River. The Babocomari River remained dry at a gage near Huachuca Siding and only 0.17 cfs was measured at its mouth (Schwalen, 1921). Aravaipa Creek also remained dry during the storm at a gage near Fieldman (USGS 9473020) and at its mouth (Schwalen, 1921).

Figure B-4c shows that the storms of late February and late March 1921 did, as expected, cause storm runoff along the upper San Pedro River. Although both storms caused streamflows to increase for a few days at Hereford Bridge, flows downstream at the Charleston gage (USGS 9471000) appeared mostly unaffected by the storms. Available gage records suggest that flows at both gages were probably regulated at the time by upstream diversions. The latter is supported by the findings of the Arizona State Water Commissioner who, in 1921, surveyed two irrigation diversions upstream of the Hereford Bridge and one irrigation diversion upstream of Charleston (**Appendix B-2**).

Winter 1935

Based on information presented in **Section 3.2.4**, ADWR believes that the Fairchild photographs of the San Pedro River Watershed were taken sometime between January and March 1935. During that time, precipitation records are available from six regional weather stations – Benson, Bisbee, Canelo, Oracle, Fairbank, and Tombstone (**Figure B-4d**). Widespread storms were detected at all of the stations in early January, early February, and early March. Isolated and smaller storms also occurred in mid January, late February, and mid March. Total precipitation measured at the stations during winter 1935 was near or above the long-term average for the season (**Table B-4a**).

In light of their extent, magnitude and duration, some of the storms during winter 1935 would have been expected to produce runoff across the watershed. Records from two stream gages support this conclusion. A stream gage along the lower San Pedro River near Mammoth (USGS 9472500) and another along lower Aravaipa Creek near Mammoth (USGS 9473000) both recorded peak flows that correspond with the larger storm events. Runoff at these gages generally receded back to baseflow conditions within a week or less. Flows in the San Pedro River were also recorded during this period at the Winkelman Bridge, but these semi-weekly measurements appear to have

been taken between runoff events (**Figure B-4d**). The available gage data do suggest that, in winter 1935, storm runoff occurred along the lower San Pedro River and along lower Aravaipa Creek for about 30 to 40% of the time. Although streamflow data are not available for this period along the Babocomari River or upper and middle San Pedro River, the frequency of storm runoff in these streams would be expected to be similar based on the occurrence of storms in the watershed.

The Fairchild photographs themselves provide perhaps the most compelling evidence of streamflow conditions at the time. Along the San Pedro and Babocomari Rivers and Aravaipa Creek, the photographs indicate low flow or baseflow conditions based on the appearance of dry stream channels and, where streamflow was present, it appeared well below bank full levels. In addition, visible flow could not be discerned along the tributaries to these streams (**Figures B-4e** through **B-4h**). This finding combined with the precipitation and streamflow data described above suggest that the Fairchild photographs were likely taken during a period of baseflow conditions between storm runoff events.

CONCLUSIONS

It is likely that the March 1899 seepage run along the San Pedro River reflects baseflow conditions and was not substantially affected by storm runoff. There is no evidence of precipitation or runoff during the first half of the month and an isolated storm on March 18 probably only caused runoff for a few days along the lower San Pedro River. A regional storm from March 26 to March 29 potentially caused localized runoff across the watershed, but only for a few days at the end of the month.

The seepage run conducted along the San Pedro River from March 16-22, 1921 may have been affected by a regional storm from March 17 to March 20. However, most of the runoff from this storm probably occurred upstream of Charleston and appears to have been regulated by irrigation diversions along this reach of the river.

Precipitation and streamflow records suggest that during winter 1935 when the Fairchild photographs are believed to have been taken, storm runoff may have occurred along the major streams of the watershed as much as 30 to 40% of the time. However,

the lack of visible overbank streamflows on the photographs and no visible flows where minor tributaries join the San Pedro River suggest that the photographs were taken during a period of baseflow between runoff events.

Tables

TABLE B-4a. EARLY REGIONAL WEATHER STATIONS [1,2]

STATION NAME	STATION (COOPID) NUMBER	PERIOD OF RECORD	ELEVATION (feet)	PRECIPITATION (inches)				
				Long-Term Average [3]		Total (percentage of long-term average [4])		
				March	*January - March*	*March 1899*	*March 1921*	*January - March 1935*
Benson	20680	1894-1975	1,093	0.51	1.93	0.08 (16%)	0.00 (0%)	3.05 (158%)
Bisbee	20768	1892-1985	1,618	1.01	3.39	0.40 (40%)	0.70 (69%)	3.10 (91%)
Canelo	21231	1910-2007	1,527	0.93	3.32	NR	0.57 (61%)	5.92 (178%)
Cochise	21870	1899-1954	1,274	0.62	2.05	0.15 (24%)	0.07 (11%)	NR
Fairbank	22902	1909-1973	1,174	0.42	1.61	NR	0.08 (19%)	1.56 (97%)
Oracle	26116	1893-1949	1,403	1.58	7.52	1.16 (73%)	NR	9.27 (123%)
Tombstone	28619	1893-2007	1,405	0.64	2.25	0.19 (30%)	0.35 (55%)	2.63 (117%)

NR = Precipitation records not available

Notes:

[1] Data source: NCDC (2008).

[2] Station locations are shown in Figure B-4a.

[3] Mean precipitation over the period of record.

[4] Calculated by comparing the precipitation measured in March 1899, March 1921, and winter 1935 to their corresponding long-term average.

TABLE B-4b. LOGISTIC REGRESSION MODELS [1]

STREAM	USGS GAGE NUMBER (location)[2,3]	PERIOD OF RECORD	NUMBER OF OBSERVATIONS[4]	MODEL CHARACTERISTICS			MODEL PERFORMANCE (percentage of runoff observations correctly predicted)
				Predictors[5]	p-value[6]	(R^2) [7]	
San Pedro River	9470500 (at Palominas)	1932-33, 1936-41	723	SPR_2	<0.0001	0.58	33.3%
	9471000 (at Charleston)	1920-26, 1929-33, 1936-42	1,715	$Bisbee_2$ and SPR_{30}	<0.0001	0.25	3.6%
	9472500 (near Mammoth)	1932-41	900	$Oracle_0$ and SPR_2	<0.0001	0.38	31.5%
	unnumbered (at Winkelman Bridge)	1923-27	361	$Oracle_2$	<0.0001	0.62	16.7%
Aravaipa Creek	9473020 (near Fieldman)	1919-21	183	$Cochise_2$ and $Cochise_{10}$	<0.0001	0.63	35.7%

Notes:

[1] Data sources: Schwalen (various dates) and USGS (2008).

[2] Gage locations are shown in Figure B-4a.

[3] Records for unnumbered gage from Schwalen.

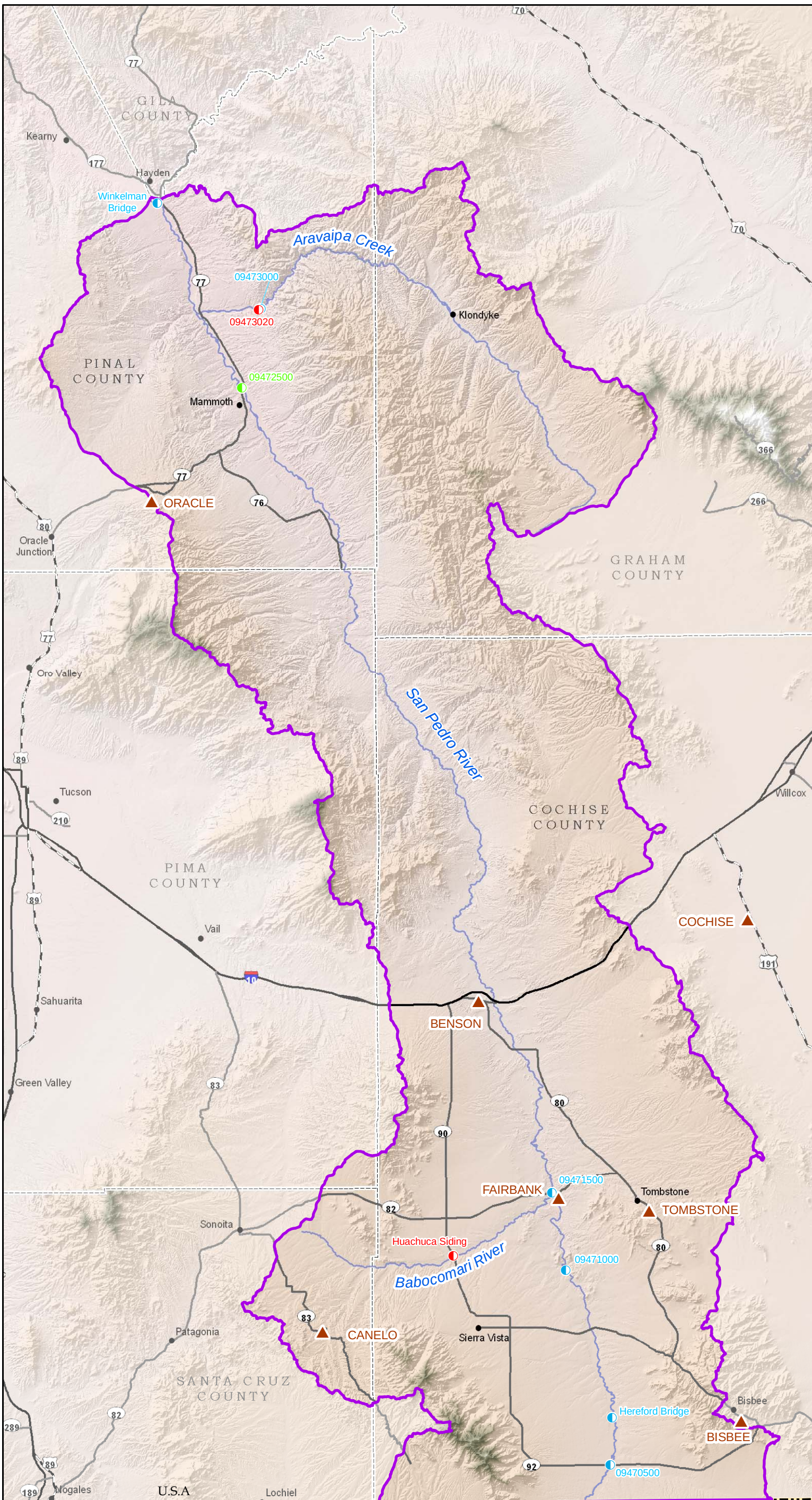
[4] Number of daily mean flow measurements collected during the winter months (January through March).

[5] Precipitation data from the weather stations listed in Table B-4a; subscripts specify the precipitation record used to predict flow conditions. For example, "$Oracle_0$" indicates the precipitation measured at the Oracle station the same day as the flow observation, and "$Bisbee_2$" indicates the total precipitation measured at the Bisbee station two days before the flow observation. SPR represents the average precipitation measured at weather stations in the region.

[6] A regression model is generally considered statistically significant if its p-value is less than (0.05).

[7] The higher the R^2 generally the better the model fit.

Figures



Legend

Stations

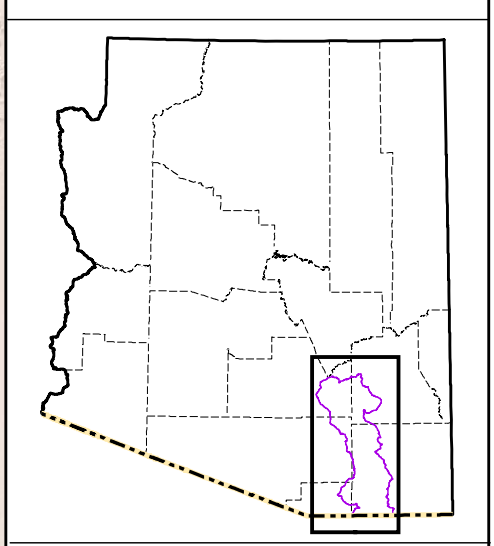
- Weather
- Stream Gage

Streamflow Regime (based on gage data)

- Ephemeral
- Intermittent
- Perennial

Data Sources:
NCDC (2008), Schwalen (various dates) and USGS (2008)

- San Pedro River Watershed
- Major Stream
- Interstate Highway
- U.S. Route
- State Highway
- City or Town
- County
- State Boundary
- International Boundary



N

ARIZONA DEPARTMENT OF WATER RESOURCES ©

0 5 10 15 Miles

Figure B-4a
Location of Early Weather and Stream Gage Stations Used to Analyze Historic Winter Streamflows

Subflow Zone Delineation Report for the San Pedro River Watershed

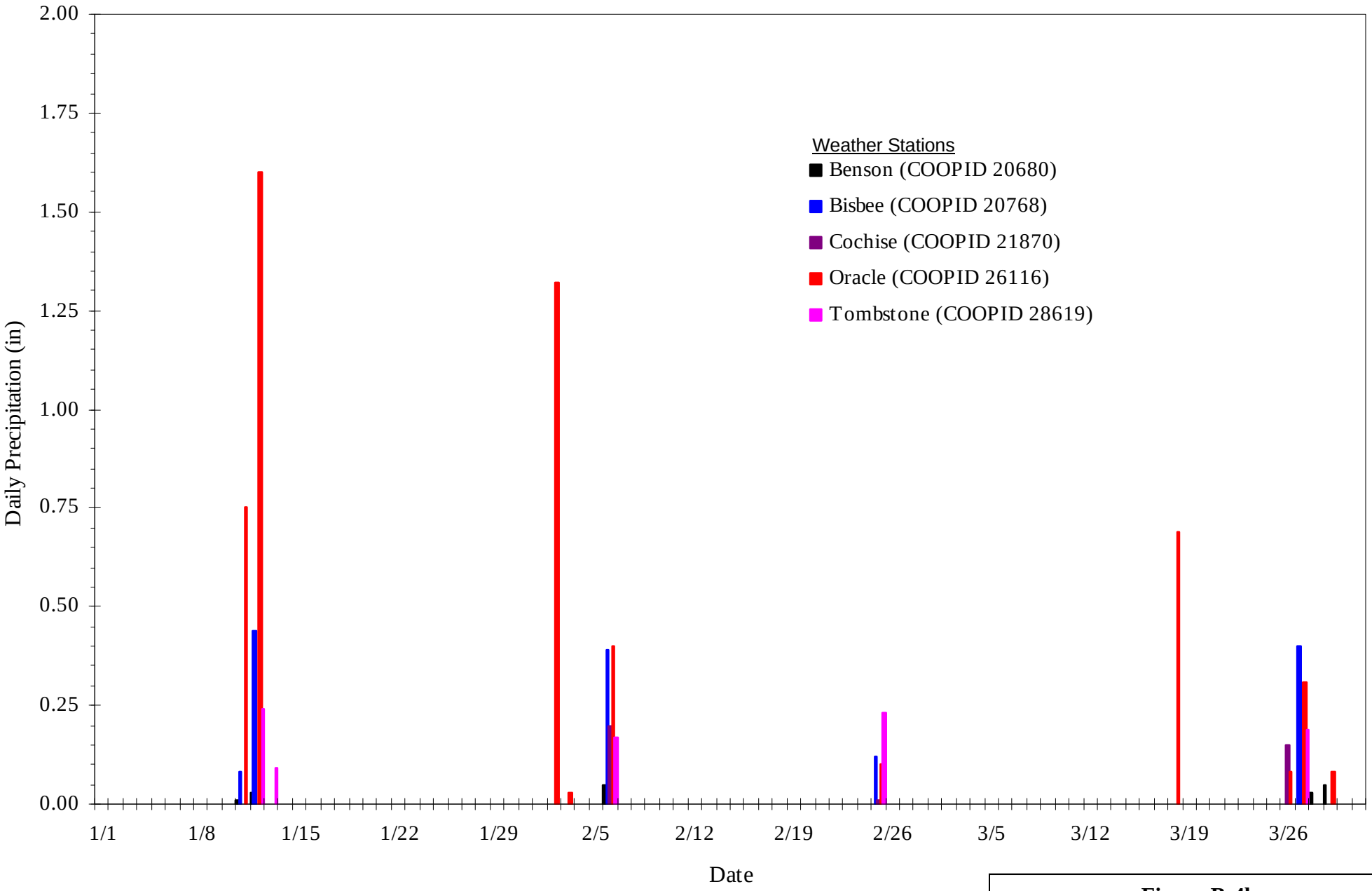


Figure B-4b
Daily Precipitation at Regional Weather Stations During Winter 1899

Subflow Zone Delineation Report for the San Pedro River Watershed

ARIZONA DEPARTMENT OF WATER RESOURCES ©

U:\WorkSpaces\StatewidePlanning\Adjudications\Projects\Hopi_HSR_Adjud\Maps\Final_HSR\PPT\FigB-4b_DailyRainfall_SPWS_JanMar_1899.ppt

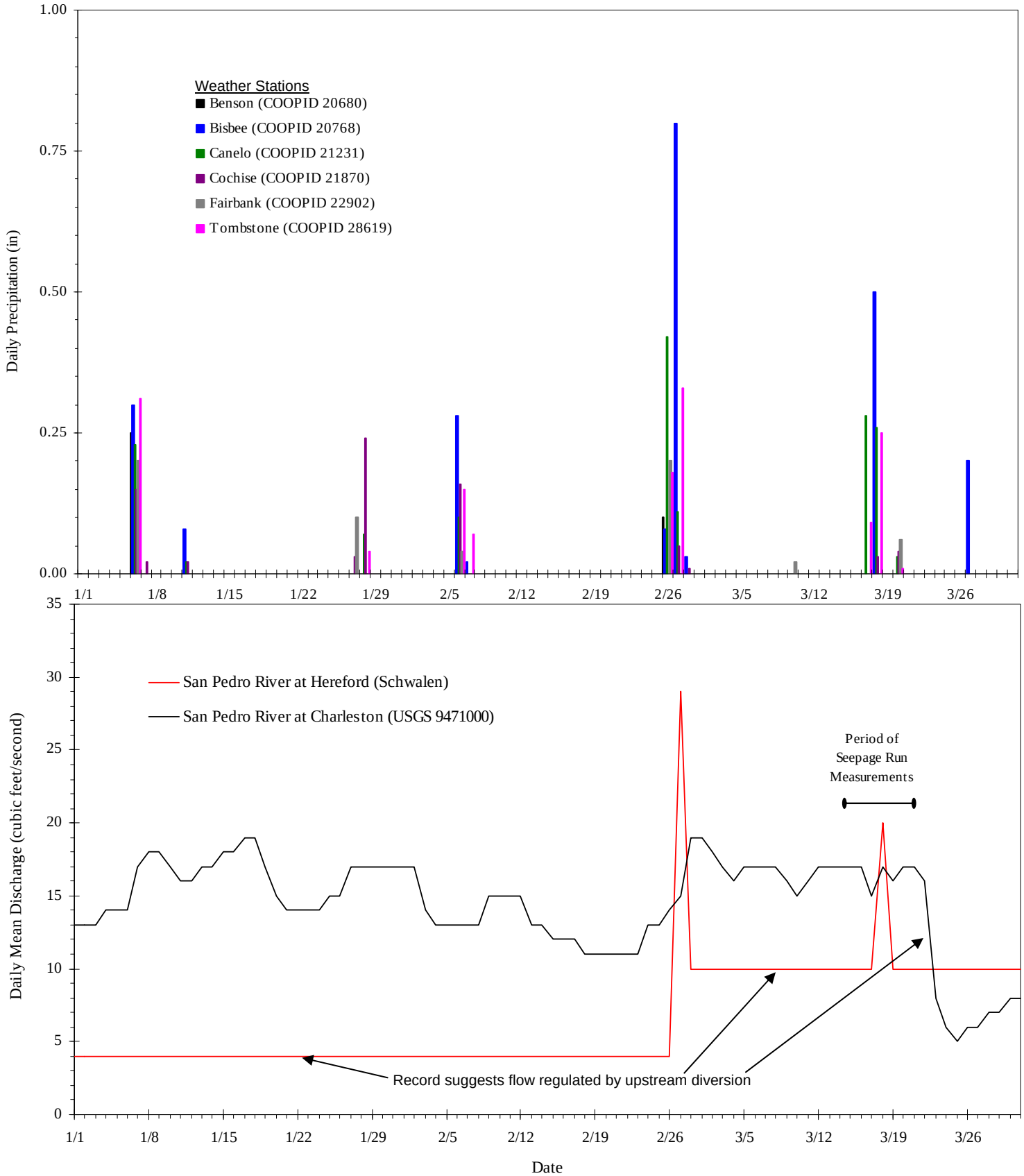


Figure B-4c
Daily Precipitation at Regional Weather Stations and Upper San Pedro River Streamflows During Winter 1921

Subflow Zone Delineation Report for the San Pedro River Watershed

ARIZONA DEPARTMENT OF WATER RESOURCES ©

U:\WorkSpaces\StatewidePlanning\Adjudications\Projects\Hopi_HSR_Adjud\Maps\Final_HSR\PPT\Fig\FigB-4c_DailyTot_Precip_JanMar_1921.ppt

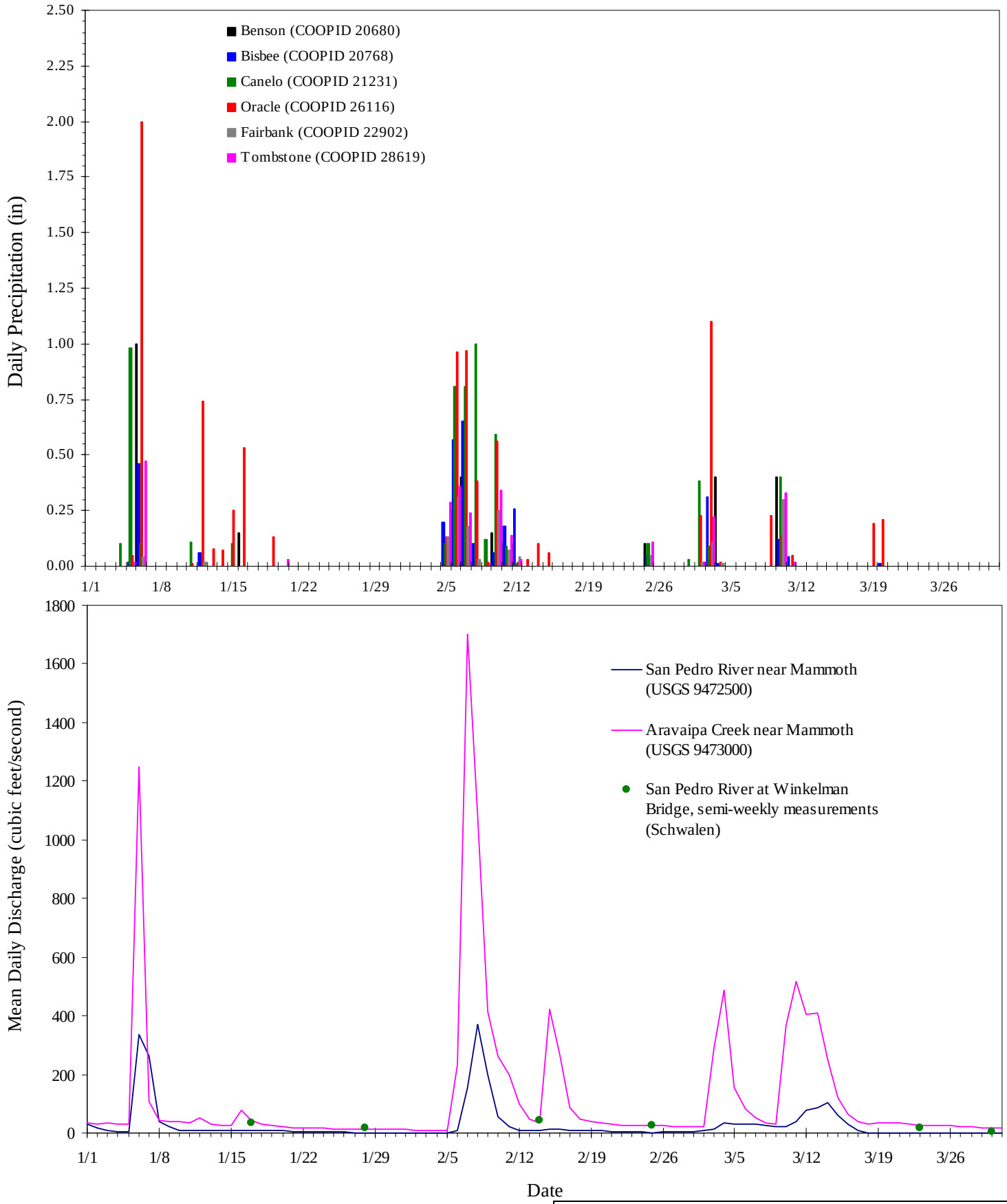


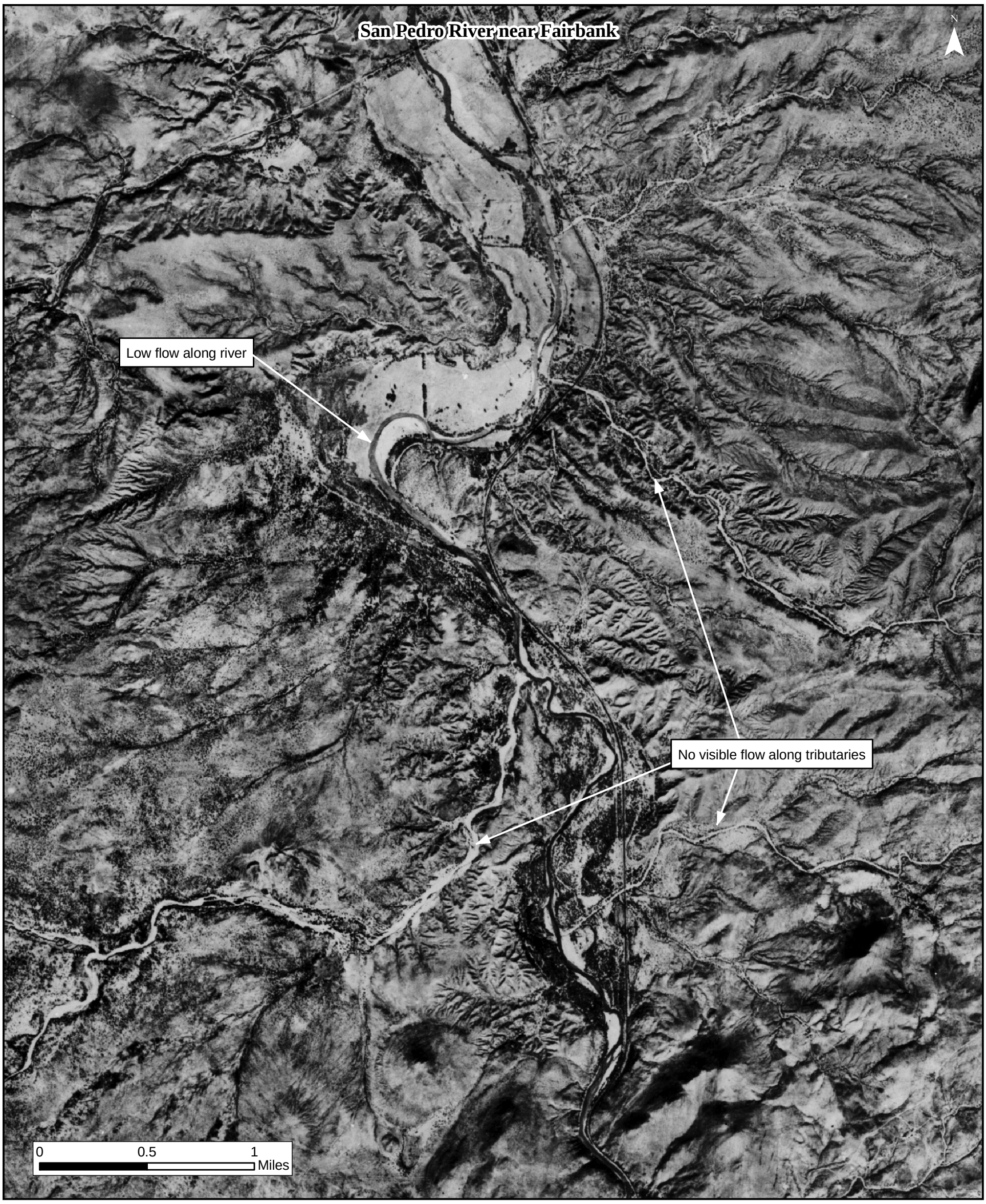
Figure B-4d

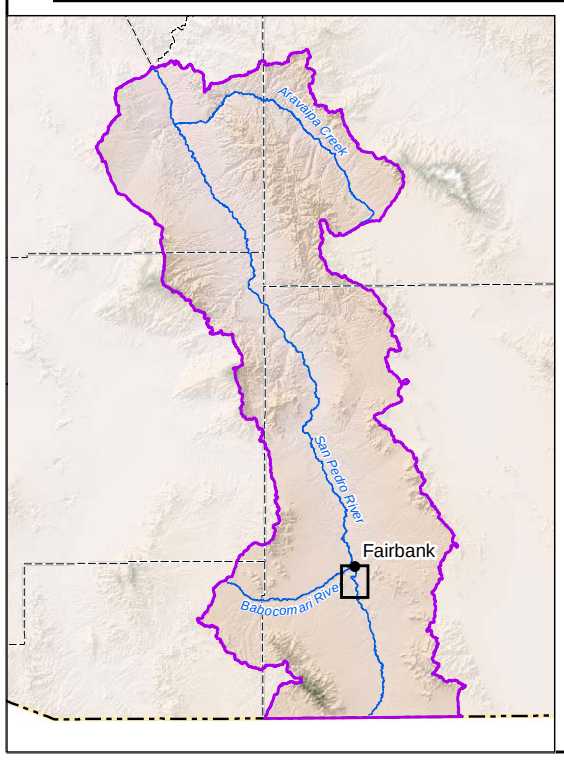
Daily Precipitation at Regional Weather Stations and Lower San Pedro River and Aravaipa Creek Streamflows During Winter 1935

Subflow Zone Delineation Report for the San Pedro River Watershed

ARIZONA DEPARTMENT OF WATER RESOURCES ©

U:\WorkSpaces\StatewidePlanning\Adjudications\Projects\Hopi_HSR_Adjud\Maps\Final_HSR\PPT\Fig\FigB-4d_DailyTot_PrecipStreamflow_JanMar_1935.ppt





Legend

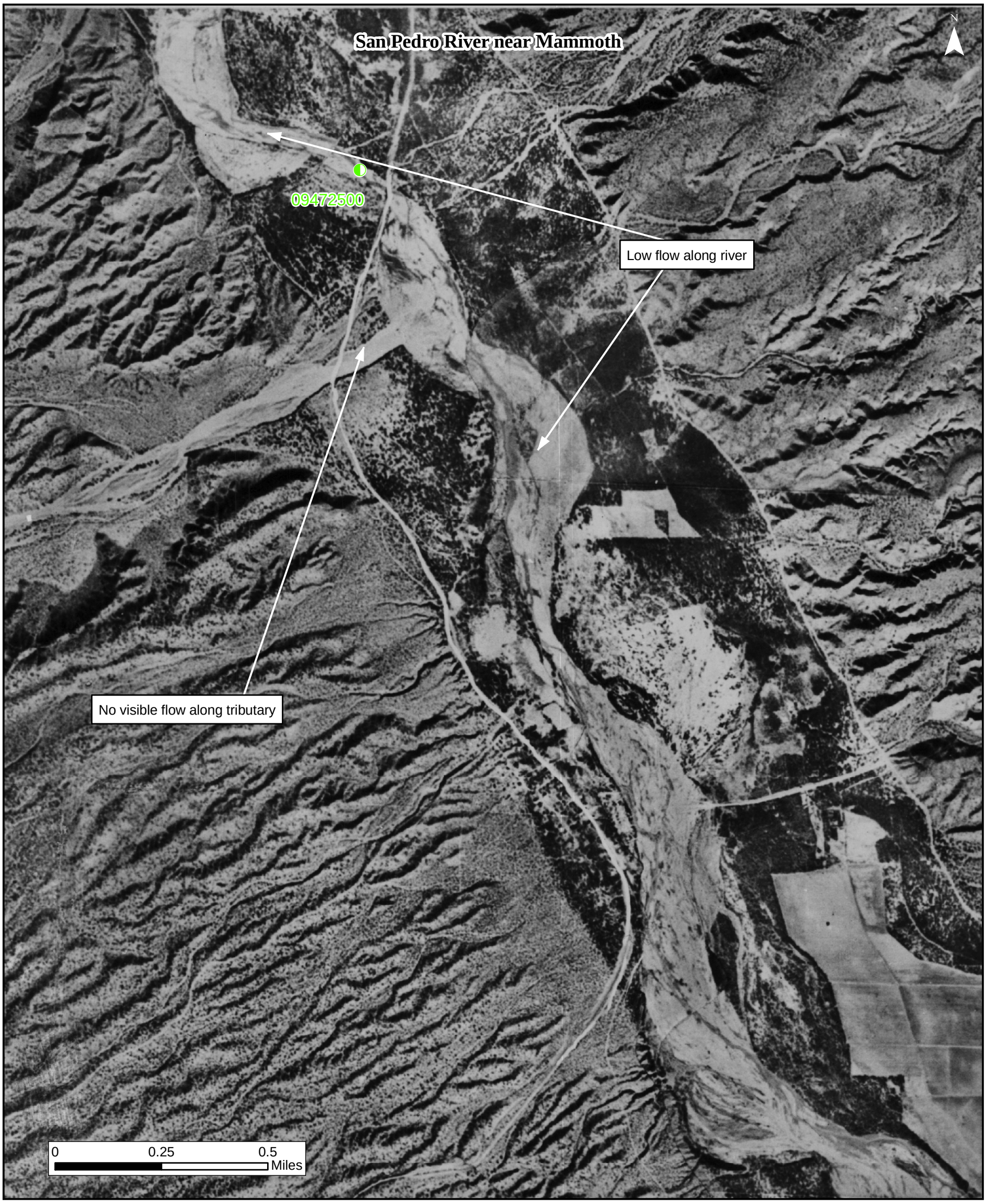
- Major Stream
- San Pedro River Watershed
- County
- International Boundary

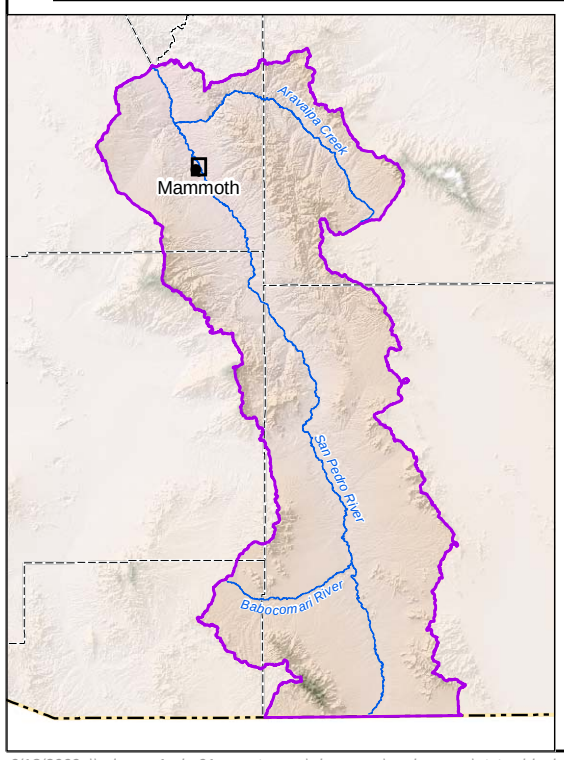
Note: Fairchild aerial photographs believed to have been taken between January and March 1935.

ARIZONA DEPARTMENT OF WATER RESOURCES ©

Figure B-4e
Fairchild Photograph Showing Streamflow Conditions Along the Upper San Pedro River and its Tributaries

Subflow Zone Delineation Report for the San Pedro River Watershed





Legend

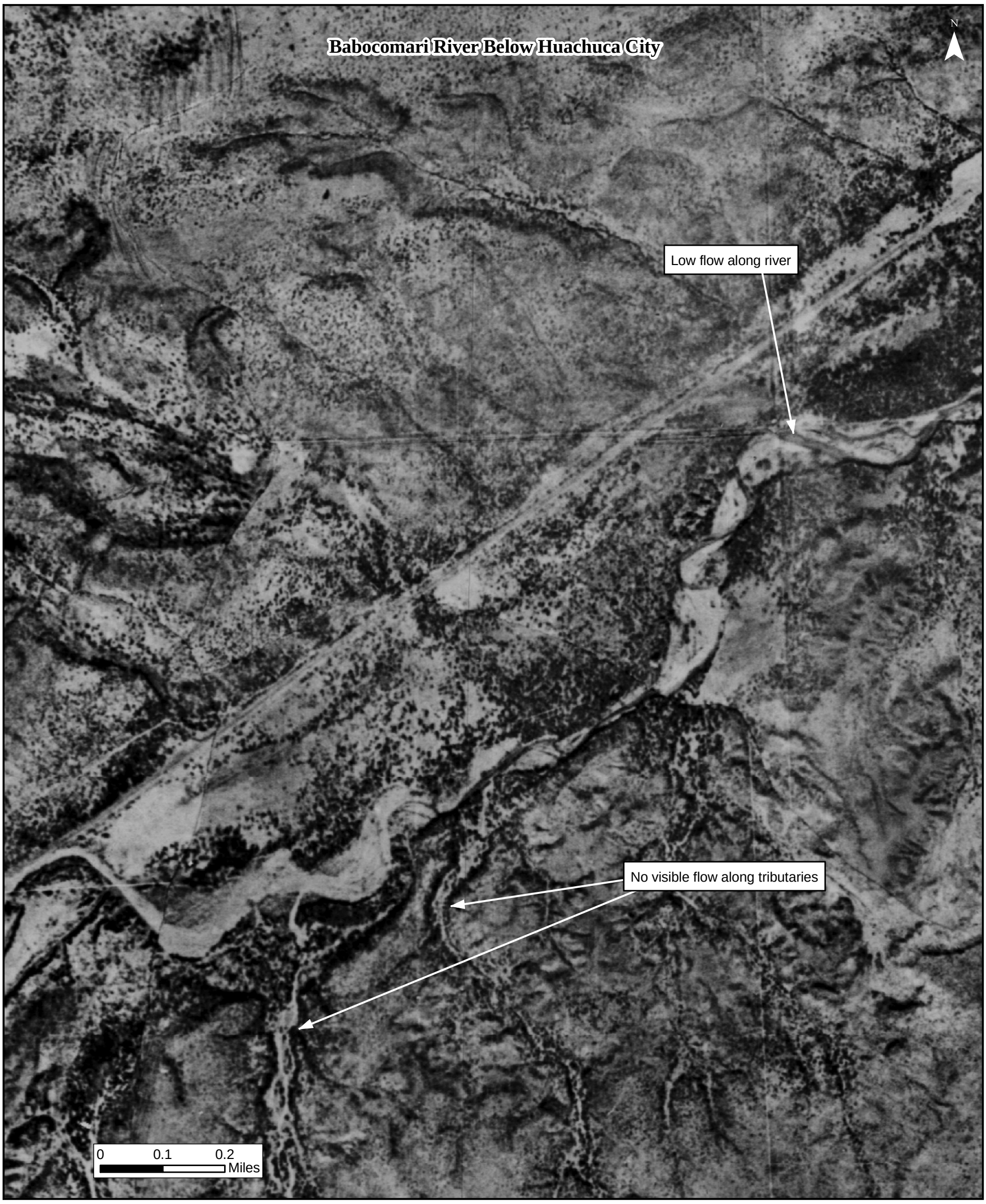
- Early USGS Stream Gage Measuring Intermittent Flows
- Major Stream
- San Pedro River Watershed
- County
- International Boundary

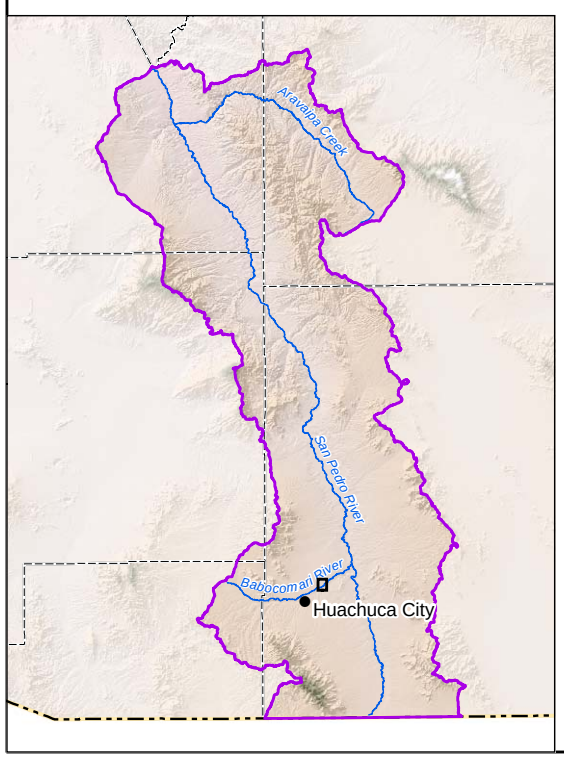
Note: Fairchild aerial photographs believed to have been taken between January and March 1935.

ARIZONA DEPARTMENT OF WATER RESOURCES ©

Figure B-4f
Fairchild Photograph Showing Streamflow Conditions Along the Lower San Pedro River and a Tributary

Subflow Zone Delineation Report for the San Pedro River Watershed





Legend

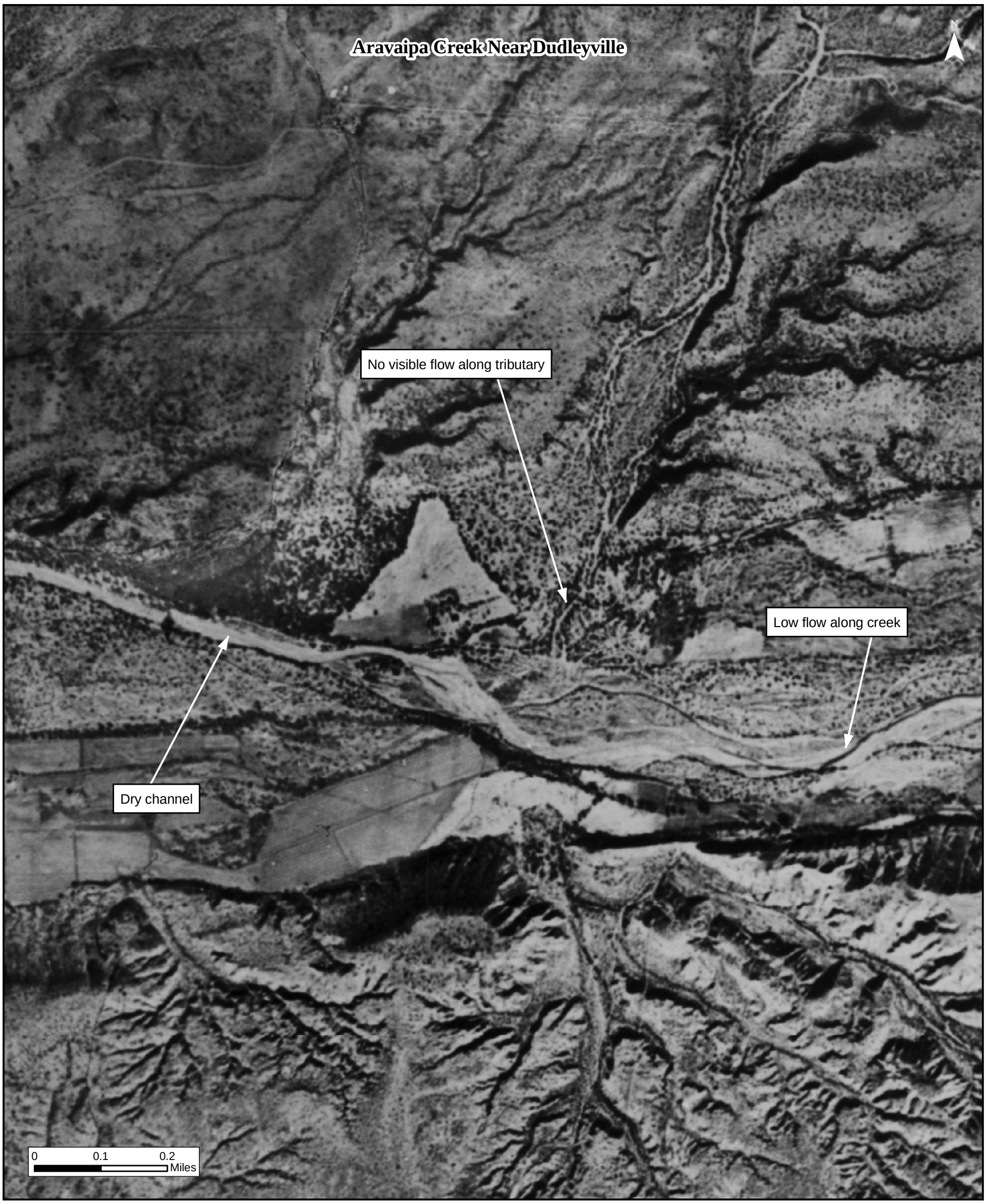
- Major Stream
- San Pedro River Watershed
- County
- International Boundary

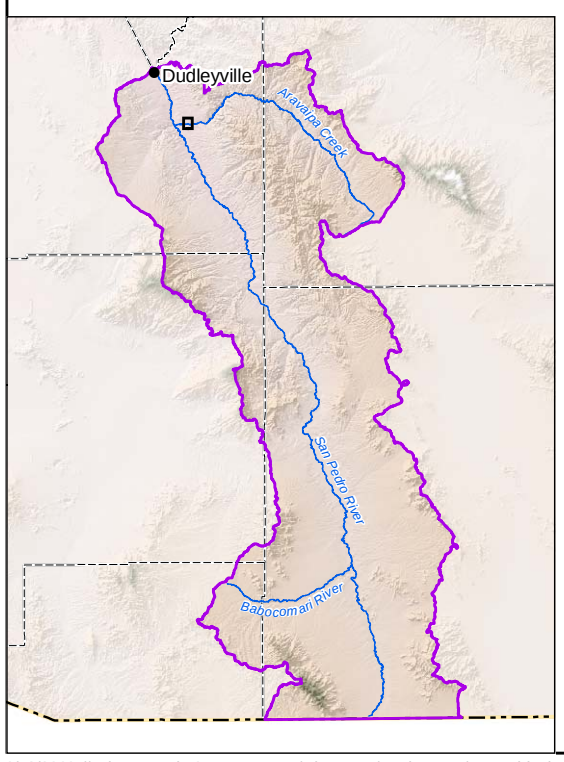
Note: Fairchild aerial photographs believed to have been taken between January and March 1935.

ARIZONA DEPARTMENT OF WATER RESOURCES ©

Figure B-4g
Fairchild Photograph Showing Streamflow Conditions Along the Lower Babocomari River and its Tributaries

Subflow Zone Delineation Report for the San Pedro River Watershed





Legend

- Major Stream
- San Pedro River Watershed
- County
- International Boundary

Note: Fairchild aerial photographs believed to have been taken between January and March 1935.

©
ARIZONA DEPARTMENT OF WATER RESOURCES

Figure B-4h
Fairchild Photograph Showing Streamflow Conditions Along Lower Aravaipa Creek and a Tributary

Subflow Zone Delineation Report for the San Pedro River Watershed