LLANO SECO RIPARIAN SANCTUARY CHANNEL STUDY: MEANDER BEND MIGRATION AND CUTOFF MODELING

Technical Report

Prepared for
River Partners
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EXECUTIVE SUMMARY

The Sacramento River meander bends near the PCGID-PID pumping plant (RM 178) continue to meander and move downstream, and the river channel is tending to move away from the pump location. Previous meander bend simulations at this location showed that the river bend near the pump site will tend to move downstream and pull away from the pump location in the future. Simulations of future migration that included removing upstream bank constraints from the upstream limb of this bend suggested that removing bank constraints at this location would allow this bend to experience cutoff in a short period of time. Additional modeling was requested to update the model runs, using the latest available river channel alignment and using recent improvements to the channel migration model. A new model was constructed incorporating a variable flow algorithm. In addition, a newly acquired 2007 channel planform was used for calibration and forward modeling of the bends in the vicinity of the pumping plant.

Three separate simulations of 50 years of future migration were performed: 1) with the existing bank constraints in place, 2) with the upstream bank constraints removed from the bend in question, and cutoff occurring, and 3) with the upstream bank constraints removed from the bend in question, and the downstream-limb bank constraints extended, and cutoff occurring . With the existing bank constraints on the bend, the southern limb of the bend tends to move downstream where it is unconstrained, and moves away from the pump. With the upstream constraints removed, and the downstream constraints in the current configuration, the river tends to move away from the pump. In the third case, with the downstream constraint extended, the river tends to remain near the pump location. These results confirm earlier modeling that was done with a 1997 channel configuration and no variable flow.

The model simulations suggest that, if the channel migration near the pump site were stabilized by extending the constraints on the downstream limb of the bend, the bend upstream could be allowed to cutoff in order to provide natural river processes and natural regeneration of the upstream floodplain area without extensive migration occurring near the pump site.

Contents

INTRODUCTION

The Sacramento River near RM 178, which is the current location of the Princeton, Cordora, Glenn and Provident Irrigation Districts' (PCGID-PID) pumping plant (Figure 1), has experienced lateral and downstream meander migration in the last century [*Larsen*, 2004]. The reach in the vicinity of the pump has evolved in shape through natural processes of river meander migration. The pump is located on the west side of the river and the tendency for eastward migration of the channel is a concern because it affects pump operations.

In 2004, River Partners and an interdisciplinary team began studies to explore measures to protect the PCGID-PID pumping plant and fish screen facility and develop management options for the Riparian Sanctuary, a component of the Sacramento River National Wildlife Refuge (SRNWR). One potential solution was to extend the rip-rap on the downstream bend to maintain a stable configuration for the pumping plant and remove rip-rap on the upstream bend to allow meander and ecological processes.[1]

Understanding the dynamics of the river given different management scenarios will provide important information to inform decisions about effective long-term pump operation. Modeling was performed in 2004 that simulated future migration patterns, with and without the existing bank constraint, given calibration from the observed locations of the channel in 1964 and in 1997, using an approximation of a constant steady "characteristic" flow rate that represented the integrated effects of the observed variable flow regime [*Larsen*, 2004]. In the current effort, the model was recalibrated, using data from 1976 to 2007 and using a variable flow regime for calibration and for simulations.

River meander migration is related to the channel planform shape, flow characteristics, bank erosion potential, and other factors [*Johannesson and Parker*, 1989]. The history of river meander migration at this site suggests why the river is currently moving away from the current pump site, and helps anticipate future migration. After a brief introduction to the historic planform shape of this reach from 1904 to 2007, which shows the history of channel migration, this report describes modeling scenarios, where the future migration of the river is simulated given different bank constraint conditions.

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[1] River Partners February 20, 2004. Project Summary. Riparian Sanctuary (Phase II): Bringing Agricultural and Ecological Interests Together - Design Development and Environmental Compliance for Facilities Protection and Habitat Restoration .

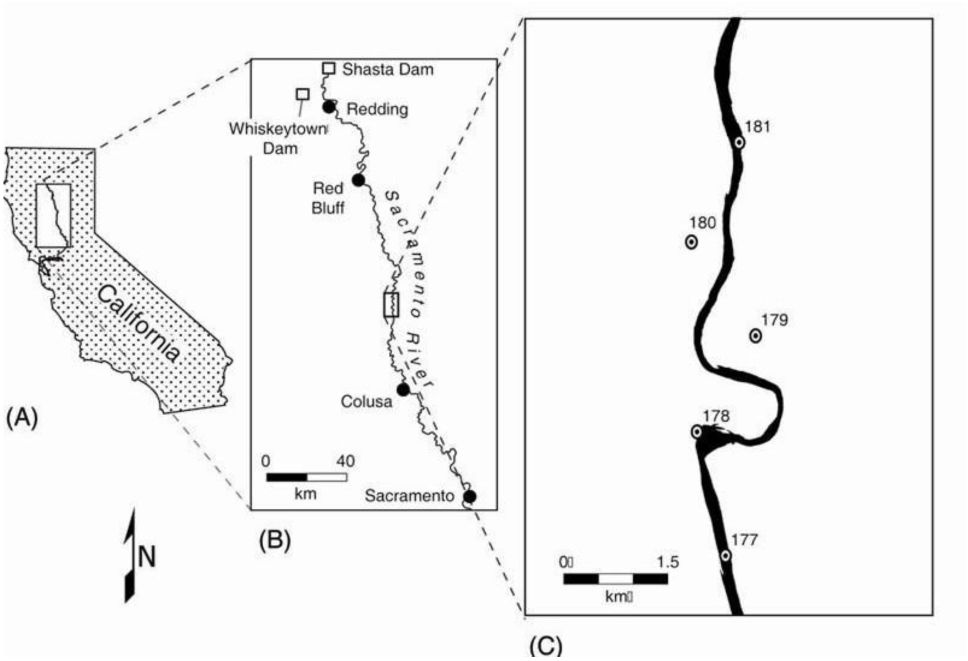

Figure 1 Location of the Sacramento River and the study reach.

As the meander bends of the river continue to move downstream, the near-bank flow of water, and eventually the river itself, is tending to move away from the pump location.

Previous meander bend modeling at this location examined five future migration scenarios [*Larsen*, 2004]. One of those simulations of 50 years of future migration, with the current conditions of bank constraint, showed that the river bend near the pump site will tend to move downstream and pull away from the pump location. Simulations that included removing upstream bank constraints from the upstream limb of this bend suggested that removing bank constraints would allow this bend to experience cutoff in a short period of time. Those model runs were performed starting from a 1997 river channel alignment, and the model used an approximation of a characteristic discharge that represented the integrated effects of the actual variable range of flow discharges.

Additional modeling was requested to update the model runs (Appendix 1), using the latest available river channel alignment for calibration and forward modeling. In addition, modeling was requested using recent improvements to the channel migration model, which allow a variable flow regime to be used. A new model was constructed incorporating a variable erosion field, and incorporating the variable flow algorithms. In addition, a newly acquired 2007 channel planform was used for calibration and was used to represent the first time period in forward modeling.

The model was calibrated using channel alignments and flow regime between the years of 1976 and 2007, and also incorporated the installation of bank constraint in approximately 1985. Model simulations were performed between years 2007 and 2057. Three separate forward simulations were performed: 1) with the existing bank constraints in place, 2) with the upstream bank constraints removed at the bend in question, and cutoff occurring, and 3) with the upstream bank constraints removed at the bend in question, and the downstream-limb bank constraints extended and cutoff occurring .

Site Description

The PCGID-PID pumping plant is located at about RM 178 on the upper Sacramento River, about 75 river miles south of Red Bluff, and about 125 river miles north of Sacramento. In most naturally migrating rivers, local meander migration is related to the shape of the local meander bend and to the shape of the river upstream [e.g. *Furbish*, 1988; 1991; *Johannesson and Parker*, 1987]. To consider the local migration near the pumping plant site (RM 178), this report looks at a longer reach that includes a section of river from roughly RM 177 to about RM 182 (Figure 2). This reach, like much of the river between Colusa (RM 143) and Red Bluff (RM 243), contains some areas having a moderate amount of bank constraint where the river does not move, some areas that are migrating and evolving in relation to the bank constraint, and some areas that are evolving freely.

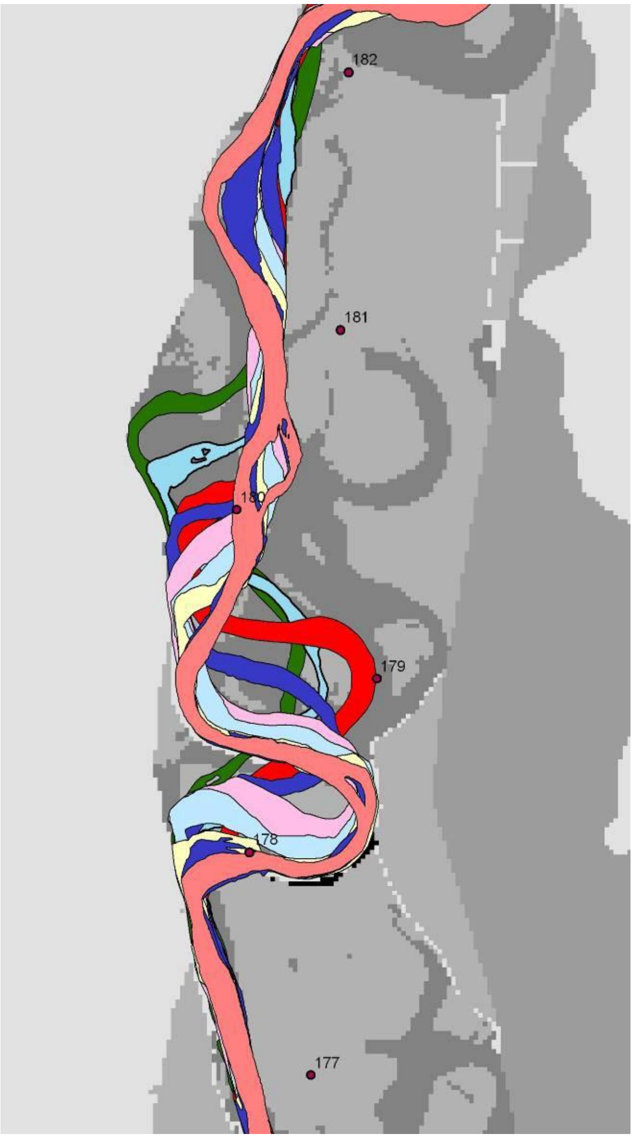

Figure 2 History of the channel location from 1904 to 2007. Red lines show man-made bank-constraints.

Figure 2 shows the history of the channel location from 1904 to 2007. Between river miles 182 and 177, a series of bends has migrated continuously, except when constrained by an erosion resistant bank or by man-made constraints. The apex (point of maximum curvature) of the upstream-most bend (on the western edge of the historic meander belt near RM 180.5 in 1904) moved from roughly RM 180.5 to RM 179 from 1904 to 2007. This bend moved downstream, but did not move laterally as it was constrained on the western bank by natural and man-made constraints. The bend that has continued to be located close to RM 178 has been similarly constrained from lateral (westward) migration and has moved downstream less than a half a mile. Between 1997 and 2007 the bend near the pump has continued to move slightly downstream. The other major bend, facing in the other direction with the outside of the curve to the east, lies between these two, and has had its apex move from about RM 179 to almost RM 178. Note that RM designations in this qualitative description of movement are used to denote the general down-valley direction, and are not meant to be exact. The large loop now occurring between RM 178 and 179 is currently of unusually large amplitude and curvature, and would have cut off had it not been constrained on its upstream limb.

Unconstrained meander bends tend to migrate naturally across the landscape [*Brice*, 1984; *Hooke*, 1984]. Bend migration tends to follow patterns that can be described by mechanical laws of fluid flow and by other methods [*Brice*, 1974; *Hooke*, 1984; *Ikeda and Parker*, 1989]. When such meander bend migration occurs, an individual bend tends to move, unless constrained, both downstream and cross-stream. In other words, a bend will tend to migrate continuously downstream. At the same time, because of the cross-stream component of migration, a bend will tend to migrate cross-stream. As the bend migrates, it also changes shape.

Natural river meander bends tend to be curved. When a bend impinges laterally on a bank that is erosion-resistant, the curved shape tends to flatten against the resistant bank. As the bend moves downstream, the outward side of the bank tends to maintain contact with the location of the resistant bank. Once it has migrated sufficiently, the “end of the bend” will move downstream from the location, and the river channel will no longer maintain contact with the point in question. This is the tendency that is affecting the pump site. Even with the existing bank protection, which constrains the downstream migration of most of the bend, the downstream-most section of the bend is unconstrained, and continues to migrate downstream, thus tending to "abandon" the pump. As this process progresses, the velocity of flow near the pump may be reduced, to an extent that flow magnitudes necessary for the fish screen may not be achieved.

As the river continues to evolve, the unconstrained section of the channel will tend to move downstream and the river channel will appear to move away from the western bank at the current location of the pumping plant. The river is "sliding along" the extreme western edge of the historic meander belt. This location, being the western edge of the meander belt zone, has functioned as a geologic control. At this site, the bend has been migrating almost entirely in the downstream direction. The outside of the bend reached the location of the pump site. Because this area was naturally resistant to erosion, the outside of the bend effectively "flattened out" and then "slid down the site," maintaining contact with the bank at the current pump location. Until recently the site was "stable" with respect to contact with the river.

Currently, the unconstrained portion of the bend is continuing to migrate naturally downstream. From the point of view of standing at the site, the channel appears to be moving away from the western bank.

Future Predictions

One approach to understanding the future channel movement near the pump site is to model its future migration. As was similarly done near this site [*Larsen et al.*, 2002; *Larsen*, 2007] and at the current location [*Larsen*, 2004], this report describes simulated channel migration using a channel migration model that is based on mathematical algorithms of physics-based relationships for flow and sediment transport – the main physical processes responsible for channel migration [*Larsen and Greco*, 2002]. "Because the model is based on physical processes, it can accommodate changes in input variables and can predict the consequences of conditions, such as bank stabilization measures that have not existed in the past."[2]

The significant difference between the applications of the model in this project compared to the previous application is the use of more recent (2007) channel planform information and the integration of a variable flow regime.

Once a model run has been calibrated with a variable flow and heterogeneous erosion surface, the simulation capabilities of the meander migration model can be used to simulate river meandering under different daily hydrograph scenarios. Modelers can therefore simulate how the river would have moved in the past under a flow regime different from the one that occurred, and forecast how the river might migrate under different potential future management scenarios [*Larsen et al.*, 2006; *Larsen et al.*, 2007].

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[2] Larsen et al. 2002.

Methods

Heterogeneous Erodibility Surface

A heterogeneous erosion surface, which was used for with model calibration and simulations, was developed by spatially combining GIS datasets of geology, vegetation cover and revetment (Figure 3). All datasets were converted to a 30 meter grid based on erodibility potential. The final erosion values were developed by a calibration process from these data sets. This GIS grid was exported as an ASCII text file and imported into the meander migration MATLAB program and used in conjunction with model calibration and subsequent model simulations.

The geology dataset used for creating a heterogeneous land erodibility surface was obtained from the California Department of Water Resources [*CDWR*, 1995]. All geology surface types shown on those geology coverages are assumed to be erodible, except for Q_r (Riverbank formation), Q_m (Modesto formation), and Q_{oc} (Old channel deposits) which represent non-erodible areas based on their soil properties; these are sometimes called areas of geologic constraint.

The vegetation dataset, used to distinguish between agricultural and riparian land cover, was derived from aerial photography taken in 1997 [*Greco and Alford*, 2003]. Based on the process of calibration, areas of natural vegetation were assigned erosion potential and agricultural lands were given different values of erosion potential. The erosion field created from the 1997 data, which were used to initially distinguish agricultural land from natural vegetation, would not significantly differ if a newer data set were used, for two main reasons. First, there has not been significant change in the balance of agricultural/natural land cover in that time period, and model results would not differ significantly with more recent data. Second, the calibration process accounts for any differences that may have occurred.

Figure 3 GIS erosion surface layer

The effect of revetment was simulated by modifying the erosion potential grid, using a GIS revetment dataset from the CDWR [*Henderson*, 2006]. The revetment was buffered and combined with the erosion potential grid [*ESRI*, 2003]; areas within the buffered revetment were given an erosion potential value of zero (i.e., non-erodible).

Variable flow rate

Although previous versions of the meander migration model have been successfully used to assess planning issues [*Larsen et al.*, 2002; *Larsen and Greco*, 2002], those applications have employed a constant flow rate. A method to incorporate a daily flow hydrograph as the basis of modeling meander migration rates as a function of variable flow rates has been developed [*Larsen et al.*, 2006]. Those methods were used in this modeling.

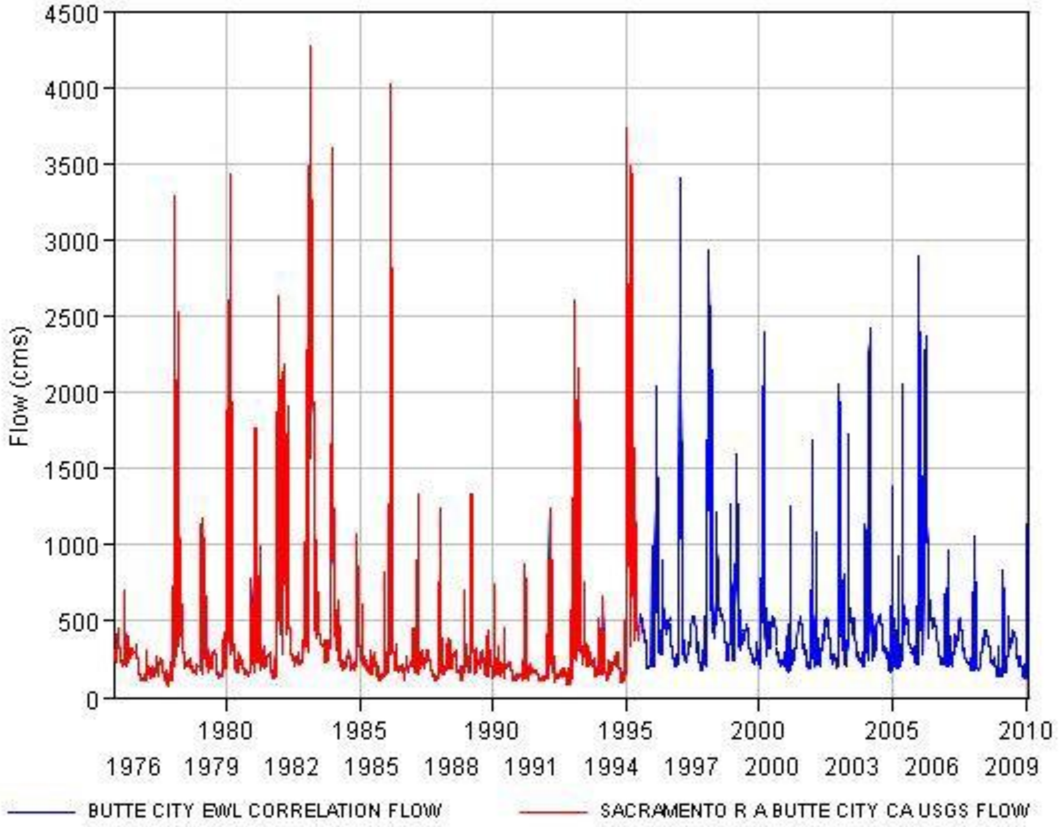

Figure 4 Flow record with synthesized data Sacramento River at Butte City

Figure 4 shows the flow record at the USGS gaging station at the Butte City Bridge (gage # 11389000 Sacramento River at Butte City, Ca). The existing record of flows ends in 1995. A regression was made with the record at Bend Bridge so that the record could be extended to 2007. The data in blue show the flows that were extended by means of the correlation. This data set was used for calibration of the model. Future predictions used the same data, projected into the future, and called 2007-2057.

Migration Modeling

Slope, channel top width, and area of flow within the designated channel come from HEC-RAS output. Average depth is calculated using channel area and channel top width ($^{(area)}/_{(top\ width)}$). The overall slope for the study reach is calculated based on HEC-RAS model information. The slope used for the study reach was 0.00030 m/m. The input parameters for the meander migration model for predictive modeling were calculated using the output of HEC-RAS and are included in Appendix 2.

Cutoff Simulation

A cutoff simulation was used to account for bend cutoffs across bend necks [*Larsen et al.*, 2004]. The sinuosity of each bend is calculated numerically by dividing the distance along the channel for a bend by the straight-line distance between the start and end points of the bend. A threshold sinuosity of 3.0 was set, by which bends were allowed to cut off given that other factors were present. The starting point of the simulated cutoff is located one-quarter of the bend upstream from the cutoff bend, and the ending point of the simulated cutoff is placed one-tenth of the length through the downstream bend. Finally, the cutoff is simulated only if erodibility is not constrained (by rip-rap, levees, and geologic constraints) along the straight line between the start and end points. If the cutoff conditions are met, the simulated river channel cutoff centerline is located in a straight line between the start and end points.

Cutoff events require that overbank flows occur [*Avery et al.*, 2003]. For a complete treatment of the timing of a cutoff, a variable hydrograph is input into the flow conditions, with cutoff only being allowed to occur when the magnitude of flow was equal to the discharge of an overbank event and cutoffs were allowed to occur when the flow and sinuosity thresholds were reached.

Model Calibration

"Calibration of the meander migration model is required because the exact erodibility of the sediments within the study reach in not known. Calibration allows calculation of an erodibility field by running the model on historic channel data. Calibration also allows fine-tuning of the model to local conditions by adjusting the coefficient of friction."[3]

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[3] Larsen et al. 2002.

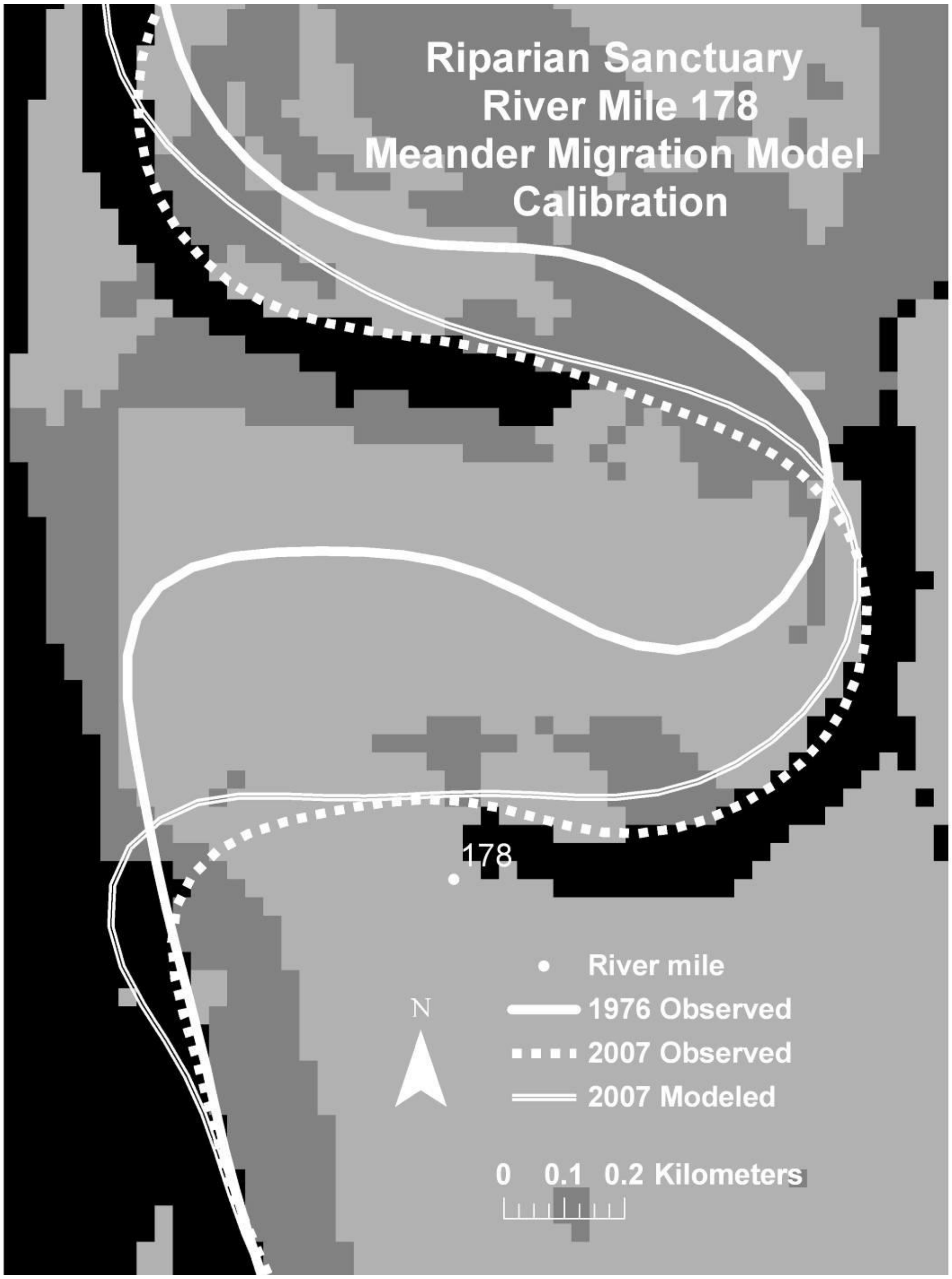

Figure 5 Sacramento River near pumping plant site, model calibration results.

Figure 5 shows the calibration of modeling. To calibrate, the observed locations of the channel in 1976 and in 2007 were used. Bank erodibility was adjusted near the channel until the 2007 modeled channel matched the observed 2007 channel location. In the calibration, the effect of the installation of the bank constraints in 1985 was simulated. These conditions were then used for model predictions.

The calibration results show good agreement (Figure 5). Based on this calibration, the overall direction and pattern of the simulations are expected to be reasonable.

RESULTS

Based on the input values for the hydraulic variables and the calibrated bank erosion values, three predictions 50 years into the future were made. The first scenario simulated future channel movement with existing conditions; the second scenario simulated future movement with the upstream bank constraint removed; and the third scenario simulated future movement with the upstream constraint removed and the downstream extended.

Two main areas of interest emerge when discussing the results of modeling. The first is the area near the pumping plant site. As described in the section on historic migration, the small bend near RM 178, hereafter referred to as Bend 178, has been migrating southward, and causing concern to the pumping plant. The second area of interest is the large bend that swings to the east, hereafter referred to as Bend A, which has been constrained from cutting off. Upstream from the two bends of major concern, from about RM 179 to RM 182, migration was simulated in all scenario cases. The pattern of simulation is similar in all cases, and is not discussed.

With existing conditions

Figure 6 shows the channel location with 50 years of predicted migration using the input parameters that were used for the calibration, and the existing bank constraints. The migration of Bend 178 is similar to the migration that has been recently occurring and that has caused concern for the operation of the pumping plant. The migration of Bend A (the large bend upstream from the pump) continues to be limited by the existing bank constraints. The model migration in this simulation shows this bend moving slightly westward.

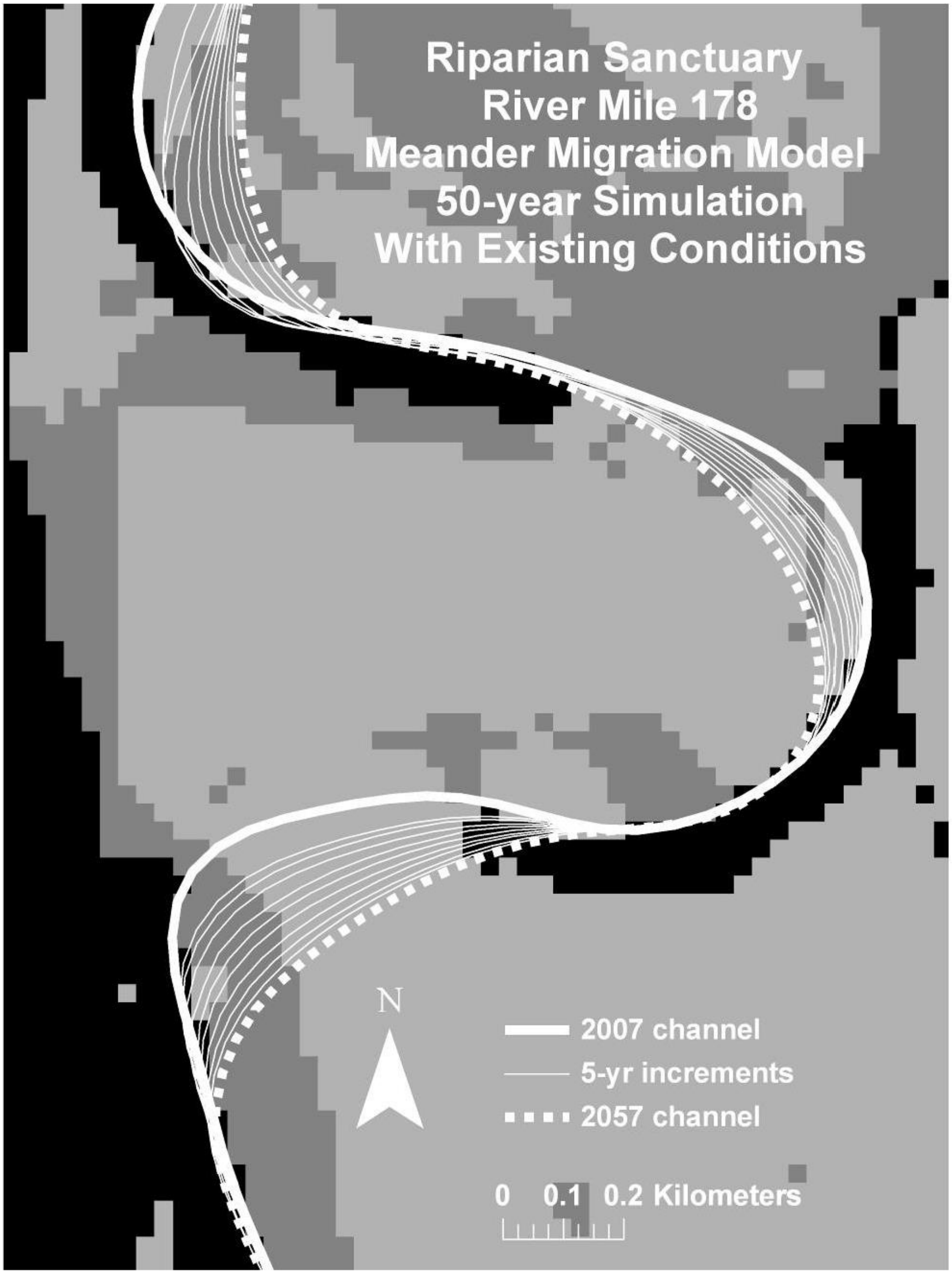

Figure 6 50-year simulated migration 'With existing conditions

With bank constraint removed from right bank of the bend upstream and the existing conditions near the pumping plant

Figure 7 shows the channel location after 50 years of predicted migration with bank constraint removed from the right bank of the bend upstream and the existing conditions near the pump. With the removal of bank constraint, the channel cuts off and there is significant migration in the upstream bend area.

In addition, the migration of Bend 178 is extensive and results in a significant amount of land reworked in the Llano Seco Riparian Sanctuary. The model simulates a large amount of migration where the bend apex “slides” along the western edge of the meander belt where westward migration is constrained. The simulation shows the apex moving extensively downstream. The migration of Bend A is no longer limited by the bank constraints as in the previous simulations, and a cutoff and subsequent migration is simulated.

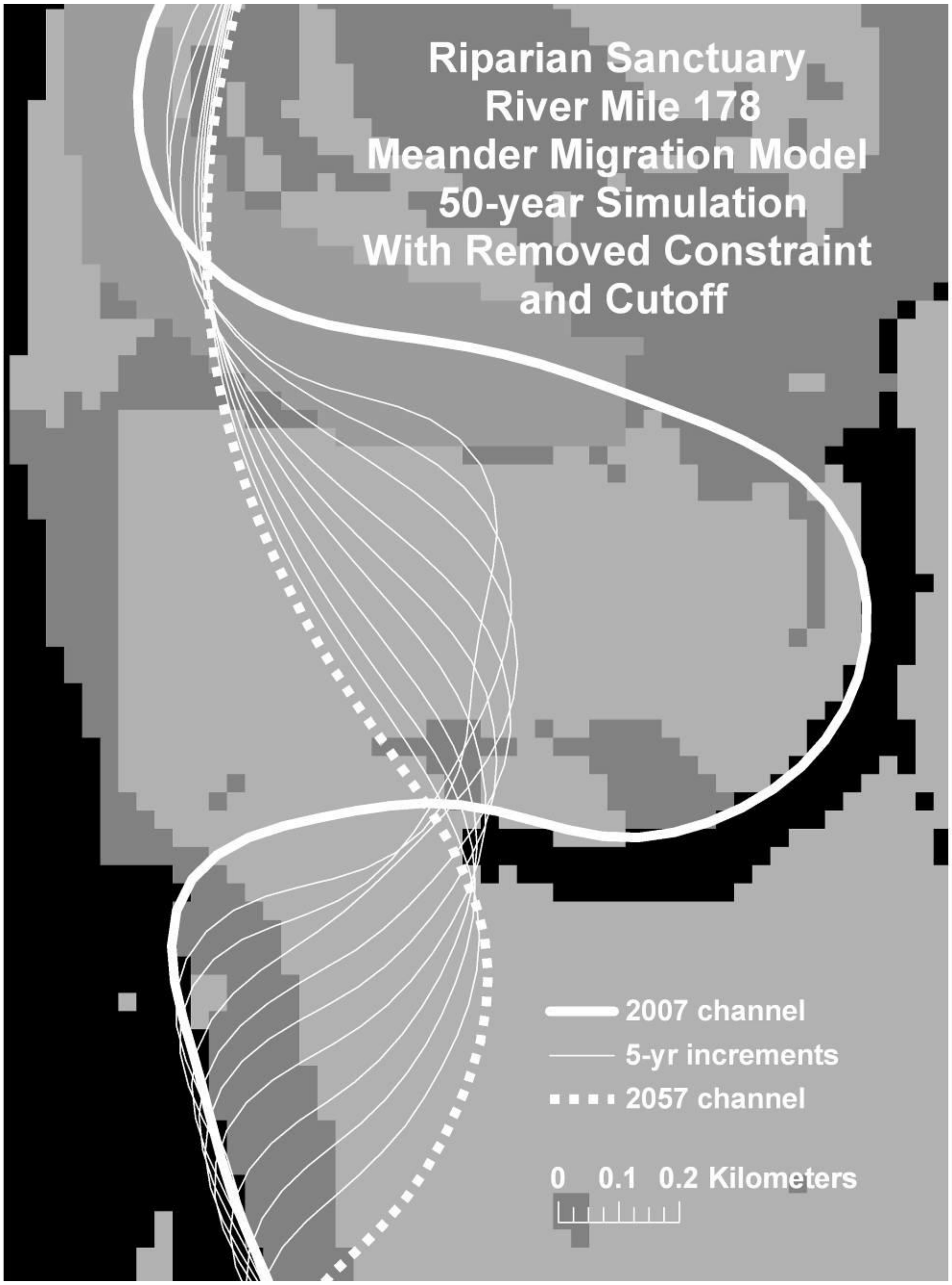

Figure 7 50-year simulated migration with bank constraint removed from the right bank of the bend upstream and the existing conditions near the pumping plant

With bank constraint removed from right bank of the bend upstream and the bank constraint extended near the pumping plant

Figure 8 shows the channel location after 50 years of predicted migration with the bank constraint removed from right bank (looking downstream) of Bend A (the large bend upstream from the pump) and the bank constraint extended near Bend 178.

With the existing bank protection, which constrains the downstream migration of most of the bend, the downstream-most section of the bend is unconstrained and continues to migrate downstream, thus tending to “abandon” the pump. As this process progresses, the velocity of flow near the pump may be reduced to an extent that flow magnitudes necessary for the fish screen may not be achieved.

Note that the modeled extended bank restraint does not extend all the way along the northern boundary of the Riparian Sanctuary, and yet the model results suggest that the flow tends to not move away from the pump in the modeled time period. This suggests that the flow may be redirected effectively without the fully extending the bank protection. Modeling was done with the minimum extension of bank protection that achieved the desired results. This was done because full extending the bank protection may unnecessarily “aim” the flow directly at the pump location, creating potentially destructive forces, and because minimum bank protection construction is less expensive.

With the removal of bank constraint, the 50-year simulation shows that Bend A will cutoff. The migration of Bend 178 is limited by the additional bank constraint. The model simulates a small amount of migration similar to the migration that has been recently occurring near the pumping plant, indicating a tendency for migration at this location. The pattern in this scenario differs from that in the previous case because of the effects of the addition of bank constraint near Bend 178. In practice, extended bank constraint could most likely eliminate all the migration that is simulated and shown in Figure 8.

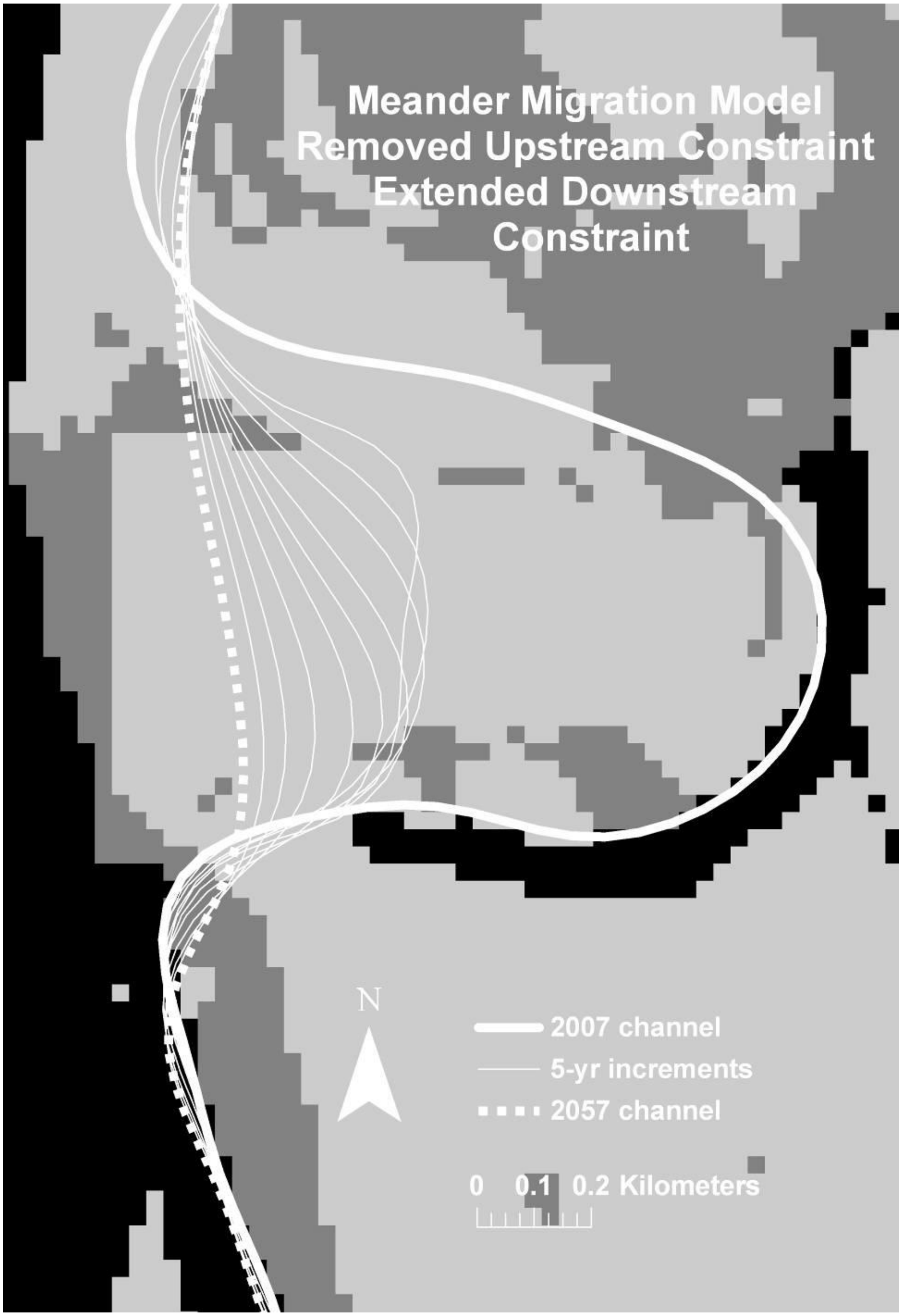

Figure 8 50-year simulated migration with the bank constraint removed from right bank of the bend upstream and the bank constraint extended near the pumping plant

Comparison with former modeling

Figure 9, 10, and 11 show a comparison with the modeling done previously [*Larsen*, 2004]. The current updated results confirm earlier modeling that was done with a 1997 channel configuration and no variable flow.

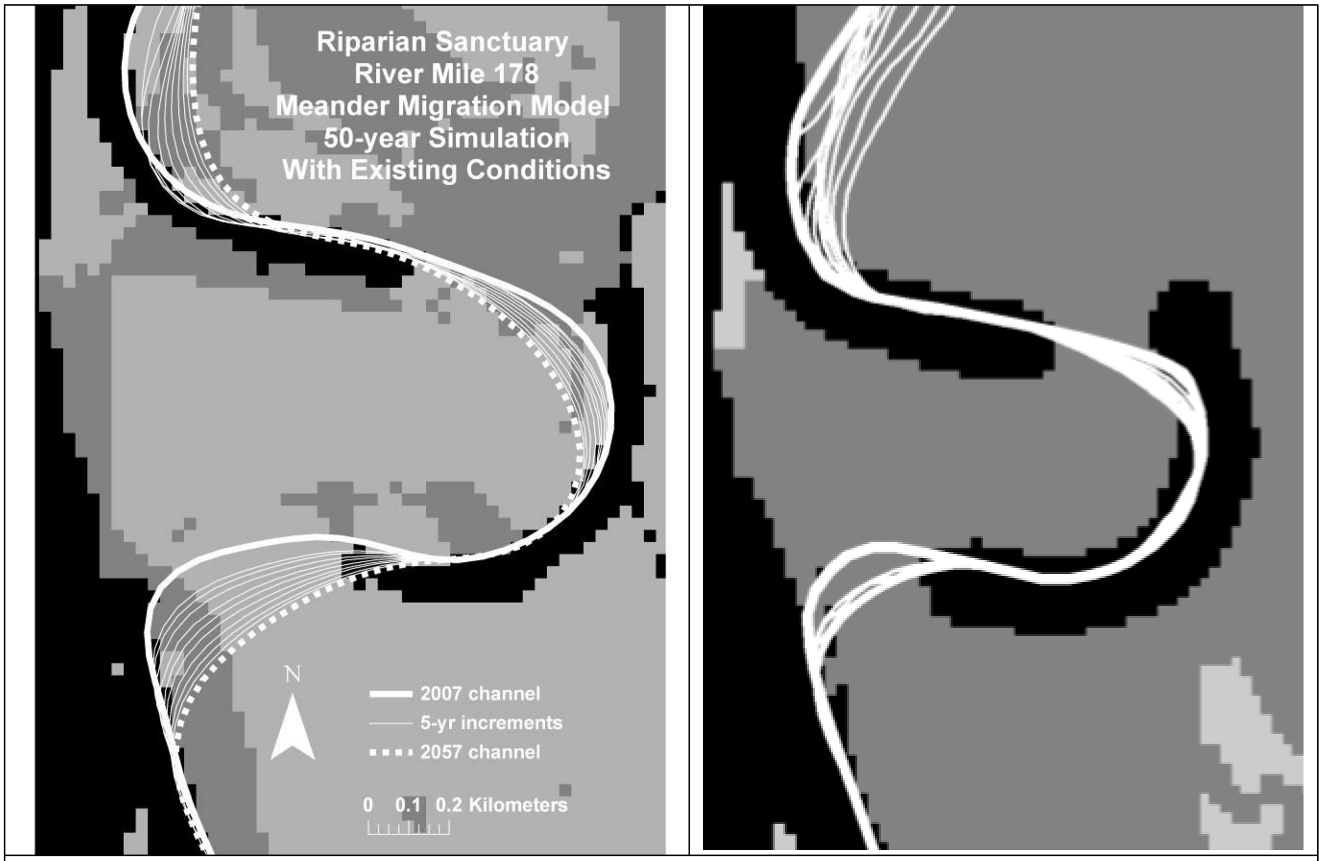

Figure 9 Existing conditions “1997” and “2007” models

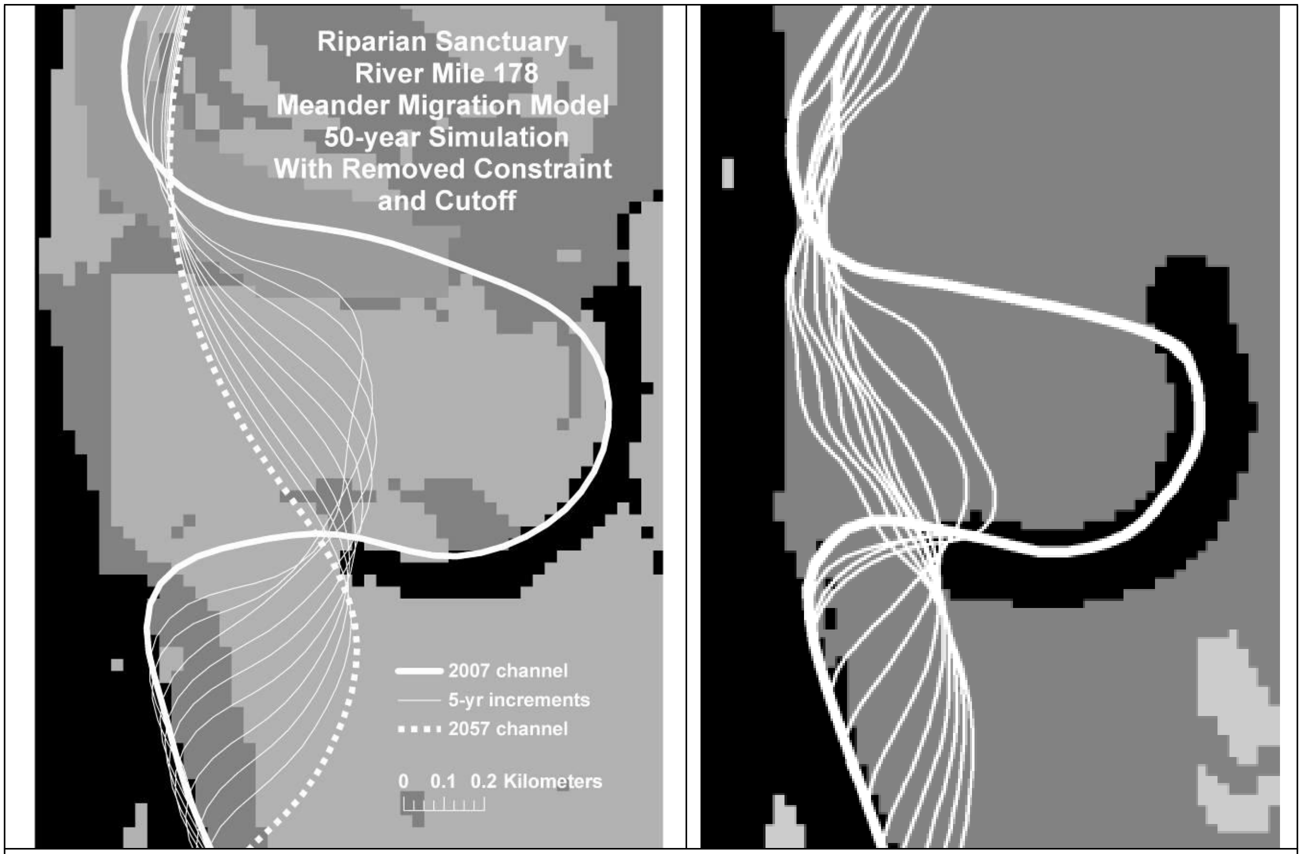

Figure 10 Upstream constraint removed “1997” and “2007” models

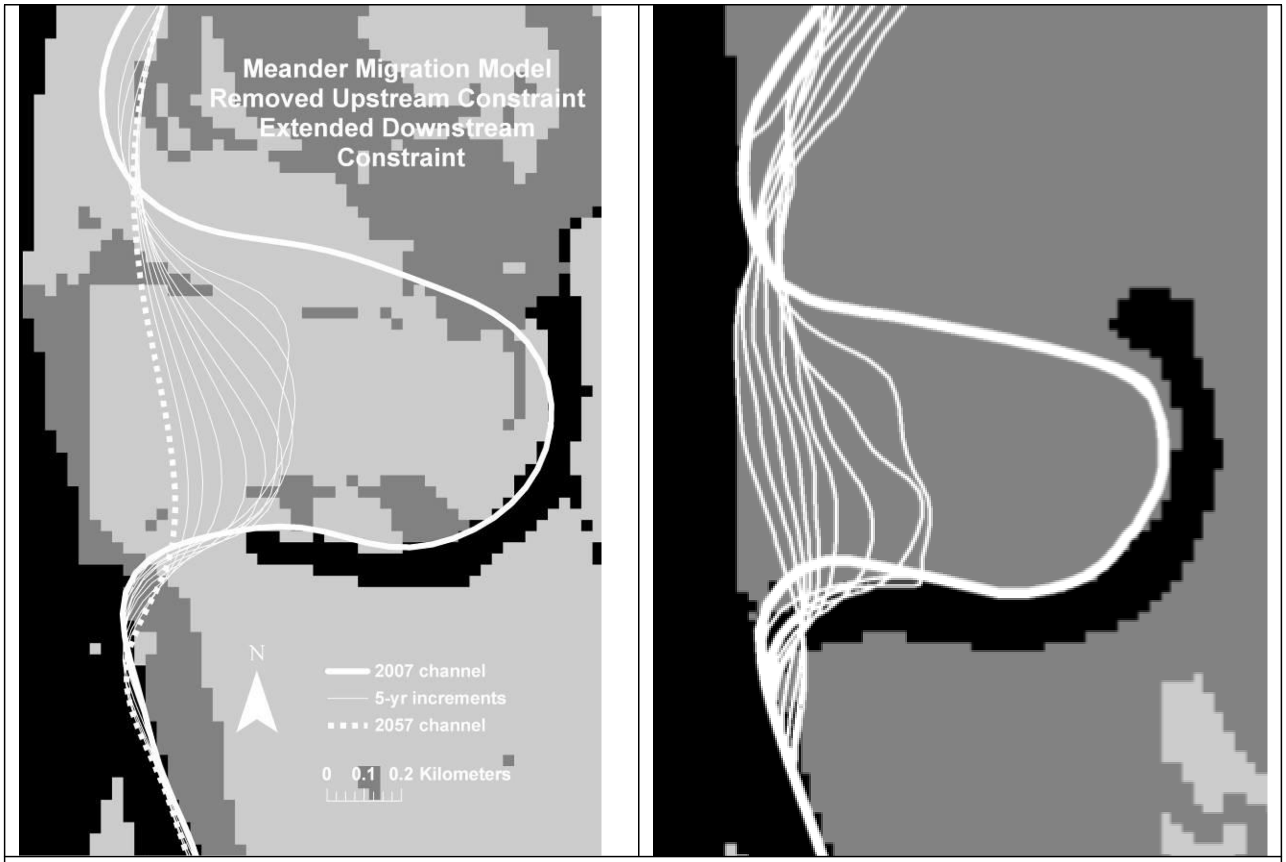

Figure 11 Upstream constraint removed and downstream extended "1997" and "2007" models

Discussion and Conclusions

The current model is newly calibrated and simulations performed using the latest improvements to the model. The model can be used to explore questions raised by future channel management, flow changes, and other environmental changes in the vicinity of the pumping plant.

Three separate forward simulations were performed: 1) with the existing bank constraints in place, 2) with the upstream bank constraints removed at the bend in question, and cutoff occurring, and 3) with the upstream bank constraints removed at the bend in question, and the downstream-limb bank constraints extended and cutoff occurring . With the current bank constraints on the bend, the southern limb of the bend tends to move downstream where it is allowed to by the existing constraints, and moves away from the pump. With the upstream constraints removed, and the downstream in the current configuration, the river tends to move away from the pump. In the third case, with the downstream constraint extended, the river tends to remain near the pump location. These results confirm earlier modeling that was done with a 1997 channel configuration and no variable flow.

The model simulations suggest that, if the channel migration near the pump site were stabilized by extending the constraints on the downstream limb of the bend, the bend upstream could be allowed to cutoff in order to provide natural river processes and natural regeneration of the upstream floodplain area without extensive migration occurring near the pump site.

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Appendices

Appendix 1 Scope of requested work

> **Subtask 4.2.a.** Use the existing meander migration and cutoff analyses, adapt these for site-specific questions developed by the Technical Committee, and create new models where appropriate, with a variable erosion field, and variable flow rates, and **assuming the current rock revetment and evolution from the current river planform** in the vicinity of the rock site(s) identified between RM 176 -178.5. Obtain most recent planform. Provide a 50-year prediction, with centerline output mapped at 5-year increments. TIME: 40 HRS
>
> **Subtask 4.2.b.** Use the existing meander migration and cutoff analyses, adapt these for site-specific questions developed by the Technical Committee, and create new models where appropriate, with a variable erosion field simulating evolution from the current river planform in the vicinity of the rock site(s) identified between RM 176 -178.5 **assuming the removal of a limited number of specified existing rock revetments**. Provide a 50-year prediction, with centerline output mapped at 5-year increments. TIME: 24 HRS

Appendix 2 Model Parameters for Calibration and Prediction Runs

Some of the model parameters are internal to the model and are recorded as metadata. “Erosion coefficients” are used to establish the erodibility of the erosion surface and are described in other sources (e.g. Larsen and Greco 2002). “Centerline properties” record the projections for geographic data (UTM zone 10 NAD 83), the starting and ending channels for the modeled migration, the date and time of the run, and model version that was used.

“Flow parameters” are derived from acquired data. The discharge, width, depth, slope and particle size were described above. The “Upper threshold” is a value set above which flows are not effective in changing the “stream power”, which is the metric used for the variable flow simulations. “Computational parameters”, “cutoff parameters” and “erosion algorithm parameters” are parameters that are internal to the model, and are recorded here as modeling metadata.

	Riparian Sanctuary RM 178 Calibraion run	**Riparian Sanctuary RM 178 with existing bank restraint run**	**Riparian Sanctuary RM 178 cutoff run**	**Riparian Sanctuary RM 178 cutoff and extended constraint run**
	UTM NAD 83 Zone 10	UTM NAD 83 Zone 10	UTM NAD 83 Zone 10	UTM NAD 83 Zone 10
	1976 Start Channel	2008 Start Channel	1976 Start Channel	1976 Start Channel
	2008 End Channel	2058 Prediction	2058 Prediction	2058 Prediction
	file written 13-Feb-2010 15:30:54	file written 13-Feb-2010 15:56:18	file written 13-Feb-2010 16:38:39	file written 14-Feb-2010 16:18:55
	Meander version: Meander 7.3.5	Meander version: Meander 7.3.5	Meander version: Meander 7.3.5	Meander version: Meander 7.3.5
FLOW PARAMETERS				
Q	= 2180 cms	= 2180 cms	= 2180 cms	= 2180 cms
H (depth)	= 4.91 m	= 4.91 m	= 4.91 m	= 4.91 m
B (width)	= 277 m	= 277 m	= 277 m	= 277 m
S (slope)	0.000297	0.000297	0.000297	0.000297
Ds	= 18 mm	= 18 mm	= 18 mm	= 18 mm
FlowThresh	425	425	425	425
Bankfull	2180	2180	2180	2180
COMPUTATIONAL PARAMETERS				
dyr	1	1	1	1
C_max	0.6	0.6	0.6	0.6
Spacing	0.5	0.5	0.5	0.5
Smoothing filter spacing	3	3	3	3
Smoothing distance	10	10	10	10
Smoothing proportion	10	10	10	10
Eo_Spacing	1	1	1	1
Cf_scale	2.5	2.5	2.5	2.5
Calc_uf	0	0	0	0
Check_curve	1	1	1	1
EROSION FIELDS				
	e0 RS 2010 final calibration initial no rr test2.asc	e0 RS 2010 final calibration_1985_rr999999_extended2xab.asc	e0 RS 2010 final calibration_1985_NOrr999999_extended2xab.asc	e0 RS 2010 final calibration_1985_NOrr999999_extended2xabWithMORE.asc
	e0 RS 2010 final calibration_1985_rr999999_extended2xab.asc			
CUTOFF PARAMETERS				
Sinu Thresh	n/a	n/a	3	3
Recur. Int.	n/a	n/a	2	2
Cutoff Routine	n/a	n/a	1	1
Upstr. Cutoff factor	n/a	n/a	0.25	0.25
Downst. Cutoff factor	n/a	n/a	0.1	0.1
Bend Distance Threshold	n/a	n/a	900	900
BEND PARAMETERS				
bend length=	8	8	8	8
straightSin=	0.0005	0.0005	0.0005	0.0005
bendSin =	0.0005	0.0005	0.0005	0.0005
EROSION ALGORITHM PARAMETERS				
a--Eo	1	1	1	1
b--Depth	0	0	0	0
d--Erosion	1	1	1	1
HYDRAULIC PARAMETERS				
g =	9.81	9.81	9.81	9.81
fstar =	1.19	1.19	1.19	1.19
alpha =	0.077	0.077	0.077	0.077
alphastar =	0.85	0.85	0.85	0.85
mu =	0.43	0.43	0.43	0.43
nu =	1.01E-06	1.01E-06	1.01E-06	1.01E-06
rhos =	1.65	1.65	1.65	1.65