signs of reducing the delta's size. Related changes may also be noticed in the Sacramento River immediately up and downstream of the mouth of Thomes Creek.

The 1952 stream conditions and adjacent land use along Thomes Creek include:

- The stream's crossings consist of a wide low-water ford at Hall Road, at approximately stream mile 1.5, and Highway 99 and Southern Pacific Railroad bridges at Richfield (stream mile 4.3).

- Land uses were primarily rangeland or dry land crops north of Thomes Creek and irrigated crops and orchards south of the stream. Scattered farm homes are located south of the stream, with a concentration in the Richfield area. The Richfield Mill exists immediately east of the railroad, on the south banks of Thomes Creek.

- Thomes Creek is wide and has a highly braided character through the entire assessment area. Total stream channel width was often in excess of 1,000 feet, while at both the Hall Creek low-water crossing (see Image Comparison 4b) and Interstate 5 crossing site (see Image Comparison 4c) total stream width was about 3,000 feet.

- Streamside vegetation is very sparse and only exists as small "islands" of short-statured growth within the channel boundaries and as stringers of moderate to large canopied trees along the external edges of the stream channel. Frequently these stringers of hardwood trees are associated with cut bank features (see Image Comparison 4b).

1994 Photos

Between 1952 and 1994 significant changes have occurred throughout the Thomes Creek segment, including:

- Additional stream crossings have been built and now include: a wide low water at the Hall Road; the Tehama-Colusa Canal crossing at stream mile 2.0; Highway 99 and Southern Pacific bridges at Richfield; and Interstate 5 bridges at stream mile 5.7. (The Corning Canal crossing was placed approximately 0.6 miles west of Interstate 5.)

- Thomes Creek continues to be highly braided throughout its reach; however, in many locations its 1952 width has been constricted. Examples include: the Hall Creek crossing (see Image Comparison 4b); levees constructed to protect the Tehama-Colusa Canal; and the Interstate 5 crossing (see Image Comparison 4c). In the latter case the original width was narrowed from 0.6 miles to less than 0.3 miles.

- Land use has changed now so that both north and south sides of the stream have irrigated crops or orchards.

- More farm buildings and structures exist through the area, almost all occurring on the south side of Thomes Creek. The Richfield Mill appears inoperable and assorted buildings and open areas take up the site. The community of Richfield is more developed than in 1952.

Image Comparison 4a. Thomes Creek confluence with the Sacramento River (delta) in 1952 (top) and 2004 (bottom). Note that Thomes Creek's mouth may be migrating further to the north, eliminating riparian forest along the Sacramento River and cutting off the 1952 river channel. In the late 1990s a new river channel formed by cutting through the large point bar and it is possible that the island created will become attached to the western land mass.

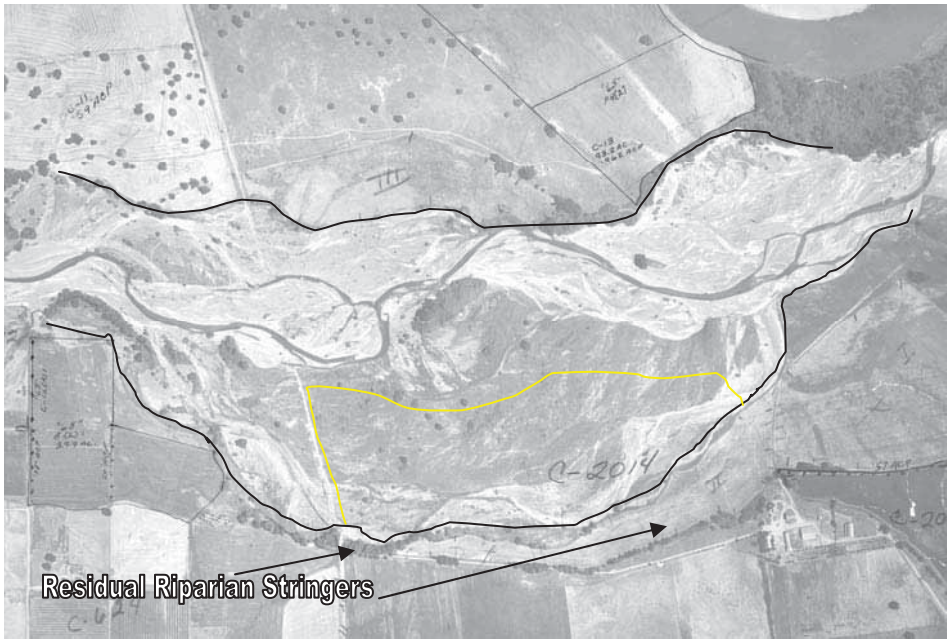

Image Comparison 4b. Thomes Creek at the Hall Road crossing in 1952 (top) and 1994 (bottom). Note the extent of the stream's overflow patterns in 1952 (black lines) and the rows of riparian trees along the outer stream banks. By 1994 significant portions of the overflow channels have been converted to agricultural land (area encircled by yellow line), which is orchard. Note the row of hardwoods still existing along the stream bank feature south of the orchard.

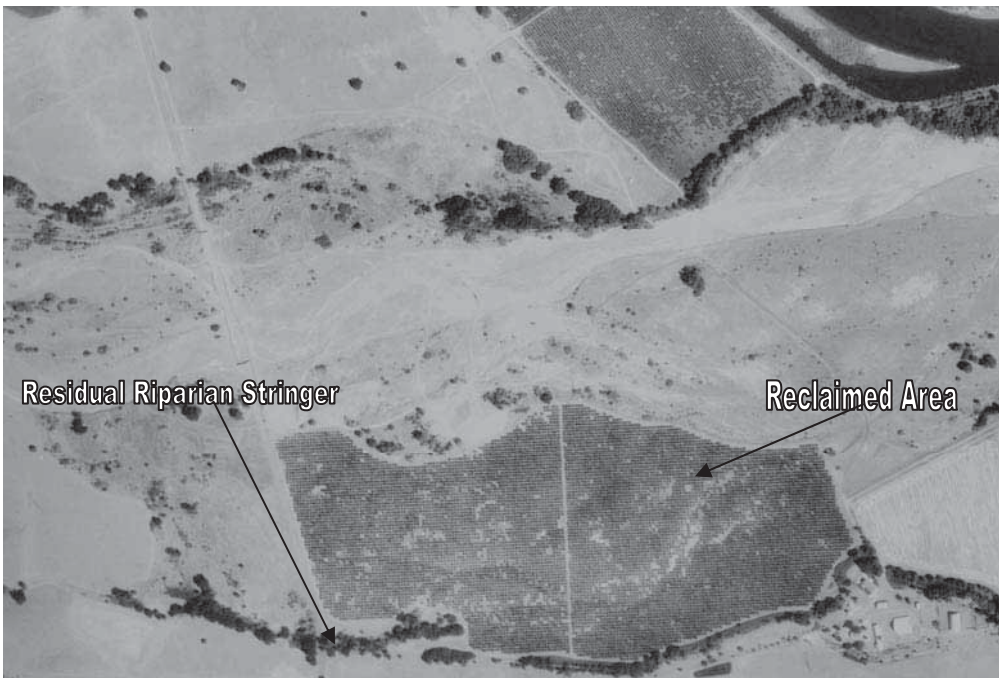

Image Comparison 4c. Thomes Creek at the Interstate 5 crossing site in 1952 (above) and 1994 (bottom). Note the braided stream condition in both images. The Interstate 5 Bridge locations and lengths are shown as a blue bar. The extent of overflow patterns in 1952 are shown by the black lines and the 1994 extent of stream constriction is shown by the yellow line. Comparing these images show the extent of channel constriction. (The feature to the west of Interstate 5 is the Corning Canal crossing.)

- Many levees have also been constructed between Interstate 5 and the Sacramento River.

- Riparian vegetation has changed. At the stream's confluence with the Sacramento River the riparian forest along the northern portion of the delta has narrowed. Riparian vegetation continues to be scant and patchy in 1994; however, dense growth occurs within some reaches (particularly immediately upstream from Richfield and immediately upstream from Interstate 5; see Image 4d). It is likely that most of this vegetation is comprised of invasive species.

- Historical outermost stream channel banks can still be identified by their residual hardwood stringers of moderate to large size trees; however, these features are often a distance from the current stream channel (see Image Comparison 4b).

Estimates of stream bank riparian foliar cover were made for various segments of Thomes Creek for the period 1952-2004 and are shown on Table 5. The segments include:

- Segment 1—Sacramento River upstream to Hall Road crossing

- Segment 2—Hall Road crossing to 0.5 miles west of the Tehama-Colusa Canal crossing

- Segment 3—0.5 miles west of the Tehama-Colusa Canal crossing to Highway 99

- Segment 4—Highway 99 to the Interstate 5 crossing site

Although estimating stream foliar cover was different with all assessment streams, the historical changes in stream flow characteristics and invasion of weeds complicates the issue for Thomes Creek. In both 1994 and 2004 images vegetation, likely *Arundo* and Tamarisk, appear to grow in dense mats within the stream channel (see Image 4d). The estimations shown in Table 5 continue to follow the same logic used in Tables 2-4 for the other assessment streams, with only shrub or tree growth along the stream banks being considered. Therefore, mid-channel invasive vegetation contributed by alien species is not considered by the estimates.

Table 5
ESTIMATED PERCENT STREAM BANK RIPARIAN FOLIAR COVER
LOWER THOMES CREEK (1952-2004)

Year	Stream Segment			
	1	2	3	4
1952	5	5	5	<5
1994	<5	5	10[a]	15[a]
2004	5	10[a]	15[a]	20[a]

Notes: [a]—These increase in foliar cover is primarily provided by low-statured vegetation which may be *Arundo* or Tamarisk.

Stream bank cover appeared to increase modestly for each stream segment between 1952 and 2004; however, it is possible that invasive plants contribute some or much of that increase.

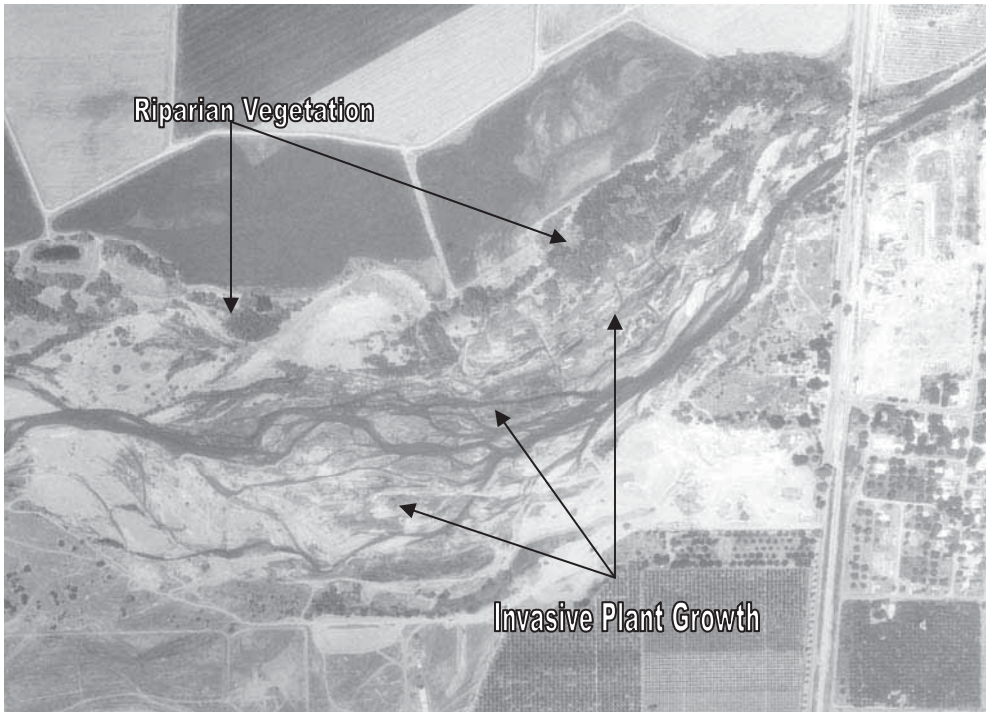

Image 4d. Thomes Creek immediately west of Richfield, in 1994. Note the vegetation occurring within the stream braids, likely *Arundo*, and larger-statured vegetation along the sides of the channel.

There are many locations where the stream's 1952 flood overflow channels have been reclaimed to agriculture. Examples include locations at the Hall Road crossing (see Image Comparison 4b) and the Interstate 5 crossing (see Image Comparison 4c). Similarly as described for the Red Bank and Elder Creek cases, the reclaimed sites retain the old stream bank cut features with narrow stringers of hardwood trees. These features are now often quite distant from the stream channel.

As in the case of Elder Creek and to a lesser extent Red Bank Creek, the narrowing of Thomes Creek channel has likely resulted in a deepening and speeding of flood waters passage through the lower system. Consequently, less sediment deposition can occur in side channels.

UPLAND HABITAT COMPARISON

Six separate upland areas were selected in the Tehama West Watershed assessment area for comparison of old and recent photographs. These specific upland sites were selected because they showed evidence of recent stream bank cutting or gullying in the earliest available photograph. Comparing the oldest available photograph with 2004 images showed how the erosion features had changed, as well as differences in riparian and upland vegetation and land use patterns.

The sites include:

- Site 1—Brickyard Creek. The site is located approximately 2 air-miles west of Red Bluff. Brickyard Creek is a tributary of Reeds Creek. The terrain is rolling grasslands with very few trees.

- Site 2—Brewery Creek. This site is located approximately 0.5 miles northwest of Red Bluff. The terrain is gently rolling grasslands with steeper gullies.

- Site 3—Oat Creek. This site is located approximately 10 air-miles southwest of Red Bluff. The terrain is rolling grasslands with adjacent steeper hills having gray pine and blue oak stands.

- Site 4—Thomes Creek/Flournoy. This site is located approximately 1 air-mile west of Flournoy. The site is centered on Thomes Creek and includes adjacent flat to rolling terrain.

- Site 5—Elder Creek. This site is located along Elder Creek, approximately 1 mile west of the Paskenta Road. The site includes rolling terrain with steeper slopes on the north bank of Elder Creek. There are scattered gray pine and blue oaks on the steeper slopes.

- Site 6—Thomes Creek/Paskenta—This site is approximately 1 mile southwest of Paskenta. Most of the site is rolling terrain, with steeper hills along the area's southern fringe. Scattered gray pine and blue oak grow on the steeper hills.

Comparisons of the photographic chrono-sequence include the following observations.

Site 1

The 1938 photograph of this portion of the Brickyard Creek drainage shows a large number of sharp erosion features, apparently recent in origin. These include steep and raw cutbanks in minor gullies draining into Brickyard Creek. Many of these erosion features are dendritic, suggesting downcutting in the main channels, leading to downcutting in the feeder channels.

Riparian growth is scant, only occurring along Brickyard Creek's main channel in a few scattered locations. The land use is rangeland in the north of the image with some dry land agriculture south of Brickyard Creek.

In the 2004 photograph (Image 5b) several features are immediately apparent—a 2004 rangeland fire has burned through the western portion of the assessment area and urban sprawl has pushed in from the east (suburbs of Red Bluff). In addition, several dams have been constructed in small draws, creating slender ponds.

The sharp erosion features noted in the 1938 photograph appear muted in the 2004 image. Although the resolution of the 1938 image is greater than the 2004 photograph, this change appears to be a product of gradual healing of the eroded gullies and suggests that the distinctive features seen in 1938 were created only shortly prior to when the photograph was taken.

Riparian vegetation appears to have changed little in extent or density between 1938 and 2004. Very little if any riparian growth is seen in 2004 adjacent to draws or gullies leading to Brickyard Creek and Brickyard Creek has only insignificant amounts of growth in small patches.

Site 2

In 1938 this assessment area is laced with sharp, down-cut gullies. No urban development has occurred in the area and vegetation appears to be grassland/rangeland. No riparian vegetation exists in any of the gullies leading into Brewery Creek or along the main creek itself.

In 2004 residential areas have extended westerly from the City of Red Bluff along both Park and Waldbridge Streets. Waldbridge Street has been extended through the southern portion of the assessment area but the central portion of the assessment area has been avoided by new development, likely due to the eroded and broken terrain. As in the case of Site 1, the sharp erosion gully features are much less apparent in 2004 than in 1938, suggesting that they have rounded and begun to heal. As in 1938, there is no riparian vegetation along the gullies or Brewery Creek. Also, the assessment area continues to exist as a grassland/rangeland.

Site 3

As shown by Figure 6a, in 1952 this assessment area is composed primarily of gently sloping and rounded terrain. Dry land agriculture is used on most of the land, except for the draws with steeper slopes and the hills to the northwest. The hills have moderately-heavy growth of gray pine and blue oak.

Sharp erosion features exist at Site 3, in a similar manner to Sites 1 and 2. Riparian growth is very restricted, only occurring in narrow, disconnected patches directly adjacent to Oat Creek and its larger tributaries. Riparian growth does not exist along any of the smaller gullies.

By 2004 (Figure 6b) some changes are apparent, relative to 1952. First, the oak/pine woodland north and south of the pond has been significantly thinned but not eliminated. Second, the erosion features sharply seen in 1952 appear to be more rounded and blend in with the adjacent uplands. Third, dense vegetation has encircled the pond, with some of the growth being emergent. It is possible that the pond's size has declined, due to sediment deposition, or that the emergent vegetation contributes to this perception. Riparian growth along Oat Creek is even more limited in 2004 than 1952. Riparian stringers do not exist in 2004, merely scattered individual shrubs or shrub-clusters.

Site 4

The vicinity southwest of Paskenta, shown in Figures 7a and 7b show similar erosion features in small headwater gullies and along bends of stream channels, in a manner similar to Sites 1-3. However, the gullying is less severe and less wide-spread than in the previous assessment areas.

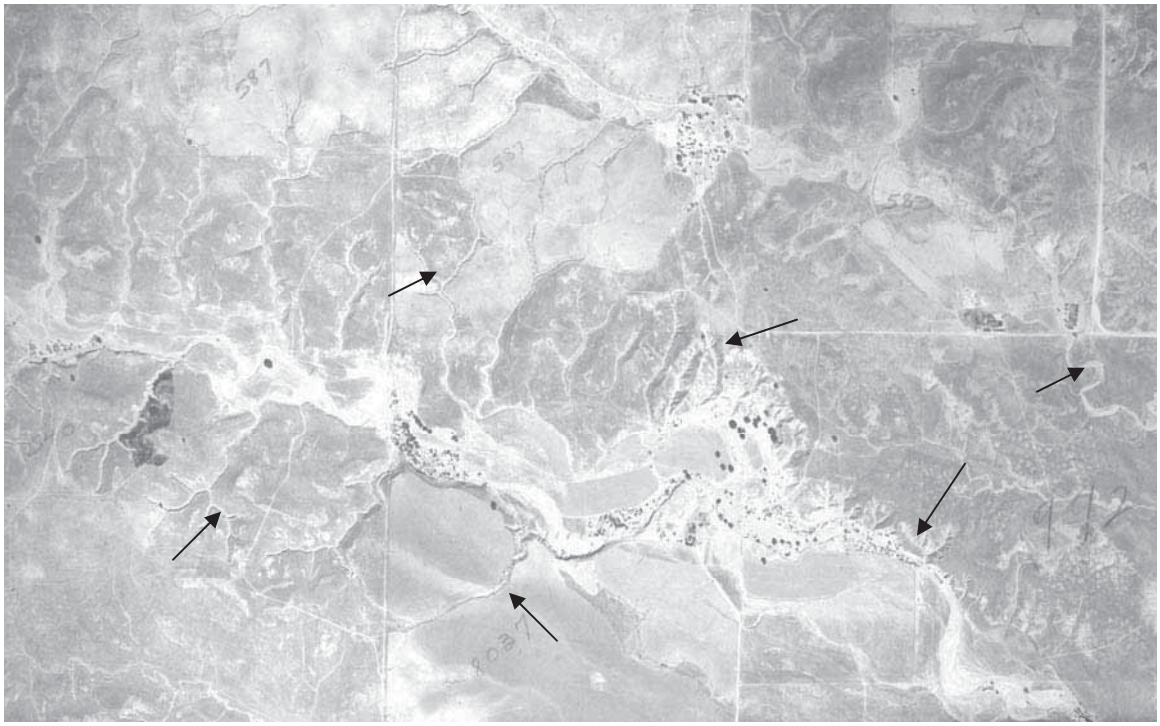

Image 5a (1938, above) and 5b (2004, below). Upland Site 1, Brickyard Creek, West of Red Bluff. Examples of sharp erosion features are pointed at by the arrows.

Image 5b (top, 1938) and 5b (bottom, 2004). Brewery Creek Drainage, immediately northwest of Red Bluff (Site 2). Examples of sharp erosion features are pointed at by the arrows. For reference, the bend of Baker Road is shown as a black line in both images.

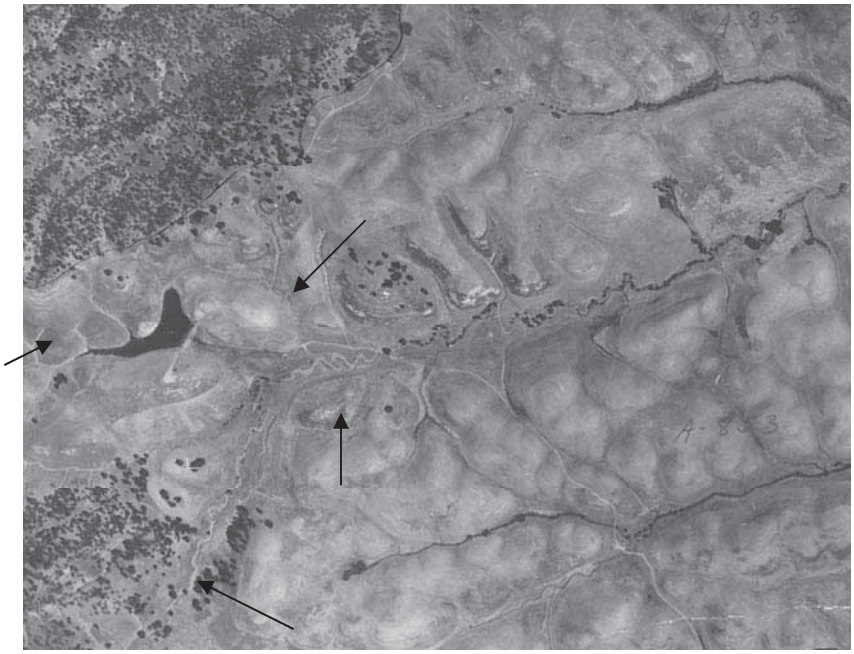

Figure 6a (top, 1952) and 6b (bottom, 2004). This assessment area (Site 3) is located along Oat Creek, approximately 2 miles south of the location called Red Banks. Significant erosion features are shown by arrows.

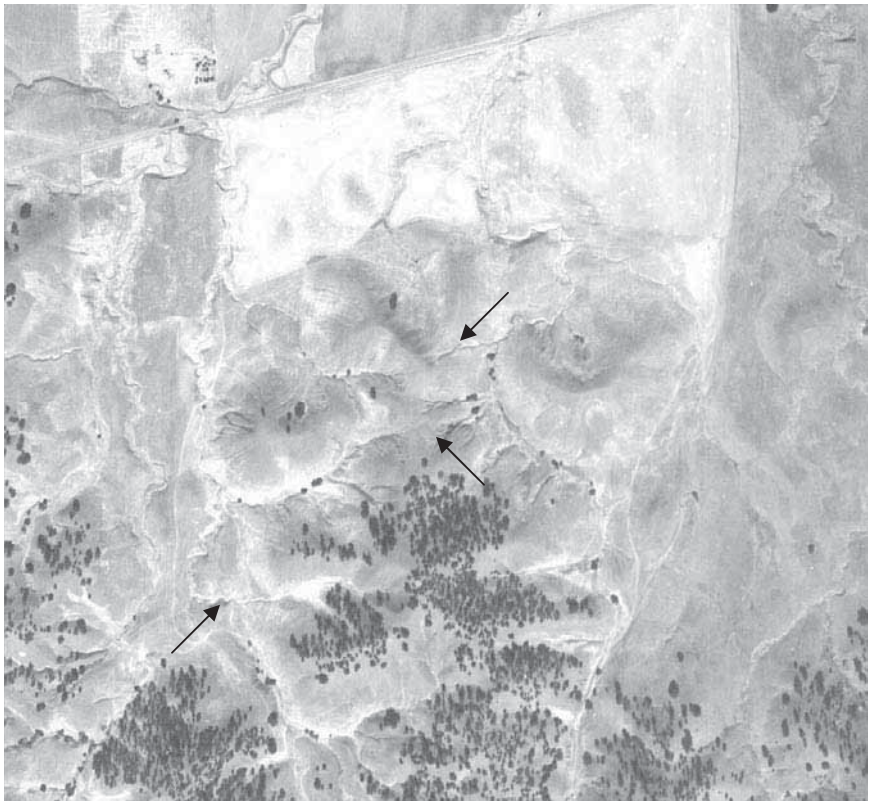

Figure 7a (top, 1938) and 7b (bottom, 2004). This area (Site 4) is located only 1 mile southwest of Paskenta. Sharp erosion features are shown by the arrows.

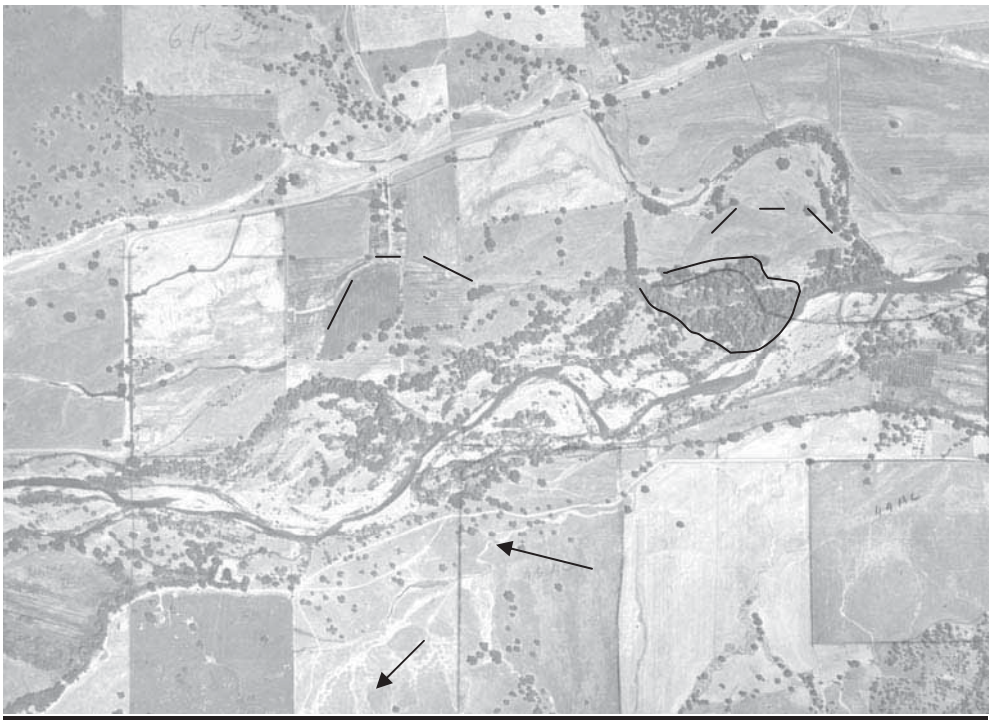

Figure 8a (top, 1952) and 8b (bottom, 2004). Significant areas of riparian growth that have been affected are circled by black lines. Gully erosion features are shown with arrows. Note old stream bend features shown with broken lines. This is Site 5.

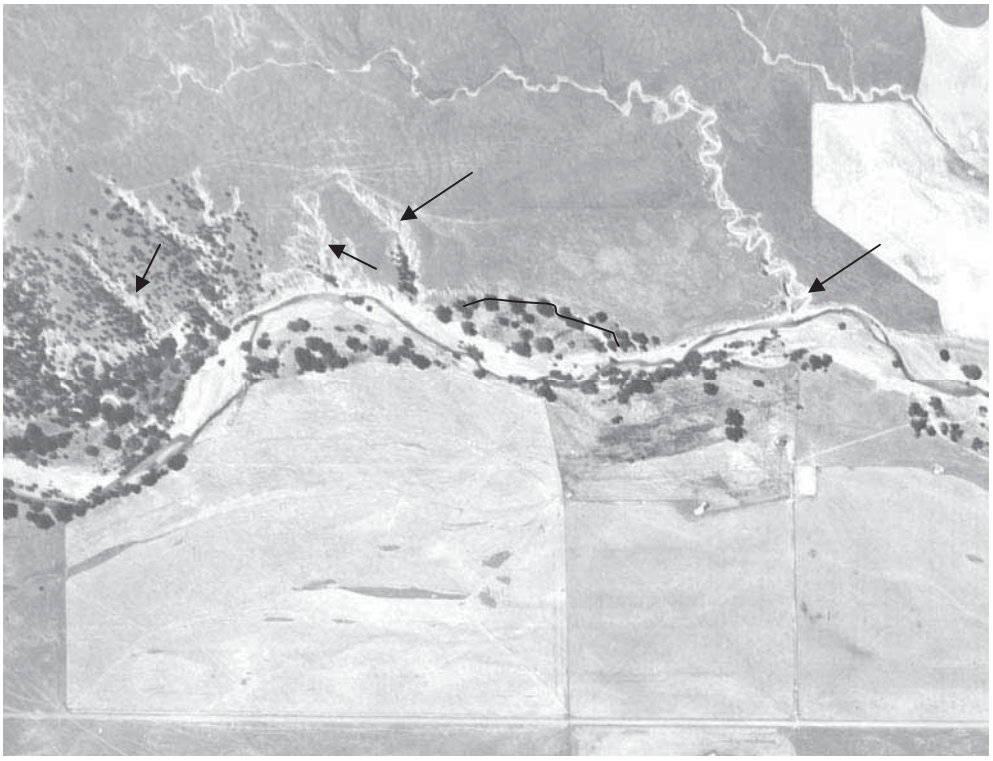

Figure 9a (top, 1947) and 9b (bottom, 2004). This is Site 6, along Elder Creek and approximately 1 mile west of the Paskenta Road. Note significant erosion features shown by the arrows. An old stream erosion feature is shown with the wavy line.

In 1938 the area was a combination of grassland/rangeland on the flats and gentle slopes with stands of gray pine and blue oaks on the steeper, adjacent hills. Riparian vegetation does not exist on any of the gullies. In 2004 the gully erosion is less pronounced but riparian growth still is totally lacking. The pine and oak woodlands are similar in extend and density, with no evidence of thinning.

Site 5

Figures 8a and 8b compare a location along Thomes Creek approximately 1 mile west of Flournoy. Fields adjacent to Thomes Creek were irrigated in both 1952 and 2004 but further away from the stream the lands are grasslands. Several small ponds were constructed prior to 1952 in the hills immediately south of the assessment area, no doubt to help in irrigating adjacent fields.

Some gully erosion can be seen in Figure 8a; however, the degree of upland erosion is less than in Sites 1-3.

Riparian vegetation shows significant change between 1952 and 2004. Specifically, Thomes Creek has eaten away at large portions of the riparian habitats that existed in 1952. Evidence of past stream bends, extending hundreds of feet to the north of the existing Thomes Creek channel, can be seen on both photographs. This suggests that the stream has varied in width and path in the past. Even so, the amount of riparian cover along the lower portion of McCarthy Creek, in the northeast quadrant of the 1952 image, is very similar in both years. In both 1952 and 2004 riparian vegetation and other shrub or tree cover is very sparse along gullies feeding into Thomes Creek.

Site 6

This assessment area along a small canyon surrounding Elder Creek is compared from 1947 and 2004 photographs. In 1947 the land north of Elder Creek is grassland/rangeland and most of the area to the south is dryland agriculture. There are scattered oaks and gray pine from Elder Creek north, on steep hills that climb away from the stream.

Along the northern bank of Elder Creek there are a number of significant erosion features, similar to what was seen in Sites 1-3. Sharp cut banks exist in the 1947 photograph, along with dendritic gully erosion patterns (as shown on Figure 9a). Riparian growth is very scant along Elder Creek and not present in side gullies.

In 2004 the erosion features appear less noticeable than in 1947, with the possible exception of the gully shown by the furthest east arrow on Figure 9a. Riparian growth - all of which exists directly along Elder Creek - appears mostly unchanged between 1947 and 2004.. Finally, agricultural efforts appear to have been curtailed south of Elder Creek between 1947 and 2004, with only grasslands/rangelands south of Elder Creek during more recent years.

SUMMARY

Aerial photographs from 1938 to 2004 were used to develop a chrono-sequence of stream changes to Reeds, Red Bank, Elder, and Thomes Creeks. Land use, infrastructure, stream characteristics, and riparian growth were compared for the period covered by the photographic record.

The earliest photographs available showed that each of the four streams had either segments or their entire assessed length that were highly braided and aggraded, with only scant to moderate amounts of riparian cover along their banks. This suggests that wide and braided conditions may represent "natural" condition for these streams. If so, riparian growth would tend to be sparse, as it would frequently be either disturbed or abandoned by stream flow.

Reeds Creek and its tributary Brickyard Creek, along with Red Bank Creek, show evidence of a recent flood event prior to 1938, with heavy stream bank cutting and possibly riparian cover reduction.

As time progressed in the photographic review, significant changes occurred for all four streams. There were improvements of existing or installations of new stream crossings. Each of these crossings resulted in constraining the stream's ability to widen or change channel and each crossing also was accompanied by levees or other structures that protected the crossing from channel deviation and damage. Other changes noted included increased rural and urban development, increased use of irrigation, and changes in land use from agriculture to commercial or residential or from dry land to irrigated uses.

During the period covered by the photographic record the streams have responded in a wide variety of manners to management activities and adjacent land uses. Reeds Creek, a relatively short stream, had significant evidence of severe flooding prior to 1938 and since that time stream and riparian conditions (including the tributary Brickyard Creek) appear to be stabilizing and improving. Changes in water relations at its mouth, including both control of flow of the Sacramento River since the mid-1940s and construction of the Red Bluff Diversion Dam in the mid-1960s, has resulted in considerably different conditions in the stream's lowest reach. Today it serves as primarily a bay for Lake Red Bluff.

Red Bank Creek also showed indications of severe flooding prior to 1938. Very little change has occurred since that time to the lower reach unaffected by the Red Bluff Diversion Dam. The stream has continued to be highly braided and with very little riparian growth. Below Highway 99 the stream becomes a summer-time arm of Lake Red Bluff.

In contrast to the other three streams, Elder Creek is highly braided east of Interstate 5; however, it narrows considerably closer to the river. The narrowness through most of the assessed portion of this stream is likely due to early-day levees, which allowed agricultural development to the structures. In more recent times the levees have been improved upon, allowing additional land to be placed into agriculture and a reduction in near-stream hardwood cover. The extent of levee construction on Elder Creek and the extent of channel narrowing that has occurred are much greater than that of the other three streams assessed.

Thomes Creek is the largest assessed stream and well-known for its prodigious sediment discharge potential. The stream channel with flood plains was as wide as 3,000 feet in several

segments. Very little riparian growth existed in the active stream channel in the earliest photographs but in some areas it appears to be increasing significantly. A large portion of that growth may be introduced weed species.

Recent highway and canal crossings have constricted the Thomes Creek stream channel to less than one-half of its previous width in several locations and agricultural development has encroached upon the pre-1952 stream channel boundaries; however, not to the same extent as with Elder Creek. Outer stream cut bank erosional features are often lined with larger riparian trees but these features are now isolated and separated from the existing stream channel and appear incongruous.

Levee construction in Elder and Thomes Creeks has resulted in the stream channels acting as ditches. Stream gradient, width, and flow rates are homogeneous and riparian growth development is not favorable.

It is possible that the mouth of Thomes Creek, a large depositional delta, may be changing at its entry point into the Sacramento River. The author suggests that continued assessments of the lower mile of Thomes Creek may present an opportunity to evaluate management and bed load changes upstream. Any significant change to sediment discharge rates may alter the existing conditions at the stream's mouth. An increase in sediment discharge may increase the delta size and push the Sacramento River further to the east, while a decrease in sediment discharge may allow the river to cut away at the delta. Any change at the delta mouth of Thomes Creek is also likely to impact segments of the Sacramento River both above and below the delta. Many confounding issues likely exist with regards to sediment discharge and river dynamics and attempts at making cause-and-effect linkages need to be made with care.

Six upland sites were also considered to compare land changes between the time of the earliest available aerial photograph and the 2004 photographic images. These sites extend from immediately west of Red Bluff to a mile southwest of Paskenta.

Land use changes tended to be very subtle in the past 50+ years, with the exception of the Brewery Creek site, west of Red Bluff. Roads and subdivisions have been placed through parts of that site. Several small ponds have been constructed in several assessment areas, possibly for livestock or to provide small-scale irrigation. In some cases, such as along Elder Creek west of the Paskenta Road, it appears that dry land agriculture had been abandoned.

Gullying and stream downcutting was very pronounced in earliest photographs of the three upland assessment areas furthest to the north (Sites 1-3). Gullying was also noted in the remaining Sites 4-6 but to a lesser extent. Between the time of the earliest photographs (1938-1952) and 2004 all sites appeared to have muting of the severity and sharpness of the erosion features—suggesting that a degree of healing has occurred during the 52-66 year period. This also suggests that a significant erosion event occurred shortly prior to 1938, which may have been more severe than any floods since that time.

Riparian vegetation is very scant in all upland sites, with the exception of the immediate periphery of perennial streams. In most cases riparian growth was similar in the older and 2004 images, with two exceptions. Along Thomes Creek, just west of Flournoy (Site 5) the stream has cut away significant amounts of mature riparian growth. Also, adjacent to Oat Creek, at Site 3, there appears to be a decrease in riparian cover during the assessment period. Upland vegetation

has changed slightly in at least one assessment area, Site 3. Blue oaks have been thinned through portions of that assessment area.