3.3.2. Departure from Potential River Conditions

There are no undisturbed or lightly disturbed “control” rivers suitable for use in an analysis of the degree to which the study reaches or sub-reaches of the lower South Fork differ from their potential condition. For this reason, we conducted our assessment of the river’s departure from its potential state by using some of the alternative methods described earlier in Section 3.3. We first examined existing longitudinal variation in selected river conditions for patterns suggestive of systemic shifts away from stable conditions. We then used historical records and air photos to reconstruct changes that have occurred on the lower South Fork, and utilized quantitative relationships from Rosgen (1996) to approximate selected aspects of “potential” channel geometry.

Existing Patterns: Channel Profile, Widths and Materials. Down-cutting and other disturbances that have been reported for the lower South Fork have the potential to change a river channel’s profile, width, and bed materials. We were unable to locate an accurate longitudinal profile of the lower South Fork’s channel (the one given in Section 2 was based on crude data of uncertain accuracy), but did have data on longitudinal variability in channel widths and materials from our Level II assessment. These data were plotted for the entire length of the lower river so that they could be inspected for patterns that might provide insights on riverine processes.

The width of the lower South Fork was highly variable at multiple spatial scales in 2001 (Figure 5). Channel widths we measured at a total of 206 points along the river varied by a factor of 7 between the mouth and the National Forest boundary, by factors of 2-4 within study reaches, and by factors of 1.1-2.5 within individual sub-reaches. This high degree of variability reflects frequent channel adjustments and seems to indicate a substantial capacity for channel widening (or narrowing) within at least some portions of the study area. There is also one pattern in the variation of channel widths along the length of the river that is intriguing but of uncertain diagnosticity. The mean channel widths of sub-reaches vary in sequential fashion along several extended segments of the river and particularly within reaches SFC-2, SFC-3, and SFC-5. In each of these three reaches, the sub-reach with the greatest mean width is followed downriver by a sequence of sub-reaches with progressively narrower channels. We are unsure if this reflects underlying patterns of change in channel slope, legacies of past episodes of channel adjustment related to down-cutting, locations of key sediment source areas, lingering effects of gravel mining, or simply random patterns. Explanations for the pattern of elevated then declining channel widths might vary among the three reaches in which the pattern is most pronounced. The widest sub-reaches in these three reaches included:

- *Sub-reach 7D within reach SFC-2* was the least stable segment of the mainstem.
- *Sub-reach 7K in reach SFC-3* was immediately below Dement Creek (a major sediment source), had severe bank erosion at its upstream end, and contained a major bar subject to scalping by commercial gravel operators.
- *Sub-reach 11 in reach SFC-5* had the greatest mean channel width measured in the study area, a stable but altered channel, and a massive gravel bar that had been modified by commercial gravel operators to the point that it was a migration barrier to fish during periods of low flow.

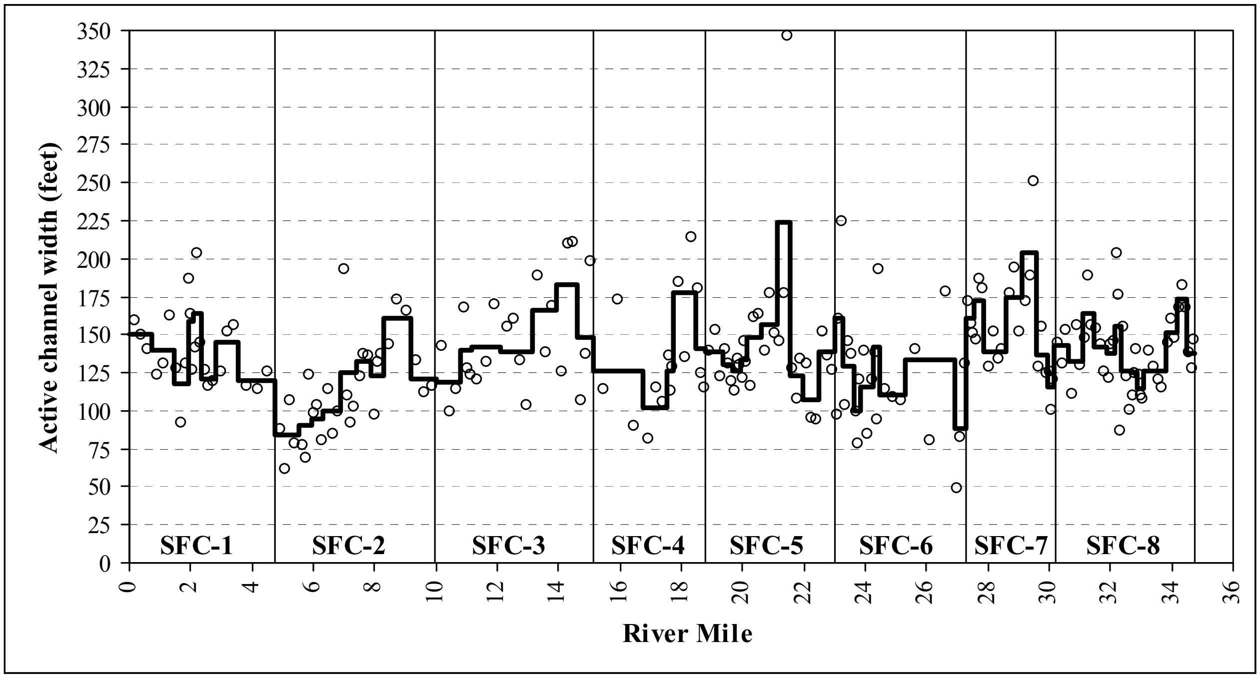

Figure 5. Active channel width versus River Mile for the lower South Fork Coquille R., Summer 2001. Open circles represent individual field measurements of channel width. The bold line represents variations in mean channel widths among individual sub-reaches of the river. Study reaches within which the sub-reaches were nested are indicated by alpha-numeric codes beginning with "SFC-".

Median (D_{50}) diameters of channel particles within riffle areas followed a typical pattern of decline as channel slopes fell in the down-river direction (Figure 6) and thus offer little diagnostic information other than to indicate the absence of clearly anomalous conditions. We did note progressive increases in the levels of fine streambed sediment with increasing proximity to the mouth, increases that were particularly large downstream of Dement in reaches SFC-1 through SFC-3 (see Appendix Table H2). The increases in fine sediment are suspected to reflect both natural deposition in response to decreasing channel slopes and the contributions of fine material from lower river tributaries and eroding banks along the mainstem.

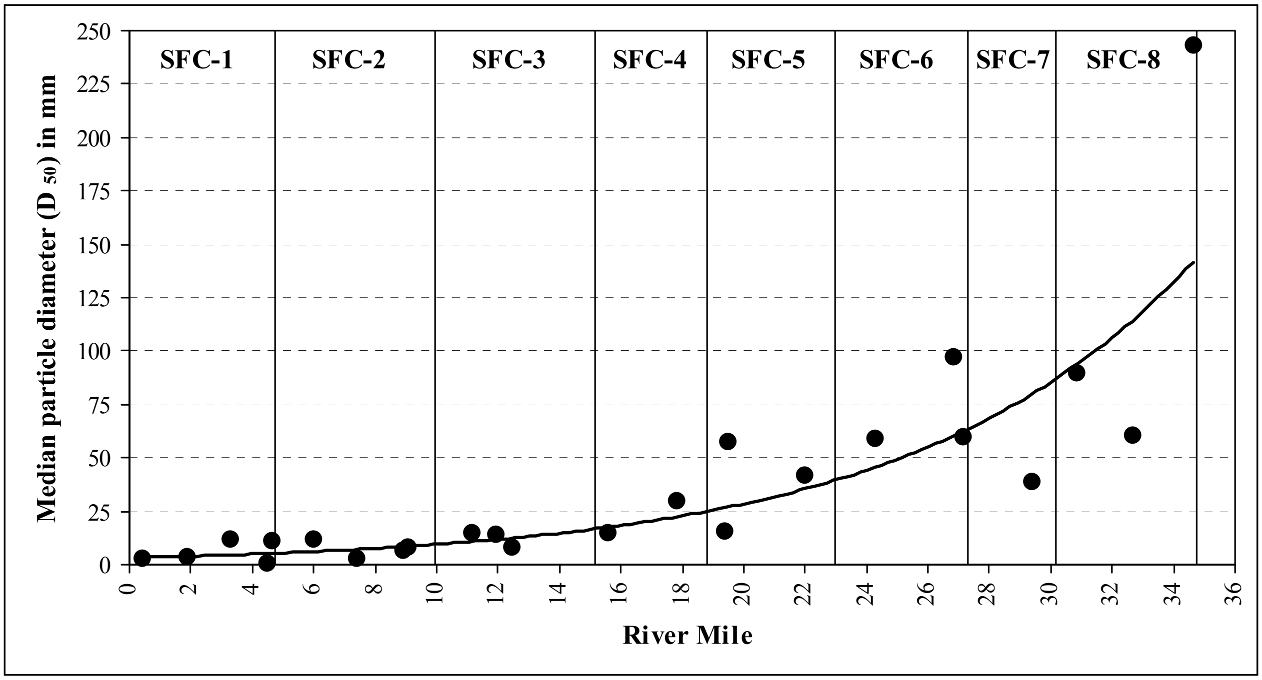

Figure 6. Median (D_{50}) particle sizes versus River Mile for Wolman pebble counts conducted on the lower South Fork Coquille River, Summer 2001. Locations of study reaches are indicated by alpha-numeric codes beginning with "SFC-".

Existing Patterns: Longitudinal Changes in Gravel Bar Area. The potential interplay between sediment supply, gravel mining, channel incision, and bank erosion along the lower-most reaches of the South Fork is an important issue that needs to be resolved. Although not a definitive approach to addressing the issue, we used data from our 206 channel transects (see Section 3.2.1) to estimate the areas of gravel surfaces exposed during low flow along the river. Our intent was to check for differences in the surface areas of bars that might be (1) evident at the study reach scale and (2) suggestive of a severe discontinuity in sediment availability. The result of this assessment was that we did not see large declines in bar area per mile of channel in the reaches below Dement (SFC-1 through SFC-3; the reaches downstream of current mining operations) when compared to study reaches farther up river. In fact, our estimates of exposed bar area/mile for each of the lower three reaches were similar to those in most of the remainder of the study area. We did, however, find that the area of exposed bar surfaces was lower in reach SFC-4 than in the other seven reaches. Reach SFC-4, between Dement and Gaylord, accounts for a sizeable portion of the section of river mined for gravel.

Existing Patterns: Longitudinal Changes in Riparian Vegetation. Riparian vegetation affects river morphology by contributing woody material to the channel and by helping banks resist erosion by binding them with dense root networks and slowing flood flows, and by encouraging sediment deposition along the channel margins. Changes in riparian conditions along a river can thus influence bank integrity and channel form.

We mapped the lower South Fork's riparian vegetation onto clear overlays of 1:12,000-scale aerial photos taken of the river in 1997, breaking the vegetation along each riverbank into four classes identified in the Oregon Watershed Assessment Manual (WPN 1999): grass/forb, shrubs, sparse trees, and dense trees. Measurements taken from the overlays were then used to estimate the percentages of total riverbank length supporting these classes of vegetation. Results of this analysis are summarized in Figure 7. The photo overlays, which could be used to help select areas for riparian restoration projects, are on file with the CWA .

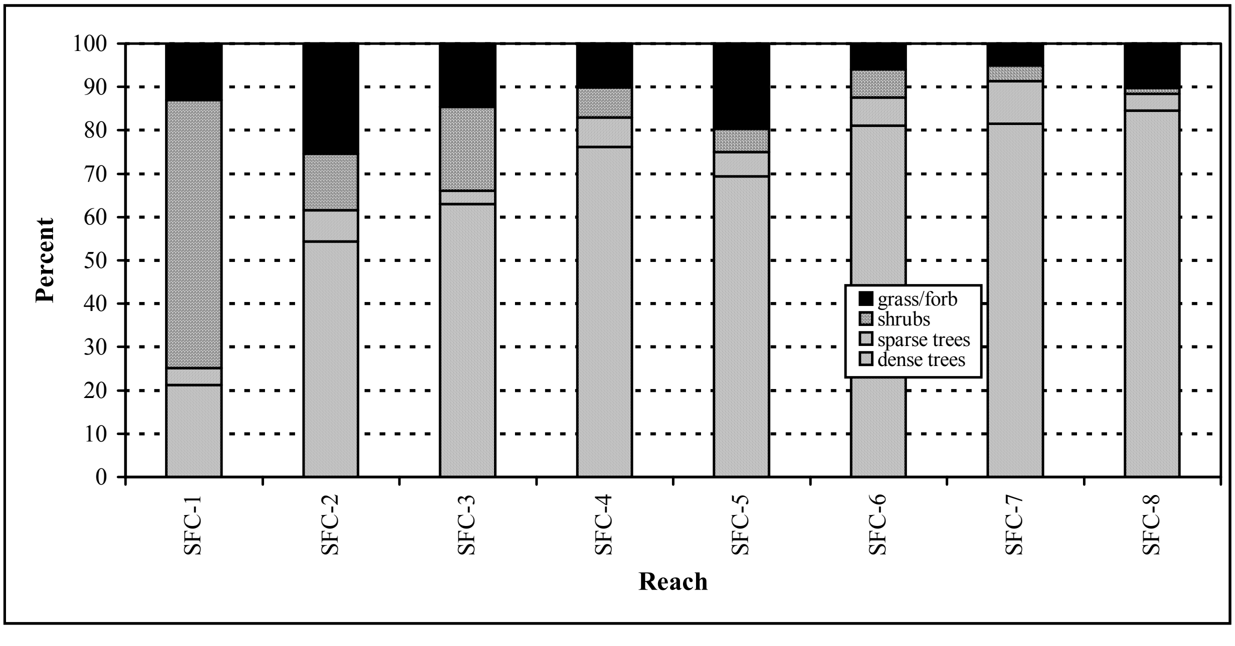

Figure 7. Percent (by riverbank length) for four classes of riparian vegetation along reaches of the lower South Fork Coquille River. Supporting data are given in Appendix Table H3.

Our photo-based analysis of the relative condition of riparian vegetation bordering the lower South Fork suggests several patterns consistent with trends in riparian disturbance and bank stability that were observed in the field or indicated by the analysis of riverbank stability summarized in Section 3.3.1. These patterns include:

- Dense stands of riparian trees were present along most of the South Fork's banks within all but the lower-most study reach (SFC-1), where shrub communities predominated.
- Riverbanks supporting shrub or grass/forb communities with very few or no trees accounted for less than a quarter of the banks within reaches above Dement (SFC-4 through SFC-8) but greater and increasing proportions of the banks as the river passed from Dement to the mouth (from SFC-3 to SFC-1).
- Banks supporting only grass/forb communities, a clear reflection of recent disturbance, were present within each of the study reaches but were most common in reach SFC-2, where channel instability and at-risk banks were most prevalent.

Historic Changes: River Alignment. Channel simplification and reductions in sinuosity are frequently associated with episodes of river down-cutting. While our surveys of the lower South Fork confirm that the river is simplified and in some areas has tall, near-vertical banks, it seemed advisable to examine possible changes in the river's historic meander pattern. Knowledge of such changes would help identify the river's "potential" state and provide insights regarding erosional processes at work in the river as well.

Two sources of information were readily available for examining planform changes that have occurred along the lower South Fork since it was in essentially pristine condition back in the mid-1800s. The first source consisted of multiple property maps available from Coos County that showed the position of the South Fork channel between the mouth and Powers (i.e., study reaches SFC-1 through SFC-6) as measured in about 1870 by General Land Office (GLO) surveyors and in about 1980 by the USGS. The second source was a map developed by Florsheim and Williams (1996) that showed changes in the position of the South Fork channel in the Middle Fork to Broadbent reach (SFC-2) between 1939 and 1992.

We acquired the maps just described, examined them for historical changes in river alignment and channel sinuosity, then used ArcView to digitize and map the channel positions shown on those portions of the maps covering study reaches that experienced significant planview changes over time. All ArcView layers created through this process are on file with the CWA.

Visual inspection and measurements of our digitized versions of river positions shown on the Coos County property maps showed little historic change in the alignment or sinuosity of the South Fork between the mouth and the Middle Fork (reach SFC-1) or between Dement and Powers (SFC-4 through SFC-6). However, substantial differences were evident between the circa 1870 and circa 1980 alignments of the river between the Middle Fork and Dement (reaches SFC 2 and SFC-3). Changes in both channel position and sinuosity occurred along this part of the river between the two periods (Figure 8). Between the Middle Fork and Broadbent (reach SFC-2), the river's sinuosity dropped 14% (from 2.48 to 2.14) as its length decreased from 6.06 miles to 5.23 miles. The circa 1870 channel within reach SFC-2 had a meander pattern that included riverbends that were both more frequent and often more acute than those now present. Reach SFC-3, from Broadbent to Dement, experienced a 5% drop in sinuosity (from 1.63 to 1.55) as its length decreased from 5.45 to 5.18 miles between the two time periods. There were no evident patterns of increase or decrease in channel widths

The changes in river meander patterns and losses of channel length that occurred within study reaches SFC-2 and SFC-3 between the mid-1800s and late-1900s likely reflect multiple changes that have occurred along the lower South Fork and within the river's watershed. For instance, some of the tighter (sharper) meander bends found along reach SFC-2 circa 1870 would be hard to imagine on a river so large without the armoring effect of large woody debris accumulations along the outsides of the bends. Such accumulations are now entirely absent from the lower river. Whatever the exact combination of causes, the losses of river length by themselves, particularly in reach SFC-2, indicate historical down-cutting, increases in channel slope, and associated increases in bank heights.

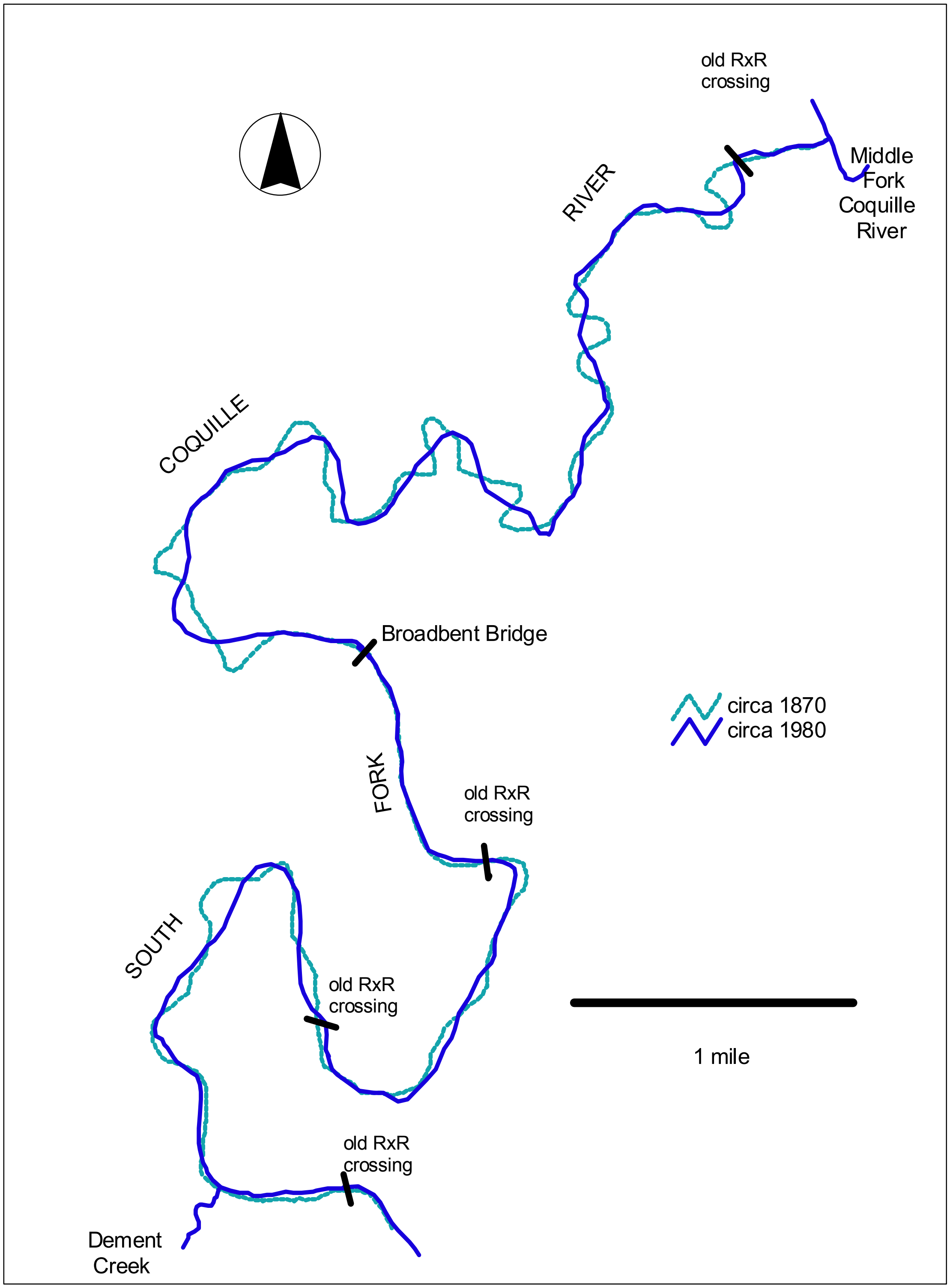

Figure 8. Changes in the alignment of the South Fork Coquille River between the Middle Fork and Dement (study reaches SFC-2 and SFC-3), 1870-1980. River positions given represent channel mid-lines.

Looking closely at planform changes that occurred in the Middle Fork to Broadbent reach (SFC-2) between 1939 and 1992, first mapped by Florsheim and Williams (1996), it is evident that much of the historic change in the lower river meander patterns occurred prior to 1939. Lateral channel migration was evident at multiple locations within this reach between 1939 and 1992, but the basic meander pattern and total reach length remained fairly stable (Figure 9). Varied segments of the reach exhibited relative constancy, channel widening, or channel narrowing. The magnitudes of changes in width were small at all but a few locations. At one of these locations, a couple of miles below Broadbent (subreach 7C), the channel was as wide or wider in 1939 than it is today in the most unstable portion of reach SFC-2 (i.e. subreach 7D). By 1992, the channel within subreach 7C had narrowed by as much as 50%, reflecting the river's ability to recover stability following disturbance.

Historic Changes: Comparisons of 1939 and 1997 Aerial Photos. Comparisons between recent and historic aerial photos are often used to evaluate changes or trends in stream channel and adjacent riparian conditions. For example, Florsheim and Williams (1996) examined eight sets of aerial photos taken of the Middle Fork to Broadbent reach (SFC-2) at varying intervals between 1939 and 1992. They concluded that over the 54-year period this section of river was (1) bordered primarily by a narrow strip of riparian vegetation and (2) experienced episodic bank migration that varied by location while averaging 0.3 feet/year across the entire reach. The level of channel migration reported was not particularly extreme even though shifts in channel position did occur at some locations, as previously discussed (see Figure 9).

We supplemented Florsheim and Williams' work by interpreting the oldest (1939 black/white images; 1:10,500-scale) and most recent aerial photos (1997 color images; 1:12,000-scale) available in order to assess changes in widths of the river's channel, riparian canopy, and riparian corridor within the study reaches. Our intent was to use the photos to develop a clearer understanding of how much change had or had not occurred within the study area during the period bracketed by the photos.

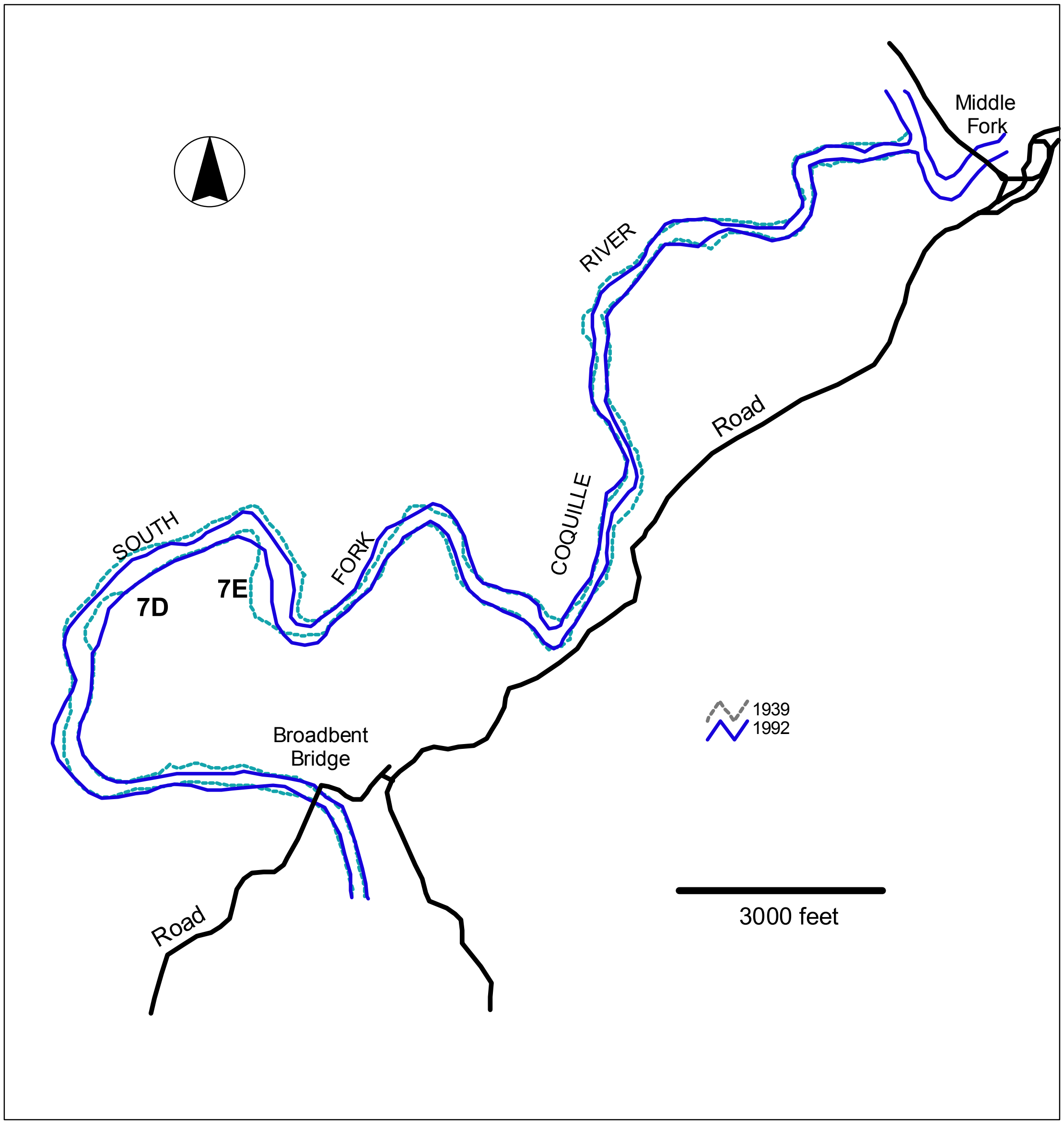

Figure 9. Shifts in channel position along the South Fork Coquille River between the Middle Fork and Broadbent, 1939-1992. Source: air photo interpretations by Florsheim and Williams (1996).

The photo-based evaluation was conducted by first making qualitative comparisons of the two photo sets to identify any gross-scale changes that were evident. We then established sample points (139 total) at constant 0.25-mile intervals along the river in the 1997 photos, carefully transfered these points to 1939 photos, scanned all photos into a computer, then used SigmaScan (Fox and Ulrich 1995) to measure and record the widths of interest for each station and year. Means and patterns of variation in conditions at the multiple stations within each study reach below Rowland (SFC-1 through SFC-5) were then compared across the two years. Good 1939 photo coverage of the reaches above Rowland was either incomplete (for SFC-6 and SFC-7) or non-existent (for SFC-8).

Qualitative comparisons. Two gross-scale patterns evident in the air photos seem worthy of note. First, most of the historic loss of riparian forests that Benner (1991) described for the lower river occurred prior to 1939. Second, gravel deposition was more extensive along most of the lower South Fork in the earlier (1939) photos than in the more recent (1997) ones, suggesting major inputs of sediment to the channel when the watershed was first developed. Much of the river channel was clearly incised in the 1939 photos, although whether the degree of incision was as great as in 1997 (or today) could not be discerned. It is possible that high levels of sediment delivered to the channel in early years partially counter-acted tendencies toward incision. It has been hypothesized that changes in watershed management that have reduced sediment inputs in the last couple of decades may have combined with commercial gravel mining that occurs in reaches SFC-3 through SFC-5 to allow additional channel incision along lower portions of the study area (Florsheim and Williams 1996). Our review of the air photos could neither confirm nor deny this chain of events.

Quantitative assessment. Measurements taken from the 1939 and 1997 air photos indicated variable changes in the widths of channel openings, riparian canopies, and riparian corridors along the five reaches of the lower South Fork that we assessed (Table 7; see Appendix J). The direction and magnitude of these changes varied among reaches and among sites within reaches, but several patterns were evident. Changes documented in each river reach downstream of Rowland (i.e., SFC-1 through SFC-5) are described below:

- *Reach SFC-1.* The mean width of channel openings increased while the riparian canopy tended to get narrower at the mainstem photo-points between the mouth and Middle Fork. Mean width of the riparian corridor changed little along the reach, suggesting that the reduction in channel opening may have resulted from increases in channel width, losses of large trees overhanging the channel, or both.

Table 7. Mean values for the widths of channel openings, the riparian canopy, and the riparian corridor at sample points within five reaches of the lower South Fork Coquille R., 1939-1997. Data were based on interpretations of air photos.

Reach	Year	Channel opening	Riparian canopy width	Corridor width
SFC-1	1939	107.6 (5.9)	80.7 (9.8)	269.0 (21.3)
(n=19)	1997	145.1 (9.7)**	64.0 (7.5)	273.1 (13.8)
SFC-2	1939	109.3 (15.3)	74.6 (9.1)	258.4 (17.8)
(n=20)	1997	144.8 (15.1)*	70.3 (10.2)	285.4 (21.4)*
SFC-3	1939	168.6 (24.2)	65.5 (9.7)	299.6 (33.1)
(n=21)	1997	139.8 (8.6)	90.0 (14.2)	319.8 (32.5)
SFC-4	1939	138.0 (10.5)	96.9 (14.8)	331.8 (25.8)
(n=14)	1997	128.9 (15.4)	78.4 (12.2)	285.7 (26.8)*
SFC-5	1939	183.8 (22.8)	129.4 (17.7)	442.6 (41.3)
(n=18)	1997	137.5 (6.2)*	98.1 (13.4)*	333.7 (25.9)*

* significantly different ($p<0.1$)
** very significantly different ($p<0.01$)

- *Reach SFC-2.* Channel opening and riparian corridor width increased while the mean width of the riparian canopy changed little along the South Fork between the Middle Fork and Broadbent between 1939 and 1997. These differences combine to reflect a substantial increase in average channel width during this period. Given that any overall increase in channel width here was not particularly dramatic between 1939 and 1992 (see Figure 9), this appears to reflect very recent morphological changes within the reach. Multiple sample points along this reach lost all of the trees on one of their banks.

- *Reach SFC-3***.** Changes were variable within the reach from Broadbent to Dement but tended toward narrower channel openings and wider riparian canopy widths. Multiple sample points along this reach had riparian canopies considerably wider in 1997 than any of the sample points had in 1939.

- *Reach SFC-4.* Between Dement and Gaylord, the South Fork experienced a significant reduction in the mean width of its riparian corridor between 1939 and 1997. Multiple sample points along the reach lost all of the trees on one of their banks during the period.

- *Reach SFC-5*. The reach between Gaylord and Rowland experienced significant reductions in channel openings between 1939 and 1997, partly reflecting strong channel narrowing and riparian encroachment at sites that had very wide openings in 1939. Contrasting with this trend, mean riparian canopy and corridor widths declined significantly during the period. Much of the riparian loss was caused by land-clearing activities that removed trees from the outer portion of formerly wide stands of trees.

Analytical Approximations of Stable Channel Geometry. Two study reaches, SFC-2 and SFC-3, appear to deviate substantially more from their historic or "potential" condition than do the other six reaches. Losses of sinuosity, channel down-cutting, riparian decline, and other changes have affected their stability. We took measurements from our planview maps of the circa 1870 and circa 1980 alignments of these two reaches as a basis for developing *very preliminary approximations* of the level of re-meandering that might be needed to re-establish natural channel stability. We also used channel geometry equations provided by Rosgen (1996; page 8-34) to calculate selected dimensions of the "potential" channel for each reach, largely for comparison to the information developed from measurements of the historical alignment.

Using direct measurements from historic channel alignments as indicators of natural stability, PWA used sine-generated curves to mathematically predict the increase in meander amplitude needed to return the river to its historic sinuosity (A. Collison, PWA, pers comm.). For the Middle Fork to Broadbent reach (SFC-2), the river would need to increase its meander amplitude by around 502 feet to re-establish the level of sinuosity assumed to be stable. For the Broadbent to Dement reach (SFC-3), the amplitude would need to increase by about 469 feet. This implies that unless the banks are stabilized through some combination of aggressive treatments with vegetation and strategic protection of most-vulnerable banks with bio-engineered toe protection, set-back allowances of these amounts may be required to permit the river to reach a natural state of equilibrium. These set-back distances would not be required everywhere, because maximum erosion would be expected to occur only on the apexes of meanders, and on the downstream ends of the meanders.

Equations and theory provided by Rosgen, plus field data from our representative channel segments, combine to suggest that idealized stable channels within these two reaches would have the following characteristics:

Reach	W/D ratio	Bankfull width	Meander length	Meander radius of curvature
SFC-2	12:1	166 ft	1660-2324 ft	415-498 ft
SFC-3	12:1	160 ft	1600-2240 ft	400-480 ft

Such channels would look substantially different than those found in the area circa 1870.

3.3.3. Implications of Our Level III Analyses With Regard to Improving Channel Stability

Within the pre-developed landscape, the lower South Fork had streamside forests dominated by large trees that overhung the river channel to a greater degree than most of the altered riparian community does today. It is clear that it also had a wood-affected channel with lower sediment transport and bank erosion rates. Wide corridors of riparian vegetation along the river apparently once transitioned from a conifer-dominated condition near what is now the National Forest boundary to hardwood communities containing few conifers along the lower study reaches. Removal or alteration of these streamside forests, changes in watershed conditions, and other factors have over time led to a simplified river system with reduced habitat quality and increased channel incision throughout most of the lower South Fork. These changes have contributed to reductions in channel stability that have been relatively minor upstream of Rowland (in reaches SFC-6 through SFC-8), greater below Rowland (in reaches SFC-1 through SFC-5), and particularly pronounced in some segments of the two study reaches between the Middle Fork and Dement (SFC-2 and SFC-3).

Along some segments of the South Fork below Rowland, and particularly below Dement, the once-extensive bottomland forest has been replaced by a narrow band of hardwoods or shrubs that often provides only limited resistance to toe erosion and lateral channel migration. Some segments of riverbank lack even this level of vegetative protection and consist of bare earth or grasses that may be grazed by livestock. Where narrow, sparse or negligible riparian buffers combine with the reduced geotechnical bank stability that has been caused by historic channel incision and associated increases in bank height, a situation is created where the risk of rapid bank erosion is high. In these high-risk situations, both the vulnerability of riverbanks to erosion and the magnitude of the erosive forces acting within the channel during floods have been increased. Natural channel migration or subtle shifts in channel alignment caused by localized "bank protection" measures within these high-risk areas can cause the river to erode bank toes, oversteepen banks, remove remaining vegetation, and erode floodplain soils at a rate unaffected by the resistance provided historically by a bottomland forest.

Given what is known about the lower South Fork, it seems clear that efforts to improve channel stability in vulnerable areas will be ineffective unless river down-cutting has been stopped or reversed and that the restorative actions taken by landowners are first planned collaboratively at a sub-reach to reach scale. Areas of high riparian integrity need to be maintained or expanded, and riparian setback distances need to be increased where possible. Stabilization efforts will require that raw banks be at (or re-contoured to) geotechnically stable angles for their heights and that riparian vegetation be restored to help resist lateral erosion. Successful vegetative plantings on the lower to mid-elevation surfaces of banks will help maintain stable bank angles. These plantings are likely to rely heavily on the ability of willows to colonize disturbed sites and will often need to be quite intensive. Cautiously applied bioengineering approaches that include the use of rock may be needed to help stabilize bank toes in some instances, but localized bank treatments that are not part of a coordinated sub-reach to reach-scale restoration effort should be avoided. Treatments implemented without such context appear to have contributed to channel instability problems seen in some of the least stable areas along the lower river.