REVIEW DRAFT

GEOMORPHIC AND RIPARIAN ASSESSMENT OF THE LOWER SOUTH FORK OF THE COQUILLE RIVER

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4. SHADOW MODELING

The CWA asked that stream shading within the study area be evaluated using the SHADOW model developed by the U.S. Forest Service (USFS 1993). SHADOW is a spreadsheet model that runs under Lotus123 and uses trigonometric relationships combined with data on sun angle, latitude, stream aspect, channel form, and riparian conditions to estimate the degree to which a stream is shaded from incoming solar radiation. The model can be used to estimate existing levels of stream shading and to predict future levels of shading that would result from changes in riparian conditions and/or channel form. SHADOW outputs thus provide an opportunity to (1) examine spatial patterns of shading along a stream or within a drainage network, and (2) identify the magnitude of potential shade improvements that could be achieved if conditions were restored to their potential along segments of stream altered by past activities. Both uses of the model were the intent of the CWA when it requested that the SHADOW model be applied to the study area. Model outputs will give the CWA a useful tool for identifying where riparian projects will help lower stream temperatures and thus improve water quality conditions in the South Fork Coquille River watershed.

4.1. DATA ACQUIRED FOR EVALUATIONS OF STREAM SHADING

A combination of field and office-based methods was used to acquire data on 16 parameters relevant to an evaluation of stream shade levels along the 154 channel segments delineated within the study area (Table 8). Information on each parameter was compiled for each channel segment and subsequently incorporated into an Excel spreadsheet. Data on 12 of the parameters were required as segment-specific inputs for SHADOW (USFS 1993). These data could be manipulated and copied within Excel then pasted into appropriate columns within the SHADOW spreadsheet in order to perform a specific analysis. Data on the other four (supplemental) parameters were useful in structuring SHADOW analyses or were of interest to the CWA for other reasons related to its riparian restoration program.

Table 8. Parameters and data types (assigned [A], field measured [F], map-based [M], interpreted from aerial photos [Ph], and predicted [Pr]) acquired for evaluating stream shade conditions along the lower South Fork Coquille River and selected tributaries.

Parameter	Model input required by SHADOW?	Data types for the South Fork	Data types for tributaries
Reach/segment identification code	yes	A	A
Selected (Y/N) for analysis	yes	A	A
Stream orientation (aspect of –90 to 0 to +90)	yes	M	M
East/West/Both (streambank designation)	yes	Ph, M	Ph, M
Channel length (feet)	yes	M	M
Active channel width (feet)	yes	F	Pr
Low flow stream width (feet)	yes	F	Pr
Percent tree overhang (decimal percent)	yes	F	Ph
Tree height (feet)	yes	F	Ph
Tree to channel distance (feet)	yes	F	Pr
Tree to channel slope (decimal percent)	yes	F	Pr
Shade density (decimal percent)	yes	F	Ph
Riparian vegetation type	no	F	Ph
Structures in riparian corridor (decimal percent)	no	Ph	Ph
Landuse type	no	M, Ph	M, Ph
Width of riparian management zone (feet)	no	M, Ph	M, Ph

Field measurements were given very strong emphasis in assembling the shade-related data for analyses of conditions along the mainstem South Fork, with values for measured parameters obtained at each of the 3-4 equally spaced channel cross-sections examined within each study segment as part of the geomorphic analysis . There were two primary reasons for this emphasis on field data. First, field measured data are more reliable than those derived from air photo interpretations or other office-based methods. We found early in the study that a high and variable level of channel incision made it difficult to impossible to generate reliable office-based estimates of parameters like tree height along many segments of the mainstem river. Second, the entire mainstem could be (and was) easily reached via kayak or on foot from multiple strategic private access points, allowing concurrent collection of extensive riparian and stream channel data that could be used for our analyses both of stream shading and (as described in Section 3.2.1) of channel morphology.

Data on shade-related parameters for stream reaches in the tributary watersheds (Dement, Yellow, and Hayes Creek) were derived primarily from interpretations of 1:12,000-scale color air photos taken during Spring 1997, predictive relationships developed from field measurements taken at a limited number of locations, and other office-based methods. Photo-interpreted data for these reaches were checked at a subsample of five intensively measured reaches in the Dement Creek watershed that were evaluated using the same transect-based methods applied along the mainstem South Fork, and at several additional reaches examined at lower intensity (Appendix Table J1). Field evaluations helped to verify or calibrate photo-based data developed for the tributaries but did not provide the high level of confidence in parameter values that was obtained for the mainstem channel segments. *Our ability to acquire additional field data to validate or calibrate the tributary data was limited by access to private lands and budgetary constraints.*

4.1.1. SHADOW Inputs

Descriptions of the data compiled for each input parameter needed to run the SHADOW model are given below. Actual parameter values incorporated into our database and used to run the model are provided in Appendix Tables J2-J5.

Reach/Segment Identification Code. A total of 154 stream segments were evaluated using the SHADOW model. These were the same segments examined during the geomorphic assessment of streams in the study area and were delineated on the basis of changes in one or more of the following: Rosgen channel type, stream orientation, riparian conditions, and landuse type. Each stream segment was identified by a unique alpha-numeric code so that data on channel and riparian conditions along the segment could be incorporated into a GIS (ArcView) and geo-referenced to digital maps of the study area. The codes used were the same as those assigned during the geomorphic assessment described earlier in this report.

Selected (Y/N) for Analysis. Each channel segment was selected ([Y]es) when shade conditions along the stream or stream system (watershed) of which the segment was a part were evaluated. Segments could be excluded ([N]o) from analyses when appropriate.

Stream Orientation (-90º to 0º to +90º). Stream orientation was measured as described in the SHADOW user's manual (USFS1993), using 7.5-minute topographic maps and a protractor to determine the rotational angle (to the nearest 5º) between due North and the actual alignment of the channel segment.

East/West/Both (Streambank Designation). The SHADOW database was structured to provide one record (a full set of parameter values) for each stream segment unless streambank conditions differed substantially between the two banks along a given segment. Where segments were represented by one record, the streambank designation was assigned a value of "B" to indicate that conditions along both banks were similar. Where conditions were substantially different along the two streambanks bordering a channel segment, two records with identical channel parameters but differing riparian conditions were incorporated into the database. Such cases accounted for 55 of the 154 channel segments in the study area, with each record identified as being for the East ("E") or West ("W") streambank as defined by rules given in the SHADOW user's manual (USFS 1993).

Channel Length (Feet). The length of each channel segment was measured from digital versions of 7.5-minute topographic maps. Segments ranged in length from 800 to 8350 feet along the mainstem South Fork and from 530 to 5135 feet on streams in the three tributary watersheds.

Active Channel Width (Feet). Active (bankfull) width was field measured within each mainstem channel segment by project staff, field measured in 10 dispersed tributary reaches by project staff or during recent ODFW aquatic surveys, and predicted for the remaining tributary reaches. Channel widths entered into the SHADOW database for segments of the mainstem South Fork were each the average of measured values obtained at 3-4 evenly spaced cross-sections in a given segment. The pattern of variation in these widths along the length of the lower South Fork and among the mainstem channel segments was shown earlier, in Section 3.3.2 of this report (see

Figure 6). The mean active channel width of the mainstem segments ranged from 84 to 223 feet and at times differed substantially between adjacent segments.

As indicated, channel widths for tributary reaches within the study area were either measured in the field or predicted. Predicted values were derived through the use of a relationship developed by regressing channel width versus distance from headwater (per 7.5 minute USGS topographic maps) for the 10 tributary reaches that were measured (Figure 10). For each unmeasured reach, active channel width was predicted as 4.8942 + (0.0011)(distance [in feet] from the tributary's headwater). Active channel widths incorporated into the SHADOW database for the 87 tributary reaches varied from 6 to 49 feet.

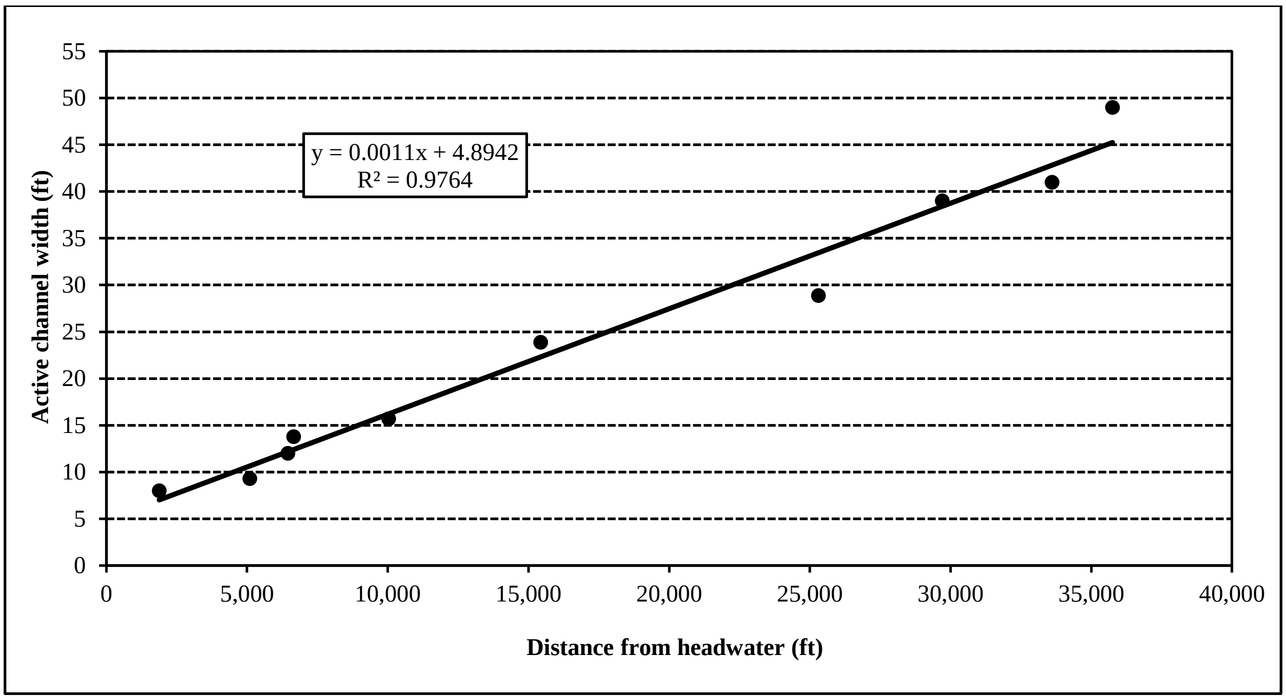

Figure 10. Active (bankfull) channel width versus distance from headwater for 10 channel segments on tributaries to the lower South Fork Coquille River, Oregon.

<u>Low-flow Stream Width (Feet)</u>. Low-flow widths were measured by project staff within each of the channel segments delineated along the mainstem South Fork, measured in seven tributary reaches for which information on active channel width was also available, and estimated for the remaining tributary reaches. Low-flow widths entered into the SHADOW database for segments of the South Fork were the means of values measured during September 2001 at the same 3-4 evenly spaced cross-sections per segment that were measured for active channel width. The pattern of variation in low flow width along the length of the lower South Fork and among the mainstem channel segments is shown in Figure 11. The mean low-flow width of the segments ranged from 30 to 197 feet and in multiple instances differed substantially between adjacent segments.

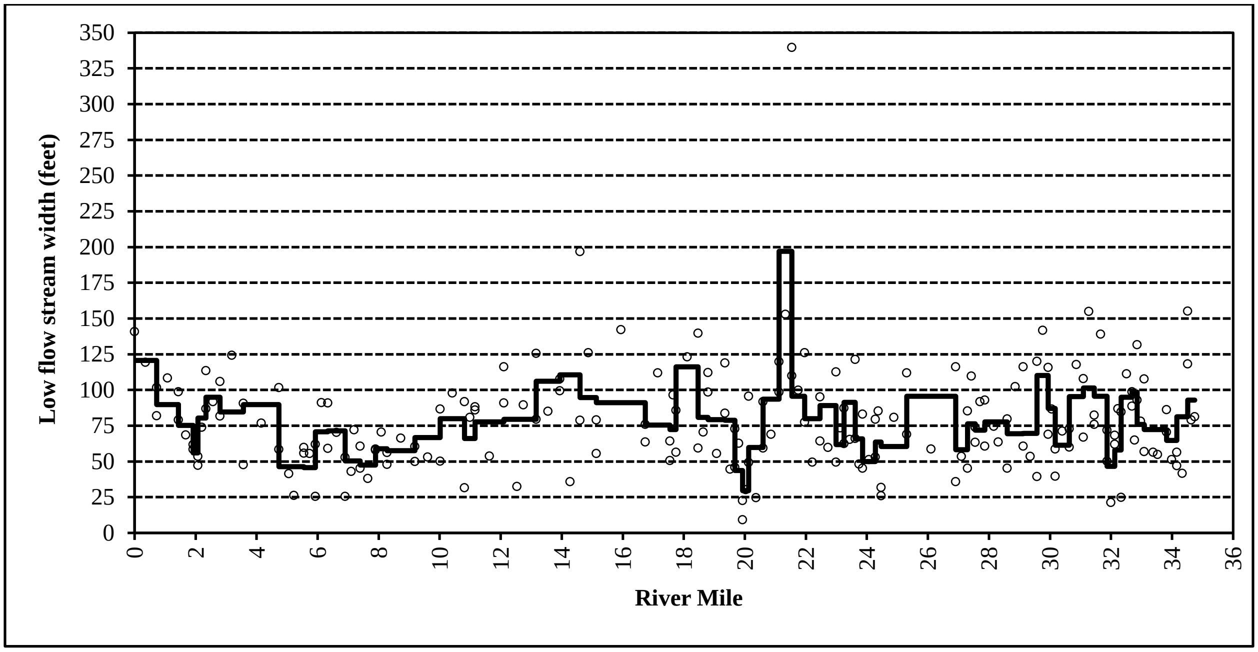

Figure 11. Low-flow width versus River Mile, lower South Fork Coquille River, Oregon, September 2001. Open circles represent individual width measurements and the bold black line depicts variation in mean width among 67 channel segments delineated during the study.

Low-flow widths entered into the SHADOW database for the tributary reaches were either measured or predicted and ranged from 0.0 to 19.0 feet. Where measurement data on low-flow width were lacking, the predicted value for a given reach was 14.7% of the measured or predicted active channel width for that reach. This was the average value found at the tributary reaches for which both low-flow width and active channel width measurements were available (mean= 14.7%; S.E.= 6.9%; n=7).

Percent Tree Overhang (Decimal Percent). The percent of active channel width and of low-flow stream width overhung by riparian vegetation were measured at the multiple cross-sections examined within each study segment of the mainstem South Fork during September 2001. Segment-specific means for percent vegetative overhang varied considerably along the lower river (Figure 12), ranging from 0 to 23% (average = 9%) for the channel and 0 to 19% (average = 3%)

for the wetted stream. The values for vegetation overhanging the wetted stream were incorporated into the SHADOW database as "Percent tree overhang" because they were more strongly related to levels of stream shading observed in the field.

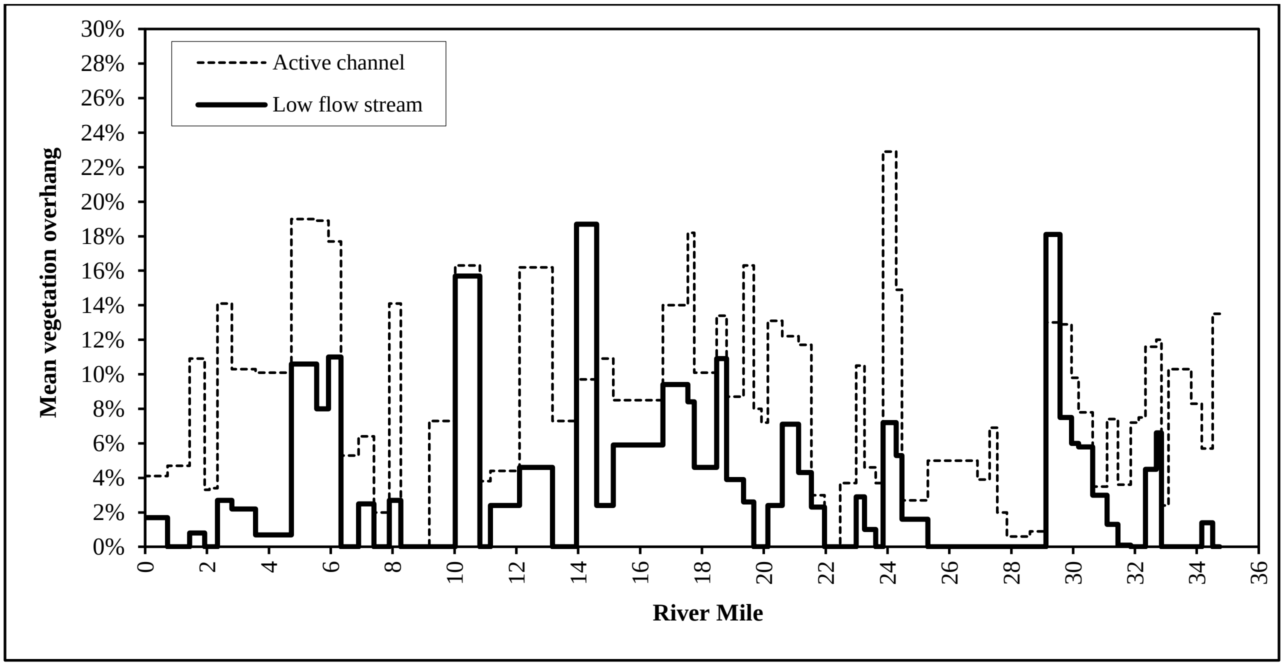

Figure 12. Longitudinal variation in the percentage of active channel width and of low-flow (wetted) stream width overhung by riparian vegetation, lower South Fork Coquille River, September 2001. Values shown are means for each of 67 study segments of the river.

Estimates of percent tree overhang for each tributary reach within the study area were developed by interpreting air photos and checked at five calibration reaches that were examined using the same transect-based field techniques used along the mainstem South Fork. Photo-interpreted values for percent tree overhang varied from 15 to 95% among the tributary reaches, averaged 82%, and differed little (mean = +2%) when checked against the means of field-measured values obtained within the calibration reaches. Photo-interpreted values were entered directly into the SHADOW database unless a particular tributary reach had been measured, in which case the mean field-measured value for percent overhang was entered.

Tree Height (Feet). Existing condition values used for this SHADOW parameter were based on direct measurements of the height of vegetation along the mainstem South Fork and on air photo interpretations plus limited field-checks of conditions for stream reaches in the tributary watersheds. On the South Fork, we measured the heights of the primary shade-producing vegetation at the bank ends of the multiple cross-sections examined within each study segment. These heights varied both within and among segments (Figure 13), with segment-specific mean heights ranging from 19 to 94 feet. A high level of variation found within individual mainstem segments often reflected patterns of riparian disturbance and caused us to use the 75th percentile height measured along each segment of channel or riverbank as a best approximation of the dominant "tree height". This approach was used so that unusually tall or short vegetation would not skew estimates of the height of dominant vegetation and allowed us to use the "shade density" parameter in SHADOW to account for measured variability in the height of shade-producing vegetation bordering individual channel segments (described later).

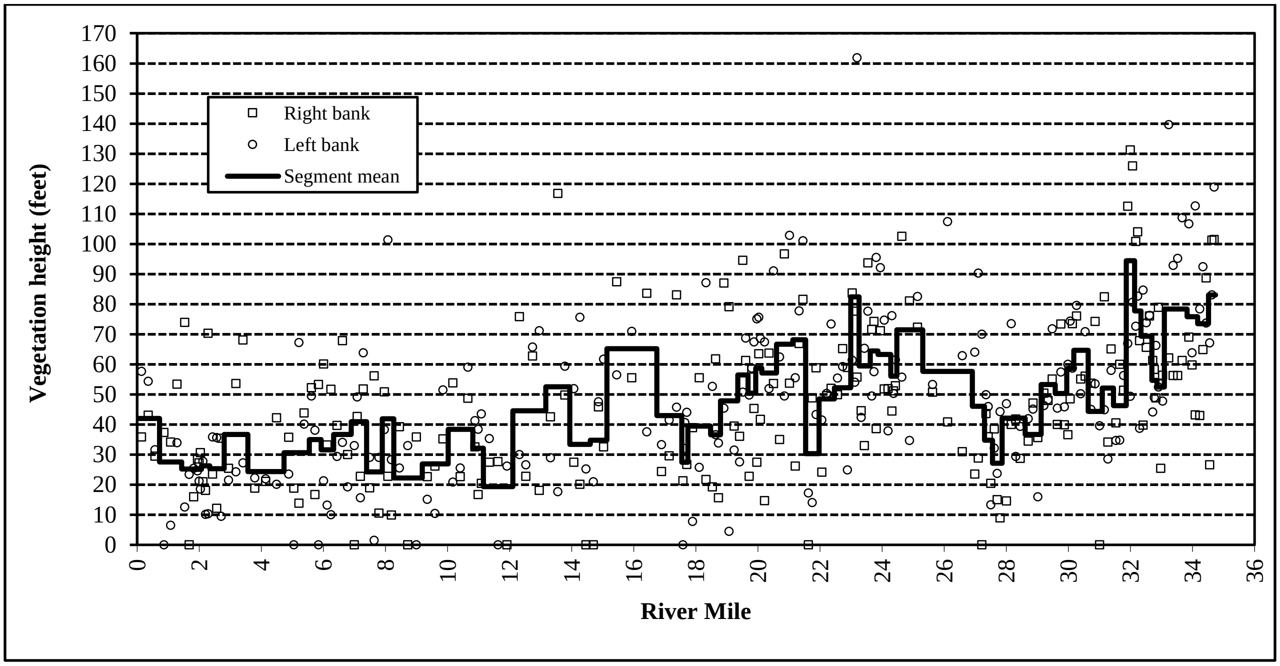

Figure 13. Longitudinal variation in the height of dominant, shade-producing riparian vegetation, lower South Fork Coquille River, September 2001. The bold line gives mean values for each of 67 study segments of the river.

The height of the dominant shade-producing vegetation bordering each of the 87 study reaches in tributary watersheds was estimated from the 1997 air photos and measured in the field at 11 (13%) of these reaches. Photo-based estimates of tree height were very similar to field values for all 5 measured reaches that had low (<2%) gradients (mean error = +3%). Photo-based estimates were therefore incorporated directly into the SHADOW database, without adjustment, for each low-gradient reach lacking measurement data. Photo-based tree height estimates for the remaining measured reaches, all of which had channel gradients >2%, were biased low. For this reason, photo-based estimates for steeper (i.e., $\geq$2%) channel segments that lacked measurement data were incorporated into the database after applying a regression-based correction derived from our data for the steeper measured reaches: tree height = 1.275 x estimate + 0.107 (r^2=0.87). Measured tree heights were used in the SHADOW database whenever available.

Tree to Channel Distance (Feet). Channel offsets for primary shade-producing vegetation were measured at the bank ends of multiple equally spaced cross-sectional transects within each study segment of the mainstem South Fork and within each of the five intensively measured tributary reaches in the Dement Creek watershed. Mean values of these measured "tree to channel" distances were entered directly into the SHADOW database. Mean offset distances measured within study segments of the South Fork ranged from 8 to 52 feet (Figure 14), while those for the measured tributary reaches varied from 3 to 13 feet. Lacking better data, the following tree to channel distances were assumed for unmeasured tributary reaches: 4 feet for first-order channels, 5 feet for second-order channels, and 10 feet for third order channels. These values were based on those found at the measured tributary reaches and fall within ranges suggested as appropriate in the user's manual for the SHADOW model (USFS 1993).

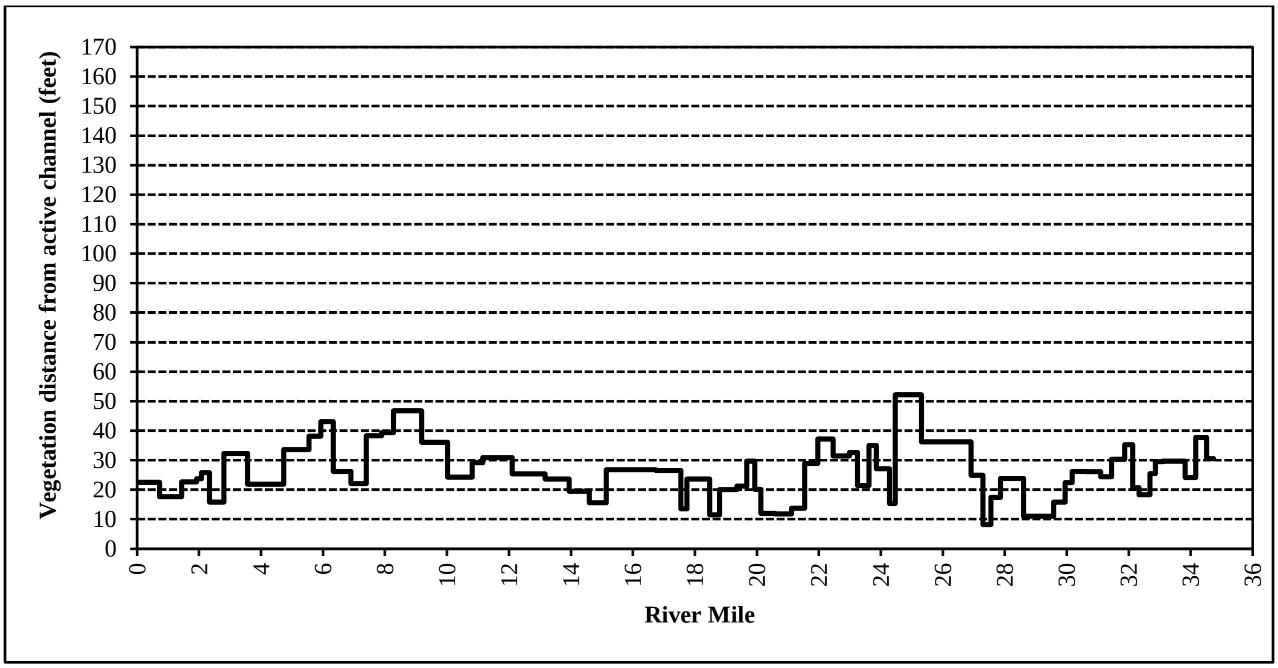

Figure 14. Longitudinal variation in the distance between the primary shade-producing vegetation and the active (bankfull) channel, lower South Fork Coquille River, September 2001. Values shown are means for each of 67 study segments of the river.

Tree to Channel Slope (Decimal Percent). Mean tree to channel slope was calculated from field measurements taken at the multiple cross-sections examined within each study segment on the mainstem and within each of the five intensively evaluated reaches in the Dement Creek watershed. Each calculated slope positioned shade-producing vegetation the appropriate height above the low flow water surface (Figure 15).

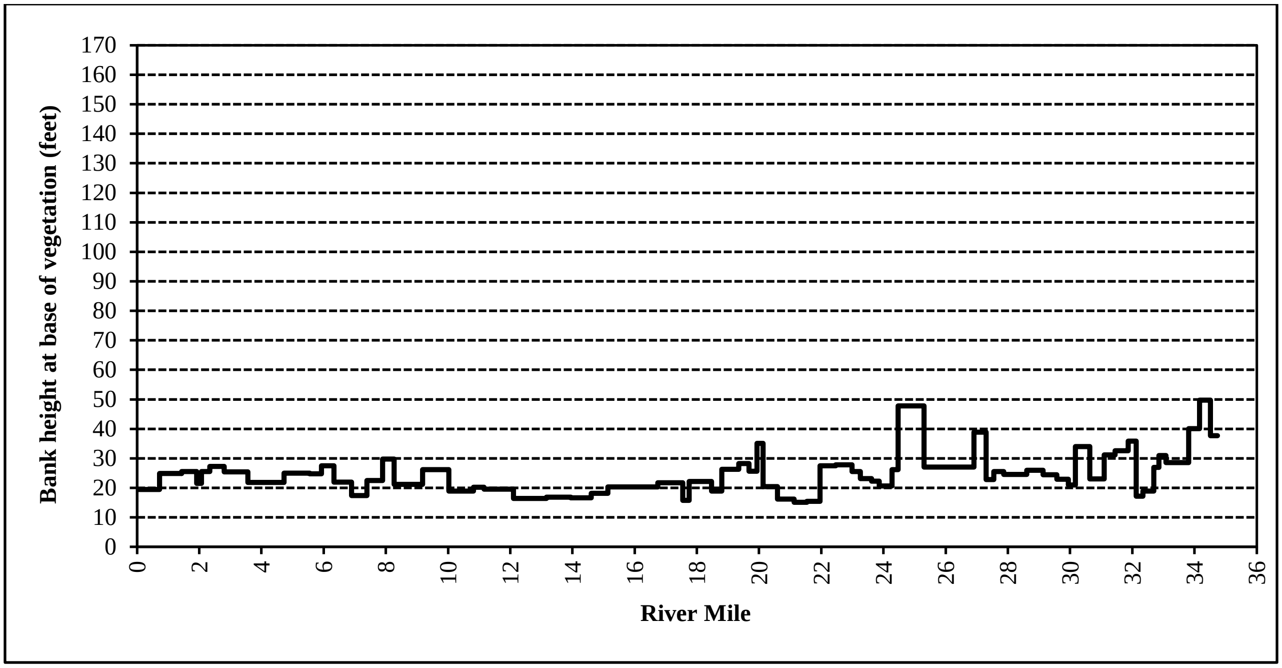

Figure 15. Longitudinal variation in bank height (relative to the low-flow water surface) at the base of primary shade-producing vegetation, lower South Fork Coquille River, September 2001. Values shown are means for each of 67 study segments of the river.

The following values for tree-to-channel slope were assigned to unmeasured tributary reaches: 0.65 for 1st order channels, 0.54 for second-order channels, and 0.43 for third-order channels. These were the means of tree-to-channel slope values that Follansbee (2002) found within the nearby North Fork Coquille watershed along channels in what he called “steep canyon”, “medium canyon”, and “small valley” streams, respectively. The values were adequate for our modeling purposes because (1) they were not substantially different from those actually found along the tributary reaches that were measured and (2) this parameter had a relatively negligible effect on SHADOW outputs given the close proximity of riparian trees to tributary channels (see above).

Shade Density (Decimal Percent). Shade density values incorporated into the SHADOW existing conditions database were either based on measurements taken at multiple cross-sectional transects within a channel segment or interpreted from air photos. Values for each segment of the lower South Fork and for the five intensively measured reaches in the Dement Creek watershed were calculated from field data as follows:

1. All measured vegetation heights for the streambank(s) were pooled.
2. Vegetation heights exceeding the 75th percentile value (i.e., potential tall outliers) for the streambank(s) were truncated to the 75th percentile height.
3. Each measured (or truncated) height was divided by the 75th percentile height.

4. The average of the values obtained in step 3 (above) was multiplied by an estimate of riparian canopy density (in decimal percent). A canopy density of 0.95, representative of the means of densiometer readings we obtained beneath hardwoods (94.9; n=46; SE=0.5), conifers (93.8; n=16; SE=0.7), mixed tree stands (94.7; n=9; SE=8), and shrubs (95.3; n=14; SE=0.5) along the lower South Fork, was used for all mainstem channel segments. Canopy densities measured on-site with a densiometer were used for each of the five measured tributary reaches.

Photo-based estimates of shade density for the measured reaches in the Dement Creek watershed were within about 10 percent or less of the values calculated from field measurements, with a slight (-3 percent) bias toward underestimating shade density. The small number of measured reaches and limited degree of apparent bias led to a decision to use unadjusted photo-based estimates for this parameter for all unmeasured tributary reaches within the study area.

4.1.2. Other Shade-related Parameters Included in the Database

Riparian Vegetation Type. Predominant riparian vegetation along channel segments was classified into types on the basis of field observations at transects or through air photo interpretation. Vegetation types included were those suggested by the OWEB watershed assessment manual (Watershed Solutions 1999): grass/forbs [G], shrubs [S], hardwood trees [H], mixed tree species [M], and conifer trees [C].

Structures in Riparian Corridor. The areal percent of the riparian corridor within 100 feet of the active stream channel that was occupied by roads, buildings, or other artificial structures was estimated from the 1997 air photos.

Landuse Type. Landuse along each of the 154 channel segments within the study area was classified as forestry (For) or agriculture/rural residential (Ag/RR). Classification was based on a combination of digital maps of zoned landuse and air photo interpretations. Actual landuse was not always consistent with zoned use. Classified use defaulted to zoned use unless actual use was consistently and dramatically different than zoned use.

Width of Riparian Management Zone. Widths of riparian management zones along the study segments were 50 feet on each side of stream channels within agricultural/rural residential lands and varied from 0 and 100 feet within forest lands.

4.2. MODEL CALIBRATION

Initial SHADOW output was compared to shade levels we actually measured within a sample of 10 (15%) of the 67 mainstem channel segments [sub-reaches] and 5 (6%) of the 87 tributary segments [reaches] within the study area. This was done to check for potential bias in raw model output and to develop regression-based calibration equations for adjusting this output for any bias present. The true shade level of each sampled channel segments was measured using a Solar Pathfinder at multiple (3-6) transects spaced at even intervals along the length of the segment. True shade for a channel segment was calculated as the mean of the Pathfinder values recorded at all measurement points and reflected an averaging of July and August values read from the Solar Pathfinder instrument at each point. July and August values were used because SHADOW predicts shade level for August 1, a date on which the sun's angle is intermediate to typical July and typical August conditions. The number of shade transects measured within a given channel segment reflected the degree of variability in riparian conditions along the segment.

The calibration effort showed that our initial SHADOW modeling provided predictions of stream shade levels that were biased toward a slight (<2 percent) over-estimation of the shade actually measured in the sampled channel segments (see Appendix Table J1). Regression-based equations developed to adjust (calibrate) raw output from the SHADOW model to account for small apparent biases in our initial shade estimates are given in Figures 16 and 17. Figure 16 gives the equation we used to adjust raw SHADOW-based estimates of percent shade for sub-reaches of the mainstem and shows how well it fits our calibration data for the 10 mainstem sub-reaches sampled. Figure 17 provides the equation used to adjust raw model-based estimates of percent shade for reaches in the tributary watersheds and indicates how well it fits our calibration data for the 5 tributary reaches sampled.

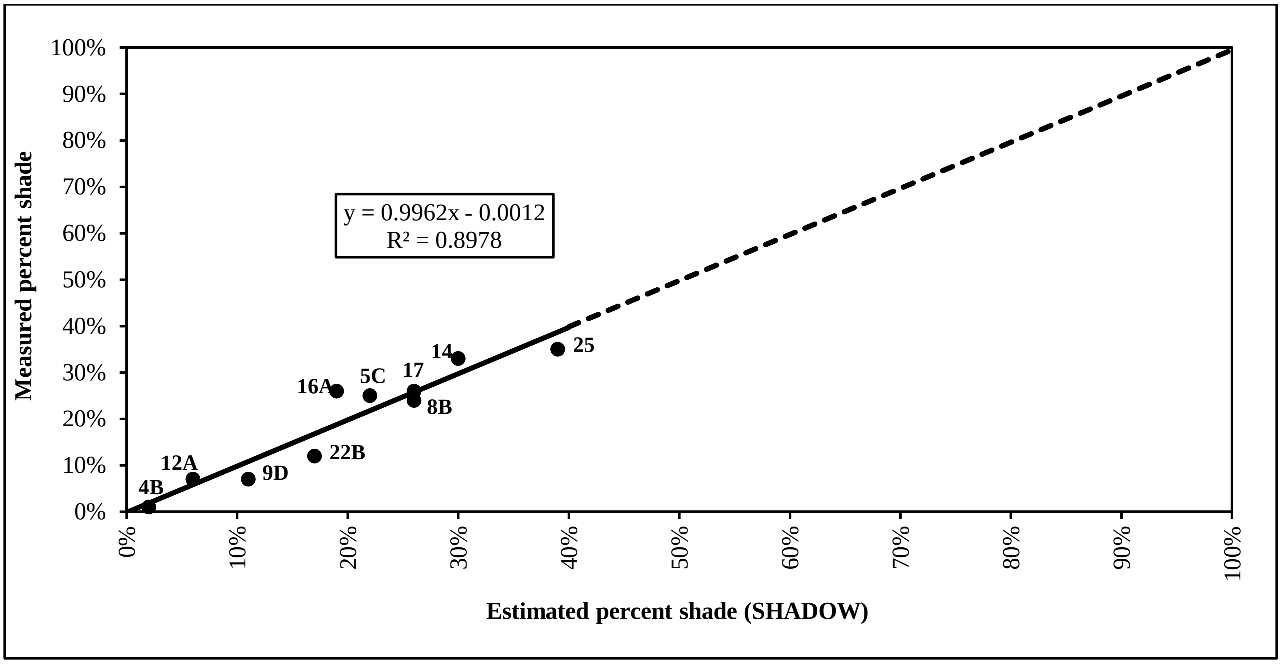

Figure 16. Unadjusted SHADOW (model) estimates of percent shade versus measured values for 10 sub-reaches of the lower South Fork Coquille R., Summer 2001.

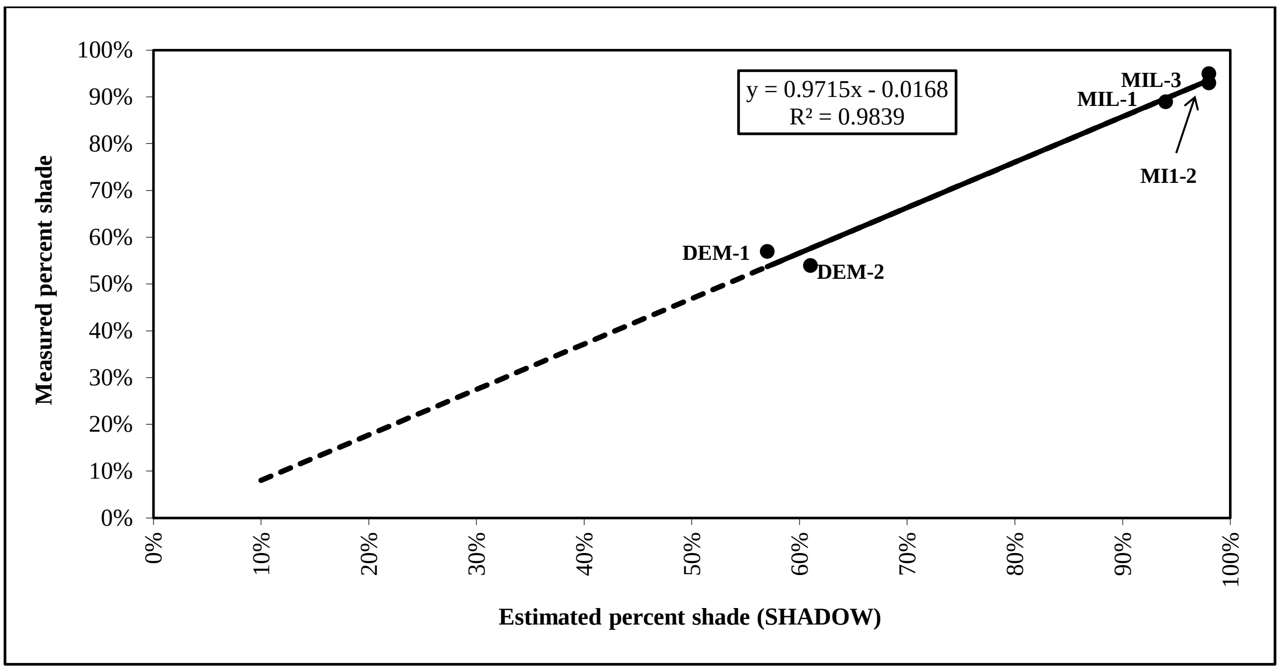

Figure 17. Unadjusted SHADOW (model) estimates of percent shade versus measured values for five reaches of tributaries to the lower South Fork Coquille R., Summer 2001.

4.3. MODELING SCENARIOS

4.3.1. Assessment of Existing and Potential Levels of Stream Shade

We ran SHADOW to model existing conditions and approximations of site potential conditions for the study area's 154 channel segments in order to assess patterns in current levels of stream shading as well as opportunities to improve shade conditions. The existing conditions modeled were those outlined earlier, in Section 4.1. Site potential conditions used in our modeling are described below, in Section 4.3.2.

4.3.2. Assumptions Made When Modeling Potential Shade

We kept the number and complexity of assumptions made to model potential shade to a minimum. This seemed appropriate given (1) uncertainties about future channel changes that may (or may not) occur along the mainstem South Fork and (2) that additional model runs with differing sets of assumptions may be made by CWA staff or associates.

Mainstem South Fork. For the mainstem, we modeled "potential" conditions by assuming only two types of changes to the inputs used to model the current situation. First, *we assumed that mean tree-to-channel distance would be reduced to 25 feet upriver from Dement and to 30 feet downriver from Dement on those banks where the distance currently exceeds these values*. This adjustment helped account for potential recovery from the disturbed riparian conditions found along much of the river and brought these tree-to-channel distances down to approximately the median values we measured for trees in streamside corridors above or below Dement during 2001. Tree-to-channel distances were assumed to remain the same as at present along riverbanks where the distances are already smaller than the values given above or in a few instances where steep talus slides adjacent to the river above Dement impede trees from encroaching upon the channel.

The second type of change we assumed in modeling "potential" shade conditions along the South Fork related to the types (and thus sizes) of stands of trees that could be growing along the various sub-reaches. We based our assumptions regarding these potential trees on field observations, riparian data collected during field surveys (see Figure 18), and results of an assessment of site potential vegetation that Follansbee (2002) conducted in streamside zones within the nearby North Fork Coquille River watershed. With the exception of the river reach surrounding Powers (SFC-

7), riparian areas along the lower South Fork between the National Forest boundary and Rowland (i.e., in reaches SFC-6 and SFC-8) appear to have the potential for supporting mature stands of conifers or mixed tree stands strongly dominated by conifers. The Powers reach itself supports predominantly mixed tree stands strongly dominated by hardwoods, as does the river reach between Rowland and Gaylord (SFC-5). We consider mature stands of trees with something similar to the current balance of hardwoods and conifers to represent site potential vegetation along these two reaches. Riparian areas bordering the four study reaches of the South Fork below Gaylord (SFC-1 through SFC-4) are dominated by stands of hardwoods with very few conifers, wherever trees are present. Historical records (Benner 1991) combine with existing riparian communities in relatively least-disturbed areas suggest that these lower-most four reaches have the potential to support mature stands of mixed hardwoods that include Oregon ash, big-leaf maple, Oregon myrtle, red alder and pockets of black cottonwood.

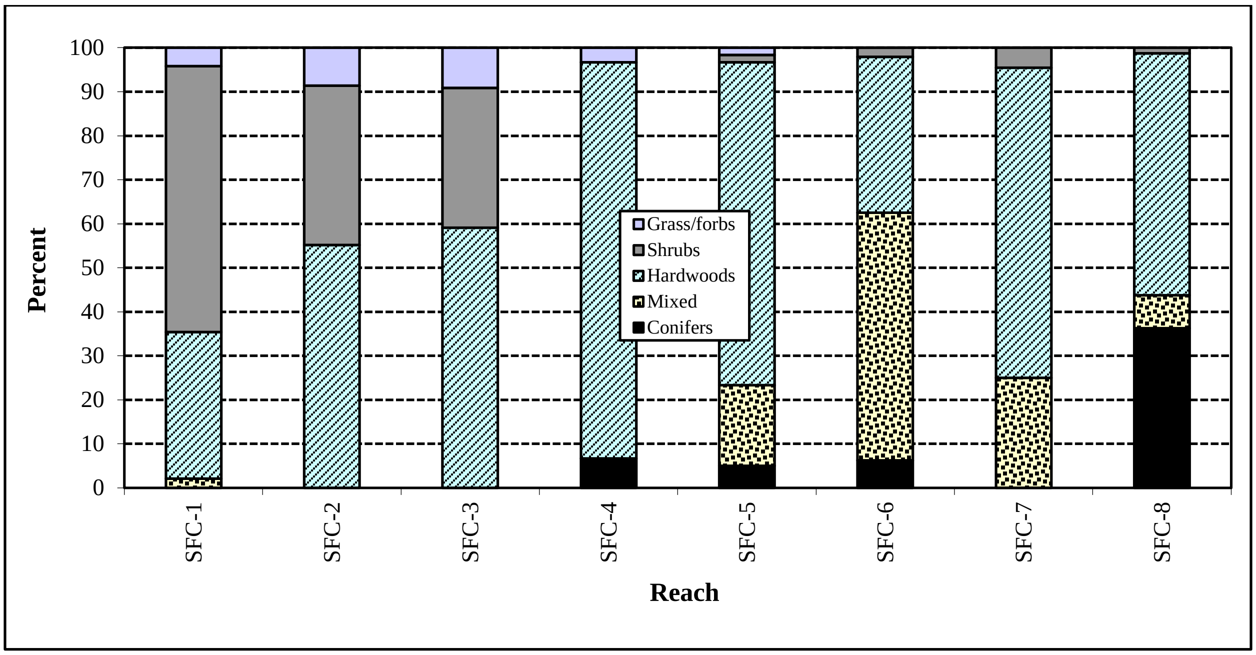

Figure 18. Percent of transect sites dominated by each of five classes of riparian vegetation, by reach, lower South Fork Coquille R., Summer 2001. See Appendix Table J6 for supporting data.

When using SHADOW to predict potential shade, we assigned specific tree heights and shade densities for the segments of the South Fork considered likely to support each of the differing types of potential communities identified (hardwoods, mixed predominantly hardwoods, and conifer-dominated). The specific heights and densities used are summarized below, along with the rationales behind their selection:

Potential community	**Tree height (ft)**	**Shade density**	**Rationale**
Hardwoods	105 feet	90%	Same potential height as assigned to similar communities in large valley settings on the N.Fk. Coquille R. by Follansbee (2002). Shade densities of about 90% were found in a few mature hardwood communities along the lower South Fork during 2001.
Mixed pred. hardwoods	110 feet	90%	Approx. maximum height of this community measured during 2001. Same height and density as Follansbee (2002) assigned to similar communities in the N.Fk. Coquille R. watershed.
Conifer-dominated	150 feet	90%	The combination of height and shade density was intended to represented a mature (but not old-growth) conifer community intermediate between pure stands of the 180-foot site potential conifers and 120-foot site potential hardwoods that ODEQ (2000) estimated for areas above the National Forest boundary. This seemed reasonable given the managed nature of private riparian areas along the lower South Fork to which this community was applied.

Tributaries. Percent tree overhang, tree height, and shade density were the only three input parameters adjusted from existing conditions when modeling potential shade for the study reaches in the Dement, Yellow, and Hayes Creek watersheds. Percent tree overhang was adjusted upward from existing conditions to 80% (when lower) along F or C-type reaches and to 90% (when lower) along reaches assigned other Rosgen types, based on some of the better conditions we observed along tributaries in the field. Mixed riparian stands of trees dominated by mature, near-stream hardwoods (110 feet trees and 90% shade density) with potentially larger trees farther from the stream were taken to represent site potential for all but one stream reach in the three watersheds. The tree height and shade density values assumed for this potential community were similar to values measured for dominant, shade-producing vegetation at the best-shaded tributary sites we examined in 2001. For a one reach on Yellow Creek, a mature hardwood stand with 105 foot trees and 90% shade density was assumed to represent site potential because the stream channel was in a valley floor setting analogous to that of segments of the mainstem South Fork given similar site potential values.

4.4 MODEL OUTPUT

Calibrated model output for the existing condition and potential condition scenarios was incorporated into databases (see Appendix Tables J7 and J8), summarized, and mapped using ArcView. Digital databases and ArcView files that can be used to review, supplement, and re-map model results are on file at the offices of the CWA in Coquille, Oregon.

Results of our SHADOW modeling reflect that both existing and potential levels of stream shading vary considerably within the study area. For the mainstem South Fork, where both existing and potential shade levels were generally lower than those of the tributary streams, our model-based estimates ranged from 0 to 40% for existing shade and from 10% to 61% for potential shade (Figure 19). Estimates of the scope for improving shade conditions within individual modeled segments of the mainstem varied between 9% and 39%.

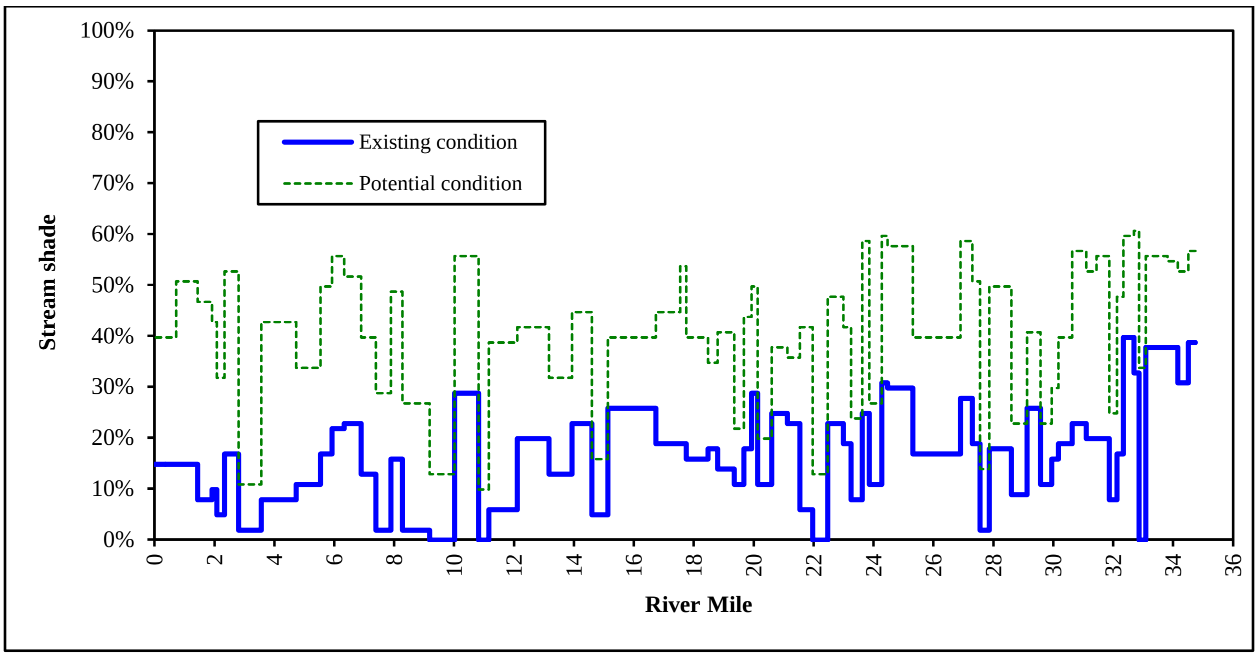

Figure 19. Estimated levels of existing and potential stream shade, versus River Mile, for the lower South Fork Coquille River, Oregon.

Differences between shade levels estimated for the lower South Fork mainstem and those estimated for the tributaries were substantial (Table 9). Existing levels estimated for segments of the mainstem averaged 16%, far below estimated watershed-scale averages of 83% to 87% shade for the 3 tributary systems evaluated. This difference reflected both lower potential shade and what were typically greater levels of riparian disturbance along the mainstem. Our model-based estimates of potential shade averaged 40% across the full length of the lower mainstem, less than half the watershed-scale averages of 93% to 94% we estimate for the tributary systems. Differences between existing and potential shade averaged 24% along the mainstem, more than twice the 6 to 10% average differences found the tributary watersheds.

Table 9. Mean estimates of existing and potential stream shade, plus scopes for improvement, along the lower South Fork Coquille River and in selected tributary watersheds, 2001. Values given for each stream/system and landuse category are length-weighted means of calibrated estimates for multiple channel segments modeled using SHADOW.

Stream/system	Landuse types	Existing shade	Potential shade	Scope for improvement
lower S. Fk. Coquille R.	Forest	27%	45%	18%
(mainstem only)	Ag/RR	15%	39%	24%
	All	**16%**	**40%**	**24%**
Dement Cr. and tributaries	Forest	85%	93%	8%
	Ag/RR	76%	90%	14%
	All	**83%**	**93%**	**10%**
Yellow Cr. and tributaries	Forest	91%	94%	3%
	Ag/RR	80%	92%	12%
	All	**87%**	**93%**	**6%**
Hayes Cr. and tributaries	Forest	84%	93%	9%
	Ag/RR	85%	92%	7%
	All	**84%**	**93%**	**9%**

Streams or stream segments within portions of the study area zoned for forest use tended to have greater existing and potential shade than did streams or segments in areas zoned for agricultural or rural residential use, although there were a few exceptions to this pattern. Despite their generally lower shade potentials, however, many segments zoned for agricultural or rural residential uses had greater scopes for improvement in shade conditions than did segments in forest areas.

Spatial patterns of variation in existing shade levels, potential shade levels, and scopes for improvement in shade levels within the study area are shown in Figures 20-22. Patterns evident in the figures include:

- Variable but low existing and potential shade levels along the mainstem South Fork.
- More variable but generally higher levels of existing shade along streams in the three tributary watersheds than along the mainstem. Estimated levels of existing shade varied from 22% to 95% among the 86 tributary reaches modeled.
- Consistently high shade potentials along all of the tributary streams. Estimated shade potentials varied from 86% to 95% among the 86 tributary reaches modeled.
- The presence of stream segments with significant scopes for improvement in shade conditions throughout most of the mainstem and at locations within each of the tributary watersheds. The greatest scope for improvement in the study area was an opportunity to increase stream shading by 73% along one of the modeled stream segments in a tributary system.
- The presence of more extensive opportunities for improving shade conditions in the Dement Creek system than in the other two tributary watersheds.
- The presence of multiple east-west trending segments of the lower South Fork that have very low shade potentials related to high natural exposure to mid-summer sun.

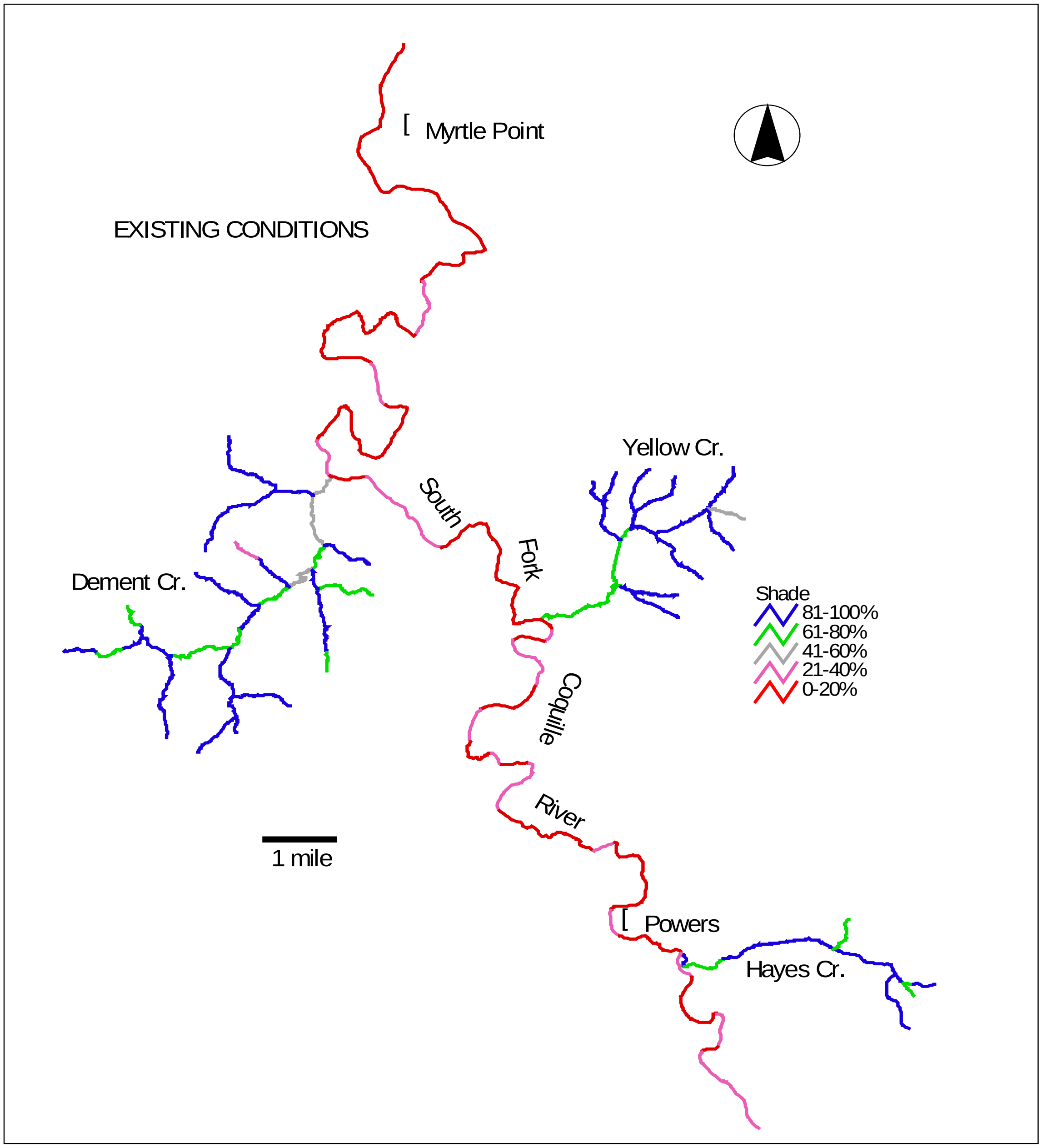

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Figure 20. Spatial variation in existing stream shade within the lower South Fork study area.

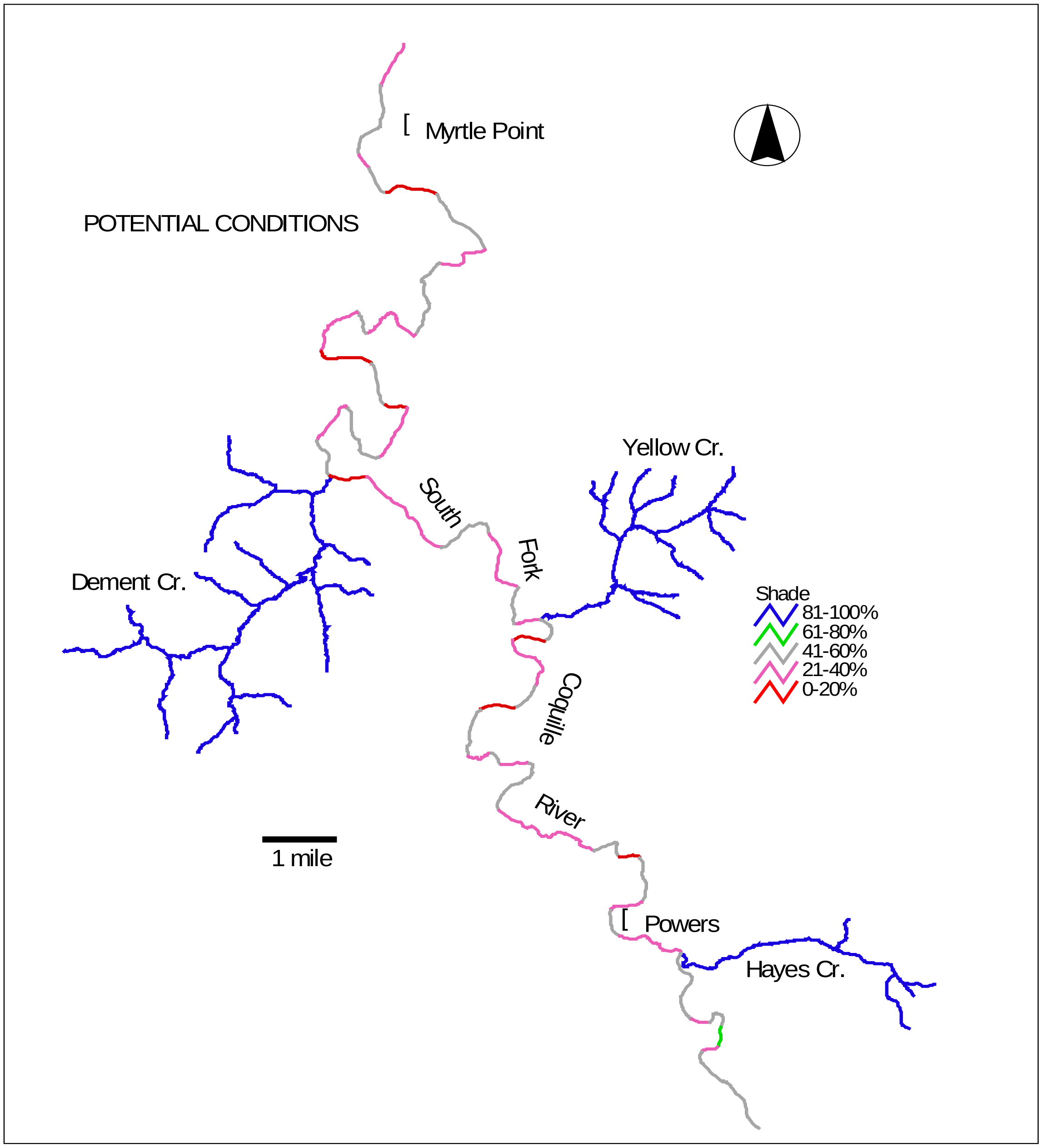

Figure 21. Spatial variation in stream shade potential within the lower South Fork study area.

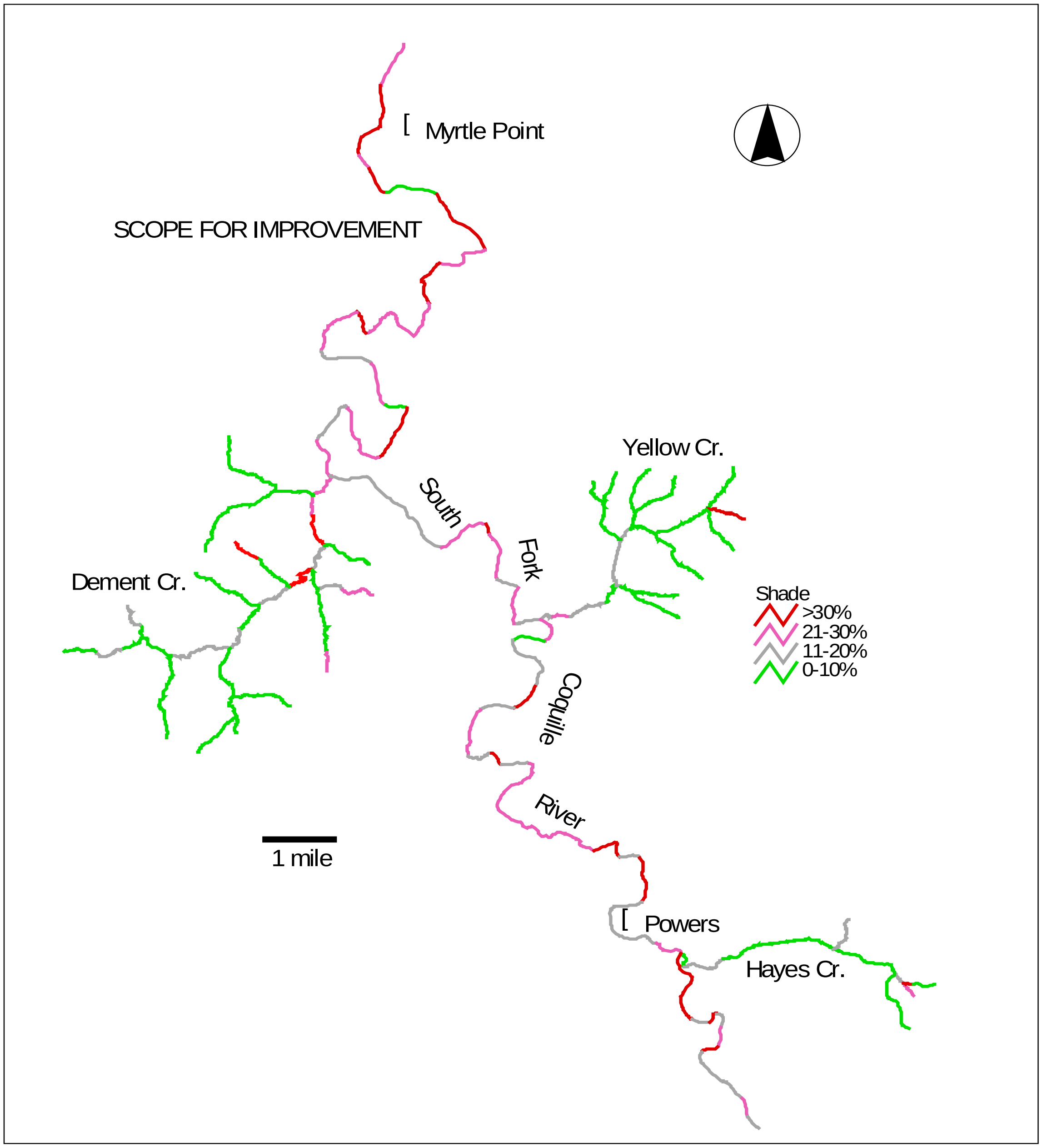

Figure 22. Spatial variation in scopes for improvement in stream shading within the lower South Fork study area.

5. RESTORATION OPPORTUNITIES AND PRIORITIES

There are abundant opportunities for improving riparian conditions along the lower South Fork Coquille River and its tributaries. In the Dement, Yellow, and Hayes Creek watersheds, excluding livestock from near-stream areas and/or planting native riparian vegetation along selected segments of the channel network would improve stream shading, reduce stream temperatures, and increase the quality of available aquatic habitat. Channel segments where riparian improvements would be most helpful in providing additional shade were shown in Figure 22. Similar opportunities for improving habitat exist along the South Fork. However, riparian restoration along the lower-most reaches of the mainstem, particularly below Dement, may be complicated by the highly incised condition of the channel and the combined effect that this incision and currently altered riparian conditions are having on channel stability in many areas.

When considering improvements to riparian conditions along the South Fork, the CWA will want keep several things in mind. These include:

- Altered watershed conditions are affecting the delivery of water, sediment, and wood to the responsive reaches of the lower river.
- Channel simplification (reduced sinuosity) between the Middle Fork and Dement has increased the channel’s slope, the level of incision, and distances between riverbends that absorb energy.
- Riparian vegetation exerts a strong influence on the morphology of channels like those found along the lowest reaches of the South Fork.
- Reduced riparian widths and altered vegetative composition are affecting bank integrity and, in at least some instances, channel form. Historically, the river was bordered by a substantial riparian forest and was unlikely to have gotten an opportunity to erode weakly vegetated floodplains or terraces.

- Gravel mining near Gaylord and below (existing permits could allow a maximum extraction rate of 85,000 cubic yards/year) may be contributing to channel erosion and continued incision. Whether this is actually happening is an important unknown at present.

- Some hard structures placed into or removed from the channel in the past (typically in association with site-specific streambank protection) appear to be contributing to channel changes and bank erosion in some areas.

- Many of the most pronounced areas of bank erosion along the lower river appear to be affected by several of the above factors.

5.1. RIPARIAN RESTORATION ALONG THE LOWER STUDY REACHES

There are multiple basic options for action along the lower-most reaches of the study area, below about Gaylord and particularly below Dement. These are outlined below.

1. *Do nothing*. This option seems likely to be a poor alternative that could well result in continued declines in the stability of the river channel.

2. *Natural River* (make watershed improvements, establish sizeable riparian setbacks, make vegetative plantings, and conduct channel and riparian monitoring). This alternative would require assurances that the period of river down-cutting has ended and would involve giving a portion of the valley floor back to the South Fork as the river slowly re-meandered toward a naturally stable form and developed a new (lower) secondary floodplain. Estimates of the maximum level of set-back that might ultimately be required along the river between Dement and the Middle Fork, potentially several generations of valley residents into the future, were given in Section 3.3.2 of this report. Set-backs for other study reaches would likely be considerably smaller. While moving toward long-term stability, the river would continue to capture substantial volumes of fine sediments as it eroded portions of its banks during large floods. The more successful the riparian restoration proved to be at stabilizing bank toes under this scenario, the more slowly the river would shift position and the smaller the final set-backs.

3. *__Strategically Stabilized River__* (make watershed improvements, adopt reach-based (collective) riparian restoration approaches that include strategic bank resloping, bioengineering and/or floodplain construction at key locations). This option is a more aggressive version of option 2, above, that emphasizes riparian planting in conjunction with structural solutions at key locations where vegetative approaches alone would be inadequate to prevent toe erosion and periodic geotechnical instability. Identification of these locations would require site-specific analysis incorporating the use of field data, bank stability relationships, and the cumulative experience of success (or failure) that CWA partners have in using willows or other vegetative treatments to stabilize similar sites without bio-engineered toe protection. All restoration planning would need to be done collaboratively at the scale of our study reaches or sub-reaches to avoid unintended (and undesirable) consequences and to assure landowner buy-in. Set-back distances would be smaller and, if carefully implemented, sediment yields to the river from bank erosion could be substantially lower than those associated with option 2. As in option 2, assurance that the period of river down-cutting had ended would be important to giving the effort a meaningful chance of success. Monitoring would be needed, to assure that CWA partners become increasingly effective at working with native materials to the degree possible.

4. *__Rock-and-ignore__*. The "rock-and-ignore" approach reflects the way in which localized spot-treatments of rock have often applied to eroding riverbanks, without any broader context than to prevent bank loss at a specific site. At whatever scale it is applied, this approach is likely to have high capital costs, damage habitat, and to have unintended consequences. There are multiple instances along the lower South Fork where hardened bank protection measures have failed to yield on-site riparian improvements, exacerbated bank erosion problems in other areas, an/or damaged partially functional riparian areas.

5.1.1. Potential Priority Areas for Early Action Along the Lower South Fork

Several sub-reaches of the lower mainstem appear to be good candidates for early CWA action. These were identified based on the relative abundance of at-risk riverbanks, the presence of a high proportion of weakly vegetated riverbanks in areas of what we judge to be high erosion hazard, or the presence of specific classes of riparian conditions. Listed in descending order of apparent problem severity, these subreaches include 7D, 7H, 7K, 7B, 5B, 1B, 4B, 7I, and 12A.

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