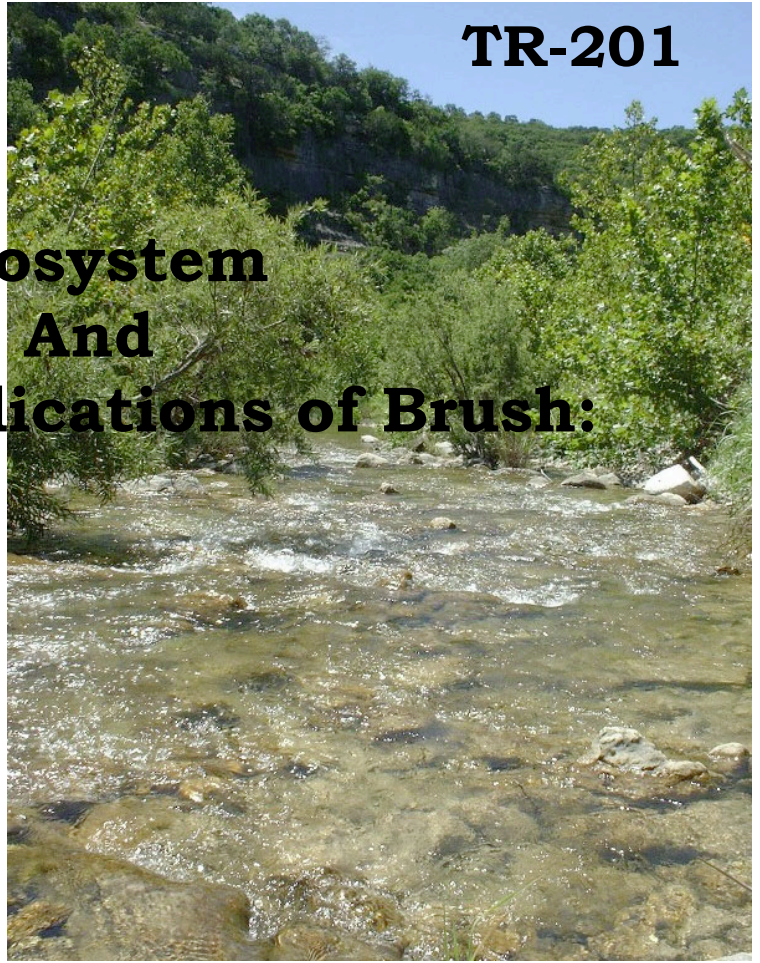


TR-201

**Ecosystem
And
Wildlife Implications of Brush:**



Management Systems Designed to
Improve Water Runoff and Percolation



**Ecosystem and Wildlife Implications of Brush:
Management Systems Designed to
Improve Water Yield**

Final Completion Report
Submitted to the

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Texas Agricultural Experiment Station

D. Albrey Arrington
Richard Conner
William Dugas
Sallie Hejl
Dawn Magness
Ranjan Muttiah
Keith Olenick
Wes Rosenthal
Raghavan Srinivasan
Kirk O. Winemiller
Michele Zinn

Texas Cooperative Extension

Neal Wilkins

Natural Resources Conservation Service

Carl Amonett
Steve Bednarz
Tim Dybala

Corps of Engineers

Rebecca Griffith
Hank Jarboe

Administrative Liaison--Texas Water Resources Institute

Ronald Lacewell
Allan Jones

Manuscript Preparation

Jan Gerston

November 1, 2002

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As the purpose of this project is to pave the way for implementation of a program of restoration on rangelands and the quality and quantity of percolation and runoff, a major player is the landowner. It is essential to gain insight on attitude regarding such a program and some definition of willingness and ability to pay in a cost-share program. Those landowners who participated in the stakeholder meetings have our deepest gratitude for contributing their time and their honesty.

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Table of Contents

	Page
Acknowledgements.....	i
Table of Contents.....	ii
List of Tables	vii
List of Figures.....	xii
Summary and Overview	1
Objectives	1
Hydrologic Modeling.....	1
Economics/Range.....	2
Terrestrial/Aquatic.....	2
Study Area	2
Scenarios.....	2
Organization of the Report.....	7
Interrelationships of Evaluation Factors.....	7
Section 1. Hydrologic Modeling.....	11
Participants.....	11
Introduction.....	11
Methods	11
Model Inputs.....	11
Climate	12
Topography	12
Soils	12
Land Use/Land Cover.....	12
Ground Control Points.....	13
Model Changes.....	14
Model Calibration.....	14
Scenario Analyses	14
Results and Discussion.....	16
Calibration	16
Twin Buttes	16
Middle Concho.....	16
South Concho.....	16
Spring Creek	16
Dove Creek.....	16
Edwards.....	16
Frio	16
Hondo.....	16
Medina.....	16
Sabinal.....	16
Seco	16
Scenarios.....	16
Twin Buttes	16
Middle Concho.....	16
South Concho.....	18
Spring and Dove	18

	Page
Edwards.....	19
Frio.....	19
Hondo.....	20
Medina.....	20
Sabinal.....	21
Seco.....	23
Comparisons Across Watersheds.....	23
Conclusions.....	25
Section 2. Rangeland/Economic Analysis.....	55
Participants.....	55
Introduction.....	55
Methods.....	55
Inputs.....	55
Model Changes.....	56
Scenario Analysis.....	70
Results and Discussion.....	70
Society and Landowner Cost Shares.....	70
Twin Buttes.....	70
Western Edwards.....	71
Eastern Edwards.....	71
Society Cost of Added Water.....	73
Twin Buttes.....	73
Middle Concho.....	73
South Concho.....	73
Spring-Dove Creek.....	73
Edwards.....	74
Frio.....	74
Hondo.....	74
Medina.....	74
Sabinal.....	74
Seco.....	74
Ecological Restoration.....	92
Twin Buttes.....	93
Middle Concho.....	93
South Concho.....	93
Spring-Dove Creek.....	93
Edwards.....	93
Frio.....	93
Hondo.....	93
Medina.....	93
Sabinal.....	93
Seco.....	93
Comparison Across Watersheds.....	93
Conclusions.....	94
Additional Considerations.....	95
Section 3. Wildlife Response to Brush Management Scenarios.....	103
Participants.....	103
Introduction.....	103

	Page
Methods	104
Site Selection	104
Survey Protocol	104
Spring Bird Surveys	104
Winter Bird Survey	104
Habitat Use Models	104
Scenario Analyses	106
Species Composition	107
Results and Discussion	107
Brush Cover	107
Twin Buttes	107
Edwards	107
Survey Summaries	109
Twin Buttes	109
Edwards	109
Model Results	109
Twin Buttes	109
Edwards	111
Scenarios	112
Twin Buttes	112
Edwards	112
Implications	113
Species Composition	113
Section 4. Aquatic Biota Responses to Alternative Brush Management Scenarios	127
Participants	127
Introduction	127
Methods	127
Biological Field Surveys	127
Development of Fish IBI (F-IBI)	132
Development of Invertebrate IBI (B-IBI)	133
Multivariate analysis of aquatic assemblages (CCA analyses)	134
Results and Discussion	139
Comparison of F-IBI and B-IBI Scores	140
Regression Analysis of F-IBI Scores and Sub-basin Land Cover Characteristics	140
Regression Analysis of F-IBI Scores and Sub-basin Modeled Discharge Characteristics	141
Predictions for Alternative Land-cover Scenarios	142
Results from multivariate analysis of assemblage patterns	142
Recommendations for future studies	146
References	161
APPENDIX A. Refinements of Riparians	165
Participants	165
Introduction	165
Methods	165

	Page
Results and Discussion.....	166
Riparian Types.....	166
Twin Buttes	166
Edwards.....	167
Ecological Restoration	167
Twin Buttes	168
Edwards.....	168
Total Cost and Society Cost of Added Water.....	168
Twin Buttes.....	168
Middle Concho	168
South Concho	168
Spring/Dove Creeks	168
Edwards	168
Frio.....	168
Hondo	168
Medina	168
Sabinal	168
Seco.....	169
Comparison Across Watersheds	169
Conclusion	169
Additional Considerations.....	169
APPENDIX B. Species Detected In Twin Buttes And Analyses	187
B1 Species detected in Twin Buttes spring surveys. Bird species listed in descending order according to number of individuals detected. 295 survey sites sampled.....	187
B2 Species detected during Twin Buttes winter surveys. 135 survey sites sampled.....	189
B3 Logistic regression models for all Twin Buttes breeding guilds (*** = $p < 0.01$, ** = $p < 0.05$, * = $p < 0.1$).....	191
B4 Logistic regression models for Twin Buttes breeding species with $N > 15$ (*** = $p < 0.01$, ** = $p < 0.05$, * = $p < 0.1$).....	192
B5 Twin Buttes logistic regression model estimates	193
APPENDIX C. Species Detected In Edwards and Analyses	194
C1 Species detected in Edwards spring surveys. 201 survey sites sampled.....	194
C2 Species detected in Edwards winter surveys. 147 survey sites sampled.....	196
C3 Logistic regression for all Edwards breeding bird guilds (*** = $p < 0.01$, ** = $p < 0.05$, * = $p < 0.1$).....	198
C4 Logistic regression models for Edwards breeding bird species with $N > 15$ (*** = $p < 0.01$, ** = $p < 0.05$, * = $p < 0.1$)	199
C5 Edwards logistic regression model estimates.....	200
APPENDIX D Bird Guilds	201
D1 Twin Buttes Breeding Bird Guilds	201
D2 Twin Buttes Winter Bird Guilds	202
D3 Edwards Breeding Bird Guilds	203
D4 Edwards Winter Bird Guilds	204
APPENDIX E	205
E1 List of birds sighted in Edwards and Twin Buttes watersheds according to current field check lists.....	205

	Page
E2 List of amphibians and reptiles in Edwards and Twin Buttes watersheds according to current distribution maps	232
E3 List of mammals in Edwards and Twin Buttes watersheds according to current distribution maps	242
APPENDIX F Aquatic Community Sampling Field Data	251
APPENDIX G Fish Species and Abundance Sample Number	275
APPENDIX H Aquatic Macro Invertebrata Taxa	282
APPENDIX I Values for IBI scores and proportional landcover by categories for sub-basins under Scenarios IV and V	310

List of Tables

		Page
Table 1.	Attributes associated with alternative brush management scenarios	9
Table 1.1.	Key model inputs for each watershed	15
Table 1.2.	Scenarios simulated	15
Table 1.3.	Total watershed area, total area of treatable brush (i.e. heavy and moderate cover) and brush removed, and water yield and stream flow increases for scenarios I through V (see Table 1.2) for Middle Concho River. Water yield and stream flow increases are expressed relative to scenario IV (top) and scenario V (bottom). For scenario V, brush removed area is equal to the area of light brush	17
Table 1.4.	Total watershed area, total area of treatable brush (i.e. heavy and moderate cover) and brush removed, and water yield and stream flow increases for scenarios I through V (see Table 1.2) for South Concho River. Water yield and stream flow increases are expressed relative to scenario IV (top) and scenario V (bottom). For scenario V, brush removed area is equal to the area of light brush	18
Table 1.5.	Total watershed area, total area of treatable brush (i.e. heavy and moderate cover) and brush removed, and water yield and stream flow increases for scenarios I through V (see Table 1.2) for Spring and Dove Creeks. Water yield and stream flow increases are expressed relative to scenario IV (top) and scenario V (bottom). For scenario V, brush removed area is equal to the area of light brush	19
Table 1.6.	Total watershed area, total area of treatable brush (i.e. heavy and moderate cover) and brush removed, and water yield and stream flow increases for scenarios I through V (see Table 1.2) for Frio River. Water yield and stream flow increases are expressed relative to scenario IV (top) and scenario V (bottom). For scenario V, brush removed area is equal to the area of light brush.....	20
Table 1.7.	Total watershed area, total area of treatable brush (i.e. heavy and moderate cover) and brush removed, and water yield and stream flow increases for scenarios I through V (see Table 1.2) for Hondo Creek. Water yield and stream flow increases are expressed relative to scenario IV (top) and scenario V (bottom). For scenario V, brush removed area is equal to the area of light brush.....	21
Table 1.8.	Total watershed area, total area of treatable brush (i.e. heavy and moderate cover) and brush removed, and water yield and stream flow increases for scenarios I through V (see Table 1.2) for Medina River. Water yield and stream flow increases are expressed relative to scenario IV (top) and scenario V (bottom). For scenario V, brush removed area is equal to the area of light brush.....	22
Table 1.9.	Total watershed area, total area of treatable brush (i.e. heavy and moderate cover) and brush removed, and water yield and stream flow increases for scenarios I through V (see Table 1.2) for Sabinal River. Water yield and stream flow increases are expressed relative to scenario IV (top) and scenario V (bottom). For scenario V, brush removed area is equal to the area of light brush.....	22

	Page	
Table 1.10.	Total watershed area, total area of treatable brush (i.e. heavy and moderate cover) and brush removed, and water yield and stream flow increases for scenarios I through V (see Table 1.2) for Seco Creek. Water yield and stream flow increases are expressed relative to scenario IV (top) and scenario V (bottom). For scenario V, brush removed area is equal to the area of light brush.....	23
Table 1.11.	Annual water savings (gallons per treated acre) from brush removal at selected	25
Table 2.1a.	Cost of Brush Management/Restoration Treatments by Brush Type-Density Category - Twin Buttes	57
Table 2.1b	Cost of Brush Management Restoration Treatments by Brush Type-Density Category - Western Edwards	59
Table 2.1c.	Cost of Brush Management Restoration Treatments by Brush Type-Density Category - Eastern Edwards.....	62
Table 2.2a.	Grazing Capacity With and Without Brush Control (Acres/AUY) - Twin Buttes.....	65
Table 2.2b.	Grazing Capacity With and Without Brush Control (Acres/AUY) - Western Edwards.....	65
Table 2.2c.	Grazing Capacity With and Without Brush Control (Acres/AUY) - Eastern Edwards	66
Table 2.3a.	Economic Evaluation Variables - Twin Buttes.....	67
Table 2.3b.	Economic Evaluation Variables - Western Edwards.....	68
Table 2.3c.	Economic Evaluation Variables - Eastern Edwards	69
Table 2.4.	Twin Buttes Landowner/State Cost Shares of Brush Control (60% Cattle - 10% Meat Goat - 30% Sheep).....	72
Table 2.5.	Western Edwards Landowner/State Cost Shares of Brush Control (20% Cattle—50% Meat Goat—30% Sheep).....	72
Table 2.6.	Eastern Edwards Landowner/State Cost Shares of Brush Control (80% Cow/Calf—20% Meat Goat).....	73
Table 2.7a.	Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot) Middle Concho - Scenario 1	74
Table 2.7b.	Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot) Middle Concho - Scenario 2	75
Table 2.7c.	Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot) Middle Concho - Scenario 3	76
Table 2.8a.	Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot) South Concho - Scenario 1	77
Table 2.8b.	Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot) South Concho - Scenario 2	77
Table 2.8c.	Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot) South Concho - Scenario 3	78
Table 2.9a.	Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot) Spring/Dove Creeks – Scenario 1	79

	Page
Table 2.9b. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot) Spring/Dove Creeks – Scenario 2	80
Table 2.9c. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot) Spring/Dove Creeks – Scenario 3	81
Table 2.10a. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot) Frio – Scenario 1	82
Table 2.10b. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot) Frio – Scenario 2	83
Table 2.10c. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot) Frio – Scenario 3	84
Table 2.11a. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot) Hondo – Scenario 1	84
Table 2.11b. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot) Hondo – Scenario 2	85
Table 2.11c. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot) Hondo – Scenario 3	85
Table 2.12a. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot) Medina – Scenario 1	86
Table 2.12b. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot) Medina – Scenario 2	87
Table 2.12c. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot) Medinal – Scenario 3	88
Table 2.13a. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot) Sabinal – Scenario 1	89
Table 2.13b. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot) Sabinal - Scenario 2	89
Table 2.13c. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot) Sabinal - Scenario 3	90
Table 2.14a. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot) Seco - Scenario 1	90
Table 2.14b. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot) Seco - Scenario 2	91
Table 2.14c. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot) Seco - Scenario 3	91
Table 3.1. Changes in the average brush percent cover by scenario over the Twin Buttes study area	108
Table 3.2. Changes in the average brush percent cover by scenario over the Edwards study area	108

	Page
Table 3.3. Logistic regression model relationships for breeding birds on the Twin Buttes study area. Sign (+/-) represents the direction of response (i.e., change in habitat occupancy) predicted from an increase in that brush type. Specific model terms are presented in Appendix IE.	110
Table 3.4. Logistic regression model relationships for Edwards breeding birds. Sign (+/-) represents the direction of response (i.e., change in habitat occupancy) predicted from an increase in that brush type. Specific model terms are presented in Appendix IIE.	111
Table 3.5. Average probability of occurrence of guilds and species across the study areas by scenario. Estimated probability of occurrence at any one site ranges from 0 to 1. Numerical values represent an average score from the accumulation of all “moving windows” sites across each study area.	115
Table 3.6. Percent of study area estimated to have a greater than 0.5 probability of occurrence under the various brush management scenarios, for guilds and species across the Twin Buttes and Edwards study areas.	116
Table 4.1. Summary of the number of aquatic survey (sample) locations by watershed, basin, and sub-basin.	128
Table 4.2. Sample location and IBI scores for collected aquatic samples.	129
Table 4.3. Individual metrics and associated scoring criteria for habitat-specific and basin-specific fish IBI calculation. Due to the varying number of metrics used per group, scores vary such that the maximum possible score is scaled to 100 points.	133
Table 4.4. Assignment of fish species for IBI species richness metric.	135
Table 4.5. Assignment of fish species for IBI trophic structure metric.	136
Table 4.6. Interpretation of IBI Scores.	137
Table 4.7. Individual metrics and associated scoring criteria for habitat-specific and basin-specific benthic macroinvertebrate IBI calculation (modified from Kerans and Karr 1994, Lammert and Allan 1999).	138
Table 4.8. Fishes collected by drainage.	143
Table 4.9. Regression model coefficients and significance.	144
Table 4.10. Mean observed F-IBI score by sub-basin, and F-IBI scores by scenario by sub-basin as predicted by the two factor (cedar and mesquite) model.	145
Table 4.11. Canonical coefficients from CCA analysis of fish data.	146
Table 4.12. Canonical coefficients from CCA analysis of invertebrate data.	147
Table A1. Cost of Water Yield Brush Control Programs by Riparian Condition - Twin Buttes.	170
Table A2. Cost of Water Yield Brush Control Programs by Riparian Condition - Twin Buttes.	171
Table A3. Treated Acres Under Each Scenario.	171
Table A4a. Cost of Added Water From Brush Control By Subbasin (Acre-Foot) Middle Concho - Scenerio 2 with Riparian Restoration Treatments.	172
Table A4b. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot) Middle Concho - Scenerio 3 with Riparian Restoration Treatments.	173

	Page
Table A5a. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot) South Concho - Scenerio 2 with Riparian Restoration Treatments	174
Table A5b. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot) South Concho - Scenerio 3 with Riparian Restoration Treatments	174
Table A6a. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot) South Concho - Scenerio 2 with Riparian Restoration Treatments	175
Table A6b. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot). South Concho - Scenerio 3 with Riparian Restoration Treatments	175
Table A7a. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot) Frio – Scenerio 2 with Riparian Restoration Treatments	176
Table A7b. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot) Frio – Scenerio 2 with Riparian Restoration Treatments	177
Table A8a. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot) Hondo – Scenerio 2 with Riparian Restoration Treatments	178
Table A8b. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot) Hondo – Scenerio 3 with Riparian Restoration Treatments	178
Table A9a. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot) Medina – Scenerio 2 with Riparian Restoration Treatments	179
Table A9b. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot) Medina – Scenerio 3 with Riparian Restoration Treatments	180
Table A10a. Cost of Added Water From Brush Control By Subbasin (Acre-Foot) Sabinal – Scenerio 2 with Riparian Restoration Treatments	181
Table A10b. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot) Sabinal – Scenerio 3 with Riparian Restoration Treatments	181
Table A11a. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot) Seco – Scenerio 2 with Riparian Restoration Treatments	182
Table A11b. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot) Seco – Scenerio 2 with Riparian Restoration Treatments	182

List of Figures

	Page
Figure 1. Watersheds included in study	3
Figure 2. Estimated total percent brush cover under 5 management scenarios, Twin Buttes study area. Scenario IV represents present condition; scenarios I, II, and III represent alternative futures under different brush management program constraints; while scenario V is a projected future condition given no brush control program on the area.....	5
Figure 3. Estimated total percent brush cover under 5 management scenarios, Edwards study area. Scenario IV represents present condition; scenarios I, II, and III represent alternative futures under different brush management program constraints; while scenario V is a projected future condition given no brush control program on the area.....	6
Figure 1.1. Watersheds included in study	26
Figure 1.2. Cumulative monthly stream flow predicted by SWAT and measured near outlet of Middle Concho River. Average measured and predicted monthly flows for the entire calibration period and the root mean square error (RMSE) between monthly predicted and measured flows are shown.....	27
Figure 1.3. Cumulative monthly stream flow predicted by SWAT and measured near outlet of South Concho River. Average measured and predicted monthly flows for the entire calibration period and the root mean square error (RMSE) between monthly predicted and measured flows are shown.....	28
Figure 1.4. Cumulative monthly stream flow predicted by SWAT and measured near outlet of Spring Creek. Average measured and predicted monthly flows for the entire calibration period and the root mean square error (RMSE) between monthly predicted and measured flows are shown.....	29
Figure 1.5. Cumulative monthly stream flow predicted by SWAT and measured near outlet of Dove Creek. Average measured and predicted monthly flows for the entire calibration period and the root mean square error (RMSE) between monthly predicted and measured flows are shown.....	30
Figure 1.6. Cumulative monthly stream flow predicted by SWAT and measured near outlet of Frio River. Average measured and predicted monthly flows for the entire calibration period and the root mean square error (RMSE) between monthly predicted and measured flows are shown.....	31
Figure 1.7. Cumulative monthly stream flow predicted by SWAT and measured near outlet of Hondo Creek. Average measured and predicted monthly flows for the entire calibration period and the root mean square error (RMSE) between monthly predicted and measured flows are shown.....	32
Figure 1.8. Cumulative monthly stream flow predicted by SWAT and measured near outlet of Medina River. Average measured and predicted monthly flows for the entire calibration period and the root mean square error (RMSE) between monthly predicted and measured flows are shown.....	33
Figure 1.9. Cumulative monthly stream flow predicted by SWAT and measured near outlet of Sabinal River. Average measured and predicted monthly flows for the entire calibration period and the root mean square error (RMSE) between monthly predicted and measured flows are shown.....	34

	Page
Figure 1.10. Cumulative monthly stream flow predicted by SWAT and measured near outlet of Seco Creek. Average measured and predicted monthly flows for the entire calibration period and the root mean square error (RMSE) between monthly predicted and measured flows are shown.....	35
Figure 1.11. Average monthly measured and predicted stream flow for watersheds in this study. Averages are for varying periods, but typically 1960 through 1998.....	36
Figure 1.12. Cumulative monthly stream flow predicted by SWAT for scenarios I through V near outlet of Middle Concho River.....	37
Figure 1.13. Cumulative monthly stream flow predicted by SWAT for scenarios I through V near outlet of South Concho River.....	38
Figure 1.14. Cumulative monthly stream flow predicted by SWAT for scenarios I through V near outlet of Spring and Dove Creeks.....	39
Figure 1.15. Cumulative monthly stream flow predicted by SWAT for scenarios I through V near outlet of Frio River.....	40
Figure 1.16. Cumulative monthly stream flow predicted by SWAT for scenarios I through V near outlet of Hondo Creek.....	41
Figure 1.17. Cumulative monthly stream flow predicted by SWAT for scenarios I through V near outlet of Medina River.....	42
Figure 1.18. Cumulative monthly stream flow predicted by SWAT for scenarios I through V near outlet of Sabinal River.....	43
Figure 1.19. Cumulative monthly stream flow predicted by SWAT for scenarios I through V near outlet of Seco Creek.....	44
Figure 1.20. Area of each watershed.....	45
Figure 1.21. Average annual precipitation in each watershed.....	46
Figure 1.22. Average annual simulated stream flow in each watershed.....	47
Figure 1.23. Fraction of total watershed area treated (i.e. area with moderate and heavy brush removed) for scenarios I, II, and III, and in a previous study (TAES 2000). Negative area for scenario V represents area of light brush added.....	48
Figure 1.24. Annual average stream flow increase, relative to scenario IV, for scenarios I, II, III, and V, and in a previous study (TAES 2000). Negative stream flow for scenario V represents a flow decrease.....	49
Figure 1.25. Annual average stream flow increase, relative to scenario V, for scenarios I, II, III, and IV.....	50
Figure 1.26. Annual average stream flow increase, per treated acre and relative to scenario IV, for scenarios I, II, III, and V, and in a previous study (TAES 2000). Negative stream flow for scenario V represents a flow decrease.....	51
Figure 1.27. Annual average stream flow increase, per treated acre and relative to scenario V, for scenarios I, II, III, and IV.....	52

	Page
Figure 1.28. Annual average water yield increase, per treated acre and relative to scenario IV, for scenarios I, II, III, and V, and in a previous study (TAES 2000). Negative water yield for scenario V represents a decrease	53
Figure 1.29. Annual average water yield increase, per treated acre and relative to scenario V, for scenarios I, II, III, and I	54
Figure 2.1. Comparison of society costs for restoration, Scenarios I, II and III	96
Figure 2.2. Comparison of society costs per acre-foot of water saved, by watershed.....	97
Figure 2.3. Comparison of society costs by scenario, Edwards.....	98
Figure 2.4. Comparison of society costs by scenario, Twin Buttes.....	99
Figure 2.5. Rangeland restoration, by watershed	100
Figure 2.6. Comparison of rangeland restoration, Edwards versus Twin Buttes	101
Figure 3.1. Twin Buttes study area survey sites. Winter survey sites were sampled in winter 2002 and spring 2001. Spring survey sites were sampled in spring 2001	117
Figure 3.2. Twin Buttes study area survey sites. Winter survey sites were sampled in winter 2002 and spring 2001. Spring survey sites were sampled in spring 2001	118
Figure 3.3. Example of a 400-m-radius landscape in the Twin Buttes study area	119
Figure 3.4. Present condition (Scenario IV) of brush cover variables across the Twin Buttes study area. Brush cover concentrations are represented at a 620m x 620m resolution.....	120
Figure 3.5. Present condition (Scenario IV) of brush cover variables across the Edwards study area. Brush cover concentrations are represented at a 620m x 620m resolution.....	121
Figure 3.6. Predicted probability of occupancy by obligate grassland birds during the breeding season for each of five brush management scenarios, Twin Buttes Study Area. Color scale represents probabilities of occurrence estimated by logistic regression model (see text)	122
Figure 3.7. Comparisons of the impact of Scenario III <i>versus</i> Scenarios IV and IV on habitat occupancy scores for grassland breeding birds across the Twin Buttes study area. Numerical values represent the estimated increase in the likelihood of occurrence of grassland breeding birds resulting from the localized habitat changes of Scenario III when compared to the present condition (Scenario IV) and a projected future scenario of “no action” (Scenario V)	123
Figure 3.8. Predicted probability of occupancy by a grassland guild of birds during the breeding season for each of five brush management scenarios, Edwards Study Area. Color scale represents probabilities of occurrence estimated by logistic regression model (see text)	124
Figure 3.9. Comparisons of the impact of Scenario III <i>versus</i> Scenarios IV and IV on habitat occupancy scores for grassland breeding birds across the Edwards study area. Numerical values represent the estimated increase in the likelihood of occurrence of grassland breeding birds resulting from the localized habitat changes of Scenario III when compared to the present condition (Scenario IV) and a projected future scenario of “no action” (Scenario V).....	125

	Page
Figure 4.1. Twin Buttes watershed with basin and sub-basin boundaries and aquatic biological survey locations illustrated. Sample locations are represented by filled circles. Typically, multiple samples were collected at each location	148
Figure 4.2. Edwards watershed with basin and sub-basin boundaries and aquatic biological survey locations illustrated. Sample locations are represented by filled circles. Typically, multiple samples were collected at each location	149
Figure 4.3. Frequency histograms of F-IBI scores by drainage by habitat.....	150
Figure 4.4. Frequency histograms of B-IBI scores by drainage by habitat	151
Figure 4.5. Twin Buttes sub-basins colored by the minimum F-IBI score.....	152
Figure 4.6. Edwards sub-basins colored by the minimum F-IBI score	153
Figure 4.7. Relationship between calculated fish (F-IBI) and benthic macroinvertebrate (B-IBI) IBI scores. There was little concordance between fish and invertebrate IBI scores ($R^2 = 0.024$; $P = 0.09$).....	154
Figure 4.8. Relationship between observed and predicted F-IBI scores by sub-basin for both the complete seven factor model and the selected two factor (cedar and mesquite) model.....	155
Figure 4.9. Twin Buttes CCA analysis results indicating the influence of physical habitat parameters on fish assemblages and the observed relationship between these parameters on observed F-IBI scores	156
Figure 4.10. Edwards CCA analysis results indicating the influence of physical habitat parameters on fish assemblages and the observed relationship between these parameters on observed F-IBI scores.....	157
Figure 4.11. Twin Buttes CCA analysis results indicating the influence of physical habitat parameters on invertebrate assemblages and the observed relationship between these parameters on observed B-IBI scores.....	158
Figure 4.12. Edwards CCA analysis results indicating the influence of physical habitat parameters on invertebrate assemblages and the observed relationship between these parameters on observed B-IBI scores	159
Figure A1. Comparison of total society costs for restoration Scenarios II, II Rip, III and III Rip.....	183
Figure A2. Comparison of society costs per acre-foot of water saved, Scenarios II, II Rip, III and III Rip	184
Figure A3. Comparison of total society costs and costs per acre-foot of water saved, Twin Buttes	185
Figure A4. Comparison of total society costs and costs per acre-foot of water saved, Edwards	186

Ecosystem and Wildlife Implications of Brush Management Systems Designed to Improve Water Runoff and Percolation

Summary and Overview

With the settlement of Texas and establishment of ranchers to produce cattle, there was an effort to maximize beef production. This caused serious overgrazing. In addition, there was a reduced incidence of fires across the landscape to clear out brush. These factors led to deterioration of the grazing lands and provided an opportunity for invasive intrusion by brush and other species onto the land and riparian zones. There has been a large-scale conversion from grasslands and savannahs to wildlands over the last 150 years (Scholes and Archer, 1997). The overall impacts are significantly impaired uplands and reduced percolation and surface flow of water from rainfall which caused changes and loss in basic aquatic and terrestrial habitat.

The State of Texas adopted a program to study and implement brush management systems across the state to improve the water availability in streams, rivers, reservoirs and aquifers, as well as to improve the rangelands. The feasibility studies have shown great promise for improving ranchland and improving the water situation. However, there is less known about the aquatic and wildlife species response implications of brush management. Certainly, there are opportunities for improving the viability of an ecosystem through brush management strategies and continuing management practices. The purpose of this study was to evaluate the changes in hydrology and biological diversity associated with brush management in two watersheds where significant data was already available.

This study focused on assessing the aquatic and terrestrial species implications related to specified brush management strategies over time. This involved an integrated analysis including modeling of the landscape, assessing biological diversity and developing economic implications for the two watersheds (Twin Buttes and Edwards regions). Thus, this study is comprised of three parts: modeling of brush management strategies temporally, assessing biological diversity (aquatic and terrestrial) and estimating economic implications. This represents a complex analysis involving variable units and multiple disciplines.

Previous feasibility studies of brush removal have been targeted at maximizing water runoff. This analysis is an extension that is designed to examine the implications of brush management under a more restrictive set of brush removal criteria that were chosen based upon wildlife considerations. To achieve the integration of hydrologic modeling, range ecology, and economic implications, there were three team meetings bringing together all components to review status and set priorities for the remainder of the work. In addition, scientists in the three basic groups of specialization interacted daily along with representatives of the Corps of Engineers to assure that each decision was reflected in other parts of the analyses. The major addition of this analysis to brush management feasibility studies being conducted as part of the Texas brush management plan is the consideration of wildlife and aquatic biota and assessing changes in biological diversity likely to result from alternative brush management scenarios.

Objectives

Due to the multiple resources considered in this study, the objectives are organized to show methods and implications for each resource. Objectives covering all aspects of the study are as follows:

Hydrologic Modeling: Quantify hydrologic parameters of alternative brush management strategies that address wildlife implications.

Economics/Range: Identify and describe selected alternative “wildlife-friendly” ecological restoration techniques and materials requirements for the dominant brush-type categories/ecosites within the Twin Buttes watershed and the Edwards Aquifer Recharge Zone watershed.

- Determine the direct and indirect (opportunity) costs of implementing and maintaining each brush and land management practice. Delineate the types and proportions of benefits and costs accruing to participating landowners as opposed to the general public.
- Identify and describe alternative legal instruments (contracts, leases, easements, etc.) that could potentially be used with participating landowners to entice their cooperation in implementing and maintaining the brush control and additional conservation measures and insure their compliance with the accompanying land use and other requirements.
- Survey landowners in the targeted watershed to determine their attitudes toward and likelihood of participation in programs designed to initiate the “wildlife-friendly” ecological restoration practices under provisions of the different legal instruments with an array of possible cost shares for both direct and indirect implementation and maintenance costs

Terrestrial/Aquatic: The previous studies are to be extended beyond the comparison of future brush management scenarios’ impacts on runoff and percolation to the likely impacts on terrestrial and aquatic species.

- Establish baseline estimates of chosen native vertebrate and invertebrate species groups, correlating these to habitat structure and composition at the landscape scale.
- Project, at landscape scale, the habitat changes likely to result from alternative brush management scenarios.
- Project the likely influence of alternative brush management scenarios on the chosen species groups.

Study Area

The regions for refining earlier Texas State Soil and Water Conservation Board funded studies by the Texas Agricultural Experiment Station with participation by the Natural Resources Conservation Service were identified cooperatively with the Corps of Engineers. One region is in the Twin Buttes drainage area, which includes the Middle Concho River, the South Concho River, and Spring and Dove Creeks. The other region includes watersheds that drain into the Edwards Aquifer recharge zone west of San Antonio and includes parts of the Frio River, Hondo Creek, Medina River, Sabinal River, and Seco Creek. The study areas are presented in Figure 1.

Scenarios

This study is an extension of earlier brush management studies for the regions selected incorporating aquatic and terrestrial responses for alternative brush management strategies (scenarios). This meant that brush management alternatives were to be developed that lead to restoration of the riparian and terrestrial landscape. To provide some insight into sensitivity of water yield, economics, and the aquatic and terrestrial impacts, five alternative scenarios were developed. For those areas where treatment is applicable, a goal of reducing the canopy cover to 3-8 percent of the land area underlies the analysis. Not all parts of a watershed are included in the treatment area. Hence, across the watershed the canopy cover can be much greater than 3-8 percent. For the analysis, oak was not treated because of the impact on property values and value to wildlife. The five scenarios are as follows:

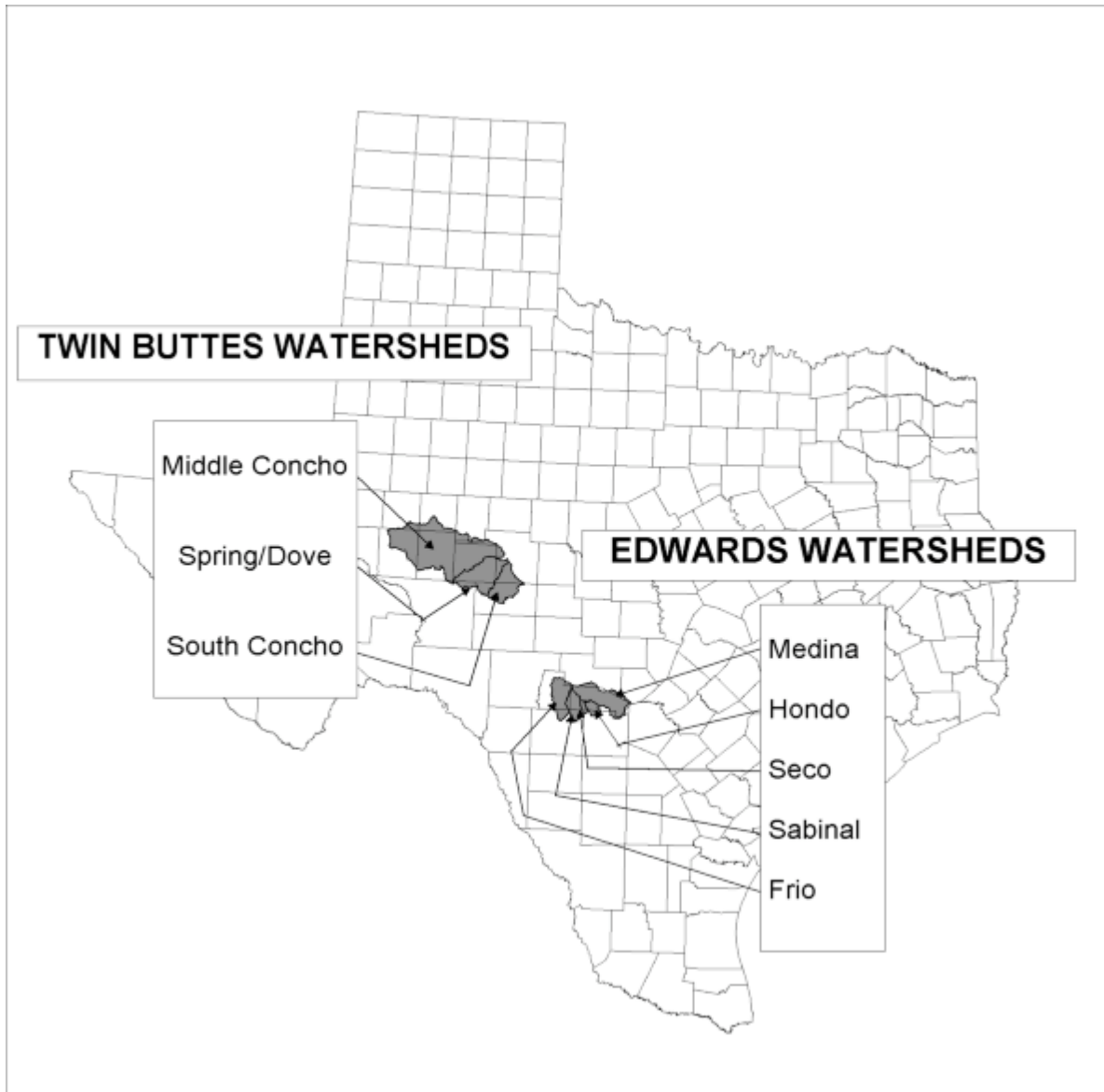


Figure 1. Watersheds included in study.

- Scenario I Brush is controlled on all of a treatment area except on slopes greater than 15 percent. This scenario allows for the greatest amount of brush control.
- Scenario II In addition to no brush control where there is a slope greater than 15 percent, this scenario also does not treat brush within 75 meters of a mapped stream course (150 meter buffer along a stream course).

- Scenario III This scenario adds another constraint to the level of brush treatment in addition to the 15 percent slope and 150 meter buffer requirements. Namely, that brush remaining after treatment will be 40 percent of the total land area within each subbasin for each of the eight watersheds.
- Scenario IV This constitutes the BASE from which the other scenarios are compared. The assumption is that current conditions continue into the future with no change.
- Scenario V Under a special request of the Corps of Engineers, a last scenario was developed whereby the current condition was allowed to become more brush infested over time. In this case, light brush was shifted to moderate, moderate brush moved to heavy brush. There was no economic analysis for Scenario V but there was an evaluation of hydrologic implications and associated aquatic and terrestrial impacts.

A brief overview of the scenarios in a thumbnail is given in the following. An “X” indicates that no brush treatment is done for the factor identified, e.g., for Scenario I there is no brush treatment if the slope is 15 percent or greater.

Scenario	>15% Slope	150m stream buffer	40%+ subwatershed residual brush
I	X		
II	X	X	
III	X	X	X
IV	base, current conditions extend into the future		
V	light brush becomes medium, medium becomes heavy (no economic analysis)		

To illustrate the implications of the scenarios, Figure 2 shows total percent brush cover associated with each management strategy for the Twin Buttes study area. The transition from Scenario I through V is very evident in moving from light brush cover (3-8 percent) in Scenario I to a range of 30-60 percent for Scenario V. Likewise, Figure 3 presents percent brush cover for the Edwards study area. The same transition is shown but it is clear that the Edwards study area is associated with significantly more brush than the Twin Buttes. Even in Scenario I, the brush cover is 20-40 percent and in Scenario V approaches 70 percent.

Across each of the scenarios presented in Figures 2 and 3, there are detailed results by sub-watershed for the hydrologic impacts (change from Scenario IV and V), economic costs of brush management and cost per acre-foot of increased runoff (except Scenario V), and then the aquatic biota and terrestrial response.

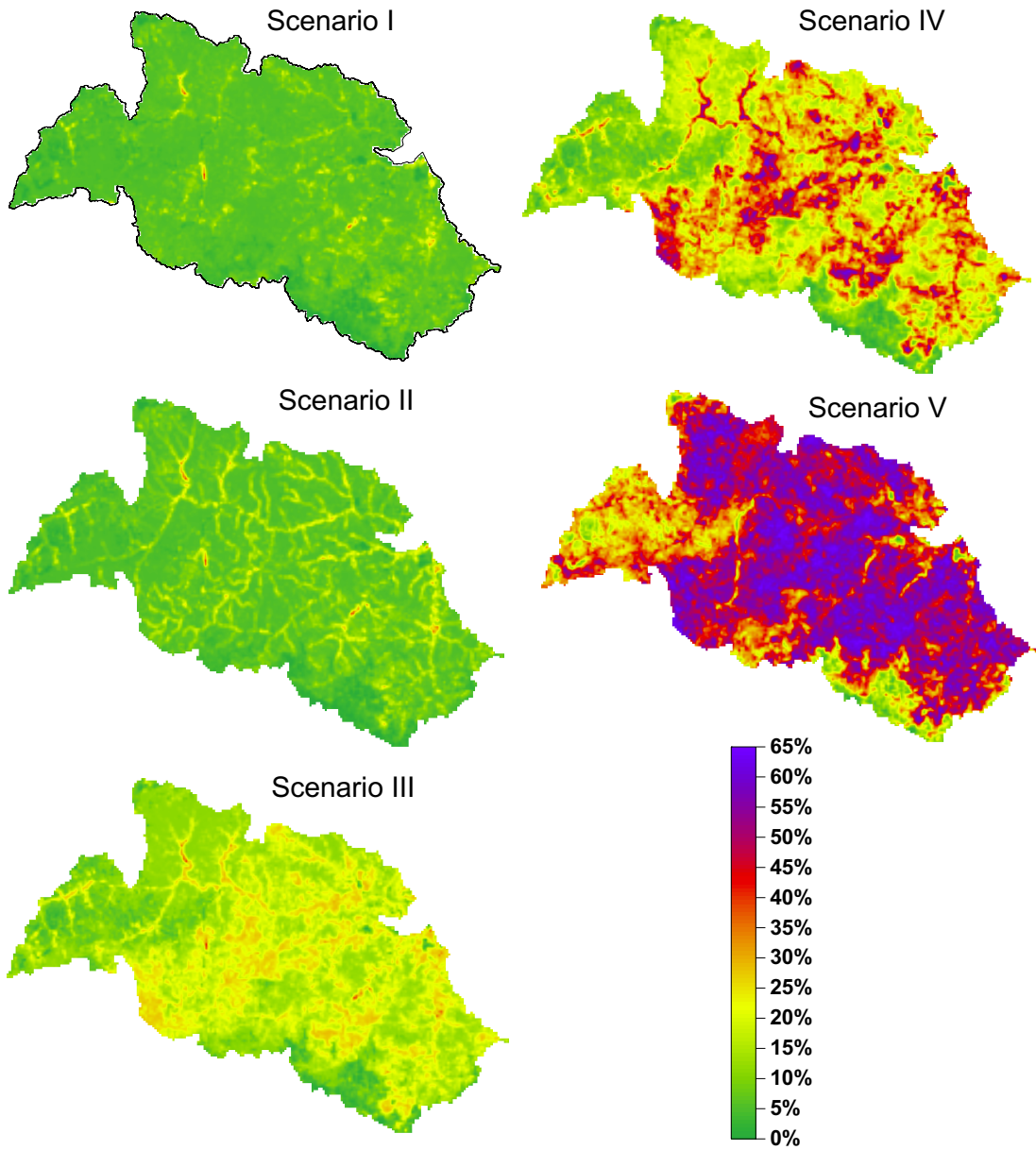


Figure 2. Estimated total percent brush cover under 5 management scenarios, Twin Buttes study area. Scenario IV represents present condition; scenarios I, II, and III represent alternative futures under different brush management program constraints; while scenario V is a projected future condition given no brush control program on the area.

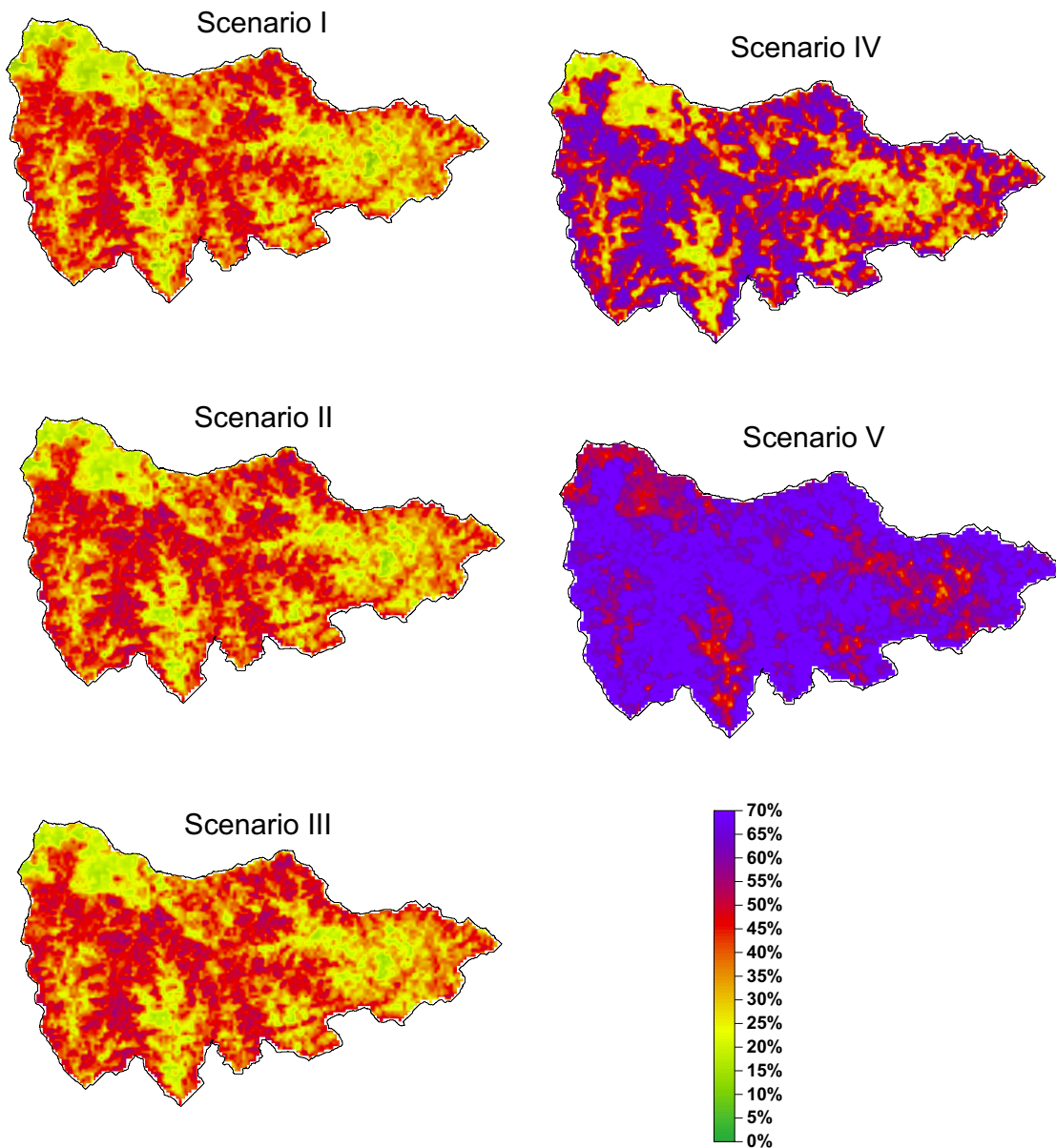


Figure 3. Estimated total percent brush cover under 5 management scenarios, Edwards study area. Scenario IV represents present condition; scenarios I, II, and III represent alternative futures under different brush management program constraints; while scenario V is a projected future condition given no brush control program on the area.

Organization of the Report

Because there are several types of analysis required for this study, each is presented in a separate section. The basis of economic, aquatic and terrestrial response to brush management is the definition of current level of brush intensity and subsequent hydrologic estimates of effects of alternative levels of brush management. Therefore, the first set of results is for the hydrologic modeling component. Hydrologic modeling is a refinement of earlier work on these same watersheds and is an integrated work product of the Texas Agricultural Experiment Station at Temple (Blackland Research and Extension Center) and the scientists at the Natural Resources Conservation Service, located at the Blacklands Center.

The second section focuses on the rangeland/brush and economic factors. It was in this part of the study that the stakeholder meetings were organized. This study examines the economic feasibility of three different brush treatment scenarios that incorporate several restoration practices including rangeland reseeding, grazing deferments and the implementation of improved grazing management systems. These restoration practices will enable treated lands to become closer to historic climax communities found in the two study areas. Brush management/restoration Scenarios I, II and III differ mainly in the amount and location of acres treated. The economics includes total cost of the brush management as well as the benefits to a landowner. For the simulated increase in runoff due to brush management assumed in scenarios I-III (compared to Scenario IV), the estimated costs of brush management and associated costs per acre-foot are developed. A last part of the effort was legal alternatives for implementing a cost share brush management program.

The final sections of the report address the aquatic and terrestrial implications of the alternative management scenarios. The focus was on developing a baseline description of current wildlife-habitat relationships, estimating relationships to project changes in aquatics and terrestrial factors, and drawing overall implications associated with the alternative scenarios. Bird guilds were selected as landscape indicators of ecological conditions because of variability in species composition and abundance within communities. In addition, bird guilds have been demonstrated as successful in reflecting the overall structure, function and composition of ecosystems (O'Connell et al., 2000). Each section is an integral part of the total study but is presented essentially as self standing. The authors for each section are specified. Tables are included in the text while Figures are located at the end of each section because of the number involved and disruption in reading.

Interrelationships of Evaluation Factors

The multiple evaluation factors of this analysis provide insight into the interrelationships among specific evaluation factors. For example, modeling indicates change in runoff associated with brush management scenarios. This is then input to the economics section where costs of brush management are estimated and converted to the expected cost to society (city, state, nation or other public entity) required to implement. The cost to society is the cost above what a rancher could expect in increased net revenue. These costs are expressed on a total and a per acre-foot of water basis.

Using the changes in the landscape, the aquatic and terrestrial components provide expectations on fish and wildlife (primarily birds). The estimate of amount of restoration associated with each of the brush management scenarios is a major addition not addressed in previous brush management studies. With the components completed and implications for many factors available, the challenge becomes the presentation and interpretation considering all the factors simultaneously. This also provides the opportunity to review the trade-offs that occur in evaluating cost to increase runoff and streamflow along with impact on aquatic and terrestrial habitat. With the results of this analysis, there is information that permits quantifying relative cost effectiveness for achieving multiple goals of restoring aquatic conditions, wildlife habitat, range restoration and off-site water production.

To provide a first simple example of the potential to optimize multi-objective outputs, a cursory overview with implications is presented. This is intended to demonstrate the power of the study and how the

components contribute. To facilitate the interpretation, Table 1 pulls data from each section. The information in Table 1 is shown for three river basins in the Twin Buttes watershed and for five in the Edwards watershed. A comparison across scenarios I-IV gives an indication of the change that would be expected going from current conditions (IV) to the three brush management strategies of I-III. Factors chosen include water yield in thousand acre feet over 10 years, cost per acre-foot of water for the brush management strategy (zero for Scenario IV), a measure of fish biotic integrity (a preliminary metric requiring further validation), and percent of total area with suitable habitat for grassland obligates in the Twin Buttes and grassland guild in the Edwards. For the terrestrial measurements (suitable habitat for birds), these are given for the total watershed and not available for sub-areas.

When compared with results from a similar previous study (TAES, 2000), where brush control was assumed to occur on all land that had moderate or heavy brush, this study suggests that both stream flow increases and water yield increases would not be significantly affected if brush control strategies that account for wildlife (e.g., slope and riparian restrictions) were imposed.

For the Twin Buttes watershed, in all cases the change in descriptions for aquatic integrity and birds is estimated to improve substantially with brush management scenarios I-III (going from about 54 to between 64 and 77, depending on the scenario). However, the cost of added water from brush management is much lower in the South Concho (about \$63/ac.ft.) compared with the Spring/Dove of about \$83/ac.ft. The Middle Concho is highest at \$135/ac.ft. or more. The percent of region designated as likely to be suitable habitat for grassland obligates goes from 85 to about 91 to 97 percent. Based on these comparisons, there is the implication that the South Concho would be first priority followed by the Spring/Dove and then Middle Concho.

Similarly, for the Edwards, the least cost region for brush management to increase runoff of water is Hondo (\$33/ac.ft.), Medina (\$36/ac.ft.), Seco (\$46 to \$55/ac.ft.) and most expensive is Frio (\$51 to \$66/ac.ft.). Thus, the amount of increased runoff associated with brush management is far greater in the Edwards compared to Twin Buttes and results in cost per acre-foot that is about 50 percent less in the Edwards. However, looking to the fish biotic integrity index, the improvement is very small (five to nine points). First, this suggests a more careful review and analysis of the fish biotic integrity index and implications of the brush management scenarios, but also suggests there is less benefit in the Edwards relative to Twin Buttes. To make the decision more complex and challenging, the percent suitable habitat for the Edwards goes from 8.1 percent to over 18 percent (a major increase in a region where grassland guild is now uncommon). This is over a doubling of suitable habitat and depending upon values perhaps very beneficial.

Thus, there is a decision within a watershed on where to focus a program and then there is the need to compare one watershed with another. There are major tradeoffs to be reviewed. For example, the Twin Buttes watershed is less cost effective than the Edwards with respect to producing added water with brush management, but the brush management results in substantially more improvement in aquatic conditions than for the Edwards.

To extend the significance of synthesizing results across all factors, going to much smaller regions is warranted. In the Twin Buttes watershed, Spring and Dove Creeks sub-watershed, subbasins 13, 15, and 21 show significant gains in aquatic conditions between brush management scenarios III and IV with subbasin 13 exhibiting substantially greater gains than either 15 or 21. Of these three subbasins, 15 and 21 are estimated to result in modest increases in probability of occurrence of grassland birds while 13 is expected to increase significantly in grassland birds in scenario III compared to IV. Similarly, subbasin 13 is estimated to produce more added water at a lower cost per acre-foot than either subbasin 15 or 21. Clearly subbasin 13 should be given high priority for implementation because it is estimated to produce significantly greater increases in all of the ecosystem functions of interest in this study.

Table 1. Attributes associated with alternative brush management scenarios.

	Scenario	Water Yield Increase Over 10 Years (1000 acre/ft)	Society \$/ acre-foot	Fish Biotic Integrity	Percent Suitable Habitat*
Middle Concho	I	285	158	76	96.8
	II	271	159	75	95.7
	III	118	135	64	90.7
	IV			54	85
South Concho	I	238	63	77	b
	II	228	63	75	b
	III	94	63	66	b
	IV			55	b
Spring/Dove	I	299	83	76	b
	II	285	83	75	b
	III	119	82	66	b
	IV			55	b
Frio	I	249	51	70	c
	II	196	51	70	c
	III	191	66	70	c
	IV			67	c
Hondo	I	124	32	a	21.4
	II	104	32	a	18.4
	III	101	33	a	18.4
	IV			a	8.1
Medina	I	776	35	70	c
	II	646	36	69	c
	III	621	36	69	c
	IV			65	c
Sabinal	I	162	45	70	c
	II	132	46	69	c
	III	128	45	68	c
	IV			65	c
Seco	I	31	55	69	c
	II	30	46	68	c
	III	30	46	68	c
	IV			60	c

* Percent of area with a >0.5 probability of occurrence of grassland species groups

a Data not available for Hondo but for all of the Edwards the value across scenario are similar.

b The results are for grassland obligates and apply to the Twin Buttes Watershed (See Middle Concho).

c The results are for grassland guild and apply to the Edwards Watershed (See Hondo).

Scenario V not included because there was no economic analysis.

The report illustrates the method whereby society's share of brush control–restoration costs are expressed as \$ per acre-foot of water estimated at the sub-subbasin level. In an extension or expansion of this study, there is the opportunity to express the costs as \$ per unit of increase in aquatic biotic integrity (F-IBI) between scenario III and IV for each sub-subbasin; or as \$ per unit increase in probability of occurrence of grassland birds between scenarios III and IV for each sub-subbasin (or even smaller land units). Similar comparisons could also be done for changes in these indicators between scenarios I or II and IV.

For example, society's share of restoration costs expressed as \$/unit increase in F-IBI between scenarios III and IV are \$33,018 for Spring – Dove subbasin 13; while they are \$61,834 and \$51,102 for subbasins 15 and 21 respectively. Similarly, with the average change in probability of occurrence of grassland birds between scenarios III and IV being 10 points for Spring–Dove subbasin 13, and 6 and 4 points for subbasins 15 and 21 respectively, then society's share of restoration costs can be expressed as \$46,225/point increase in the probability of occurrence of grassland birds for Spring-Dove–13, \$92,751 and \$102,204 per point increase for Spring-Dove–15 and S-D–21 respectively.

This reports demonstrates that the methodology used herein can provide decision-makers information that would allow combinations of restoration goals to be met in the most cost-effective manner.

Section 1. Hydrologic Modeling

Participants

NRCS

Amonett, Carl
Bednarz, Steve
Dybala, Tim

TAES

Dugas, Wm.
Muttiah, Ranjan
Rosenthal, Wes

Introduction

A report entitled “Brush Management/Water Yield Feasibility Studies of Eight Watersheds in Texas” has been published (TAES, 2000) summarizing the hydrologic and economic implications of brush management on selected Texas watersheds. In that study, a hydrologic model was used to simulate the effect of removing all brush with moderate and heavy canopy cover. This study was undertaken to examine the implications of brush management under a more restrictive set of removal criteria based upon wildlife considerations. A sample of the watersheds examined in TAES (2000) was used in these analyses to examine wildlife and economic implications of more restrictive brush removal strategies. The objective of this study is to quantify hydrologic implications of brush management strategies to related wildlife and aquatic ecological implications.

Methods

Methods used in this study follow those described in TAES (2000). The Soil and Water Assessment Tool (SWAT) model (Arnold et al., 1998) was used to simulate water yield (discussed in detail in next section) and to simulate stream flow in watersheds under current conditions and under conditions associated with various vegetation changes (brush removal).

SWAT is a continuation of a long-term effort of nonpoint source pollution modeling by the USDA-Agricultural Research Service (ARS), including development of CREAMS (Knisel, 1980), SWRRB (Williams et al., 1985; Arnold et al., 1990), and ROTO (Arnold et al., 1995a). SWAT was developed to predict the impact of management (e.g. climate and vegetative changes, reservoir management, groundwater withdrawals, and water transfer) on water, sediment, and agricultural chemical yields in large un-gauged basins. To satisfy the objective, the model (a) is physically based; (b) uses readily available inputs; (c) is computationally efficient to operate on large basins in a reasonable time; and (d) is continuous-time and capable of simulating long periods. SWAT allows a basin to be divided into hundreds or thousands of grid cells or sub-watersheds.

This study examined eight watersheds in two regions of Texas (Figure 1.1).

1. Watersheds that drain into the Twin Buttes Reservoir near San Angelo, Texas (i.e. the Middle Concho River, the South Concho River, and Spring and Dove Creeks).
2. Watersheds that drain into the Edwards Aquifer recharge zone west of San Antonio, Texas (i.e. the area above the upstream edge of aquifer recharge zone for the Frio River, Hondo Creek, the Medina River, the Sabinal River, and Seco Creek).

Model Inputs

A compilation of Geographic Information System (GIS) data (i.e. soils, land use, weather, management, and topography) in GRASS and Arcview formats and other required model parameters (e.g. base flow days) were generated for input into SWAT.

Climate

Daily precipitation totals were obtained for National Weather Service (NWS) stations within and adjacent to the watersheds. Data from nearby stations were substituted for missing precipitation data

in each station record. Daily maximum and minimum temperatures were obtained for the same NWS stations. A weather generator was used to generate missing temperature data and all solar radiation for each climate station.

Topography

The United States Geological Survey (USGS) database known as Digital Elevation Model (DEM) describes the surface of a watershed as a topographical database. The DEM available for the project area is the 1:24,000 scale map (U.S. Geological Survey, 1999). The resolution of the DEM is 30 meters, allowing detailed delineation of subbasins within each watershed. Sub-watershed boundaries for each watershed, defined using 30 m digital elevation models, were manually checked against USGS Digital Raster Graphic images at 1:24K scale.

Soils

The soils database describes the surface and upper subsurface of soils in a watershed and is used to determine a water budget for the soil profile, daily runoff, and erosion. The SWAT model uses information about each soil horizon (e.g., thickness, depth, texture, and water holding capacity). The NRCS (USDA-Natural Resources Conservation Service) soils database used for this project were developed from three sources:

1. The majority of the information is a grid cell digital map created from 1:24,000 scale soil sheets with a cell resolution of 250 meters. This database is known as the Computer Based Mapping System (CBMS) or Map Information Assembly Display System (MIADS) (Nichols, 1975) soils data.
2. The Soil Survey Geographic (SSURGO) is available as printed county soil surveys for over 90% of Texas counties. Each soil delineation (mapping unit) is described as a single soil series.
3. The State Soil Geographic (STATSGO) 1:250,000-scale soils data base NRCS soils data base is currently available for all of the counties of Texas. In the STATSGO database, each soil delineation of a STATSGO soil is a mapping unit made up of more than one soil series. Dominant SSURGO soil series within an individual STATSGO polygon were selected to represent that area.

The GIS layer representing the soils within the project area is a compilation of CBMS, SSURGO, and STATSGO information. The most detailed information was selected for each county and was patched together to create the final soils layer.

SWAT uses the soils series name as the data link between the soils GIS layer and the soils properties tabular database. County soil surveys were used to verify data for selected dominant soils within each watershed.

Land Use/Land Cover

Land use and land cover affect surface erosion and water runoff in a watershed. Development of a detailed land use/land cover layer for watersheds in the project area was accomplished by classifying Landsat-7 Enhanced Thematic Mapper Plus ETM+ data. Portions of summer Landsat-7 scenes were classified using ground truth points collected by NRCS field personnel. Summer imagery was used to obtain relatively cloud-free scenes during the growing season for the project areas. Images were radiometrically and precision terrain corrected (personal communication, Gordon Wells, TNRIS, 2001).

Ground Control Points

Ground control points (GCP) were located and described by NRCS field personnel in each watershed. Global Positioning System receivers were utilized to locate the latitude and longitude of the control points. A database was developed from the GCP's with information including land cover, estimated canopy coverage, aerial extent, and other pertinent information about each point. This database was converted into an ArcInfo™ point coverage.

ERDAS's Imagine™ was used for imagery classification. Landsat-7 images were imported into Imagine (GIS software). Adjoining scenes in each watershed were histogram matched or regression corrected to the scene containing the highest number of GCPs to adjust for differences in scenes because of dates, time of day, atmospheric conditions, etc. Adjoining scenes were mosaiced and trimmed into one image that covered an individual watershed.

ArcInfo coverage of ground points was employed to instruct the software to recognize differing land uses based on their spectral properties. Individual ground control points were "grown" into areas approximating the aerial extent as reported by the data collector. Spectral signatures were collected by overlaying these areas over the imagery and collecting pixel values from the six imagery layers. A supervised maximum likelihood classification of the image was then performed with the spectral signatures for various land use classes. Ground data was used to perform an accuracy assessment of the resulting image. A sampling of the initial classification was further verified by NRCS field personnel.

This process resulted in a land use/land cover GIS map that includes more detailed divisions of land use/land cover. Although vegetation classes varied slightly among all watersheds, land use and cover was generally classified as follows:

Heavy Cedar	Mostly pure stands of cedar (juniper) with average canopy cover greater than 30 percent.
Heavy Mesquite	Mostly pure stands of mesquite with average canopy cover greater than 30 percent.
Heavy Oak	Mostly pure stands of various species of oak with average canopy cover greater than 30 percent.
Heavy Mixed	Mixture of brush species with average canopy cover greater than 30 percent.
Moderate Cedar	Mostly pure stands of cedar (juniper) with average canopy cover 10 to 30 percent.
Moderate Mesquite	Mostly pure stands of mesquite with average canopy cover 10 to 30 percent.
Moderate Oak	Mostly pure stands of various species of oak with average canopy cover 10 to 30 percent.
Moderate Mixed	Mixture of brush species with average canopy cover 10 to 30 percent.
Light Brush	Either pure stands or mixed with average canopy cover less than 10 percent.
Open Range	Various species of native grasses or improved pasture.
Cropland	All cultivated cropland.
Water	Ponds, reservoirs and large perennial streams.
Barren	Bare Ground
Urban	Developed residential or industrial land.
Other	Other small insignificant categories

Accuracy of classified images was 70% - 80%. Brush species also were split into three categories—those on less than 15% slope, those on greater than 15% slope, and those within 75 meters of defined streams. This allowed for brush removal in any or all of the three categories.

All data were assembled at the highest level of detail possible to accurately define the physical characteristics of each watershed. Selected key model inputs are summarized in Table 1.1.

Model Changes

For this study, the SWAT model was modified from the version used in TAES (2000) as follows:

1. The canopy interception algorithm was changed to reflect recent tree interception measurements over a spectrum of juniper canopy densities on the Edwards Plateau (personal communication, K. Owens, TAES, Uvalde) based on data from <http://uvalde.tamu.edu/intercept/>. The fraction of a daily rainfall event (mm/d) intercepted was calculated as follows: $\text{fraction} = X \cdot 0.1182 \cdot \ln(\text{rainfall}) + 1$, where X was assumed to be 0.2 and 0.5 for moderate and heavy juniper and juniper-mixed canopies, respectively. In general, interception was reduced by about 50% using this equation relative to algorithms used in TAES (2000).
2. The equation for calculation of potential evapotranspiration (PET) using the Priestley-Taylor equation was corrected (it was in error for the TAES (2000) study). This decreased PET relative to that calculated in TAES (2000) by about 25%.
3. The GRASS interface for the SWAT model was modified to allow greater input detail during translation from GIS data to SWAT input data.

Model Calibration

The model was calibrated against measured stream flow by varying selected model inputs and model parameters (e.g. runoff curve number, soil evaporation compensation factor, shallow aquifer storage, shallow aquifer re-evaporation, and channel transmission loss, Table 1.1). The calibration period of record was usually defined by the stream flow measurement period, but generally was between 1960 and 1998. A base flow filter (Arnold et al., 1995b) was used to determine the fraction of base flow and surface runoff at selected gauging stations.

Required inputs for each subbasin (e.g. soils, land use/land cover, topography, and climate) were extracted and formatted using the SWAT/GRASS input interface. The input interface divided each subbasin into virtual subbasins or hydrologic response units (HRU). A single land use and soil were selected for each HRU.

Scenario Analyses

After calibration, the model simulated the hydrology on a daily basis in each watershed for the 39-year period 1960 through 1998. Simulations were made for five scenarios reflecting various land cover changes (Table 1.2). Scenarios were numbered to reflect varying intensity of brush on the landscape (I = least, V = greatest). Scenario IV assumed stable current vegetation conditions on the landscape for the 39-year period. Other scenarios reflected various vegetation changes. Scenario V was imposed to reflect a future vegetation condition assuming continued increased brush density. Specifically, light brush was converted to moderate mixed brush and moderate density brush was converted to heavy for scenario V. The vegetation change imposed in TAES (2000) was equivalent to scenario I, except there were no slope restrictions and riparian buffers. To simulate the "brush removal" condition, input files for all areas of heavy and moderate brush (except oak) were converted to native grass rangeland (good condition). Appropriate adjustments were made in growth parameters to simulate the replacement of brush with native grass. All other calibration parameters and inputs were held constant.

Table 1.1. Key model inputs for each watershed.

Watershed	ESCO	Curve No. Change	GWQmin (mm)	REPAPmn (mm)	Trans. Loss*-Sub (mm/hr)	Trans. Loss*-Ch. (mm/hr)	Bank Coeff.
Twin Buttes							
Dove Ck.	0.1	-9	2	2.04	45	3	.5
Middle Concho	0.1	-9	2	2.05	50	37	0
South Concho	0.1	-9	2	2.07	60	20	.75
Spring Ck.	0.1	-9	2	2.04	45	50	.5
Edwards							
Frio	0.98	-10	0	10	30	25	0.8
Hondo	0.98	-10	0	10	30	25	0.46
Medina	0.98	-10	0	2	30	23	0.22
Sabinal	0.98	-10	0	10	30	25	0.65
Seco	0.98	-10	0	10	30	25	0.83

ESCO. Soil evaporation compensation coefficient. Controls vertical partitioning of soil evaporation. The smaller the number, the deeper in the soil profile water is extracted for evaporation.

GWQmn. Depth of water required in shallow aquifer for return flow to occur.

REVAPmn. Depth of water required in shallow aquifer for re-evaporation to occur.

Bank Coeff. Fraction of transmission loss that is stored in the river bank and returned quickly to stream flow. The remainder enters the shallow aquifer.

*Source: P. Waldo, NRCS Geologist, Ft. Worth (personal communication, 2002) who calculated values from measured stream flows at multiple locations and from geologic information.

Table 1.2. Scenarios simulated.

Scenario	Description
I	Remove all heavy and moderate cedar and mesquite on slopes < 15%.
II	Same as I, except also exclude brush removal in 75 m riparian zone on either side of defined streams.
III	Same as II, except only remove brush cover to 40% in any subwatershed.
IV	Existing conditions.
V	Convert existing light brush density to moderate density and moderate to heavy.

Results and Discussion

Calibration

Twin Buttes

Middle Concho. Predicted cumulative stream flow matched cumulative measured flow and average monthly predicted and measured flows over the 39-year period were within 5% of each other in this watershed (Figure 1.2). However, the root mean square error (RMSE) between monthly predicted and measured flows was about three times the mean measured monthly flow. Errors were less for annual predictions. The large monthly RMSE implies the model does not accurately predict monthly flows.

South Concho. Stream flow was about 50% greater in this watershed (Figure 1.3) than in the Middle Concho. The model under predicted cumulative flow for the first 25 years and over predicted flow for the remainder of the period. Average monthly predicted and measured flows were within about 10% of each other, but the RMSE was more than twice mean monthly flow.

Spring Creek. For calibration purposes, Spring and Dove Creeks were analyzed separately. Average monthly predicted and measured flows were within 1% of each other in Spring Creek (Figure 1.4), which had the lowest flow of any of the Twin Buttes watersheds. The RMSE of monthly flows was about three times mean monthly flow, although cumulative traces were very close.

Dove Creek. Average monthly predicted and measured flows again were almost equal (Figure 1.5) and the RMSE of monthly flows was more than twice the mean monthly flow.

Edwards

Frio. Average monthly predicted and measured flows were within 5% of each other (Figure 1.6). The RMSE of monthly flows was only slight greater than mean monthly flow.

Hondo. Average monthly predicted and measured flows were within 1% of each other (Figure 1.7). The RMSE of monthly flows was less than twice the mean monthly flow.

Medina. The period of record was much shorter for this watershed. Average monthly predicted and measured flows were within 10% of each other (Figure 1.8). Due in part to the smaller number of months for measured flows, the RMSE of monthly flows was more than twice the mean monthly flow.

Sabinal. Average monthly predicted and measured flows were within 10% of each other (Figure 1.9). The RMSE of monthly flows was less than twice the mean monthly flow.

Seco. Average monthly predicted and measured flows were within 1% of each other (Figure 1.10). The RMSE of monthly flows was about twice the mean monthly flow.

In summary, average monthly flows varied by an order of magnitude between the nine watersheds and average monthly flows were accurately predicted by the model (Figure 1.11). There was a slight tendency for predictions to be greater at high flows and differences between predicted and measured stream flows for any given month were large.

Scenarios

Twin Buttes

Middle Concho. Moderate and heavy brush covered about 50% of the total watershed area (Table 1.3). (Note: Total watershed area in this watershed includes about 588,000 acres of non-contributing subbasins. See TAES (2000) for more details.) For scenarios I through III, 67, 63, and 24% of the treatable brush was removed, respectively. For scenario V, more than 577,000 acres of light brush was converted to moderate brush, which increased the area of treatable brush.

Table 1.3. Total watershed area, total area of treatable brush (i.e. heavy and moderate cover) and brush removed, and water yield and stream flow increases for scenarios I through V (see Table 1.2) for Middle Concho River. Water yield and stream flow increases are expressed relative to scenario IV (top) and scenario V (bottom). For scenario V, brush removed area is equal to the area of light brush.

MIDDLE CONCHO RIVER - 1960 through 1998						
	UNITS	SCENARIO				
		I	II	III	IV	V
Total Area	acres	1,600,828	1,600,828	1,600,828	1,600,828	1,600,828
Total Brush Area	acres	759,872	759,872	759,872	759,872	1,337,85
Brush Removed	acres	506,529	481,744	179,213	0	-577,98
Water Yield	Acre-feet/year	114,022	112,131	92,646	77,468	59,08
Water Yield Increase	Acre-feet/year	36,554	34,664	15,178	0	-18,38
Water Yield Increase	Gal/ac brush removed/yr	23,516	23,446	27,598	0	-10,36
Stream Flow	Acre-feet/year	18,148	17,513	13,691	9,569	6,56
Stream Flow Increase	Acre-feet/year	8,579	7,944	4,122	0	-3,00
Stream Flow Increase	Gal/ac brush removed/yr	5,519	5,373	7,495	0	-1,69

MIDDLE CONCHO RIVER - 1960 through 1998						
	UNITS	SCENARIO				
		I	II	III	IV	V
Water Yield Increase	Acre-feet/year	54,937	53,046	33,561	18,382	0
Water Yield Increase	Gal/ac brush removed/yr	16,506	16,311	14,442	10,363	0
Stream Flow Increase	Acre-feet/year	11,586	10,951	7,129	3,007	0
Stream Flow Increase	Gal/ac brush removed/yr	3,481	3,367	3,068	1,695	0

Absolute water yield and stream flow increases, relative to scenario IV, were essentially equal for scenarios I and II (Table 1.3, top). Thus, excluding the riparian corridor had little effect on acres of brush treated and on the hydrology. There was, however, a large difference in water yield and stream flow increases between scenarios II and III (Table 1.3, top). Leaving 40% of the brush on the watershed in scenario III reduced absolute water yield and stream flow by about 50% relative to scenario II, likely because of the large amount of canopy interception and high transpiration rates (due to high leaf area and deep rooting patterns) of brush species not removed. Increases of water yield and stream flow per unit treated area were similar for all scenarios.

For each scenario, stream flow increases were considerably less than water yield increases due to transmission losses in subbasins and the main channel (Table 1.1). Stream flow increases associated with brush removal for scenarios I and II were about 70% of mean measured flows (Figure 1.2) and were approximately 38% higher than those shown in TAES (2000). Cumulative stream flow over the 39-year simulation period from scenarios I through V ordered from largest to smallest, respectively. Most of the difference in cumulative stream flow after 39 years occurred during a few months with large stream flows (Figure 1.12).

The increase in brush area in scenario V (Table 1.2) resulted in a decrease in water yield and stream flow, relative to scenario IV. The stream flow decrease was about 25% of measured flow (Figure 1.2).

Water yield and stream flow increases were greater when expressed relative to scenario V (more brush) (Table 1.3, bottom). Increases of water yield and stream flow, per unit treated acre, both decreased because the relative change from moderate to heavy and light to moderate brush (scenario V) is less than the change from moderate and heavy to grass in other scenarios.

South Concho. Qualitatively, results in the South Concho were similar to the Middle Concho (Table 1.4, top). Treatable brush covered about 58% of the total watershed area. For scenarios I through III, 94, 89, and 37% of the brush was removed, respectively.

Table 1.4. Total watershed area, total area of treatable brush (i.e. heavy and moderate cover) and brush removed, and water yield and stream flow increases for scenarios I through V (see Table 1.2) for South Concho River. Water yield and stream flow increases are expressed relative to scenario IV (top) and scenario V (bottom). For scenario V, brush removed area is equal to the area of light brush.

SOUTH CONCHO RIVER - 1960 through 1998						
	UNITS	SCENARIO				
		I	II	III	IV	V
Total Area	acres	312,944	312,944	312,944	312,944	312,944
Total Brush Area	acres	182,921	182,921	182,921	182,921	263,840
Brush Removed	acres	171,258	162,854	67,232	0	-80,920
Water Yield	Acre-feet/year	71,460	70,238	52,938	40,891	28,861
Water Yield Increase	Acre-feet/year	30,565	29,344	12,043	0	-12,033
Water Yield Increase	Gal/ac brush removed/yr	58,157	58,713	58,371	0	-48,456
Stream Flow	Acre-feet/year	39,416	38,548	27,302	19,408	12,811
Stream Flow Increase	Acre-feet/year	20,008	19,140	7,894	0	-6,598
Stream Flow Increase	Gal/ac brush removed/yr	38,068	38,297	38,259	0	-26,568

SOUTH CONCHO RIVER - 1960 through 1998						
	UNITS	SCENARIO				
		I	II	III	IV	V
Water Yield Increase	Acre-feet/year	42,599	41,377	24,077	12,033	0
Water Yield Increase	Gal/ac brush removed/yr	55,044	55,308	52,955	48,456	0
Stream Flow Increase	Acre-feet/year	26,605	25,738	14,492	6,598	0
Stream Flow Increase	Gal/ac brush removed/yr	34,378	34,404	31,874	26,568	0

Absolute water yield and stream flow increases, relative to scenario IV, were essentially equal for scenario I and II and stream flow increases were less than water yield increases due to transmission losses. Stream flow increases for scenarios I and II were about equal to mean measured flow (Figure 1.3) and were approximately 24% higher than in TAES (2000). Cumulative stream flow again ordered largest to smallest for scenarios I through V (Figure 1.13). There was a gradual, steady increase throughout the period.

As in the Middle Concho, there was a large difference in water yield and stream flow increase between scenario II and III, and water yield and stream flow increases, per unit treated area, were about equal for scenarios I, II, and III. Increases, per unit treated area, were considerably greater in the South Concho than in the Middle Concho, likely due to soil differences and greater precipitation.

There was a smaller relative increase in treatable brush area in scenario V in this watershed. This assumed the vegetation change decreased water yield and stream flow. The stream flow decrease (Table 1.4, top) was about 35% of measured flow (Figure 1.3).

Water yield and stream flow increases were greater when expressed relative to scenario V (more brush) (Table 1.4, bottom). Increases, per unit treated acre, were less for the same reasons stated above for the Middle Concho.

Spring and Dove. Results were similar in Spring and Dove Creeks (Table 1.5, top) to those in the South Concho. Brush covered about 64% of the total watershed area. For scenarios I through III, 95, 90, and 37% of the brush was removed, respectively.

Absolute water yield and stream flow increases, relative to scenario IV, were essentially equal for scenario I and II. Stream flow increases were about equal to the sum of mean measured flow for the two watersheds (Figs. 4 and 5), and stream flow increases were essentially equal to those in TAES (2000). Most of the differences in cumulative stream flow occurred in association with a few months with large stream flows (Figure 1.12). Cumulative totals again were ordered with scenarios (Figure 1.14).

There was a large difference in water yield and stream flow increase between scenario II and III. Increases, per unit treated area, were about equal for scenarios I, II, and III.

The vegetation change in association with scenario V decreased water yield and stream flow (Table 1.5, top). The stream flow decrease was about 25% of measured flow (Figs. 4 and 5).

Water yield and stream flow increases were greater when expressed relative to scenario V (more brush) (Table 1.5, bottom). Increases, per unit treated acre, were less for the same reasons stated above for the Middle Concho.

Table 1.5. Total watershed area, total area of treatable brush (i.e. heavy and moderate cover) and brush removed, and water yield and stream flow increases for scenarios I through V (see Table 1.2) for Spring and Dove Creeks. Water yield and stream flow increases are expressed relative to scenario IV (top) and scenario V (bottom). For scenario V, brush removed area is equal to the area of light brush.

SPRING & DOVE CREEKS - 1960 through 1998						
	UNITS	SCENARIO				
		I	II	III	IV	V
Total Area	acres	449,652	449,652	449,652	449,652	449,652
Total Brush Area	acres	286,742	286,742	286,742	286,742	401,278
Brush Removed	acres	272,611	258,941	106,981	0	-114,536
Water Yield	Acre-feet/year	89,045	87,245	66,091	50,778	40,215
Water Yield Increase	Acre-feet/year	38,268	36,468	15,313	0	-10,563
Water Yield Increase	Gal/ac brush removed/yr	45,741	45,891	46,641	0	-30,051
Stream Flow	Acre-feet/year	37,103	36,036	25,249	17,897	13,064
Stream Flow Increase	Acre-feet/year	19,206	18,139	7,352	0	-4,833
Stream Flow Increase	Gal/ac brush removed/yr	22,956	22,826	22,392	0	-13,748

SPRING & DOVE CREEKS - 1960 through 1998						
	UNITS	SCENARIO				
		I	II	III	IV	V
Water Yield Increase	Acre-feet/year	48,830	47,031	25,876	10,563	0
Water Yield Increase	Gal/ac brush removed/yr	41,099	41,033	38,063	30,051	0
Stream Flow Increase	Acre-feet/year	24,038	22,972	12,184	4,833	0
Stream Flow Increase	Gal/ac brush removed/yr	20,232	20,042	17,923	13,748	0

Edwards

Frio. About 81% of this watershed was covered by moderate or heavy brush (Table 1.6, top). For scenarios I, II, and III, 37, 30, and 28% of the brush was removed, respectively. The area of brush removed in the Edwards' watersheds was less than in the Twin Buttes watersheds because of the restriction of not removing brush on steeper slopes. Because the percentages of brush remaining were near 40% in scenarios I and II, there was little effect of scenario III in the Edwards' watersheds. For scenario V, about 25% more brush area was added.

Absolute water yield and stream flow increases, relative to scenario IV (Table 1.6, top), were essentially equal for scenarios II and III, and these were about 20% less than the yield and flow increases for scenario I. These trends are consistent with areas of brush removed.

Stream flow increases were about 80% of water yield increases. Water yield and stream flow increases were closer in the Edwards watersheds because sub-basin transmission losses were returned to streams through the fractured limestone and storage in stream banks. Stream flow increases were about 20 to 25% of measured stream flow (Figure 1.6). Cumulative stream flow showed a consistent increase for

all five scenarios (Figure 1.15). Water yield and stream flow increases were greater when expressed relative to scenario V (more brush) (Table 1.6, bottom) and increases, per unit treated acre, decreased for the same reasons stated above for the Middle Concho.

Table 1.6. Total watershed area, total area of treatable brush (i.e. heavy and moderate cover) and brush removed, and water yield and stream flow increases for scenarios I through V (see Table 1.2) for Frio River. Water yield and stream flow increases are expressed relative to scenario IV (top) and scenario V (bottom). For scenario V, brush removed area is equal to the area of light brush.

FRIO RIVER - 1960 through 1998						
	UNITS	SCENARIO				
		I	II	III	IV	V
Total Area	acres	249,642	249,642	249,642	249,642	249,642
Total Brush Area	acres	202,359	202,359	202,359	202,359	247,693
Brush Removed	acres	74,998	60,267	56,194	0	-45,334
Water Yield	Acre-feet/year	207,609	200,836	200,139	175,667	158,671
Water Yield Increase	Acre-feet/year	31,942	25,169	24,473	0	-16,995
Water Yield Increase	Gal/ac brush removed/yr	138,785	136,083	141,910	0	-122,156
Stream Flow	Acre-feet/year	125,772	120,511	120,055	100,982	88,725
Stream Flow Increase	Acre-feet/year	24,791	19,530	19,072	0	-12,258
Stream Flow Increase	Gal/ac brush removed/yr	107,705	105,587	110,596	0	-88,099

FRIO RIVER - 1960 through 1998						
	UNITS	SCENARIO				
		I	II	III	IV	V
Water Yield Increase	Acre-feet/year	48,938	42,165	41,468	16,995	0
Water Yield Increase	Gal/ac brush removed/yr	132,521	130,108	133,090	122,156	0
Stream Flow Increase	Acre-feet/year	37,047	31,786	31,330	12,258	0
Stream Flow Increase	Gal/ac brush removed/yr	100,321	98,081	100,553	88,089	0

Hondo. About 82% of this watershed was covered by moderate or heavy brush (Table 1.7, top). For scenarios I, II, and III, 42, 36, and 36 % of the brush was removed, respectively. Absolute water yield and stream flow increases, relative to scenario IV (Table 1.7, top), were essentially equal for scenarios II and III, and these were about 20% less than the yield and flow increases for scenario I. These trends are consistent with areas of brush removed. Stream flow increases were about 85% of water yield increases and were about 35% of measured stream flow (Figure 1.7). Cumulative stream flow showed a consistent increase for all five scenarios (Figure 1.16). Water yield and stream flow increases were greater when expressed relative to scenario V (more brush) (Table 1.7, bottom) and increases, per unit treated acre, decreased for the same reasons stated above for the Middle Concho.

Medina. About 82% of this watershed was covered by moderate or heavy brush (Table 1.8, top). For scenarios I, II, and III, 44, 38, and 36% of the brush was removed, respectively. Absolute water yield and stream flow increases, relative to scenario IV (Table 1.8, top), were slightly less for scenario III and for II, and both of these were about 18% less than the yield and flow increases for scenario I. These trends are consistent with areas of brush removed. Stream flow increases were about 32% of water yield increases and were about 28% of measured stream flow (Figure 1.8). Cumulative stream flow showed a consistent increase for all five scenarios (Figure 1.17). Water yield and stream flow increases were greater when expressed relative to scenario V (more brush) (Table 1.8, bottom) and increases, per unit treated acre, decreased for the same reasons stated above for the Middle Concho.

Absolute water yield and stream flow increases, relative to scenario IV (Table 1.9, top), were essentially equal for scenarios II and III and these were about 20% less than the increase for scenario

I. These are consistent with areas of brush removed. Stream flow increases were about 80% of water yield increases and were about 20 to 25% of measured stream flow (Figure 1.9). Cumulative stream flow showed a steady consistent increase for all five scenarios (Figure 1.18).

Table 1.7. Total watershed area, total area of treatable brush (i.e. heavy and moderate cover) and brush removed, and water yield and stream flow increases for scenarios I through V (see Table 1.2) for Hondo Creek. Water yield and stream flow increases are expressed relative to scenario IV (top) and scenario V (bottom). For scenario V, brush removed area is equal to the area of light brush.

HONDO CREEK - 1960 through 1998						
		SCENARIO				
	UNITS	I	II	III	IV	V
Total Area	acres	61,227	61,227	61,227	61,227	61,227
Total Brush Area	acres	49,604	49,604	49,604	49,604	60,299
Brush Removed	acres	21,294	18,210	17,786	0	-10,695
Water Yield	Acre-feet/year	73,954	71,327	67,398	58,056	50,824
Water Yield Increase	Acre-feet/year	15,864	13,253	12,972	0	-7,231
Water Yield Increase	Gal/ac brush removed/yr	242,759	237,150	237,655	0	-220,340
Stream Flow	Acre-feet/year	47,350	44,999	44,671	33,847	28,818
Stream Flow Increase	Acre-feet/year	13,503	11,152	10,824	0	-5,029
Stream Flow Increase	Gal/ac brush removed/yr	206,629	199,555	198,302	0	-226,623

HONDO CREEK - 1960 through 1998						
		SCENARIO				
	UNITS	I	II	III	IV	V
Water Yield Increase	Acre-feet/year	23,095	20,484	20,203	7,231	0
Water Yield Increase	Gal/ac brush removed/yr	353,411	366,542	370,132	220,340	0
Stream Flow Increase	Acre-feet/year	18,532	16,181	15,853	5,029	0
Stream Flow Increase	Gal/ac brush removed/yr	283,586	289,544	290,437	226,623	0

Sabinal. About 82% of this watershed was covered by moderate or heavy brush (Table 1.9, top). For scenarios I, II, and III, 39, 32, and 31% of this brush was removed, respectively. For scenario V, brush area increased about 20%.

Table 1.8. Total watershed area, total area of treatable brush (i.e. heavy and moderate cover) and brush removed, and water yield and stream flow increases for scenarios I through V (see Table 1.2) for Medina River. Water yield and stream flow increases are expressed relative to scenario IV (top) and scenario V (bottom). For scenario V, brush removed area is equal to the area of light brush.

MEDINA RIVER - 1960 through 1998						
	UNITS	SCENARIO				
		I	II	III	IV	V
Total Area	acres	405,397	405,397	405,397	405,397	405,397
Total Brush Area	acres	329,922	329,922	329,922	329,922	396,581
Brush Removed	acres	145,948	123,908	118,560	0	-66,659
Water Yield	Acre-feet/year	452,635	436,341	434,346	354,526	313,905
Water Yield Increase	Acre-feet/year	98,042	82,452	79,721	0	-41,233
Water Yield Increase	Gal/ac brush removed/yr	218,894	216,831	219,106	0	-201,560
Stream Flow	Acre-feet/year	172,318	146,516	120,714	94,912	81,191
Stream Flow Increase	Acre-feet/year	32,417	26,492	25,802	0	-13,721
Stream Flow Increase	Gal/ac brush removed/yr	72,376	69,668	70,914	0	-67,075

MEDINA RIVER - 1960 through 1998						
	UNITS	SCENARIO				
		I	II	III	IV	V
Water Yield Increase	Acre-feet/year	139,275	123,685	120,954	41,233	0
Water Yield Increase	Gal/ac brush removed/yr	310,953	325,264	332,431	201,560	0
Stream Flow Increase	Acre-feet/year	46,138	40,213	39,523	13,721	0
Stream Flow Increase	Gal/ac brush removed/yr	103,010	105,751	108,625	67,075	0

Table 1.9. Total watershed area, total area of treatable brush (i.e. heavy and moderate cover) and brush removed, and water yield and stream flow increases for scenarios I through V (see Table 1.2) for Sabinal River. Water yield and stream flow increases are expressed relative to scenario IV (top) and scenario V (bottom). For scenario V, brush removed area is equal to the area of light brush.

SABINAL RIVER - 1960 through 1998						
	UNITS	SCENARIO				
		I	II	III	IV	V
Total Area	acres	131,795	131,795	131,795	131,795	131,795
Total Brush Area	acres	107,739	107,739	107,739	107,739	128,922
Brush Removed	acres	42,323	35,233	33,537	0	-21,183
Water Yield	Acre-feet/year	101,797	97,957	97,367	81,053	72,098
Water Yield Increase	Acre-feet/year	20,744	16,904	16,314	0	-8,956
Water Yield Increase	Gal/ac brush removed/yr	159,698	156,322	158,513	0	-137,751
Stream Flow	Acre-feet/year	81,556	77,976	77,402	62,464	54,439
Stream Flow Increase	Acre-feet/year	19,093	15,514	14,938	0	-8,025
Stream Flow Increase	Gal/ac brush removed/yr	146,990	143,468	145,143	0	-123,446

SABINAL RIVER - 1960 through 1998						
	UNITS	SCENARIO				
		I	II	III	IV	V
Water Yield Increase	Acre-feet/year	29,699	25,859	25,269	8,956	0
Water Yield Increase	Gal/ac brush removed/yr	152,387	149,358	150,474	137,751	0
Stream Flow Increase	Acre-feet/year	27,117	23,537	22,963	8,025	0
Stream Flow Increase	Gal/ac brush removed/yr	139,138	135,947	136,742	123,446	0

Seco. About 86% of this watershed was covered by moderate or heavy brush (Table 1.10, top). For scenarios I, II, and III, 35, 28, and 28% of the brush was removed, respectively. Absolute water yield and stream flow increases, relative to scenario IV (Table 1.10, top), were equal for scenarios II and III, and both of these were only 3% less than the yield and flow increases for scenario I. These trends are consistent with areas of brush removed. Stream flow increases were about 87% of water yield increases and were about 23% of measured stream flow (Figure 1.10). Cumulative stream flow showed a consistent increase for all five scenarios (Figure 1.19). Water yield and stream flow increases were greater when expressed relative to scenario V (more brush) (Table 1.10, bottom) and increases, per unit treated acre, decreased for the same reasons stated above for the Middle Concho.

Table 1.10. Total watershed area, total area of treatable brush (i.e. heavy and moderate cover) and brush removed, and water yield and stream flow increases for scenarios I through V (see Table 1.2) for Seco Creek. Water yield and stream flow increases are expressed relative to scenario IV (top) and scenario V (bottom). For scenario V, brush removed area is equal to the area of light brush.

SECO CREEK - 1960 through 1998						
	Units	SCENARIO				
		I	II	III	IV	V
Total Area	acres	28,834	28,834	28,834	28,834	28,834
Total Brush Area	acres	25,360	25,360	25,360	25,360	28,646
Brush Removed	acres	8,734	7,106	7,106	0	-3,286
Water Yield	Acre-feet/year	24,218	24,142	24,142	20,304	18,788
Water Yield Increase	Acre-feet/year	3,914	3,836	3,836	0	-1,608
Water Yield Increase	Gal/ac brush removed/yr	146,024	175,902	175,902	0	-159,455
Stream Flow	Acre-feet/year	18,399	18,356	18,356	14,967	13,453
Stream Flow Increase	Acre-feet/year	3,432	3,389	3,389	0	-1,514
Stream Flow Increase	Gal/ac brush removed/yr	128,042	155,405	155,405	0	-150.05

SECO CREEK - 1960 through 1998						
	Units	SCENARIO				
		I	II	III	IV	V
Water Yield Increases	acre-feet/year	5,522	5,444	5,444	1,608	0
Water Yield Increases	gal/ac brush removed/yr	206,016	249,639	249,639	159,455	0
Stream Flow Increases	acre-feet/year	4,946	4,903	4,903	1,514	0
Stream Flow Increases	gal/ac brush removed/yr	184,527	224,830	224,830	150,098	0

Comparisons Across Watersheds

Watershed area varied from less than 30,000 to 1,600,000 acres (Figure 1.20). Along with precipitation, these differences in areas affected measured flows and simulated stream flows for the different scenarios.

Average annual precipitation decreased from east to west (Figs. 1 and 21). In general, precipitation ranged from 28 to 33 inches for the Edwards' watersheds and from 18 to 21 inches for the Twin Buttes' watersheds. The 18-inch average in the Middle Concho is near the minimum value suggested by Griffin and McCarl (1989) where brush control is problematic.

Simulated stream flows under current vegetation conditions (scenario IV) were greater in the Edwards' watersheds (Figure 1.22), which had more precipitation (Figure 1.21), and flows were, in general, proportional to watershed area (Figure 1.20).

The fraction of watershed area where brush was removed, for each scenario, was consistent across watersheds (Figure 1.23). In the Edwards' watersheds, about 20 to 35% of the total watershed area

was treated; there were small differences between scenarios I, II, and III; and the area assumed to have increased brush density in scenario V was about 10 to 30%. For the Twin Buttes' watersheds, the treated fraction for scenario I was slightly greater than scenario II and varied from 30 to 60%, was much lower for scenario III, and was about 30% for scenario V. In all eight watersheds, the fraction removed in the previous study (TAES, 2000) was about equal to the fraction removed in scenario I in this study except for the Seco and Middle Concho.

Simulated stream flow increases associated with the various scenarios (Figure 1.24) showed a similar pattern to simulated stream flow (Figure 1.22). In the Edwards' watersheds, there was little difference in stream flow increases associated with scenarios I, II, and III, but in general, increases were greatest for scenario I. Increases varied from about 4,000 to slightly greater than 30,000 acre-feet/year. These stream flow increases were similar to those shown in TAES (2000), except for the Medina, which in the current study had a lesser increase due to a lower stream bank coefficient that allowed for more storage in the bank before release. The slight differences in simulated stream flow between these two studies were due to different brush control strategies, model changes (e.g. revised interception algorithms and PET equation), different watershed delineations for the Edwards watersheds, and different inputs (e.g. channel and subbasin transmission rates, stream bank coefficients, etc.). Stream flow decreases associated with scenario V varied from 2,000 to more than 10,000 acre-feet/year.

In the Twin Buttes' watersheds, stream flow increases always ordered with scenario I > II > III (Figure 1.24) and there was a much smaller increase in flow associated with scenario III because much less brush was removed in association with this scenario (Figure 1.23). Stream flow increases for scenario I in this study were similar to TAES (2000). Stream flow decreases associated with scenario V varied from 2,000 to 5,000 acre-feet/year. Stream flow increases, relative to scenario V (Figure 1.25), showed the same pattern when comparisons were made across scenarios or watersheds, but, as expected, were greater than those expressed relative to scenario IV (Figure 1.24).

Stream flow increase, when expressed per unit treated acre, showed little effect of scenario I, II, or III in all watersheds, and showed a much smaller increase in the Twin Buttes' watersheds (Figure 1.26), where precipitation is much less (Figure 1.21). In the Edwards' watersheds, increases varied from 70,000 to 200,000 gallons/(treated acre year). These increases are similar to those shown in TAES (2000), except for Hondo and Medina due to different bank coefficients, and are comparable to those measured or calculated for other watersheds in this area after imposition of a treatment (Table 1.11). The decrease in stream flow associated with scenario V varied from 40,000 to 160,000 gallons/(acre year).

In the Twin Buttes' watersheds, there was essentially no difference in stream flow increase, per unit treated acre, between scenarios I, II, and III (Figure 1.26). Increases varied from 5,000 to 40,000 gallons/(acre year) and are similar to those shown in TAES (2000) and to those simulated in the North Concho River (Table 1.11). Stream flow increases were greater when expressed relative to scenario V (Figure 1.27).

Water yield increases, relative to scenario IV, also were greater in the Edwards' watersheds (Figure 1.28). Increases were essentially equal for scenarios I, II, and III, ranged from 130,000 to 220,000 gallons/(acre year), and tended to be greater than those shown in TAES (2000) (for the same reasons there were differences in absolute stream flow increase). Decreases associated with scenario V varied from 100,000 to 210,000 gallons/(acre year). For the Twin Buttes' watersheds, increases varied from 20,000 to 50,000 gallons/(acre year) and increases were only slightly greater than those in TAES (2000). Decreases for scenario V varied from 10,000 to 50,000 gallons/(acre year). Water yield increases were greater when expressed relative to scenario V (Figure 1.29).

Table 1.11. Annual water savings (gallons per treated acre) from brush removal at selected locations.

Location	Reference	Land Use Change	Water Savings
Sonora	Thurrow and Taylor (1995)	60% Juniper/40% grass to 100% grass	100,000
Annandale	Owens and Knight (1992)	Removal all Juniper	130,000*
Seco Ck.	Dugas et al. (1998)	Removal all Juniper (3 year average after treatment)	30,000
Seco Ck.	Dugas et al. (1998)	Removal all Juniper (2 years after treatment)	130,000
Seco Ck.	Wright (1996)	Remove 70% of Juniper (14 months after treatment)	120,000
N. Concho	UCRA (1998)	Remove all Brush (Mesquite and Juniper)	30,000

*Calculated from ratio of average runoff to precipitation and from measured increase in runoff.

Conclusions

A hydrologic simulation model was used to quantify hydrologic implications of brush management strategies (Scenarios I through V, Table 1.2) that were selected to account for wildlife implications. Simulated changes in stream flow and water yield (equal to the sum of surface runoff + shallow aquifer flow + lateral soil flow minus transmission losses) were evaluated for eight watersheds in two regions of Texas (Figure 1.1). Watershed area varied from less than 30,000 to 1,600,000 acres and precipitation was about 30 inches per year for the Edwards' watersheds and about 20 inches per year for the Twin Buttes' watersheds.

In the Edwards' watersheds, there was little difference in stream flow increases associated with scenarios I, II, and III, but in general, increases were greatest for scenario I. Stream flow decreases associated with scenario V (more moderate and heavy brush) varied from 2000 to more than 10,000 acre-feet/year. In the Twin Buttes' watersheds, there were much smaller increases in flows. Stream flow increases, when expressed per unit treated acre, also were much smaller in the Twin Buttes' watersheds, where precipitation is much less. Water yield increases also were greater in the Edwards' watersheds.

When compared with results from a similar previous study (TAES, 2000) where brush control was assumed to occur on all land that had moderate or heavy brush, this study suggests that both stream flow increases and water yield increases would not be significantly affected if brush control strategies that accounted for wildlife (e.g. slope and riparian restrictions) were imposed. This conclusion, however, needs to be tempered by the differences in the model and methods between the two studies.

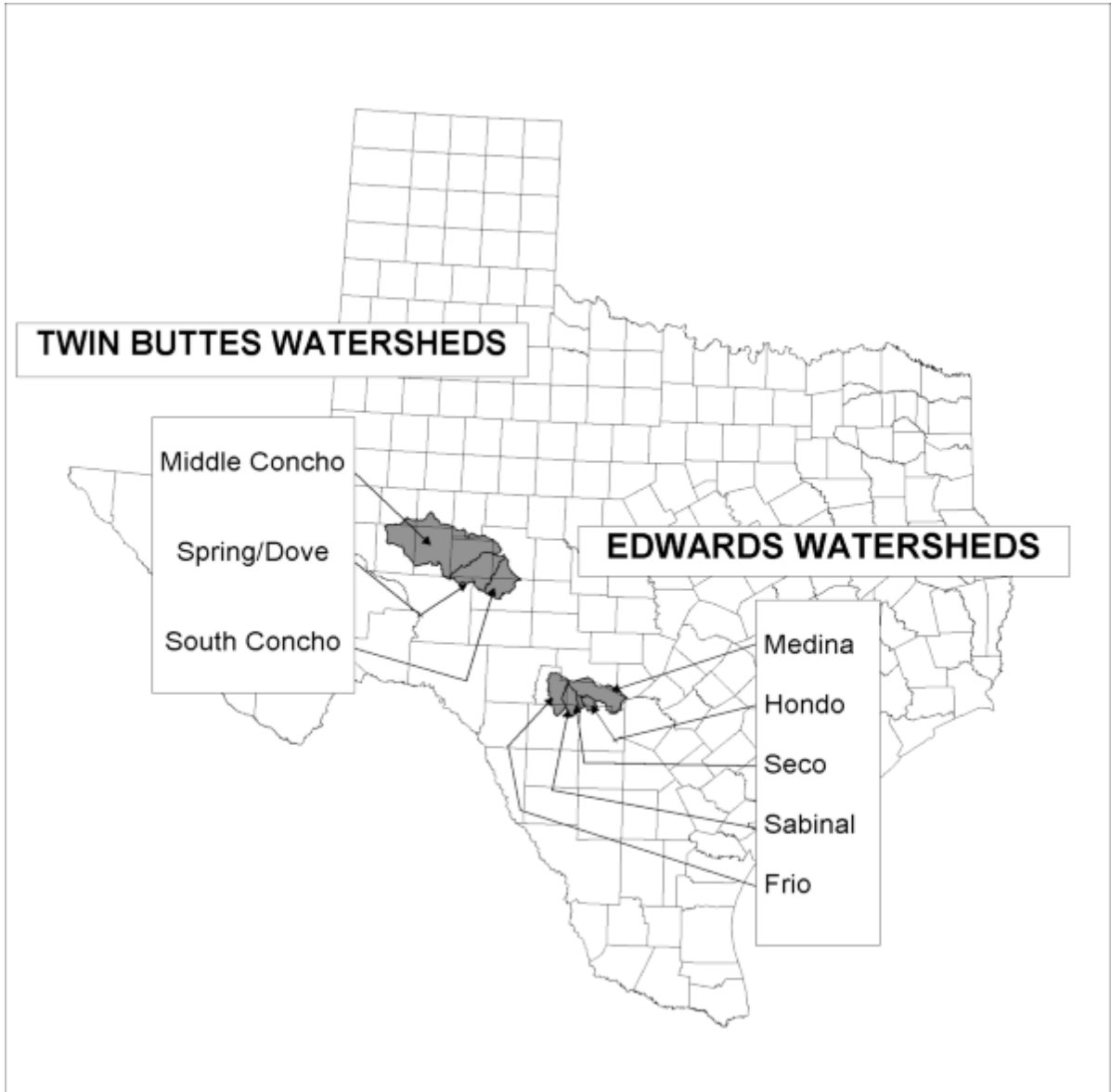


Figure 1.1. Watersheds included in study.

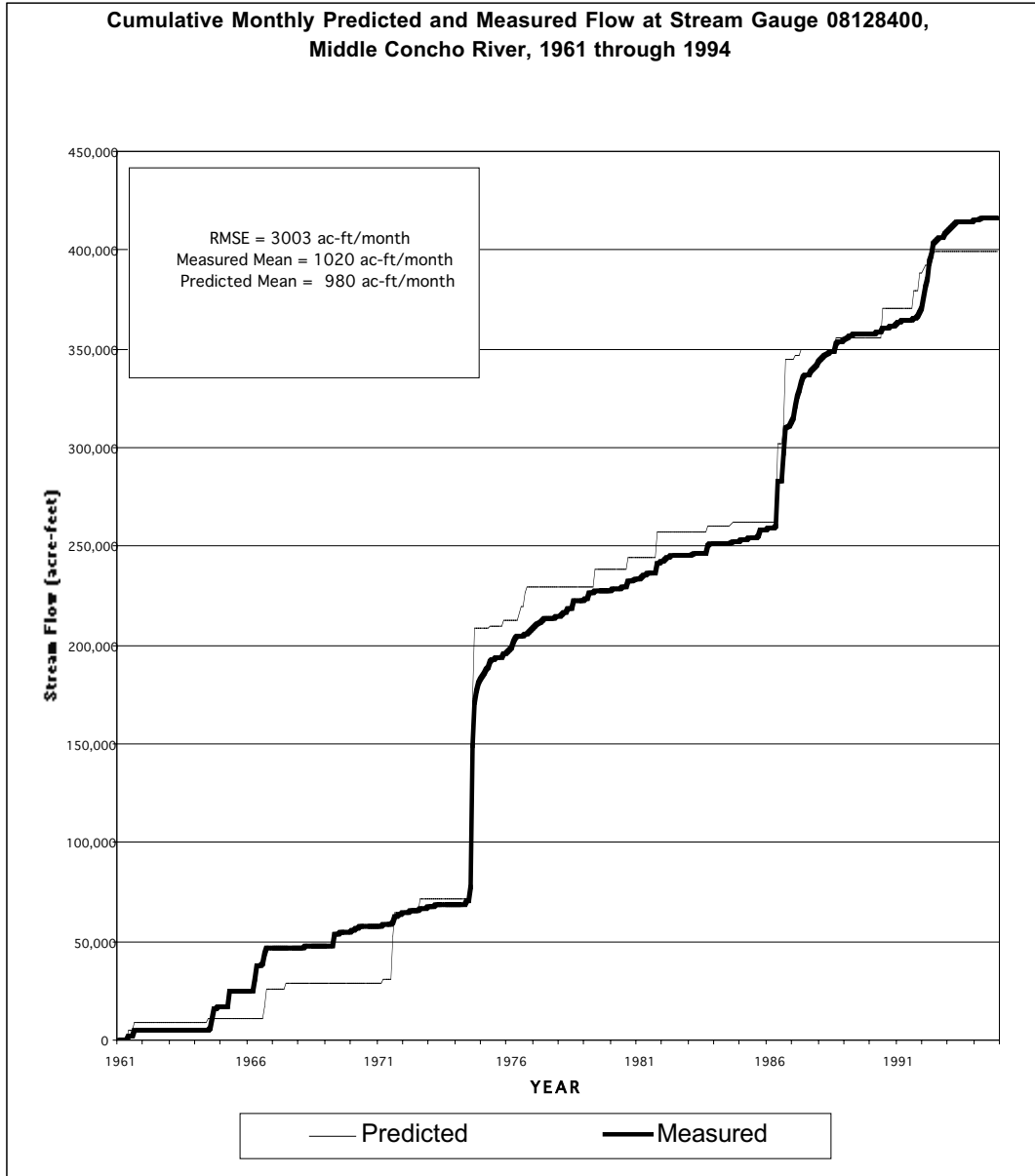


Figure 1.2. Cumulative monthly stream flow predicted by SWAT and measured near outlet of Middle Concho River. Average measured and predicted monthly flows for the entire calibration period and the root mean square error (RMSE) between monthly predicted and measured flows are shown.

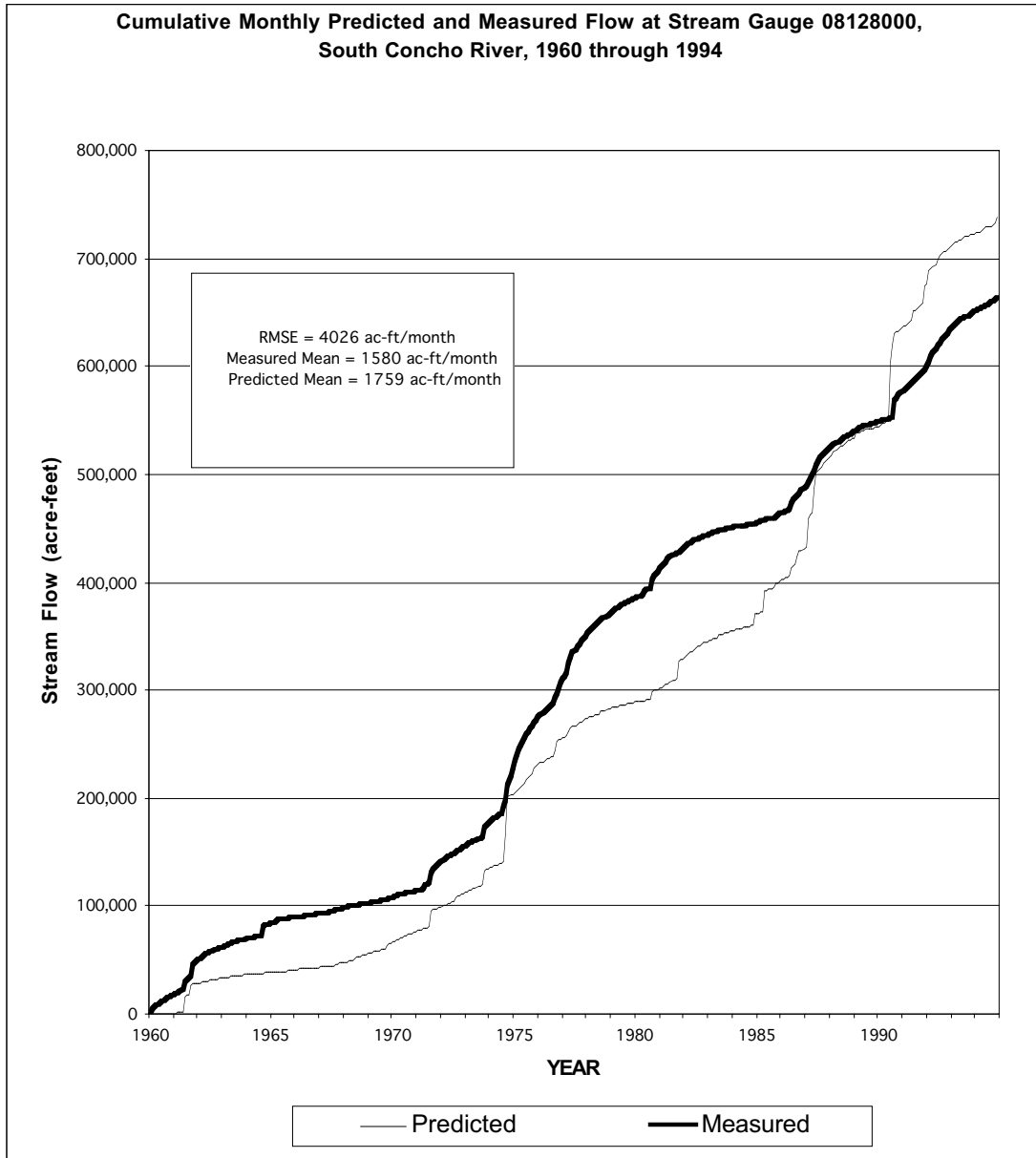


Figure 1.3. Cumulative monthly stream flow predicted by SWAT and measured near outlet of South Concho River. Average measured and predicted monthly flows for the entire calibration period and the root mean square error (RMSE) between monthly predicted and measured flows are shown.

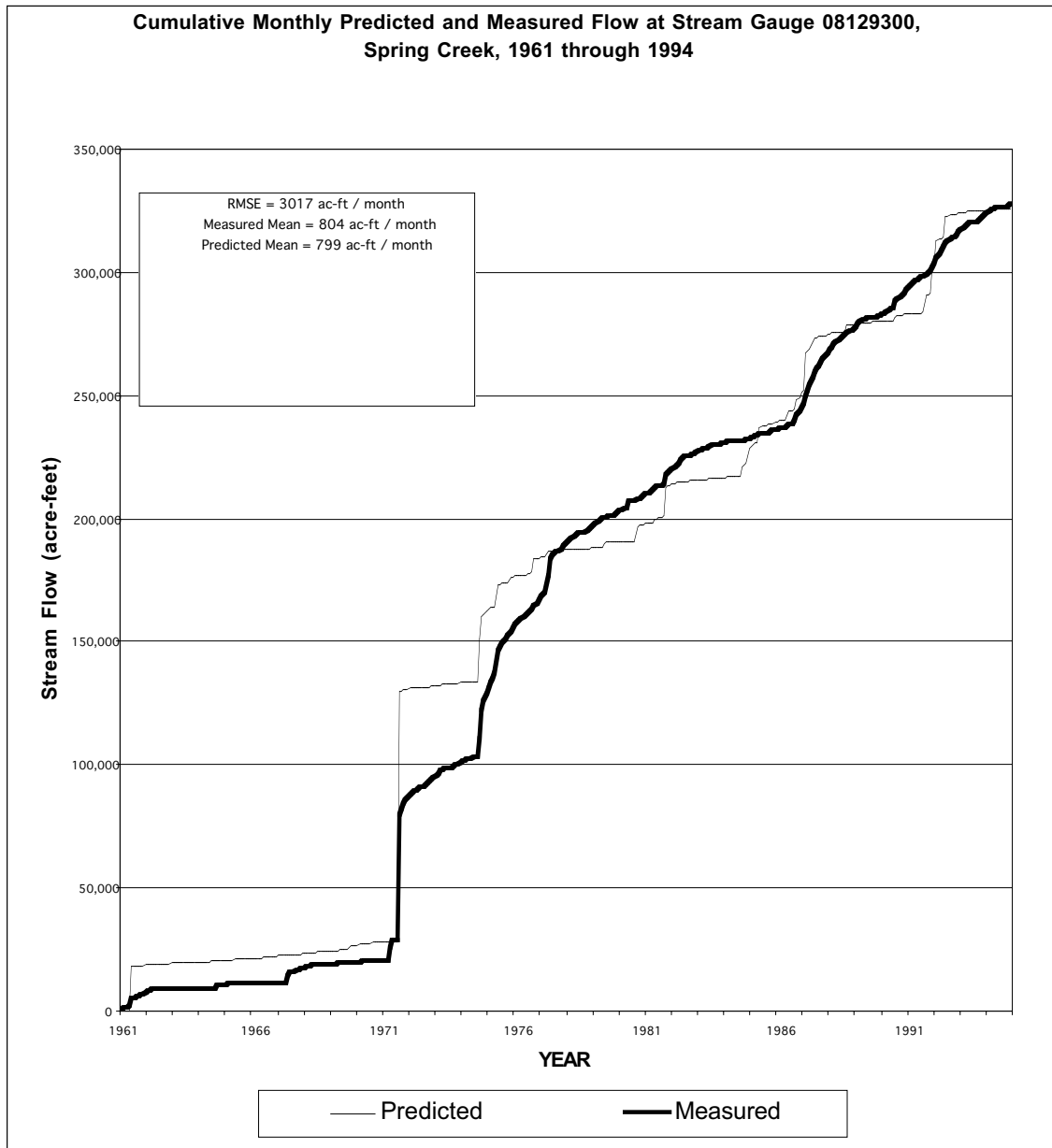


Figure 1.4. Cumulative monthly stream flow predicted by SWAT and measured near outlet of Spring Creek. Average measured and predicted monthly flows for the entire calibration period and the root mean square error (RMSE) between monthly predicted and measured flows are shown.

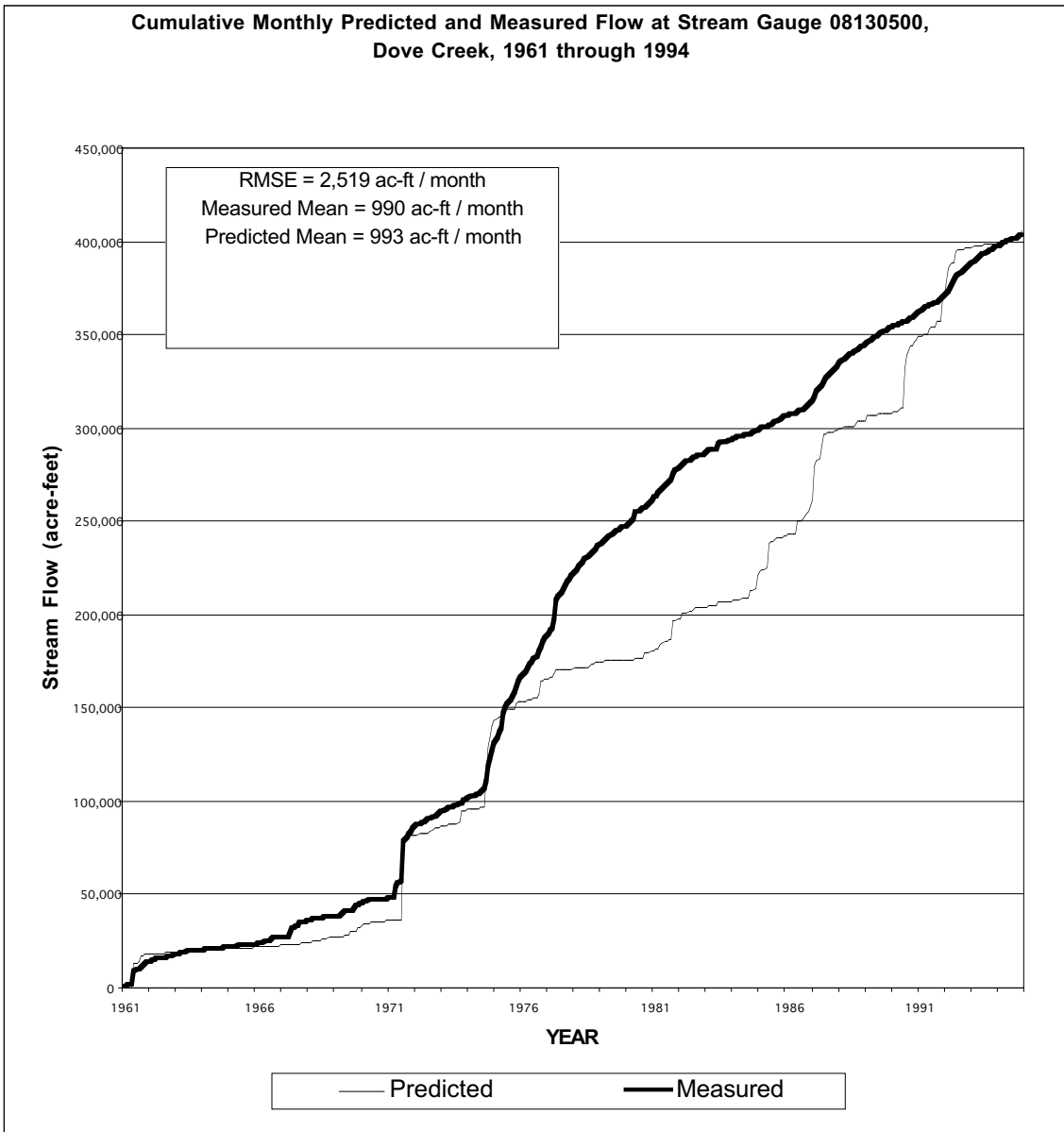


Figure 1.5. Cumulative monthly stream flow predicted by SWAT and measured near outlet of Dove Creek. Average measured and predicted monthly flows for the entire calibration period and the root mean square error (RMSE) between monthly predicted and measured flows are shown.

Cumulative Monthly Predicted and Measured Flow at Stream Gauge 08195000,
Frio River, 1960 through 1998

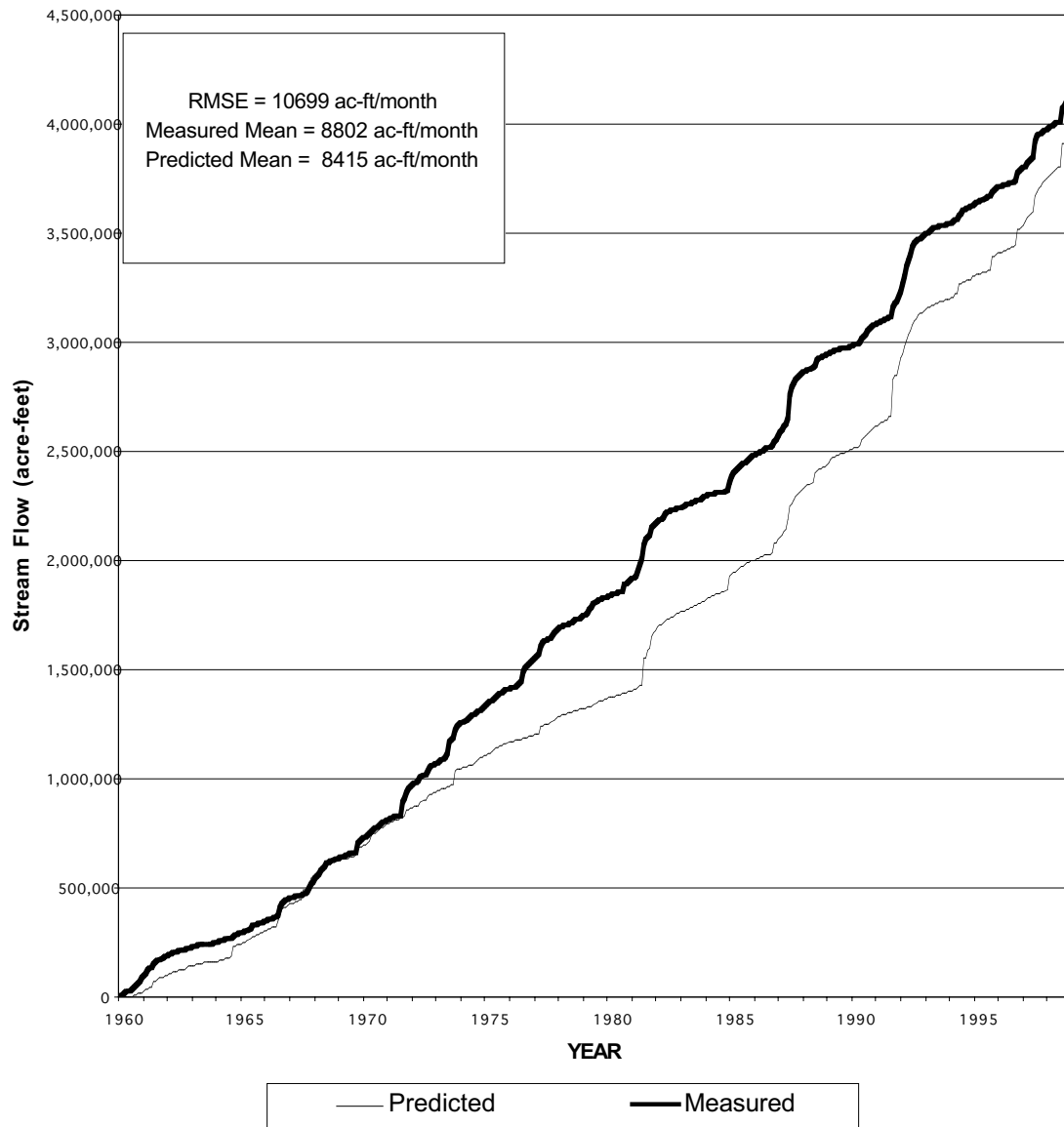


Figure 1.6. Cumulative monthly stream flow predicted by SWAT and measured near outlet of Frio River. Average measured and predicted monthly flows for the entire calibration period and the root mean square error (RMSE) between monthly predicted and measured flows are shown.

Cumulative Monthly Predicted and Measured Flow at Stream Gauge in Hondo Ck., 1960 through 1998

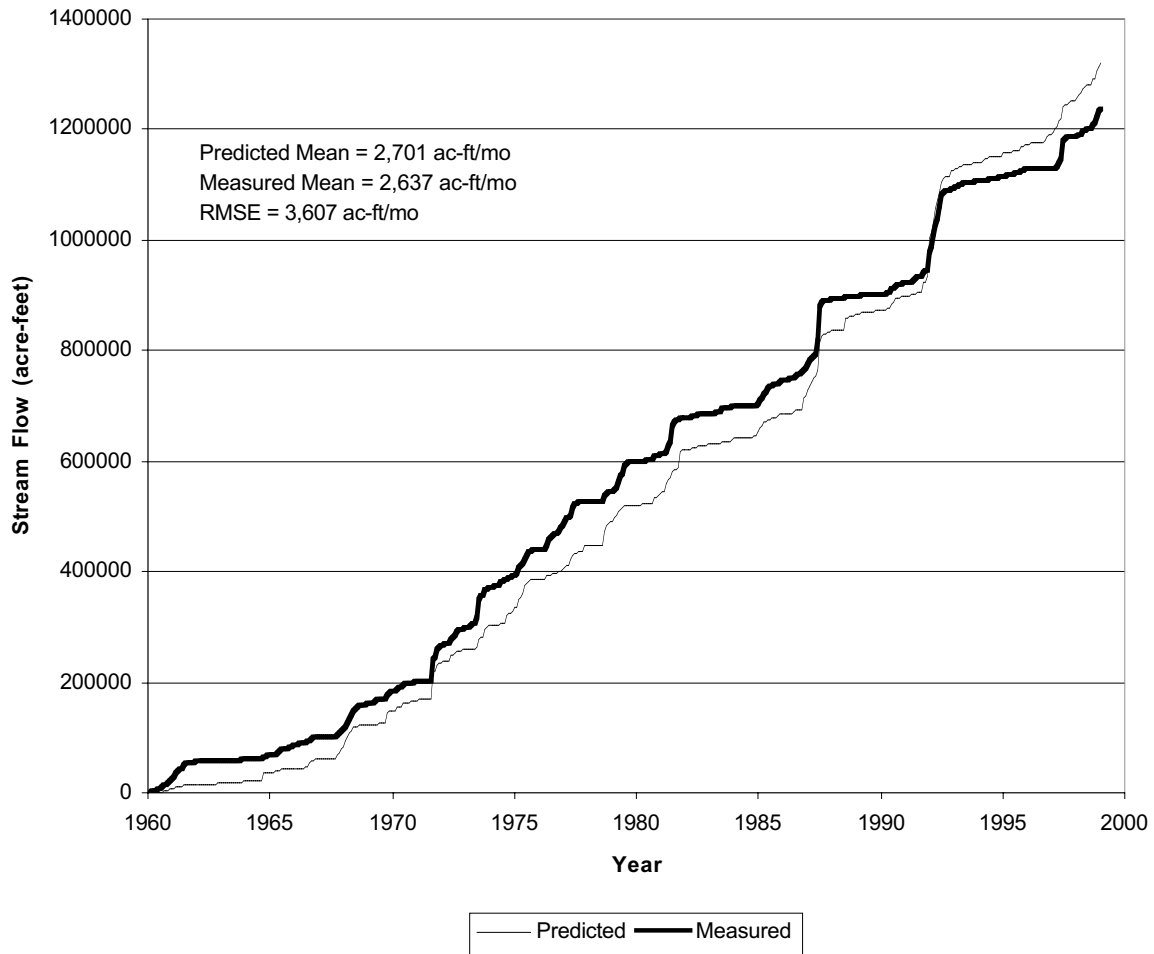


Figure 1.7. Cumulative monthly stream flow predicted by SWAT and measured near outlet of Hondo Creek. Average measured and predicted monthly flows for the entire calibration period and the root mean square error (RMSE) between monthly predicted and measured flows are shown.

Cumulative Monthly Predicted and Measured Flow at Stream Gauge in Medina River, 1960 through 1998

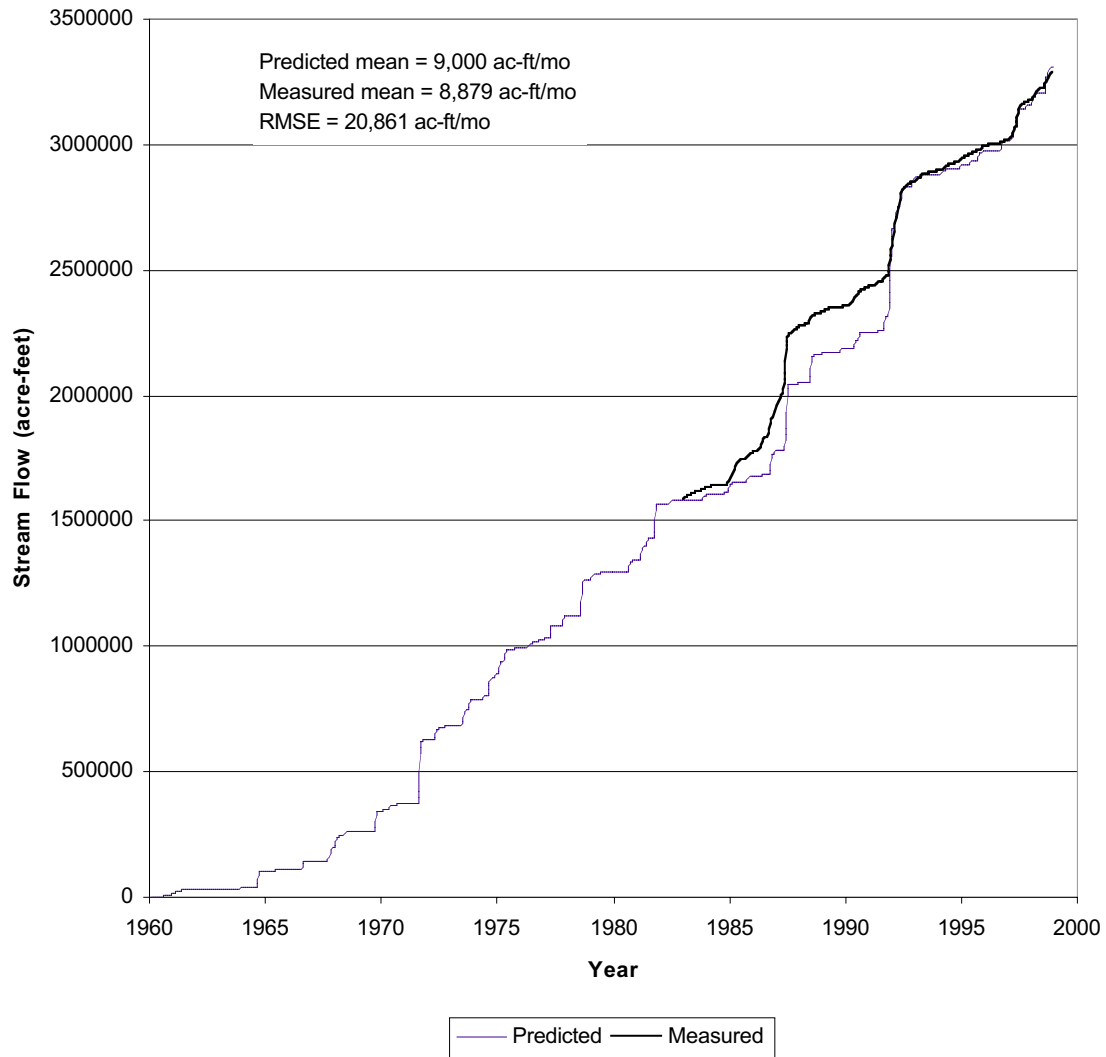


Figure 1.8. Cumulative monthly stream flow predicted by SWAT and measured near outlet of Medina River. Average measured and predicted monthly flows for the entire calibration period and the root mean square error (RMSE) between monthly predicted and measured flows are shown.

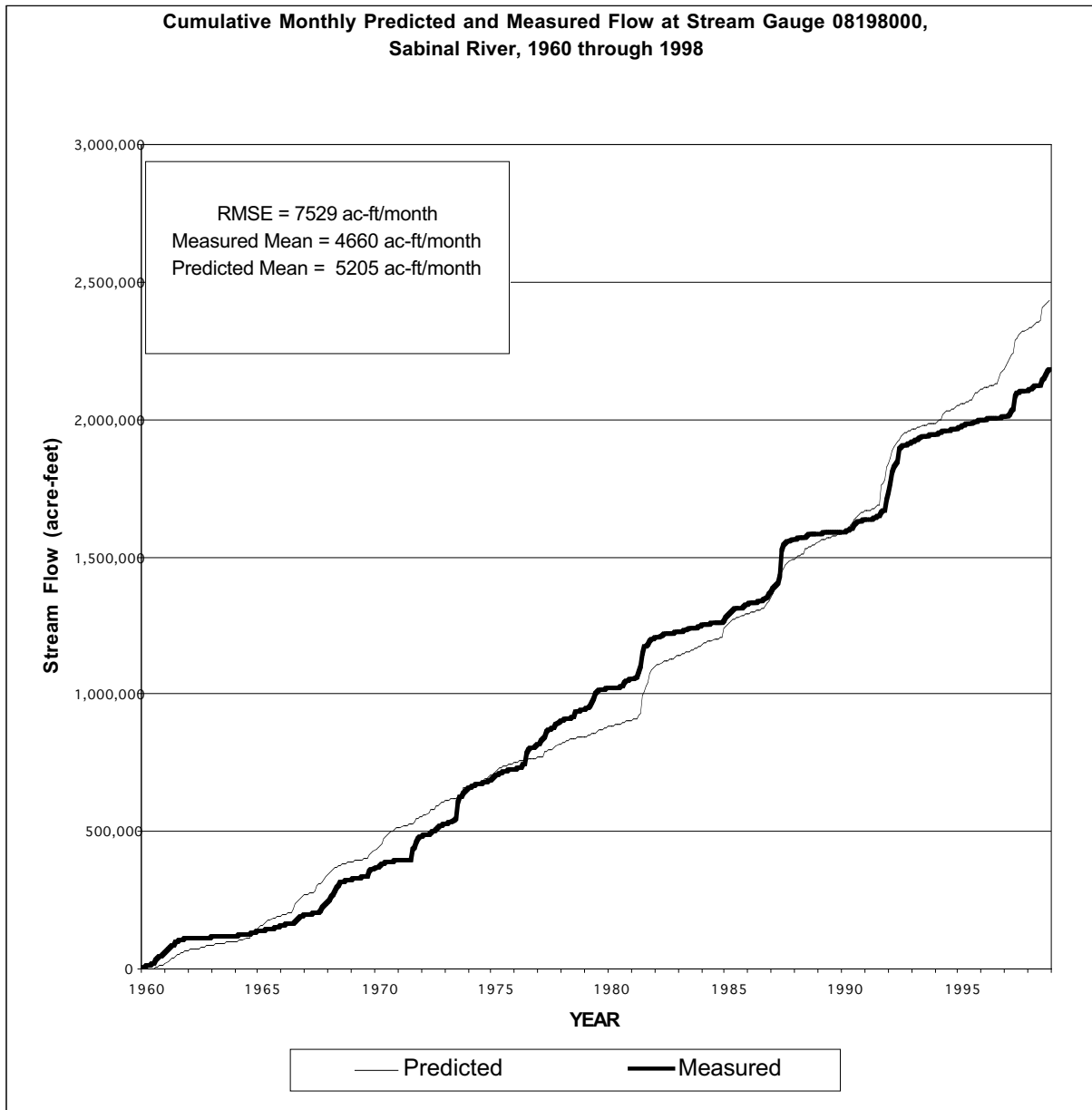


Figure 1.9. Cumulative monthly stream flow predicted by SWAT and measured near outlet of Sabinal River. Average measured and predicted monthly flows for the entire calibration period and the root mean square error (RMSE) between monthly predicted and measured flows are shown.

Cumulative Monthly Predicted and Measured Flow at Stream Gauge
In Seco Ck., 1962 through 1998

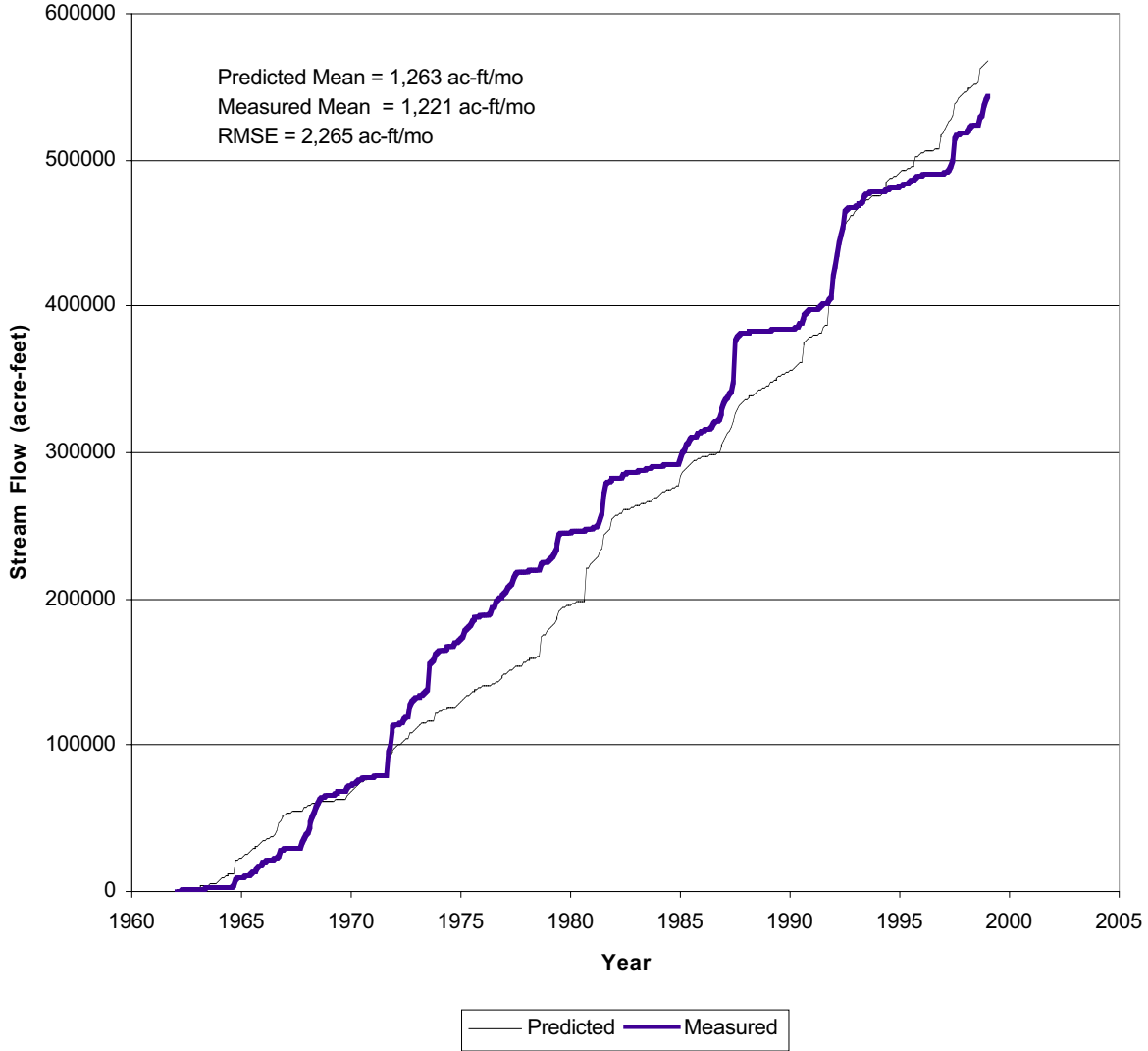


Figure 1.10. Cumulative monthly stream flow predicted by SWAT and measured near outlet of Seco Creek. Average measured and predicted monthly flows for the entire calibration period and the root mean square error (RMSE) between monthly predicted and measured flows are shown.

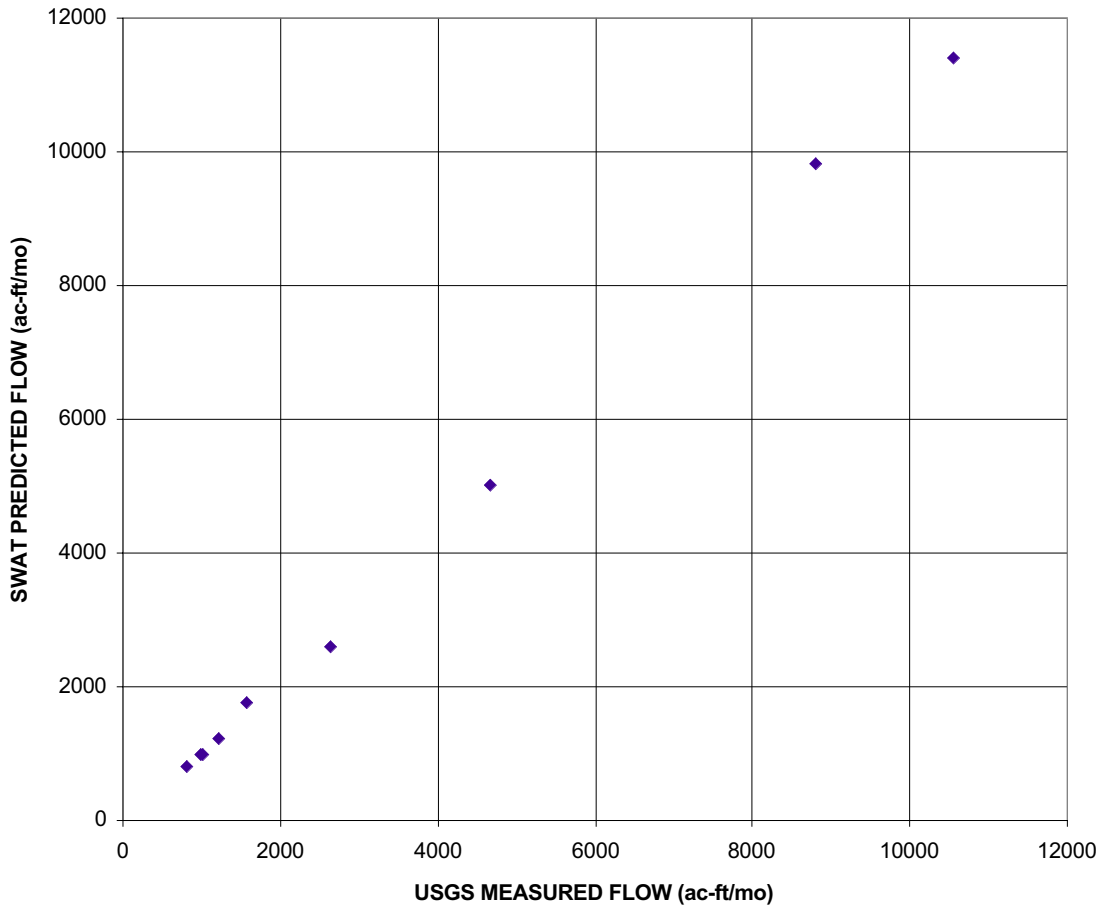


Figure 1.11. Average monthly measured and predicted stream flow for watersheds in this study. Averages are for varying periods, but typically 1960 through 1998.

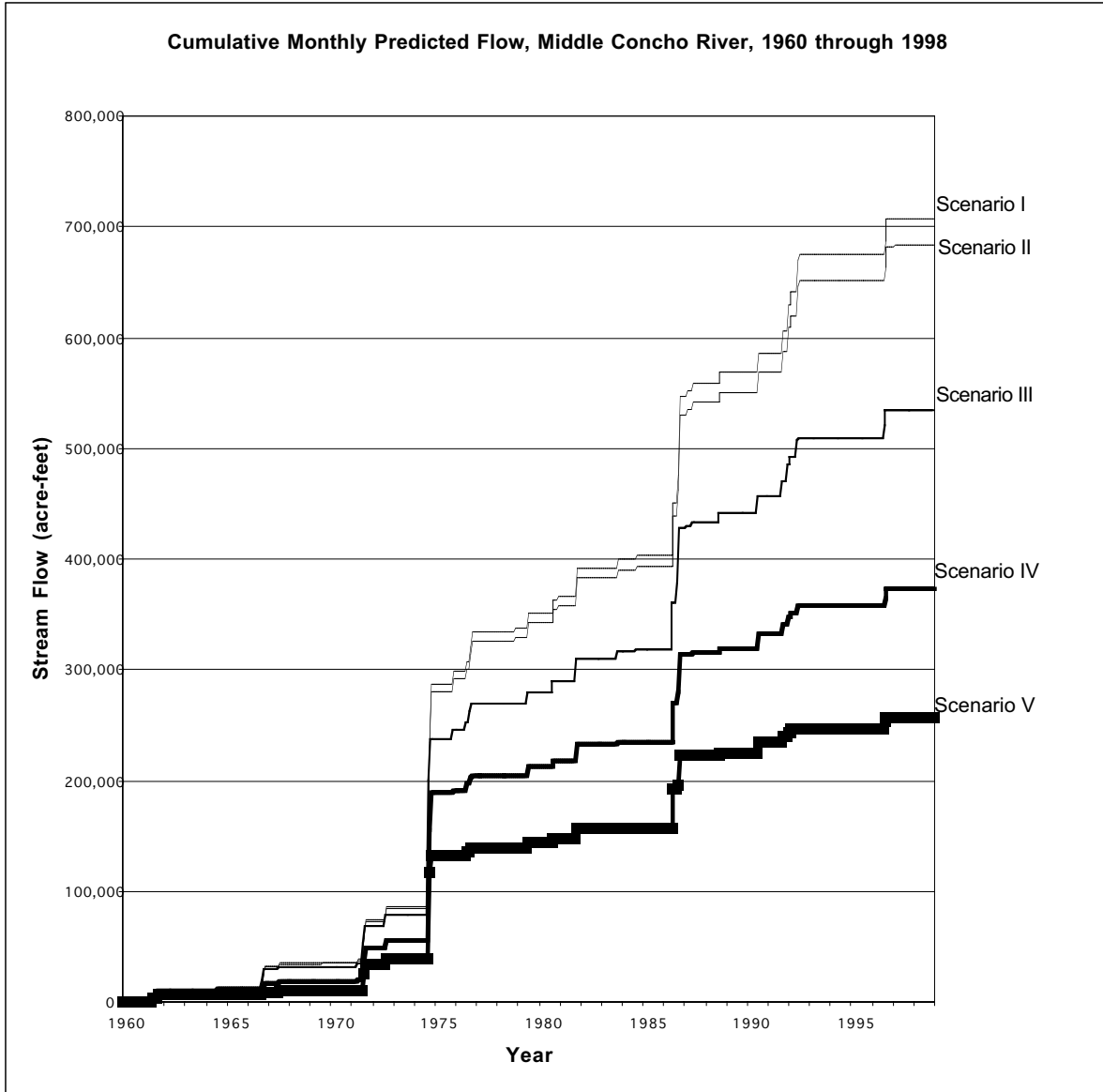


Figure 1.12. Cumulative monthly stream flow predicted by SWAT for scenarios I through V near outlet of Middle Concho River.

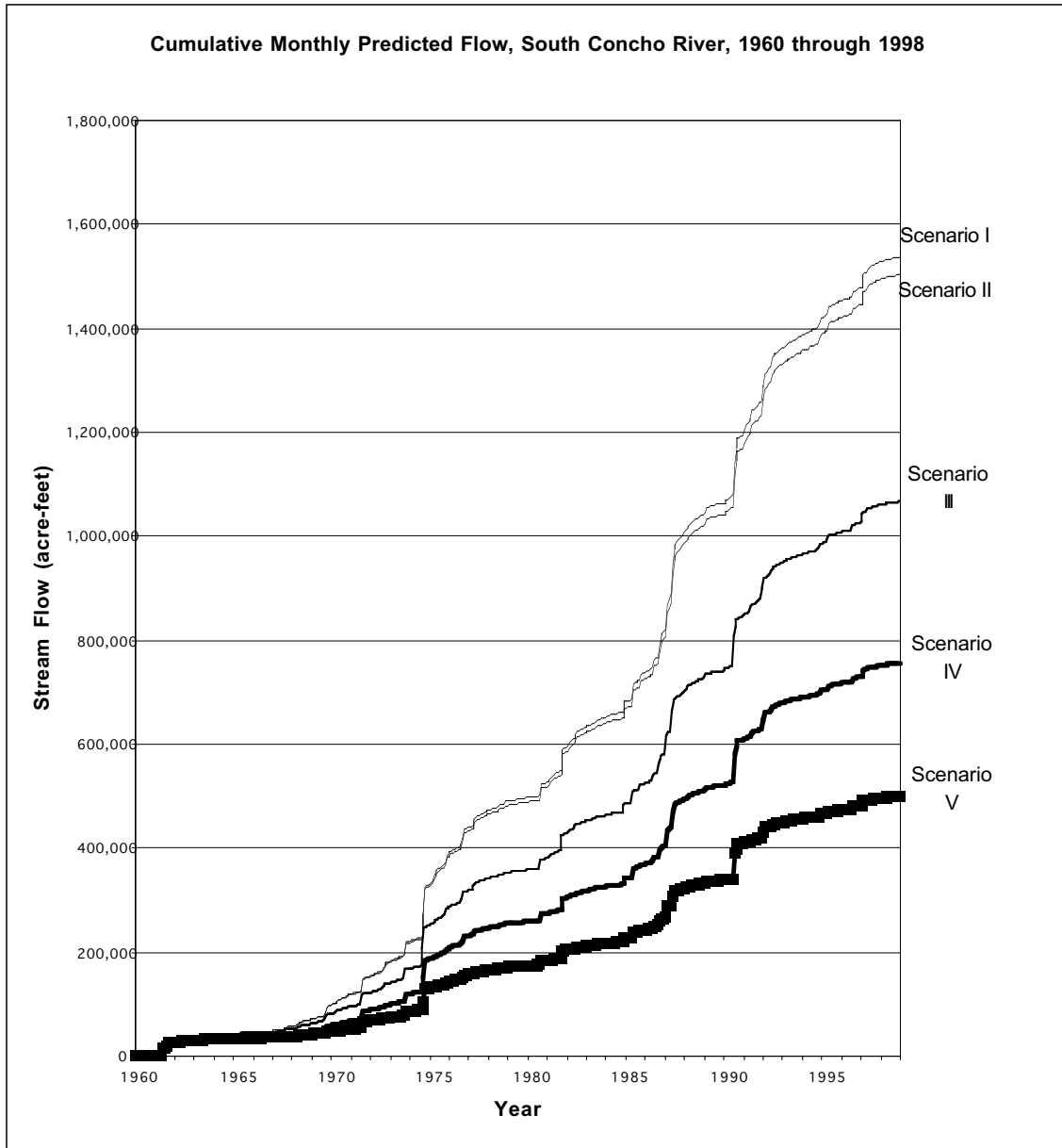


Figure 1.13. Cumulative monthly stream flow predicted by SWAT for scenarios I through V near outlet of South Concho River.

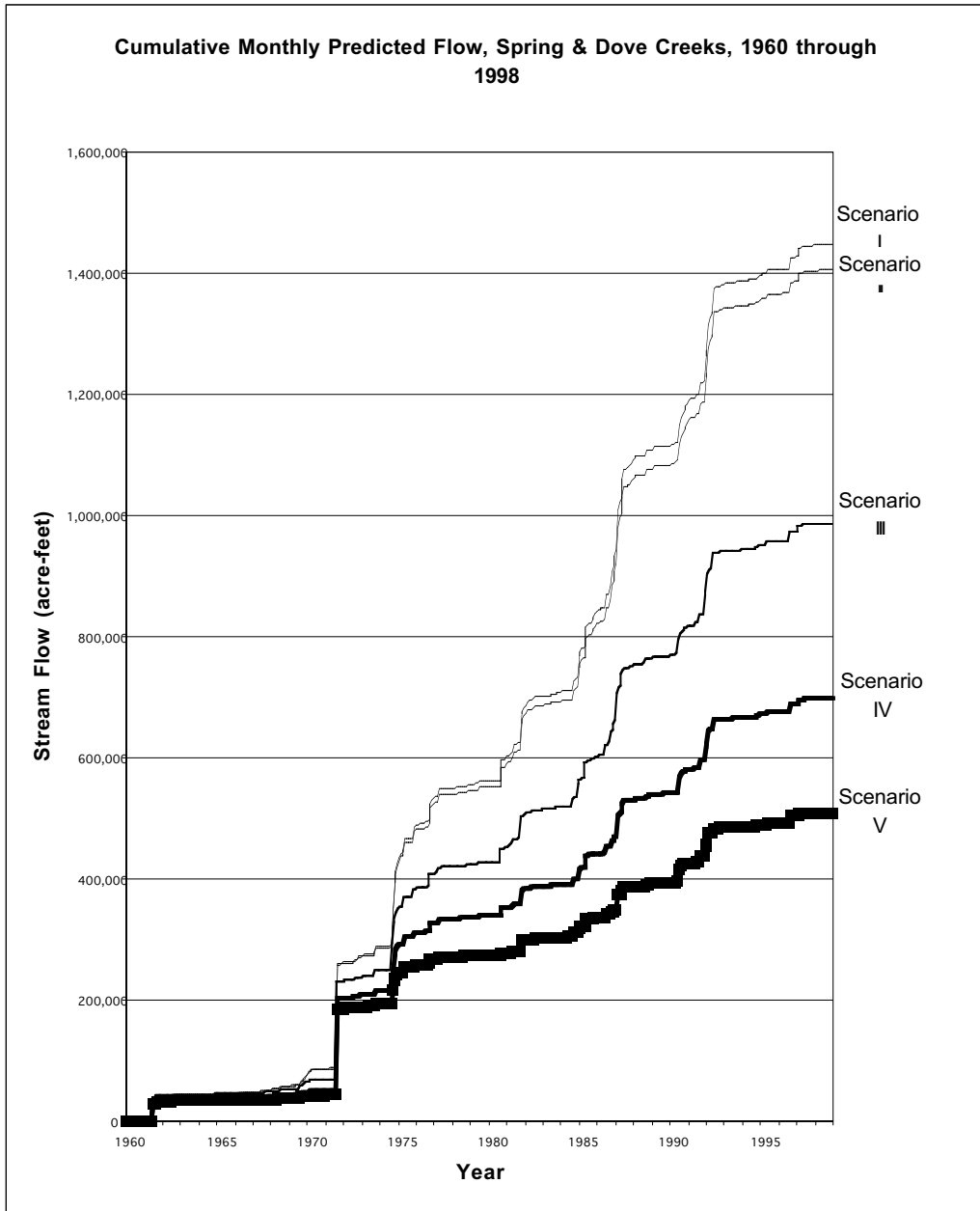


Figure 1.14. Cumulative monthly stream flow predicted by SWAT for scenarios I through V near outlet of Spring and Dove Creeks

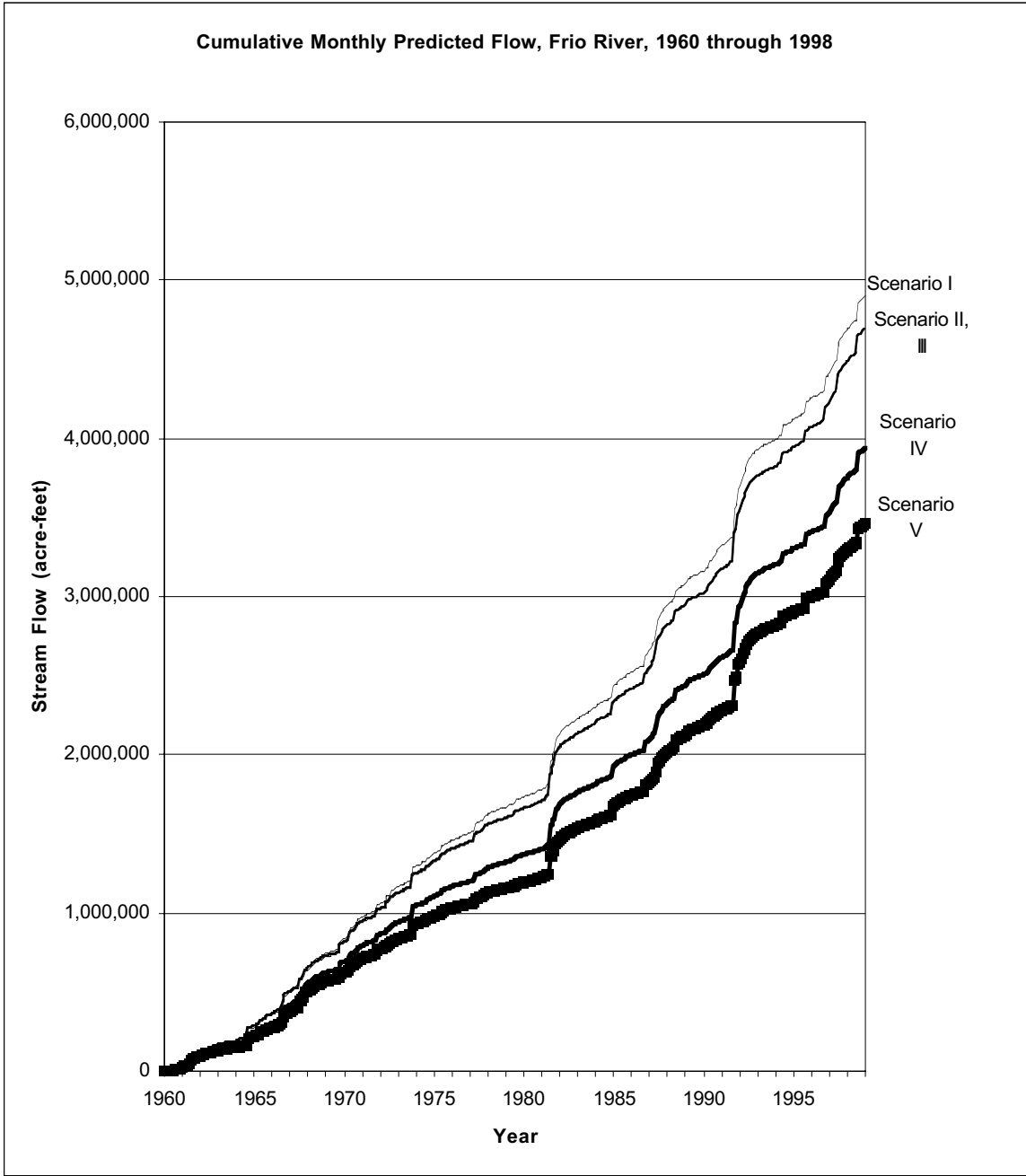


Figure 1.15. Cumulative monthly stream flow predicted by SWAT for scenarios I through V near outlet of Frio River.

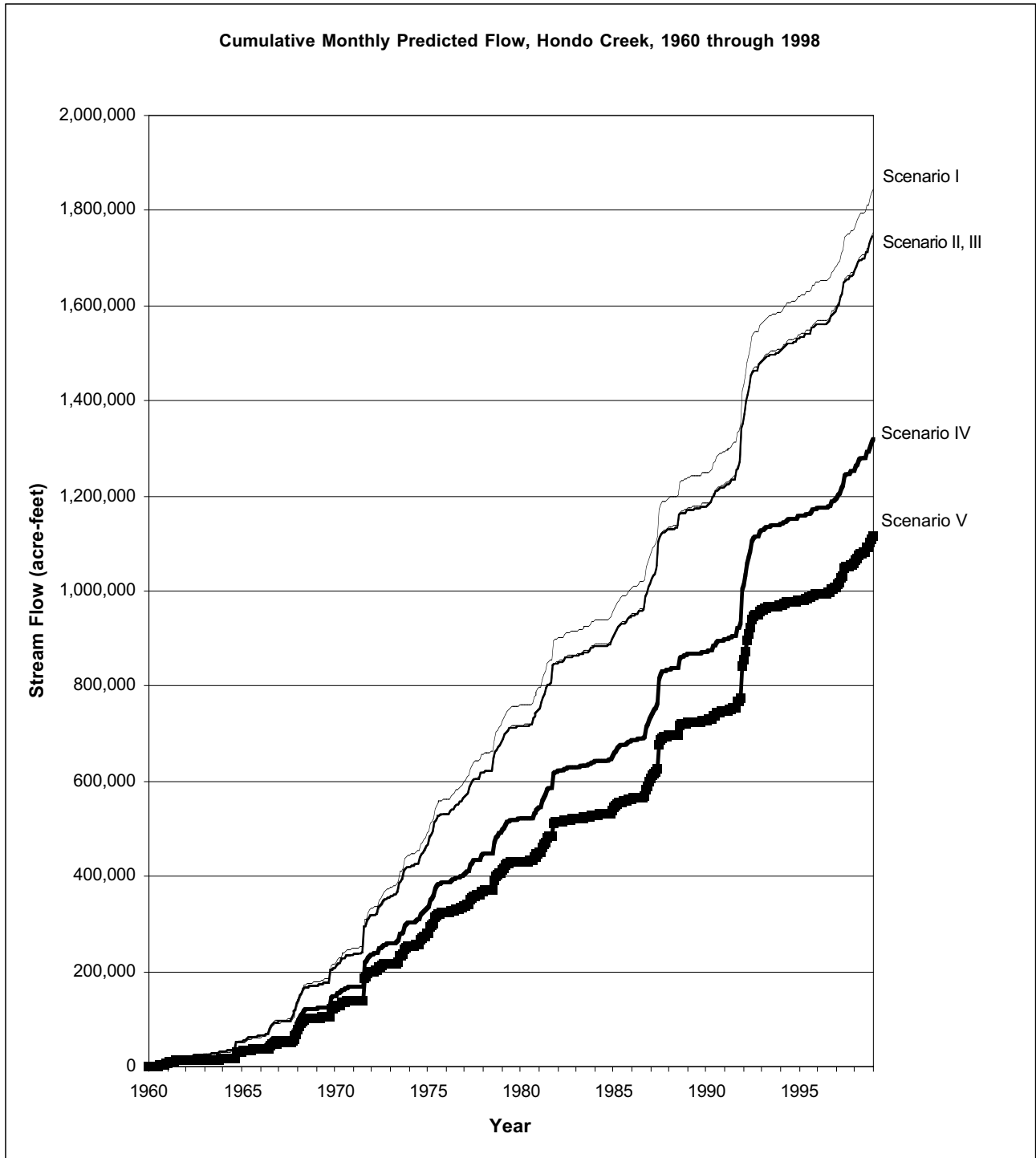


Figure 1.16. Cumulative monthly stream flow predicted by SWAT for scenarios I through V near outlet of Hondo Creek.

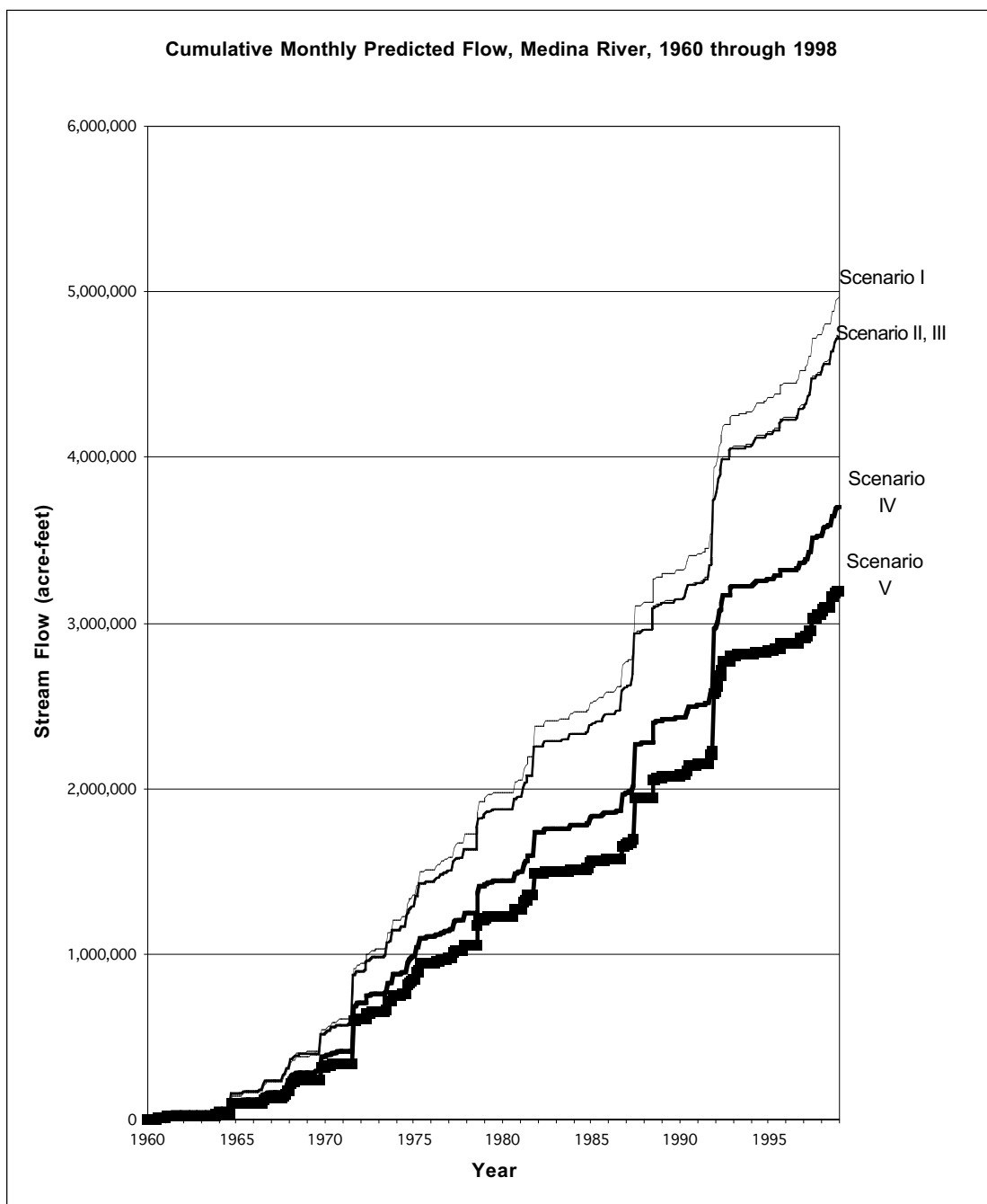


Figure 1.17. Cumulative monthly stream flow predicted by SWAT for scenarios I through V near outlet of Medina River.

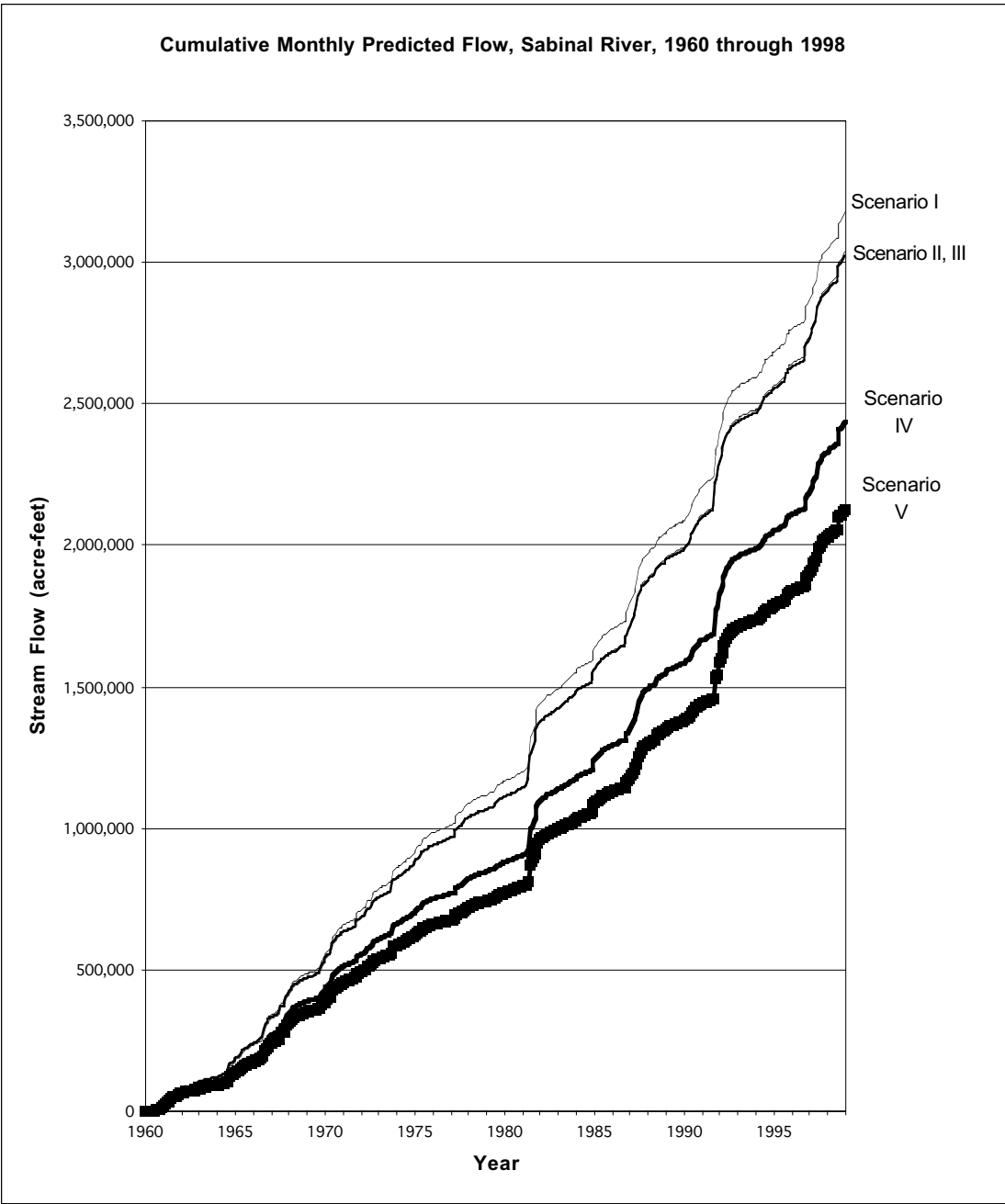


Figure 1.18. Cumulative monthly stream flow predicted by SWAT for scenarios I through V near outlet of Sabinal River.

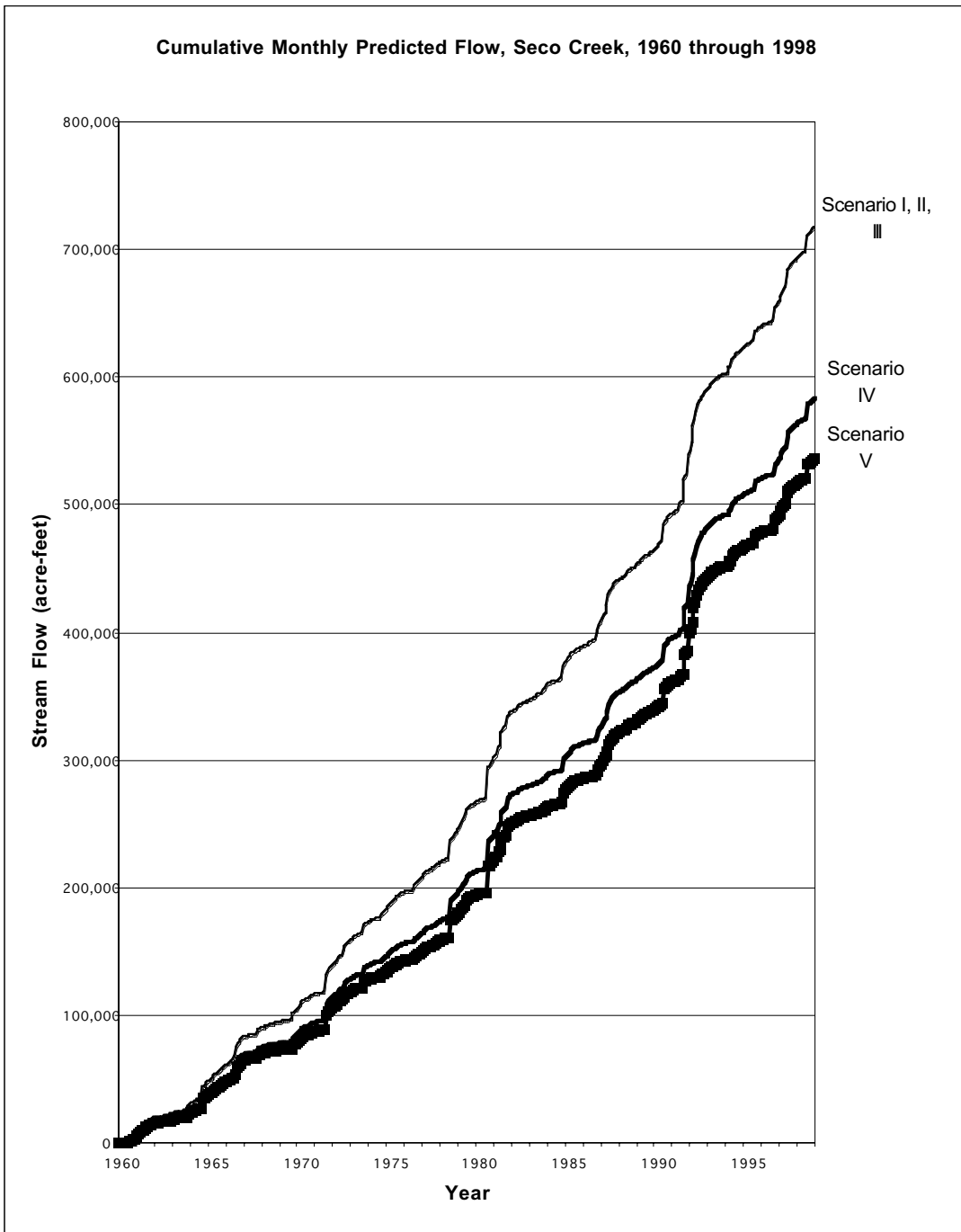


Figure 1.19. Cumulative monthly stream flow predicted by SWAT for scenarios I through V near outlet of Seco Creek.

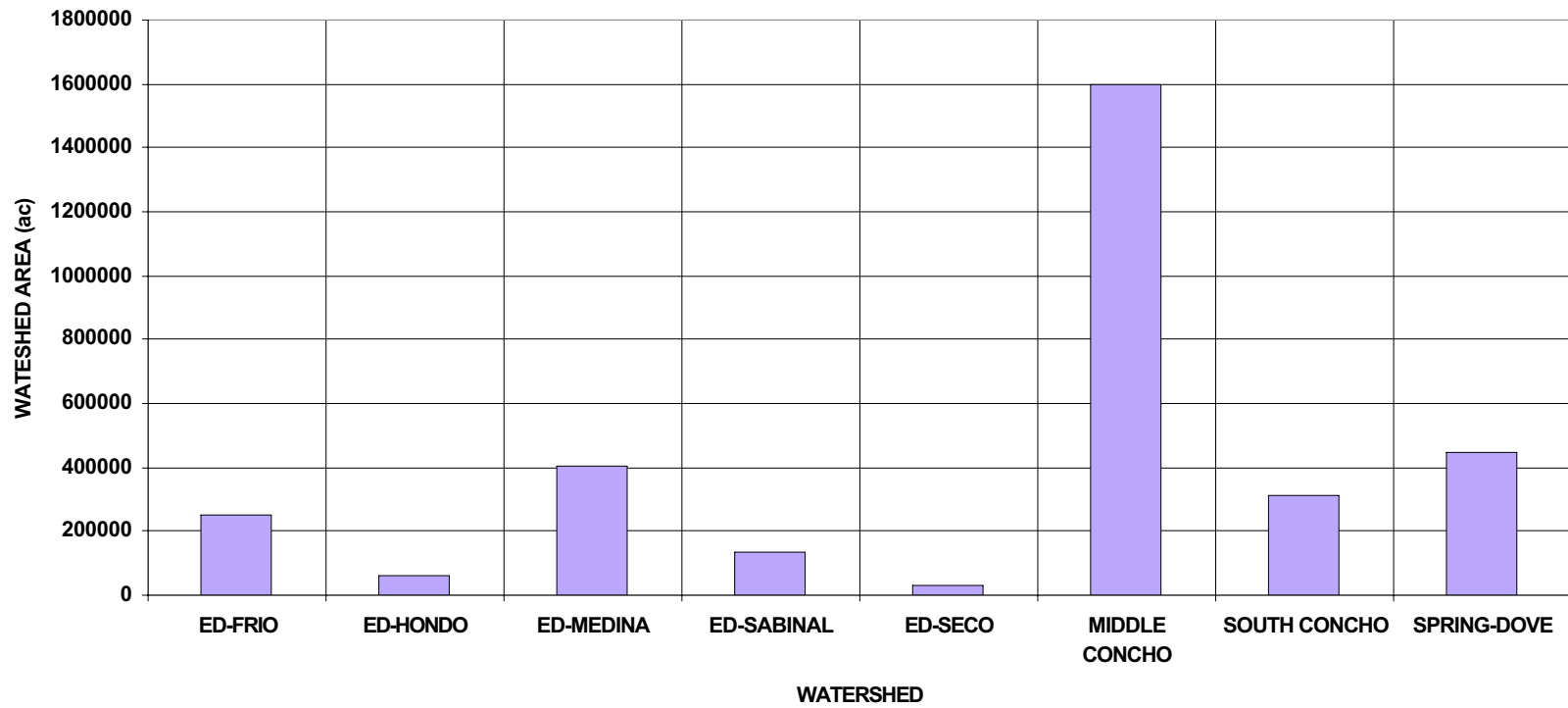


Figure 1.20. Area of each watershed.

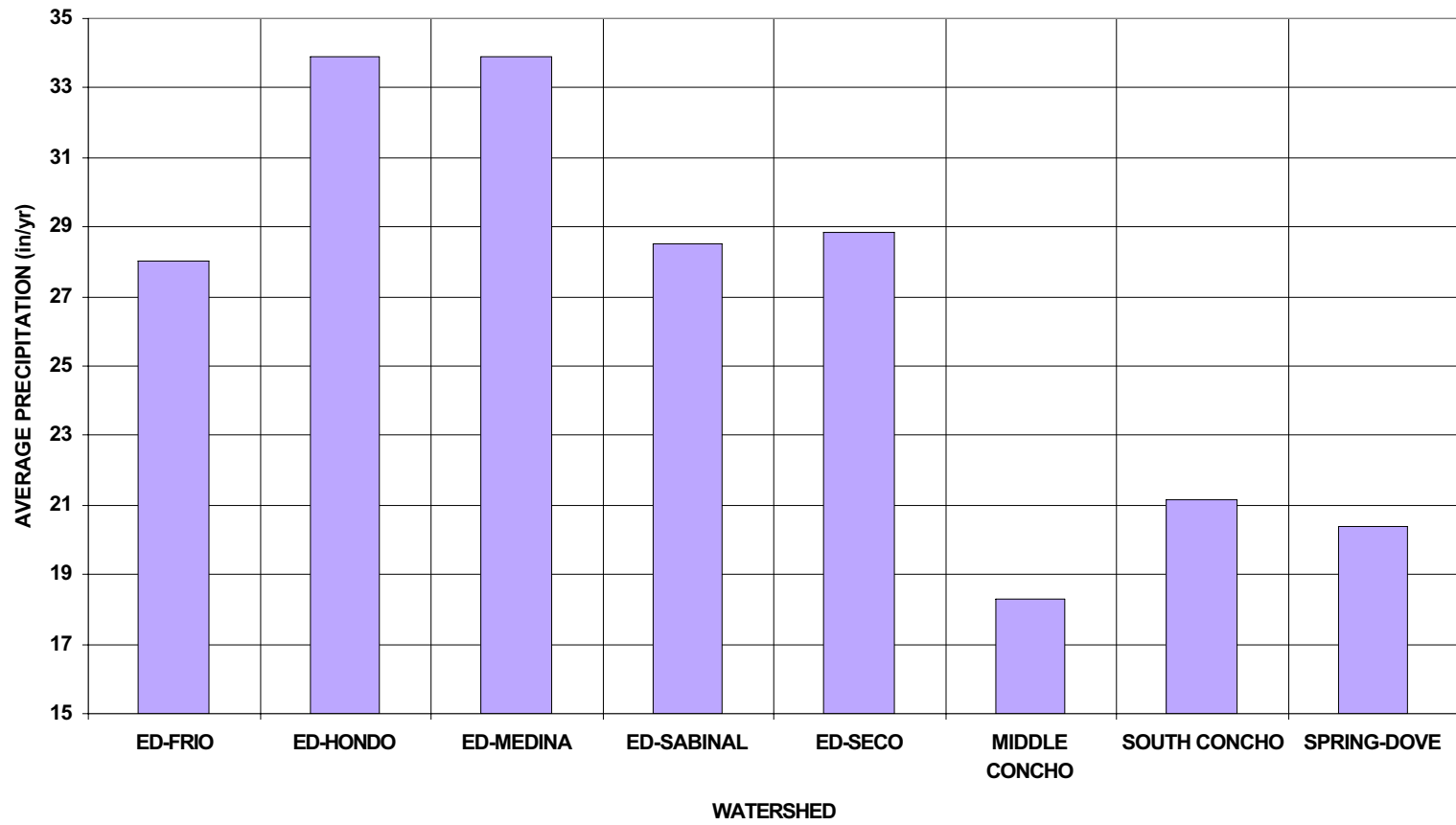


Figure 1.21. Average annual precipitation in each watershed.

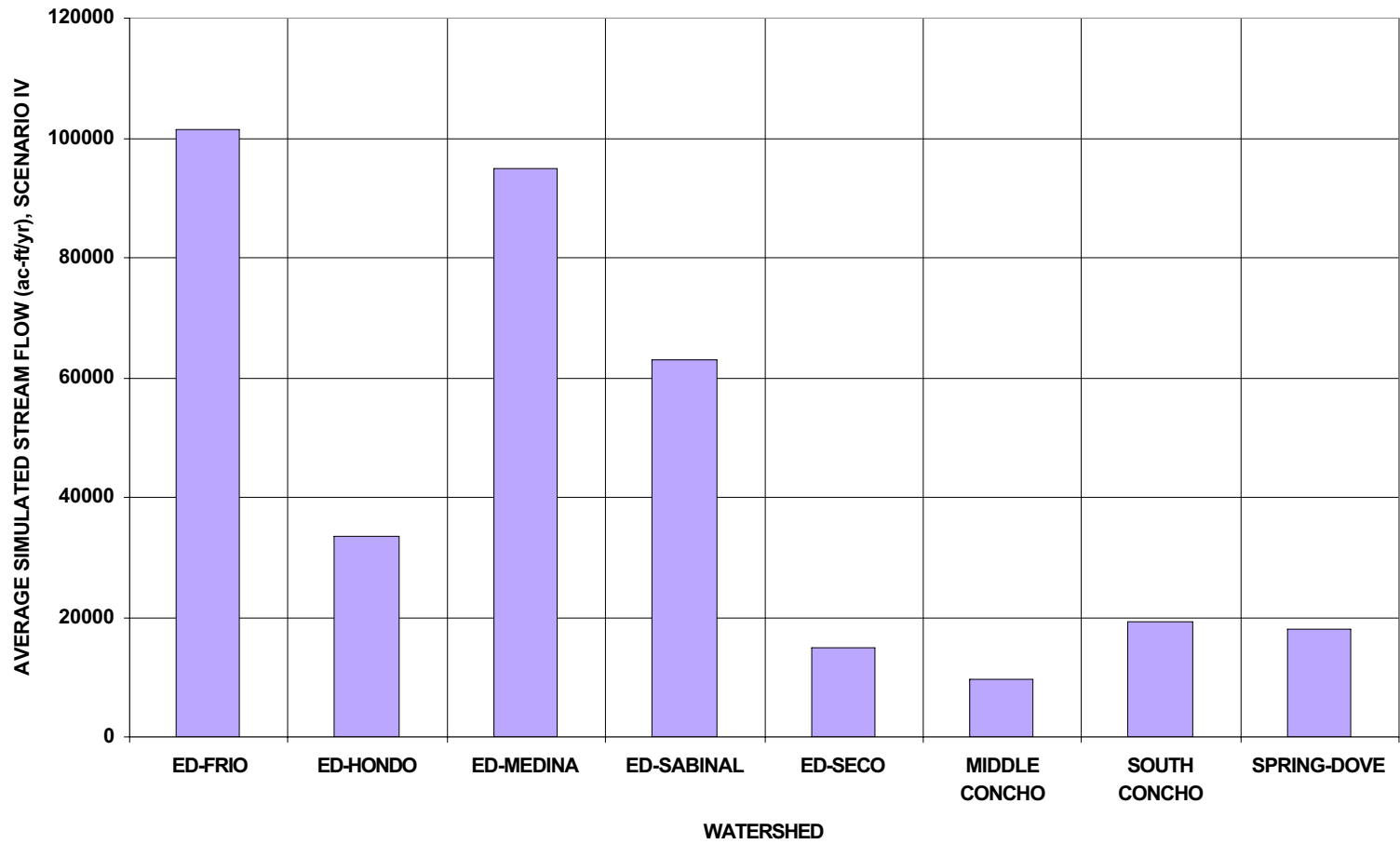


Figure 1.22. Average annual simulated stream flow in each watershed.

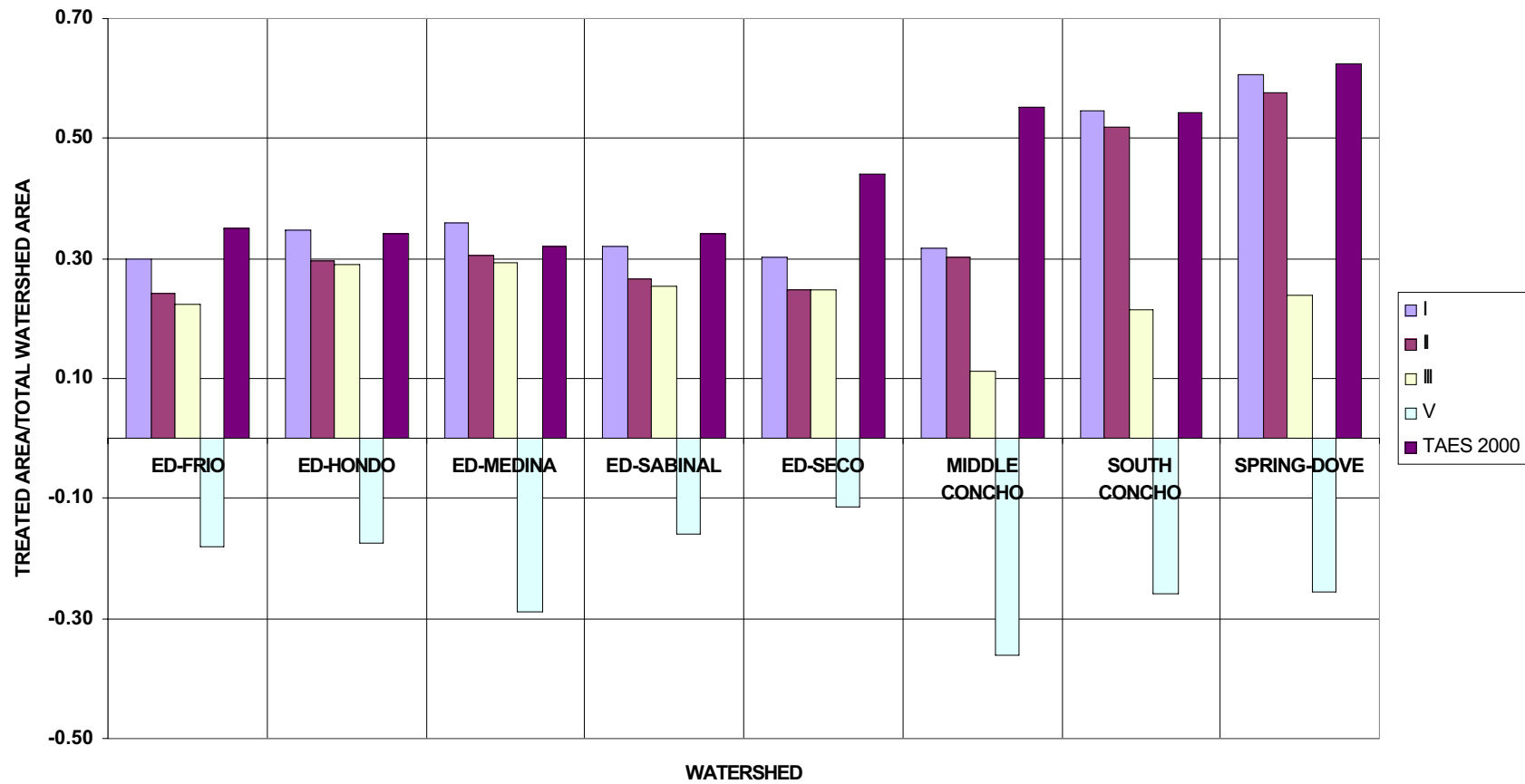


Figure 1.23. Fraction of total watershed area treated (i.e. area with moderate and heavy brush removed) for scenarios I, II, and III, and in a previous study (TAES 2000). Negative area for scenario V represents area of light brush added.

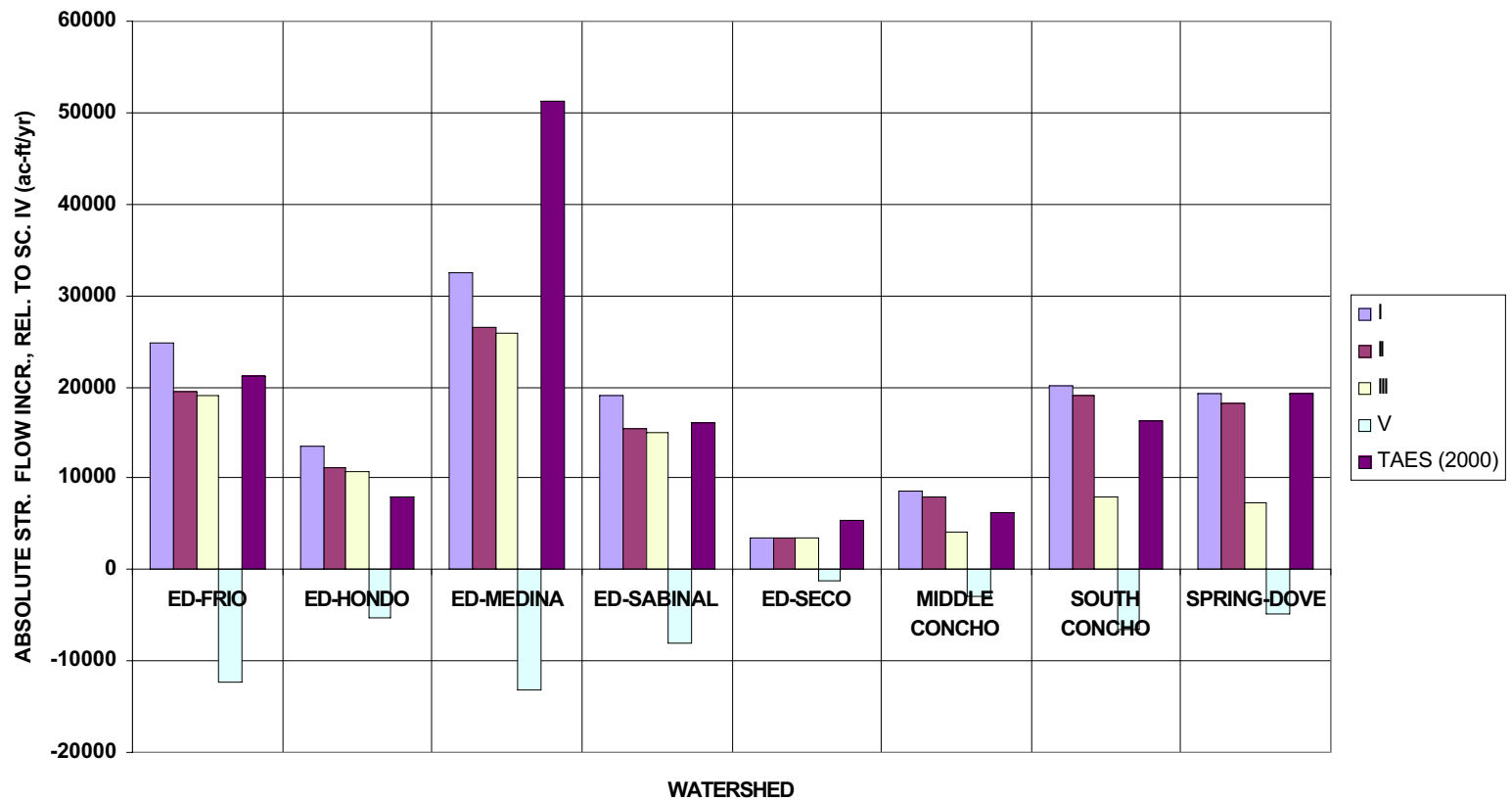


Figure 1.24. Annual average stream flow increase, relative to scenario IV, for scenarios I, II, III, and V, and in a previous study (TAES 2000). Negative stream flow for scenario V represents a flow decrease.

CORPS BRUSH/WILDLIFE STUDIES

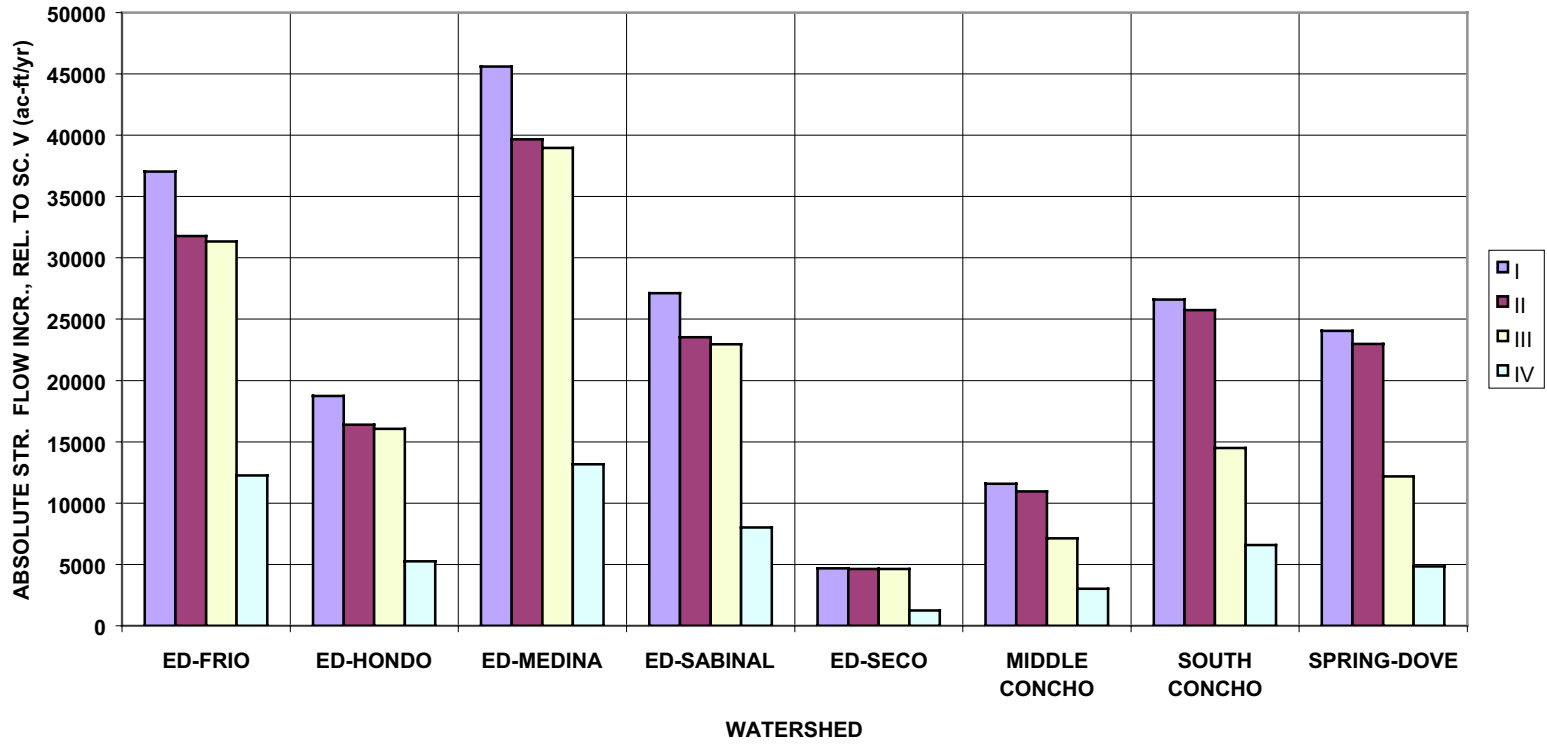


Figure 1.25. Annual average stream flow increase, relative to scenario V, for scenarios I, II, III, and IV.

CORPS BRUSH/WILDLIFE STUDIES

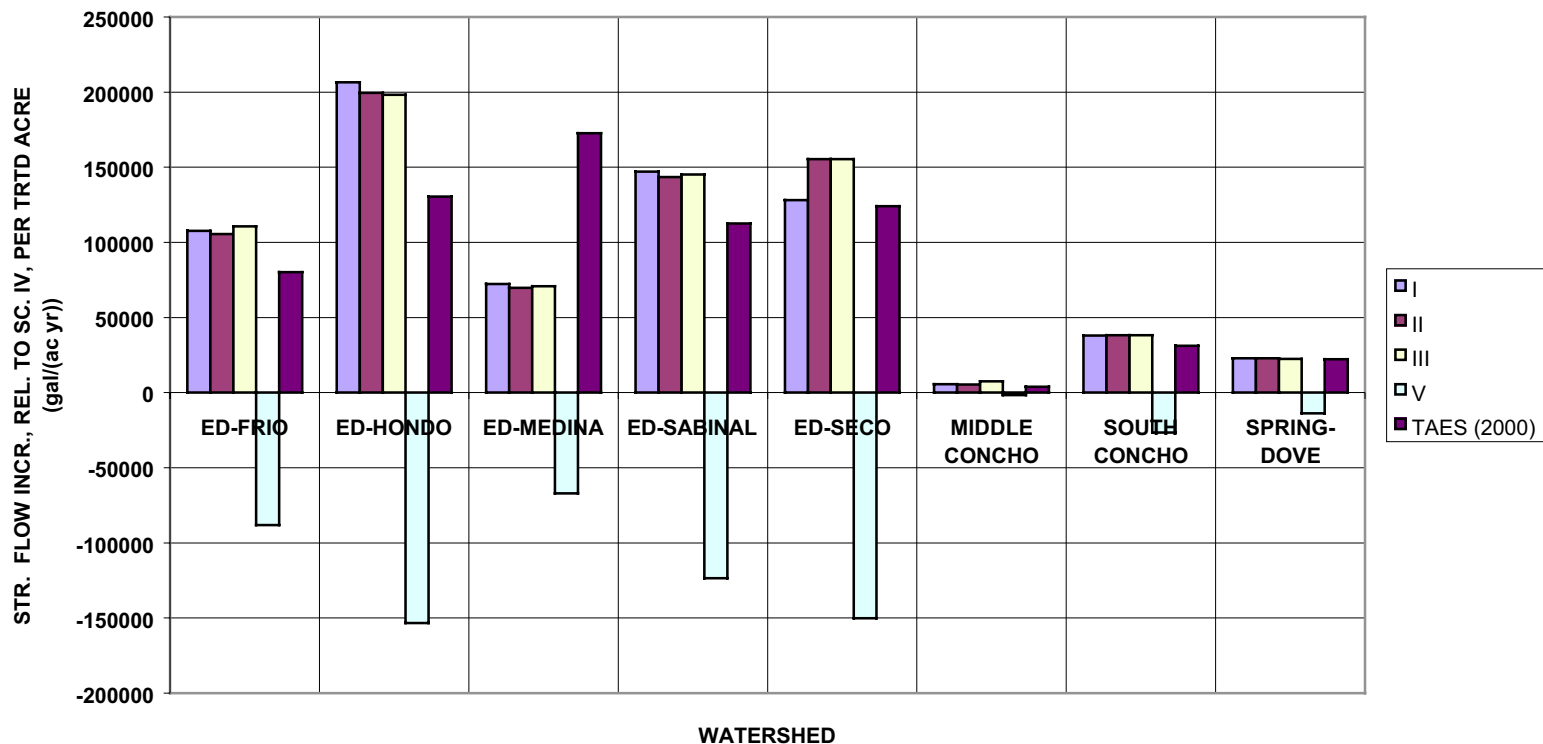


Figure 1.26. Annual average stream flow increase, per treated acre and relative to scenario IV, for scenarios I, II, III, and V, and in a previous study (TAES 2000). Negative stream flow for scenario V represents a flow decrease.

CORPS BRUSH/WILDLIFE STUDIES

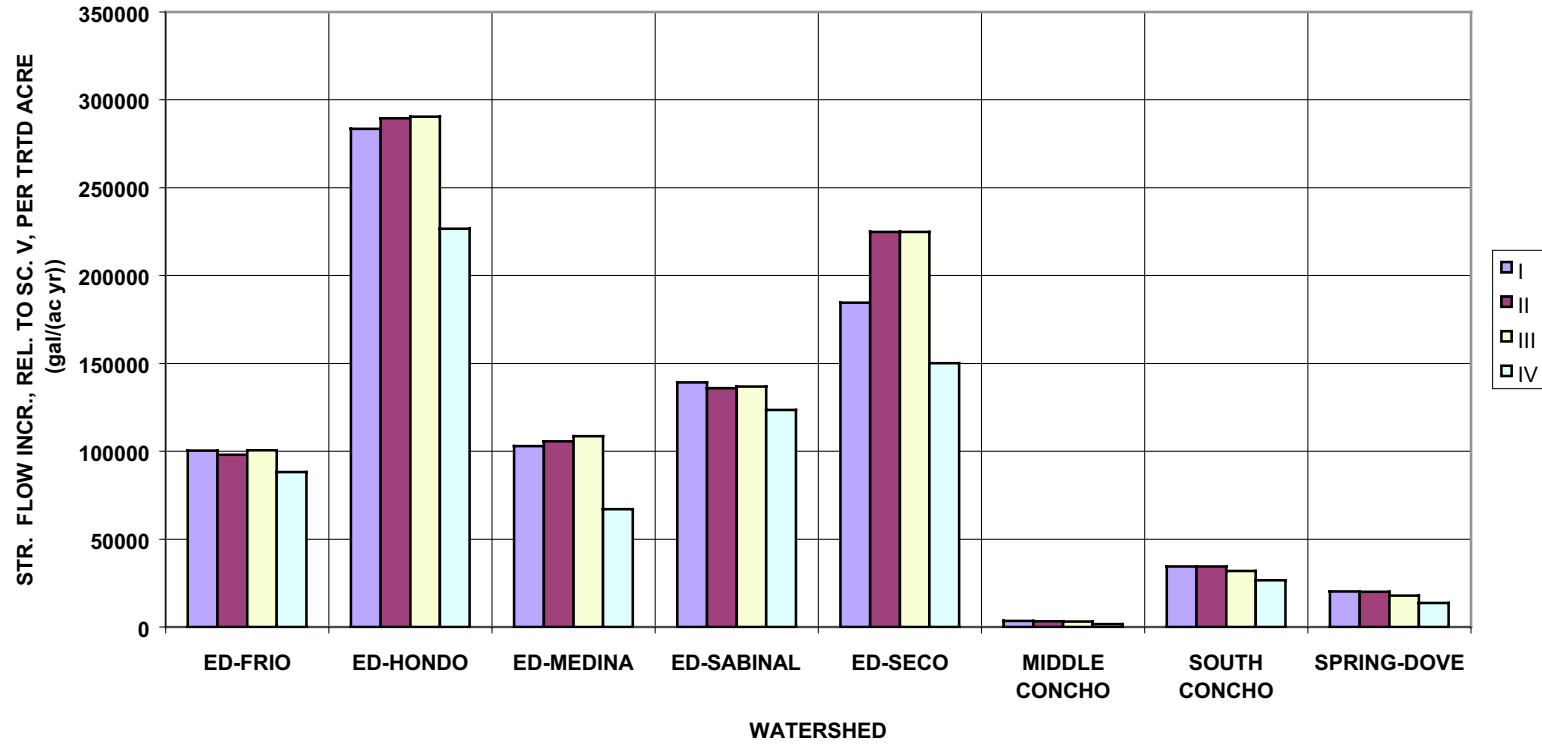


Figure 1.27. Annual average stream flow increase, per treated acre and relative to scenario V, for scenarios I, II, III, and IV.

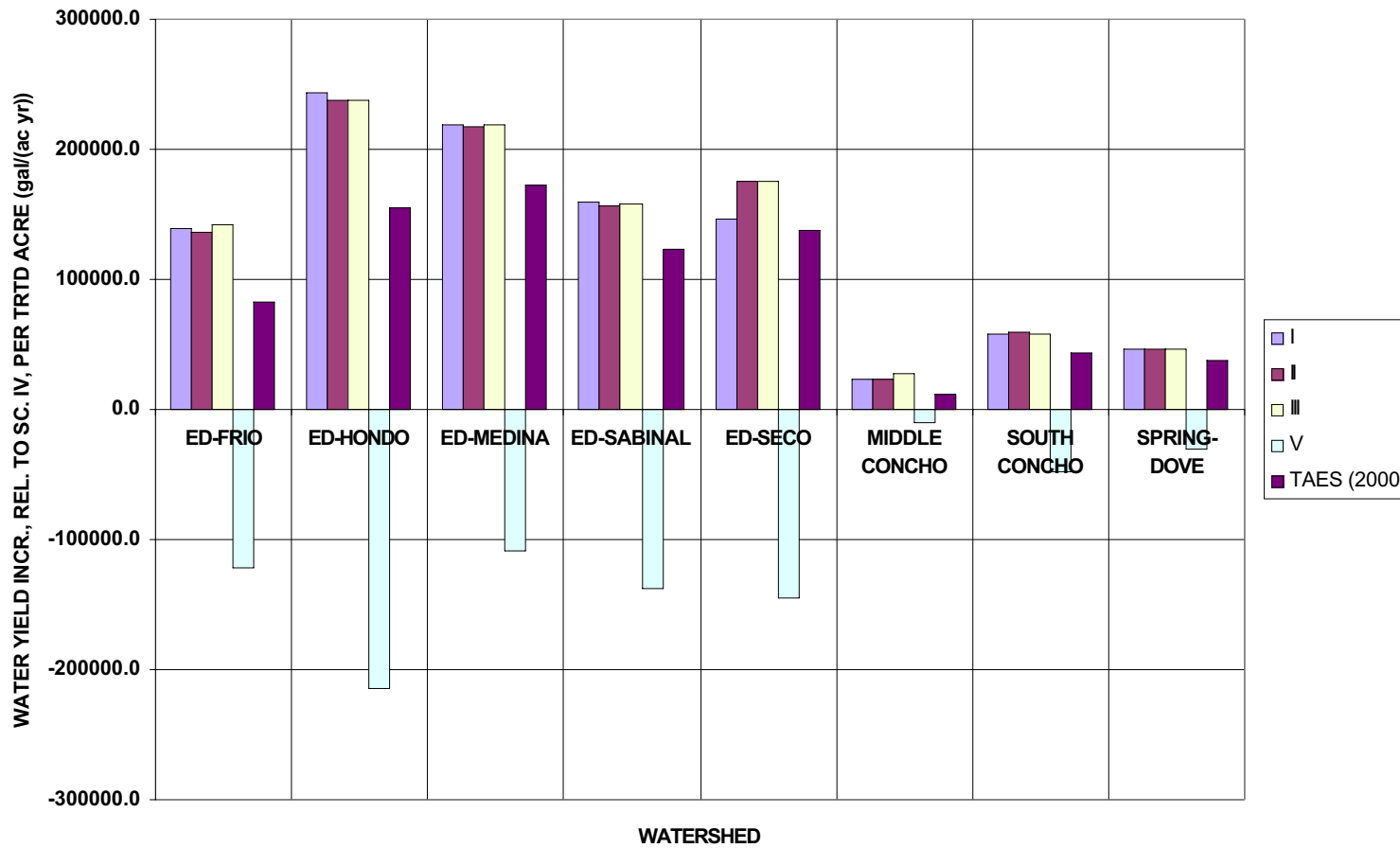


Figure 1.28. Annual average water yield increase, per treated acre and relative to scenario IV, for scenarios I, II, III, and V, and in a previous study (TAES 2000). Negative water yield for scenario V represents a decrease.

CORPS BRUSH/WILDLIFE STUDIES

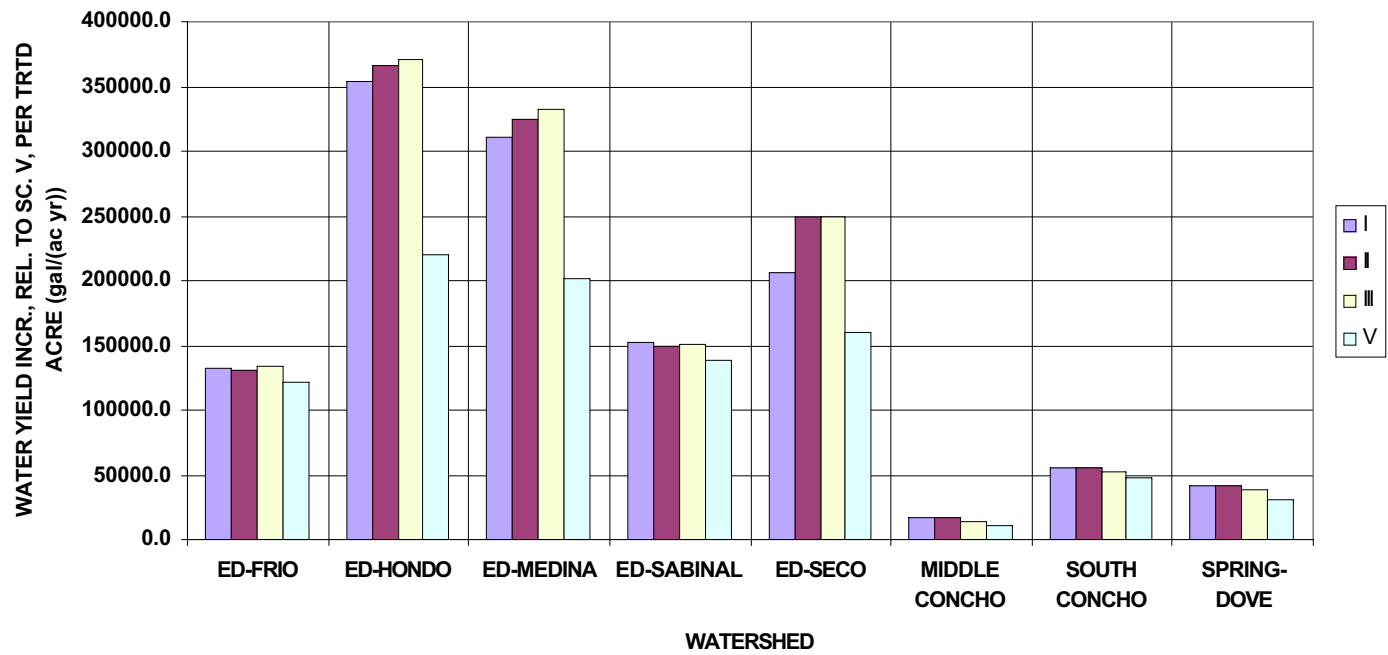


Figure 1.29. Annual average water yield increase, per treated acre and relative to scenario V, for scenarios I, II, III, and I.

Section 2. Rangeland/Economic Analysis

Participants

TAES

Olenick, Keith L.
Wilkins, Neal
Hamilton, Wayne T.
Conner, J. Richard
Kreuter, Urs P.

Introduction

The previous chapter presented the hydrologic implications of different brush management/restoration scenarios for the Twin Buttes and Edwards Aquifer recharge zone watersheds. By using data included in that section and economic analysis methodology used in the TAES study (2000), this chapter will examine the economic implications for three different brush management/restoration strategies.

Specifically, the objectives of this portion of the study are to identify the different brush control and ecological restoration treatments and associated costs for the dominant brush-types within the Twin Buttes and Edwards Aquifer recharge zone watersheds. Next, assumptions, methodology, and results for the private and society cost of implementing each brush control scenario are presented. Lastly, an estimate of society's cost of additional water for both watersheds and all subbasins within them is made. In all references to society cost, the assumption is made that there is no incentive for the landowner to incur the cost.

Methods

The methodology used in this chapter is similar to that used in the economic feasibility portions of the TAES study (2000). This technique integrates information from hydrologic modeling, focus groups, and range scientists to form an economic model that is used to study the economic implications of each brush control scenario for all sub-basins within the eight watersheds found in the two study areas over a 10 year time horizon. First, changes in carrying capacity caused by brush management and animal enterprise inputs were utilized in the estimation of landowner benefits per acre of each targeted brush type-density category. Next, per acre benefits of brush management/restoration to livestock and wildlife enterprises was subtracted from the total per acre cost of brush control and restoration efforts to arrive at society's cost share. The amount and type of brush removed for each brush management scenario was then multiplied by society's cost share for each respective brush type-density to arrive at a total society cost of brush management/restoration for all sub-basins within the eight Edward/Twin Buttes watersheds. Lastly, the total society cost of brush management for each scenario was divided by the additional water produced under each scenario to estimate society's cost of additional acre-feet of water. Geographic differences between the Eastern and Western portions of the Edwards Aquifer recharge zone watershed necessitated the use of separate carrying capacity, brush treatments and costs, and livestock enterprise assumptions.

Inputs

Data gathered from focus groups and range scientists was used to estimate differences in livestock carrying capacity, develop the brush control and restoration techniques and costs for the dominant brush-types, and characterize typical livestock/wildlife enterprises. The amount and type of brush removed and additional water provided by each scenario was provided by the Blackland Research Center, Texas Agriculture Experiment Station, Temple, Texas. Where the previous TAES study (2000) used the investment analysis program ECON to conduct economic analyses, this study used Microsoft Excel.

One of the biggest obstacles of engaging in brush control practices is cost. A key assumption of this model is that costs of brush management/restoration treatments in excess of rancher benefits would need to be paid for by Society. Society can be State of Texas, U.S. Government, a city, county or other entity.

Brush control and restoration techniques and prices for both watersheds are shown in Tables 2.1a, 2.1b and 2.1c. The discount rate used is six percent. Initial and follow-up brush treatments were provided by focus groups and range scientists. Reseeding costs were determined by using current market prices for an area-specific native grass mix purchased in bulk. The per acre costs of cross fencing were calculated by taking the cross distance in feet of the mean ranch size of that particular study area, multiplying by the per foot cost of fencing, \$1.25 and dividing this product by the mean ranch size in acres. Ranches were assumed to be square in shape with mean ranch size determined from a 2002 Texas Agricultural Experiment Station landowner survey (Narayanan et al., 2002). Grazing deferment costs were calculated by taking the inverse of the Year 0 carrying capacity for that particular brush type and multiplying by the cost to lease one animal unit for one year, \$100. The cost of an additional water source was determined by dividing the cost of a water well, \$12,000, by the mean ranch size in acres of the respective study area.

Estimated livestock carrying capacity changes are presented in Tables 2.2a, 2.2b and 2.2c. These figures follow those used in the TAES study (2000) except where mechanical means of initial brush control are conducted and reseeding follows. Tables 2.3a, 2.3b and 2.3c show the livestock and wildlife enterprise assumptions. For a detailed description of how this information was used to estimate the appropriate landowner share of total cost see TAES, 2000.

Model Changes

For this study, the economic analysis model was modified from those included in the TAES study (2000) in the following ways:

1. The initial study did not incorporate ecological restoration practices such as rangeland reseeding, grazing deferments, and implementation of improved grazing management systems through additional cross fencing and water sources.
2. Livestock carrying capacity for brush types where mechanical means of brush control are recommended have increased in this study due to rangeland reseeding.
3. The discount rate used to determine present values for brush management cost and changes in incremental livestock/wildlife enterprise income was changed from 8 percent in the TAES study (2000) to 6 percent in this study.
4. For some brush types, recommended follow up brush treatments, i.e. individual plant treatments or prescribed burns, may occur once more often and/or in different years following initial treatment.
5. The investment analysis tool ECON was not used in the livestock/wildlife enterprise modeling. Instead, this study relied on spreadsheets developed on Microsoft Excel.
6. In this study, the Sabinal watershed uses livestock/wildlife enterprise assumptions for the Western Edwards. In the TAES study (2000), the Sabinal watershed uses assumptions for the Eastern Edwards.

Table 2.1a. Cost of Brush Management/Restoration Treatments by Brush Type–Density Category—Twin Buttes.

Heavy Cedar—Mechanical¹			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Mech. Choice	85.00	85.00
0	Reseeding	30.00	30.00
0	Grazing Deferment	1.43	1.43
0	Cross fencing	2.66	2.66
0	Additional Water Source	3.88	3.88
3	IPT or Burn	15.00	12.59
7	IPT or Burn	10.00	6.65
		Total	142.21
¹ Choice of tree dozing with rake, stack and burn, tree shearing with stump spray and later burn, or excavation and later burn.			
Heavy Mesquite—Chemical			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Aerial Herbicide	26.00	26.00
0	Cross fencing	2.66	2.66
0	Additional Water Source	3.88	3.88
3	IPT or Burn	15.00	12.59
7	IPT or Burn	10.00	6.65
		Total	51.78
Heavy Mesquite – Mechanical Choice¹			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Mech. Choice	85.00	85.00
0	Reseeding	30.00	30.00
0	Grazing Deferment	2.63	2.63
0	Cross fencing	2.66	2.66
0	Additional Water Source	3.88	3.88
3	IPT or Burn	15.00	12.59
7	IPT or Burn	10.00	6.65
		Total	143.42
¹ Choice of tree dozing with rake, stack and burn, tree shearing with stump spray and later burn, or excavation and later burn.			
Heavy Mixed Brush – Mechanical Choice¹			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Treedoze	85.00	85.00
0	Reseeding	15.00	15.00
0	Grazing Deferment	2.00	2.00
0	Cross fencing	2.66	2.66
0	Additional Water Source	3.88	3.88
3	IPT or Burn	15.00	12.59
7	IPT or Burn	10.00	6.65
		Total	127.78
¹ Choice of tree dozing with rake, stack and burn, tree shearing with stump spray and later burn, or excavation and later burn.			

Table 2.1a. Cost of Brush Management/Restoration Treatments by Brush Type–Density Category—Twin Buttes.

Moderate Cedar – Mechanical¹			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Tree Doze, Reseeding	55.00	55.00
0	Reseeding	15.00	15.00
0	Grazing Deferment	1.92	1.92
0	Cross fencing	2.66	2.66
0	Additional Water Source	3.88	3.88
3	IPT or Burn	15.00	12.59
7	IPT or Burn	10.00	6.65
		Total	97.71
1 Choice of tree dozing with rake, stack and burn, tree shearing with stump spray and later burn, or excavation and later burn.			
Moderate Mesquite – Chemical			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Aerial or IPT Herbicide	26.00	26.00
0	Cross fencing	2.66	2.66
0	Additional Water Source	3.88	3.88
3	IPT or Burn	20.00	16.79
7	IPT or Burn	15.00	9.98
		Total	59.31
Moderate Mesquite – Mechanical Choice¹			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Choice of Mechanical Method	55.00	55.00
0	Reseeding	15.00	15.00
0	Grazing Deferment	3.13	3.13
0	Cross fencing	2.66	2.66
0	Additional Water Source	3.88	3.88
3	IPT or Burn	20.00	16.79
7	IPT or Burn	15.00	9.98
		Total	106.43
1 Choice of tree dozing, stack, & burn, tree shearing with stump spray and later burn, or excavation and later burn.			
Moderate Mixed – Mechanical Choice¹			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Choice of Mechanical Method	55.00	55.00
0	Reseeding	15.00	15.00
0	Grazing Deferment	2.50	2.50
0	Cross fencing	2.66	2.66
0	Additional Water Source	3.88	3.88
3	IPT or Burn	15.00	12.59
7	IPT or Burn	10.00	6.65
		Total	98.28
1 Choice of tree dozing with rake, stack and burn, tree shearing with stump spray and later burn, or excavation and later burn.			

Table 2.1b. Cost of Brush Management/Restoration Treatments by Brush Type-Density Category—Western Edwards.

Heavy Cedar—Two Way Chain¹			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Mech. Choice	90.00	90.00
0	Reseeding	30.00	30.00
0	Grazing Deferment	2.00	2.00
0	Cross fencing	8.86	8.86
0	Additional Water Source	13.84	13.84
3	IPT or Burn	25.00	20.99
7	IPT or Burn	20.00	13.30
		Total	178.99
1 Two way chain, stack, and burn.			
Heavy Cedar—Tree Doze¹			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Mech. Choice	145.00	145.00
0	Reseeding	30.00	30.00
0	Grazing Deferment	2.00	2.00
0	Cross fencing	8.86	8.86
0	Additional Water Source	13.84	13.84
3	IPT or Burn	25.00	20.99
7	IPT or Burn	20.00	13.30
		Total	233.99
1 Doze, stack, and burn.			
Heavy Cedar—Tree Shear or Flat Cutting¹			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Mech. Choice	130.00	130.00
0	Reseeding	30.00	30.00
0	Grazing Deferment	2.00	2.00
0	Cross fencing	8.86	8.86
0	Additional Water Source	13.84	13.84
3	IPT or Burn	25.00	20.99
7	IPT or Burn	20.00	13.30
		Total	218.99
1 Tree shear or flat cutting by hand, stack, and burn.			
Heavy Mesquite—Chemical¹			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Aerial Herbicide	35.00	35.00
0	Cross fencing	8.86	8.86
0	Additional Water Source	13.84	13.84
3	IPT or Burn	25.00	20.99
7	IPT or Burn	20.00	13.30
		Total	91.99
1 Aerial or individual chemical application may be used.			
Heavy Mesquite – Rootplow¹			

Table 2.1b. Cost of Brush Management/Restoration Treatments by Brush Type-Density Category—Western Edwards.

Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Rootplow	155.00	155.00
0	Reseeding	30.00	30.00
0	Grazing Deferment	3.33	3.33
0	Cross fencing	8.86	8.86
0	Additional Water Source	13.84	13.84
3	IPT or Burn	25.00	20.99
7	IPT or Burn	20.00	13.30
		Total	245.32
l Rootplow, rake, stack, and burn.			
Heavy Mesquite – Rootplow with Pre-Doze¹			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Pre-doze and Rootplow	180.00	180.00
0	Reseeding	30.00	30.00
0	Grazing Deferment	3.33	3.33
0	Cross fencing	8.86	8.86
0	Additional Water Source	13.84	13.84
3	IPT or Burn	25.00	20.99
7	IPT or Burn	20.00	13.30
		Total	270.32
l Heavy tree-doze, rootplow, rake, stack, and burn.			
Heavy Mixed Brush – Tree Doze¹			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Treedoze	160.00	160.00
0	Reseeding	15.00	15.00
0	Grazing Deferment	2.50	2.50
0	Cross fencing	8.86	8.86
0	Additional Water Source	13.84	13.84
3	IPT or Burn	25.00	20.99
7	IPT or Burn	20.00	13.30
		Total	234.49
l Heavy tree-doze, rootplow, rake, stack, and burn.			
Moderate Cedar – Tree Doze¹			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Tree Doze, Reseeding	95.00	95.00
0	Reseeding	15.00	15.00
0	Grazing Deferment	2.50	2.50
0	Cross fencing	8.86	8.86
0	Additional Water Source	13.84	13.84
3	IPT or Burn	25.00	20.99
7	IPT or Burn	20.00	13.30
		Total	169.49
l Doze, rake, stack, and burn.			

Table 2.1b. Cost of Brush Management/Restoration Treatments by Brush Type-Density Category—Western Edwards.

Moderate Cedar – Tree Shearing or Flat Cutting¹			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Tree Doze, Reseeding	75.00	75.00
0	Reseeding	15.00	15.00
0	Grazing Deferment	2.50	2.50
0	Cross fencing	8.86	8.86
0	Additional Water Source	13.84	13.84
3	IPT or Burn	25.00	20.99
7	IPT or Burn	20.00	13.30
		Total	149.49
1 Tree shear or flat cutting by hand, stack, and burn.			
Moderate Mesquite – Chemical¹			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Aerial or IPT Herbicide	35.00	35.00
0	Cross fencing	8.86	8.86
0	Additional Water Source	13.84	13.84
3	IPT or Burn	25.00	20.99
7	IPT or Burn	20.00	13.30
		Total	91.99
1 Either aerial or individual chemical applications may be used.			
Moderate Mesquite – Mechanical Choice¹			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Choice of Mechanical Method	60.00	60.00
0	Reseeding	15.00	15.00
0	Grazing Deferment	4.00	4.00
0	Cross fencing	8.86	8.86
0	Additional Water Source	13.84	13.84
3	IPT or Burn	25.00	20.99
7	IPT or Burn	20.00	13.30
		Total	135.99
1 Choice of tree dozing, stack, & burn, tree shearing, stump spray and later burn, or low power grubbing and burning.			
Moderate Mixed – Mechanical Choice¹			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Choice of Mechanical Method	60.00	60.00
0	Reseeding	15.00	15.00
0	Grazing Deferment	2.86	2.86
0	Cross fencing	8.86	8.86
0	Additional Water Source	13.84	13.84
3	IPT or Burn	25.00	20.99
7	IPT or Burn	20.00	13.30
		Total	134.85
1 Choice of tree dozing, stack, & burn, tree shearing, stump spray and later burn, or low power grubbing and burning			

Table 2.1c. Cost of Brush Management Restoration Treatments by Brush Type—Density Category—Eastern Edwards.

Heavy Cedar—Mechanical¹			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Mech. Choice	165.00	165.00
0	Reseeding	30.00	30.00
0	Deferment	1.67	1.67
0	Cross fencing	8.86	8.86
0	Additional Water Source	13.84	13.84
3	IPT or Burn	25.00	20.99
7	IPT or Burn	20.00	13.30
		Total	253.66
¹ Choice of tree dozing with rake, stack and burn, tree shearing with stump spray and later burn, or excavation and later burn.			
Heavy Mesquite—Chemical			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Aerial Herbicide	35.00	35.00
0	Cross fencing	8.86	8.86
0	Additional Water Source	13.84	13.84
3	IPT or Burn	25.00	20.99
7	IPT or Burn	20.00	13.30
		Total	91.99
Heavy Mesquite – Rootplow¹			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Rootplow	160.00	160.00
0	Reseeding	30.00	30.00
0	Grazing Deferment	2.86	2.86
0	Cross fencing	8.86	8.86
0	Additional Water Source	13.84	13.84
3	IPT or Burn	25.00	20.99
7	IPT or Burn	20.00	13.30
		Total	249.85
¹ Rootplow, rake, stack, and burn.			
Heavy Mesquite – Rootplow with Pre-Doze¹			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Pre-doze and Rootplow	185.00	185.00
0	Reseeding	30.00	30.00
0	Grazing Deferment	2.86	2.86
0	Cross fencing	8.86	8.86
0	Additional Water Source	13.84	13.84
3	IPT or Burn	25.00	20.99
7	IPT or Burn	20.00	13.30
		Total	274.85

¹ Heavy tree-doze, rootplow, rake, stack, and burn.

Table 2.1c. Cost of Brush Management Restoration Treatments by Brush Type—Density Category—Eastern Edwards.

Heavy Mixed Brush – Rootplow¹			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Treedoze	160.00	160.00
0	Reseeding	15.00	15.00
0	Grazing Deferment	2.22	2.22
0	Cross fencing	8.86	8.86
0	Additional Water Source	13.84	13.84
3	IPT or Burn	25.00	20.99
7	IPT or Burn	20.00	13.30
		Total	234.21
1 Rootplow, rake, stack, and burn.			
Heavy Mixed Brush – Rootplow with Pre-Doze¹			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Treedoze	185.00	185.00
0	Reseeding	15.00	15.00
0	Grazing Deferment	2.22	2.22
0	Cross fencing	8.86	8.86
0	Additional Water Source	13.84	13.84
3	IPT or Burn	25.00	20.99
7	IPT or Burn	20.00	13.30
		Total	259.21
1 Heavy tree-doze, rootplow, rake, stack, and burn.			
Moderate Cedar – Mechanical¹			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Tree Doze, Reseeding	100.00	100.00
0	Reseeding	15.00	15.00
0	Grazing Deferment	2.22	2.22
0	Cross fencing	8.86	8.86
0	Additional Water Source	13.84	13.84
3	IPT or Burn	25.00	20.99
7	IPT or Burn	20.00	13.30
		Total	174.21
1 Doze or shear, stack, and burn.			
Moderate Mesquite – Chemical¹			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Aerial or IPT Herbicide	35.00	35.00
0	Cross fencing	8.86	8.86
0	Additional Water Source	13.84	13.84
3	IPT or Burn	25.00	20.99
7	IPT or Burn	20.00	13.30
		Total	91.99
1 Either aerial or individual chemical applications may be used.			

Table 2.1c. Cost of Brush Management Restoration Treatments by Brush Type—Density Category—Eastern Edwards.

Moderate Mesquite – Mechanical Choice¹			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Choice of Mechanical Method	60.00	60.00
0	Reseeding	15.00	15.00
0	Grazing Deferment	4.00	4.00
0	Cross fencing	8.86	8.86
0	Additional Water Source	13.84	13.84
3	IPT or Burn	25.00	20.99
7	IPT or Burn	20.00	13.30
		Total	135.99
1 Choice of tree dozing, stack, & burn, tree shearing, stump spray and later burn, or low power grubbing and burning.			
Moderate Mixed – Mechanical Choice¹			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Choice of Mechanical Method	60.00	60.00
0	Reseeding	15.00	15.00
0	Grazing Deferment	2.86	2.86
0	Cross fencing	8.86	8.86
0	Additional Water Source	13.84	13.84
3	IPT or Burn	25.00	20.99
7	IPT or Burn	20.00	13.30
		Total	134.85
1 Choice of tree dozing, stack, & burn, tree shearing, stump spray and later burn, or low power grubbing and burning			

Table 2.2a. Grazing Capacity With and Without Brush Control (Acres/AUY)—Twin Buttes.

Brush Type / Category	Brush Control	Program Year									
		0	1	2	3	4	5	6	7	8	9
Heavy Cedar	Control (Mech)	70.0	55.0	45.0	33.3	33.3	33.3	33.3	29.2	29.2	29.2
	No Control	70.0	70.0	70.1	70.2	70.3	70.4	70.5	70.6	70.7	70.8
Heavy Mesquite	Control (Chem)	38.0	33.0	28.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
	Control (Mech)	38.0	33.0	28.0	23.8	23.8	23.8	23.8	20.8	20.8	20.8
	No Control	38.0	38.0	38.1	38.1	38.2	38.2	38.3	38.3	38.4	38.4
Heavy Mixed Brush	Control (Mech)	50.0	43.0	36.0	28.6	28.6	28.6	28.6	25.0	25.0	25.0
	No Control	50.0	50.0	50.1	50.2	50.3	50.4	50.5	50.5	50.6	50.6
Moderate Cedar	Control (Mech)	52.0	43.0	35.0	33.3	33.3	33.3	33.3	29.2	29.2	29.2
	No Control	52.0	52.3	52.7	53.0	53.4	53.8	54.1	54.4	54.7	54.9
Moderate Mesquite	Control (Chem)	32.0	28.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
	Control (Mech)	32.0	28.0	25.0	23.8	23.8	23.8	23.8	20.8	20.8	20.8
	No Control	32.0	32.2	32.4	32.6	32.8	33.0	33.2	33.4	33.6	33.7
Moderate Mixed Brush	Control (Mech)	40.0	35.0	30.0	28.6	28.6	28.6	28.6	25.0	25.0	25.0
	No Control	40.0	40.2	40.5	40.8	41.0	41.3	41.6	41.8	42.0	42.2

Table 2.2b. Grazing Capacity With and Without Brush Control (Acres/AUY)—Western Edwards.

Brush Type / Category	Brush Control	Program Year									
		0	1	2	3	4	5	6	7	8	9
Heavy Cedar	Control (Mech)	50.0	43.3	36.7	28.6	28.6	28.6	28.6	25.0	25.0	25.0
	No Control	50.0	50.1	50.1	50.2	50.2	50.3	50.3	50.4	50.4	50.5
Heavy Mesquite	Control (Chem)	30.0	26.7	23.3	20.0	20.0	20.0	20.0	20.0	20.0	20.0
	Control (Mech)	30.0	26.7	23.3	19.0	19.0	19.0	19.0	16.7	16.7	16.7
	No Control	30.0	30.0	30.1	30.1	30.2	30.3	30.3	30.4	30.4	30.3
Heavy Mixed Brush	Control (Mech)	40.0	35.0	30.0	23.8	23.8	23.8	23.8	20.8	20.8	20.8
	No Control	40.0	40.0	40.1	40.2	40.2	40.3	40.3	40.4	40.4	40.4
Moderate Cedar	Control (Mech)	40.0	35.0	30.0	23.8	23.8	23.8	23.8	20.8	20.8	20.8
	No Control	40.0	40.1	40.2	40.3	40.4	40.5	40.6	40.7	40.8	40.9
Moderate Mesquite	Control (Chem)	25.0	23.2	21.6	20.0	20.0	20.0	20.0	20.0	20.0	20.0
	Control (Mech)	25.0	23.2	21.6	19.0	19.0	19.0	19.0	16.7	16.7	16.7
	No Control	25.0	25.1	25.3	25.4	25.6	25.7	25.8	26.0	26.1	26.3
Moderate Mixed Brush	Control (Mech)	35.0	31.6	28.3	23.8	23.8	23.8	23.8	20.8	20.8	20.8
	No Control	35.0	35.2	35.4	35.6	35.8	36.0	36.2	36.4	36.6	36.8

Table 2.2c. Grazing Capacity With and Without Brush Control (Acres/AUY)—Eastern Edwards.

Brush Type / Category	Brush Control	Program Year									
		0	1	2	3	4	5	6	7	8	9
Heavy Cedar	Control (Mech)	60.0	50.0	40.0	28.6	28.6	28.6	28.6	25.0	25.0	25.0
	No Control	60.0	60.1	60.1	60.2	60.3	60.3	60.4	60.5	60.5	60.6
Heavy Mesquite	Control (Chem)	35.0	30.0	25.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
	Control (Mech)	35.0	30.0	25.0	19.0	19.0	19.0	19.0	16.7	16.7	16.7
	No Control	35.0	35.0	35.1	35.1	35.2	35.2	35.2	35.3	35.3	35.4
Heavy Mixed Brush	Control (Mech)	45.0	38.2	31.6	23.8	23.8	23.8	23.8	20.8	20.8	20.8
	No Control	45.0	45.1	45.1	45.2	45.2	45.3	45.3	45.4	45.4	45.5
Moderate Cedar	Control (Mech)	45.0	40.0	35.0	28.6	28.6	28.6	28.6	25.0	25.0	25.0
	No Control	45.0	45.3	45.5	45.8	46.0	46.3	46.5	46.8	47.0	47.3
Moderate Mesquite	Control (Chem)	25.0	23.2	21.6	20.0	20.0	20.0	20.0	20.0	20.0	20.0
	Control (Mech)	25.0	23.2	21.6	19.0	19.0	19.0	19.0	16.7	16.7	16.7
	No Control	25.0	25.1	25.3	25.4	25.6	25.7	25.8	26.0	26.1	26.3
Moderate Mixed Brush	Control (Mech)	35.0	31.6	28.3	23.8	23.8	23.8	23.8	20.8	20.8	20.8
	No Control	35.0	35.2	35.4	35.6	35.8	36.0	36.2	36.4	36.6	36.8

Table 2.3a. Economic Evaluation Variables—Twin Buttes.

Livestock Composition		Discount Rate	
Cattle Percentage	60%		6%
Meat Goat Percentage	10%	Ranch Size (Acres)	
Sheep Percentage	30%		1000
Cattle Enterprise		Meat Goat Enterprise	
Cow Animal Unit Equivalent	1.00	Nannie Animal Unit Equivalent	0.17
Bull Animal Unit Equivalent	1.25	Billy Animal Unit Equivalent	0.21
Number of Cows per Bull	25.00	Number of Nannies per Billy	33.00
Birthing Rate	90%	Birthing Rate	80%
Calf Weaning Weight (pounds)	525	Price per Kid	\$50.00
Calf Price per Pound	\$0.77	Nannie Salvage Price	\$20.00
Cow Salvage Price	\$400.00	Variable Cost per Nannie/Kid	\$21.42
Variable Cost per Cow/Calf	\$130.09	Nannie Purchase Price	\$60.00
Cow Purchase Price	\$700.00		
Bull Purchase Price	\$1,500.00	Billy Purchase Price	\$250.00
Bull Salvage Value	\$625.00	Billy Salvage Value	\$50.00
Death Loss	2.50%	Death Loss	2.50%
Cow Useful Life (years)	9	Nanny Useful Life (years)	6
Bull Useful Life (years)	6	Billy Useful Life (years)	4
Sheep Enterprise		Wildlife Enterprise	
Ewe Animal Unit Equivalent	0.20	Increase in Per Acre Revenue From Controlling Heavy Brush.	\$0.50
Ram Animal Unit Equivalent	0.25		
Number of Ewes per Ram	33.00	Increase in Per Acre Revenue From Controlling Moderate Brush.	\$0.00
Birthing Rate	75%		
Wool produced per Ewe or Ram (lbs)	8.00		
Lamb Weaning Weight (pounds)	70		
Lamb Price per Pound	\$0.85		
Ewe Salvage Price	\$20.00		
Variable Cost per Ewe/Lamb	\$27.72		
Ewe Purchase Price	\$70.00		
Wool Price Per Pound	\$1.00		
Ram Purchase Price	\$250.00		
Ram Salvage Value	\$50.00		
Death Loss	2.50%		
Ewe Useful Life (years)	6		
Billy Useful Life (years)	4		

Table 2.3b. Economic Evaluation Variables—Western Edwards.

Livestock Composition		Discount Rate	
Cattle Percentage	20%	Discount Rate	6%
Meat Goat Percentage	50%	Ranch Size (Acres)	
Sheep Percentage	30%	Ranch Size (Acres)	1000
Cattle Enterprise		Meat Goat Enterprise	
Cow Animal Unit Equivalent	1.00	Nanny Animal Unit Equivalent	0.17
Bull Animal Unit Equivalent	1.25	Billy Animal Unit Equivalent	0.21
Number of Cows per Bull	25.00	Number of Nannys per Billy	33.00
Birthing Rate	90%	Birthing Rate	135%
Calf Weaning Weight (lbs)	450	Nanny Weaning Weight (lbs)	50
Calf Price Per Pound	\$0.95	Nanny Price Per Pound	\$0.85
Cow Salvage Price	\$400.00	Nanny Salvage Price	\$20.00
Variable Cost per Cow/Calf	\$133.69	Variable Cost per Nanny/Kid	\$22.21
Cow Purchase Price	\$700.00	Nanny Purchase Price	\$70.00
Bull Purchase Price	\$1,500.00	Billy Purchase Price	\$250.00
Bull Salvage Value	\$625.00	Billy Salvage Value	\$40.00
Death Loss	2.50%	Death Loss	2.50%
Cow Useful Life (years)	9	Nanny Useful Life (years)	6
Bull Useful Life (years)	6	Billy Useful Life (years)	4
Sheep Enterprise		Wildlife Enterprise	
Ewe Animal Unit Equivalent	0.20	Increase in Per Acre Revenue From Controlling Heavy Brush.	\$1.75
Ram Animal Unit Equivalent	0.25	Increase in Per Acre Revenue From Controlling Moderate Brush.	\$0.00
Number of Ewes per Ram	33.00		
Birthing Rate	65%		
Wool produced per Ewe or Ram (lbs)	8.00		
Lamb Weaning Weight (pounds)	65		
Lamb Price per Pound	\$0.85		
Ewe Salvage Price	\$20.00		
Variable Cost per Ewe/Lamb	\$26.74		
Ewe Purchase Price	\$70.00		
Wool Price Per Pound	\$1.00		
Ram Purchase Price	\$250.00		
Ram Salvage Value	\$40.00		
Death Loss	2.50%		
Ewe Useful Life (years)	6		
Billy Useful Life (years)	4		

Table 2.3c. Economic Evaluation Variables—Eastern Edwards.

Livestock Composition		Discount Rate	
Cattle Percentage	80%		6%
Meat Goat Percentage	20%	Ranch Size (Acres)	
Sheep Percentage	0%		1000
Cattle Enterprise		Meat Goat Enterprise	
Cow Animal Unit Equivalent	1.00	Nanny Animal Unit Equivalent	0.17
Bull Animal Unit Equivalent	1.25	Billy Animal Unit Equivalent	0.21
Number of Cows per Bull	25.00	Number of Nannys per Billy	33.00
Birthing Rate	90%	Birthing Rate	115%
Calf Weaning Weight (lbs)	450	Nanny Weaning Weight (lbs)	50
Calf Price Per Pound	\$0.95	Nanny Price Per Pound	\$0.85
Cow Salvage Price	\$400.00	Nanny Salvage Price	\$20.00
Variable Cost per Cow/Calf	\$127.09	Variable Cost per Nanny/Kid	\$21.94
Cow Purchase Price	\$700.00	Nanny Purchase Price	\$70.00
Bull Purchase Price	\$1,500.00	Billy Purchase Price	\$250.00
Bull Salvage Value	\$625.00	Billy Salvage Value	\$40.00
Death Loss	2.50%	Death Loss	2.50%
Cow Useful Life (years)	9	Nanny Useful Life (years)	6
Bull Useful Life (years)	6	Billy Useful Life (years)	4
Sheep Enterprise		Wildlife Enterprise	
Ewe Animal Unit Equivalent	0.20	Increase in Per Acre Revenue From Controlling Heavy Brush.	\$1.75
Ram Animal Unit Equivalent	0.25	Increase in Per Acre Revenue From Controlling Moderate Brush.	\$0.00
Number of Ewes per Ram	33.00		
Birthing Rate	65%		
Wool produced per Ewe or Ram (lbs)	8.00		
Lamb Weaning Weight (pounds)	65		
Lamb Price per Pound	\$0.85		
Ewe Salvage Price	\$20.00		
Variable Cost per Ewe/Lamb	\$26.74		
Ewe Purchase Price	\$70.00		
Wool Price Per Pound	\$1.00		
Ram Purchase Price	\$250.00		
Ram Salvage Value	\$40.00		
Death Loss	2.50%		
Ewe Useful Life (years)	6		
Billy Useful Life (years)	4		

Scenario Analysis

Using Landsat photography data, the Blackland Research Center provided data on brush types and density. Brush was divided into four brush types (cedar, mesquite, mixed brush, oak) and three density categories (light, moderate, heavy). The Blackland Research Center also quantified the amount of treated acres for each scenario. Treated brush type-density categories included heavy cedar, moderate cedar, heavy mesquite, moderate mesquite, heavy mixed brush, and moderate mixed brush. Under all three brush management scenarios, cedar and mesquite brush type density categories were treated with initial and follow-up treatments to reduce canopy cover to 3 to 8 percent and maintain it at that level for 10 years. For mixed brush, post-treatment canopy cover would vary from 10% to 33%. Oak was not treated in our analyses due to its wildlife value and landowner concerns about effects on property values. All categories of light brush were not treated in any scenario. An important difference between brush management under the three scenarios and the one assumed for the TAES study (2000) is that, in this study, no brush occurring on land slopes greater than 15% was treated because mechanical control in these areas would be dangerous to equipment operators, and soil erosion losses would increase. In addition, restoration treatments such as rangeland reseeding, grazing deferrals, and implementation of improved grazing management systems through additional cross fencing and water sources was used in addition to initial and follow-up brush removal practices.

Under Scenario I, the least restrictive scenario, all acres of brush classified in one of the six targeted brush-type density categories was treated. However, brush in these categories occurring on slopes greater than 15 percent was not controlled. The difference between the amount of brush controlled under this scenario and the brush management occurring under the TAES study (2000) was due to this slope constraint. For the Twin Buttes and Edwards, the amounts of moderate and heavy brush occurring on slopes greater than 15 percent were not controlled.

Scenario II is identical to Scenario I except that all brush occurring within 75 meters of a mapped stream course was not targeted for treatment. Because of the importance of riparian areas to wildlife, this scenario is designated as more wildlife-friendly than Scenario I.

Brush management Scenario III has the same slope constraint as Scenarios I and II as well as the same 150 meter riparian buffer as Scenario II. In contrast to these two, Scenario III requires that residual brush levels following brush removal be 40 percent of the total land area for each subbasin within the five Edwards and three Twin Buttes watersheds. In subbasins where the amount of brush controlled must be reduced from Scenario II, each of the six targeted brush type-densities is reduced by an equal percentage to arrive at the 40 percent residual brush cover threshold. This scenario is considered the most wildlife-friendly of the three due to the protection of riparian area vegetation and the requirement that residual levels of brush for all subbasins be 40 percent of total land cover.

Scenario IV is the base for comparison. The assumption is that the watershed will essentially remain unchanged over time. A last scenario not included in the range/economics analysis is one in which continued increasing infestation of brush is assumed over time (Scenario V).

While the amount and cost of brush controlled differs for each scenario, the methodology used to calculate total society costs and society costs of additional water yield for each scenario are identical.

Results and Discussion

Society and Landowner Cost Shares

Twin Buttes

Present values of the total cost of brush control and ecological restoration treatments for the six brush type-density categories range from \$143.42 per acre for mechanical control of heavy mesquite to \$59.31 per acre for chemical control of moderate mesquite (Table 2.4). The highest rancher share expressed as a percentage of the total treatment cost was 25.63 percent for chemical control of heavy mesquite while the

lowest was 8.15 percent for moderate mixed brush. The highest society share, also expressed as a percentage of total treatment cost, was 91.85 percent for mechanical control of moderate mixed brush. The lowest society share was 74.37 percent for chemical control of heavy mesquite.

Western Edwards

As mentioned previously, geographic differences between the Eastern and Western portions of the Edwards Aquifer recharge zone necessitated the use of separate carrying capacity, brush treatments and costs, and livestock enterprise assumptions. These different assumptions yielded different landowner/society cost shares for each region.

For the Western Edwards, present values of the total cost of brush management/restoration treatments range from \$270.32 per acre for rootplowing with pre-doze treatments of heavy mesquite to \$91.99 for chemical treatments of heavy and moderate mesquite (Table 2.5). The highest and lowest rancher shares expressed as a percentage of total treatment costs were 30.30 and 8.83 percent for chemical control of heavy mesquite and mechanical control of moderate mesquite, respectively. For society cost share, the highest percentage, 91.17 percent, was for mechanical control of moderate mesquite, and the lowest percent, 69.7 percent, was found for chemical control of heavy mesquite.

Eastern Edwards

The most expensive brush type-density to treat was rootplowing with pre-dozing of heavy mesquite at \$274.85 per acre; the least expensive was chemical control of moderate and heavy mesquite at \$91.99 (Table 2.6). The highest and lowest rancher shares were 36.88 and 7.88 percent for chemical control of heavy mesquite and mechanical control of moderate cedar, respectively. Society shares ranged from 92.12 percent for mechanical control of moderate cedar and 63.12 percent for chemical control of heavy mesquite.

Table 2.4. Twin Buttes Landowner/Society Cost Shares of Brush Control (60% Cattle—10% Meat Goat—30% Sheep).

Brush Type / Category	Control Practice	PV of Total Cost (\$/Acre)	Rancher Share (\$/Acre)	Rancher Percent	Society Share (\$/Acre)	Society Percent
Heavy Cedar	Doze or Shear	142.21	14.44	10.15%	127.77	89.85%
	Chemical	51.78	13.27	25.63%	38.51	74.37%
Heavy Mesquite	Mechanical Choice	143.42	15.00	10.46%	128.42	89.54%
	Mechanical Choice	127.78	14.30	11.19%	113.48	88.81%
Heavy Mixed Brush	Mechanical Choice	97.71	8.87	9.08%	88.84	90.92%
Moderate Cedar	Chemical	59.31	6.28	10.59%	53.03	89.41%
	Mechanical Choice	106.43	8.89	8.35%	97.54	91.65%
Moderate Mesquite	Mechanical Choice	98.28	8.01	8.15%	90.27	91.85%

Table 2.5. Western Edwards Landowner / Society Cost Shares of Brush Control (20% Cattle—50% Meat Goat—30% Sheep).

Brush Type / Category	Control Practice	PV of Total Cost (\$/Acre)	Rancher Share (\$/Acre)	Rancher Percent	Society Share (\$/Acre)	Society Percent
Heavy Cedar	Two Way Chain	178.99	26.66	14.89%	152.33	85.11%
	Tree Doze	233.99	26.66	11.39%	207.33	88.61%
	Tree Shear or Flat Cutting	218.99	26.66	12.17%	192.33	87.83%
Heavy Mesquite	Chemical	91.99	27.87	30.30%	64.12	69.70%
	Rootplow	245.32	30.79	12.55%	214.53	87.45%
	Rootplow with Pre-doze	270.32	30.79	11.39%	239.53	88.61%
Heavy Mixed Brush	Tree Doze	234.49	28.88	12.32%	205.61	87.68%
Moderate Cedar	Tree Doze	169.49	15.23	8.99%	154.26	91.01%
	Tree Shear or Flat Cutting	149.49	15.23	10.19%	134.26	89.81%
Moderate Mesquite	Chemical	91.99	9.01	9.79%	82.98	90.21%
	Mechanical Choice	135.99	12.01	8.83%	123.98	91.17%
Moderate Mixed Brush	Mechanical Choice	134.85	12.20	9.05%	122.65	90.95%

Table 2.6. Eastern Edwards Landowner / Society Cost Shares of Brush Control (80% Cow/Calf—20% Meat Goat).

Brush Type / Category	Control Practice	PV of Total Cost (\$/Acre)	Rancher Share (\$/Acre)	Rancher Percent	Society Share (\$/Acre)	Society Percent
Heavy Cedar	Doze or Shear	253.66	31.89	12.57%	221.77	87.43%
Heavy Mesquite	Chemical	91.99	33.93	36.88%	58.06	63.12%
	Rootplow	249.85	38.37	15.36%	211.48	84.64%
	Rootplow with Pre-doze	274.85	38.37	13.96%	236.48	86.04%
Heavy Mixed Brush	Rootplow	234.21	33.97	14.50%	200.24	85.50%
	Rootplow with Pre-doze	259.21	33.97	13.11%	225.24	86.89%
Moderate Cedar	Doze or Shear	174.21	13.72	7.88%	160.49	92.12%
Moderate Mesquite	Chemical	91.99	10.43	11.34%	81.56	88.66%
	Mechanical Choice	135.99	13.64	10.03%	122.35	89.97%
Moderate Mixed Brush	Mechanical Choice	134.85	14.25	10.57%	120.60	89.43%

Society Cost of Added Water

Twin Buttes

Middle Concho. Total society costs for implementing Scenarios I, II, and III were \$45.1M, \$42.9M, and \$16.0M, respectively (Tables 2.7a, 2.7b and 2.7c). Scenario I is 181 percent more costly than Scenario III—the largest percentage increase between Scenarios I and III for the watersheds within the Twin Buttes. Society’s costs per acre-foot of additional water yielded were \$158—Scenario I, \$159—Scenario II, and \$135—Scenario III.

South Concho. Total society costs for Scenarios I, II, and III (Tables 2.8a, 2.8band 2.8c), were \$15.1M, \$14.3M, and \$5.9M, respectively. Society cost per acre-foot of additional water yielded was \$63 for all scenarios.

Spring-Dove Creek. For Scenarios I, II, and III, total society costs were \$24.7M, \$23.4M and \$9.8M respectively (Tables 2.9a, 2.9b and 2.9c). Society costs per acre-foot of additional water were \$83 for Scenarios I and II and \$82 for Scenario III.

In summary, total society costs differed very slightly between Scenarios I and II in all watersheds (Fig. 2.1). In contrast, total society costs between Scenarios I/II and Scenario III are quite large, indicating substantially more brush is being treated in the first two brush management/restoration plans. Society costs per acre-foot of added water are relatively constant between different scenarios in individual watersheds. However, these costs range from \$159 for Scenario II in the Middle Concho to \$63 for all scenarios in the South Concho (Figure 2.2). As one might expect, great variation exists in the per acre cost of added water between sub-basins within watersheds. From an economic efficiency perspective, brush management and restoration is most attractive in the South Concho watershed.

Edwards

Frio. For the three scenarios, society costs of implementing brush management and restoration practices were \$12.6M, \$10.0M, and \$9.4M (Tables 2.10a, 2.10b and 2.10c). Society’s costs per acre-foot of additional water yielded are \$51 for Scenarios I and II and \$49 for Scenario III.

Hondo. Total society costs in the watershed for Scenario I were \$3.9M, \$3.3M for Scenario II, and \$3.3M for Scenario III (Tables 2.11a, 2.11b and 2.11c). Cost per acre-foot of additional water yielded were \$32 for Scenarios I and II, and \$33 for Scenario III.

Medina. Total society costs for implementing the three different brush management/restoration scenarios were \$27.2M, \$23.1M, and \$22.1M (Tables 2.12a, 2.12b and 2.12c). Society cost per acre-foot of additional water were \$35 for Scenario I and \$36 for Scenarios II and III.

Sabinal. For Scenarios I, II, and III, total society costs are \$7.2M, \$6.0M, and \$5.7M (Tables 2.13a, 2.13b and 2.13c). . Per acre-foot cost of additional water for society were \$45 for Scenarios I and III and \$46 for Scenario II.

Seco. Total society Costs for the three scenarios were \$1.6M, \$1.4M, and \$1.4M for the three scenarios (Tables 2.14a, 2.14b and 2.14c). Society cost per acre-foot of additional water were an identical \$46 for all scenarios.

Table 2.7a. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot).

Middle Concho—Scenario 1					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	0	0	0	0	-
2	388,750	91,371,364	280	2,187	178
3	0	0	0	0	-
4	0	0	0	0	-
5	367,473	81,755,341	251	1,957	188
6	0	0	0	0	-
7	1,455,667	223,419,230	686	5,348	272
8	131,176	32,402,626	99	776	169
9	1,470,107	299,250,690	918	7,164	205
10	56,914	11,913,576	37	285	200
11	0	0	0	0	-
12	1,693,792	301,341,356	925	7,214	235
13	1,512,840	370,477,910	1,137	8,869	171
14	755,414	198,688,706	610	4,756	159
15	497,907	123,721,212	380	2,962	168
16	3,660,528	842,880,196	2,586	20,178	181
17	2,038,873	570,178,502	1,750	13,649	149
18	2,897,486	726,704,216	2,230	17,397	167
19	750,152	193,778,098	595	4,639	162
20	91,467	23,945,607	73	573	160
21	2,523,777	594,765,659	1,825	14,238	177
22	1,648,321	475,090,810	1,458	11,373	145
23	5,072,115	1,722,451,068	5,285	41,234	123
24	3,007,399	946,281,140	2,904	22,653	133
25	3,427,003	1,051,778,398	3,227	25,178	136
26	4,218,490	1,158,992,704	3,556	27,745	152
27	5,052,259	1,336,623,831	4,101	31,997	158
28	2,346,399	534,052,403	1,639	12,785	184
Total	45,064,307			285,157	158

Table 2.7b. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot).

Middle Concho—Scenario 2					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	0	0	0	0	-
2	378,738	88,557,647	272	2,120	179
3	0	0	0	0	-
4	0	0	0	0	-
5	340,691	75,140,439	231	1,799	189
6	0	0	0	0	-
7	1,372,545	209,399,223	643	5,013	274
8	114,635	29,308,982	90	702	163
9	1,401,529	279,524,263	858	6,692	209
10	52,661	11,999,008	37	287	183
11	0	0	0	0	-
12	1,637,637	282,373,163	866	6,760	242
13	1,405,618	339,474,264	1,042	8,127	173
14	691,542	180,372,534	553	4,318	160
15	472,336	117,245,591	360	2,807	168
16	3,472,977	805,759,130	2,472	19,289	180
17	1,953,768	547,573,838	1,680	13,108	149
18	2,753,592	683,536,070	2,097	16,363	168
19	700,335	180,676,019	554	4,325	162
20	88,086	22,984,786	71	550	160
21	2,434,984	570,809,580	1,751	13,665	178
22	1,591,476	461,625,349	1,416	11,051	144
23	4,850,224	1,665,624,936	5,111	39,873	122
24	2,861,372	892,989,955	2,740	21,377	134
25	3,232,261	988,256,018	3,032	23,658	137
26	4,044,096	1,103,388,621	3,386	26,414	153
27	4,806,438	1,266,327,999	3,886	30,315	159
28	2,237,796	501,190,114	1,538	11,998	187
Total	42,895,336			270,609	159

Table 2.7c. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot).

Middle Concho—Scenario 3					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	0	0	0	0	-
2	145,304	35,112,688	108	841	173
3	0	0	0	0	-
4	0	0	0	0	-
5	0	0	0	0	-
6	0	0	0	0	-
7	0	0	0	0	-
8	0	0	0	0	-
9	0	0	0	0	-
10	0	0	0	0	-
11	0	0	0	0	-
12	445,200	87,000,778	267	2,083	214
13	781,230	212,954,335	653	5,098	153
14	335,092	97,457,549	299	2,333	144
15	15,147	5,159,438	16	124	123
16	0	0	0	0	-
17	870,534	264,918,935	813	6,342	137
18	1,130,424	317,758,785	975	7,607	149
19	290,752	80,669,006	248	1,931	151
20	40,703	10,887,432	33	261	156
21	664,657	166,083,987	510	3,976	167
22	626,381	190,582,942	585	4,562	137
23	2,314,092	881,715,726	2,705	21,107	110
24	1,620,719	559,393,687	1,716	13,391	121
25	1,659,320	542,779,712	1,665	12,994	128
26	1,958,594	616,657,109	1,892	14,762	133
27	2,453,103	709,979,540	2,179	16,996	144
28	681,865	168,760,988	518	4,040	169
Total	16,033,118			118,447	135

Table 2.8a. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot).

South Concho—Scenario 1					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	783,601	639,082,182	1,961	15,299	51
2	332,005	263,924,552	810	6,318	53
3	991,965	780,796,011	2,396	18,691	53
4	737,987	501,821,432	1,540	12,013	61
5	686,979	471,468,078	1,447	11,286	61
6	122,874	63,513,968	195	1,520	81
7	547,864	398,048,022	1,221	9,529	57
8	482,185	348,997,154	1,071	8,355	58
9	551,439	325,741,603	1,000	7,798	71
10	692,716	389,732,444	1,196	9,330	74
11	2,082,796	1,620,683,900	4,973	38,797	54
12	751,582	492,924,195	1,513	11,800	64
13	2,289,124	1,238,790,172	3,801	29,655	77
14	56,342	40,064,266	123	959	59
15	1,225,486	801,860,118	2,460	19,196	64
16	1,354,411	845,734,663	2,595	20,246	67
17	1,100,096	659,718,577	2,024	15,793	70
18	299,160	77,450,465	238	1,854	161
Total	15,088,612			238,440	63

Table 2.8b. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot).

South Concho—Scenario 2					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	724,718	598,961,040	1,838	14,338	51
2	318,924	254,471,687	781	6,092	52
3	960,066	763,866,554	2,344	18,286	53
4	707,321	486,914,198	1,494	11,656	61
5	632,366	441,565,269	1,355	10,571	60
6	121,227	62,703,385	192	1,501	81
7	506,201	372,899,956	1,144	8,927	57
8	461,155	336,871,727	1,034	8,064	57
9	524,237	310,829,681	954	7,441	70
10	641,199	365,822,898	1,123	8,757	73
11	2,002,511	1,574,829,042	4,832	37,700	53
12	721,900	477,061,384	1,464	11,420	63
13	2,170,864	1,184,195,959	3,634	28,348	77
14	48,699	35,550,868	109	851	57
15	1,173,335	775,219,423	2,379	18,558	63
16	1,277,918	813,793,215	2,497	19,481	66
17	1,051,542	635,716,079	1,951	15,218	69
18	286,688	68,625,815	211	1,643	175
Total	14,330,871			228,854	63

Table 2.8c. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot).

South Concho—Scenario 3					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	0	0	0	0	#DIV/0!
2	0	0	0	0	#DIV/0!
3	247,476	197,292,290	605	4,723	52
4	252,297	177,572,447	545	4,251	59
5	235,069	169,202,732	519	4,051	58
6	59,208	31,234,879	96	748	79
7	33,742	22,714,382	70	544	62
8	105,097	78,350,790	240	1,876	56
9	256,031	154,412,946	474	3,696	69
10	346,393	201,054,441	617	4,813	72
11	933,418	764,926,085	2,347	18,312	51
12	352,287	239,242,397	734	5,727	62
13	1,088,645	617,334,557	1,894	14,778	74
14	33,350	24,651,101	76	590	57
15	640,185	435,341,897	1,336	10,422	61
16	691,796	451,228,529	1,385	10,802	64
17	531,105	333,778,659	1,024	7,990	66
18	107,888	26,101,404	80	625	173
Total	5,913,987			93,947	63

Table 2.9a. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot).

Spring/Dove Creeks—Scenario 1					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	2,832,021	1,139,275,790	3,496	27,273	104
2	1,759,978	1,177,504,360	3,613	28,188	62
3	2,366,236	1,627,881,605	4,995	38,970	61
4	765,254	608,994,620	1,869	14,579	52
5	16,504	10,289,249	32	246	67
6	925,991	486,517,053	1,493	11,647	80
7	1,143,199	569,392,446	1,747	13,631	84
8	450,397	209,210,688	642	5,008	90
9	936,215	388,611,003	1,192	9,303	101
10	959,787	401,731,255	1,233	9,617	100
11	1,518,470	767,222,827	2,354	18,366	83
12	1,703,706	929,601,019	2,852	22,254	77
13	833,600	538,965,486	1,654	12,902	65
14	1,266,090	676,787,667	2,077	16,202	78
15	1,200,346	512,761,426	1,573	12,275	98
16	1,178,762	453,366,900	1,391	10,853	109
17	926,790	365,215,282	1,121	8,743	106
18	784,547	303,884,575	932	7,275	108
19	137,822	50,554,173	155	1,210	114
20	1,336,029	519,001,715	1,593	12,424	108
21	1,012,154	501,000,017	1,537	11,993	84
22	122,398	38,216,962	117	915	134
23	520,376	193,445,641	594	4,631	112
Total	24,696,670			298,505	83

Table 2.9b. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot).

Spring/Dove Creeks—Scenario 2					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	2,652,849	1,078,093,029	3,308	25,808	103
2	1,679,866	1,137,098,018	3,489	27,221	62
3	2,255,889	1,566,354,514	4,806	37,497	60
4	719,795	577,955,724	1,773	13,836	52
5	14,340	8,684,638	27	208	69
6	901,070	474,048,833	1,455	11,348	79
7	1,089,991	543,269,391	1,667	13,005	84
8	411,844	188,783,873	579	4,519	91
9	872,680	360,996,295	1,108	8,642	101
10	921,745	383,918,859	1,178	9,191	100
11	1,437,831	727,117,530	2,231	17,406	83
12	1,622,793	882,521,827	2,708	21,127	77
13	779,427	511,075,905	1,568	12,235	64
14	1,224,521	654,644,816	2,009	15,671	78
15	1,184,362	505,756,903	1,552	12,107	98
16	1,125,918	431,938,574	1,325	10,340	109
17	882,753	348,417,670	1,069	8,341	106
18	757,700	293,841,069	902	7,034	108
19	130,937	46,950,211	144	1,124	116
20	1,259,003	485,104,253	1,489	11,613	108
21	951,304	474,493,958	1,456	11,359	84
22	115,973	34,738,471	107	832	139
23	483,637	169,700,752	521	4,062	119
Total	23,476,228			284,526	83

Table 2.9c. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot).

Spring/Dove Creeks—Scenario 3					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	908,131	378,572,171	1,162	9,063	100
2	322,910	224,005,495	687	5,362	60
3	232,577	159,194,543	488	3,811	61
4	415,240	339,236,444	1,041	8,121	51
5	6,758	4,162,712	13	100	68
6	477,340	258,897,236	794	6,198	77
7	538,543	278,395,515	854	6,664	81
8	156,048	74,235,764	228	1,777	88
9	257,314	112,503,630	345	2,693	96
10	430,477	188,698,649	579	4,517	95
11	761,244	399,586,648	1,226	9,566	80
12	964,621	542,662,251	1,665	12,991	74
13	462,245	310,901,541	954	7,443	62
14	593,896	329,743,594	1,012	7,894	75
15	556,505	252,856,766	776	6,053	92
16	653,522	266,990,297	819	6,391	102
17	530,515	221,471,332	680	5,302	100
18	377,918	153,107,384	470	3,665	103
19	63,789	23,132,172	71	554	115
20	471,240	190,155,158	583	4,552	104
21	408,812	210,386,011	646	5,036	81
22	0	21,107	0	1	0
23	196,976	69,981,336	215	1,675	118
Total	9,786,621			119,429	82

Table 2.10a. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot).

Frio—Scenario 1					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	1,439,481	1,124,918,882	3,452	26,929	53
2	922,060	756,154,712	2,320	18,102	51
3	546,776	429,544,080	1,318	10,283	53
4	645,042	501,789,672	1,540	12,012	54
5	299,355	263,627,913	809	6,311	47
6	240,464	194,723,517	597	4,661	52
7	304,771	282,057,145	865	6,752	45
8	602,519	523,017,756	1,605	12,520	48
9	544,506	422,817,099	1,297	10,122	54
10	774,341	652,055,947	2,001	15,610	50
11	103,004	82,596,566	253	1,977	52
12	311,401	236,023,641	724	5,650	55
13	613,273	560,528,784	1,720	13,418	46
14	358,051	375,113,803	1,151	8,980	40
15	206,303	171,270,477	526	4,100	50
16	180,516	181,630,576	557	4,348	42
17	587,653	668,383,291	2,051	16,000	37
18	559,093	512,411,750	1,572	12,267	46
19	197,479	196,417,566	603	4,702	42
20	130,545	141,755,303	435	3,393	38
21	262,135	251,464,137	772	6,020	44
22	494,083	311,159,198	955	7,449	66
23	401,508	295,053,022	905	7,063	57
24	473,997	313,875,942	963	7,514	63
25	801,995	564,173,364	1,731	13,506	59
26	598,363	397,332,104	1,219	9,512	63
Total	12,598,715			249,202	51

Table 2.10b. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot).

Frio—Scenario 2					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	1,280,400	993,747,761	3,049	23,789	54
2	787,310	642,336,279	1,971	15,377	51
3	382,564	295,626,757	907	7,077	54
4	483,495	372,311,349	1,142	8,913	54
5	231,115	198,671,857	610	4,756	49
6	173,174	137,175,094	421	3,284	53
7	245,692	225,041,564	691	5,387	46
8	553,975	475,642,141	1,459	11,386	49
9	492,706	374,891,345	1,150	8,974	55
10	569,916	478,079,745	1,467	11,445	50
11	66,652	53,132,441	163	1,272	52
12	214,907	155,872,124	478	3,731	58
13	404,839	371,757,207	1,141	8,899	45
14	320,684	333,347,074	1,023	7,980	40
15	129,751	104,789,824	322	2,509	52
16	143,065	144,550,541	444	3,460	41
17	525,051	593,470,085	1,821	14,207	37
18	432,313	383,484,533	1,177	9,180	47
19	149,649	145,121,723	445	3,474	43
20	102,515	113,910,096	350	2,727	38
21	196,797	182,696,422	561	4,374	45
22	398,456	248,227,007	762	5,942	67
23	270,962	189,677,616	582	4,541	60
24	362,461	237,166,355	728	5,678	64
25	631,465	439,292,694	1,348	10,516	60
26	476,830	312,342,334	958	7,477	64
Total	10,026,745			196,356	51

Table 2.10c. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot).

Frio—Scenario 3					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	1,381,342	835,249,117	2,563	19,995	69
2	961,279	583,116,558	1,789	13,959	69
3	548,013	305,134,261	936	7,305	75
4	634,569	383,437,149	1,177	9,179	69
5	291,960	205,453,452	630	4,918	59
6	226,632	141,324,820	434	3,383	67
7	313,466	232,775,761	714	5,572	56
8	535,396	363,206,296	1,114	8,695	62
9	511,132	283,507,274	870	6,787	75
10	811,805	491,409,053	1,508	11,764	69
11	90,211	54,917,624	169	1,315	69
12	287,012	160,042,828	491	3,831	75
13	588,611	384,256,591	1,179	9,199	64
14	393,497	344,788,729	1,058	8,254	48
15	176,951	108,151,588	332	2,589	68
16	209,138	149,408,964	458	3,577	58
17	632,463	611,904,665	1,878	14,648	43
18	578,795	395,765,572	1,214	9,474	61
19	190,286	149,751,843	460	3,585	53
20	144,242	117,495,332	361	2,813	51
21	270,897	188,982,573	580	4,524	60
22	513,321	259,157,763	795	6,204	83
23	376,682	196,276,006	602	4,699	80
24	474,934	246,448,445	756	5,900	81
25	807,032	454,822,313	1,396	10,888	74
26	613,309	324,890,070	997	7,778	79
Total	12,562,974			190,833	66

Table 2.11a. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot).

Hondo—Scenario 1					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	291,473	370,006,778	1,135	8,858	33
2	165,148	172,794,881	530	4,137	40
3	333,236	480,414,993	1,474	11,501	29
4	384,933	554,277,913	1,701	13,269	29
5	302,726	356,580,660	1,094	8,536	35
6	137,917	248,835,338	764	5,957	23
7	788,763	1,129,570,631	3,466	27,041	29
8	431,129	520,435,227	1,597	12,459	35
9	644,373	814,949,703	2,501	19,509	33
10	457,234	535,762,158	1,644	12,826	36
Total	3,936,934			124,090	32

Table 2.11b. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot).

Hondo—Scenario 2					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	240,813	299,697,220	920	7,174	34
2	121,929	129,337,919	397	3,096	39
3	291,292	415,609,256	1,275	9,949	29
4	316,184	428,786,401	1,316	10,265	31
5	222,617	257,661,586	791	6,168	36
6	127,485	233,445,728	716	5,588	23
7	703,643	970,987,965	2,979	23,244	30
8	367,734	440,726,057	1,352	10,551	35
9	589,500	738,988,447	2,268	17,691	33
10	383,459	427,637,116	1,312	10,237	37
Total	3,364,655			103,964	32

Table 2.11c. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot).

Hondo—Scenario 3					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	240,813	299,697,220	920	7,174	34
2	121,929	129,337,919	397	3,096	39
3	291,292	415,609,256	1,275	9,949	29
4	316,184	428,786,401	1,316	10,265	31
5	222,617	257,661,586	791	6,168	36
6	60,957	111,947,278	344	2,680	23
7	703,643	970,987,965	2,979	23,244	30
8	367,734	440,726,057	1,352	10,551	35
9	589,500	738,988,447	2,268	17,691	33
10	383,459	427,637,116	1,312	10,237	37
Total	3,298,127			101,055	33

Table 2.12a. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot).

Medina—Scenario 1					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	1,517,604	1,240,285,929	3,806	29,691	51
2	959,234	856,727,922	2,629	20,509	47
3	1,786,039	1,601,630,177	4,914	38,341	47
4	797,254	702,259,299	2,155	16,811	47
5	503,826	713,854,314	2,190	17,089	29
6	1,740,368	1,970,601,190	6,047	47,174	37
7	712,072	978,515,879	3,003	23,425	30
8	959,182	1,368,142,016	4,198	32,752	29
9	826,299	1,107,042,464	3,397	26,501	31
10	544,324	772,960,958	2,372	18,504	29
11	519,426	755,710,343	2,319	18,091	29
12	803,705	1,014,423,964	3,113	24,284	33
13	1,372,481	1,691,342,357	5,190	40,489	34
14	1,140,600	1,720,670,286	5,280	41,191	28
15	237,890	365,130,693	1,120	8,741	27
16	1,033,233	1,391,676,356	4,270	33,315	31
17	736,960	859,434,157	2,637	20,574	36
18	694,607	809,780,049	2,485	19,385	36
19	428,412	518,455,666	1,591	12,411	35
20	3,057,210	3,815,469,918	11,707	91,338	33
21	1,074,041	1,244,297,132	3,818	29,787	36
22	757,458	983,554,897	3,018	23,545	32
23	582,367	624,275,031	1,916	14,944	39
24	511,768	661,989,906	2,031	15,847	32
25	793,765	911,397,797	2,797	21,818	36
26	624,963	649,699,033	1,994	15,553	40
27	705,292	952,201,922	2,922	22,795	31
28	942,502	947,357,319	2,907	22,679	42
29	462,572	371,223,723	1,139	8,887	52
30	82,268	95,122,278	292	2,277	36
31	128,312	134,535,398	413	3,221	40
32	165,634	590,477,557	1,812	14,135	12
Total	27,201,668			776,105	35

Table 2.12b. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot).

Medina – Scenario 2					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	1,285,838	1,049,035,495	3,219	25,113	51
2	775,525	688,762,673	2,113	16,488	47
3	1,336,019	1,126,386,688	3,456	26,964	50
4	591,654	500,282,238	1,535	11,976	49
5	440,646	621,706,130	1,908	14,883	30
6	1,284,632	1,396,666,006	4,286	33,435	38
7	598,911	801,913,165	2,461	19,197	31
8	786,365	1,071,079,174	3,287	25,640	31
9	695,101	890,682,429	2,733	21,322	33
10	451,109	634,258,100	1,946	15,183	30
11	452,335	636,863,550	1,954	15,246	30
12	695,920	871,043,791	2,673	20,852	33
13	1,199,517	1,412,119,188	4,333	33,805	35
14	989,766	1,437,272,258	4,410	34,407	29
15	198,824	305,916,628	939	7,323	27
16	895,667	1,193,573,568	3,662	28,573	31
17	650,810	755,469,025	2,318	18,085	36
18	569,449	673,780,472	2,067	16,130	35
19	378,422	453,574,395	1,392	10,858	35
20	2,750,319	3,373,054,349	10,350	80,747	34
21	962,248	1,126,649,341	3,457	26,971	36
22	686,786	885,596,177	2,717	21,200	32
23	497,312	518,803,539	1,592	12,420	40
24	416,552	523,857,310	1,607	12,541	33
25	671,345	749,127,626	2,299	17,933	37
26	519,078	510,632,109	1,567	12,224	42
27	662,246	885,421,339	2,717	21,196	31
28	915,520	924,076,908	2,835	22,121	41
29	425,472	339,976,967	1,043	8,139	52
30	80,403	93,135,712	286	2,230	36
31	107,246	110,880,472	340	2,654	40
32	127,282	443,382,713	1,360	10,614	12
Total	23,098,316			646,470	36

Table 2.12c. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot).

Medina—Scenario 3					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	1,285,838	1,049,035,495	3,219	25,113	51
2	775,525	688,762,673	2,113	16,488	47
3	1,336,019	1,126,386,688	3,456	26,964	50
4	591,654	500,282,238	1,535	11,976	49
5	440,646	621,706,130	1,908	14,883	30
6	1,284,632	1,396,666,006	4,286	33,435	38
7	598,911	801,913,165	2,461	19,197	31
8	786,365	1,071,079,174	3,287	25,640	31
9	695,101	890,682,429	2,733	21,322	33
10	342,663	493,463,124	1,514	11,813	29
11	452,335	636,863,550	1,954	15,246	30
12	615,408	788,683,337	2,420	18,880	33
13	1,199,517	1,412,119,188	4,333	33,805	35
14	908,333	1,346,453,230	4,131	32,233	28
15	103,700	163,375,677	501	3,911	27
16	821,503	1,117,309,667	3,428	26,747	31
17	650,810	755,469,025	2,318	18,085	36
18	569,449	673,780,472	2,067	16,130	35
19	344,645	422,511,727	1,296	10,114	34
20	2,750,319	3,373,054,349	10,350	80,747	34
21	802,496	960,957,978	2,949	23,004	35
22	590,118	778,411,742	2,388	18,634	32
23	473,944	506,332,189	1,554	12,121	39
24	416,552	523,857,310	1,607	12,541	33
25	671,345	749,127,626	2,299	17,933	37
26	519,078	510,632,109	1,567	12,224	42
27	561,807	767,301,360	2,354	18,368	31
28	791,985	815,437,619	2,502	19,521	41
29	425,472	339,976,967	1,043	8,139	52
30	80,403	93,135,712	286	2,230	36
31	107,246	110,880,472	340	2,654	40
32	127,282	443,382,713	1,360	10,614	12
Total	22,121,098			620,713	36

Table 2.13a. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot).

Sabinal – Scenario 1					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	763,855	620,294,101	1,903	14,849	51
2	173,872	164,912,889	506	3,948	44
3	396,934	363,637,102	1,116	8,705	46
4	1,022,319	1,172,952,384	3,599	28,079	36
5	912,591	951,652,492	2,920	22,782	40
6	324,519	427,995,636	1,313	10,246	32
7	118,201	87,195,434	268	2,087	57
8	525,886	633,729,304	1,945	15,171	35
9	1,500,024	1,207,881,481	3,706	28,915	52
10	355,388	356,253,040	1,093	8,528	42
11	879,274	602,376,681	1,848	14,420	61
12	267,152	170,112,994	522	4,072	66
Total	7,240,015			161,803	45

Table 2.13b. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot).

Sabinal—Scenario 2					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	551,325	446,689,576	1,371	10,693	52
2	113,847	105,290,583	323	2,521	45
3	271,001	241,107,277	740	5,772	47
4	858,318	987,179,110	3,029	23,632	36
5	741,316	760,240,821	2,333	18,199	41
6	275,223	356,720,371	1,095	8,539	32
7	110,767	74,440,755	228	1,782	62
8	487,984	573,271,967	1,759	13,724	36
9	1,318,878	1,017,060,451	3,121	24,347	54
10	314,138	304,732,214	935	7,295	43
11	756,534	514,125,566	1,578	12,308	61
12	204,479	127,126,119	390	3,043	67
Total	6,003,809			131,855	46

Table 2.13c. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot).

Sabinal—Scenario 3					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	551,325	458,463,614	1,407	10,975	50
2	113,847	107,450,484	330	2,572	44
3	271,001	248,062,817	761	5,938	46
4	858,318	1,004,584,207	3,082	24,049	36
5	741,316	775,416,609	2,379	18,563	40
6	275,223	364,338,044	1,118	8,722	32
7	89,966	62,341,557	191	1,492	60
8	274,998	331,900,708	1,018	7,945	35
9	1,318,878	1,036,435,284	3,180	24,811	53
10	266,796	266,298,000	817	6,375	42
11	756,534	528,818,380	1,623	12,659	60
12	204,479	130,962,007	402	3,135	65
Total	5,722,680			127,237	45

Table 2.14a. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot).

Seco—Scenario 1					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	160,018	127,971,059	393	3,063	52
2	167,910	162,078,729	497	3,880	43
3	117,498	111,600,732	342	2,672	44
4	72,858	57,819,991	177	1,384	53
5	480,178	348,656,130	1,070	8,346	58
6	112,323	87,730,748	269	2,100	53
7	139,916	80,630,741	247	1,930	72
8	83,813	55,871,648	171	1,338	63
9	142,060	102,521,086	315	2,454	58
10	42,258	28,663,653	88	686	62
11	106,289	76,997,959	236	1,843	58
12	50,388	34,998,135	107	838	60
Total	1,675,509			30,535	55

Table 2.14b. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot).

Seco—Scenario 2					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	128,963	114,843,246	352	2,749	47
2	132,399	128,118,572	393	3,067	43
3	75,004	75,848,332	233	1,816	41
4	59,436	53,339,468	164	1,277	47
5	439,280	391,662,334	1,202	9,376	47
6	88,477	72,408,344	222	1,733	51
7	104,514	89,656,937	275	2,146	49
8	76,685	90,464,468	278	2,166	35
9	103,935	95,427,779	293	2,284	45
10	35,745	37,690,257	116	902	40
11	76,899	57,414,774	176	1,374	56
12	42,681	43,647,482	134	1,045	41
Total	1,364,019			29,936	46

Table 2.14c. Total Society Cost and Cost of Added Water from Brush Control by Sub-Basin (acre-foot).

Seco—Scenario 3					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	128,919	114,843,246	352	2,749	47
2	132,399	128,118,572	393	3,067	43
3	75,004	75,848,332	233	1,816	41
4	59,436	53,339,468	164	1,277	47
5	439,280	391,662,334	1,202	9,376	47
6	88,477	72,408,344	222	1,733	51
7	104,514	89,656,937	275	2,146	49
8	76,685	90,464,468	278	2,166	35
9	103,935	95,427,779	293	2,284	45
10	35,745	37,690,257	116	902	40
11	76,899	57,414,774	176	1,374	56
12	42,681	43,647,482	134	1,045	41
Total	1,363,974			29,936	46

For the Edwards' watersheds as a whole, total society costs for implementing Scenario I in each watershed ranged from 17 percent (Hondo) to 26 percent (Frio) greater than the costs for implementing Scenario II. Total costs between Scenarios II and III were similar in all watersheds because the slope constraint, riparian constraint, and amount of oak in the Edwards come close to satisfying the 40 percent residual cover requirement. The trend of larger differences between Scenario I and II than between Scenario II and III existed for all watersheds within the Edwards. Society costs per acre-foot of additional water varied from \$32 (Hondo, Scenarios I and II) to \$51 (Frio, Scenarios I and II). Like the Twin Buttes, sub-basins within the Edwards' watersheds exhibited great variability in the per acre cost of added water. To achieve the least expensive additional water provided by the three Scenarios, brush management/restoration efforts should be concentrated on the Hondo and Medina watersheds.

Ecological Restoration

Considering the rangeland component, this study focuses on rangeland activities but there are opportunities for improved management of the riparian zone. Appendix A provides insight related to riparian management practices that complement this analysis. In addition to providing increased off-site water yield, brush control coupled with appropriate grazing management can restore rangeland vegetation towards a more historic climax plant community. In Texas, the encroachment of woody species such as honey mesquite (Archer et al., 1994) and juniper, or cedar, (redberry juniper in Twin Buttes region, ashe juniper in the Edwards Aquifer Recharge Zone) in native grassland savannas has become pronounced over the last 50-80 years (Ansley et al., 1995; Smeins et al., 1997). It is thought that brush species in the Twin Buttes region, a former grassland savanna, began to dominate in the late 1800s (Upper Colorado River Authority, 2000). Much of the Edwards Plateau region, in which the Edwards Aquifer Recharge Zone is wholly contained, became dominated by woody plants during the 20th century (Smeins et al., 1997). Causes of the invasion of brush species include suppression of fire, overgrazing by livestock, dissemination of seed by livestock (mesquite), and possibly increases in the levels of atmospheric carbon dioxide (Ansley et al., 1996).

As mentioned previously, a distinct difference between this study and the TAES study (2000), and a very important aspect of this research, is the incorporation of restoration practices in addition to initial and follow-up brush control treatments. These additional restoration practices will enable the rangelands of the Twin Buttes and Edwards to become closer to historic climax plant communities with respect to vegetative composition. Specifically, the types of change one could expect from the chosen brush management/restoration treatments would be the recovery of many climax plant community grasses and forbs, reduced abundance of mesquite and juniper, and resulting improvements in hydrologic functioning and wildlife habitat.

Initial brush control treatments for this project are the same mechanical and chemical treatments used in the TAES study (2000). Mechanical treatments include such practices as tree dozing, rootplowing, rootplowing with pre-doze, tree shearing, tree shearing with stump spray, and individual plant excavation or grubbing. Chemical treatments include herbicide applied aerially or through individual plant treatments.

Where mechanical treatments are used, rangeland reseeding will follow. Though average rainfall differences between the two watersheds do exist, grass species to be planted are fairly similar for each study area. The native mix to be planted includes such climax grass species as sideoats gramma, little bluestem, Indian grass, and switchgrass. In many areas within both watersheds, the abundance of climax grasses has decreased markedly due to over-grazing and the concomitant increase in brush due to causes cited previously,

To improve the chances of successful reseeding, full year grazing deferments will be performed in the first year on seeded rangelands. Not only will the grazing deferments help in the establishment of seeded plants, they will help climax grasses and forbs, which are generally preferred plants by livestock, become more abundant and robust.

In addition to initial brush control treatments and reseedling (where mechanical treatments are used), infrastructure will be built in the first year to enable ranchers to improve their grazing systems. Our model calls for the installation of an additional cross fence and water source to enable ranchers to rotate livestock into more pastures, increasing the efficiency of grazing. In addition to helping vegetative composition improve, the existence of an additional pasture will facilitate the accumulating of fine fuel loads for prescribed burns.

Follow-up treatments, occurring in years 3 and 7, are designed to keep brush canopy levels between 3 and 8 percent for mesquite and juniper brush categories during the 10-year horizon. For mixed brush, post-treatment canopy levels would be between 10 and 33%. Types of follow-up treatments are prescribed burns or individual plant treatments of herbicides.

Twin Buttes

Middle Concho. Total acres restored under Scenarios I, II, and III are 506,529, 481,744, and 179,212, respectively (Figure 2.5).

South Concho. Acres restored under Scenario I were 171,258, 162,854 for Scenario II, and 67,232 for Scenario III (Figure 2.5).

Spring-Dove Creek. For this watershed, 272,611 acres were restored under Scenario I, 258,941 acres were controlled for Scenario II, and 106,981 acres are controlled under Scenario III (Figure 2.5).

To summarize, acres of treated and restored rangelands differ very little between Scenario I and Scenario II in the Twin Buttes' watersheds. Very large differences in restored rangelands existed between Scenario I/II and Scenario III for all three watersheds. In fact, compared with Scenario III, Scenario I treated over 150 percent more acres.

Edwards

Frio. Total acres restored under Scenarios I, II, and III were 74,998, 60,267, and 56,194, respectively (Figure 2.5).

Hondo. Acres restored under Scenario I were 21,294, 18,210 for Scenario II, and 17,786 for Scenario III (Figure 2.5).

Medina. For this watershed, 145,948 acres were restored under Scenario I, 123,908 acres were restored under Scenario II, and 118,560 acres were restored under Scenario III (Figure 2.5).

Sabinal. Restored acreages under Scenarios I, II, and III are 42,323, 35,233, and 33,537, respectively (Figure 2.5).

Seco. Scenario I called for the restoration of 8,734 acres while both Scenarios II and III restored 7,106 acres (Figure 2.5).

In the Edwards study area, the amount of restored rangeland was very similar, if not the same, for Scenarios II and III in all watersheds. The largest differences in the amount of restored land for all five watersheds was between Scenario I and Scenario II.

Comparison Across Watersheds

Because of slope differences and rocky terrain, treatment costs for the six targeted brush type-density categories were higher in the Eastern and Western portions of the Edwards than they were in the Twin Buttes.

With few exceptions, total society costs for the three different brush management/restoration scenarios were higher for the Twin Buttes' watersheds than those for the Edwards (Figure 2.1). This is due to the larger watershed sizes and acres of brush treated. The watersheds of the Twin Buttes showed much larger differences in total society costs between Scenarios I/II and Scenario III than those of the Edwards.

When total society costs for all watersheds within their respective study area were combined, cost differences for the Edwards between the most expensive and least expensive Scenarios, Scenarios I and III, were roughly 26 percent (Figure 2.3). For the entire Twin Buttes, Scenario I is 167 percent more costly than Scenario III (Figure 2.4). When the five Edwards' watersheds are combined and compared with the combined watersheds of the Twin Buttes, implementation of Scenarios I and II are less costly on a total society cost basis for the Edwards while Scenario III is cheaper for the Twin Buttes.

Cost of added water is less expensive for the Edwards than the Twin Buttes for all watersheds and scenarios (Figure 2.2). The most expensive watershed on a cost per acre-foot of added water basis was the Middle Concho. Costs were roughly double those of the next highest watershed. While cost of added water varied between watersheds and study areas, all watersheds displayed a pattern of similar costs of added water between brush management/restoration scenarios.

Compared with the Edwards, cost of added water for the entire Twin Buttes study area were 163 percent higher for Scenario I, 160 percent higher for Scenario II, and 144 percent higher for Scenario III (Figures 2.3 and 2.4). Cost of added water were similar for all scenarios for all of the Edwards' watersheds, while Scenario III had slightly lower cost of added water than Scenarios I and II for the combined Twin Buttes' watersheds.

For the three brush management/restoration scenarios, the amount of restored acres for all of the Twin Buttes' watersheds was higher than the Edwards, with the exception of Scenario III for the South Concho and Spring-Dove Creeks, which treated less brush than Scenarios I, II, and III for the Medina (Figure 2.5). By far, the watershed with the most restored acres under the three brush management/restoration scenarios was the Middle Concho.

Restored acres for the whole Twin Buttes were higher for all scenarios than the combined Edwards' watersheds (Figure 2.6). The percentage increases in restored acres for the Twin Buttes compared with the entire Edwards were 224 percent for Scenario I, 269 percent for Scenario II, and 52 percent for Scenario III.

Conclusions

By integrating data from hydrologic modeling, focus groups, and range scientists, an economic model was used to study the economic feasibility of three different brush management/restoration scenarios in the Edwards and Twin Buttes. Total treatment costs, landowner costs, and society cost of the six targeted brush type-density categories were reported. Overall, treatment costs per treated acre were higher for the Edwards than the Twin Buttes.

Three brush management/restoration scenarios were analyzed. The scenarios differ in the amount and location of residual brush cover. Highest levels of brush are removed under Scenario I followed by Scenario II and then Scenario III.

The Edwards' watersheds showed small differences in the total society cost for each scenario, with Scenarios I and II showing larger differences than Scenarios II and III. Acres of brush removed were close for all scenarios. With one exception, the Hondo, the watersheds within the Edwards showed very similar cost for acre-foot of added water for the three scenarios.

Watersheds of the Twin Buttes had minor cost differences between Scenarios I and II and substantial differences between Scenarios I/II and Scenario III. These differences reflect the different levels of brush removed. For each watershed except for the Middle Concho, society cost for added water was nearly identical for all Scenarios.

Total cost for Scenarios I and II were generally higher for the Twin Buttes' watersheds than for the Edwards'. This trend was caused by the size of the watersheds and corresponding increase in brush removed. When watersheds from each study area are combined, the Twin Buttes has significantly higher costs for Scenarios I and II while being slightly less expensive for Scenario III. If watersheds within their

respective study area are combined, the Edwards experienced much lower cost for added water than the Twin Buttes.

Amounts of restored acres were much higher for the Twin Buttes' watersheds than those of the Edwards in almost all instances. The Twin Buttes' watersheds showed largest differences between Scenarios I/II and Scenario III while the Edwards' watersheds had their largest differences in restored acres between Scenario I and II. When combining all watersheds into their respective study area, restored acres were significantly higher for the Twin Buttes than the Edwards in Scenarios I and II, while the difference for Scenario III was not quite as dramatic.

Additional Considerations.

Success of each brush management/restoration scenario in improving off-site water yield and restoring rangelands depends on the willingness of landowners in the two study areas to participate. One reason why landowners may be reluctant to participate in the three scenarios is the perceived impacts to hunting enterprises, especially deer hunting. These impacts could include loss of wildlife habitat due to fragmentation, loss of thermal and/or escape cover, loss of wildlife diversity, and a potential loss of food sources (Rollins, 2000). Scenario III may be a more satisfactory option for landowners with this concern than Scenarios I and II because of the residual brush requirement. In the Twin Buttes area, however, these same negative impacts on deer habitat may enhance habitat for quail.

Another reason why brush management/restoration programs may cause landowners to be reluctant is the importance of brush to property values. The top motives for the purchase of the majority of landholdings throughout the state are recreation followed by the desire for rural homesites (Wilkins et al., 2000). Agriculture production, which generally benefits from decreased levels of brush, is not the driving force behind property purchases that it once was.

One cost not incorporated into the economic model is the transaction costs associated with implementing any cost-share program. These include costs associated with contract development, monitoring, and any public hearings. Contract development and monitoring costs would be most expensive for scenarios calling for increased brush control.

In order for brush management/restoration programs to work, the public must be willing to enroll their land in such a program. Landowner surveys conducted by the TAES (Narayanan, et al., 2002) indicate that landowners in the Edwards would include only 49 percent of their moderate cover and 53 percent of their heavy cover in a brush management program. In the Twin Buttes, landowners were willing to include 59 percent of their moderate cover and 64 percent of their heavy cover into a brush management program. With respect to Scenarios II and III, 26.5 percent of survey respondents in the Edwards said that requiring a 75 yard riparian buffer zone would either "reduce interest" or "prevent participation" in a program with that restriction. 15.1 percent of survey respondents in the Twin Buttes said that the riparian buffer restriction would either "reduce interest" or "prevent participation." Obviously, there are big differences in landowner attitudes regarding the desirability of various aspects of a brush control program. It is important to note, however, that a good majority of all the landowners surveyed in both watersheds were willing to participate to some degree in a brush control restoration program.

Finally, some aspects of the expected changes in ecosystem health and services provided by brush management and restoration treatments can be extremely difficult or impossible to economically quantify. Improvements in ecosystem stability and resilience, changes in non-game animal composition and abundance, and alterations of carbon sequestration capacity, all important concepts from an ecological viewpoint, are not included in this model because of logistic reasons. Obviously, there are big differences in landowner attitudes regarding land use and the desirability of various aspects of a brush control program. It is important to note, however, that a good majority of all the landowners surveyed in both watersheds were willing to participate to some degree in a brush control restoration program.

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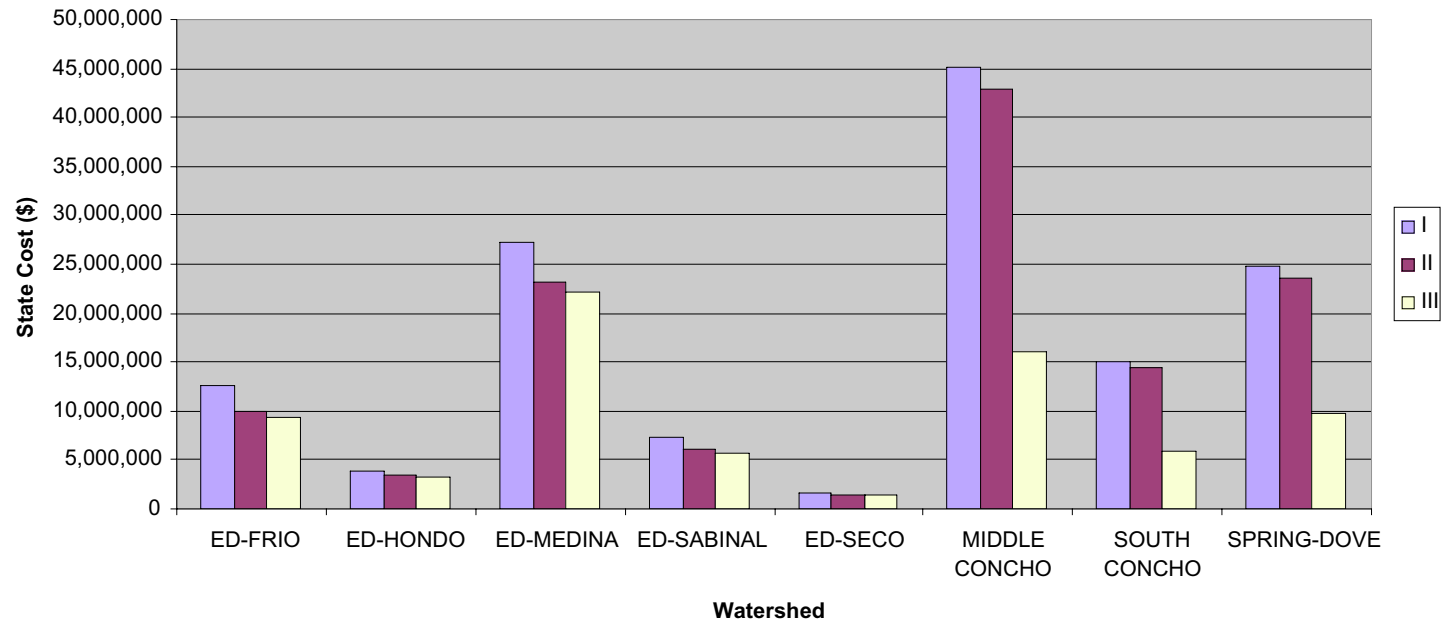


Figure 2.1. Comparison of Society costs for restoration, Scenarios I, II and III.

CORPS BRUSH/WILDIFE STUDIES

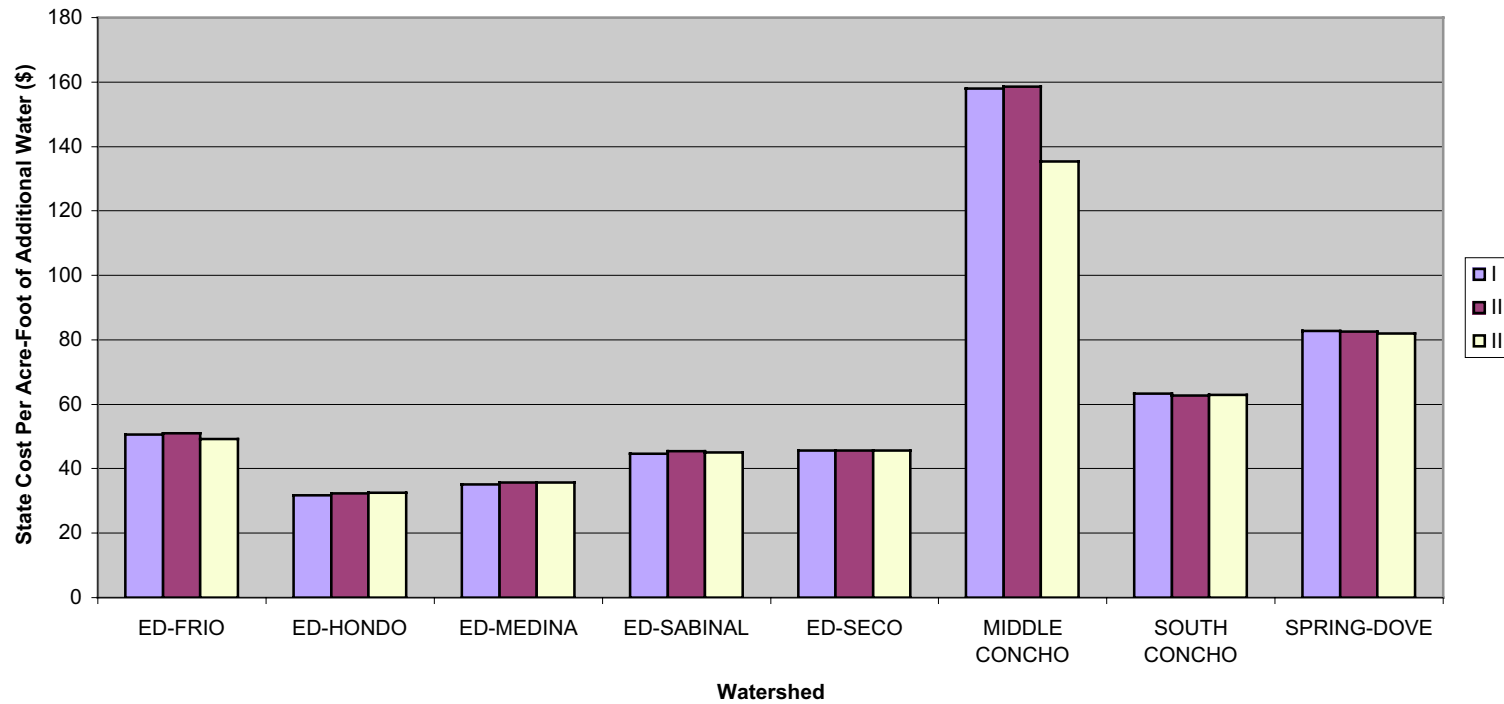


Figure 2.2 Comparison of Society Costs per Acre-Foot of Water Saved, by Watershed.

CORPS BRUSH/WILDLIFE STUDIES

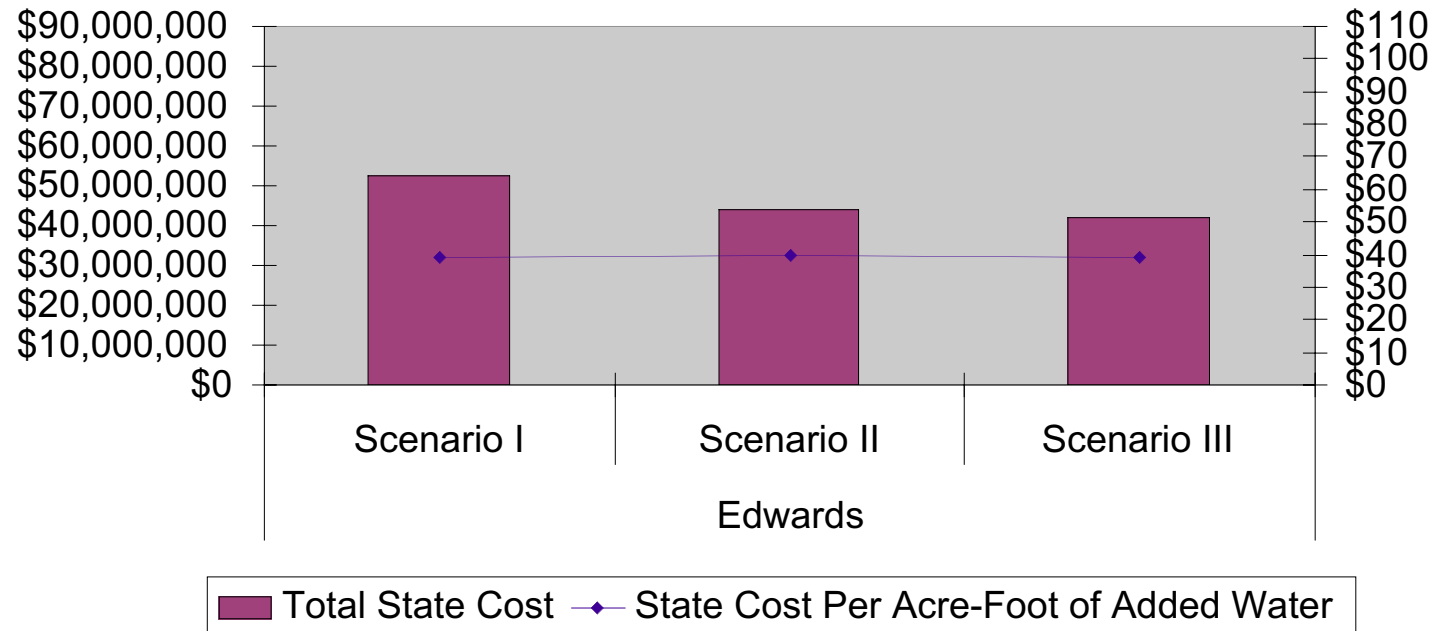


Figure 2.3. Comparison of Society Costs by Scenario, Edwards.

TWIN BUTTES - ALL WATERSHEDS COMBINED

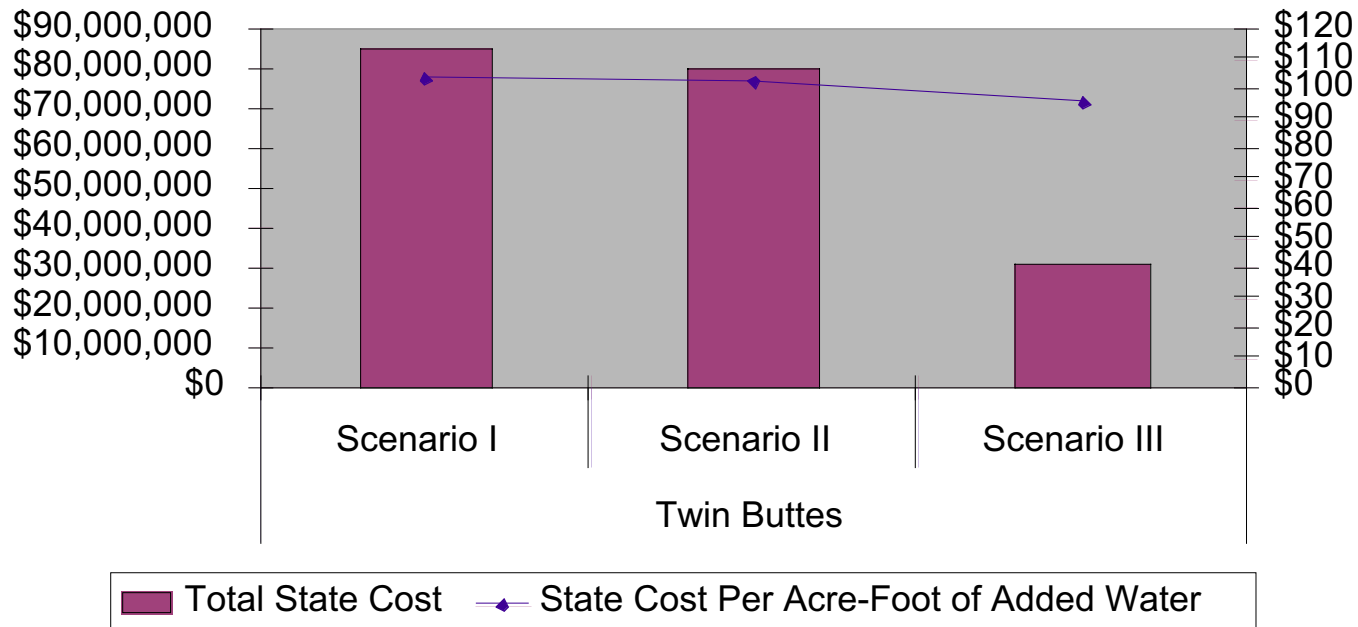


Figure 2.4. Comparison of Society Costs by Scenario, Twin Buttes.

CORPS BRUSH/WILDIFE STUDIE

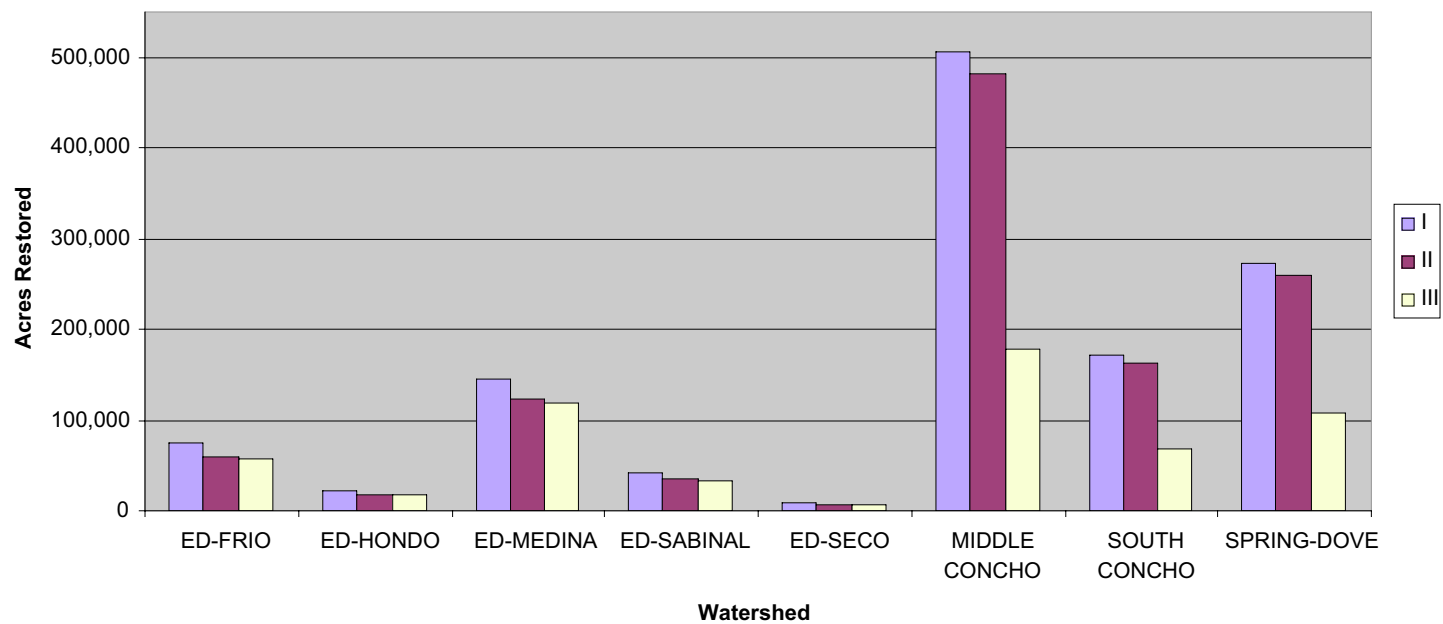


Figure 2.5. Rangeland restoration, by watershed.

CORPS BRUSH/WILDIFE STUDIES

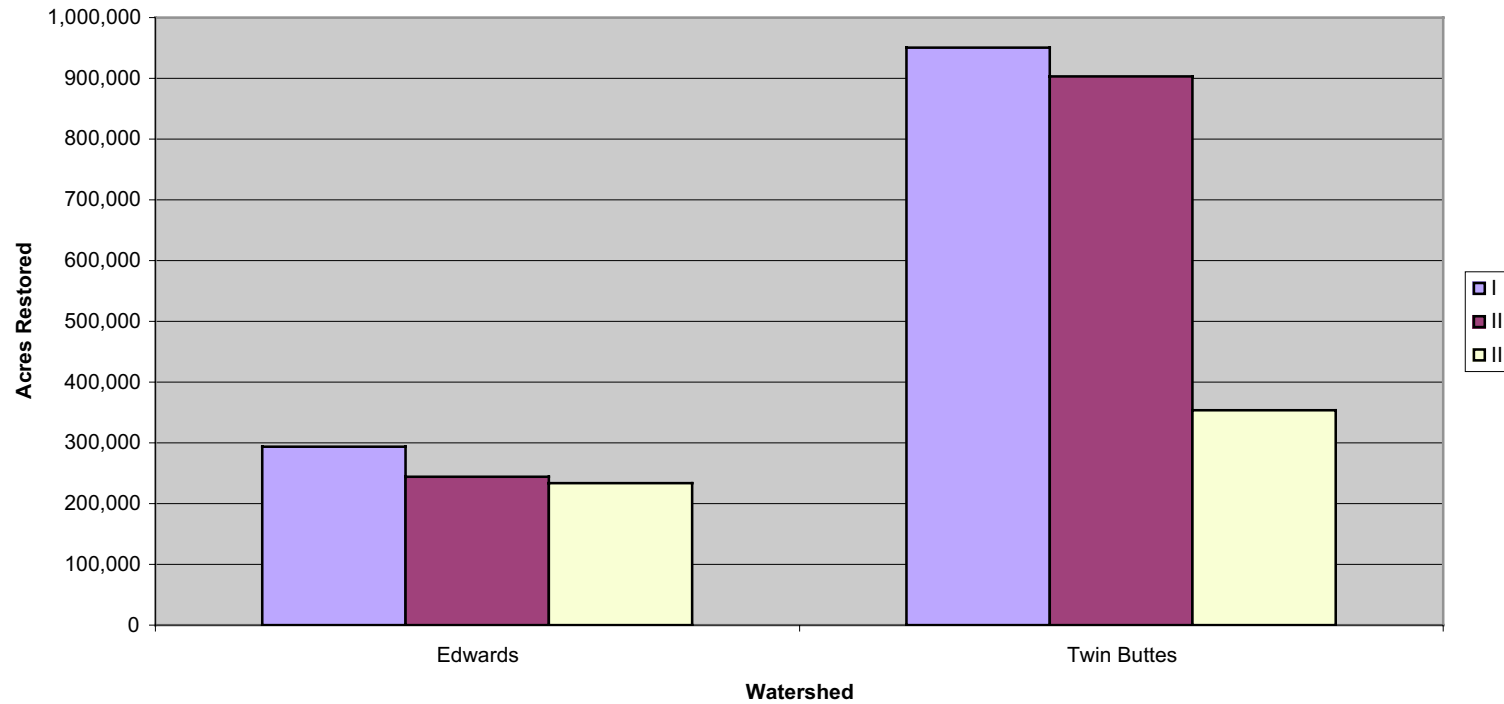


Figure 2.6. Comparison of rangeland restoration, Edwards versus Twin Buttes.

Section. 3 Wildlife Response to Brush Management Scenarios

Participants

Texas A&M University, Department of Wildlife and Fisheries Sciences

Wilkins, R. Neal

Hejl, Sallie J.

Magness, Dawn R.

Bedford, Theresa L.

Introduction

Within the past 150 years, rangeland vegetation has undergone a large-scale conversion from grasslands and savannas to woodlands (Scholes and Archer 1997). This shift is termed brush encroachment because the brush species that have always existed within the landscape have increased in number and cover. Continuous grazing by domestic livestock and exclusion from fire are identified as major contributors to brush encroachment (Van Auken 2000). In Texas, the loss of native grassland habitats has been substantial; e.g., Samson and Knopf (1994) report a 90 percent reduction of tallgrass prairie, a 30 percent reduction of mixed grass prairie, and a 80 percent reduction of shortgrass prairie since European settlement. For many grassland-associated species, this habitat loss is likely made worse by brush encroachment.

An unsurprising consequence of losing grassland habitat is the decline of grassland-associated wildlife. In fact, grassland bird species show more declining trends than any other avian species group in North America (Peterjohn and Sauer 1999). Texas rangelands provide breeding and wintering habitat for many species that require grasslands (obligate species) as well as those species that prefer grassland habitats (facultative species) (Vickery et al. 1999). Presumably, these species have declined on rangelands in the Edwards' Plateau. However, the Edwards Plateau also provides habitat for many brush or woodland associated species. The federally endangered Golden-cheeked Warbler (*Dendroica chrysoparia*), for example, breeds in forested or brushy habitats on the Edwards Plateau (Kroll 1980).

A landscape-scale brush management program may provide a unique opportunity to restore grassland habitats on the Edwards Plateau. Although grassland species could benefit from changing brush dominated areas to grasslands, careful planning may be required to ensure that results will mimic historical landscape patterns as much as possible. Observations from the 1860's indicate that the Edwards Plateau was a mosaic of grasslands, savannas, and scrub forest (Weniger 1988). In order to meet objectives of restoring ecological function, properly designed brush management plans should account for the habitat requirements needed to maintain viable populations of brush or woodland associated species while improving habitat for grassland-associated species. However, as there is with any change in habitat, any brush management strategy implemented across the landscape will result in a shift in the wildlife community resulting in gains or losses for particular species, depending on changes in habitat.

This report summarizes the current association of bird species and bird-guilds with brush species and brush cover in the Twin Buttes and Edwards watersheds, and predicts changes in habitat occupancy under five brush management scenarios. We chose to use bird guilds as landscape indicators of ecological condition, as did O'Connell et al. (2000) for the U. S. Environmental Protection Agency's Environmental Monitoring and Assessment Program. Because of variability in species composition and abundance within communities, O'Connell et al. suggested that bird data should be grouped at an ecologically relevant higher order of organization than the species' level to use as a measure of ecological condition. A response guild, a group of species that require similar habitat, food, or other elements for survival (Verner 1984, Szaro 1986), was that appropriate level. O'Connell et al. successfully used the bird-guild approach across a region to reflect the overall structure, function, and composition of ecosystems, the three primary attributes of biodiversity according to Noss (1990). Noss also suggested monitoring at more than one level of hierarchical organization. We monitored two levels. We examined individual species' responses

to vegetation patterns in addition to guild response patterns. In addition to analyzing bird occupancy patterns, we more fully described the composition of these watersheds by summarizing the diversity of wildlife found in these areas. We reviewed the scientific literature and records from these two watersheds for all wildlife species. We created a list of wildlife species likely to occur in each watershed and described the habitat association for each species.

Methods

Site Selection

Rancher participation limited the selection of survey sites. We used the existing, private roads (paved, gravel, and 2-track) to set up and access the sites. Survey sites were separated by at least 800 m in the Twin Buttes study area and at least 400m in the Edwards study area. The first site was placed near the entrance of the ranch. Each site was displaced from the road by walking a random distance (50 to 100m) and azimuth from the road. The second site was placed at a randomly assigned distance from the first site using a Global Positioning System (GPS) and was also displaced from the road. This process continued until the minimum distance requirement could no longer be met. We entered the location of each site into a GPS unit and downloaded it into Arc View. For these analyses, we considered each site to be an independent observation.

Survey Protocol

Spring Bird Surveys

Two observers sampled breeding birds with the fixed-radius point count method (Hutto et al. 1986) so the relative abundance between different survey areas could be compared. Two observers sampled Twin Buttes in 2001 and Edwards in 2002. A primary observer recorded the distance of each bird from plot center in five intervals (<25 m, 26-50 m, 51-75 m, 76-100 m, and >100 m) to determine which fixed-radius to use. The primary observer was the same at every survey site. The observers conducted point counts for 10 minutes (Dettmers et al. 1999) and recorded three detection time intervals (0-3 minutes, 3-5 minutes, and 5-10 minutes), so potential density biases from movement could be examined (Granholtm 1983), and for comparison with different studies. Point counts were conducted between 15 minutes after sunrise until 11 am when wind conditions were less than 18 km per hour. The observers visited each site one time during the breeding season (April to June). Although detection changes throughout the breeding season, we decided on one count per year because of the benefits associated with a larger sample size (Ralph et al. 1993). We attempted to sample each habitat type throughout the breeding season so that the effects of detection differences would be minimized. The Twin Buttes study area had 295 survey sites and the Edwards study area had 201 survey sites (Figures 3.1 and 3.2).

Winter Bird Surveys

Two observers ran a 100m transect through each survey point along one of three randomly chosen azimuths (0, 120, or 240 degrees). The observers systematically searched five meters on both sides of the centerline to detect secretive grassland species. A primary observer recorded the perpendicular distance of each bird from the centerline in six intervals (<5 m, 6-25 m, 26-50 m, 51-75 m, 76-100 m, and >100 m). The primary observer was the same at every survey site. The primary observer also recorded the search time dedicated to each transect. Surveys were conducted between 30 minutes after sunrise until 2 pm when wind conditions were less than 18 km per hour. We visited each site one time during the winter season (January to March 2002). In winter, 135 of the 295 spring sites were surveyed in the Twin Buttes study area and 147 of the 201 spring sites were surveyed in the Edwards study area (Figure 3.1 and 3.2).

Habitat Use Models

We defined a landscape as the 50.24 ha area encompassed by a 400-m radius around each survey site in the Twin Buttes study area (Canterbury et al. 2000) and as the 12.97 ha area encompassed by a 200-m radius around each survey site in the Edwards study area. The 295 landscapes in the Twin Buttes study

area and the 201 landscapes in the Edwards study area were used to build logistic regression models to predict the probability of occupancy of bird species and guilds. Each landscape was clipped out of the brush cover type layer and the computer program, FRAGSTATS (McGarigal and Marks 1995), was used to calculate the percent of the landscape (PLAND) occupied by each brush cover type (Figure 3.3).

The PLAND of the 15 brush cover types in the Twin Buttes study area were combined into four variables representing the average percent cover of the major brush types in each landscape using the following equations:

Equation 1: $\text{Juniper Percent Cover} = (\text{PLAND hvy juniper} * 0.65) + (\text{PLAND mod juniper} * 0.20) + (\text{PLAND lgt juniper} * 0.05)$

Equation 2: $\text{Mesquite Percent Cover} = (\text{PLAND hvy mesquite} * 0.65) + (\text{PLAND mod mesquite} * 0.20) + (\text{PLAND lgt mesquite} * 0.05)$

Equation 3: $\text{Mix Percent Cover} = (\text{PLAND hvy mix} * 0.65) + (\text{PLAND mod mix} * 0.20) + (\text{PLAND lgt mix} * 0.05)$

Equation 4: $\text{Oak Percent Cover} = (\text{PLAND hvy oak} * 0.65) + (\text{PLAND mod oak} * 0.20)$

The heavy cover types are multiplied by 0.65 because it is the mid-point between 0.3 and 1.0; the range of the heavy cover type. The moderate cover types are multiplied by 0.2, the mid-point of the moderate cover type, and the light cover types are multiplied by 0.05, the mid-point of the light cover type. These four variables are the independent variables in the logistic regressions for the Twin Buttes study area. All four variables were transformed by the natural log (y+1) to normalize the data.

In a similar manner, the PLAND of the 18 brush cover types in the Edwards study area were combined into four variables representing the average percent cover of the major brush types in each landscapes using the following equations:

Equation 5: $\text{Cedar Percent Cover} = (\text{PLAND hvy cedar} * 0.65) + (\text{PLAND hvy cedar_hvy oak} * 0.325) + (\text{PLAND hvy cedar_mod oak} * 0.45) + (\text{PLAND mod cedar_mod oak} * 0.1) + (\text{PLAND mod cedar} * 0.2) + (\text{lgt cedar} * 0.05)$

Equation 6: $\text{Oak Percent Cover} = (\text{PLAND hvy oak} * 0.65) + (\text{PLAND hvy cedar_hvy oak} * 0.325) + (\text{PLAND hvy cedar_mod oak} * 0.2) + (\text{PLAND mod cedar_mod oak} * 0.1) + (\text{PLAND mod oak} * 0.2) + (\text{PLAND lgt oak} * 0.05)$

Equation 7: $\text{Mix Percent Cover} = (\text{PLAND hvy mix} * 0.65) + (\text{PLAND mod mix} * 0.2) + (\text{PLAND lgt mix} * 0.05)$

Equation 8: $\text{Mesquite Percent Cover} = (\text{PLAND hvy mesquite} * 0.65) + (\text{PLAND mod mesquite} * 0.2) + (\text{PLAND lgt mix} * 0.05)$

The mid-point of the heavy cover types and moderate cover types are the same as the Twin Buttes equations. The brush cover type, hvy cedar_hvy oak, was multiplied by 0.325 for the cedar and oak equations because it was assumed that both vegetation types equally contributed to the average heavy multiplier of 0.65. Similarly, the 0.65 multiplier of the brush cover type, hvy cedar_mod oak, was broken into 0.45 for the cedar cover and 0.2 for the oak cover. The 0.2 multiplier of the brush cover type, mod cedar_mod oak, was broken into a 0.1 multiplier for cedar and a 0.1 for oak. These four variables are the independent variables used in the logistic regressions for the Edwards study area. Juniper, oak, and mesquite cover were transformed by taking the natural log (y+1).

The dependent variable in a logistic regression analysis is binary. In this case, the dependent variable takes on the value of 0 (bird or guild absent) and one (bird or guild present). Logistic regressions build a model similar to a linear model, except the model predicts the values of y in a range between 0 and 1 instead of negative infinity and positive infinity. The logit model is:

$$\text{Equation 9: } y = \exp(Xb + e) / [1 + \exp(Xb + e)]$$

Rearranging the terms and logging both sides makes:

$$\text{Equation 10: } \log [y/(1-y)] = Xb + e = \beta_0 + \beta_j x_{ij} + e_i \text{ for all } i = 1, \dots, n$$

The probability of a bird or guild being present is represented as:

$$\text{Equation 11: } \text{Prob}(Y_{ij} = 1 | x_{ij}) = e^{\beta_0 + \beta_j x_{ij}} / 1 + e^{\beta_0 + \beta_j x_{ij}}$$

This equation can be used to predict the presence or absence of individual species and guilds across an entire study areas for the different scenarios.

Logistic regression models were built for every bird species detected at 15 or more survey sites. Species were grouped into breeding habitat guilds for spring surveys and foraging guilds for winter surveys (Ehrlich et al. 1988). In addition, grassland-associated species were placed into a grassland obligate or a grassland facultative group (Vickery et al. 1999). Breeding birds associated with riparian areas were also grouped (Ehrlich et al. 1988).

Scenario Analyses

In order to relate landscape variables to particular locations, we centered a template of a given radius at each of several thousand equally spaced grid points across each watershed – this termed a “moving window.” At each grid point, the variables of interest were calculated from the surrounding landscape within the “window.” See figure 3.3 for an example of a window template. The result was a dataset with variables assigned to each grid point. A moving window analysis was used to calculate the percent of the landscape (PLAND) covered by each brush cover type for the both study areas. We used FRAGSTATS to place a “moving window” over each grid in steps equal to the column width of the land use grid. The window size was a 400-m radius circle in the Twin Buttes study area and a 200-m radius circle in the Edwards study area so as to conform to the landscape of consideration in building the logistic models. At each step (18,337 locations on the Twin Buttes, and 8,494 locations on the Edwards) the PLAND for each brush cover type was calculated for the surrounding window. As a result we built a new grid for all 15 vegetation types in Twin Buttes and all 18 brush cover types in the Edwards. In the process, every 31 x 31m pixel was assigned the average percent of the landscape calculated using every window including that pixel. Three separate moving window analysis were run for each study area to cover all the vegetation changes in the five brush scenarios. First, a moving window analysis was run over all the brush cover type pixels in the entire study area. Second, a moving window analysis was run where only areas with a 15 or greater percent slope had brush cover type pixels and the rest of the study area was blank. Third, a moving window was run where only areas with the slope over 15 percent or within the 75 m stream buffers had brush cover type pixels and the rest of the study area was blank. The moving window PLAND grids were aggregated by a factor of 20 using the mean to create new grids with 620 X 620 m pixel size. The x coordinate, y coordinate, and PLAND value for all the pixels in these grids were then exported into Microsoft Excel spreadsheets.

The 45 excel spreadsheets for the Twin Buttes were linked together in Microsoft Access by their common x and y coordinates. The 54 Excel spreadsheets for the Edwards were also linked together. The Twin Buttes study area, excluding the upper Middle Concho sub-basins, had 18,337 locations and the Edwards study area had 8,494 locations. The PLAND for each of the brush cover type variables at each location (over the entire study area, on slope over 15 percent and on slopes over 15 percent and within the stream buffers) were used to calculate the four independent variables used in the logistic regressions for each scenario.

Equations 1 to 8 were used to calculate the independent variables for the logistic regression models for every location across the study areas. The PLAND of the brush cover variables for Scenario I were adjusted by changing the treatable cover types outside of the greater than 15 percent slope areas to their post treatment cover types while not changing the treatable cover types within the 15 percent slope areas.

The PLAND of the brush cover variables for Scenario II were calculated by changing the treatable cover types within the stream buffered or the greater than 15 percent slope areas to their post treatment cover types while not changing the treatable cover types within these areas. The PLAND of the brush cover variables for Scenario III were calculated the same way as Scenario II. If the moderate and heavy cover types left after changing the treatable cover types were less than 40 percent, treatable heavy and moderate cover types outside of the untreated area would be left untreated until the 40 percent requirement was met. The brush cover types taken to meet the 40 percent requirement were chosen based on the proportion available. If not enough heavy or moderate cover types were available to meet the 40 percent requirement, then all treatable brush types were left untreated. The PLAND of the brush variables for Scenario IV were calculated by leaving all the brush cover types untreated. The PLAND of the brush cover type variables for Scenario V were calculated by changing every moderate brush cover type to heavy and every light brush cover type to moderate.

The independent variables calculated for each scenario were used in Equation 11 for each bird or guild model. The probability a bird species or guild would be present at each location across the study area was calculated for each scenario.

Species Composition

To create the list of bird species likely to occur in each watershed, we used bird field checklists from three state parks (Garner, Lost Maples, San Angelo), one region (Concho Valley region), one chamber of commerce (Uvalde: Nature quest), and one camp (H. E. Butt foundation). To create the amphibian, reptile, and mammal lists, we used distribution maps in Dixon (2000) and Davis and Schmidly (1994). We used field guides to describe the habitat associations of each species.

Results and Discussion

Brush Cover

Twin Buttes

The total brush cover on the Twin Buttes was estimated at 23.7 percent, most of which was mesquite and juniper (Table 3.1). Concentrations of juniper were aggregated in the more central portions of the study area, whereas concentrations of mesquite were more widely distributed (Figure 3.4). Scenario I was projected to reduce total brush cover by 73 percent. The exclusion of riparian areas from brush removal in Scenario II resulted in a modest effect on overall brush cover. However, the 40 percent retention constraints of Scenario III resulted in only a 32.1 percent reduction of total brush cover (Table 3.1). If in fact, the changes projected under future Scenario V were to occur (i.e., continued brush encroachment), then we projected total brush cover to almost double, much of the increase coming from expansion of juniper.

Edwards

The total brush cover on the Twin Buttes was estimated at 48.7 percent, most of which was juniper and oak, as well as mixed brush which is primarily a juniper/oak mix. (Table 3.2). With the exception of scattered aggregations of more open country in major drainage bottoms, the concentrations of juniper, oak and mixed brush were well distributed across the area (Figure 3.5). Because the present condition includes heavy concentrations of juniper on slopes >15 percent (where mechanical brush management is not feasible), the differences among Scenarios I, II, and III were only slight; resulting in a 24.4 to 22.4 percent decrease in total brush cover. Continued brush encroachment under Scenario V was projected to result in a 32.6 percent increase in total brush cover with 64.6 percent of the total landscape dominated by one or more species of brush (Table 3.2).

Table 3.1. Changes in the average brush percent cover by scenario over the Twin Buttes study area.

Brush Type	Scenario				
	I	II	III	IV	V
	-----% Cover-----				
Juniper	1.9	2.3	5.9	9	21.3
Mesquite	2.1	3.1	7.5	11.8	19.1
Mixed	0.8	0.9	1.1	1.3	3
Oak	1.6	1.6	1.6	1.6	1.8
Total	6.4	7.9	16.1	23.7	45.2
%Change^a	-73.0	-66.7	-32.1	0.0	90.7

^a %Change represents the percent increase/decrease in total estimated brush cover when compared to Scenario IV (the present condition).

Table 3.2. Changes in the average brush percent cover by scenario over the Edwards study area.

Brush Type	Scenario				
	I	II	III	IV	V
	-----% Cover-----				
Juniper	7.3	7.9	7.9	14	16.1
Mesquite	1.5	1.7	1.7	2.6	4.7
Mixed	13.6	14.1	14.1	20	26.5
Oak	14.4	14.1	14.1	12.1	17.3
Total	36.8	37.8	37.8	48.7	64.6
%Change	-24.4	-22.4	-22.4	0.0	32.6

^a %Change represents the percent increase/decrease in total estimated brush cover when compared to Scenario IV (the present condition).

Survey Summaries¹

Twin Buttes

During the spring surveys we detected 3,874 individuals of 76 species within the 100-m sampling radius of 295 sample locations (Appendix B1). On average, we detected 8.8 species at each location (SE = 0.2, SD = 2.7). The maximum number of species detected at a sample site was 19. The most common species recorded was the Northern Mockingbird; and greater than 63 percent of total individuals detected were represented by only 12 species.

During the winter surveys, we detected 2,702 individuals of 69 species within a 100m area along each transect at 135 sample locations (Appendix B2). On average, 4.7 species were detected at each location (SE = 0.3, SD = 3.0). The maximum number of species detected at a sample site was 16. The most common species recorded was the Western Meadowlark; yet the white-crowned sparrow was detected at the most sites. Greater than 56 percent of total individuals detected were represented by seven species.

Edwards.

During the spring surveys, we detected 2,941 individuals of 79 species within the 100-m sampling radius of 201 sample locations (Appendix C1). On average, we detected 9.8 species at each location (SE = 0.2, SD = 3.0). The maximum number of species detected at a sample site was 19. The most common species was the Tufted Titmouse; and greater than 43 percent of total individuals were represented by eight species.

During the winter surveys, we detected 2,177 individuals of 56 species within a 100m area along each transect at 147 sample locations (Appendix C2). On average, 5.6 species were detected at each location (SE = 0.2, SD = 2.6). The maximum number of species detected at a sample site was 13. The most common species recorded was the Chipping Sparrow; yet northern cardinals were detected at the most sites. Greater than 57 percent of total individuals were represented by five species.

Model Results.

The focus was on the breeding birds detected in the spring surveys when building the logistic regression models. Breeding birds are likely to have stronger habitat ties than wintering birds because they are confined to a breeding territory while nesting. Breeding and wintering bird guilds are listed in Appendices D1-4.

Twin Buttes

Logistic regression models were built for the seven guilds, the grassland obligate group, the grassland facultative group, and the riparian group (Appendix B3). The sample size (N) and McFadden's rho-squared (Rho^2) were used to evaluate the models. Rho-squared is similar to an R-squared and always falls between 0 and 1. As the rho-squared value increases, the fit of the model increases. A rho-squared value between 0.2 and 0.4 is considered very satisfactory (Hensher and Johnson 1981). A cut-off of 0.1 was used to decide which models are sufficient to model across the scenarios.

The grassland obligate group and brush guild have the strongest models. The grassland obligates are negatively associated with all brush types (Table 3.3). Juniper and oak are the most significant variables in the model. The brush guild is positively associated with all brush types, and juniper and oak are the most significant variables in the model (Table 3.3). The deciduous group had an insufficient sample size and the grassland facultative group and grassland guild are present at nearly every site. Although these models did not have a sufficient rho-squared, it is notable that woodland guild had a significant positive association with oak cover and the scrub guild had a significant positive association with juniper cover.

¹ For reporting efficiency, the larger volumes of summary data for bird surveys are presented in Appendices B (Twin Buttes) and C (Edwards).

The riparian guild also had a significant positive association with oak cover, the brush cover type that represents the mixed deciduous forests associated with streams with year round water.

Table 3.3. Logistic regression model relationships for breeding birds on the Twin Buttes study area. Sign (+/-) represents the direction of response (i.e., change in habitat occupancy) predicted from an increase in that brush type. Specific model terms are presented in Appendix IE.

Species/Group	Juniper	Mesquite	Mixed	Oak
Grassland Obligates	_-**** ^a	-	-	_-***
Brush Guild	+***	+	+	+***
Black-chinned Hummingbird	+	-	+	+***
Tufted Titmouse	+	_*	+***	+***
Western Scrub Jay	+***	+	+	-
Yellow-billed Cuckoo	-	-	-	+***
Cassin's Sparrow	_-**	+	-	_-***
Lark Sparrow	_-**	-	-	_-***
Western Meadowlark	_-***	+	-	-

^a statistical significance, *** = p<0.01, ** = p<0.05, * = p<0.1.

Logistic regression models were built for the 36 species that were present at 15 or more survey sites (Appendix B4). Seven species have sufficient models. The three grassland-associated species, Cassin's Sparrow, Lark Sparrow, and Western Meadowlark, have significant negative associations with juniper cover (Table 3.3). Cassin's Sparrow and Lark Sparrow also have a significant negative association with oak cover (Table 3.3). Mesquite cover did not seem to affect the presence or absence of these grassland-associated species. This could be due to mesquite's association with deeper soils types that produce more grass cover. Black-chinned Hummingbird, Tufted Titmouse, and Yellow-billed Cuckoo have significant positive associations with oak cover. Tufted Titmouse and Yellow-billed Cuckoo glean insects off of deciduous tree leaves and nest in deciduous trees. Oak probably provides the best surface area for this type of foraging technique and may offer superior nest sites. Western Scrub Jay has a significant positive association with juniper cover. This relationship may be attributed to this species affinity towards nesting in stands of dense brush.

Edwards

Logistic regression models were built for the seven guilds, the grassland obligate group, the grassland facultative group, and the riparian group (Appendix C3). The grassland guild had the strongest model. The grassland guild had a significant negative relationship with all four brush cover types (Table 3.4). The grassland facultative group was present at nearly every site and the grassland obligate group did not have a large enough sample size to build sufficient models. The other guilds' models did not meet the minimum rho-squared requirement. However, it is notable that the savanna guild had significant negative association with cedar and significant positive relationships with both oak cover and mesquite cover, the two brush species associated with grassland savannas. The deciduous guild had a significant positive association with oak cover and mix cover. Many deciduous guild species forage on the leaves and bark of the trees represented in the oak and mix brush cover types.

Table 3.4. Logistic regression model relationships for Edwards breeding birds. Sign (+/-) represents the direction of response (i.e., change in habitat occupancy) predicted from an increase in that brush type. Specific model terms are presented in Appendix IIE.

Species/Group	Juniper	Mesquite	Mixed	Oak
Grassland Guild	- ***	- *	- ***	- *
Golden-cheeked Warbler	+ ***	-	+ ***	+ ***
Northern Mockingbird	- **	-	- ***	+
Scissortail Flycatcher	-	-	- ***	-
Vermillion Flycatcher	- *	-	- **	- **
Lark Sparrow	- **	-	- ***	-
Black-and-white Warbler	+ ***	-	+ **	+ ***
Northern Bobwhite	- ***	-	+	-
Red-eyed Vireo	+ **	+ *	+ *	+ **
Canyon Wren	+	-	+ *	+ **
Western Scrub Jay	+ ***	-	+	-
White-eyed Vireo	+ *	+	+ ***	+
Blue-gray Gnatcatcher	+	+	+ **	+ ***
Lesser Goldfinch	- **	+	-	+ *

^a statistical significance, *** = $p < 0.01$, ** = $p < 0.05$, * = $p < 0.1$.

Logistic regression models were built for the 35 species that were present at 15 or more survey sites (Appendix C4). Thirteen species had sufficient models (Table 3.4). The endangered Golden-cheeked Warbler, the Black-and-white Warbler, and the Red-eyed Vireo had significant positive relationships with juniper cover, oak cover, and mix cover. Golden-cheeked Warblers forage on deciduous trees and use the

bark of mature juniper to build their nests. The grassland-associated Lark Sparrow and Scissor-tailed Flycatcher have significant negative relationships with mix cover, but the grassland-associated Northern Bobwhite has no significant relationship to mix cover. However, Lark Sparrow and Northern Bobwhite have significant negative relationships to juniper cover. These grassland-associated species have no significant relationships to oak cover and were often present in oak savanna habitat. The Vermillion flycatcher has significant negative relationships with juniper cover, oak cover, and mix cover. Good summer habitat is widely spaced junipers and oaks (Oberholser 1974). The Lesser Goldfinch has a significant negative association with juniper cover and a significant positive relationship with oak cover, which they use for foraging. Lesser Goldfinches use lightly wooded areas in Texas (Oberholser 1974). As in Twin Buttes, the Western Scrub Jay has a significant positive relationship with juniper cover. Scrub Jays feed on cedar berries and nest in dense shrubs. Oberholser (1974:589) noted that "Texas Scrub Jays seem almost as tied to juniper on rough ground as is the Golden-cheeked Warbler". The Northern Mockingbird, often associated with edges (Oberholser 1974), has a significant negative relationship with juniper cover and mix cover. Associated with tangled thickets and thick undergrowth (Oberholser 1974), the White-eyed Vireo has a significant positive relationship with juniper cover and mix cover. Canyon Wren and Blue-gray Gnatcatcher have significant positive relationships with oak cover and mix cover. Blue-gray Gnatcatchers forage on deciduous leaves and are known to favor oaks in the breeding season (Oberholser 1974). Canyon Wrens are present only in areas with predominant limestone outcrops or cliffs on which they nest.

Scenarios

Twin Buttes

The logistic regression models for the two guilds and seven species that were sufficient were applied across the study area for each scenario using the intercept and slope estimates (Appendix B5). The average probability of the guild or species being an index of habitat quality under each scenario (Table 3.5). The scenarios represent a gradient in the amount brush cover with Scenario I having the least juniper, mesquite, and mix cover and Scenario V having the most juniper, mesquite, and mix cover (Table 3.1). Oak stays the same in Scenario I, II, III, and IV because it is not a treatable brush cover type, but slightly increases in Scenario V as the moderate oak cover type changed to a heavy oak cover type.

As the brush cover increased, the probability of occurrence for grassland obligates decreased from 0.824 in Scenario I to 0.594 in Scenario V. The brush guild had the opposite trend with probability of occurrence increasing from 0.546 in Scenario I to 0.924 in Scenario V.

The grassland-associated Cassin's Sparrow, Lark Sparrow, and Western Meadowlark all followed the same trend as the grassland obligate group and had a decreasing probability of occurrence from Scenario I to Scenario V. The probability of occurrence of the Western Scrub Jay increased from 0.003 in Scenario I to 0.254 in Scenario V as the juniper cover increased. The probability of occurrence of species that had significant relationships with oak cover was driven by the other variables. These relationships are complex because the magnitude of any variable's influence is dependent on the size of the slope estimate for that variable. For example, the Yellow-billed Cuckoo's insignificant negative associations with juniper, mesquite, and mix cover caused the probability of occurrence to increase from 0.068 in Scenario IV to 0.117 in Scenario I. These negative associations offset the positive association of increasing the oak cover in Scenario V, so the probability of occurrence dropped to 0.049. The probability of occurrence of the Tufted Titmouse is another example, but here lowering the cover of juniper, mix, and mesquite had the same effect as increasing all the brush cover types. The increase in oak cover makes the probability of occurrence in Scenario V almost equal to the probability of occurrence in Scenario I.

Edwards

The logistic regression models for the grassland guild and the 13 species were applied across the study area for every scenario using each model's intercept and slope estimates (Appendix C5). The average

probability of the guild or species being present across the study area changed for each scenario (Table 3.5). The scenarios in the Edwards also represent a gradient in the amount of brush cover (Table 3.2). Cedar, mix, and mesquite cover increased along the gradient with the lowest covers in Scenario I and the highest covers in Scenario V. Oak cover increases from the value in Scenario IV with the treatments in scenarios I, II and III because many of the treatable brush cover types are changed to an oak cover type after treatment. Oak also increases in Scenario V as the moderate oak cover type changes to a heavy oak cover type and the light oak cover type changes to a moderate oak cover type.

The probability of occurrence of the grassland guild decreased from 0.319 in Scenario I to 0.028 in Scenario V. The probability of occurrence of the Golden-cheeked warbler, Black-and-white Warbler, Red-eyed Vireo, Western Scrub Jay, and White-eyed Vireo all increased from Scenario I to Scenario V. The probability of occurrence of the Northern Mockingbird, Scissortailed Flycatcher, Vermillion Flycatcher, Lark Sparrow, Northern Bobwhite, and Lesser Goldfinch all decreased from Scenario I to Scenario V. The probability of occurrence of the Canyon Wren and Blue-gray Gnatcatcher stayed the same for Scenario I through 4, but increase in Scenario V.

These models do not work equally well for all species. Some species (e.g., Golden-cheeked Warbler) have unique needs that are not represented in these analyses. Golden-cheeked Warblers nest in mature, closed-canopy juniper on slopes. Our model suggests that the amount of warbler habitat would decrease precipitously in Scenarios I-III (Tables 3.5 and 3.6). That is not likely. Because most of the warblers nest on slopes, and none of the treatments would occur on slopes, warbler habitat should remain the same after treatments. Similarly, if no treatments occur (Scenario V), warbler habitat is not likely to increase because juniper-oak communities already occupy most slope habitat and any increase in brush cover is not necessarily the mature brush cover preferred by Golden-cheeked Warblers.

Implications

The two grassland guilds appear to be among the most responsive of the bird groups we modeled. Likewise, they are probably the best indicator groups for the gauging the restoration of grassland ecosystems. While each of the component species are likely to respond to habitat changes not accounted for here, they do appear to genuinely respond to changes in landscape level brush concentrations.

As applied to the Twin Buttes, the difference in level of response of grassland obligates to the various scenarios was modest when viewing the landscape in its entirety (Tables 3.5 and 3.6). However, when spatial variability is considered, the relative importance of landscape changes due to scenario treatments reveals a set of patterns that may guide management (Figure 3.6). For example, when comparing the present condition to Scenario III, several local areas of high priority for treatment are revealed (Figure 3.7). Likewise, areas where concentrated brush treatments are not likely to result in measurable habitat improvements at the landscape scale can be identified.

For the grassland guild on the Edwards study area, the differences between scenarios I-III are slight. However, the predicted improvement for a grassland guild resulting from any of the scenarios is substantial. When comparing the present condition to Scenario III, the mean likelihood of occurrence increases by 79 percent (Table 3.5), and the percent of the study area with a likelihood of >0.5 would more than double (Table 3.6, Figure 3.8). Because much of the Edwards area has slopes >15 percent, much of the brush is not treatable under our scenarios. However, treating those areas that are accessible should result in a substantial percentage increase in grassland restoration (Figure 3.9).

Species Composition.

A listing of the breeding bird guilds from the winter and summer surveys in Twin Buttes is presented in Appendix D1 and D2, and for the Edwards in Appendix D3 and D4. There were 254 bird species recorded in Edwards and 329 in Twin Buttes watersheds (Appendix E1). Distribution maps indicate that 95 amphibian and reptile species occur in Edwards and 93 in Twin Buttes (Appendix E2) and that 62 mammal species occur in Edwards and 62 in Twin Buttes watersheds (Appendix E3).

Therefore, we sampled a good proportion of the total bird fauna (37 percent). Excluding nocturnal raptors, waterbirds, and shorebirds, we sampled approximately 53 percent of the terrestrial bird species, those birds most expected to be affected by brush management. By examining the guild and species levels, we discovered how brush management is likely to affect wildlife species within the Edwards and Twin Buttes watersheds.

Table 3.5. Average probability of occurrence of guilds and species across the study areas by scenario. Estimated probability of occurrence at any one site ranges from 0 to 1. Numerical values represent an average score from the accumulation of all “moving windows” sites across each study area.

Study Area	Species/Group	Scenario I	Scenario II	Scenario III	Scenario IV	Scenario V
Twin Buttes	Grassland Obligates	0.824	0.812	0.74	0.699	0.594
	Brush Guild	0.546	0.584	0.763	0.809	0.924
	Black-chinned Hummingbird	0.064	0.054	0.035	0.026	0.02
	Tufted Titmouse	0.263	0.251	0.212	0.199	0.254
	Western Scrub Jay	0.003	0.005	0.032	0.092	0.254
	Yellow-billed Cuckoo	0.117	0.108	0.081	0.068	0.049
	Cassin's Sparrow	0.76	0.754	0.712	0.691	0.625
	Lark Sparrow	0.866	0.848	0.759	0.702	0.533
	Western Meadowlark	0.116	0.103	0.043	0.033	0.009
Edwards	Grassland Guild	0.319	0.293	0.292	0.163	0.028
	Golden-cheeked Warbler	0.225	0.239	0.239	0.414	0.698
	Northern Mockingbird	0.263	0.243	0.243	0.119	0.031
	Scissor-tailed Flycatcher	0.096	0.087	0.087	0.044	0.005
	Vermillion Flycatcher	0.104	0.098	0.098	0.066	0.009
	Lark Sparrow	0.259	0.242	0.242	0.145	0.031
	Black-and-white Warbler	0.2	0.204	0.204	0.273	0.474
	Northern Bobwhite	0.062	0.054	0.053	0.027	0.008
	Red-eyed Vireo	0.09	0.097	0.097	0.176	0.446
	Canyon Wren	0.089	0.087	0.087	0.088	0.185
	Western Scrub Jay	0.16	0.17	0.17	0.28	0.29
	White-eyed Vireo	0.236	0.246	0.246	0.359	0.545
	Blue-grey Gnatcatcher	0.275	0.273	0.273	0.273	0.523

Mean Probability of Occurrence

0.0-0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-0.90	0.9-1.0
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Table 3.6. Percent of study area estimated to have a greater than 0.5 probability of occurrence under the various brush management scenarios, for guilds and species across the Twin Buttes and Edwards study areas.

Study Area	Species/Group	Scenario I	Scenario II	Scenario III	Scenario IV	Scenario V
Twin Buttes	Grassland Obligates	96.8	95.7	90.7	85	67.8
	Brush Guild	63.2	69.7	92	92.8	99.3
	Black-chinned Hummingbird	2.1	1.5	0.8	0.5	0.3
	Tufted Titmouse	10.6	9.5	7	6.2	11.2
	Western Scrub Jay	0	0	0	1.3	38.5
	Yellow-billed Cuckoo	2.9	2.2	1.4	0.9	0.5
	Cassin's Sparrow	92.1	91.5	88.2	85.3	75
	Lark Sparrow	99.7	98.9	95.3	87.2	60.3
	Western Meadowlark	0	0	0.005	0.005	0
	Edwards	Grassland Guild	21.7	18.4	18.4	8.1
Golden-cheeked Warbler		10.1	12	12	45.8	83.9
Northern Mockingbird		9.1	7.3	7.2	1.7	0
Scissor-tailed Flycatcher		0.06	0.05	0	0	0
Vermillion Flycatcher		1.5	1.2	1	0.3	0
Lark Sparrow		6.1	11.4	11.4	4.7	0
Black-and-white Warbler		2	4.5	4.5	10.2	50.7
Northern Bobwhite		0.08	0.08	0.06	0	0
Red-eyed Vireo		0.01	0.01	0.01	0.1	37.6
Canyon Wren		0.1	0.09	0.09	0	2
Western Scrub Jay		0	0	0	1	0.3
White-eyed Vireo		0	0.04	0.04	20	72.5
Blue-grey Gnatcatcher		9.5	9	9	3.3	56.3

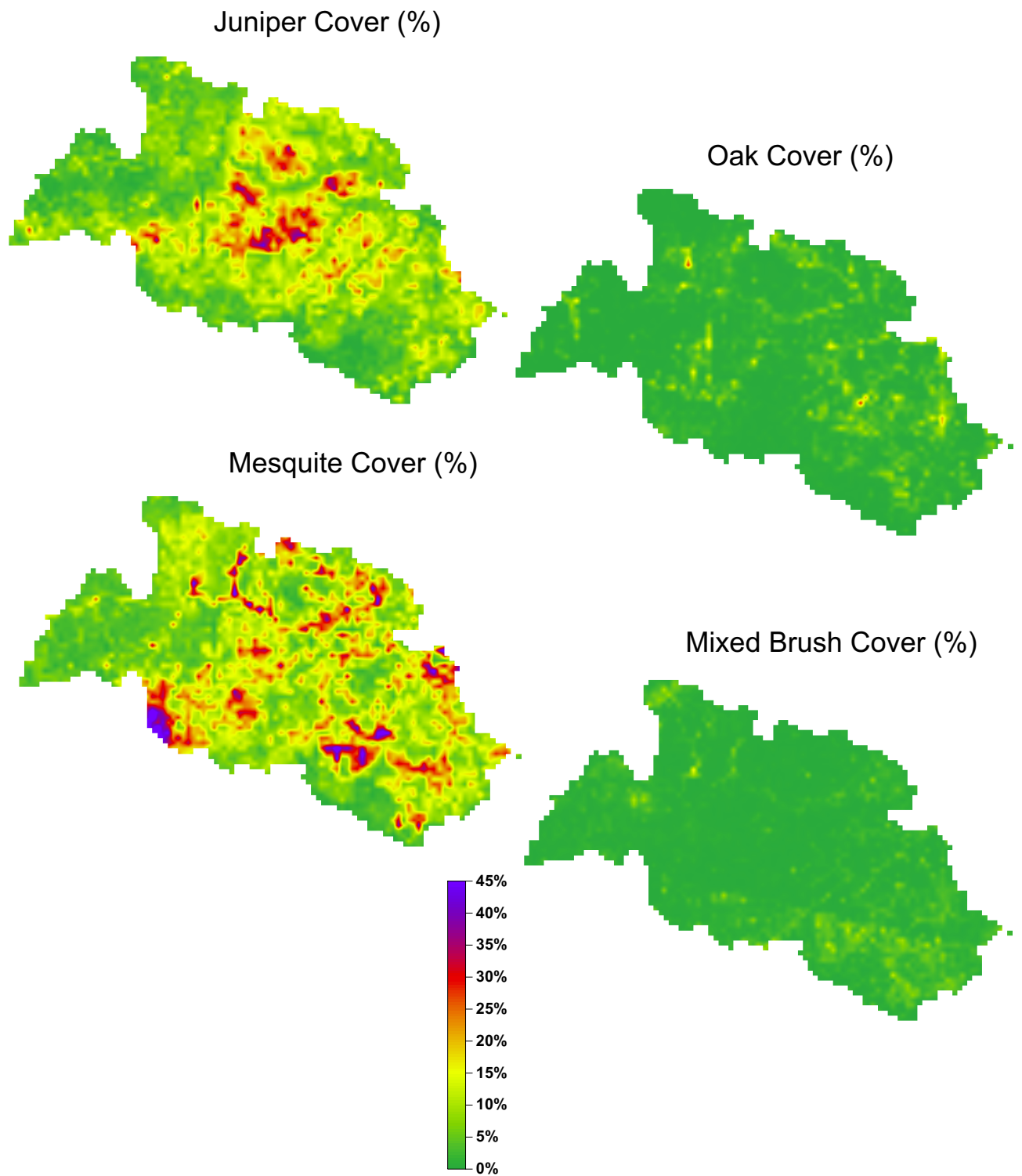


Figure 3.4. Present condition (Scenario IV) of brush cover variables across the Twin Buttes study area. Brush cover concentrations are represented at a 620m x 620m resolution.

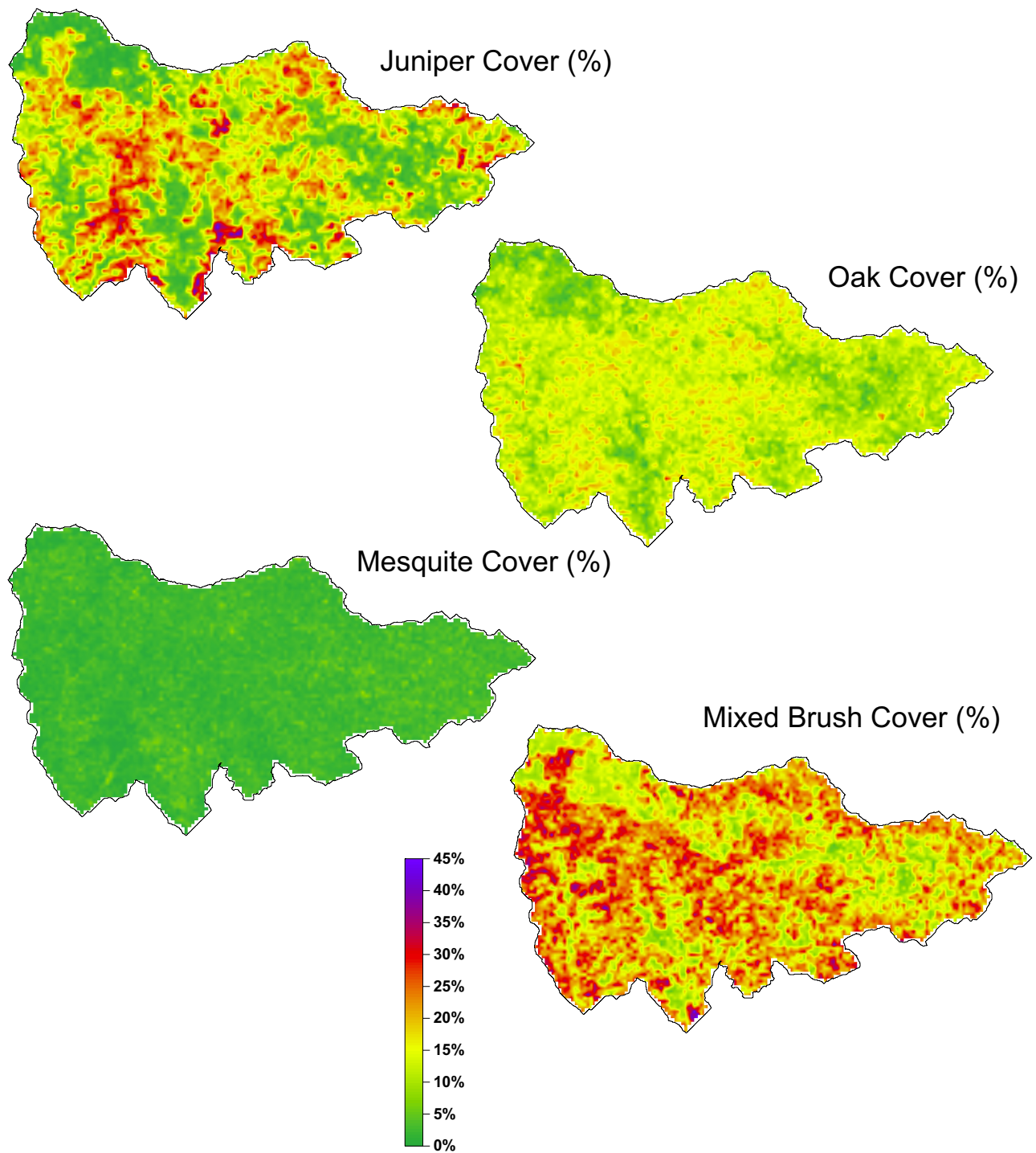


Figure 3.5. Present condition (Scenario IV) of brush cover variables across the Edwards study area. Brush cover concentrations are represented at a 620m x 620m resolution.

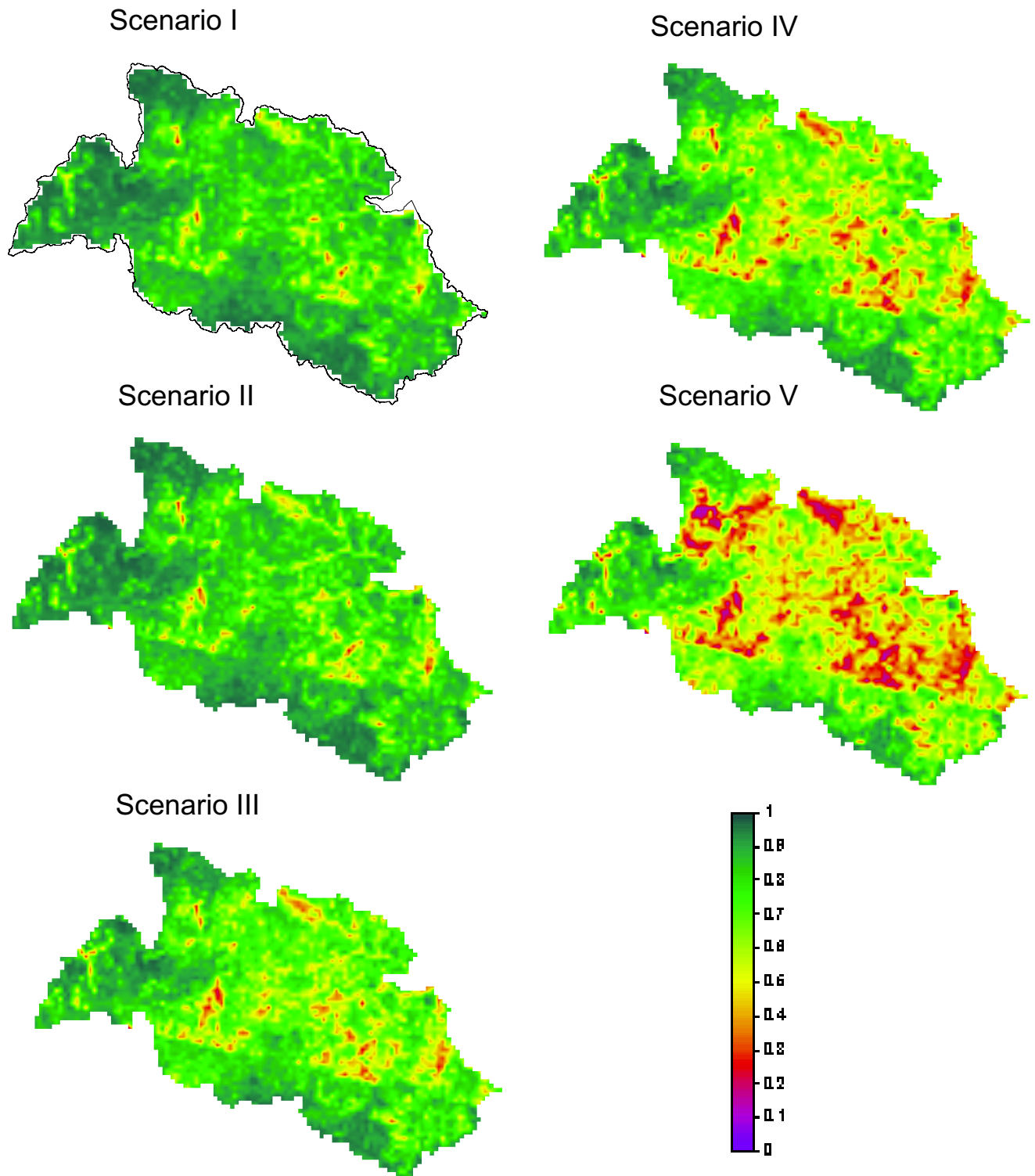


Figure 3.6. Predicted probability of occupancy by obligate grassland birds during the breeding season for each of five brush management scenarios, Twin Buttes Study Area. Color scale represents probabilities of occurrence estimated by logistic regression model (see text).

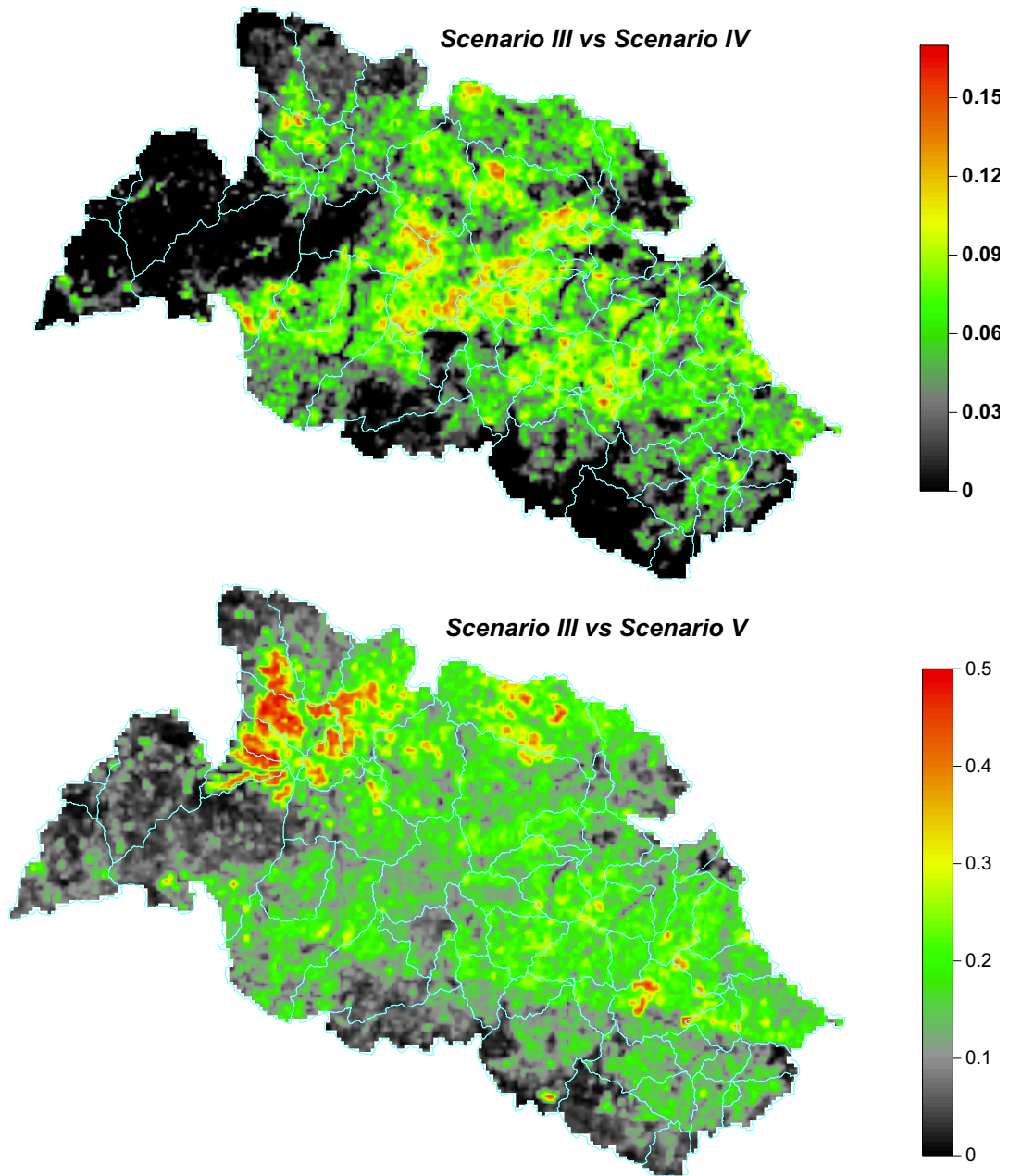


Figure 3.7. Comparisons of the impact of Scenario III *versus* Scenarios IV and IV on habitat occupancy scores for grassland breeding birds across the Twin Buttes study area. Numerical values represent the estimated increase in the likelihood of occurrence of grassland breeding birds resulting from the localized habitat changes of Scenario III when compared to the present condition (Scenario IV) and a projected future scenario of “no action” (Scenario V).

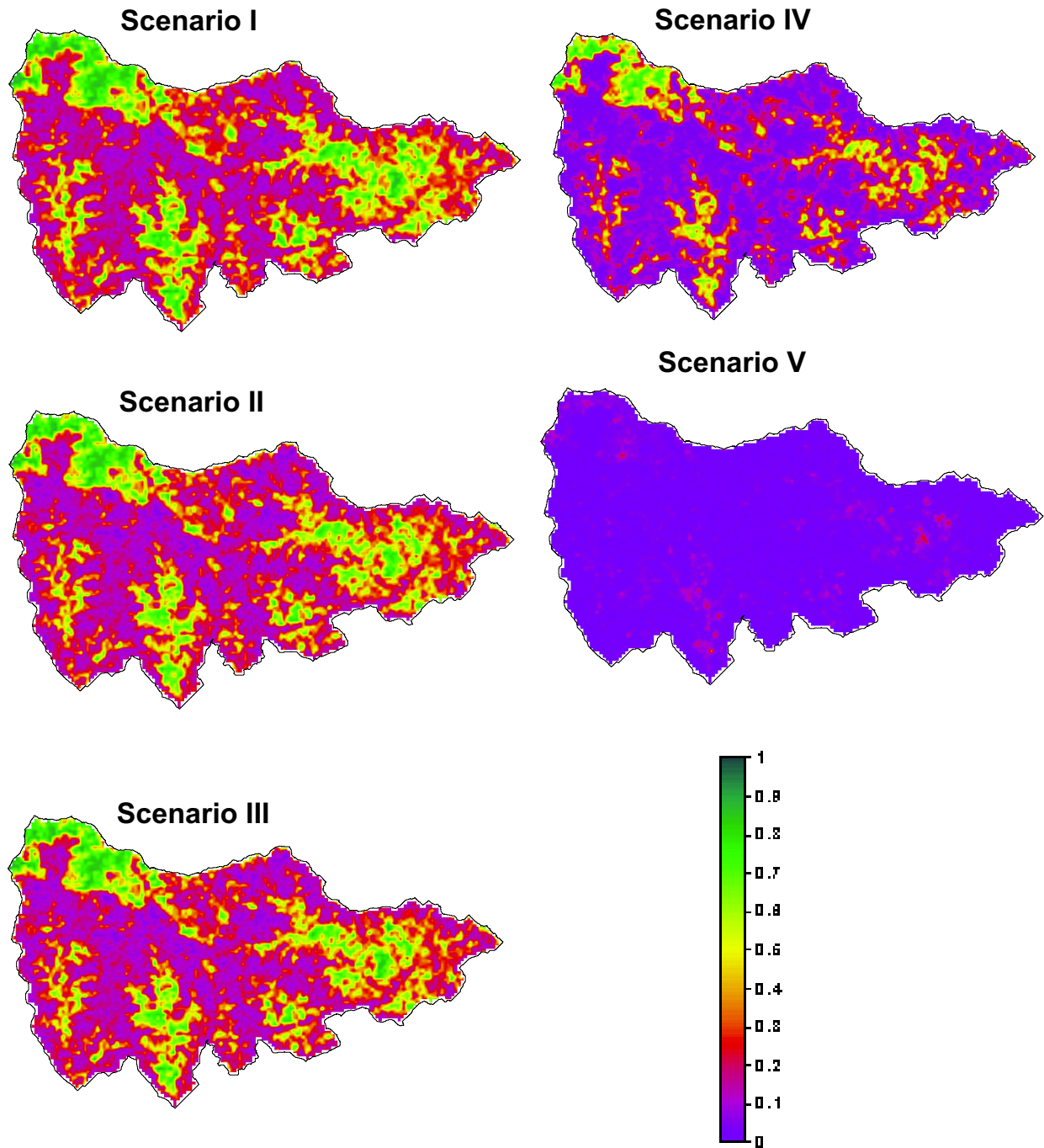


Figure 3.8. Predicted probability of occupancy by a grassland guild of birds during the breeding season for each of five brush management scenarios, Edwards Study Area. Color scale represents probabilities of occurrence estimated by logistic regression model (see text).

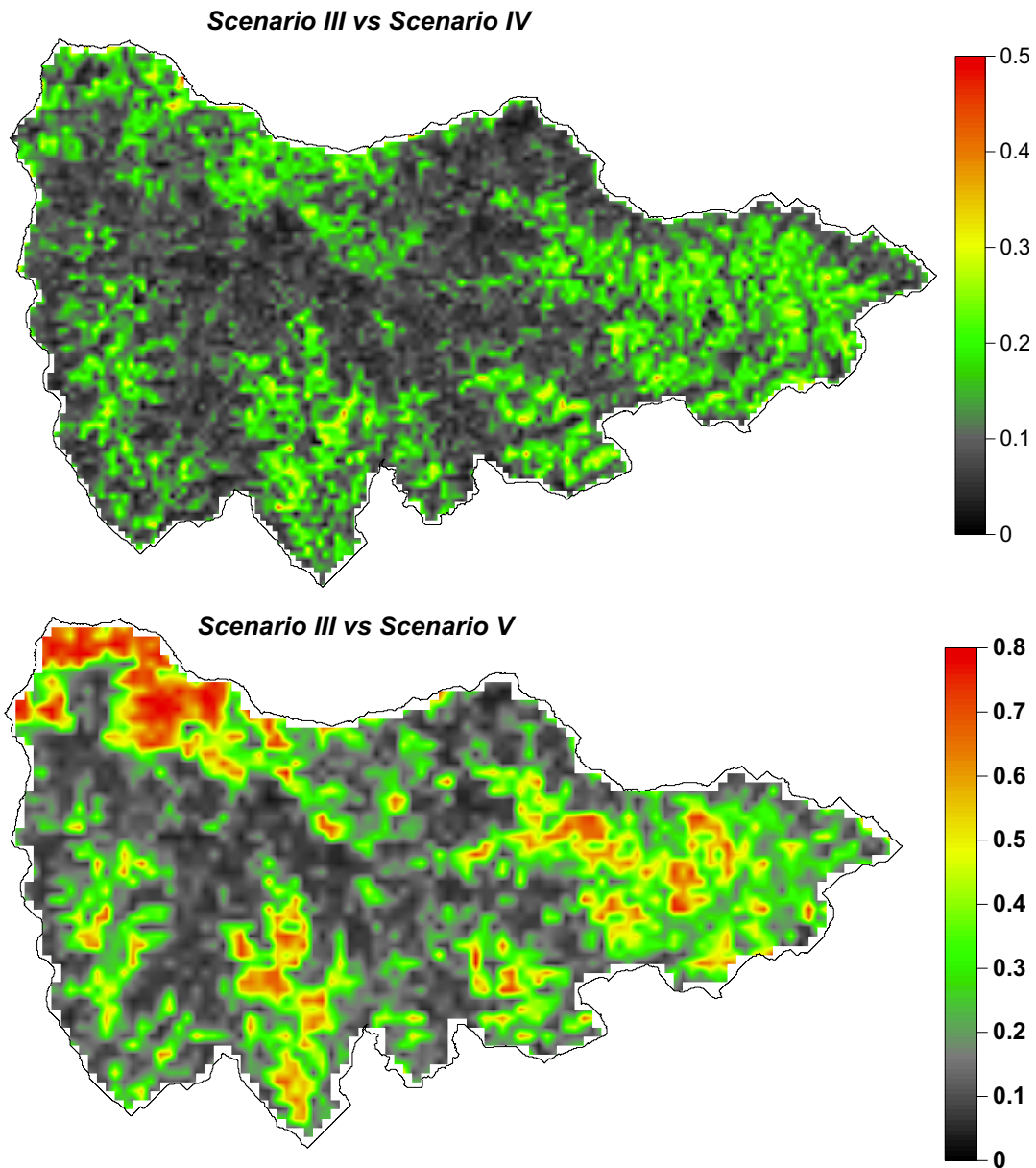


Figure 3.9. Comparisons of the impact of Scenario III *versus* Scenarios IV and IV on habitat occupancy scores for grassland breeding birds across the Edwards study area. Numerical values represent the estimated increase in the likelihood of occurrence of grassland breeding birds resulting from the localized habitat changes of Scenario III when compared to the present condition (Scenario IV) and a projected future scenario of “no action” (Scenario V).

Section 4. Aquatic Biota Responses to Alternative Brush Management Scenarios

Participants

TAES

Winemiller, Kirk O.
Arrington, D. Albrey
Wilkins, Neal R.

Introduction

The purpose of the aquatic biota project subcomponent is to provide the means for assessing changes in aquatic biological diversity likely to result from alternative brush management scenarios in the Twin Buttes and Edwards aquifer recharge zone watersheds. Specific objectives of this study were (1) to establish baseline conditions characterizing stream habitats and aquatic biota within the project boundaries; (2) to establish baseline relationships between integrative measures of aquatic habitat quality and landscape features (land cover) and hydrologic (discharge) conditions within sampled sub-basins; and (3) to project the likely influence of alternative brush management scenarios on aquatic communities residing in streams within the study watersheds.

Methods

Biological Field Surveys

The Environmental Protection Agency's draft EMAP Guidelines for field monitoring/assessment of biota were used to assess water bodies within the study areas. The Texas Natural Resource Conservation Commission Guidelines for Receiving Water Assessments also were consulted in order to maximize transferability of field methodologies. Appendix F indicates collection sites and environmental data.

In this study of biological indicators of ecological integrity, 131 sites were selected for biological surveys. Sites were nested within watersheds, basins, and sub-basins (Figures 4.1 and 4.2; Tables 4.1 and 4.2). Because our sampling was conducted during prolonged drought conditions, many streambeds, particularly upstream ephemeral reaches, were dry. As a result, aquatic sampling was limited to stream reaches that contained water in areas having points of access. We consulted maps and selected property owners were consulted to determine areas of access. During June-July 2001, field surveys were conducted to obtain baseline data for stream habitats and fish and benthic aquatic macroinvertebrate assemblages.

At each survey location, before biological sampling was initiated, we collected location coordinates using a hand-held global positioning system (GPS), estimated riparian vegetation coverage, characterized general weather conditions and identified the local aquatic habitat as either 'riffle,' 'run' or 'pool'. We measured the following parameters at five points (near bank, 1/4 width, 1/2 width, 3/4 width, and near other bank) along three transects perpendicular to the longitudinal axis of the stream channel (from shoreline to shoreline): water depth, water velocity (using a Marsh McBirney digital flowmeter), substrate composition (visual estimates of percentage coverage of categories), percent coverage by woody debris, and percent coverage by aquatic vegetation. At each survey location, we measured the following physicochemical water parameters *in situ*: dissolved oxygen (mg/L), conductivity (μ S), and temperature ($^{\circ}$ C) using a YSI Model 85 multiparameter meter and probe, and pH using a Hach digital probe.

Table 4.1. Summary of the number of aquatic survey (sample) locations by watershed, basin, and sub-basin.

Watershed	Basin	Sub-basin Number	Number of Aquatic Surveys
Edwards	Frio	6010101	1
Edwards	Frio	6010301	15
Edwards	Frio	6010501	12
Edwards	Frio	6010503	8
Edwards	Frio	6010801	3
Edwards	Hondo	downstream of sub-basin	6
Edwards	Medina	2010301	4
Edwards	Medina	2010401	1
Edwards	Medina	2010501	2
Edwards	Medina	2010601	3
Edwards	Medina	2020201	1
Edwards	Medina	2020303	5
Edwards	Sabinal	6060101	8
Edwards	Sabinal	6060201	8
Edwards	Sabinal	6060301	6
Edwards	Sabinal	6060501	2
Edwards	Seco	7060105	3
Twin Buttes	Middle Concho	25	5
Twin Buttes	Middle Concho	27	8
Twin Buttes	South Concho	16	12
Twin Buttes	Spring-Dove	13	3
Twin Buttes	Spring-Dove	15	10
Twin Buttes	Spring-Dove	21	5

Table 4.2. Sample location and IBI scores for collected aquatic samples.

Sample Number	Fish IBI Score	Invertebrate IBI Score	Drainage	Habitat Classification	Basin	Sub-basin Number
BC-01	77	21	Twin Buttes	Run/Pool	South Concho	16
BC-02	77	25	Twin Buttes	Run/Pool	South Concho	16
BC-03	72	23	Twin Buttes	Run/Pool	South Concho	16
BC-04	68	29	Twin Buttes	Run/Pool	South Concho	16
BC-05	68	25	Twin Buttes	Run/Pool	South Concho	16
BC-06	60	23	Twin Buttes	Riffle	South Concho	16
BC-07	86	21	Twin Buttes	Riffle	South Concho	16
BC-08	78	21	Twin Buttes	Run/Pool	South Concho	16
BC-09	68	17	Twin Buttes	Run/Pool	South Concho	16
BC-10	68	27	Twin Buttes	Run/Pool	South Concho	16
BC-11	52	29	Twin Buttes	Run/Pool	South Concho	16
BC-12	73	27	Twin Buttes	Run/Pool	South Concho	16
BC-13	49	19	Twin Buttes	Run/Pool	Middle Concho	27
BC-14	49	23	Twin Buttes	Run/Pool	Middle Concho	27
BC-15	39	25	Twin Buttes	Run/Pool	Middle Concho	27
BC-16	74	25	Twin Buttes	Run/Pool	Middle Concho	27
BC-17	79	31	Twin Buttes	Run/Pool	Middle Concho	27
BC-18	59	25	Twin Buttes	Run/Pool	Middle Concho	27
BC-19	71	21	Twin Buttes	Run/Pool	Middle Concho	27
BC-20	59	21	Twin Buttes	Run/Pool	Middle Concho	27
BC-21	56	23	Twin Buttes	Run/Pool	Middle Concho	25
BC-22	12	19	Twin Buttes	Riffle	Middle Concho	25
BC-23	37	21	Twin Buttes	Run/Pool	Middle Concho	25
BC-24	30	21	Twin Buttes	Run/Pool	Middle Concho	25
BC-25	65	23	Twin Buttes	Run/Pool	Middle Concho	25
BC-26	58	27	Twin Buttes	Run/Pool	Spring-Dove	15
BC-27	49	23	Twin Buttes	Run/Pool	Spring-Dove	15
BC-28	0	23	Twin Buttes	Riffle	Spring-Dove	15
BC-29	49	19	Twin Buttes	Run/Pool	Spring-Dove	15
BC-30	41	23	Twin Buttes	Run/Pool	Spring-Dove	15
BC-31	41	21	Twin Buttes	Run/Pool	Spring-Dove	15
BC-32	41	23	Twin Buttes	Run/Pool	Spring-Dove	15
BC-33	58	25	Twin Buttes	Run/Pool	Spring-Dove	15
BC-34	46	27	Twin Buttes	Run/Pool	Spring-Dove	15
BC-35	59	23	Twin Buttes	Run/Pool	Spring-Dove	15
BC-36	46	15	Twin Buttes	Run/Pool	Spring-Dove	13
BC-37	32	23	Twin Buttes	Run/Pool	Spring-Dove	13
BC-38	52	17	Twin Buttes	Run/Pool	Spring-Dove	13
BC-39	61	25	Twin Buttes	Run/Pool	Spring-Dove	21
BC-40	56	23	Twin Buttes	Riffle	Spring-Dove	21
BC-41	69	21	Twin Buttes	Run/Pool	Spring-Dove	21
BC-42	58	15	Twin Buttes	Riffle	Spring-Dove	21
BC-43	86	21	Twin Buttes	Run/Pool	Spring-Dove	21
BC-44	62	15	Edwards	Run/Pool	Frio	6010503
BC-45	42	21	Edwards	Run/Pool	Frio	6010503
BC-46	39	21	Edwards	Run/Pool	Frio	6010503
BC-47	57	19	Edwards	Run/Pool	Frio	6010503
BC-48	56	27	Edwards	Run/Pool	Frio	6010503
BC-49	75	21	Edwards	Riffle	Frio	6010503
BC-50	66	23	Edwards	Run/Pool	Frio	6010501
Sample Number	Fish IBI Score	Invertebrate IBI Score	Drainage	Habitat Classification	Basin	Sub-basin Number
BC-51	76	33	Edwards	Run/Pool	Frio	6010501
BC-52	65	27	Edwards	Riffle	Frio	6010501
BC-53	59	13	Edwards	Run/Pool	Frio	6010501

BC-54	61	27	Edwards	Riffle	Frio	6010501
BC-55	82	§	Edwards	Run/Pool	Frio	6010501
BC-56	62	§	Edwards	Run/Pool	Frio	6010501
BC-57	59	19	Edwards	Run/Pool	Frio	6010501
BC-58	37	23	Edwards	Riffle	Frio	6010501
BC-59	61	§	Edwards	Run/Pool	Frio	6010501
BC-60	70	15	Edwards	Riffle	Frio	6010501
BC-61	37	21	Edwards	Riffle	Frio	6010501
BC-62	66	17	Edwards	Riffle	Frio	6010503
BC-63	70	27	Edwards	Run/Pool	Frio	6010503
BC-64	54	§	Edwards	Run/Pool	Frio	6010301
BC-65	73	25	Edwards	Riffle	Frio	6010301
BC-66	68	21	Edwards	Run/Pool	Frio	6010301
BC-67	73	23	Edwards	Riffle	Frio	6010301
BC-68	70	29	Edwards	Run/Pool	Frio	6010301
BC-69	77	23	Edwards	Run/Pool	Frio	6010301
BC-70	51	25	Edwards	Riffle	Frio	6010301
BC-71	64	25	Edwards	Run/Pool	Frio	6010301
BC-72	65	§	Edwards	Riffle	Frio	6010301
BC-73	67	27	Edwards	Run/Pool	Frio	6010301
BC-74	79	23	Edwards	Run/Pool	Frio	6010301
BC-75	51	19	Edwards	Run/Pool	Frio	6010301
BC-76	57	21	Edwards	Run/Pool	Frio	6010301
BC-77	56	15	Edwards	Run/Pool	Frio	6010301
BC-78	34	25	Edwards	Run/Pool	Frio	6010301
BC-79	77	27	Edwards	Run/Pool	Frio	6010101
BC-80	70	27	Edwards	Run/Pool	Frio	6010801
BC-81	78	23	Edwards	Riffle	Frio	6010801
BC-82	76	23	Edwards	Run/Pool	Frio	6010801
BC-83	63	23	Edwards	Run/Pool	Sabinal	6060101
BC-84	40	23	Edwards	Riffle	Sabinal	6060101
BC-85	76	17	Edwards	Run/Pool	Sabinal	6060101
BC-86	78	21	Edwards	Run/Pool	Sabinal	6060101
BC-87	74	23	Edwards	Run/Pool	Hondo	†
BC-88	70	15	Edwards	Riffle	Hondo	†
BC-89	55	25	Edwards	Run/Pool	Hondo	†
BC-90	75	17	Edwards	Riffle	Hondo	†
BC-91	84	23	Edwards	Run/Pool	Hondo	†
BC-92	75	21	Edwards	Riffle	Hondo	†
BC-93	85	23	Edwards	Run/Pool	Seco	7060105
BC-94	54	23	Edwards	Run/Pool	Seco	7060105
BC-95	37	23	Edwards	Riffle	Seco	7060105
BC-96	56	23	Edwards	Run/Pool	Sabinal	6060501
BC-97	61	23	Edwards	Riffle	Sabinal	6060501
BC-98	72	25	Edwards	Run/Pool	Sabinal	6060301
BC-99	62	27	Edwards	Run/Pool	Sabinal	6060301
BC-100	52	21	Edwards	Run/Pool	Sabinal	6060301
BC-101	64	21	Edwards	Run/Pool	Sabinal	6060301
BC-102	51	23	Edwards	Run/Pool	Sabinal	6060301
Sample Number	Fish IBI Score	Invertebrate IBI Score	Drainage	Habitat Classification	Basin	Sub-basin Number
BC-103	63	25	Edwards	Run/Pool	Sabinal	6060301
BC-104	84	27	Edwards	Run/Pool	Medina	2010301
BC-105	74	23	Edwards	Run/Pool	Sabinal	6060101
BC-106	56	21	Edwards	Run/Pool	Sabinal	6060101
BC-107	65	25	Edwards	Riffle	Sabinal	6060101
BC-108	66	17	Edwards	Run/Pool	Sabinal	6060101
BC-109	76	27	Edwards	Run/Pool	Sabinal	6060201

BC-110	57	27	Edwards	Run/Pool	Sabinal	6060201
BC-111	61	21	Edwards	Run/Pool	Sabinal	6060201
BC-112	§	27	Edwards	Run/Pool	Sabinal	6060201
BC-113	62	19	Edwards	Run/Pool	Sabinal	6060201
BC-114	73	23	Edwards	Run/Pool	Sabinal	6060201
BC-115	52	21	Edwards	Run/Pool	Sabinal	6060201
BC-116	52	25	Edwards	Run/Pool	Sabinal	6060201
BC-117	60	25	Edwards	Run/Pool	Medina	2010301
BC-118	83	23	Edwards	Riffle	Medina	2010301
BC-119	§	25	Edwards	Riffle	Medina	2010301
BC-120	60	25	Edwards	Run/Pool	Medina	2010401
BC-121	82	27	Edwards	Run/Pool	Medina	2010501
BC-122	53	21	Edwards	Riffle	Medina	2010501
BC-123	53	23	Edwards	Riffle	Medina	2010601
BC-124	60	29	Edwards	Run/Pool	Medina	2010601
BC-125	79	31	Edwards	Run/Pool	Medina	2010601
BC-126	66	23	Edwards	Run/Pool	Medina	2020201
BC-127	91	25	Edwards	Riffle	Medina	2020303
BC-128	72	25	Edwards	Run/Pool	Medina	2020303
BC-129	78	19	Edwards	Riffle	Medina	2020303
BC-130	79	19	Edwards	Run/Pool	Medina	2020303
BC-131	76	25	Edwards	Run/Pool	Medina	2020303

§ IBI Score not calculated. † Sample collected downstream of southernmost identified sub-basin.

Fish surveys were conducted using a seine net (6.4 m x 1.8 m with 4 mm mesh). At each site, the level of effort was documented to facilitate estimation of catch per unit effort and to allow duplication of the effort at a later time. Collection effort was continued until no additional fish species were collected with additional seine hauls. In some instances, large fish were identified, weighed, and measured in the field, then released alive. Otherwise, all specimens from a given site were preserved in 15 percent formalin as a single sample, labeled, and returned to the lab for identification and measurement. Individual fish were identified to species. After identification and enumeration in the laboratory, these specimens were deposited into Texas A&M University's Texas Cooperative Wildlife Collection (TCWC accession number 1681).

Benthic macroinvertebrate surveys were conducted using a Surber sampler (Merritt and Cummins 1984). Two Surber samples were taken at each survey location. Surber samples were non-randomly positioned within the survey location to encompass variation in benthic habitat characteristics (e.g., cobble, mud, sand, submerged vegetation). Invertebrate samples were preserved in the field in 75 percent EtOH with Rose Bengal added to stain invertebrates. Individual invertebrates were identified to family (Plafkin et al. 1989), except Ephemeroptera that were identified to order, and enumerated. A reference collection of these specimens has been retained in K.O. Winemiller's laboratory at Texas A&M University. Individual Surber samples were processed as distinct and individual samples, however, the benthic macroinvertebrate index of biotic integrity (B-IBI) was calculated based on pooled results from the paired Surber samples at each location (see Development of B-IBI below). Fish species and abundance are presented in Appendix G with aquatic macro invertebrate taxa in Appendix H.

Development of Fish IBI (F-IBI)

Karr and Dudley (1981) defined biotic integrity as "a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region." Karr (1981) and his associates (Karr et al. 1986) developed the original index of biotic integrity (IBI) for stream fishes in Indiana and Illinois. Since its original development, the IBI has been modified and adapted for use as an indicator of stream health in other

regions of the Midwest (e.g., Lyons 1992, Barbour 1999) and the country (Moyle and Randall 1998, Gamon and Simon 2000).

The fish IBI (F-IBI) score for a stream is calculated from a series of metrics that reflect the essential structural and functional features of the fish community. Metrics employed for the Edwards and Twin Buttes F-IBIs are described in Table 4.3. We modified metrics developed for Texas' Brazos-Navasota River watershed IBI (Winemiller and Gelwick 1998) and other published IBIs (Karr et al. 1986, Lyons 1992). Natural fluvial fish communities of the Edwards and Twin Buttes watersheds differ from the Brazos-Navasota River watershed and Midwestern communities in several respects which had to be taken into account in developing the scoring criteria. The team first searched and databased earlier fish collections from the Edwards and Twin Buttes watersheds that were archived in the Texas Cooperative Wildlife Collection (TCWC – College Station, TX) and the Texas Natural History Collection (TNHC – Austin, TX). Surveys dating from the 1940s to the present were evaluated to assess species ranges, assemblage composition, and interannual variation observed in past collections. Next was development of a distinct scoring criteria for the Edwards and Twin Buttes watersheds (Table 4.3) based on species ranges and characteristic differences between samples from the two distinct watersheds. Furthermore, because fish assemblages sampled from riffles are typically different from run/pool habitats (e.g., different maximum species richness and abundance patterns), a separate set of scoring criteria was developed for riffle and run/pool habitats within each basin. Ten metrics were employed in run/pool F-IBI calculations; however, only six metrics were used in riffle F-IBI calculations. In order to standardize maximum possible F-IBI scores, we, therefore, standardized categorical scores so that the maximum possible score scales to 100 (Table 4.3).

Scoring criteria used for Midwestern streams were modified to allow a relatively high percentage of omnivorous fishes to be associated with a relatively high degree of ecological integrity (reflected in scoring criteria in Table 4.3). Like Lyons (1992), this study included madtoms (*Noturus* species) in our tally of darter species at each site. Madtoms are not darters, they occupy habitats and ecological niches similar to darters, and thus are valuable indicators of ecosystem health. Some species were classified as intolerant forms that were not classified as such by Lyons (1992). Because the streams and rivers of our region tend to be warmer (with lower dissolved oxygen concentrations) and more turbid than Wisconsin streams, we used a less restrictive interpretation of intolerance. Thus, in addition to the species listed as intolerant by Lyons, all species of darters were included (Percidae) and the freckled madtom (*Noturus nocturnus*) as intolerant forms. Percentage of green sunfish (*Lepomis cyanellus*) was only used for run/pool F-IBI calculations. Green sunfish are tolerant fish that are good colonizers of disturbed stream habitats, and as a consequence, sites dominated by green sunfish are likely to be degraded. However, the western mosquitofish (*Gambusia affinis*), an efficient colonizer highly tolerant of degraded conditions, was an ideal indicator species for each of the watersheds and both habitat types. Mosquitofish do not naturally occur in Midwestern streams, but they are almost always present and sometimes common in most Texas streams. Therefore, following Winemiller and Gelwick (1998), the percentage of mosquitofish to indicate domination by a tolerant, ubiquitous species under degraded conditions were used. Percentage of omnivores serves as an indicator of altered community trophic structure, with high percentages reflecting a degraded system. Even under pristine conditions, many of the rivers and streams of the Edwards and Twin Buttes watersheds commonly contain two species of omnivorous minnows, red shiners (*Cyprinella lutrensis*) and bullhead minnows (*Pimephales vigilax*). The scoring criteria used for Midwestern streams was modified to allow a relatively high percentage of omnivorous fishes to be associated with a relatively high degree of ecological integrity (reflected in scoring criteria in Table 4.3). Because scoring criteria for the percentage of omnivores had to be adjusted upward for our region, the percentage of invertebrate feeders (invertivores) had to be adjusted downward. Because fish samples from Twin Buttes riffles only contained invertivores, we did not include trophic characterization as a metric for F-IBI scores (Table 4.3).

Table 4.3. Individual metrics and associated scoring criteria for habitat-specific and basin specific fish IBI calculation. Due to the varying number of metrics used per group, scores vary such that the maximum possible score is scaled to 100 points.

	Riffle IBI Scoring Criteria*					Run/Pool IBI Scoring Criteria**				
	16.6	11.6	8.3	3.3	0	10	7	5	2	0
Number of native species	6+	4-5	3	2	1	9+	7-8	5-6	3-4	0-2
Number of darter species	2		1		0	2		1		0
Number of sunfish species	2		1		0	4+	3	2	1	0
Number of intolerant species	4+	3	2	1	0	4+	3	2	1	0
Percent tolerant species	0-39	40-49	50-69	70-79	80-100	0-39	40-49	50-69	70-79	80-100
Percent green sunfish	not used					0-1	2-9	10-19	20-29	30-100
Percent mosquitofish	0-1	2-9	10-19	20-29	30-100	0-1	2-9	10-19	20-29	30-100
Percent omnivores	not used					0-9	10-19	20-29	30-39	40-100
Percent invertivores	not used					81-100	50-80	20-49	10-19	0-9
Percent carnivores	not used					7-100	4-6	2-3	.1-1	0

* 6 Metrics Used

**10 Metrics Used

Unlike Lyons (1992), these F-IBI scores were not adjusted based on the total density of fishes in seine samples. Lyons reasoned that Wisconsin streams with better biological integrity should support more individual fishes. In contrast, some of the least impacted streams in the study regions actually yielded samples with fewer individual fishes. It appears that in central Texas, streams with good integrity can have high fish densities (often unshaded sites with high primary productivity), or they can have low fish densities (highly shaded sites with clear water and little algal production). Furthermore, because streams of the region may naturally be dominated by soft substrates (sand, clay, and mud), the percentage of lithophilous spawning fishes may not be a valid indicator of fish community health. Most of the native fishes of our region are capable of completing their life cycles in systems with little or no clean hard substrates. Therefore, the percentage of lithophils was not employed as an F-IBI metric here.

Species assignments for the species richness metrics are given in Table 4.4, and species assignments for trophic metrics are given in Table 4.5. Refer to Lyons (1992) and Winemiller and Gelwick (1998) for additional justification of the F-IBI metrics and scoring rationale. The criteria used for qualitative assessment of stream biological integrity from F-IBI scores are given in Table 4.6. This numerical scale for scoring integrity categories derives from Lyons (1992).

Development of Invertebrate IBI (B-IBI)

In recent years, IBIs have been developed based on benthic invertebrates (e.g., Lenat 1993) rather than fishes as originally proposed by Karr (1981). A rationale for focusing on benthic invertebrates is that many of these taxa are highly sensitive to landscape impacts that affect streams, such as siltation and poor water quality (Ohio EPA 1988, Fore et al. 1996, Chessman 1999, Whiles et al. 2000). A benthic macroinvertebrate IBI (B-IBI) score was calculated for each site using the pooled Surber samples and a series of metrics that reflect the essential structural and functional features of the invertebrate assemblage. Metrics employed for the Edward's and Twin Buttes B-IBIs are described in Table 4.7. Metrics were selected from previously developed benthic macroinvertebrate IBIs (Kerans and Karr 1994, Barbour et al. 1999, Lammert and Allan 1999). As in these previous efforts, this benthic invertebrate IBI dealt with taxonomy at the family and ordinal scales of resolution. Species-level identification of aquatic invertebrates requires a high degree of systematic expertise, a requirement that reduces the transferability, efficiency, and speed of ecological assessments (i.e., key motivations for IBI development). Preexisting B-IBIs were modified based on the range of values observed in our samples. Again, because different regions and habitats normally support different numbers of species and ecological forms, basin-specific and habitat-specific scoring criteria were employed (Table 4.7).

Seven previously recommended metrics were chosen to be included in the B-IBI. Following Kerans and Karr (1994), dominance was defined as the proportion of individuals in the most abundant taxon. Measures of relative abundance of select taxa have are widely used in B-IBIs (Plafkin et al. 1989, Kerans and Karr 1994, Barbour et al. 1999, Lammert and Allan 1999). The following relative abundance metrics were included: percent unionid muscles, percent corbiculid clams, percent Ephemeroptera, and percent chironomids. Negative anthropogenic impacts on lentic systems are expected to result in increased dominance, percent corbiculid clams, and percent chironomids within benthic macroinvertebrate communities, whereas less impacted systems are expected to have higher proportions of unionid muscles and Ephemeroptera taxa. We employed two richness measures: trichopteran family richness and total taxonomic richness. Both of these richness measures are expected to decline with anthropogenic impacts to lentic systems (Kerans and Karr 1994, Barbour et al. 1999).

Multivariate analysis of aquatic assemblages (CCA analyses)

Canonical correspondence analysis (CCA) was used to evaluate the relationships between species, samples, and environmental conditions at the time of sampling. The input data used to estimate the regression equation are presented in Appendix I for Scenarios IV and V. CCA is a direct gradient analysis technique that constrains the ordering of species and site scores to yield maximum correlation with environmental variables (ter Braak and Milauer 1998). In CCA, species abundances are assumed to be a unimodal function of environmental gradients, and environmental factors likely contributing to the observed gradient are measured and included in the analysis. Environmental variables included in these analyses were: mean stream width (wetted portion of channel reach), coefficient of variation in stream width (wetted portion), mean water depth, water depth coefficient of variation, mean water velocity, water velocity coefficient of variation, percentages of substrate composed of sand, mud, clay, pebble, cobble and bedrock, percentage of substrate covered by detritus, water temperature, dissolved oxygen content of water, water pH, and water conductivity. A separate CCA analyses were conducted for fish species collected in seine samples and invertebrate taxa collected in Surber samples. Results from these analyses permit ordination of species and sites in relation to dominant environmental gradients, and reveal the set of environmental factors associated with the structure of fish and invertebrate assemblages among our samples.

Interpretation of the importance of environmental parameters included in the CCA analysis is based upon t-values of canonical coefficients (ter Braak and Milauer 1998). Because canonical coefficients have larger variance than regression coefficients, a simple Student t-test is inappropriate. Nonetheless, canonical coefficient t-values $\geq |2.1|$ indicate the environmental variable has an effect and contributes to the fit of species and sample scores (ter Braak and Milauer 1998). In Tables 4.8 (fish) and 4.9 (invertebrates) we presented only those environmental variables with absolute t-values ≥ 2.1 .

Table 4.4. Assignment of fish species for IBI species richness metric.

<u>Non-native:</u>	<i>Cyprinus carpio</i>
<u>Darters:</u>	<i>Etheostoma lepidum</i> <i>Etheostoma spectabile</i> <i>Percina carbonaria</i> <i>Noturus nocturnus*</i>
<u>Suckers:</u>	<i>Moxostoma congestum</i>

Sunfish: *Lepomis auritus*
 Lepomis cyanellus
 Lepomis gulosus
 Lepomis macrochirus
 Lepomis megalotis
 Lepomis microlophus

Intolerant: *Astyanax mexicanus*
 Campostoma anomalum
 Cyprinella lepida
 Cyprinella venusta
 Dionda argentosa
 Dionda serena
 Etheostoma lepidum
 Etheostoma spectabile
 Mircopterus punctulatus
 Mircopterus treculi
 Notropis amabilis
 Notropis ludibundus
 Noturus nocturnes
 Percina carbonaria

Tolerant: *Ameirus natalis*
 Ameirus melas
 Cyprinella lutrensis
 Cyprinus carpio
 Gambusia affinis
 Lepomis cyanellus
 Lepisosteus oculatus
 Pimephales vigilax

Not placed: *Dorosoma cepedianum*, *Herichthys cyanoguttatum*, *Ictalurus punctatus*, *Lepomis hybrid*,
 Micropterus salmoides, *Notemigonus crysoleucas*

* Madtom included with darters

Table 4.5. Assignment of fish species for IBI trophic structure metric.

<u>Omnivores:</u>	<i>Cyprinus carpio</i> <i>Cyprinella lutrensis</i> <i>Dorosoma cepedianum</i> <i>Notemigonus crysoleucas</i> <i>Moxostoma congestum</i> <i>Pimephales vigilax</i>
<u>Invertivores:</u>	<i>Ameirus natalis</i> <i>Ameirus melas</i> <i>Astyanax mexicanus</i> <i>Campostoma anomalum</i> <i>Cyprinella lepida</i> <i>Cyprinella venusta</i> <i>Dionda argentosa</i> <i>Dionda serena</i> <i>Etheostoma lepidum</i> <i>Etheostoma spectabile</i> <i>Gambusia affinis</i> <i>Herichthys cyanoguttatum</i> <i>Ictalurus punctatus</i> <i>Lepomis auritus</i> <i>Lepomis hybrid</i> <i>Lepomis macrochirus</i> <i>Lepomis megalotis</i> <i>Lepomis microlophus</i> <i>Notropis amabilis</i> <i>Notropis ludibundus</i> <i>Noturus nocturnus</i> <i>Percina carbonaria</i>
<u>Top carnivores:</u>	<i>Lepomis cyanellus</i> <i>Lepomis gulosus</i> <i>Lepisosteus oculatus</i> <i>Mircopterus punctulatus</i> <i>Micropterus salmoides</i> <i>Mircopterus treculi</i>

Table 4.6. Interpretation of IBI Scores.

Fish IBI Score criteria and assignment:

IBI Score	Assessment	Color	Fish Community and Stream Attribute
75-100	Excellent	Blue	Comparable to the best situations with minimal human disturbance; most of the regionally expected species for habitat and stream size, including the most intolerant forms, are present with a balanced trophic structure.
60-74	Good	Green	Species richness somewhat below expectation, especially due to the loss of the most intolerant forms; some species, especially top carnivores, are present with less than optimal abundances; trophic structure may show signs of imbalance.
40-59	Fair	Yellow	Signs of additional deterioration include decreased species richness, loss of intolerant forms, increased abundance of tolerant species, and/or highly skewed trophic structure (e.g., greater frequency of omnivores and lower frequency of invertebrate feeders and carnivores).
25-39	Poor	Orange	Relatively few species; dominated by omnivores, tolerant forms, and habitat generalists; few or no top carnivores.
0-24	Very Poor	Red	Very few species present, mostly exotic or tolerant forms; few large or old fish; diseased fish common.

Invertebrate IBI Score criteria and assignment:

IBI Score	Assessment	Color	Fish Community and Stream Attribute
28-35	Excellent	Blue	Comparable to the best situations with minimal human disturbance; most of the regionally expected species for habitat and stream size, including the most intolerant forms, are present with a balanced trophic structure.
22-27	Good	Green	Species richness somewhat below expectation, especially due to the loss of the most intolerant forms; some species, especially top carnivores, are present with less than optimal abundances; trophic structure may show signs of imbalance.
18-21	Fair	Yellow	Signs of additional deterioration include decreased species richness, loss of intolerant forms, increased abundance of tolerant species, and/or highly skewed trophic structure (e.g., greater frequency of omnivores and lower frequency of invertebrate feeders and carnivores).
14-17	Poor	Orange	Relatively few species; dominated by omnivores, tolerant forms, and habitat generalists; few or no top carnivores.
0-13	Very Poor	Red	Very few species present, mostly exotic or tolerant forms; few large or old fish; diseased fish common.

Table 4.12. Mean observed F-IBI score by sub-basin, and F-IBI scores by scenario by sub-basin as predicted by the two factor (cedar and mewquite) model.

Watershed	Sub-basin		Observed	Scenario I	Scenario II	Scenario III	Scenario IV	Scenario V
	Number							
Edwards	2010301		76	68	67	67	63	62
Edwards	2010401		60	65	64	64	60	59
Edwards	2010501		68	71	71	71	68	66
Edwards	2010601		64	68	67	67	64	63
Edwards	2020201		66	70	73	73	68	65
Edwards	2020303		79	75	74	73	68	65
Edwards	6010101		77	75	75	74	71	68
Edwards	6010301		63	69	68	68	65	64
Edwards	6010501		61	67	66	66	63	62
Edwards	6010503		61	68	68	68	65	64
Edwards	6010801		75	73	73	73	69	67
Edwards	6060101		65	65	64	64	60	59
Edwards	6060201		62	64	63	63	59	59
Edwards	6060301		61	72	72	72	69	66
Edwards	6060501		59	77	76	74	72	68
Edwards	7060105		59	69	68	68	60	59
Twin Buttes	MC 25		40	76	74	64	54	36
Twin Buttes	MC 27		60	76	75	64	53	36
Twin Buttes	SC 16		71	77	75	66	55	39
Twin Buttes	SD 13		43	76	74	65	51	36
Twin Buttes	SD 15		44	76	76	66	57	39
Twin Buttes	SD 21		66	77	76	66	58	41

Figure 1

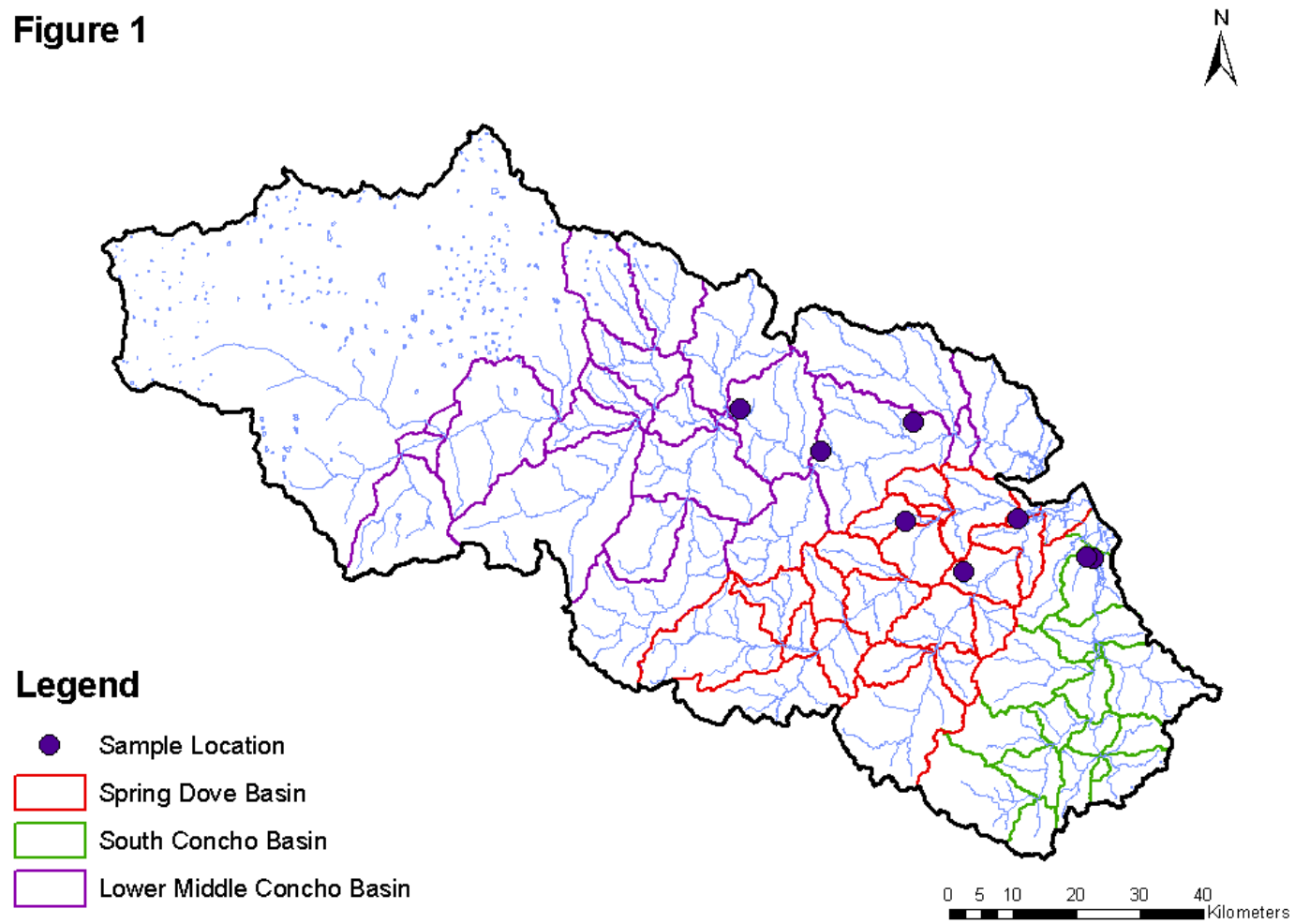


Figure 4.1. Twin Buttes watershed with basin and sub-basin boundaries and aquatic biological survey locations illustrated. Sample locations are represented by filled circles. Typically, multiple samples were collected at each location.

Figure 2

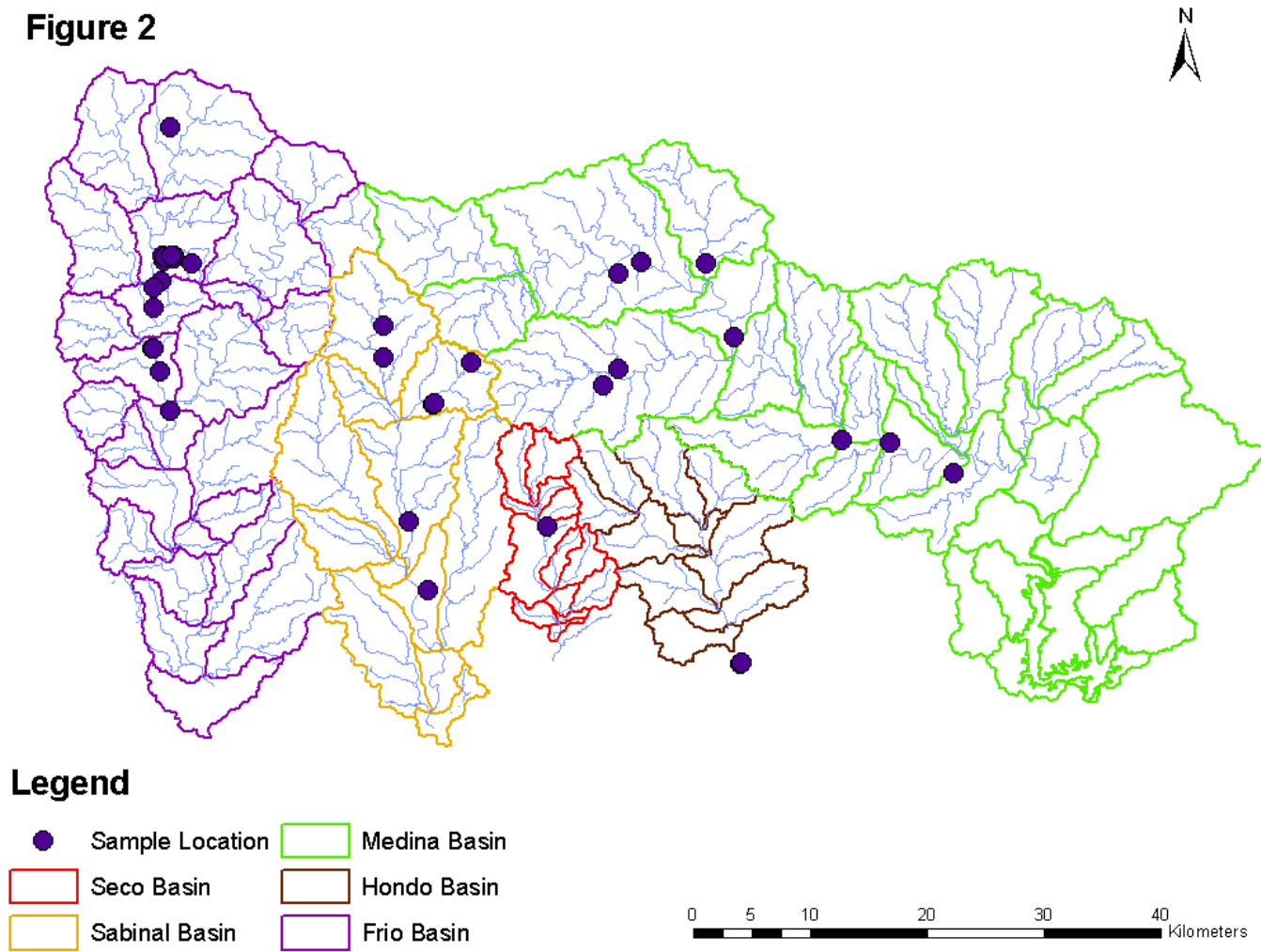


Figure 4.2 Edwards watershed with basin and sub-basin boundaries and aquatic biological survey locations illustrated. Sample locations are represented by filled circles. Typically, multiple samples were collected at each location.

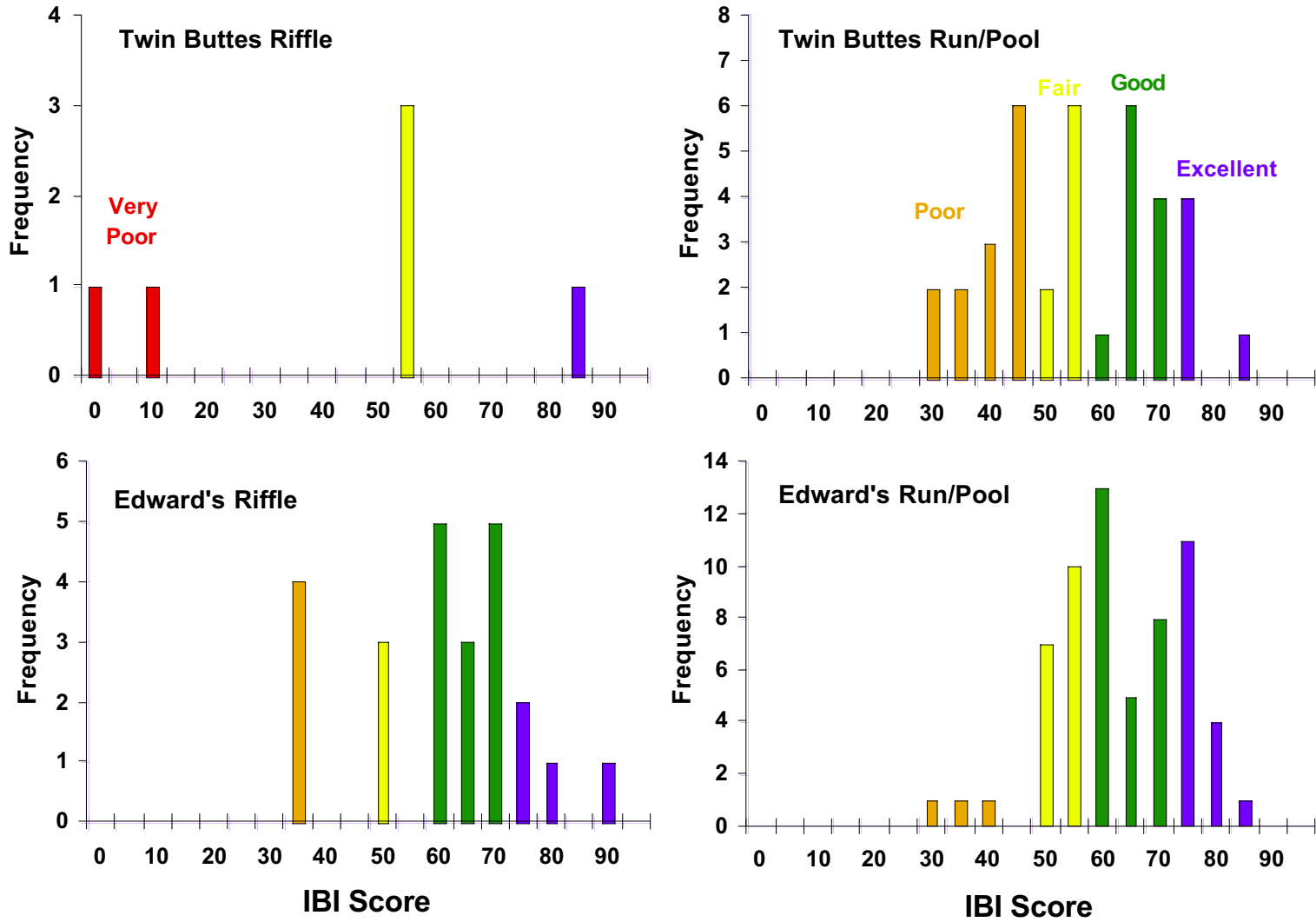


Figure 4.3. Frequency histograms of F-IBI scores by drainage by habitat.

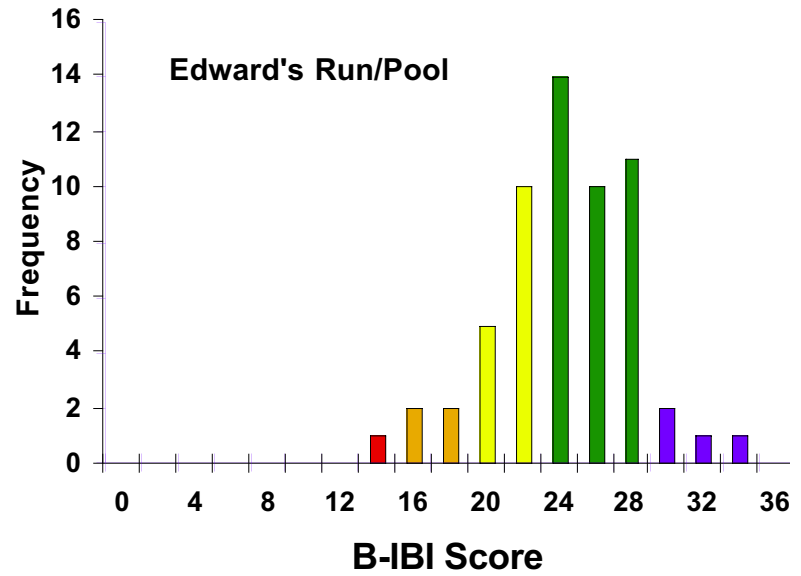
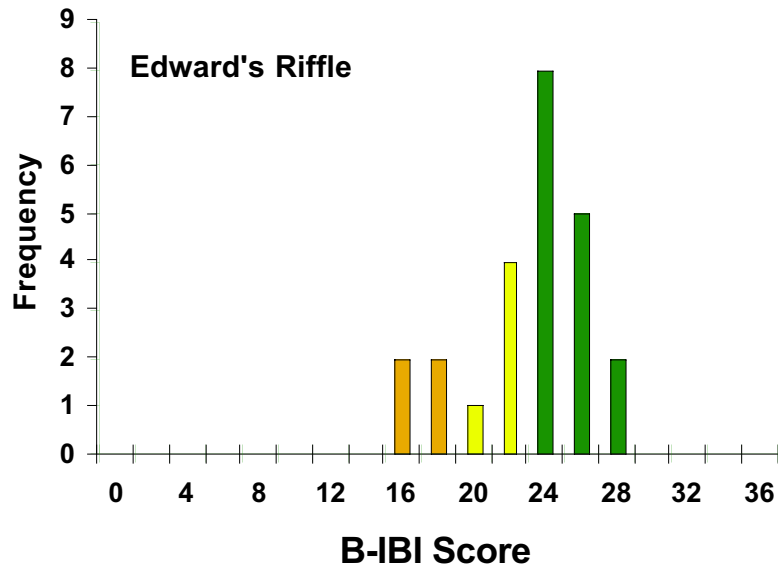
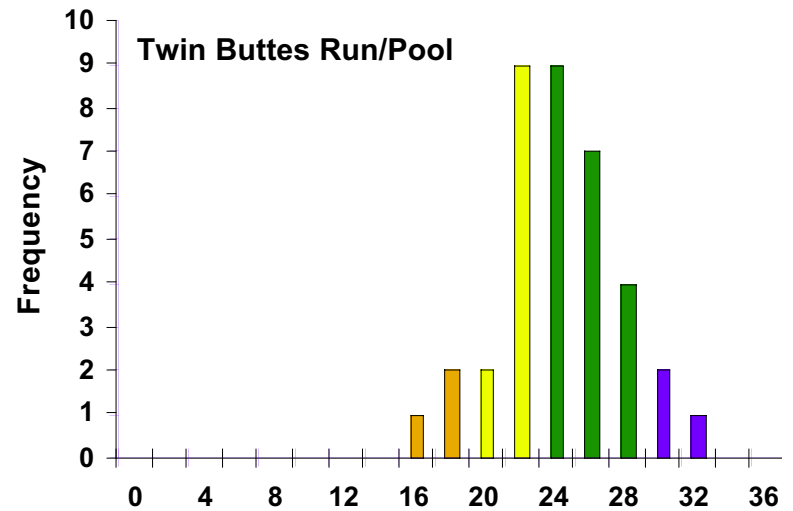
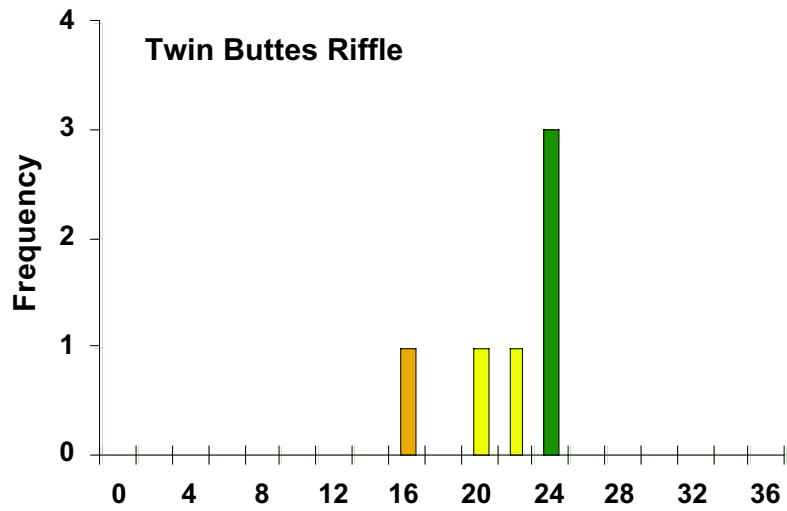


Figure 4.4. Frequency histograms of B-IBI scores by drainage by habitat.

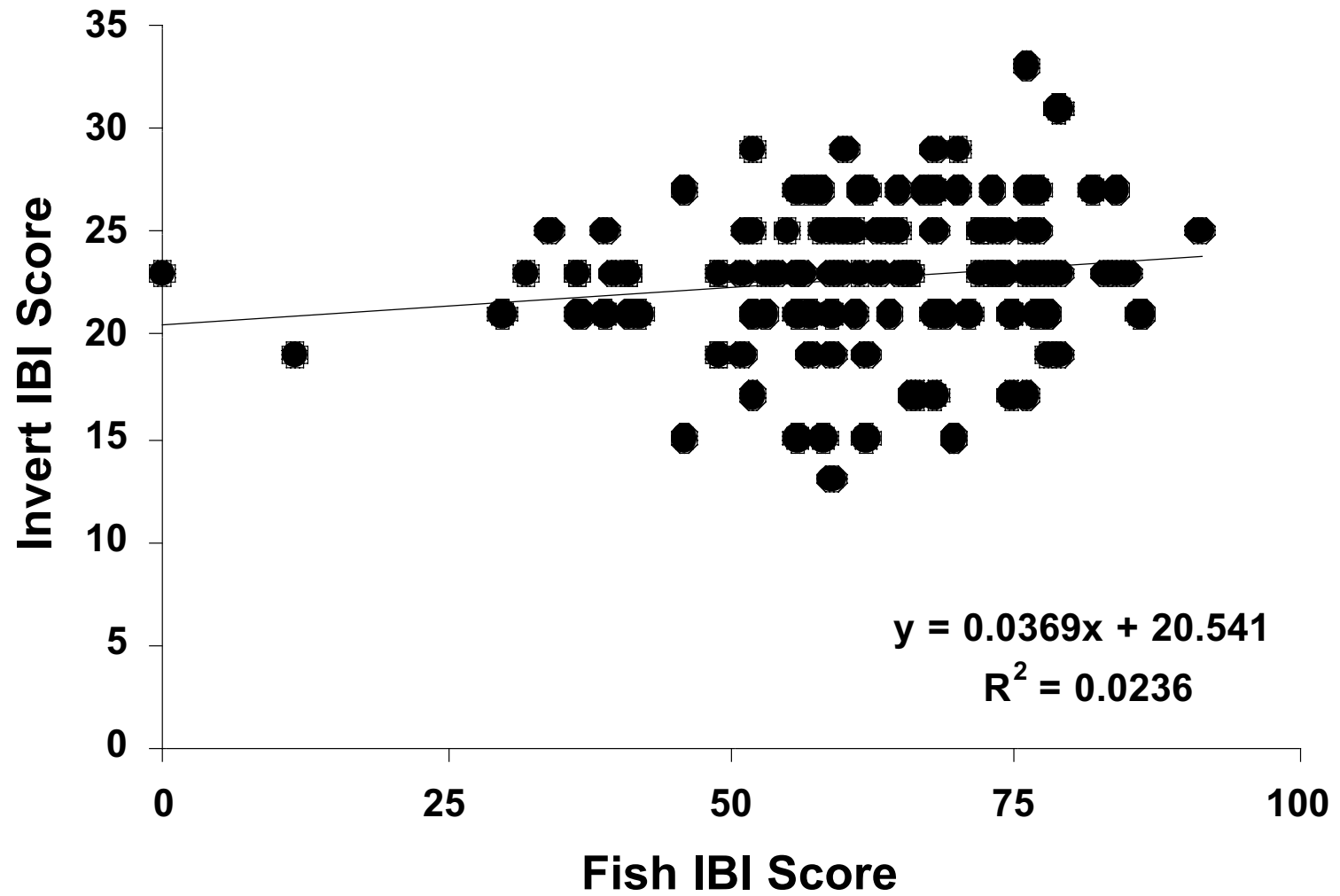


Figure 4.5. Relationship between calculated fish (F-IBI) and benthic macroinvertebrate (B-IBI) IBI scores. There was little concordance between fish and invertebrate IBI scores ($R^2 = 0.024$; $P = 0.09$).

Figure 5

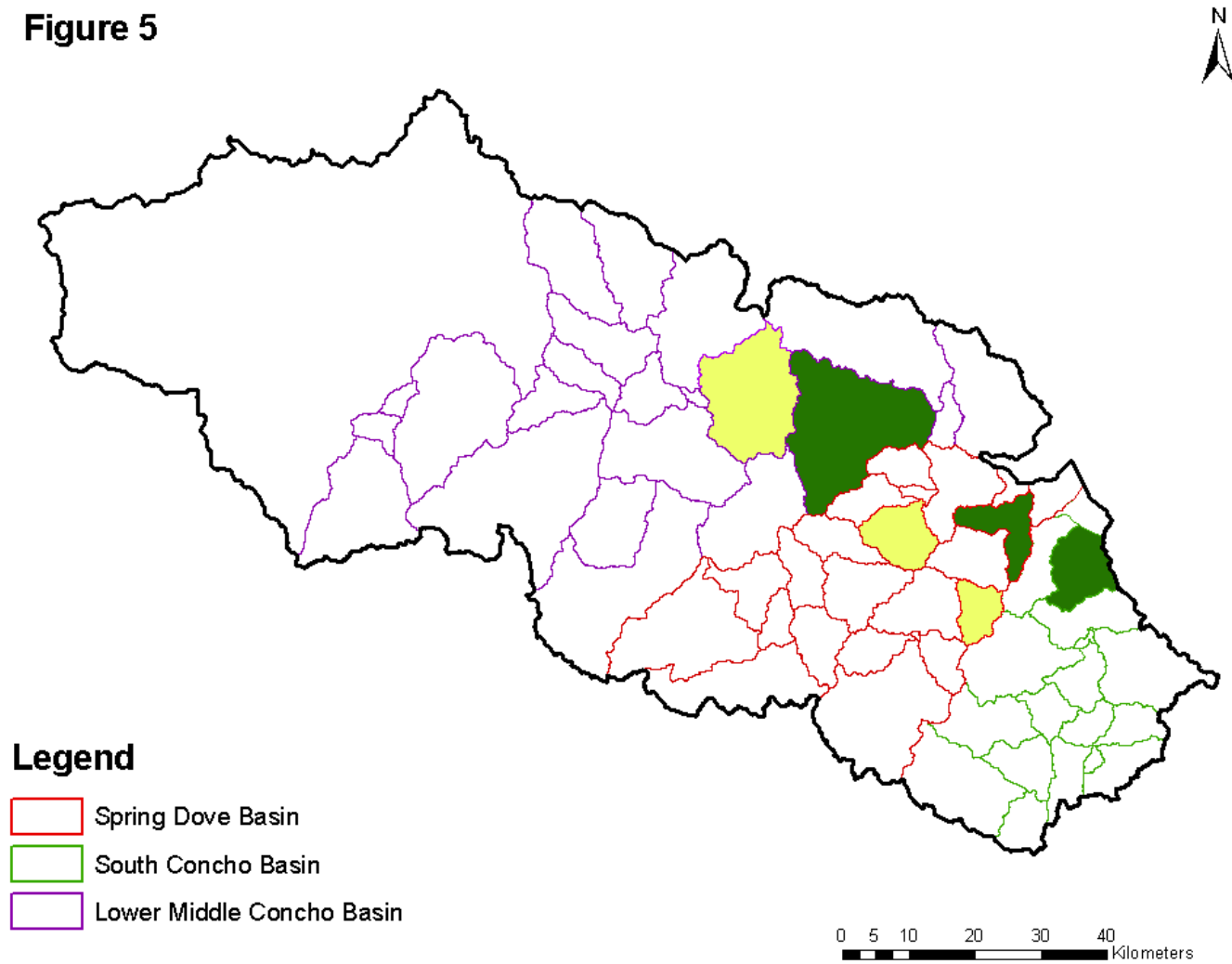


Figure 4.6. Twin Buttes sub-basins colored by the minimum F-IBI score.

Figure 6

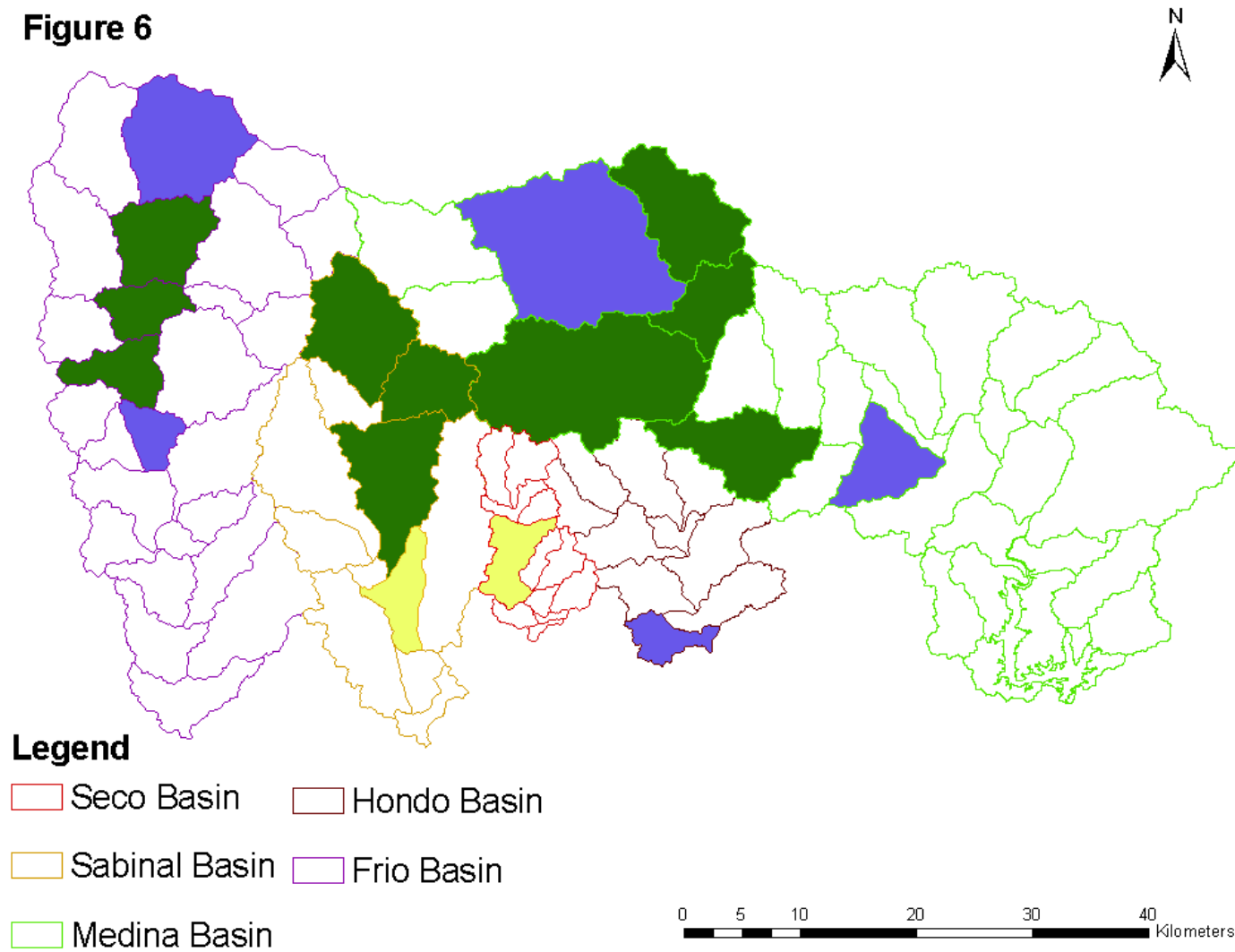


Figure 4.7. Edwards sub-basins colored by the minimum F-IBI score.

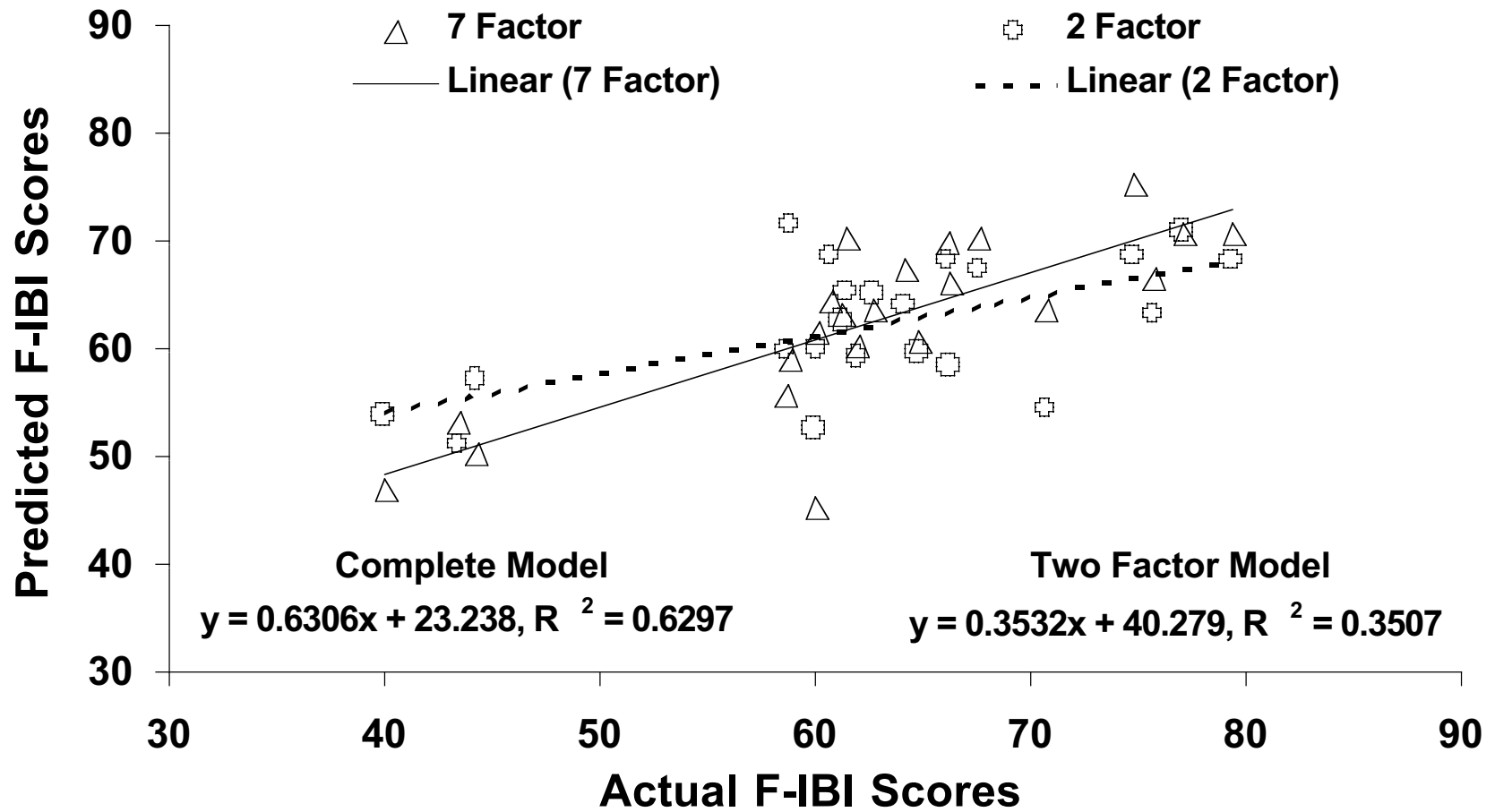


Figure 4.8. Relationship between observed and predicted F-IBI scores by sub-basin for both the complete seven factor model and the selected two factor (cedar and mesquite) model.

Twin Buttes Fish CCA

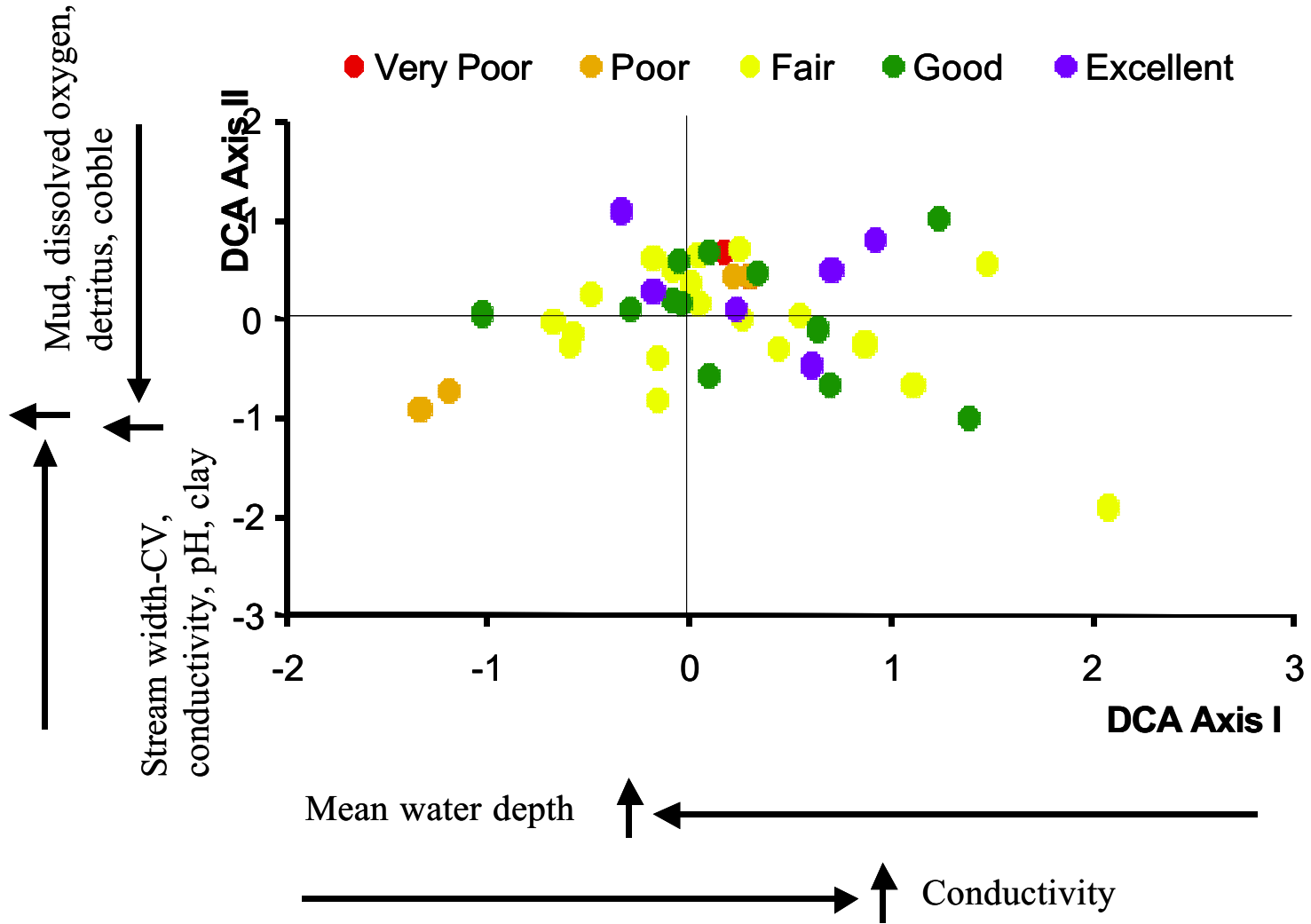


Figure 4.9. Twin Buttes CCA analysis results indicating the influence of physical habitat parameters on fish assemblages and the observed relationship between these parameters on observed F-IBI scores.

Edwards Fish CCA

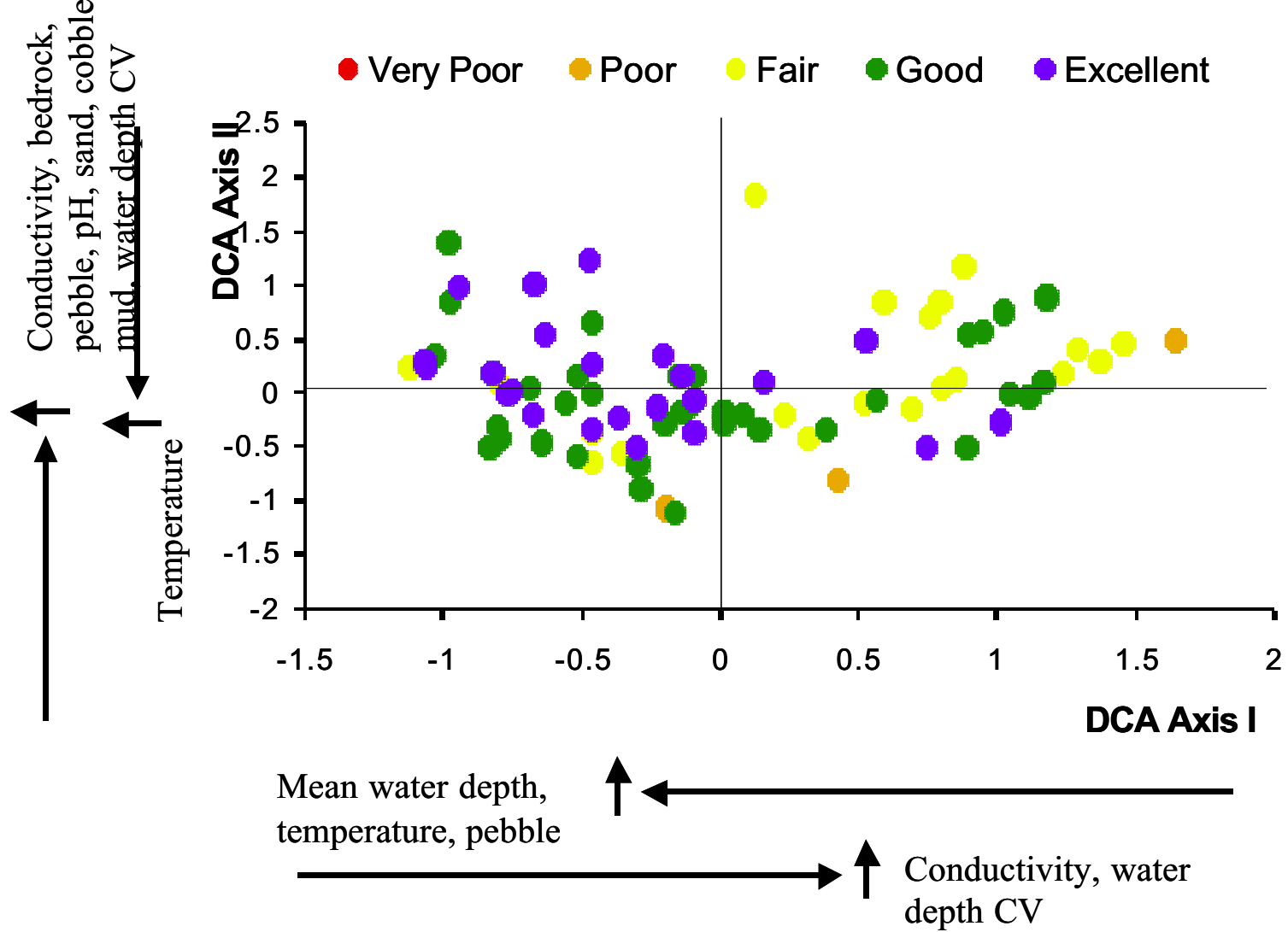


Figure 4.10. Edwards CCA analysis results indicating the influence of physical habitat parameters on fish assemblages and the observed relationship between these parameters on observed F-IBI scores.

Twin Buttes Invertebrate CCA

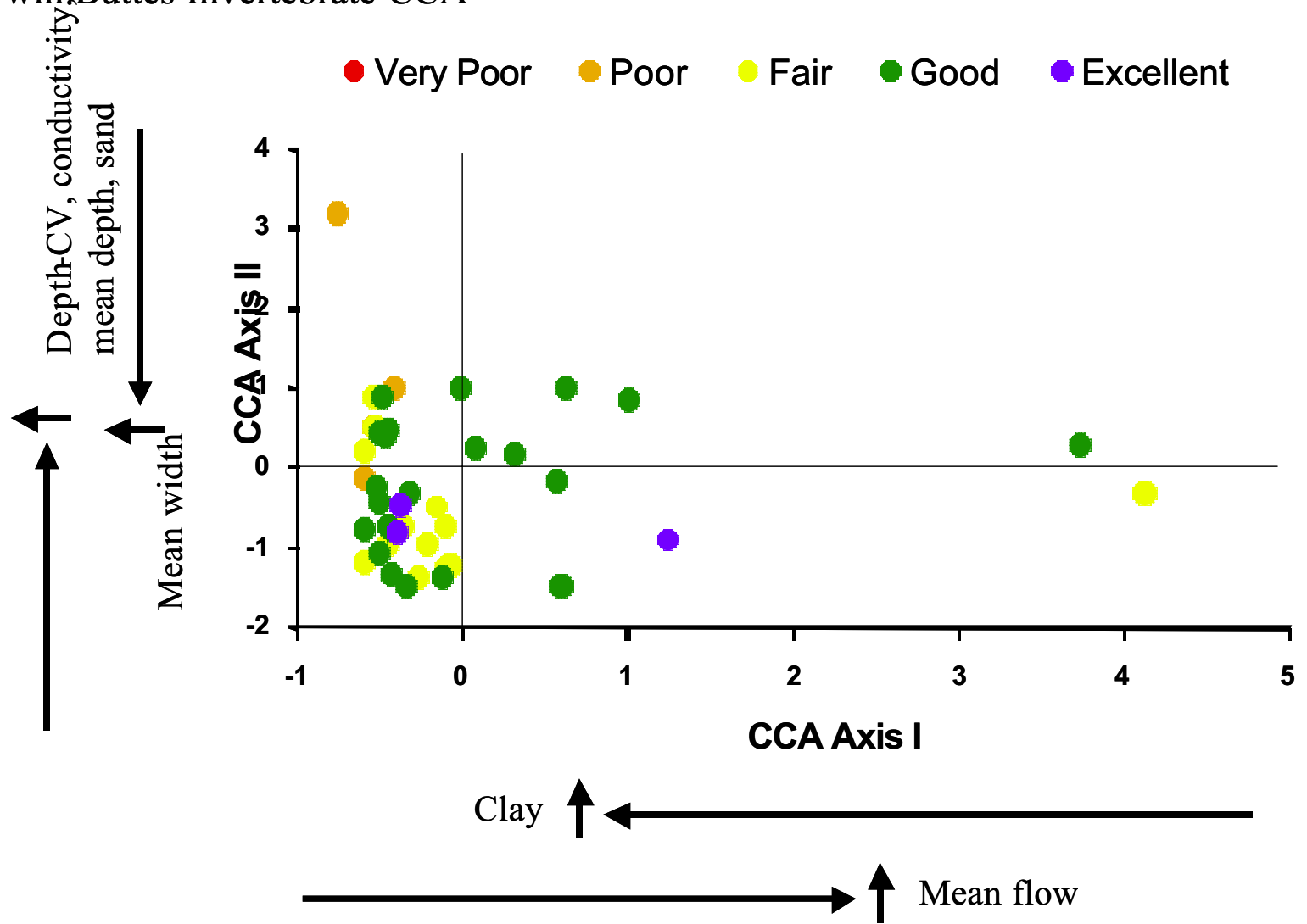


Figure 4.11. Twin Buttes CCA analysis results indicating the influence of physical habitat parameters on invertebrate assemblages and the observed relationship between these parameters on observed B-IBI scores.

Edwards Invertebrate CCA

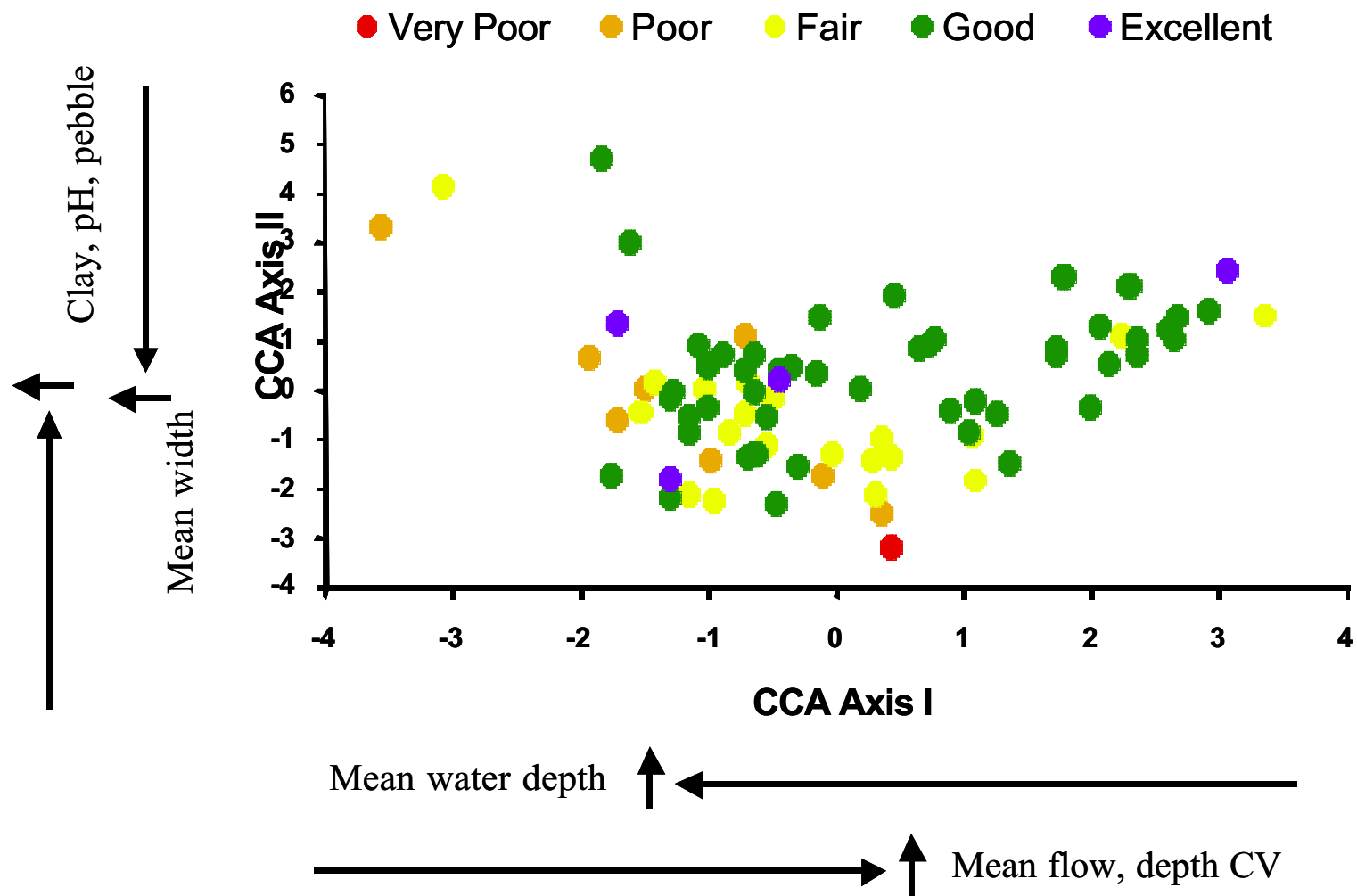


Figure 4.12. Edwards CCA analysis results indicating the influence of physical habitat parameters on invertebrate assemblages and the observed relationship between these parameters on observed B-IBI scores.

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APPENDIX A. Refinement of Riparian Areas

Participants:

TAES

Olenick, Keith L.
Hamilton, Wayne T.
Wilkins, Neal
Conner, J. Richard
Kreuter, Urs P.

Introduction

This appendix is to supplement the range/economics chapter of the report. In this section, various riparian-specific restoration treatments are incorporated to existing brush management/restoration practices for Scenarios II and III for all watersheds within both study areas.

Specifically, the objectives of this supplement effort are to identify the different broad riparian types in both watersheds with respect to soils, water flows, landform type, vegetation, and management emphasis. Appropriate treatments and associated costs for all riparian types are then summarized. Finally, total society cost of each scenario and society cost for added acre-feet of water for all watersheds within both study areas assuming the identified riparian restoration treatments are conducted are estimated and compared across treatments and with Scenarios II and III in Chapter II.

Methods

Methodology used in Chapter II to calculate total society cost and cost of additional water closely mirrors that which is used in this appendix. The key difference in this section is the treatment of light, moderate, and heavy brush occurring within the 150m riparian buffer. For Scenarios II and III in Chapter II, all brush occurring in the buffer was not treated and no other treatments were performed. Here, total acres of light, moderate, and heavy brush occurring in the riparian buffer zone on slopes less than 15% were summed to form an estimated total treatable riparian acres figure for Scenarios II and III (in this section of the report, these scenarios will be referred to as Scenario II Rip and Scenario III Rip). This figure was then multiplied by a study area-specific estimated percentage of each riparian type to arrive at total acres of each riparian condition. Treatment costs for each riparian condition were calculated by multiplying the amount of each riparian type occurring in each sub-basin by the treatment cost for that riparian type. Next, riparian restoration treatment costs were added to estimated society costs for the non-riparian areas to arrive at a total society cost of additional water. Like Chapter II, the total society cost of additional water was divided by the additional acre feet yielded from Scenario II and III to estimate the society cost per additional acre-foot of water.

For non-riparian buffer zone areas, assumptions for changes in livestock carrying capacity, brush management/restoration techniques and costs, livestock/wildlife enterprises, and discount rate are identical to those used in Chapter II. Like Chapter II, this analysis also assumes restoration treatments such as reseeding, grazing deferments, and implementation of improved grazing management systems were used for non-riparian areas.

Recommended riparian restoration treatments and associated costs were identified by range scientists. Because existing riparian types differ between the Edwards and the Twin Buttes, different assumptions are used for each (Tables A1 and A2). Cross fencing and additional water source costs are identical to those used in Chapter II. Cost of buffer fencing was determined by taking the stream length distance of one acre in the riparian zone assumed to be 150m wide. Next, this distance was multiplied by the cost of fencing (\$1.25) and then by the number of sides of the corridor (2). Ten year grazing deferment costs were calculated by taking the inverse of the grazing capacity of the riparian type to compute the number of animal units that one acre of that riparian type would support. Next, a yearly lease value of \$100 was

multiplied by the number of animal units that could be supported by the acre. This product was then discounted for each of the ten years in the investment analysis using the 6% discount rate assumed in Chapter II.

Costs associated with treating riparian acres were assumed to be entirely society costs. Where grazing deferments exists, an explicit assumption is that the society will pay the cost of deferments directly to landowners.

The Blackland Research Center provided the data used to determine the amount of brush located in the buffer zone. Acres of brush to be treated with riparian treatments was calculated by first taking the total amount of light, moderate, and heavy brush located in the riparian area. Next, this sum was multiplied by the percentage of all brush in a particular sub-basin occurring on slopes less than 15% to arrive at an estimated amount of treatable acres of riparian brush. Similar to Chapter II, all treatments are only conducted on sub-basins that receive an average yearly rainfall of 18 inches or more.

Assumptions for water yield used for Scenarios II Rip and III Rip are identical to those assumed for Scenario II and III in Chapter II. Because the relatively small amounts restoration treatments performed in the eight watersheds will not dramatically alter vegetation over Scenarios II and III, we feel this is a safe assumption.

Results and Discussion

Riparian Types

Twin Buttes

The Twin Buttes was divided into three broad riparian conditions. Riparian Type I is described as a shallow draw. Angelo Silty Clay Loam [AnB] is usually associated with a Type I riparian area. It is a first order stream zone whose flow is ephemeral, usually flowing for short periods following major rainfalls. Its landform is a shallow draw with parabolic valley floor having 3-5% channel gradient (max ~8%). It has very few channel cuts and is straight with few meanders. Land classified as Type I generally does not contain "riparian" woody plants, but are often dominated at their upper ends by mesquite and redberry juniper. Dominant grasses include sideoats grama, Texas wintergrass and Wrights threawn. The management emphasis includes mechanical control of juniper and mesquite regrowth adjacent to channel as well as prescribed fire or individual plant treatments.

Riparian Type II, dry creeks and draws, are generally 2nd order streams with Rio Concho and Angelo soils [RV, RO][AnA, AnB]. It has intermittent surface flow with a moderately confined channel. The stream channel is identifiable and has some meandering. Stream gradient is 1-3% (max~5%). Woody shrubs include lotebush, juniper, mesquite, Texas persimmon, and dominant grasses include buffalograss and vinemesquite. The management emphasis for Type II riparian areas in the Twin Buttes include the thinning of juniper and mesquite, buffer fencing where possible, grazing deferment, and prescribed fire or individual plant treatments.

Riparian Type III are areas having perennial streams that are primarily 3rd order, though some are of higher order. Soils are almost exclusively Rio Concho [RV, RO]. The perennial stream flow may pool at infrequent intervals. The associated landform of Type III is a relatively broad flood plain with unconfined channels and a 1-3% channel gradient. Woody indicators include hackberry, walnut, oak, and pecan, which increases in abundance down stream. In addition, large juniper and mesquite can be found as well as littleleaf sumac. Herbs include vinemesquite, buffalograss, sideoats grama, cane bluestem, and Texas wintergrass. The management emphasis includes selective removal of juniper and buffer fencing, though excluded areas may be flash-grazed at multi-year intervals. Individual plant treatments are the recommended follow-up treatment.

Edwards

Four broad riparian classifications exist in the Edwards. Type I is characterized by largely unmapped headwaters that are primarily 1st order streams. Various upland soils including Tarrant-Rock and Brackett [TSX, BKX] are associated with this riparian type. Water flow is ephemeral, generally flowing for short periods following major rainfall events. The landform is V-shaped with small valleys, steep sided slopes, and highly confined channels. There are no woody plant indicators for Type I, though this riparian classification is often dominated at the upper end by large juniper. The management emphasis calls for mechanical control of juniper adjacent to the channel and follow-up treatments of prescribed fire or individual plant treatments.

Type II riparian areas contain small streams of 2nd order. Dominant soils are Brackett [BRX, BKX] at the upper end, Krum-Denton [KRX] in the middle ranges, and Frio [FR] at the lower ends. Flow is intermittent. Landforms are highly variable, but include a moderately confined channel with parabola shaped valleys that may be incised if overgrazed. Channel gradient is 3-7% (Max~10%). Woody plant indicators include elm and black walnut. Understory vegetation of Type II areas in good condition are tall grasses (switchgrass, eastern gama). Management emphasis should be the establishment of tallgrass on upper reaches of stream segments, buffer fencing, and prescribed fire or individual plant treatments as follow-up treatments.

Riparian classification III areas are 3rd order perennial streams. Soils are almost exclusively Frio [FR]. Relatively broad flood plains, unconfined channels, and a 1-5% channel gradient (max~7%) characterize the landform. Woody indicators include elm, walnut, pecan, and bald cypress, though bald cypress is more commonly found at the down stream end of this riparian type. Buffer fencing is recommended with flash-grazing for 3 to 4 days out of the year. Selective removal juniper should be followed in later years by individual plant treatments. Tallgrass species should be reestablished.

Type IV riparian areas contain large rivers characterized by Frio [FR] and Orif-Karnes [OKX] soils. Water flow is perennial. Broad alluvial plains with substantial channel disturbance zones are the dominant landforms. Examples include the Medina and Frio rivers. Woody indicators include willow and sycamore in disturbance zone with adjacent cypress and pecan on terraces. Management should emphasize the protection of woody riparian vegetation. Buffer fencing is recommended.

Ecological Restoration

In addition to brush control, reseeding, and improved grazing management systems, this appendix incorporates additional riparian restoration practices including the establishment of buffer fencing and flash-grazing or total absence of grazing restrictions.

Brush control treatments chosen for all riparian types is selective. Tree shearing and excavation, also known as grubbing, of cedar and mesquite will lower the abundance of these species, thus making room for other riparian woody plants. Redberry juniper, the dominant juniper species found in the Twin Buttes, will need to be stump-sprayed with herbicide if tree shearing is chosen.

Seeded grasses for both areas will include native tallgrass species such as switchgrass, Indiangrass, littlebluestem, and Eastern gama. The establishment of these grasses on upper reaches of streams will produce a ready seed source for downstream areas.

The construction of a buffer fence around certain riparian types will enable the riparian unit to be treated as a separate unit for management purposes. Where flash-grazing is recommended, livestock will be only be allowed to graze for several days each year. This restriction should facilitate the success of seeded tallgrasses and help currently existing grasses recover. In addition, highly palatable woody species will be able to recover with substantially lower grazing pressure.

Twin Buttes

The amounts of light, moderate, and heavy brush occurring in the riparian buffer zone on slopes less than 15% to be treated under Scenarios II Rip and III Rip in this analysis are 39,087, 11,727, and 18,712 acres for the Middle Concho, South Concho, and Spring/Dove Creeks, respectively (Table A3). For the entire Twin Buttes study area, the amount of restored riparian acres is 69,529 acres.

Edwards

Riparian treatments total 12,177, 2,901, 21,752, 6,292 and 1,241 for the Frio, Hondo, Medina, Sabinal, and Seco watersheds, respectively (Table A3). Total riparian land treated was 44,363 acres for the entire Edwards.

Total Society Cost and Society Cost of Added Water

Twin Buttes

Middle Concho. For Scenarios II Rip and III Rip, total society costs are \$53M and \$25.8M, respectively (Tables A4a and A4b). The incremental society cost of riparian treatments, which was equal to total society cost of Scenario II Rip minus the total society cost of Scenario II (or Scenario III Rip minus Scenario III) is \$9.7M. Costs per additional acre-foot of water associated with Scenario II Rip and Scenario III Rip were \$194 and \$218, respectively.

South Concho. Total society costs for Scenario II Rip and Scenario III Rip were \$17.6M and \$9.1M, respectively (Tables 5a and 5b). Incremental society cost of riparian treatments for the South Concho was \$3.2M. Costs per additional acre-foot of water were \$77 for Scenario II Rip and \$97 for Scenario III Rip.

Spring/Dove Creeks. Total society costs for implementing brush management/restoration Scenarios II Rip and III Rip were \$28.6M and \$14.9M respectively (Tables 4a and 4b). The society cost of the riparian restoration treatments was \$5.1M. Estimates for cost per additional acre-foot of water for the two scenarios were \$101 and \$125, respectively.

Large differences between Scenarios II Rip and III-Rip are similar to the trend existing between Scenarios II and III presented in Chapter 2 (Figure A1). Compared with Scenario II, total society costs for Scenario II Rip were between 22% (Spring/Dove Creeks) and 23% (Middle Concho and South Concho) more expensive. For Scenario III Rip, percentage increases in total society costs over Scenario III ranged from 53% (Spring/Dove Creeks) to 61% (Middle Concho). The range of percentage costs increases for cost of added acre-feet of water for Scenarios II Rip and III Rip over Scenarios II and III, respectively, are identical to those for the total society Costs (Figure A3). The South Concho watershed yielded the lowest cost of additional acre-feet of water for both Scenarios II Rip and III Rip.

Edwards

Frio. For Scenarios II Rip and III Rip, total society costs were \$13.8M and \$13.2M, respectively (Table A5a and A5b). Society costs of treating riparian areas was \$3.8M. Costs per additional acre-foot of water for the two scenarios were \$70 and \$69, respectively.

Hondo. Total society costs were \$4.3M for Scenario II Rip and \$4.2M for Scenario III Rip (Tables 6a and 6b). Riparian restoration treatments cost was \$0.9M. Cost per additional acre-foot of water for Scenarios II Rip and III Rip were \$41 and \$42, respectively.

Medina. For Scenarios II Rip and III Rip, total society costs were \$29.8M and \$28.9M, respectively (Tables 7a and 7b). Riparian treatments cost \$6.7M. Cost per additional acre-foot of water are estimated for Scenario II Rip at \$46 and Scenario III Rip costs at \$47.

Sabinal. Total society costs were \$8.0M and \$7.7M for Scenarios II Rip and III Rip, respectively (Tables 8a and 8b). Costs of riparian treatments were \$2.0M. An estimated \$60 was the cost per additional acre-foot of water for both Scenarios.

Seco. For Scenarios II Rip and III Rip, total society costs were \$1.7M and \$1.7M, respectively (Tables 9a and 9b). Riparian treatments for both scenarios were \$0.3M. Cost per additional acre-foot of water was \$56 for both Scenarios.

Total society costs for Scenarios II Rip and III Rip are very similar for all watersheds within the Edwards (Figure A1). Compared with Scenario II, Scenario II Rip is between 24% (Seco) and 38% (Frio) more expensive. For Scenario III Rip, percentage increases over Scenario III ranged from 24% (Seco) to 40% (Frio). Like the Twin Buttes, the range of percentage costs increases for cost of added acre-feet of water for Scenarios II Rip and III Rip over Scenarios II and III, respectively, are identical to those for the total society Costs (Figure A3). From a water production viewpoint, the Hondo and Medina watersheds were more efficient at yielding additional water.

Comparison Across Watersheds

As might be expected, the amount of restored riparian areas were higher for the combined Twin Buttes' watersheds than for the entire Edwards. The percentage increase of riparian acres treated is 57% more for the combined three watersheds of the Twin Buttes than the five Edwards' watersheds.

When comparing the different watersheds of the Twin Buttes and Edwards, the most expensive watershed to implement Scenario II Rip is the Middle Concho while the Medina is the most costly for Scenario III Rip (Figure A1). When comparing total society costs for the entire Edwards and the entire Twin Buttes, Scenario II Rip for the Twin Buttes cost 72% more than Scenario II Rip for the Edwards (Figures A3 and A4). In contrast, Scenario III Rip for the entire Edwards study area is 12% more costly than Scenario III Rip for the combined Twin Buttes' watersheds.

Society cost of additional acre-feet of water for each of the Edwards' watershed was cheaper than for any of the Twin Buttes watersheds (Figure A2). When combining watersheds into their respective study area, society cost of additional acre-feet of water for Scenario II Rip in the Twin Buttes was 143% more expensive than Scenario II Rip in the Edwards. The percentage difference for Scenario III Rip was an even greater 189%.

Conclusion

While the methodology used in this section to determine cost implications for two brush management/restoration scenarios was very similar to that used in Chapter II, the restoration treatments assumed are much different. In the model presented in this appendix, restoration treatments were conducted in the riparian buffer zone in addition to other brush management and restoration practices performed in Chapter II.

By incorporating the riparian type-specific restoration recommendations, treated riparian areas will be restored closer to a historical climax vegetative community. The total amount of treated riparian areas is larger for the Twin Buttes than the Edwards.

Total society cost and cost for additional water added were very similar for Scenarios II Rip and III Rip in the Edwards' watersheds. Significant differences existed between Scenarios II Rip and III Rip in the Twin Buttes' watersheds due to the large difference in upland brush treated. When comparing entire study areas, total society costs for Scenario II Rip were much higher for the Twin Buttes while the Edwards was slightly higher for Scenario III Rip. Similar to the results reached in Chapter II, the cost of added water was much cheaper for Scenarios II Rip and III Rip in the Edwards.

Additional Considerations

The estimated proportions of each riparian condition type are most useful on a watershed and study area spatial scale. Because of variations of amounts and types of streams in individual sub-basins, useful comparisons between total society costs and society costs of additional water added on a sub-basin scale are subject to error.

Table A1. Cost of Water Yield Brush Control Programs by Riparian Condition - Twin Buttes.

% of Type I Riparian Area	65%	% of Type III Riparian Area	10%
% of Type II Riparian Area	25%		
Riparian Condition I - Mechanical¹			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Tree Shearing	125.00	125.00
0	Reseeding	20.00	20.00
0	Cross Fencing	3.88	3.88
0	Additional Water Source	2.66	2.66
0	Deferment (30 acres per AU Y)	3.33	3.33
3	IPT or Burn	25.00	20.99
7	IPT or Burn	20.00	13.30
		Total	189.16
¹ Tree shearing with stump spray and later burn, or excavation and later burn.			
Riparian Condition II - Mechanical¹			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Tree Shearing	125.00	125.00
0	Reseeding	20.00	20.00
0	Buffer fencing	221.29	221.29
0	Additional Water Source	2.66	2.66
0-10	Deferment (25 acres per AU Y)	4.00	31.21
3	IPT or Burn	25.00	20.99
7	IPT or Burn	20.00	13.30
		Total	434.45
¹ Tree shearing with stump spray and later burn, or excavation and later burn.			
Riparian Condition III - Mechanical¹			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Tree Shearing	125.00	125.00
0	Reseeding	20.00	20.00
0	Buffer fencing	221.29	221.29
0	Additional Water Source	2.66	2.66
0-10	Deferment (20 ac per AU Y)	5.00	39.01
3	IPT	25.00	20.99
7	IPT	20.00	13.30
		Total	442.25
¹ Tree shearing with stump spray and later burn, or excavation and later burn.			

Table A2. Cost of Water Yield Brush Control Programs by Riparian Condition - Twin Buttes.

% of Type I Riparian Area	65%	% of Type III Riparian Area	10%
% of Type II Riparian Area	25%		
Riparian Condition I - Mechanical¹			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Tree Shearing	125.00	125.00
0	Reseeding	20.00	20.00
0	Cross Fencing	3.88	3.88
0	Additional Water Source	2.66	2.66
0	Deferment (30 acres per AUy)	3.33	3.33
3	IPT or Burn	25.00	20.99
7	IPT or Burn	20.00	13.30
	Total		189.16
¹ Tree shearing with stump spray and later burn, or excavation and later burn.			
Riparian Condition II - Mechanical¹			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Tree Shearing	125.00	125.00
0	Reseeding	20.00	20.00
0	Buffer fencing	221.29	221.29
0	Additional Water Source	2.66	2.66
0-10	Deferment (25 acres per AUy)	4.00	31.21
3	IPT or Burn	25.00	20.99
7	IPT or Burn	20.00	13.30
	Total		434.45
¹ Tree shearing with stump spray and later burn, or excavation and later burn.			
Riparian Condition III - Mechanical¹			
Year	Treatment	Treatment Cost(\$)/Acre	Present Value(\$)/Acre
0	Tree Shearing	125.00	125.00
0	Reseeding	20.00	20.00
0	Buffer fencing	221.29	221.29
0	Additional Water Source	2.66	2.66
0-10	Deferment (20 ac per AUy)	5.00	39.01
3	IPT	25.00	20.99
7	IPT	20.00	13.30
	Total		442.25
¹ Tree shearing with stump spray and later burn, or excavation and later burn.			

Table A3. Treated Riparian Acres for Scenarios II-Rip and III-Rip.

	ED-FRIO	ED-HONDO	ED-MEDINA	ED-SABINAL	ED-SECO	MIDDLE CONCHO	SOUTH CONCHO	SPRIND/DOVE CREEKS
Acres of treated riparian brush in scenarios II rip and III rip	12,177	2,901	21,752	6,292	1,241	39,087	11,727	18,712

Table A4a. Cost of Added Water From Brush Control By Subbasin (Acre-Foot).

Middle Concho - Scenario 2 With Riparian Restoration Treatments					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	0	0	0	0	-
2	427,116	88,557,647	272	2,120	201
3	0	0	0	0	-
4	0	0	0	0	-
5	451,012	75,140,439	231	1,799	251
6	0	0	0	0	-
7	1,800,533	209,399,223	643	5,013	359
8	191,823	29,308,982	90	702	273
9	1,912,289	279,524,263	858	6,692	286
10	85,924	11,999,008	37	287	299
11	0	0	0	0	-
12	1,913,561	282,373,163	866	6,760	283
13	1,836,307	339,474,264	1,042	8,127	226
14	959,436	180,372,534	553	4,318	222
15	651,577	117,245,591	360	2,807	232
16	4,479,460	805,759,130	2,472	19,289	232
17	2,302,156	547,573,838	1,680	13,108	176
18	3,409,287	683,536,070	2,097	16,363	208
19	905,588	180,676,019	554	4,325	209
20	101,357	22,984,786	71	550	184
21	2,952,863	570,809,580	1,751	13,665	216
22	1,815,599	461,625,349	1,416	11,051	164
23	5,752,176	1,665,624,936	5,111	39,873	144
24	3,394,902	892,989,955	2,740	21,377	159
25	3,915,082	988,256,018	3,032	23,658	165
26	4,762,132	1,103,388,621	3,386	26,414	180
27	5,798,890	1,266,327,999	3,886	30,315	191
28	2,813,816	501,190,114	1,538	11,998	235
Total	52,632,885			270,609	194

Table A4b. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot).

Middle Concho - Scenario 3 With Riparian Restoration Treatments					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	0	0	0	0	-
2	193,682	35,112,688	108	841	230
3	0	0	0	0	-
4	0	0	0	0	-
5	110,321	0	0	0	-
6	0	0	0	0	-
7	427,988	0	0	0	-
8	77,187	0	0	0	-
9	510,759	0	0	0	-
10	33,264	0	0	0	-
11	0	0	0	0	-
12	721,124	87,000,778	267	2,083	346
13	1,211,920	212,954,335	653	5,098	238
14	602,986	97,457,549	299	2,333	258
15	194,388	5,159,438	16	124	1,574
16	1,006,483	0	0	0	-
17	1,218,922	264,918,935	813	6,342	192
18	1,786,119	317,758,785	975	7,607	235
19	496,005	80,669,006	248	1,931	257
20	53,975	10,887,432	33	261	207
21	1,182,536	166,083,987	510	3,976	297
22	850,505	190,582,942	585	4,562	186
23	3,216,043	881,715,726	2,705	21,107	152
24	2,154,250	559,393,687	1,716	13,391	161
25	2,342,141	542,779,712	1,665	12,994	180
26	2,676,630	616,657,109	1,892	14,762	181
27	3,445,555	709,979,540	2,179	16,996	203
28	1,257,885	168,760,988	518	4,040	311
Total	25,770,667			118,447	218

Table A5a. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot).

South Concho - Scenario 2 With Riparian Restoration Treatments					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	1,019,283	598,961,040	1,838	14,338	71
2	381,582	254,471,687	781	6,092	63
3	1,129,122	763,866,554	2,344	18,286	62
4	863,495	486,914,198	1,494	11,656	74
5	850,286	441,565,269	1,355	10,571	80
6	126,303	62,703,385	192	1,501	84
7	695,251	372,899,956	1,144	8,927	78
8	564,146	336,871,727	1,034	8,064	70
9	628,070	310,829,681	954	7,441	84
10	828,453	365,822,898	1,123	8,757	95
11	2,369,405	1,574,829,042	4,832	37,700	63
12	836,080	477,061,384	1,464	11,420	73
13	2,648,933	1,184,195,959	3,634	28,348	93
14	82,068	35,550,868	109	851	96
15	1,379,267	775,219,423	2,379	18,558	74
16	1,551,566	813,793,215	2,497	19,481	80
17	1,275,170	635,716,079	1,951	15,218	84
18	336,471	68,625,815	211	1,643	205
Total	17,564,953			228,854	77

Table A5b. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot).

South Concho - Scenario 3 With Riparian Restoration Treatments					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	294,566	0	0	0	-
2	62,658	0	0	0	-
3	416,532	197,292,290	605	4,723	88
4	408,472	177,572,447	545	4,251	96
5	452,990	169,202,732	519	4,051	112
6	64,284	31,234,879	96	748	86
7	222,791	22,714,382	70	544	410
8	208,088	78,350,790	240	1,876	111
9	359,864	154,412,946	474	3,696	97
10	533,646	201,054,441	617	4,813	111
11	1,300,312	764,926,085	2,347	18,312	71
12	466,467	239,242,397	734	5,727	81
13	1,566,714	617,334,557	1,894	14,778	106
14	66,719	24,651,101	76	590	113
15	846,118	435,341,897	1,336	10,422	81
16	965,445	451,228,529	1,385	10,802	89
17	754,734	333,778,659	1,024	7,990	94
18	157,671	26,101,404	80	625	252
Total	9,148,070			93,947	97

Table A6a. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot).

South Concho - Scenario 2 With Riparian Restoration Treatments					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	1,019,283	598,961,040	1,838	14,338	71
2	381,582	254,471,687	781	6,092	63
3	1,129,122	763,866,554	2,344	18,286	62
4	863,495	486,914,198	1,494	11,656	74
5	850,286	441,565,269	1,355	10,571	80
6	126,303	62,703,385	192	1,501	84
7	695,251	372,899,956	1,144	8,927	78
8	564,146	336,871,727	1,034	8,064	70
9	628,070	310,829,681	954	7,441	84
10	828,453	365,822,898	1,123	8,757	95
11	2,369,405	1,574,829,042	4,832	37,700	63
12	836,080	477,061,384	1,464	11,420	73
13	2,648,933	1,184,195,959	3,634	28,348	93
14	82,068	35,550,868	109	851	96
15	1,379,267	775,219,423	2,379	18,558	74
16	1,551,566	813,793,215	2,497	19,481	80
17	1,275,170	635,716,079	1,951	15,218	84
18	336,471	68,625,815	211	1,643	205
Total	17,564,953			228,854	77

Table A6b. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot).

South Concho - Scenario 3 With Riparian Restoration Treatments					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	294,566	0	0	0	-
2	62,658	0	0	0	-
3	416,532	197,292,290	605	4,723	88
4	408,472	177,572,447	545	4,251	96
5	452,990	169,202,732	519	4,051	112
6	64,284	31,234,879	96	748	86
7	222,791	22,714,382	70	544	410
8	208,088	78,350,790	240	1,876	111
9	359,864	154,412,946	474	3,696	97
10	533,646	201,054,441	617	4,813	111
11	1,300,312	764,926,085	2,347	18,312	71
12	466,467	239,242,397	734	5,727	81
13	1,566,714	617,334,557	1,894	14,778	106
14	66,719	24,651,101	76	590	113
15	846,118	435,341,897	1,336	10,422	81
16	965,445	451,228,529	1,385	10,802	89
17	754,734	333,778,659	1,024	7,990	94
18	157,671	26,101,404	80	625	252
Total	9,148,070			93,947	97

Table A7a. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot).

Frio - Scenario 2 With Riparian Restoration Treatments					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	1,697,166	993,747,761	3,049	23,789	71
2	1,111,287	642,336,279	1,971	15,377	72
3	581,339	295,626,757	907	7,077	82
4	664,999	372,311,349	1,142	8,913	75
5	304,216	198,671,857	610	4,756	64
6	237,400	137,175,094	421	3,284	72
7	327,118	225,041,564	691	5,387	61
8	704,056	475,642,141	1,459	11,386	62
9	676,656	374,891,345	1,150	8,974	75
10	860,529	478,079,745	1,467	11,445	75
11	94,956	53,132,441	163	1,272	75
12	301,536	155,872,124	478	3,731	81
13	625,629	371,757,207	1,141	8,899	70
14	408,164	333,347,074	1,023	7,980	51
15	186,459	104,789,824	322	2,509	74
16	222,447	144,550,541	444	3,460	64
17	654,099	593,470,085	1,821	14,207	46
18	608,300	383,484,533	1,177	9,180	66
19	198,471	145,121,723	445	3,474	57
20	152,648	113,910,096	350	2,727	56
21	285,823	182,696,422	561	4,374	65
22	536,458	248,227,007	762	5,942	90
23	397,977	189,677,616	582	4,541	88
24	497,589	237,166,355	728	5,678	88
25	842,397	439,292,694	1,348	10,516	80
26	640,800	312,342,334	958	7,477	86
Total	13,818,520			196,356	70

Table A7b. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot).

Frio - Scenario 3 With Riparian Restoration Treatments					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	1,451,217	835,249,117	2,563	19,995	73
2	1,015,597	583,116,558	1,789	13,959	73
3	581,339	305,134,261	936	7,305	80
4	664,999	383,437,149	1,177	9,179	72
5	304,216	205,453,452	630	4,918	62
6	237,400	141,324,820	434	3,383	70
7	327,118	232,775,761	714	5,572	59
8	560,559	363,206,296	1,114	8,695	64
9	541,973	283,507,274	870	6,787	80
10	860,529	491,409,053	1,508	11,764	73
11	94,956	54,917,624	169	1,315	72
12	301,536	160,042,828	491	3,831	79
13	625,629	384,256,591	1,179	9,199	68
14	408,164	344,788,729	1,058	8,254	49
15	186,459	108,151,588	332	2,589	72
16	222,447	149,408,964	458	3,577	62
17	654,099	611,904,665	1,878	14,648	45
18	608,300	395,765,572	1,214	9,474	64
19	198,471	149,751,843	460	3,585	55
20	152,648	117,495,332	361	2,813	54
21	285,823	188,982,573	580	4,524	63
22	536,458	259,157,763	795	6,204	86
23	397,977	196,276,006	602	4,699	85
24	497,589	246,448,445	756	5,900	84
25	842,397	454,822,313	1,396	10,888	77
26	640,800	324,890,070	997	7,778	82
Total	13,198,700			190,833	69

Table A8a. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot).

Hondo - Scenario 2 With Riparian Restoration Treatments					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	310,766	299,697,220	920	7,174	43
2	164,166	129,337,919	397	3,096	53
3	373,561	415,609,256	1,275	9,949	38
4	415,859	428,786,401	1,316	10,265	41
5	327,951	257,661,586	791	6,168	53
6	160,325	233,445,728	716	5,588	29
7	855,715	970,987,965	2,979	23,244	37
8	476,558	440,726,057	1,352	10,551	45
9	676,832	738,988,447	2,268	17,691	38
10	506,186	427,637,116	1,312	10,237	49
Total	4,267,920			103,964	41

Table A8b. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot).

Hondo - Scenario 3 With Riparian Restoration Treatments					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	310,766	299,697,220	920	7,174	43
2	164,166	129,337,919	397	3,096	53
3	373,561	415,609,256	1,275	9,949	38
4	415,859	428,786,401	1,316	10,265	41
5	327,951	257,661,586	791	6,168	53
6	93,797	111,947,278	344	2,680	35
7	855,715	970,987,965	2,979	23,244	37
8	476,558	440,726,057	1,352	10,551	45
9	676,832	738,988,447	2,268	17,691	38
10	506,186	427,637,116	1,312	10,237	49
Total	4,201,392			101,055	42

Table A9a. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot).

Medina - Scenario 2 With Riparian Restoration Treatments					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	1,701,891	1,049,035,495	3,219	25,113	68
2	1,134,017	688,762,673	2,113	16,488	69
3	1,829,509	1,126,386,688	3,456	26,964	68
4	791,369	500,282,238	1,535	11,976	66
5	570,542	621,706,130	1,908	14,883	38
6	1,839,687	1,396,666,006	4,286	33,435	55
7	883,163	801,913,165	2,461	19,197	46
8	1,167,633	1,071,079,174	3,287	25,640	46
9	915,379	890,682,429	2,733	21,322	43
10	696,568	634,258,100	1,946	15,183	46
11	578,705	636,863,550	1,954	15,246	38
12	933,919	871,043,791	2,673	20,852	45
13	1,522,814	1,412,119,188	4,333	33,805	45
14	1,347,784	1,437,272,258	4,410	34,407	39
15	335,742	305,916,628	939	7,323	46
16	1,207,965	1,193,573,568	3,662	28,573	42
17	785,120	755,469,025	2,318	18,085	43
18	754,466	673,780,472	2,067	16,130	47
19	477,020	453,574,395	1,392	10,858	44
20	3,184,491	3,373,054,349	10,350	80,747	39
21	1,180,980	1,126,649,341	3,457	26,971	44
22	838,392	885,596,177	2,717	21,200	40
23	645,193	518,803,539	1,592	12,420	52
24	545,186	523,857,310	1,607	12,541	43
25	812,699	749,127,626	2,299	17,933	45
26	613,452	510,632,109	1,567	12,224	50
27	745,617	885,421,339	2,717	21,196	35
28	953,003	924,076,908	2,835	22,121	43
29	468,673	339,976,967	1,043	8,139	58
30	82,851	93,135,712	286	2,230	37
31	127,612	110,880,472	340	2,654	48
32	200,004	443,382,713	1,360	10,614	19
Total	29,871,445			646,470	46

Table A9b. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot).

Medina - Scenario 3 With Riparian Restoration Treatments					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	1,701,891	1,049,035,495	3,219	25,113	68
2	1,134,017	688,762,673	2,113	16,488	69
3	1,829,509	1,126,386,688	3,456	26,964	68
4	791,369	500,282,238	1,535	11,976	66
5	570,542	621,706,130	1,908	14,883	38
6	1,839,687	1,396,666,006	4,286	33,435	55
7	883,163	801,913,165	2,461	19,197	46
8	1,167,633	1,071,079,174	3,287	25,640	46
9	915,379	890,682,429	2,733	21,322	43
10	588,121	493,463,124	1,514	11,813	50
11	578,705	636,863,550	1,954	15,246	38
12	853,408	788,683,337	2,420	18,880	45
13	1,522,814	1,412,119,188	4,333	33,805	45
14	1,266,351	1,346,453,230	4,131	32,233	39
15	240,618	163,375,677	501	3,911	62
16	1,133,801	1,117,309,667	3,428	26,747	42
17	785,120	755,469,025	2,318	18,085	43
18	754,466	673,780,472	2,067	16,130	47
19	443,244	422,511,727	1,296	10,114	44
20	3,184,491	3,373,054,349	10,350	80,747	39
21	1,021,228	960,957,978	2,949	23,004	44
22	741,724	778,411,742	2,388	18,634	40
23	621,825	506,332,189	1,554	12,121	51
24	545,186	523,857,310	1,607	12,541	43
25	812,699	749,127,626	2,299	17,933	45
26	613,452	510,632,109	1,567	12,224	50
27	645,178	767,301,360	2,354	18,368	35
28	829,468	815,437,619	2,502	19,521	42
29	468,673	339,976,967	1,043	8,139	58
30	82,851	93,135,712	286	2,230	37
31	127,612	110,880,472	340	2,654	48
32	200,004	443,382,713	1,360	10,614	19
Total	28,894,227			620,713	47

Table 10a. Cost of Added Water From Brush Control By Subbasin (Acre-Foot).

Sabinal - Scenario 2 With Riparian Restoration Treatments					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	749,269	446,689,576	1,371	10,693	70
2	189,423	105,290,583	323	2,521	75
3	370,718	241,107,277	740	5,772	64
4	1,241,001	987,179,110	3,029	23,632	53
5	976,479	760,240,821	2,333	18,199	54
6	374,843	356,720,371	1,095	8,539	44
7	129,607	74,440,755	228	1,782	73
8	585,037	573,271,967	1,759	13,724	43
9	1,649,113	1,017,060,451	3,121	24,347	68
10	384,635	304,732,214	935	7,295	53
11	1,019,605	514,125,566	1,578	12,308	83
12	293,314	127,126,119	390	3,043	96
Total	7,963,046			131,855	60

Table A10b. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot).

Sabinal - Scenario 3 With Riparian Restoration Treatments					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	749,269	458,463,614	1,407	10,975	68
2	189,423	107,450,484	330	2,572	74
3	370,718	248,062,817	761	5,938	62
4	1,241,001	1,004,584,207	3,082	24,049	52
5	976,479	775,416,609	2,379	18,563	53
6	374,843	364,338,044	1,118	8,722	43
7	108,806	62,341,557	191	1,492	73
8	372,051	331,900,708	1,018	7,945	47
9	1,649,113	1,036,435,284	3,180	24,811	66
10	337,293	266,298,000	817	6,375	53
11	1,019,605	528,818,380	1,623	12,659	81
12	293,314	130,962,007	402	3,135	94
Total	7,681,918			127,237	60

Table A11a. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot).

Seco - Scenario 2 With Riparian Restoration Treatments					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	156,967	114,843,246	352	2,749	57
2	161,990	128,118,572	393	3,067	53
3	128,025	75,848,332	233	1,816	71
4	79,490	53,339,468	164	1,277	62
5	504,381	391,662,334	1,202	9,376	54
6	125,246	72,408,344	222	1,733	72
7	136,638	89,656,937	275	2,146	64
8	99,363	90,464,468	278	2,166	46
9	140,958	95,427,779	293	2,284	62
10	48,268	37,690,257	116	902	53
11	110,319	57,414,774	176	1,374	80
12	58,681	43,647,482	134	1,045	56
Total	1,750,326			29,936	58

Table A11b. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot).

Seco - Scenario 3 With Riparian Restoration Treatments					
Subbasin No.	Total Society Cost (Dollars)	Added Gallons/Acre/Year	Added Acre/Feet/Year	10 year Added Water (Acre-Feet)	Society Cost for Added Water (Dollars Per Acre Foot)
1	156,923	114,843,246	352	2,749	57
2	161,990	128,118,572	393	3,067	53
3	128,025	75,848,332	233	1,816	71
4	79,490	53,339,468	164	1,277	62
5	504,381	391,662,334	1,202	9,376	54
6	125,246	72,408,344	222	1,733	72
7	136,638	89,656,937	275	2,146	64
8	99,363	90,464,468	278	2,166	46
9	140,958	95,427,779	293	2,284	62
10	48,268	37,690,257	116	902	53
11	110,319	57,414,774	176	1,374	80
12	58,681	43,647,482	134	1,045	56
Total	1,750,282			29,936	58

APPENDIX B: SPECIES DETECTED IN TWIN BUTTES AND ANALYSES

Appendix B1: Species detected in Twin Buttes spring surveys. Bird species listed in descending order according to number of individuals detected. 295 survey sites sampled.

Common Name	Latin Name	# of Individuals	# of Sites Present
Northern Mockingbird	<i>Mimus polyglottos</i>	435	215
Lark Sparrow	<i>Chondestes grammacus</i>	338	210
Cassin's Sparrow	<i>Aimophila cassinii</i>	311	173
Mourning Dove	<i>Zenaida macroura</i>	236	137
Bewick's Wren	<i>Thryomanes bewickii</i>	221	154
Brown-headed Cowbird	<i>Molothrus ater</i>	200	138
Painted Bunting	<i>Passerina ciris</i>	188	146
Turkey Vulture	<i>Cathartes aura</i>	141	92
Ash-throated Flycatcher	<i>Myiarchus cinerascens</i>	135	110
Northern Bobwhite	<i>Colinus Virginians</i>	116	87
Northern Cardinal	<i>Cardinalis cardinalis</i>	112	85
Bullock's Oriole	<i>Icterus bullocki</i>	95	69
Canyon Towhee	<i>Pipilo fuscus</i>	89	78
Scissor-tailed Flycatcher	<i>Tyrannus forficatus</i>	87	68
Tufted Titmouse	<i>Baeolophus bicolor</i>	82	59
Common Nighthawk	<i>Chordeiles minor</i>	69	50
Black-throated Sparrow	<i>Amphispiza bilineata</i>	64	54
Golden-fronted Woodpecker	<i>Melanerpes aurifrons</i>	57	50
Scaled Quail	<i>Callipepla squamata</i>	56	37
House Finch	<i>Carpodacus mexicanus</i>	53	31
Western Meadowlark	<i>Sturnella neglecta</i>	51	36
Cactus Wren	<i>Campylorhynchus brunneicapillus</i>	49	45
Ladder-backed Woodpecker	<i>Picoides scalaris</i>	44	42
Vermillion Flycatcher	<i>Pyrocephalus rubinus</i>	42	38
Bell's Vireo	<i>Vireo bellii</i>	37	25
Horned Lark	<i>Eremophila alpestris</i>	34	12
Great-tailed Grackle	<i>Quiscalus mexicanus</i>	33	7
Rufous-crowned Sparrow	<i>Aimophila ruficeps</i>	32	26
Wild Turkey	<i>Meleagris gallopavo</i>	32	16
Killdeer	<i>Charadrius vociferus</i>	27	20
Scott's Oriole	<i>Icterus parisorum</i>	27	26
Western Scrub Jay	<i>Aphelocoma californica</i>	27	20
Western Kingbird	<i>Tyrannus verticalis</i>	26	20
Yellow-billed Cuckoo	<i>Coccyzus americanus</i>	25	21
Common Raven	<i>Corvus corax</i>	24	20
White-winged Dove	<i>Zenaida asiatica</i>	24	11
Blue Grosbeak	<i>Guiraca caerulea</i>	21	20
Black-chinned Hummingbird	<i>Archilochus alexandri</i>	20	18
Blue-grey Gnatcatcher	<i>Poliophtila caerulea</i>	18	14
Grasshopper Sparrow	<i>Ammodramus savannarum</i>	18	11
House Sparrow	<i>Passer domesticus</i>	18	8

Chipping Sparrow	<i>Spizella passerina</i>	16	13
Red-tailed Hawk	<i>Buteo jamaicensis</i>	15	12
Greater Roadrunner	<i>Geococcyx californianus</i>	14	13
Summer Tanager	<i>Piranga rubra</i>	14	11
Orchard Oriole	<i>Icterus spurius</i>	12	9
Great-horned Owl	<i>Bubo virginianus</i>	10	4
Red-winged Blackbird	<i>Agelaius phoeniceus</i>	9	5
Pyrrhuloxia	<i>Cardinalis sinuatus</i>	8	7
Loggerhead Shrike	<i>Lanius ludovicianus</i>	7	3
Bank Swallow	<i>Riparia riparia</i>	6	1
Curve-billed Thrasher	<i>Toxostoma curvirostre</i>	5	4
Eastern Phoebe	<i>Sayornis phoebe</i>	5	5
Yellow-breasted Chat	<i>Icteria virens</i>	5	3
Bushtit	<i>Psaltriparus minimus</i>	4	3
Great Blue Heron	<i>Ardea herodias</i>	4	4
Green Heron	<i>Butorides virescens</i>	4	2
Yellow-throated Vireo	<i>Vireo flavifrons</i>	3	2
Eastern Wood-Pewee	<i>Contopus virens</i>	2	2
Field Sparrow	<i>Spizella pusilla</i>	2	1
Gray Vireo	<i>Vireo vicinior</i>	2	2
Inca Dove	<i>Columbina inca</i>	2	2
American Redstart	<i>Setophaga ruticilla</i>	1	1
Black Vulture	<i>Coragyps atratus</i>	1	1
Carolina Chickadee	<i>Poecile carolinensis</i>	1	1
Chihuahuan Raven	<i>Corvus cryptoleucus</i>	1	1
Cliff Swallow	<i>Petrochelidon pyrrhonota</i>	1	1
Great-crested Flycatcher	<i>Myiarchus crinitus</i>	1	1
Lesser Goldfinch	<i>Carduelis psaltria</i>	1	1
Swainson's Hawk	<i>Buteo swainsoni</i>	1	1
White-eyed Vireo	<i>Vireo griseus</i>	1	1
Wilson's Warbler	<i>Wilsonia pusilla</i>	1	1
Yellow Warbler	<i>Dendroica petechia</i>	1	1
Grand Total		3874	

Appendix B2: Species detected during Twin Buttes winter surveys. 135 survey sites sampled.

Common Name	Latin Name	# of Individuals	# of Sites Present
Western Meadowlark	Sturnella neglecta	378	28
White-crowned Sparrow	<i>Zonotrichia leucophrys</i>	343	34
Lark Bunting	<i>Calamospiza melanocorys</i>	228	10
Northern Mockingbird	<i>Mimus polyglottos</i>	195	64
Cedar Waxwing	<i>Bombycilla cedrorum</i>	172	4
Vesper Sparrow	<i>Poocetes gramineus</i>	115	21
Chipping Sparrow	<i>Spizella passerina</i>	106	12
Bewick's Wren	<i>Thryomanes bewickii</i>	93	57
Tufted Titmouse	<i>Baeolophus bicolor</i>	90	21
Scaled Quail	<i>Callipepla squamata</i>	71	2
Morning Dove	<i>Zenaida macroura</i>	69	24
Great-tailed Grackle	<i>Quiscalus mexicanus</i>	60	1
Wild Turkey	<i>Meleagris gallopavo</i>	52	6
Cassin's Sparrow	<i>Aimophila cassinii</i>	51	18
Northern Cardinal	<i>Cardinalis cardinalis</i>	51	22
Mallard	<i>Anas platyrhynchos</i>	46	3
Canyon Towhee	<i>Pipilo fuscus</i>	39	28
Golden-fronted Woodpecker	<i>Melanerpes aurifrons</i>	37	23
Horned Lark	<i>Eremophila alpestris</i>	33	2
House Finch	<i>Carpodacus mexicanus</i>	32	17
Turkey Vulture	<i>Cathartes aura</i>	31	7
Field Sparrow	<i>Spizella pusilla</i>	27	11
Cactus Wren	<i>Campylorhynchus brunneicapillus</i>	24	14
Ruby-crowned Kinglet	<i>Regulus calendula</i>	24	17
Red-tailed Hawk	<i>Buteo jamaicensis</i>	21	15
Savanna Sparrow	<i>Passerculus sandwichensis</i>	20	5
Common Raven	<i>Corvus corax</i>	19	16
Killdeer	<i>Charadrius vociferus</i>	19	14
European Starling	<i>Sturnus vulgaris</i>	17	2
Ladder-backed Woodpecker	<i>Picoides scalaris</i>	17	13
Yellow-rumped Warbler	<i>Dendroica coronata</i>	14	8
Lincoln Sparrow	<i>Melospiza lincolni</i>	13	6
Western Scrub Jay	<i>Aphelocoma californica</i>	12	7
Brown-headed Cowbird	<i>Molothrus ater</i>	11	3
Lark Sparrow	<i>Chondestes grammacus</i>	11	3
Black-throated Sparrow	<i>Amphispiza bilineata</i>	10	7
Loggerhead Shrike	<i>Lanius ludovicianus</i>	10	8
Song Sparrow	<i>Melospiza melodia</i>	10	6
Spotted Towhee	<i>Pipilo maculatus</i>	9	6
Dark-eyed Junco	<i>Junco hyemalis</i>	8	1
Double-crested Cormorant	<i>Phalacrocorax auritus</i>	8	1
Curve-billed Thrasher	<i>Toxostoma curvirostre</i>	7	4
Eastern Phoebe	<i>Sayornis phoebe</i>	7	5

Pyrrhuloxia	<i>Cardinalis sinuatus</i>	7	5
Black Vulture	<i>Coragyps atratus</i>	6	2
Bushtit	<i>Psaltriparus minimus</i>	6	2
Northern Harrier	<i>Circus cyaneus</i>	6	5
Rufous-crowned Sparrow	<i>Aimophila ruficeps</i>	6	3
Sage Thrasher	<i>Oreoscoptes montanus</i>	6	5
Grasshopper Sparrow	<i>Ammodramus savannarum</i>	5	4
Lesser Goldfinch	<i>Carduelis psaltria</i>	5	1
American Kestrel	<i>Falco sparverius</i>	4	4
American Robin	<i>Turdus migratorius</i>	4	1
American Widgeon	<i>Anas americana</i>	4	1
Greater Roadrunner	<i>Geococcyx californianus</i>	4	4
Orange-crowned Warbler	<i>Vermivora celata</i>	4	3
Wood Duck	<i>Aix sponsa</i>	4	1
Vermilion Flycatcher	<i>Pyrocephalus rubinus</i>	3	3
Brown Creeper	<i>Certhia americana</i>	2	2
House Wren	<i>Troglodytes aedon</i>	2	2
Marsh Wren	<i>Cistothorus palustris</i>	2	2
American Goldfinch	<i>Carduelis tristis</i>	1	1
Belted Kingfisher	<i>Ceryle alcton</i>	1	1
Blue-headed Vireo	<i>Vireo solitarius</i>	1	1
Brewer's Sparrow	<i>Spizella breweri</i>	1	1
Brown Thrasher	<i>Toxostoma rufum</i>	1	1
Carolina Wren	<i>Thryothorus ludovicianus</i>	1	1
Great-horned Owl	<i>Bubo virginianus</i>	1	1
House Sparrow	<i>Passer domesticus</i>	1	1
Lesser Scaup	<i>Aythya affinis</i>	1	1
Long-billed Dowitcher	<i>Limnodromus griseus</i>	1	1
Rock Wren	<i>Salpinctus obsoletus</i>	1	1
Say's Phoebe	<i>Sayornis saya</i>	1	1
Grand Total		2702	

Appendix B3: Logistic regression models for all Twin Buttes breeding guilds (= $p < 0.01$, * = $p < 0.05$, * = $p < 0.1$).**

	N	Rho2	Loglikelihood	df	Ln+1 Juniper Cover	Ln+1 Mesquite Cover	Ln+1 Mix Cover	Ln+1 Oak Cover
Deciduous Guild	14	0.396	-56.382	4	-	+	-	+***
Grassland Facultative	293	0.178	-16.760	4	+	+*	+	-
Grassland Guild	266	0.146	-97.100	4	-*	-*	-	-***
Grassland Obligates	177	0.125	-199.452	4	-***	-	-	-***
Brush Guild	239	0.119	-145.018	4	+***	+	+	+***
Riparian	91	0.060	-182.641	4	-	+	-	+***
Generalist Guild	223	0.049	-165.344	4	+***	-	-	+
Woodland Guild	242	0.041	-140.618	4	+	+	+	+**
Scrub Guild	209	0.024	-179.265	4	+**	+	+	+
Savanna Guild	246	0.018	-34.434	4	-	+	+	-

Appendix B4: Logistic regression models for Twin Buttes breeding species with N>15 (= p<0.01, * = p<0.05, * = p<0.1).**

	N	Partners in Flight Priority	Rho2	Loglikelihood	df	Ln+1 Juniper Cover	Ln+1 Mesquite Cover	Ln+1 Mix Cover	Ln+1 Oak Cover
Black-chinned Hummingbird	18	High	0.252	-67.841	4	+	-	+	****
Tufted Titmouse	59		0.170	-147.841	4	+	_*	+***	+***
Western Scrub Jay	20		0.159	-73.201	4	+***	+	+	-
Yellow-billed Cuckoo	21	High	0.157	-75.799	4	-	-	-	+***
Cassin's Sparrow	173	High	0.112	-200.928	4	_**	+	-	_***
Lark Sparrow	210	Physiographic	0.111	-178.380	4	_**	-	-	_***
Western Meadowlark	36		0.103	-109.562	4	_***	+	-	-
Northern Cardinal	85		0.087	-177.479	4	+**	+**	+	+***
Bell's Vireo	25	Highest	0.085	-85.700	4	-	+*	_*	+**
Black-throated Sparrow	54		0.075	-140.618	4	+***	+	-	-
Bewick's Wren	154	Physiographic	0.073	-204.928	4	+***	+	+	+***
Painted Bunting	146	High	0.071	-205.145	4	+**	+	+*	+**
Scaled Quail	37		0.049	-111.524	4	+	-	+	_**
Northern Mockingbird	215		0.048	-173.709	4	+***	-	_*	+
Vermillion Flycatcher	38	Physiographic	0.046	-113.455	4	_**	-	+	+*
Blue Grosbeak	20		0.036	-73.201	4	+	+	+	-
Canyon Towhee	78		0.035	-170.703	4	+**	+	_*	-
Scissor-tailed Flycatcher	68	Global	0.034	-159.529	4	_**	+	+	_**
Bullock's Oriole	69		0.032	-160.729	4	-	+*	-	_***
Rufous-crowned Sparrow	26	High	0.032	-88.062	4	+**	+	+	-
Common Raven	20		0.030	-73.201	4	_**	+	+	-
Scott's Oriole	26		0.029	-88.062	4	+*	-	+	+
Western Kingbird	20		0.029	-73.201	4	-	-	-	+
Cactus Wren	45		0.027	-126.158	4	+	+**	-	-
Common Nighthawk	50		0.025	-134.434	4	_**	+	-	-
Ladderbacked Woodpecker	42	Physiographic	0.025	-120.881	4	-	+	-	+
Mourning Dove	137		0.022	-204.353	4	-	+	+	+
Brown-headed Cowbird	138		0.020	-204.495	4	+	-	_**	+**
Killdeer	20		0.018	-73.201	4	-	+	-	+
Ash-throated Flycatcher	110		0.017	-195.305	4	-	+	+*	-
House Finch	31		0.017	-99.264	4	+	+	-	+
Wild Turkey	16	Physiographic	0.010	-62.244	4	-	+	+	-
Golden-fronted Woodpecker	50		0.009	-134.434	4	-	+	-	+
Turkey Vulture	92		0.005	-183.445	4	+	-	+	-
Northern Bobwhite	87	High	0.002	-179.265	4	+	-	+	+

Appendix B5: Twin Buttes logistic regression model estimates.

	Constant		ln+1 Juniper Cover		ln+1 Mesquite Cover		ln+1 Mix Cover		Ln+1 Oak Cover	
	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.
Grassland Obligates	3.11	0.744	-0.738	0.245	-0.049	0.229	-0.392	0.273	-1.133	0.246
Brush Guild	-1.967	0.781	1.028	0.291	0.343	0.27	0.159	0.379	0.946	0.351
Black-chinned Hummingbird	-3.374	1.476	0.057	0.456	-0.86	0.568	0.314	0.555	2.172	0.498
Tufted Titmouse	-2.067	0.856	0.032	0.292	-0.536	0.311	1.084	0.315	1.259	0.285
Western Scrub Jay	-8.968	1.771	2.257	0.548	0.416	0.449	0.573	0.429	-0.275	0.452
Yellow-billed Cuckoo	-2.795	1.282	-0.364	0.413	-0.144	0.461	-0.496	0.538	1.648	0.416
Cassin's Sparrow	2.314	0.703	-0.501	0.236	0.063	0.226	-0.418	0.27	-1.145	0.247
Lark Sparrow	3.731	0.814	-0.538	0.256	-0.316	0.248	-0.323	0.28	-0.935	0.243
Western Meadowlark	1.156	0.871	-1.448	0.349	0.023	0.315	-0.414	0.469	-0.395	0.361

APPENDIX C: SPECIES DETECTED IN EDWARDS AND ANALYSES

Appendix C1: Species detected in Edwards spring surveys. 201 survey sites sampled.

Common Name	Latin Name	# of Individuals	# of Sites Present
Tufted Titmouse	Baeolophus bicolor	233	147
Northern Cardinal	<i>Cardinalis cardinalis</i>	225	157
Bewick's Wren	<i>Thryomanes bewickii</i>	160	122
Brown-headed Cowbird	<i>Molothrus ater</i>	157	91
Cedar Waxwing	<i>Bombycilla cedrorum</i>	145	3
Mourning Dove	<i>Zenaida macroura</i>	137	79
Cliff Swallow	<i>Petrochelidon pyrrhonota</i>	120	9
Golden-cheeked Warbler	<i>Dendroica chrysoparia</i>	101	70
Ash-throated Flycatcher	<i>Myiarchus cinerascens</i>	95	79
Carolina Chickadee	<i>Poecile carolinensis</i>	87	58
White-eyed Vireo	<i>Vireo griseus</i>	79	63
Summer Tanager	<i>Piranga rubra</i>	77	67
Turkey Vulture	<i>Cathartes aura</i>	71	49
Blue-grey Gnatcatcher	<i>Polioptila caerulea</i>	69	53
Lark Sparrow	<i>Chondestes grammacus</i>	69	45
Western Scrub Jay	<i>Aphelocoma californica</i>	65	49
Black-and-white Warbler	<i>Mniotilta varia</i>	63	51
Rufous-crowned Sparrow	<i>Aimophila ruficeps</i>	59	47
House Finch	<i>Carpodacus mexicanus</i>	57	40
Ladder-backed Woodpecker	<i>Picoides scalaris</i>	55	48
Black-chinned Hummingbird	<i>Archilochus alexandri</i>	48	43
Chipping Sparrow	<i>Spizella passerina</i>	47	35
Northern Mockingbird	<i>Mimus polyglottos</i>	47	38
Carolina Wren	<i>Pipilo fuscus</i>	41	34
Painted Bunting	<i>Passerina ciris</i>	40	36
Bushtit	<i>Psaltriparus minimus</i>	38	13
Field Sparrow	<i>Spizella pusilla</i>	34	24
Blue Grosbeak	<i>Guiraca caerulea</i>	33	29
Wild Turkey	<i>Meleagris gallopavo</i>	32	28
Yellow-billed Cuckoo	<i>Coccyzus americanus</i>	31	28
Lesser Goldfinch	<i>Carduelis psaltria</i>	30	19
Vermillion Flycatcher	<i>Pyrocephalus rubinus</i>	27	22
Eastern Phoebe	<i>Sayornis phoebe</i>	26	21
Red-eyed Vireo	<i>Vireo olivaceus</i>	25	24
Scissor-tailed Flycatcher	<i>Scissor-tailed Flycatcher</i>	25	18
Canyon Wren	<i>Catherpes mexicanus</i>	24	22
Northern Bobwhite	<i>Colinus virginianus</i>	20	15
Great-tailed Grackle	<i>Quiscalus mexicanus</i>	17	12
Indigo Bunting	<i>Passerina cyanea</i>	17	14
Greater Roadrunner	<i>Geococcyx californianus</i>	15	15
Yellow-throated Vireo	<i>Vireo flavifrons</i>	14	13
Scott's Oriole	<i>Scott's Oriole</i>	13	12

Black Vulture	<i>Coragyps atratus</i>	12	12
Nashville Warbler	<i>Vermivora ruficapilla</i>	12	10
Black-capped Vireo	<i>Vireo atricapillus</i>	11	7
Common Raven	<i>Corvus corax</i>	11	7
Eastern Wood Pewee	<i>Contopus virens</i>	11	10
Acadian Flycatcher	<i>Empidonax vireescens</i>	10	9
Barn Swallow	<i>Hirundo rustica</i>	9	7
Cassin's Sparrow	<i>Aimophila cassinii</i>	9	7
Golden-fronted Woodpecker	<i>Melanerpes aurifrons</i>	7	7
Orange-crowned Warbler	<i>Vermivora celata</i>	7	4
Ruby-crowned Kinglet	<i>Regulus calendula</i>	7	6
White-winged Dove	<i>Zenaida asiatica</i>	6	4
Eastern Bluebird	<i>Sialia sialis</i>	5	3
Orchard Oriole	<i>Icterus spurius</i>	5	4
Red-shouldered Hawk	<i>Buteo lineatus</i>	5	5
Common Ground Dove	<i>Columbina passerina</i>	4	4
Grasshopper Sparrow	<i>Ammodramus savannarum</i>	4	3
American Kestrel	<i>Falco sparverius</i>	3	3
Belted Kingfisher	<i>Ceryle alcyon</i>	3	2
Killdeer	<i>Charadrius vociferus</i>	3	2
Lincoln's Sparrow	<i>Melospiza lincolni</i>	3	2
Red-tailed Hawk	<i>Buteo jamaicensis</i>	3	3
Yellow Warbler	<i>Dendroica petechia</i>	3	3
Yellow-throated Warbler	<i>Dendroica dominica</i>	3	3
Cave Swallow	<i>Petrochelidon fulva</i>	2	2
Great-crested Flycatcher	<i>Myiarchus crinitus</i>	2	2
Purple Martin	<i>Progne subis</i>	2	2
Yellow-bellied Flycatcher	<i>Empidonax flaviventris</i>	2	1
Clay-colored Sparrow	<i>Spizella pallida</i>	1	1
Common Nighthawk	<i>Chordeiles minor</i>	1	1
Cooper's Hawk	<i>Accipiter cooperii</i>	1	1
Great-blue Heron	<i>Ardea herodias</i>	1	1
Green Heron	<i>Butorides virescens</i>	1	1
House Wren	<i>Troglodytes aedon</i>	1	1
Swainson's Hawk	<i>Buteo swainsoni</i>	1	1
Wilson's Warbler	<i>Wilsonia pusilla</i>	1	1
Yellow-headed Blackbird	<i>Xanthocephalus xanthocephalus</i>	1	1
Grand Total		2941	

Appendix C2: Species detected in Edwards winter surveys. 147 survey sites sampled.

Common Name	Latin Name	# of Individuals	# of Sites Present
Chipping Sparrow	Spizella passerina	691	25
Tufted Titmouse	<i>Baeolophus bicolor</i>	188	68
Morning Dove	<i>Zenaida macroura</i>	136	25
Field Sparrow	<i>Spizella pusilla</i>	116	20
Cedar Waxwing	<i>Bombycilla cedrorum</i>	114	7
Ruby-crowned Kinglet	<i>Regulus calendula</i>	98	51
Northern Cardinal	<i>Cardinalis cardinalis</i>	88	56
Vesper Sparrow	<i>Poocetes gramineus</i>	87	11
Carolina Chickadee	<i>Poecile carolinensis</i>	83	29
Bewick's Wren	<i>Thryomanes bewickii</i>	48	42
Eastern Phoebe	<i>Sayornis phoebe</i>	41	32
Lincoln's Sparrow	<i>Melospiza lincolni</i>	40	15
Western Scrub Jay	<i>Aphelocoma californica</i>	40	24
House Finch	<i>Carpodacus mexicanus</i>	37	23
Ladder-backed Woodpecker	<i>Picoides scalaris</i>	37	33
American Robin	<i>Turdus migratorius</i>	32	7
Common Raven	<i>Corvus corax</i>	31	23
Savannah Sparrow	<i>Passerculus sandwichensis</i>	25	11
Spotted Towhee	<i>Pipilo maculatus</i>	24	16
Bushtit	<i>Psaltiriparus minimus</i>	23	4
Black Vulture	<i>Coragyps atratus</i>	20	11
Rufous-crowned Sparrow	<i>Aimophila ruficeps</i>	19	11
Northern Mockingbird	<i>Mimus polyglottos</i>	18	16
Orange-crowned Warbler	<i>Vermivora celata</i>	18	11
Canyon Wren	<i>Catherpes mexicanus</i>	11	9
Dark-eyed Junco	<i>Junco hyemalis</i>	10	2
Greater Roadrunner	<i>Geococcyx californianus</i>	9	8
Red-tailed Hawk	<i>Buteo jamaicensis</i>	9	8
Carolina Wren	<i>Pipilo fuscus</i>	6	4
Hermit Thrush	<i>Catharus guttatus</i>	6	4
Lesser Goldfinch	<i>Carduelis psaltria</i>	6	2
American Kestrel	<i>Falco sparverius</i>	5	5
Golden-crowned Kinglet	<i>Regulus satrapa</i>	5	3
Golden-fronted Woodpecker	<i>Melanerpes aurifrons</i>	5	5
Grasshopper Sparrow	<i>Ammodramus savannarum</i>	5	4
Killdeer	<i>Charadrius vociferus</i>	5	4
Yellow-bellied Sapsucker	<i>Sphyrapicus varius</i>	5	4
Yellow-rumped Warbler	<i>Dendroica coronata</i>	5	4
Eastern Meadowlark	<i>Sturnella neglecta</i>	4	1
White-eyed Vireo	<i>Vireo griseus</i>	4	3
Leconte's Sparrow	<i>Ammodramus leconteii</i>	3	3
Northern Harrier	<i>Circus cyaneus</i>	3	3
Song Sparrow	<i>Melospiza melodia</i>	3	2

Eastern Bluebird	<i>Sialia sialis</i>	2	1
Barred Owl	<i>Strix varia</i>	1	1
Belted Kingfisher	<i>Ceryle alcyon</i>	1	1
Black Phoebe	<i>Sayornis nigricans</i>	1	1
Blue-headed Vireo	<i>Vireo solitarius</i>	1	1
Canyon Towhee	<i>Pipilo fuscus</i>	1	1
Great-blue Heron	<i>Ardea herodias</i>	1	1
Green Kingfisher	<i>Butorides virescens</i>	1	1
Loggerhead Shrike	<i>Lanius ludovicianus</i>	1	1
Merlin	<i>Falco columbarius</i>	1	1
Peregrine Falcon	<i>Falco peregrinus</i>	1	1
Red-winged Blackbird	<i>Agelaius phoeniceus</i>	1	1
White-crowned Sparrow	<i>Zonotrichia leucophrys</i>	1	1
Grand Total		2177	

Appendix C3: Logistic regression for all Edwards breeding bird guilds (= p<0.01, * = p<0.05, * = p<0.1).**

	N	Rho2	Loglikelihood	df	Ln+1 Cedar Cover	Oak Cover	Mix Cover	Ln+1 Mesquite Cover
Grassland Guild	56	0.295	-118.918	4	- ***	- *	- ***	- *
Grassland Facultative	183	0.269	-60.602	4	-***	+	-	+
Grassland Obligate	8	0.255	-33.63	4	-	-	-	-
Savanna Guild	167	0.097	-91.363	4	-***	***	-	+*
Deciduous Guild	134	0.074	-127.939	4	+	***	***	+
Generalist Guild	90	0.049	-138.224	4	-**	***	-	-
Woodland Guild	194	0.029	-30.378	4	-	+	-	-
Riparian	130	0.024	-130.535	4	+	-	-	+
Scrub Guild	116	0.011	-136.922	4	+	-	+	-

Appendix C4: Logistic regression models for Edwards breeding bird species with N>15 (* = p<0.01, ** = P<0.05, * = p<0.1).**

Species	N	Partners in Flight Priority	Rho2	Loglikelihood	df	Ln+1 Cedar Cover	Oak Cover	Mix Cover	Ln+1 Mesquite Cover
Golden-cheeked Warbler	70	Highest	0.319	-129.92	4	+ ***	+ ***	+ ***	-
Northern Mockingbird	38		0.288	-97.455	4	- **	+	- ***	-
Scissortail Flycatcher	18	Global	0.277	-60.602	4	-	-	- ***	-
Vermillion Flycatcher	22	Physiographic	0.270	-69.419	4	- *	- **	- **	-
Lark Sparrow	45	Physiographic	0.245	-106.887	4	- **	-	- ***	-
Black-and-white Warbler	51		0.203	-113.85	4	+ ***	+ ***	+ **	-
Northern Bobwhite	15	High	0.179	-53.355	4	- ***	-	+	-
Red-eyed Vireo	24		0.162	-73.512	4	+ **	+ **	+ *	+ *
Canyon Wren	22		0.153	-69.419	4	+	+ **	+ *	-
Western Scrub Jay	49		0.114	-111.635	4	+ ***	-	+	-
White-eyed Vireo	63		0.106	-124.986	4	+ *	+	+ ***	+
Blue-gray Gnatcatcher	53		0.102	-115.951	4	+	+ ***	+ **	+
Lesser Goldfinch	19	Physiographic	0.101	-62.891	4	- **	+ *	-	+
Carolina Wren	34		0.084	-91.363	4	+	+ *	+ ***	+
Chipping Sparrow	35		0.079	-92.937	4	-	-	- **	+
Mourning Dove	79		0.078	-134.687	4	- ***	+ **	-	+
House Finch	40		0.068	-100.303	4	-	+	- **	-
Wild Turkey	28	Physiographic	0.065	-81.143	4	-	+	- **	+
Yellow-billed Cuckoo	28	High	0.064	-81.143	4	- ***	+ *	+	-
Eastern Phoebe	21		0.055	-67.297	4	-	+	-	+ *
Tufted Titmouse	147		0.051	-116.966	4	+	+ *	+	+
Ladderbacked Woodpecker	48	Physiographic	0.050	-110.49	4	+	+ ***	-	+
Greater Roadrunner	15		0.049	-53.355	4	-	+	-	+
Blue Grosbeak	29		0.047	-82.944	4	+	+	-	+ *
Brown-headed Cowbird	91		0.047	-138.423	4	-	+	-	-
Field Sparrow	24	Physiographic	0.046	-73.512	4	-	+	-	-
Painted Bunting	36	High	0.043	-94.477	4	-	+	-	+
Northern Cardinal	157		0.036	-105.629	4	+	+	+	-
Carolina Chickadee	49		0.028	-111.635	4	-	+	+ **	+
Summer Tanager	67		0.027	-127.939	4	-	+	-	+
Ash-throated Flycatcher	79		0.022	-134.687	4	+	+ *	-	+
Rufous-crowned Sparrow	47	High	0.021	-109.317	4	+	+	+	-
Turkey Vulture	49		0.019	-111.635	4	- *	+	+	-
Black-chinned Hummingbird	43	High	0.018	-104.343	4	+	+	+	-
Bewick's Wren	122	Physiographic	0.014	-134.687	4	- *	+	+	+

Appendix C5: Edwards logistic regression model estimates.

	Constant		ln+1 Cedar Cover		Oak Cover		Mix Cover		ln+1 Mesquite Cover	
	Estimate	S.E	Estimate	S.E	Estimate	S.E	Estimate	S.E	Estimate	S.E
Grassland Guild	3.964	0.859	-0.841	0.236	-0.082	0.045	-0.101	0.028	-0.774	0.438
Golden-cheeked Warbler	-7.580	1.373	1.297	0.291	0.131	0.050	0.103	0.028	-0.003	0.375
Northern Mockingbird	2.020	0.807	-0.568	0.268	0.021	0.048	-0.174	0.041	-0.054	0.458
Scissortail Flycatcher	1.755	1.001	-0.621	0.387	-0.052	0.064	-0.158	0.058	-0.335	0.618
Vermillion Flycatcher	2.105	0.941	-0.595	0.355	-0.152	0.064	-0.095	0.043	-0.205	0.570
Lark Sparrow	2.803	0.798	-0.626	0.245	-0.072	0.046	-0.108	0.031	-0.348	0.438
Black-and-white Warbler	-5.871	1.229	0.846	0.271	0.132	0.050	0.060	0.027	-0.272	0.376
Northern Bobwhite	0.842	1.107	-1.199	0.386	-0.057	0.066	0.008	0.034	-1.129	0.709
Red-eyed Vireo	-8.341	1.904	0.975	0.420	0.136	0.067	0.067	0.037	0.779	0.462
Canyon Wren	-6.112	1.700	0.388	0.344	0.164	0.068	0.063	0.037	-0.686	0.528
Western Scrub Jay	-3.340	0.913	0.988	0.270	-0.032	0.045	0.020	0.023	-0.169	0.361
White-eyed Vireo	-3.780	0.860	0.383	0.215	0.049	0.041	0.072	0.022	0.097	0.334
Blue-gray Gnatcatcher	-4.250	0.936	0.026	0.216	0.159	0.046	0.054	0.024	0.062	0.349
Lesser Goldfinch	-1.527	0.998	-0.752	0.309	0.106	0.059	-0.043	0.038	0.113	0.531

APPENDIX D: BIRD GUILDS

Appendix D1: TWIN BUTTES BREEDING BIRD GUILDS

(F=Grassland Facultative, O=Grassland Obligate, R= Riparian Associated)

<i>GRASSLAND</i>		<i>WOODLAND</i>	
Bobwhite Quail	F	Black-chinned Hummingbird	
Cassin's Sparrow	O	Blue Grosbeak	
Chihuahuan Raven	F	Brown-headed Cowbird	F
Grasshopper Sparrow	O	Bullock's Oriole	
Horned Lark	O	Bushtit	
Killdeer	F	Chipping Sparrow	
Lark Sparrow	F	Eastern Phoebe	R
Western Meadowlark	O	Golden-fronted Woodpecker	
		Great-horned Owl	
		Inca Dove	
		Red-tailed Hawk	
		Tufted Titmouse	
		Vermillion Flycatcher	R
		White-winged Dove	R
		Wild Turkey	
		Yellow-billed Cuckoo	
		DECIDUOUS WOODLAND	
		Carolina Chickadee	R
		Eastern Wood-Pewee	
		Great-crested Flycatcher	
		Summer Tanager	
		Yellow-throated Vireo	
		BRUSH	
		Bell's Vireo	R
		Bewick's Wren	
		Canyon Towhee	F
		Curve-billed Thrasher	
		Field Sparrow	
		Northern Cardinal	
		Painted Bunting	
		Pyrrhuloxia	
		White-eyed Vireo	R
		Yellow-breasted Chat	R
		GENERALIST	
		Blue-gray Gnatcatcher	
		Common Raven	
		Northern Mockingbird	
		MIGRATION	
		American Redstart	
		Wilson's Warbler	
		Yellow Warbler	

Appendix D2: TWIN BUTTES WINTER BIRD GUILDS
(F=Grassland Facultative, O=Grassland Obligate)

**GROUND GLEANS
SEEDS (GRASS OR FORB)**

Black-throated Sparrow	
Brewer's Sparrow	
Brown-headed Cowbird	F
Canyon Towhee	F
Cassin's Sparrow	O
Chipping Sparrow	
Dark-eyed Junco	
Field Sparrow	
Grasshopper Sparrow	O
Horned Lark	O
House Finch	
House Sparrow	
Killdeer	F
Lark Bunting	O
Lark Sparrow	F
Lincoln Sparrow	
Morning Dove	F
Rufous-crowned Sparrow	F
Savanna Sparrow	O
Scaled Quail	F
Song Sparrow	
Spotted Towhee	
Vesper Sparrow	O
Western Meadowlark	O

**GROUND GLEANS
FRUIT OR BERRIES**

American Robin	
Cactus Wren	
Curve-billed Thrasher	
Greater Roadrunner	
Northern Cardinal	
Northern Mockingbird	
Pyrrhuloxia	
Sage Thrasher	
Scrub Jay	
Starling	

FLYCATCH

Eastern Phoebe	
Say's Phoebe	F
Vermilion Flycatcher	

**GROUND GLEANS
OTHER**

Bewick's Wren
Brown Thrasher
Carolina Wren
Common Raven
Great-tailed Grackle
House Wren
Marsh Wren
Rock Wren
Wild Turkey

FOLIAGE GLEAN

American Goldfinch
Blue-headed Vireo
Bushtit
Cedar Waxwing
Lesser Goldfinch
Orange-crowned Warbler
Ruby-crowned Kinglet
Tufted Titmouse

BIRDS OF PREY

American Kestrel	F
Black Vulture	
Great Horned Owl	

Loggerhead Shrike	F
Northern Harrier	O

BARK GLEAN

Brown Creeper
Golden-fronted Woodpecker
Ladder-backed Woodpecker

AQUATIC

American Wigeon	F
Belted Kingfisher	
Double-crested Cormorant	
Lesser Scaup	
Long-billed Dowitcher	F
Mallard	F
Wood Duck	

Appendix D3: EDWARDS BREEDING BIRD GUILDS
(F=Grassland Facultative, O=Grassland Obligate, R= Riparian Associated)

GRASSLAND GUILD

Cassin's Sparrow O

Grasshopper Sparrow O
 Killdeer F

SAVANNA GUILD

American Kestrel F

Barn Swallow R

Black Vulture R

Cave Swallow R

Cliff Swallow R

Common Nighthawk F

Eastern Bluebird F

Ladder-backed Woodpecker

Lesser Goldfinch

Mourning Dove

Purple Martin R

Scissor-tailed Flycatcher F

MARSH/RIVER GUILD

Belted Kingfisher R

Great-blue Heron R

Green Heron R

MIGRATION

Cedar Waxwing

Clay-colored Sparrow

House Wren

Lincoln's Sparrow

Nashville Warbler

Orange-crowned Warbler

Ruby-crowned Kinglet

Wilson's Warbler

Yellow Warbler

GENERALIST GUILD

Blue-gray Gnatcatcher

HUMAN AND OTHER

Canvon Wren

WOODLAND GUILD

Black-chinned Hummingbird

Blue Grosbeak R

Brown-headed Cowbird F

Bushtit

Chipping Sparrow

Common Ground Dove

Eastern Phoebe R

Golden-cheeked Warbler

Golden-fronted Woodpecker

Red-shouldered Hawk R

Red-tailed Hawk

Tufted Titmouse

Vermillion Flycatcher R

White-winged Dove R

DECIDUOUS GUILD

Acadian Flycatcher R

Black-and-white Warbler

Carolina Chickadee R

Carolina Wren

Cooper's Hawk R

Eastern Wood Pewee

Great-crested Flycatcher

Indigo Bunting

Red-eyed Vireo

Summer Tanager

BRUSH GUILD

Bewick's Wren

Field Sparrow

Northern Cardinal

SCRUB GUILD

Ash-throated Flycatcher F

Black-capped Vireo

Greater Roadrunner

House Finch

Orchard Oriole

Rufous-crowned Sparrow F

Scott's Oriole

Western Scrub Jay

Appendix D4: EDWARDS WINTER BIRD GUILDS
(F=Grassland Facultative, O=Grassland Obligate)

GROUND GLEANS

SEEDS (GRASS OR FORB)

Canyon Towhee	F ^T
Carolina Wren	
Chipping Sparrow	
Common Ground Dove	F
Dark-eyed Junco	
Eastern Meadowlark	O
Field Sparrow	
Grasshopper Sparrow	O
House Finch	
Killdeer	F
Le Conte's Sparrow	O
Lincoln's Sparrow	
Mourning Dove	F
Red-winged Blackbird	F
Rufous-crowned Sparrow	F
Savannah Sparrow	O
Song Sparrow	
Spotted Towhee	
Vesper Sparrow	O
White-crowned Sparrow	

GROUND GLEANS

FRUIT OR BERRIES

American Robin
Greater Roadrunner
Hermit Thrush
Northern Cardinal
Northern Mockingbird
Scrub Jay

GROUND GLEANS

OTHER

Common Raven
Bewick's Wren
Canyon wren

FLYCATCH

Black Phoebe
Eastern Bluebird

FOLIAGE GLEAN

Blue-headed Vireo
Bushtit
Carolina Chickadee
Cedar Waxwing
Golden-crowned Kinglet
Lesser Goldfinch
Orange-crowned Warbler
Ruby-crowned Kinglet
Tufted Titmouse
White-eyed Vireo

BIRDS OF PREY

American kestrel	F
Barred Owl	
Black Vulture	
Loggerhead Shrike	F
Merlin	F
Northern Harrier	O
Peregrine Falcon	F
Red-tailed Hawk	

BARK GLEAN

Golden-fronted Woodpecker
Ladder-backed Woodpecker
Yellow-bellied Sapsucker

AQUATIC

Belted Kingfisher
Canada Goose
Great Blue Heron
Green Kingfisher
Lesser Scaup

Appendix E1. List of birds sighted in Edwards and Twin Buttes watersheds according to current field check lists.

Species	Lost Maples State Natural Area ¹	H. E. Butt Foundation Camp ¹	Texas Hill Country River Region ¹	Garner State Park ¹	San Angelo State Park ¹	Concho Valley Region ¹	Habitat	Comments ²
	Edward's Watershed			Twin Buttes Watershed				
LOONS								
Common Loon (<i>Gavia immer</i>)					T	I, Rg, S, T	forested lakes and rivers; oceans and bays in winter	
GREBES								
Pied-billed Grebe (<i>Podilymbus podiceps</i>)	B, R	R	U	U	T	I, Rg, S, T	marshes, ponds; salt water in winter if freshwater habitats freeze	
Horned Grebe (<i>Podiceps auritus</i>)					T	I, Rg, S, T	marshes and lakes in summer; in winter, mainly on salt water but also on the Great Lakes	
Red-necked Grebe (<i>Podiceps grisegena</i>)					T		ponds and lakes in summer; bays and estuaries in winter	
Eared Grebe (<i>Podiceps nigricollis</i>)			U		T	I, Rg, S, T	marshy lakes and ponds; open bays and ocean in winter	
Western Grebe (<i>Aechmophorus occidentalis</i>)					T	I, Rg, S, T	breeds on large lakes with tules of rushes; winters mainly on shallow coastal bay and estuaries	
Clark's Grebe (<i>Aechmophorus clarkii</i>)					T	I, Rg, S, T	breeds on large lakes with tules of rushes; winters mainly on shallow coastal bay and estuaries	
PELICANS								
American White Pelican (<i>Pelecanus erythrorhynchos</i>)					T	I, Rg, S, T	shallow lakes and coastal lagoons	
Brown Pelican (<i>Pelecanus occidentalis</i>)					T	I, Rg, S, T	sandy coastal beaches and lagoons	SE, FE

CORMORANTS								
Double-crested Cormorant (<i>Phalacrocorax auritus</i>)		R	U		T	I, Rg, S, T	lakes, rivers, swamps, and coasts	
Neotropic Cormorant (<i>Phalacrocorax brasilianus</i>)					T	I, Rg, S, T	brackish and fresh water	
BITTERNS AND HERONS								
American Bittern (<i>Botaurus lentiginosus</i>)					T	I, Rg, S, T	freshwater and brackish marshes and marshy lake shores	
Least Bittern (<i>Ixobrychus exilis</i>)						I, Rg, S, T	freshwater marshes where cattails and reeds predominate	
Great Blue Heron (<i>Ardea herodias</i>)	B, R	R	U	U	T	I, Rg, S, T	lakes, ponds, rivers, and marshes	
Great Egret (<i>Ardea alba</i>)		R	U		T	I, Rg, S, T	freshwater and salt marshes, marshy ponds, and tidal flats	
Snowy Egret (<i>Egretta thula</i>)			U		T	I, Rg, S, T	salt marshes, ponds, rice fields, and shallow coastal bays	
Little Blue Heron (<i>Egretta caerulea</i>)	B, R		U		T	I, Rg, S, T	Freshwater swamps and lagoons in the South; coastal thickets on islands in the North	
Tricolored Heron (<i>Egretta tricolor</i>)						I, Rg, S, T	swamps, bayous, coastal ponds, salt marshes, mangrove islands, mud flats, and lagoons	
Reddish Egret (<i>Egretta rufescens</i>)						I, Rg, S, T	salt and brackish waters, breeding in shallow bays and lagoons; in mangroves (Florida); among cacti, willows and other shrubs (Texas)	ST
Cattle Egret (<i>Bubulcus ibis</i>)	B, R		U		T	I, Rg, S, T	dry land in open fields where it feeds alongside livestock, but breeds near water with other herons	
Green Heron (<i>Butorides virescens</i>)	B, R	R	U	U	T	I, Rg, S, T	breeds mainly in freshwater or brackish marshes with clumps of trees; feeds along margin of any body of water	
Black-crowned Night-Heron (<i>Nycticorax nycticorax</i>)		R			T	I, Rg, S, T	marshes, swamps, and wooded streams	
Yellow-crowned Night-Heron (<i>Nycticorax violacea</i>)						I, Rg, S, T	wooded swamp and coastal thickets	
IBISES AND SPOONBILLS								
White-faced Ibis (<i>Plegadis chihi</i>)			U		T	I, Rg, S, T	salt marshes and brushy coastal islands in Louisiana and Texas,	ST

							freshwater marshes in the West	
Roseate Spoonbill (<i>Ajaia ajaja</i>)						I, Rg, S, T	mangroves	
STORKS								
Wood Stork (<i>Mycteria americana</i>)						I, Rg, S, T	on or near the coast, breeding chiefly in cypress swamps; also in mangroves	ST
AMERICAN VULTURES								
Black Vulture (<i>Coragyps altratus</i>)	B, R	R	U	U	T	I, Rg, S, T	open country wherever carrion is present, but breeds in light woodlands and thickets	
Turkey Vulture (<i>Cathartes aura</i>)	B, R	R	U	U	T	I, Rg, S, T	mainly deciduous forests and woodlands; often seen over adjacent farmland	
SWANS, GEESE, AND DUCKS								
Black-bellied Whistling-Duck (<i>Dendrocygna autumnalis</i>)			U			I, Rg, S, T	wooded streams and ponds	
Greater White-fronted Goose (<i>Anser albifrons</i>)					T	I, Rg, S, T	breeds on marshy tundra; winters on marshes and bays	G
Snow Goose (<i>Chen caerulescens</i>)					T	I, Rg, S, T	breeds on the tundra and winters in salt marshes and marshy coastal bays; less commonly in freshwater marshes and adjacent grain fields	G
Ross's Goose (<i>Chen rossii</i>)						I, Rg, S, T	Arctic tundra in the breeding season, salt or fresh marshes in the winter	G
Canada Goose (<i>Branta canadensis</i>)					T	I, Rg, S, T	lakes, bays, rivers, and marshes; often feeds in open grassland and stubble fields	G
Tundra Swan (<i>Cygnus columbianus</i>)					T	I, Rg, S, T	Arctic tundra; winters on marshy lakes and bays	
Wood Duck (<i>Aix sponsa</i>)	B, R	R	U	U	T	I, Rg, S, T	wooded rivers and ponds; wooded swamps; visits freshwater marshes in late summer and fall	G
Gadwall (<i>Anas strepera</i>)			U		T	I, Rg, S, T	freshwater marshes, ponds, and rivers; locally in salt marshes	G
American Wigeon (<i>Anas americana</i>)	B, R	R	U		T	I, Rg, S, T	marshes, ponds, and shallow lakes	G

Mallard (<i>Anas platyrhynchos</i>)		R	U		T	I, Rg, S, T	ponds, lakes, and marshes; semi-domesticated birds may be found on almost any body of water	G
Blue-winged Teal (<i>Anas discors</i>)	B, R	R	U	U	T	I, Rg, S, T	marshes, shallow ponds, and lakes	G
Cinnamon Teal (<i>Anas cyanoptera</i>)			U		T	I, Rg, S, T	prairie marshes, ponds, slow-moving streams bordered with reeds	G
Northern Shoveler (<i>Anas clypeata</i>)					T	I, Rg, S, T	marshes and prairie potholes; sometimes on salt or brackish marshes	G
Northern Pintail (<i>Anas acuta</i>)					T	I, Rg, S, T	marshes , prairie potholes, and tundra; sometimes salt marshes in winter	G
Green-winged Teal (<i>Anas crecca</i>)	B, R				T	I, Rg, S, T	marshes, ponds, and marshy lakes	G
Canvasback (<i>Aythya valisineria</i>)					T	I, Rg, S, T	nests on marshes; winters on lakes, bays and estuaries	G
Redhead (<i>Aythya americana</i>)					T	I, Rg, S, T	nests in marshes, but at other times is found on lakes and bays; often on salt water in winter	G
Ring-necked Duck (<i>Aythya collaris</i>)		R			T	I, Rg, S, T	wooded lakes, ponds, and rivers; seldom on salt water except in the southern states	G
Greater Scaup (<i>Aythya marila</i>)						I, Rg, S, T	lakes, bays, and ponds; in winter, often on salt water	G
Lesser Scaup (<i>Aythya affinis</i>)		R	U		T	I, Rg, S, T	ponds and marshes; in migration and winter it occurs on lakes, rivers, and ponds, and in the southern states on salt water	G
Bufflehead (<i>Bucephala albeola</i>)		R			T	I, Rg, S, T	northern lakes and ponds; in winter, mainly on salt bays and estuaries	G
Common Goldeneye (<i>Bucephala clangula</i>)					T	I, Rg, S, T	nests on lakes and ponds in the North; in migration and winter mainly along the coast in bays and inlets	G
Hooded Merganser (<i>Lophodytes cucullatus</i>)						I, Rg, S, T	wooded ponds, lakes, and rivers; sometimes in tidal channels in winter	G
Red-breasted Merganser (<i>Mergus serrator</i>)					T	I, Rg, S, T	northern lakes and tundra ponds; in winter, principally on the ocean and in salt bays	G
Common Merganser (<i>Mergus merganser</i>)					T	I, Rg, S, T	wooded rivers and ponds; in winter, also on salt bays	G

Ruddy Duck (<i>Oxyura jamaicensis</i>)					T	I, Rg, S, T	freshwater marshes, marshy lakes and ponds; sometimes shallow salt bays and rivers in winter	G
KITES, HAWKS, EAGLES, AND ALLIES								
Osprey (<i>Pandion haliaetus</i>)	B, R		U		T	I, Rg, S, T	lakes, rivers, and seacoasts	
White-tailed Kite (<i>Elanus leucurus</i>)						I, Rg, S, T	farmlands and prairies with scattered trees or fencerows; mesquite grasslands	
Mississippi Kite (<i>Ictinia mississippiensis</i>)	B, R	R			T	I, Rg, S, T	open woodland and mixed scrub near water	
Bald Eagle (<i>Haliaeetus leucocephalus</i>)	B, R	R			T	I, Rg, S, T	lakes, rivers, marshes, and seacoasts	ST, FT(PDL)
Northern Harrier (<i>Circus cyaneus</i>)	B, R	R	U	U	T	I, Rg, S, T	marshes and open grasslands	
Sharp-shinned Hawk (<i>Accipiter striatus</i>)	B, R	R	U	U	T	I, Rg, S, T	dense coniferous forests, less often in deciduous forests; in migration and winter it may be seen in almost any habitat	
Cooper's Hawk (<i>Accipiter cooperii</i>)	B, R	R	U	U	T	I, Rg, S, T	deciduous and, less often, coniferous forests, especially where these are interrupted by meadows and clearings	
Common Black-Hawk (<i>Buteogallus anthracinus</i>)						I, Rg, S, T	wooded canyons and riverside woodlands	ST
Harris's Hawk (<i>Parabuteo unicinctus</i>)				U	T	I, Rg, S, T	semi-arid regions in scrub with mesquite, cacti, and yucca	
Red-shouldered Hawk (<i>Buteo lineatus</i>)	B, R	R	U	U		I, Rg, S, T	deciduous woodlands, especially where there is standing water	
Broad-winged Hawk (<i>Buteo platypterus</i>)	B, R		U	U		I, Rg, S, T	chiefly deciduous woodland	
Short-tailed Hawk (<i>Buteo brachyurus</i>)	B, R						chiefly cypress and mangrove swamps	
Swainson's Hawk (<i>Buteo swainsoni</i>)	B, R		U	U	T	I, Rg, S, T	open plains, grasslands, and prairie	
Zone-tailed Hawk (<i>Buteo albonotatus</i>)	B, R	R	U	U		I, Rg, S, T	forested canyons and riverside woodlands	ST
Red-tailed Hawk (<i>Buteo jamaicensis</i>)	B, R	R	U	U	T	I, Rg, S, T	mainly deciduous forest and adjacent open country; habitat more	

							variable in the West	
Ferruginous Hawk (<i>Buteo regalis</i>)	B, R		U	U	T	I, Rg, S, T	prairies, brushy open country, badlands	
Rough-legged Hawk (<i>Buteo lagopus</i>)					T	I, Rg, S, T	tundra; winters on open plains, agricultural areas, and marshes	
Golden Eagle (<i>Aquila chrysaetos</i>)	B, R	R			T	I, Rg, S, T	mainly deciduous forests and woodlands; often seen over adjacent farmland	
CARACARAS AND FALCONS								
Crested Caracara (<i>Caracara cheriway</i>)		R	U				prairies, savannahs, desert scrub, and seashores	
American Kestrel (<i>Falco sparverius</i>)	B, R	R	U	U	T	I, Rg, S, T	towns and cities, parks, farmlands, and open country	
Merlin (<i>Falco columbarius</i>)	B, R		U	U	T	I, Rg, S, T	coniferous forests; more widespread in winter	
Peregrine Falcon - American Peregrine Falcon, E; Arctic Peregrine Falcon, T - (<i>Falco peregrinus</i>)	B, R		U		T	I, Rg, S, T	open country, especially along rivers, also near lakes, and the coast; migrates chiefly along the coast	SE (American), ST (Arctic)
Prairie Falcon (<i>Falco mexicanus</i>)			U			I, Rg, S, T	barren mountains, dry plains, and prairies	
GROUSE, AND TURKEYS								
Wild Turkey (<i>Meleagris gallopavo</i>)	B, R	R	U	U	T	I, Rg, S, T	open woodlands, pine-oak forests	G
NEW WORLD QUAIL								
Scaled Quail (<i>Callipepla squamata</i>)			U		T	I, Rg, S, T	dry grasslands and brushy deserts	G
Northern Bobwhite (<i>Colinus virginianus</i>)	B, R	R	U	U	T	I, Rg, S, T	brushed pastures, grassy roadsides, farmlands, and open woodlands	G
RAILS, GALLINULES, AND COOTS								
Clapper Rail (<i>Rallus longirostris</i>)						I, Rg, S, T	salt marshes	G
Virginia Rail (<i>Rallus limicola</i>)					T	I, Rg, S, T	freshwater and brackish marshes; may visit salt marshes in winter	G

Sora (<i>Porzana carolina</i>)					T	I, Rg, S, T	chiefly freshwater marshes and marshy ponds; rice fields and salt marshes in winter	G
Purple Gallinule (<i>Porphyryla martinica</i>)	B, R					I, Rg, S, T	freshwater marshes with lily pads, pickerelweed, and other aquatic vegetation	G
Common Moorhen (<i>Gallinula chloropus</i>)						I, Rg, S, T	freshwater marshes and ponds with cattails and other aquatic vegetation	G
American Coot (<i>Fulica americana</i>)		R	U		T	I, Rg, S, T	open ponds and marshes; in winter, also in saltwater bays and inlets	
CRANES								
Sandhill Crane (<i>Grus canadensis</i>)	B, R			U	T	I, Rg, S, T	large freshwater marshes, prairie ponds, and marshy tundra; also on prairies and grainfields during migration and in winter	G
PLOVERS								
Black-bellied Plover (<i>Pluvialis squatarola</i>)					T	I, Rg, S, T	tundra; in migration and in winter it occurs on beaches and coastal marshes, less commonly on inland marshes, lakeshores, and plowed fields	
American Golden-Plover (<i>Pluvialis dominica</i>)					T	I, Rg, S, T	tundra; in migration, on coastal beaches and mudflats and inland on prairies and plowed fields	
Snowy Plover (<i>Charadrius alexandrinus</i>)					T	I, Rg, S, T	flat, sandy beaches; alkali beds; and sandy areas with little vegetation	
Wilson's Plover (<i>Charadrius wilsonia</i>)						I, Rg, S, T	sand beaches and mud flats	
Semipalmated Plover (<i>Charadrius semipalmatus</i>)					T	I, Rg, S, T	beaches and tidal flats, shallow pools in salt marshes; lakeshores in the interior during migration	
Killdeer (<i>Charadrius vociferus</i>)	B, R	R	U	U	T	I, Rg, S, T	open country generally--plowed fields, golf courses, and short-grass prairies	
Mountain Plover (<i>Charadrius montanus</i>)						I, Rg, S, T	arid plains, short-grass prairies, and fields	FPT
STILTS AND AVOCETS								
Black-necked Stilt (<i>Himantopus mexicanus</i>)			U		T	I, Rg, S, T	salt marshes and shallow coastal bays in the East; also freshwater	

							marshes in the West	
American Avocet <i>(Recurvirostra americana)</i>		R			T	I, Rg, S, T	freshwater marshes and shallow marshy lakes; breeds locally in salt or brackish marshes; many move to the coast in winter	
SANDPIPERS AND ALLIES								
Greater Yellowlegs <i>(Tringa melanoleuca)</i>		R	U		T	I, Rg, S, T	prefers pool, lakeshores, and tidal mud flats in migration, but open wet tundra and marshy ground in the breeding season	
Lesser Yellowlegs <i>(Tringa flavipes)</i>		R			T	I, Rg, S, T	marshy ponds, lake and river shores, mud flat; in the breeding season, boreal bogs	
Solitary Sandpiper <i>(Tringa solitaria)</i>	B, R	R	U		T	I, Rg, S, T	inland ponds and bogs, wet swampy places, and woodland streams	
Willet <i>(Catoptrophorus semipalmatus)</i>						I, Rg, S, T	coastal beaches, freshwater and salt marshes, lakeshores, and wet prairies	
Spotted Sandpiper <i>(Actitis macularia)</i>	B, R	R	U	U	T	I, Rg, S, T	almost anyplace with water nearby, both in open country and in wooded areas	
Upland Sandpiper <i>(Bartramia longicauda)</i>	B, R				T	I, Rg, S, T	open grassland, prairies, and hayfields in breeding season; also, while on migration, open country generally	
Whimbrel <i>(Numenius phaeopus)</i>						I, Rg, S, T	Arctic tundra, preferring freshwater pools near the coast; on migration, chiefly coastal salt meadows, mud flats, and grassy slopes along the coast	
Long-billed Curlew <i>(Numenius americanus)</i>					T	I, Rg, S, T	chiefly grass plains and prairies; in migration, lake and river shores, mud flats, salt marshes, and sand beaches	
Hudsonian Godwit <i>(Limosa haemastica)</i>						I, Rg, S, T	tundra; chiefly mud flats on migration	
Marbled Godwit <i>(Limosa fedoa)</i>						I, Rg, S, T	extensive grasslands; on migration, salt marshes, tidal creeks, mud flats, and sea beaches	
Ruddy Turnstone <i>(Arenaria interpres)</i>						I, Rg, S, T	coastal tundra; in winter on rocky, pebbly, and sandy coasts and	

							beaches	
Sanderling (<i>Calidris alba</i>)						I, Rg, S, T	ocean beaches, sandbars, occasionally mud flats; inland lake and river shores	
Semipalmated Sandpiper (<i>Calidris pusilla</i>)					T	I, Rg, S, T	coastal beaches, lake and river shores, flats, and pools in salt marshes	
Western Sandpiper (<i>Calidris mauri</i>)			U		T	I, Rg, S, T	shores, mud flats, grassy pools, and wet meadows	
Least Sandpiper (<i>Calidris minutilla</i>)			U		T	I, Rg, S, T	grassy pools, bogs, and marshes with open areas; also flooded fields and mud flats	
White-rumped Sandpiper (<i>Calidris fuscicollis</i>)						I, Rg, S, T	tundra; flats, grassy pools, wet meadows, and shores in winter	
Baird's Sandpiper (<i>Calidris bairdii</i>)					T	I, Rg, S, T	chiefly inland areas with grassy pools, wet meadows, and lake and river shores; in summer on the tundra	
Pectoral Sandpiper (<i>Calidris melanotos</i>)					T	I, Rg, S, T	wet, short-grass areas; grassy pools; golf courses and airports after heavy rains; and salt creeks and meadows	
Dunlin (<i>Calidris alpina</i>)					T	I, Rg, S, T	beaches, extensive mud and sand flats, tidal inlets and lagoons; also inland lake and river shores	
Stilt Sandpiper (<i>Micropalama himantopus</i>)						I, Rg, S, T	grassy pools and shores of ponds and lakes	
Buff-breasted Sandpiper (<i>Tryngites subruficollis</i>)						I, Rg, S, T	short-grass fields, meadows, and prairies; breeds in dry tundra	
Long-billed Dowitcher (<i>Limnodromus scolopaceus</i>)					T	I, Rg, S, T	breeds in muskeg; in migration and winter occurs on mud flats, marshy pools, and margins of freshwater ponds	
Common Snipe (<i>Gallinago gallinago</i>)	B, R	R	U	U	T	I, Rg, S, T	freshwater marshes, ponds, flooded meadows, and fields; more rarely in salt marshes	G
American Woodcock (<i>Scolopax minor</i>)					T	I, Rg, S, T	moist woodland and thickets near open fields	G
Wilson's Phalarope (<i>Phalaropus tricolor</i>)					T	I, Rg, S, T	prairie pools and marshes, lake and river shores, marshy pools along the coast	
Red-necked Phalarope (<i>Phalaropus lobatus</i>)					T	I, Rg, S, T	open ocean, beaches, flats, lake and river shores	

GULLS, TERNS, AND SKIMMERS								
Laughing Gull (<i>Larus atricilla</i>)					T	I, Rg, S, T	salt marshes, bays, and estuaries; very rare inland	
Franklin's Gull (<i>Larus pipixcan</i>)					T	I, Rg, S, T	prairie marshes and sloughs; often feeds in plowed fields	
Bonaparte's Gull (<i>Larus philadelphia</i>)					T	I, Rg, S, T	forested lakes and rivers; winters along the coast, in estuaries, and at the mouth of large rivers	
Ring-billed Gull (<i>Larus delawarensis</i>)					T	I, Rg, S, T	lakes and rivers; many move to salt water in the winter	
Herring Gull (<i>Larus argentatus</i>)					T	I, Rg, S, T	lakes, rivers, estuaries, and beaches; common in all aquatic habitats	
Common Tern (<i>Sterna hirundo</i>)					T	I, Rg, S, T	lakes, ponds, rivers, coastal beaches, and islands	
Forster's Tern (<i>Sterna forsteri</i>)					T	I, Rg, S, T	salt marshes in the East; freshwater marshes in the West	
Least Tern ("Interior") (<i>Sterna antillarum</i>)					T	I, Rg, S, T	sandy and pebbly beaches along the coast; sandbars in large rivers; often on land fills	SE, FE
Black Tern (<i>Chlidonias nigra</i>)					T	I, Rg, S, T	freshwater marshes and marshy lakes in summer; sandy coasts in migration and in winter	
PIGEONS AND DOVES								
Rock Dove (<i>Columba livia</i>)			U	U	T	I, Rg, S, T	city parks, suburban gardens, and farmland	I
Eurasian Collared-Dove (<i>Streptopelia decaocto</i>)			U			I, Rg, S, T	prefers open, dry areas with low scrub and scattered trees	I
White-winged Dove (<i>Zenaida asiatica</i>)	B, R		U	U	T	I, Rg, S, T	open arid country with dense thickets of shrubs and low trees	G
Mourning Dove (<i>Zenaida macroura</i>)	B, R	R	U	U	T	I, Rg, S, T	open fields, parks, and lawns with many trees and shrubs	G
Inca Dove (<i>Columbina inca</i>)	B, R	R	U	U	T	I, Rg, S, T	mesquite thickets or cacti in semi- arid country; also parks, yards, and ranches	
Common Ground-Dove (<i>Columbina passerina</i>)			U			I, Rg, S, T	open areas such as fields, gardens, farmland, and roadsides	
CUCKOOS, ROADRUNNERS, AND ANIS								

Yellow-billed Cuckoo (<i>Coccyzus americanus</i>)	B, R	R	U	U	T	I, Rg, S, T	moist thickets, willows, overgrown pastures, and orchards
Greater Roadrunner (<i>Geococcyx californianus</i>)	B, R	R		U	T	I, Rg, S, T	open arid country with scattered thickets
Groove-billed Ani (<i>Crotophaga sulcirostris</i>)	B, R						arid agricultural land especially where there are cattle
BARN OWLS							
Barn Owl (<i>Tyto alba</i>)				U	T	I, Rg, S, T	open country, forest edge and clearings, cultivated areas, and cities
TYPICAL OWLS							
Eastern Screech-Owl (<i>Otus asio</i>)	B, R	R	U	U	T	I, Rg, S, T	open deciduous woods, wood lots, suburban areas, lakeshores, old orchards
Western Screech-Owl (<i>Otus kennicottii</i>)					T	I, Rg, S, T	woodlands, orchards, yards with many trees
Great Horned Owl (<i>Bubo virginianus</i>)	B, R	R	U	U	T	I, Rg, S, T	ubiquitous, frequently forest, desert, open country, swamps, and even city parks
Elf Owl (<i>Micrathene whitneyi</i>)						I, Rg, S, T	desert, dry open woodland, and streamside thickets with trees
Burrowing Owl (<i>Athene cunicularia</i>)					T	I, Rg, S, T	plains, deserts, fields, and airports
Barred Owl (<i>Strix varia</i>)	B, R	R	U	U		I, Rg, S, T	low, wet woods and swamp forest
Long-eared Owl (<i>Asio otus</i>)					T	I, Rg, S, T	deciduous and evergreen forests
Short-eared Owl (<i>Asio flammeus</i>)					T	I, Rg, S, T	freshwater and salt marshes; open grassland, prairies, dunes; open country generally during migration
NIGHTJARS							
Lesser Nighthawk (<i>Chordeiles acutipennis</i>)	B, R			U	T	I, Rg, S, T	open dry scrublands; desert valleys; prairies and pastures
Common Nighthawk (<i>Chordeiles minor</i>)	B, R	R	U	U	T	I, Rg, S, T	aerial, but open country generally; also cities and towns
Common Poorwill (<i>Phalaenoptilus nuttallii</i>)	B, R	R	U	U	T	I, Rg, S, T	desert, chaparral, sagebrush, and other arid uplands
Chuck-will's-widow (<i>Caprimulgus carolinensis</i>)	B, R	R	U	U		I, Rg, S, T	open woodland and clearings near agricultural country

Whip-poor-will (<i>Caprimulgus vociferus</i>)	B, R				T	I, Rg, S, T	dry open woodland near fields	
SWIFTS								
Chimney Swift (<i>Chaetura pelagica</i>)	B, R	R	U	U	T	I, Rg, S, T	breeds and roosts in chimneys; feeds entirely on the wing	
HUMMINGBIRDS								
Green Violet-ear (<i>Colibri thalassinus</i>)	B, R						most U. S. sightings have been in areas with dense vegetation	
Broad-billed Hummingbird (<i>Cynanthus latirostris</i>)						I, Rg, S, T	desert canyons; mesquite and other thickets in arid country	
Blue-throated Hummingbird (<i>Lampornis clemenciae</i>)	B, R						streamside growth in canyons	
Ruby-throated Hummingbird (<i>Archilochus colubris</i>)	B, R	R	U		T	I, Rg, S, T	suburban gardens, parks, and woodlands	
Black-chinned Hummingbird (<i>Archilochus alexandri</i>)	B, R	R	U	U	T	I, Rg, S, T	mountain and alpine meadows, woodlands, canyons with thickets, chaparral, and orchards	
Anna's Hummingbird (<i>Calypte anna</i>)						I, Rg, S, T	chaparral, brushy oak woodlands, and gardens	
Calliope Hummingbird (<i>Stellula calliope</i>)						I, Rg, S, T	montane and subalpine forest clearings, brushy edges, and alpine meadows	
Broad-tailed Hummingbird (<i>Selasphorus platycercus</i>)			U			I, Rg, S, T	mountain meadows, pinon-juniper woodlands, dry pinedosa pines, fir or mixed forests, and canyon vegetation	
Rufous Hummingbird (<i>Selasphorus rufus</i>)	B, R			U	T	I, Rg, S, T	mountain meadows, forest edges; in migration and winter often in gardens with hummingbird feeding stations	
KINGFISHERS								
Ringed Kingfisher (<i>Ceryle torquata</i>)			U				tree-lined rivers, streams, and lakes	
Belted Kingfisher (<i>Ceryle alcyon</i>)	B, R	R	U	U	T	I, Rg, S, T	rivers, lakes, and saltwater estuaries	
Green Kingfisher (<i>Chloroceryle americana</i>)	B, R	R	U	U		I, Rg, S, T	woodland streams and pools	

WOODPECKERS AND ALLIES								
Lewis's Woodpecker (<i>Melanerpes lewis</i>)						I, Rg, S, T	open pine-oak woodlands, oak or cottonwood groves in grasslands, ponderosa pine country	
Red-headed Woodpecker (<i>Malanerpes erythrocephalus</i>)					T	I, Rg, S, T	open country, farms, rural roads, open park-like woodland, and golf courses	
Acorn Woodpecker (<i>Melanerpes formicivorus</i>)		R			T	I, Rg, S, T	open oak and pine-oak forests	
Golden-fronted Woodpecker (<i>Melanerpes aurifrons</i>)	B, R	R	U	U	T	I, Rg, S, T	open woods in dry country and river bottoms with trees	
Red-bellied Woodpecker (<i>Centurus carolinus</i>)					T	I, Rg, S, T	open and swamp woodland; comes into parks during migration and to feeders in winter	
Yellow-bellied Sapsucker (<i>Sphyrapicus varius</i>)	B, R	R	U	U	T	I, Rg, S, T	young, open deciduous or mixed forest with clearings; in migration, parks, yards, gardens	
Red-naped Sapsucker (<i>Sphyrapicus nuchalis</i>)	B, R				T	I, Rg, S, T	edges of coniferous forests, woodlands, groves of aspen and alder	
Ladder-backed Woodpecker (<i>Picoides scalaris</i>)	B, R	R	U	U	T	I, Rg, S, T	arid areas with thickets and trees	
Downy Woodpecker (<i>Picoides pubescens</i>)	B, R			U		I, Rg, S, T	wood lots, parks, and gardens; suet feeders in winter	
Northern Flicker (<i>Colaptes auratus</i>)	B, R	R		U	T	I, Rg, S, T	open country with trees; parks and large gardens	
TYRANT FLYCATCHERS								
Olive-sided Flycatcher (<i>Contopus cooperi</i>)	B, R	R		U	T	I, Rg, S, T	boreal spruce and fir forests, usually near openings, burns, ponds, and bogs	
Western Wood-Pewee (<i>Contopus sordidulus</i>)				U	T	I, Rg, S, T	open woodland and woodland edges; orchards	
Eastern Wood-Pewee (<i>Contopus virens</i>)	B, R	R	U	U	T	I, Rg, S, T	forest, open woodland, orchards, and shade trees in parks and along roadsides	
Acadian Flycatcher (<i>Empidonax virescens</i>)	B, R	R	U	U		I, Rg, S, T	beech-maple or hemlock forest, usually under the canopy but also in clearings; often in wooded ravines	
Willow Flycatcher ("Southwestern") (<i>Empidonax traillii</i>)	B, R				T	I, Rg, S, T	swampy thickets, upland pastures, and old abandoned orchards	SE, FE

Least Flycatcher (<i>Empidonax minimus</i>)	B, R				T	I, Rg, S, T	widely distributed in open country, nesting in shade trees, orchards, villages, city parks, rural roadsides, and woodland borders
Black Phoebe (<i>Sayornis nigricans</i>)	B, R	R	U	U		I, Rg, S, T	shady areas near water, streams, ponds and lake banks; in winter, city parks, open chaparral
Eastern Phoebe (<i>Sayornis phoebe</i>)	B, R	R	U	U	T	I, Rg, S, T	open woodland near streams; cliffs, bridges, and buildings with ledges
Say's Phoebe (<i>Sayornis saya</i>)	B, R		U	U	T	I, Rg, S, T	plains, sparsely vegetated countryside, dry sunny locations, often near ranch houses, barns, and other buildings
Vermilion Flycatcher (<i>Pyrocephalus rubinus</i>)	B, R	R	U	U	T	I, Rg, S, T	trees and shrubs in open river bottoms and along roadsides
Ash-throated Flycatcher (<i>Myiarchus cinerascens</i>)	B, R	R	U	U	T	I, Rg, S, T	deserts with cactus and mesquite thickets; also dry woods
Great Crested Flycatcher (<i>Myiarchus crinitus</i>)	B, R	R	U	U		I, Rg, S, T	open forest, orchards, and large trees in farm country
Brown-crested Flycatcher (<i>Myiarchus tyrannulus</i>)			U			I, Rg, S, T	arid lands in areas with cacti or large trees
Great Kiskadee (<i>Pitangus sulphuratus</i>)						I, Rg, S, T	rivers, streams, and lakes bordered with dense vegetation; also in more open country and in parks in most of its range
Couch's Kingbird (<i>Tyrannus couchii</i>)			U				borders of woodlands and brushy streamside thickets
Cassin's Kingbird (<i>Tyrannus vociferans</i>)						I, Rg, S, T	savannas, rangelands, pinon-juniper woodlands
Western Kingbird (<i>Tyrannus verticalis</i>)	B, R	R	U	U	T	I, Rg, S, T	open country; ranches, roadsides, streams, and ponds with trees
Eastern Kingbird (<i>Tyrannus tyrannus</i>)	B, R	R	U		T	I, Rg, S, T	open country; farms, orchards, roadsides, and lake and river shores
Scissor-tailed Flycatcher (<i>Tyrannus forficatus</i>)	B, R	R	U	U	T	I, Rg, S, T	open country along roadsides and on ranches with scattered trees and bushes; also fence wires and posts

SHRIKES							
Northern Shrike (<i>Lanius excubitor</i>)						I, Rg, S, T	open woodlands and brushy swamps in summer; open grasslands with fence posts and scattered trees in

							winter	
Loggerhead Shrike <i>(Lanius ludovicianus)</i>	B, R	R	U	U	T	I, Rg, S, T	grasslands, orchards, and open areas, with scattered trees; open grassy woodlands; deserts in the West	
VIREOS								
White-eyed Vireo <i>(Vireo griseus)</i>	B, R	R	U	U	T	I, Rg, S, T	dense swampy thickets and hillsides with blackberry and briar tangles	
Bell's Vireo <i>(Vireo belii)</i>	B, R	R	U	U	T	I, Rg, S, T	dense bottomland thickets, willow scrub, and mesquite	
Black-capped Vireo <i>(Vireo atricapillus)</i>	B, R	R	U			I, Rg, S, T	dense oak scrub and juniper thickets	SE, FE
Gray Vireo <i>(Vireo vicinior)</i>						I, Rg, S, T	dry brush, especially juniper in the pinon- and juniper-covered slopes of the southwestern mountains; scrub oak and other types of chaparral	
Yellow-throated Vireo <i>(Vireo flavifrons)</i>	B, R	R	U	U		I, Rg, S, T	tall deciduous trees at the edge of forests, along streams, roadsides, orchards, parks, and estates	
Blue-headed Vireo <i>(Vireo solitarius)</i>	B, R		U	U	T	I, Rg, S, T	coniferous and mixed forests	
Warbling Vireo <i>(Vireo gilvus)</i>			U		T	I, Rg, S, T	deciduous woodland, especially near streams; in isolated groves and shade trees	
Philadelphia Vireo <i>(Vireo philadelphicus)</i>	B, R				T	I, Rg, S, T	open second-growth woodlands, old clearings and burned-over areas, and thickets along streams and lakes	
Red-eyed Vireo <i>(Vireo olivaceus)</i>	B, R	R	U	U	T	I, Rg, S, T	deciduous forest, and shade trees in residential areas	
JAYS, MAGPIES, AND CROWS								
Blue Jay <i>(Cyanocitta cristata)</i>	B, R		U		T	I, Rg, S, T	chiefly oak forest, but now also city parks and suburban yards, especially where oak trees predominate	
Western Scrub-Jay <i>(Aphelocoma californica)</i>	B, R	R	U	U	T	I, Rg, S, T	scrub oak, woodlands, and chaparral, but does not breed in low scrub because it needs watch posts; also inhabits suburban gardens	
Clark's Nutcracker <i>(Nucifraga columbiana)</i>						I, Rg, S, T	stands of juniper and ponderosa pine or of whitebark pine and larch on	

							high mountain ranges, near the tree line	
American Crow <i>(Corvus brachyrhynchos)</i>		R					deciduous growth along rivers and streams; orchards and city parks; also mixed and coniferous woods, but avoids closed coniferous forests and desert expanses	
Chihuahuan Raven <i>(Corvus cryptoleucus)</i>		R	U	U	T	I, Rg, S, T	arid grasslands and mesquite; plains and deserts	
Common Raven <i>(Corvus corax)</i>	B, R	R	U	U	T	I, Rg, S, T	coniferous forests and rocky coasts; in the West also in deserts and arid mountains	
LARKS								
Horned Lark <i>(Eremophila alpestris)</i>					T	I, Rg, S, T	plains, fields, airports, and beaches	
SWALLOWS								
Purple Martin <i>(Progne subis)</i>	B, R	R	U	U	T	I, Rg, S, T	open woodland, residential areas, and agricultural land	
Tree Swallow <i>(Tachycineta bicolor)</i>					T	I, Rg, S, T	lakeshores, flooded meadows, marshes, and streams	
Violet-green Swallow <i>(Tachycineta thalassina)</i>						I, Rg, S, T	breeds in forests, wooded foothills, mountains, suburban areas	
Northern Rough-winged Swallow <i>(Stelgidopteryx serripennis)</i>	B, R	R	U	U	T	I, Rg, S, T	riverbanks; prefers drier sites than the Bank Swallow	
Bank Swallow <i>(Riparia riparia)</i>					T	I, Rg, S, T	rivers and streams; especially near sandbanks; more widespread during migration	
Cliff Swallow <i>(Petrochelidon pyrrhonota)</i>	B, R	R	U	U	T	I, Rg, S, T	open country near buildings or cliffs; lakeshores and marshes on migration	
Cave Swallow <i>(Petrochelidon fulva)</i>	B, R		U		T	I, Rg, S, T	chiefly open country near caves and cliffs	
Barn Swallow <i>(Hirundo rustica)</i>	B, R	R	U	U	T	I, Rg, S, T	agricultural land, suburban areas, marshes, lake shores	
CHICKADEES AND TITMICE								
Carolina Chickadee <i>(Poecile carolinensis)</i>	B, R	R	U	U	T	I, Rg, S, T	deciduous woodlands and residential areas	

Tufted Titmouse (<i>Baeolophus bicolor</i>)	B, R	R	U	U	T	I, Rg, S, T	swampy or moist woodland and shade trees in villages and city parks; in winter, at feeders
VERDIN							
Verdin (<i>Auriparus flaviceps</i>)		R	U	U	T	I, Rg, S, T	brushy desert; mesquite thickets
BUSHTITS							
Bushtit (<i>Psaltriparus minimus</i>)	B, R	R	U	U	T	I, Rg, S, T	varied; deciduous growth, usually streamside; in the coastal forest, it lives in second-growth alder thickets or in edges of coniferous forests composed of maple, dogwood, and birch; also in oak woodland, chaparral, and juniper brush
NUTHATCHES							
Red-breasted Nuthatch (<i>Sitta canadensis</i>)		R		U	T	I, Rg, S, T	coniferous forests; more widespread in migration and winter
White-breasted Nuthatch (<i>Sitta carolinensis</i>)			U			I, Rg, S, T	deciduous and mixed forest
CREEPERS							
Brown Creeper (<i>Certhia americana</i>)	B, R	R		U	T	I, Rg, S, T	deciduous and mixed woodlands
WRENS							
Cactus Wren (<i>Campylorhynchus brunneicapillus</i>)	B, R	R	U	U	T	I, Rg, S, T	arid desert thickets and cacti
Rock Wren (<i>Salpinctes obsoletus</i>)	B, R	R		U	T	I, Rg, S, T	rock-strewn slopes, canyons, cliffs, and dams, in arid country
Canyon Wren (<i>Catherpes mexicanus</i>)	B, R	R	U	U		I, Rg, S, T	rocky canyons and cliffs; old stone buildings
Carolina Wren (<i>Thryothorus ludovicianus</i>)	B, R	R	U	U	T	I, Rg, S, T	woodland thickets, ravines, and rocky slopes covered with brush
Bewick's Wren (<i>Thryomanes bewickii</i>)	B, R	R	U	U	T	I, Rg, S, T	thickets, brush piles, and hedgerows in farming country; also open woodland and scrubby areas, often near streams

House Wren (<i>Troglodytes aedon</i>)	B, R	R	U		T	I, Rg, S, T	residential areas, city parks, farmlands, and woodland edges
Winter Wren (<i>Troglodytes troglodytes</i>)	B, R	R		U	T	I, Rg, S, T	dense tangles and thickets in coniferous and mixed forests
Sedge Wren (<i>Cistothorus platensis</i>)					T	I, Rg, S, T	grassy freshwater marshes and sedges; also brackish marshes and wet meadows in winter
Marsh Wren (<i>Cistothorus palustris</i>)	B, R	R			T	I, Rg, S, T	freshwater and brackish marshes with cattails, reeds, bulrushes, or sedges
KINGLETS							
Golden-crowned Kinglet (<i>Regulus satrapa</i>)	B, R	R		U	T	I, Rg, S, T	dense, old conifer stands; also in deciduous forests and thickets in winter
Ruby-crowned Kinglet (<i>Regulus calendula</i>)	B, R	R	U	U	T	I, Rg, S, T	coniferous forests in summer; also deciduous forests and thickets in winter
GNATCATCHERS							
Blue-gray Gnatcatcher (<i>Polioptila caerulea</i>)	B, R	R	U	U	T	I, Rg, S, T	open, moist woodlands and brushy streamside thickets
Black-tailed Gnatcatcher (<i>Polioptila melanura</i>)			U				desert and arid country; dry washes in the low desert
THRUSHES, AND ALLIES							
Eastern Bluebird (<i>Sialia sialis</i>)	B, R	R	U	U	T	I, Rg, S, T	open farmland with scattered trees
Western Bluebird (<i>Sialia mexicana</i>)						I, Rg, S, T	open woodlands and pastures where old trees provide nest sites
Mountain Bluebird (<i>Sialis currucoides</i>)	B, R					I, Rg, S, T	breeds in high mountain meadows with scattered trees and bushes; in winter descends to lower elevations; where it occurs on plains and grasslands
Townsend's Solitaire (<i>Myadestes townsendi</i>)	B, R	R	U			I, Rg, S, T	open coniferous forests, edges, or burns with single standing trees in the mountains
Gray-cheeked Thrush (<i>Catharus minimus</i>)					T	I, Rg, S, T	nests in coniferous forests, especially in dense stands of stunted spruce and balsam; widespread in migration

Swainson's Thrush (<i>Catharus ustulatus</i>)	B, R				T	I, Rg, S, T	coniferous forests and willow thickets	
Hermit Thrush (<i>Catharus guttatus</i>)	B, R	R	U	U	T	I, Rg, S, T	coniferous and mixed forests; deciduous woodlands and thickets in winter	
Wood Thrush (<i>Hylocichla mustelina</i>)						I, Rg, S, T	moist, deciduous woodlands with a thick understory; also well-planted parks and gardens	
American Robin (<i>Turdus migratorius</i>)	B, R	R	U	U	T	I, Rg, S, T	towns, gardens, open woodland, and agricultural land	

THRASHERS, AND ALLIES								
Gray Catbird (<i>Dumetella carolinensis</i>)	B, R		U		T	I, Rg, S, T	thickets and brush, residential areas and gardens	
Northern Mockingbird (<i>Mimus polyglottos</i>)	B, R	R	U	U	T	I, Rg, S, T	residential areas, city parks, farmlands, open country with thickets, and desert brush	
Sage Thrasher (<i>Oreoscoptes montanus</i>)				U	T	I, Rg, S, T	dry sagebrush plains and arid areas as in rocky canyons; winters in dense thickets and lowland scrub	
Brown Thrasher (<i>Toxostoma rufum</i>)					T	I, Rg, S, T	thickets, fields with scrub, and woodland borders	
Long-billed Thrasher (<i>Toxostoma longirostre</i>)	B, R		U			I, Rg, S, T	dense tangles and thickets in both open country and wooded areas and in both moist and dry regions	
Curve-billed Thrasher (<i>Toxostoma curvirostre</i>)	B, R		U	U	T	I, Rg, S, T	arid desert brushland and cactus	
Crissal Thrasher (<i>Toxostoma crissale</i>)						I, Rg, S, T	dense underbrush near desert streams; edge of canyon chaparral in the hot, low desert	
STARLINGS								
European Starling (<i>Sturnus vulgaris</i>)	B, R		U	U	T	I, Rg, S, T	cities, suburban areas, farmlands, and ranches	I
PIPITS								
American Pipit (<i>Anthus rubescens</i>)	B, R			U	T	I, Rg, S, T	Arctic and alpine tundra; during migration and winter, beaches, barren fields, agricultural land, and golf courses	

Sprague's Pipit (<i>Anthus spragueii</i>)	B, R				T	I, Rg, S, T	short-grass plains and plowed fields
WAXWINGS							
Cedar Waxwing (<i>Bombcilla cedrorum</i>)	B, R	R	U	U	T	I, Rg, S, T	open woodlands, orchards, and residential areas
SILKY-FLYCATCHERS							
Phainopepla (<i>Phainopepla nitens</i>)						I, Rg, S, T	desert scrub, but does not have strong preference for desert; it favors hot country with single, tall trees, preferably with mistletoe or other berries available when flying insects are scarce
WOOD-WARBLERS							
Blue-winged Warbler (<i>Vermivora pinus</i>)	B, R					I, Rg, S, T	abandoned fields and pastures grown up to saplings; forest clearings and edges with clumps of catbrier, blackberry, and various bushes and young trees
Golden-winged Warbler (<i>Vermivora chrysoptera</i>)	B, R						abandoned fields and pastures grown up to saplings but usually in moister situations
Tennessee Warbler (<i>Vermivora peregrina</i>)	B, R	R				I, Rg, S, T	open mixed woodlands in the breeding season; in trees and bushes during migration
Orange-crowned Warbler (<i>Vermivora celata</i>)	B, R	R		U	T	I, Rg, S, T	thickets and brushy woodlands
Nashville Warbler (<i>Vermivora ruficapilla</i>)	B, R	R	U	U	T	I, Rg, S, T	woodland edges; thickets in open mixed forest or brushy borders of swamps
Northern Parula (<i>Parula americana</i>)	B, R		U	U	T	I, Rg, S, T	breeds in wet chiefly coniferous woods, swamps, and along lakes and ponds; more widespread on migration
Yellow Warbler (<i>Dendroica petechia</i>)	B, R	R		U	T	I, Rg, S, T	moist thickets, especially along streams and in swampy areas; gardens
Chestnut-sided Warbler (<i>Dendroica pensylvanica</i>)	B, R						young, open second-growth woodland and scrub

Magnolia Warbler (<i>Dendroica magnolia</i>)			U					breeds in open stands of young spruce and fir; in migration is found almost any place where shrubbery or trees occur	
Yellow-rumped Warbler (<i>Dendroica coronata</i>)	B, R	R	U	U	T		I, Rg, S, T	coniferous and mixed forests; widespread during migration and winter	
Townsend's Warbler (<i>Dendroica townsendi</i>)	B, R							coniferous forests; in old stands of Douglas firs, where it forages in the upper canopy	
Black-throated Green Warbler (<i>Dendroica virens</i>)	B, R		U				I, Rg, S, T	open stands of hemlock or pine; in migration in a variety of habitats	
Golden-cheeked Warbler (<i>Dendroica chrysoparia</i>)	B, R	R	U	U				rocky hillsides clothed with juniper	SE, FE
Blackburnian Warbler (<i>Dendroica fusca</i>)	B, R							most numerous in mixed forests of hemlock, spruce, and various hardwoods, usually ranging high in the trees	
Yellow-throated Warbler (<i>Dendroica dominica</i>)	B, R	R	U	U				forests of pine, cypress, sycamore, and oak, in both swampy places and dry uplands	
Pine Warbler (<i>Dendroica pinus</i>)							I, Rg, S, T	pine forests	
Palm Warbler (<i>Dendroica palmarum</i>)							I, Rg, S, T	in summer, bogs in the North; during migration, open places, especially weedy fields and borders of marshes	
Blackpoll Warbler (<i>Dendroica striata</i>)	B, R							breeds in coniferous forests; during migration is found chiefly in tall trees	
Black-and-white Warbler (<i>Mniotilta varia</i>)	B, R	R	U	U	T		I, Rg, S, T	primary and secondary forest, chiefly deciduous; in migration in parks, gardens, and lawn areas with trees and shrubs	
American Redstart (<i>Setophaga ruticilla</i>)	B, R				T		I, Rg, S, T	second-growth woodlands; thickets with saplings	
Prothonotary Warbler (<i>Protonotaria citrea</i>)	B, R		U				I, Rg, S, T	wooded swamps, flooded bottomland forest, and streams with dead trees	
Worm-eating Warbler (<i>Helmitheros vermivorus</i>)	B, R						I, Rg, S, T	chiefly dry wooded hillsides	
Ovenbird (<i>Seiurus aurocapillus</i>)							I, Rg, S, T	mature, dry forest with little undergrowth	

Northern Waterthrush (<i>Seiurus noveboracensis</i>)	B, R				T	I, Rg, S, T	cool bogs, wooded swamps, and lake shores in the breeding season; almost any wooded habitat in migration
Louisiana Waterthrush (<i>Seiurus motacilla</i>)	B, R		U			I, Rg, S, T	prefers swift-moving brooks on hillsides and, where the Northern Waterthrush is absent, occurs in river swamps and along sluggish streams
Kentucky Warbler (<i>Oporornis formosus</i>)	B, R					I, Rg, S, T	low, moist, rich woodland with luxuriant undergrowth; often in ravines
Mourning Warbler (<i>Oporornis philadelphia</i>)	B, R				T	I, Rg, S, T	dense thickets of blackberries and briars in forest clearings; also in wet woods with thick undergrowth
MacGillivray's Warbler (<i>Oporornis tolmiei</i>)	B, R		U		T	I, Rg, S, T	coniferous forest edges, burns, brushy cuts, or second-growth alder thickets and streamside growth
Common Yellowthroat (<i>Geothlypis trichas</i>)	B, R		U	U	T	I, Rg, S, T	moist thickets and grassy marshes
Wilson's Warbler (<i>Wilsonia pusilla</i>)	B, R	R	U	U	T	I, Rg, S, T	moist thickets in woodland and along streams; alder and willow thickets and bogs
Canada Warbler (<i>Wilsonia canadensis</i>)	B, R						cool, moist woodland that is nearly mature and has much undergrowth
Rufous-capped Warbler (<i>Basileuterus rufifrons</i>)	B, R						U. S. sightings have primarily come from canyon bottoms bordered by brushy thorn scrub or oak slopes
Yellow-breasted Chat (<i>Icteria virens</i>)	B, R	R	U	U	T	I, Rg, S, T	dense thickets and brush, often with thorns; streamside tangles and dry brushy hillsides
TANAGERS							
Summer Tanager (<i>Piranga rubra</i>)	B, R	R	U	U	T	I, Rg, S, T	open woodlands and shade trees
Western Tanager (<i>Piranga ludoviciana</i>)	B, R					I, Rg, S, T	coniferous or mixed pine-oak forests
SPARROWS, BUNTINGS, AND ALLIES							
Olive Sparrow (<i>Arremonops rufivirgatus</i>)			U				brushy areas, woodland borders and clearings, and overgrown fields

Green-tailed Towhee (<i>Pipilo chlorurus</i>)	B, R	R			T	I, Rg, S, T	sagebrush, mountain chaparral, pinon-juniper stands and thickets bordering alpine meadows
Eastern Towhee (<i>Pipilo erythrophthalmus</i>)					T	I, Rg, S, T	thickets and brushy woodland edges
Spotted Towhee (<i>Pipilo maculatus</i>)	B, R	R	U	U	T	I, Rg, S, T	thickets and brushy woodland edges
Canyon Towhee (<i>Pipilo fuscus</i>)	B, R	R	U	U	T	I, Rg, S, T	brushy and rocky hills in arid country
Cassin's Sparrow (<i>Aimophila cassinii</i>)	B, R		U		T	I, Rg, S, T	sparsely vegetated country; barren rocky areas with scattered cacti and yuccas, and short grass; it uses such plants, as well as fence posts and wires, as song perches
Rufous-crowned Sparrow (<i>Aimophila ruficeps</i>)	B, R	R	U	U	T	I, Rg, S, T	open oak woodlands; treeless dry uplands with grassy vegetation and bushes, often near rocky outcrops
American Tree Sparrow (<i>Spizella arborea</i>)					T	I, Rg, S, T	arctic willow and birch thickets, fields, weedy woodland edges, and roadside thickets in winter
Chipping Sparrow (<i>Spizella passerina</i>)	B, R	R	U	U	T	I, Rg, S, T	grassy woodland edges, gardens, city parks, brushy pastures, and lawns
Clay-colored Sparrow (<i>Spizella pallida</i>)	B, R	R	U		T	I, Rg, S, T	brushy grasslands and prairies
Brewer's Sparrow (<i>Spizella breweri</i>)			U		T	I, Rg, S, T	sagebrush and alpine meadows
Field Sparrow (<i>Spizella pusilla</i>)	B, R	R	U	U	T	I, Rg, S, T	abandoned fields and pastures grown up to weeds, scattered bushes, and small saplings
Vesper Sparrow (<i>Pooecetes gramineus</i>)	B, R	R	U	U	T	I, Rg, S, T	fields, pastures, and roadsides in farming country
Lark Sparrow (<i>Chondestes grammacus</i>)	B, R	R	U	U	T	I, Rg, S, T	grasslands with scattered bushes and trees; open country generally in winter
Black-throated Sparrow (<i>Amphispiza bilineata</i>)	B, R	R	U		T	I, Rg, S, T	desert with cactus, mesquite, and creosote bush, and also sagebrush; often found where it is rocky
Lark Bunting (<i>Calamospiza melanocorys</i>)	B, R	R		U	T	I, Rg, S, T	open plains and fields
Savannah Sparrow (<i>Passerculus sandwichensis</i>)	B, R		U	U	T	I, Rg, S, T	fields, prairies, salt marshes, and grassy dunes

Baird's Sparrow (<i>Ammodramus bairdii</i>)					T	I, Rg, S, T	dry upland prairies
Grasshopper Sparrow (<i>Ammodramus savannarum</i>)	B, R		U		T	I, Rg, S, T	open grassy and weedy meadows, pastures, and plains
Henslow's Sparrow (<i>Ammodramus henslowii</i>)							local in moist or dry grassland with scattered weeds and small shrubs
Le Conte's Sparrow (<i>Ammodramus leconteii</i>)					T	I, Rg, S, T	moist grassland and boggy meadows; also dry fields in winter
Fox Sparrow (<i>Passerella iliaca</i>)					T	I, Rg, S, T	coniferous forest undergrowth in summer; dense woodland thickets, weedy pastures, and brushy roadsides in winter
Song Sparrow (<i>Melospiza melodia</i>)	B, R	R		U	T	I, Rg, S, T	thickets, pastures, undergrowth in gardens, and city parks
Lincoln's Sparrow (<i>Melospiza lincolnii</i>)	B, R	R	U	U	T	I, Rg, S, T	brushy bogs, willow, or alder thickets; winters in woodland thickets and brushy pastures
Swamp Sparrow (<i>Melospiza georgiana</i>)	B, R	R			T	I, Rg, S, T	freshwater marshes and open wooded swamps; in migration with other sparrows in weedy fields, parks, and brush piles
White-throated Sparrow (<i>Zonotrichia albicollis</i>)	B, R	R	U		T	I, Rg, S, T	brushy undergrowth in coniferous woodlands; winters in brush woodland, pastures, and suburban areas
Harris's Sparrow (<i>Zonotrichia querula</i>)		R			T	I, Rg, S, T	breeds in mossy bogs and scrub forests, migrates through the prairie regions, and winters in dense river-bottom thickets, woodland borders, clearings, and brush piles
White-crowned Sparrow (<i>Zonotrichia leucophrys</i>)	B, R	R	U	U	T	I, Rg, S, T	nests in dense brush, especially where near open grassland; winters in open woods and gardens
Dark-eyed Junco (<i>Junco hyemalis</i>)	B, R	R			T	I, Rg, S, T	coniferous or mixed forests; winters in fields, gardens, city parks, and roadside thickets
McCown's Longspur (<i>Calcarius mccownii</i>)						I, Rg, S, T	arid plains
Chestnut-collared Longspur (<i>Calcarius ornatus</i>)	B, R					I, Rg, S, T	dry elevated prairies and short-grass plains
GROSBEAKS, AND ALLIES							

Northern Cardinal (<i>Cardinalis cardinalis</i>)	B, R	R	U	U	T	I, Rg, S, T	woodland edges, thickets, brushy swamps, and gardens
Pyrrhuloxia (<i>Cardinalis sinuatus</i>)	B, R	R	U	U	T	I, Rg, S, T	desert brush, especially along stream beds
Rose-breasted Grosbeak (<i>Pheucticus ludovicianus</i>)		R				I, Rg, S, T	moist woodland adjacent to open fields with tall shrubs; also old and overgrown orchards
Black-headed Grosbeak (<i>Pheucticus melanocephalus</i>)	B, R				T	I, Rg, S, T	open, deciduous woodland near water, such as river bottoms, lakeshores, and swampy places with a mixture of trees and shrubs
Blue Grosbeak (<i>Guiraca caerulea</i>)	B, R	R	U	U	T	I, Rg, S, T	brushy, moist pastures and roadside thickets
Lazuli Bunting (<i>Passerina amoena</i>)	B, R		U		T	I, Rg, S, T	dry, brushy ravines and slopes; cleared areas and weedy pastures
Indigo Bunting (<i>Passerina cyanea</i>)	B, R		U		T	I, Rg, S, T	brushy slopes, abandoned farmland, old pastures and fields grown up to scrub, woodland clearings, and forest edge adjacent to fields
Varied Bunting (<i>Passerina versicolor</i>)	B, R					I, Rg, S, T	dense desert brush, especially along stream beds
Painted Bunting (<i>Passerina ciris</i>)	B, R	R	U	U	T	I, Rg, S, T	brushy tangles, hedgerows, briar patches, woodland edges, and swampy thickets
Dickcissel (<i>spiza americana</i>)	B, R		U	U		I, Rg, S, T	open country in grain or hay fields and in weed patches
BLACKBIRDS AND ORIOLES							
Bobolink (<i>Dolichonyx oryzivorus</i>)						I, Rg, S, T	prairies and meadows; marshes during migration
Red-winged Blackbird (<i>Agelaius phoeniceus</i>)	B, R	R	U	U	T	I, Rg, S, T	marshes, swamps, and wet and dry meadows; pastures
Eastern Meadowlark (<i>Sturnella magna</i>)	B, R	R	U	U	T	I, Rg, S, T	meadows, pastures, and prairies; in migration, in open country generally
Western Meadowlark (<i>Sturnella neglecta</i>)	B, R	R	U	U	T	I, Rg, S, T	meadows, plains, and prairies
Yellow-headed Blackbird (<i>Xanthocephalus xanthocephalus</i>)	B, R	R	U		T	I, Rg, S, T	freshwater marshes
Rusty Blackbird (<i>Euphagus carolinus</i>)						I, Rg, S, T	wooded swamps and damp woods with pools during migration; boreal bogs in the breeding season

Brewer's Blackbird (<i>Euphagus cyanocephalus</i>)	B, R		U		T	I, Rg, S, T	prairies, fields, and farm yards
Common Grackle (<i>Quiscalus quiscula</i>)	B, R		U		T	I, Rg, S, T	lawns, parks, fields, open woodland
Great-tailed Grackle (<i>Quiscalus mexicanus</i>)		R	U	U	T	I, Rg, S, T	farmlands with scattered trees and thickets
Bronzed Cowbird (<i>Molothrus aeneus</i>)	B, R	R	U	U		I, Rg, S, T	pastures, roadside thickets, ranches, open country generally; also parks and orchards
Brown-headed Cowbird (<i>Molothrus ater</i>)	B, R	R	U	U	T	I, Rg, S, T	agricultural land, fields, woodland edges, and suburban areas
Orchard Oriole (<i>Icterus spurius</i>)	B, R	R	U	U	T	I, Rg, S, T	orchards, shade trees in parks and gardens, and scattered trees along lakes and streams
Hooded Oriole (<i>Icterus cucullatus</i>)	B, R	R	U	U			originally streamside growth, but has adapted to tree plantations, city parks, and suburbs with palm or eucalyptus trees and shrubbery
Baltimore Oriole (<i>Icterus galbula</i>)	B, R	R		U	T	I, Rg, S, T	deciduous woodland and shade trees; before its decline, the American elm was a favorite nesting site for the Eastern bird
Bullock's Oriole (<i>Icterus bullockii</i>)	B, R		U		T	I, Rg, S, T	deciduous woodland and shade trees
Scott's Oriole (<i>Icterus parisorum</i>)	B, R	R	U	U		I, Rg, S, T	breeds in the pinon-juniper woodlands of semidesert areas; in yucca trees or palms in deserts; or in sycamores or cottonwoods in canyons
FINCHES AND ALLIES							
Purple Finch (<i>Carpodacus purpureus</i>)	B, R	R		U		I, Rg, S, T	mixed and coniferous woodlands; ornamental conifers in gardens
Cassin's Finch (<i>Carpodacus cassinii</i>)		R					open coniferous stands at high elevations
House Finch (<i>Carpodacus mexicanus</i>)	B, R	R	U	U	T	I, Rg, S, T	cities and residential areas in the East; also in desert brush in Texas and the Far West
Red Crossbill (<i>Loxia curvirostra</i>)	B, R					I, Rg, S, T	coniferous forests; visits ornamental evergreens in winter
Pine Siskin (<i>Carduelis pinus</i>)	B, R	R	U	U	T	I, Rg, S, T	coniferous and mixed woodlands, alder thickets, and brushy pastures

Lesser Goldfinch (<i>Carduelis psaltria</i>)	B, R	R	U	U	T	I, Rg, S, T	oak savannas, woodlands, suburban gardens	
American Goldfinch (<i>Carduelis tristis</i>)	B, R	R	U	U	T	I, Rg, S, T	brushy thickets, weedy grasslands, and nearby trees	
OLD WORLD SPARROWS								
House Sparrow (<i>Passer domesticus</i>)	B, R	R	U	U	T	I, Rg, S, T	cities, towns, and agricultural areas	I

¹ B=Bandera, I=Irion, R=Real, Rg=Reagan, S=Schleicher, T=Tom Green,
Up=Upton, U=Uvalde

²FE=federally endangered, FT=federally threatened, I=introduced, G=game, PDL=proposed de-listing, PT=proposed threatened, SE=state endangered,
ST=State Threatened,

Appendix E2. List of amphibians and reptiles in Edwards and Twin Buttes watersheds according to current distribution maps.

Species	Watershed ¹	County(ies) ²	Habitat	Comments ³
Frogs and Toads				
Blanchard's Cricket Frog (<i>Acris crepitans blanchardi</i>)	E TB	B, R, U, I, Rg, S, T, Up	sunny ponds of shallow water with good growth of vegetation in the water or on shore; slow-moving streams with sunny banks	
Eastern Green Toad (<i>Bufo debilis delibis</i>)	E TB	B, R, U, I, Rg, S, T, Up	shelter of rocks in semiarid regions; also found in prairies	
Red-spotted Toad (<i>Bufo punctatus</i>)	E TB	B, R, U, I, Rg, S, T, Up	desert and rocky regions and prairie grasslands, usually near source of permanent water or dampness, natural or man-made	
Texas Toad (<i>Bufo speciosus</i>)	E TB	B, R, U, I, Rg, S, T, Up	prairie grasslands and open woodlands; adapted for dry conditions	
Gulf Coast Toad (<i>Bufo valliceps valliceps</i>)	E	B, R, U,	various humid locations, from roadsideditches to the barrier beaches of the Gulf of Mexico	
Southwestern Woodhouse's Toad (<i>Bufo woodhousii australis</i>)	TB	I, Rg, Up	sandy areas near marshes, irrigation ditches, backyards, and temporary rain pools	
Woodhouse's Toad (<i>Bufo woodhousii woodhousii</i>)	E TB	B, R, U, I, S, T	sandy areas near marshes, irrigation ditches, backyards, and temporary rain pools	
Eastern Barking Frog (<i>Eleutherodactylus augusti latitans</i>)	E	B, R, U	damp limestone caves and crevices, especially where rain is frequent	
Eastern Narrowmouth Toad (<i>Gastrophryne carolinensis</i>)	E	B, R	near water, especially along the edge of ponds or ditches and under moist debris and decaying vegetative matter	
Great Plains Narrowmouth Toad (<i>Gastrophryne olivacea</i>)	E TB	B, R, U, I, S, T	montane woodlands, grasslands, and desert from sea level to 4000'; moist or damp areas from marshes to leaf litter and rodent burrows	
Cope's Gray Tree Frog/Gray Tree Frog (<i>Hyla chrysoscelis/versicolor</i>)	E	B, R, U	trees of shrubs growing in or near permanent water	
Green Tree Frog (<i>Hyla cinerea</i>)	E	B, R, U	vegetation near permanent water; during the day frequently found asleep on underside of large leaves or in other moist, shady places	
Spotted Chorus Frog (<i>Pseudacris clarki</i>)	E TB	R, U, Rg, S, T	shortgrass prairie	
Strecker's Chorus Frog (<i>Pseudacris streckeri</i>)	E	B, R, U	moist areas, including wooded and open fields, swamps, and streams	

Rio Grande Leopard Frog (<i>Rana berlandieri</i>)	E TB	B, R, U, I, Rg, S, T, Up	any water or moist conditions, natural or artificial
Plains Leopard Frog (<i>Rana blairi</i>)	TB	I, T	prairies and other grassy, moist areas, along margins of ponds, streams, marshes
Bullfrog (<i>Rana catesbeiana</i>)	E TB	B, R, U, T	aquatic; prefers ponds, lakes, and slow-moving streams large enough to avoid crowding and with sufficient vegetation to provide easy cover
Couch's Spadefoot (<i>Scaphiopus couchi</i>)	E TB	B, R, U, I, Rg, S, T, Up	tolerant of dry terrain; likes shortgrass prairie as well as mesquite savannah and creosote bush desert
Plains Spadefoot (<i>Spea bombifrons</i>)	TB	I, Rg, S, T, Up	shortgrass prairie where soil is loose and dry, rainfall low; likes sandy and gravelly soils
New Mexico Spadefoot (<i>Spea multiplicata</i>)	TB	I, Rg, S, T, Up	tolerates wide range of conditions from semiarid to arid; prefers shortgrass plains and shady, gravelly areas such as alkali flats, washes, and river floodplains
Cliff Chirping Frog (<i>Syrrophus marnocki</i>)	E TB	B, R, U, S, T, Up	crevices and caves of limestone hills
Lizards			
Green Anole (<i>Anolis carolinensis</i>)	E TB	B, R, U, I, S, T	arboreal; encountered on vertical surfaces like fence posts and walls; but favors tree boles, shrubs, vines, tall grasses, palm fronds
Texas Spotted Whiptail (<i>Cnemidophorus gularis gularis</i>)	E TB	B, R, U, I, Rg, S, T, Up	semiarid prairie grasslands, open brushy areas; also arid washes and canyons, frequently in vicinity of streams
Trans-pecos Striped Whiptail (<i>Cnemidophorus inornatus heptogrammus</i>)	TB	I, Rg, S, T, Up	arid and semiarid grasslands with some low brush; flatlands, gentle slopes
Six-lined Racerunner (<i>Cnemidophorus sexlineatus sexlineatus</i>)	E	B, R, U	dry sunny areas; grasslands, open woodlands, usually on well-drained soils
Prairie-lined Racerunner (<i>Cnemidophorus sexlineatus viridis</i>)	TB	I, Rg, T, Up	dry sunny areas; grasslands, open woodlands, usually on well-drained soils
Colorado Checkered Whiptail (<i>Cnemidophorus tesselatus</i>)	TB	I, Rg, Up	rocky locations on sand or gravel supporting grass or sparse brush
Western Marbled Whiptail (<i>Cnemidophorus tigris marmoratus</i>)	TB	Rg, Up	arid and semiarid desert to open woodlands; where vegetation is sparse enough to make running easy
Texas Banded Gecko (<i>Coleonyx brevis</i>)	E TB	B, R, U, I, Rg, Up	rock outcrops and canyon beds in desert areas; found beneath shelving rocks, vegetative debris, and discarded boards
Texas Earless Lizard (<i>Cophosaurus texanus texanus</i>)	E TB	B, R, U, I, Rg, S, T	stretches of broken rock, limestone cliffs, dry sandy streambeds, rocky washes

Eastern Collared Lizard (<i>Crotaphytus collaris collaris</i>)	E TB	B, R, U, I, Rg, S, T, Up	hardwood forests to arid areas with large rocks for basking; more frequent in hilly regions, especially among limestone ledges that provide crevices for good cover	
Reticulate Collared Lizard (<i>Crotaphytus reticulatus</i>)	E	U	semiarid brushland, escarpments, isolated rock piles, pack rat burrows	ST
Many-lined Skink; undescribed subspecies (<i>Eumeces multivirgatus ssp.</i>)	TB	I, Rg, S, T, Up	mountainous wooded areas to 8200'	
Great Plains Skink (<i>Eumeces obsoletus</i>)	E TB	B, R, U, I, Rg, S, T, Up	open rocky grasslands of the Great Plains; near permanent or semipermanent water in otherwise drier areas	
Short-lined Skink (<i>Eumeces tetragrammus brevilineatus</i>)	E TB	B, R, U, I, Rg, S, T, Up	arid and semiarid country; rocky ravines, grassy zones, scrub, forest, woodland, sea level to 6500'	
Texas Alligator Lizard (<i>Gerrhonotus infernalis</i>)	E	B, R, U	rocky slopes with some scrub vegetation	
Mediterranean Gecko (<i>Hemidactylus turcicus turcicus</i>)	E TB	B, U, T	under palm leaves and in crevices of tree bark and rocky outcrops; most common in occupied buildings	I
Plateau Earless Lizard (<i>Holbrookia lacerata lacerata</i>)	E TB	B, R, U, I, Rg, S, T, Up	arid areas with sparse vegetation; seasonally dry prairie brushland	
Northern Earless Lizard (<i>Holbrookia maculata maculata</i>)	TB	Rg, Up	sandy soil areas in grassy prairie, cultivated fields, dry streambeds, desert grasslands	
Western Slender Glass Lizard (<i>Ophisaurus attenuatus</i>)	E	B, R	dry grassland and dry open woodland	
Texas Horned Lizard (<i>Phrynosoma cornutum</i>)	E TB	B, R, U, I, Rg, S, T, Up	from sea level to 6000' in dry areas, most open country with loose soil supporting grass, mesquite, cactus	ST
Roundtail Horned Lizard (<i>Phrynosoma modestum</i>)	TB	I, Rg, S, T, Up	sandy, gravelly washes and other semiarid regions of scrub vegetation	
Texas Spiny Lizard (<i>Sceloporus olivaceus</i>)	E TB	B, R, U, I, Rg, S, T, Up	primarily arboreal; in mesquite, live oak. And other trees; also on man-made structures that provide shelter	
Eastern Tree Lizard (<i>Sceloporus ornatus ornatus</i>)	E TB	B, R, U, I, Rg, S, T, Up	trees, rocks, fence posts, and buildings in arid regions; often near streams, and dry washes	
Crevice Spiny Lizard (<i>Sceloporus poinsetti poinsetti</i>)	E TB	B, R, U, I, Rg, S, T, Up	limestone and other exposed rocky outcrops in arid and semiarid areas	
Southern Prairie Lizard (<i>Sceloporus undulatus consobrinus</i>)	E TB	B, R, U, I, Rg, S, T, Up	generally sunny locations; favors rotting logs, open woodlands, open grassy dunes, prairie	
Rose-bellied Lizard (<i>Sceloporus variabilis marmoratus</i>)	E	B, U	arid regions, from sea level to 7500'; frequents mesquite branches, cacti, and, less often, rocks	
Ground Skink (<i>Scincella lateralis</i>)	E TB	B, R, U, I, Rg, S, T	humid forests, hardwood hammocks, and forested grasslands, generally where leaf litter is	

			abundant	
Desert Side-blotched Lizard (<i>Uta stansburiana stenjnegeri</i>)	TB	I, Rg, S, T, Up	arid and semiarid regions with coarse, gravelly soil and low-growing vegetation	
Salamanders				
Barred Tiger Salamander (<i>Ambystoma tigrinum mavortium</i>)	E TB	B, R, U, I, Rg, S, T, Up	varied; arid sagebrush plains, pine barrens, mountain forests, and damp meadows where ground is easily burrowed; also in mammal and invertebrate burrows; sea level to 11000'	
Texas Salamander (<i>Eurycea neotenes</i>)	E	B, R, U	small cave streams, springs, seeps, and headwaters of creeks	
Western Slimy Salamander (<i>Plethodon albagula</i>)	E	B, R, U	shaded ravine slopes, shale banks, wooded floodplains, cave entrances; near sea level to 5500'	
Snakes				
Broad-banded Copperhead (<i>Agkistrodon contortrix laticinctus</i>)	E TB	B, R, U, I, Rg, S, T	wooded hillsides with rock outcrops above streams or ponds; edges of swamps and periodically flooded areas in coastal plain; near canyon springs and dense cane stands along Rio Grande; sea level to 5000'	
Trans-pecos Copperhead (<i>Agkistrodon contortrix pictigaster</i>)	TB	Up	wooded hillsides with rock outcrops above streams or ponds; edges of swamps and periodically flooded areas in coastal plain; near canyon springs and dense cane stands along Rio Grande; sea level to 5000'	
Trans-pecos Copperhead X Broad-banded Copperhead (<i>Agkistrodon contortrix pictigaster X A. c. laticinctus</i>)	TB	I, Rg	wooded hillsides with rock outcrops above streams or ponds; edges of swamps and periodically flooded areas in coastal plain; near canyon springs and dense cane stands along Rio Grande; sea level to 5000'	
Western Cottonmouth (<i>Agkistrodon piscivorus leucostoma</i>)	E TB	B, R, U, I, Rg, S, T	lowland swamps, lakes, rivers, bayheads, sloughs, irrigation ditches, canals, rice fields, to small clear rocky mountain streams; sea level to ca. 1500'	
Texas Glossy Snake (<i>Arizona elegans arenicola</i>)	E	U	dry, open sandy areas, coastal chaparral, creosote-mesquite desert, sagebrush flats, and oak-hickory woodland; below sea level to 5500'	
Kansas Glossy Snake (<i>Arizona elegans elegans</i>)	TB	I, Rg, T, Up	dry, open sandy areas, coastal chaparral, creosote-mesquite desert, sagebrush flats, and oak-hickory woodland; below sea level to 5500'	
Trans-Pecos Rat Snake (<i>Bogertophis subocularis subocularis</i>)	E	B, R, U	Chihuahuan Desert; agave-creosote bush-ocotillo-dominated slopes to rocky areas characterized by persimmon-shinoak or cedar;	

			ca. 1500-4500'	
Eastern Yellow-bellied Racer (<i>Coluber constrictor flaviventris</i>)	E TB	B, R, U T	abandoned fields, grassland, sparse brushy areas along prairie land, open woodland, mountain meadows, rocky wooded hillsides, grassy-bordered streams, and pine flatwoods; sea level to ca. 7000'	
Western Diamondback Rattlesnake (<i>Crotalus atrox</i>)	E TB	B, R, U, I, Rg, S, T, Up	arid and semiarid areas from plains to mountains; brushy desert, rocky canyons, bluffs along rivers, sparsely vegetated foothills; sea level to 7000'	
Mottled Rock Rattlesnake (<i>Crotalus lepidus lepidus</i>)	E	B, R, U	chiefly rocky mountainous areas; talus slopes, gorges, rimrock, limestone outcrops, rocky streambeds; 1500-9600'	
Black-tailed Rattlesnake (<i>Crotalus molossus molossus</i>)	E TB	B, R, U I, Rg, S, T, Up	most common in rocky mountainous areas; among rimrock and limestone outcrops, wooded stony canyons, chaparral, rocky streambeds; near sea level to ca. 9000'	
Prairie Rattlesnake (<i>Crotalus viridis viridis</i>)	TB	I, Rg, S, T, Up	Great Plains grassland to brush-covered sand dunes on Pacific coast, and to timberline in the Rockies and the coniferous forests of the Northwest; rocky outcrops, talus slopes, stony canyons, and prairie dog towns sea level to 11000'	
Prairie Ring-necked Snake (<i>Diadophis punctatus arnyi</i>)	E	B, R, U	moist situations in varied habitat; forests, grassland, rocky wooded hillsides, chaparral, into upland desert along streams; sea level to ca. 7000'	
Regal Ring-necked Snake (<i>Diadophis punctatus regalis</i>)	TB	I, Rg, S, T, Up	moist situations in varied habitat; forests, grassland, rocky wooded hillsides, chaparral, into upland desert along streams; sea level to ca. 7000'	
Texas Indigo Snake (<i>Drymarchon corais erebennus</i>)	E	B, R, U	in Texas: dry grassland and thickets near ponds and rivers	ST ?
Baird's Rat Snake (<i>Elaphe bairdi</i>)	E TB	B, R, U S	hardwood forest, wooded canyons, swamps, rocky timbered upland, farmland, old fields, barnyards; from wet to arid situations; sea level to 4400'	
Great Plains Rat Snake (<i>Elaphe guttata emoryi</i>)	TB	I, Rg, S, T, Up	wooded groves, rocky hillsides, meadowland; along watercourses, around springs, woodlots, barnyards, and abandoned houses; sea level to ca. 6000'	

Great Plains Rat Snake X Southwestern Rat Snake (<i>Elaphe guttata emoryi</i> X <i>E. g. meahllmorum</i>)	E	B, R, U	wooded groves, rocky hillsides, meadowland; along watercourses, around springs, woodlots, barnyards, and abandoned houses; sea level to ca. 6000'
Texas Rat Snake (<i>Elaphe obsoleta lindheimeri</i>)	E TB	B, R, U I, Rg, S, T	hardwood forest, wooded canyons, swamps, rocky timbered upland, farmland, old fields, barnyards; from wet to arid situations; sea level to 4400'
Western Hook-nosed Snake (<i>Gyalopion canum</i>)	TB	I, Rg, T	arid regions dominated by creosote bush, mesquite, and shadescale, and juniper-grassland or pinon-juniper associations
Dusky Hog-nosed Snake (<i>Heterodon nasicus gloydi</i>)	E TB	B, R, U, I, Rg, S, T, Up	sand and gravelly-soiled prairie, scrubland, river floodplains; sea level to 8000'
Eastern Hog-nosed Snake (<i>Heterodon platirhinos</i>)	E	B, R, U	prefers open sandy-soiled areas; thinly wooded upland hillsides, cultivated fields, woodland meadows; sea level to 2500'
Texas Night Snake (<i>Hypsiglena torquata jani</i>)	E TB	B, R, U, I, Rg, S, T, Up	semiarid and arid sandy or rocky situations from plains and desert flats, to heavy brush chaparral and blue oak-Digger pine woodland; sea level to 7000'
Gray-banded King Snake (<i>Lampropeltis alterna</i>)	TB	Rg, Up	arid mesquite-creosote bush desert flats, barren rocky hillsides, canyons, limestone ledges, ranging into semimoist mountainous situations; 1200-7500'
Desert King Snake (<i>Lampropeltis getula splendida</i>)	E TB	B, R, U, I, Rg, S, T, Up	diverse; New jersey pine barrens to Florida Everglades; dry rocky wooded hillsides to river swamps and coastal marshes, and prairie, desert, and chaparral; sea level to 6900'
Mexican Milk Snake (<i>Lampropeltis triangulum annulata</i>)	E	B, R, U	diverse situations: semiarid to damp coastal bottomland to Rocky Mountains and tropical hardwood forests; pine forests, open deciduous woodland, meadows, rocky hillsides, prairie, high plains, sand dunes, farmland, and suburban areas; sea level to ca. 8000'
Central Plains Milk Snake (<i>Lampropeltis triangulum gentilis</i>)	TB	I, Rg, S, T, Up	diverse situations: semiarid to damp coastal bottomland to Rocky Mountains and tropical hardwood forests; pine forests, open deciduous woodland, meadows, rocky hillsides, prairie, high plains, sand dunes, farmland, and suburban areas; sea level to ca. 8000'
New Mexico Blind Snake (<i>Leptotyphlops dulcis dissectus</i>)	TB	Up	semiarid deserts, prairies, hillsides, mountain slopes with sandy or loamy soil suitable for burrowing; sea level to 5000'

Plains Blind Snake <i>(Leptotyphlops dulcis dulcis)</i>	E TB	B, R, U, I, Rg, S, T, Up	semiarid deserts, prairies, hillsides, mountain slopes with sandy or loamy soil suitable for burrowing; sea level to 5000'	
Western Coachwhip <i>(Masticophis flagellum testaceus)</i>	E TB	B, R, U, I, Rg, S, T, Up	dry, relatively open situations; pine and palmetto flatwoods, rocky hillsides, grassland prairies, desert scrub, thorn forest, and chaparral; sea level to ca. 7000'	
Schott's Whip Snake <i>(Masticophis schotti schotti)</i>	E	B, R, U	from grassland and arid brushy flatland to rugged mountainous terrain dominated by pinon-juniper and open pine-oak woodlands; sea level to 9400'	
Central Texas Whip Snake <i>(Masticophis taeniatus girardi)</i>	E TB	B, R, U, I, Rg, S, T, Up	from grassland and arid brushy flatland to rugged mountainous terrain dominated by pinon-juniper and open pine-oak woodlands; sea level to 9400'	
Texas Coral Snake <i>(Micrurus fulvius tenere)</i>	E TB	B, R, U, S, T	moist, densely vegetated hammocks near ponds or streams in hardwood forests; pine flatwoods; rocky hillsides and canyons	
Blotched Water Snake <i>(Nerodia erythrogaster transversa)</i>	E TB	B, R, U, I, Rg, S, T	river swamps and the forested edges of streams, ponds, lakes, and bayous	
Concho Water Snake <i>(Nerodia harteri paucimaculata)</i>	TB	I, T	swift rocky streams and rivers	ST, FT
Diamondback Water Snake <i>(Nerodia rhombifer rhombifer)</i>	E TB	B, R, U, I, Rg, S, T, Up	margins of lakes, rivers, streams, swamps, marshes, canals, ditches, and ponds	
Rough Green Snake <i>(Opheodrys aestivus)</i>	E TB	B, R, U, I, Rg, S, T	vines, bushes, and trees near water; sea level to 5000'	
Bull Snake <i>(Pituophis catenifer sayi)</i>	E TB	B, R, U, I, Rg, S, T, Up	dry, sandy pine-oak woodlands and pine flatwoods, cultivated fields, prairies, open brushland, rocky desert, chaparral; sea level to 9000'	
Graham's Crayfish Snake <i>(Regina grahami)</i>	TB	T	sluggish streams, ponds, lakes, and ditches where crayfish are abundant	
Texas Long-nosed Snake <i>(Rhinocheilus lecontei tessellatus)</i>	E TB	B, R, U, I, Rg, S, T, Up	dry open prairie, desert brushland, coastal chaparral to tropical habitat in Mexico; sea level to 5400'	
Texas Patch-nosed Snake <i>(Salvadora grahamiae lineata)</i>	E TB	B, R, U, I, Rg, S, T, Up	western form prefers open woodland and forested mountainous slopes above 4000'; eastern subspecies, prairie and brushland to rocky canyons, creek beds, and rugged hillsides; sea level to 6500'	
Desert Massasauga <i>(Sistrurus catenatus edwardsi)</i>	TB	I, Rg, S, T, Up	sphagnum bogs, swamps, marshland, and flood plains to dry woodland in the East; grassy wetland, rocky hillsides, sagebrush prairie, into	

			desert grassland in the West	
Western Massasauga (<i>Sistrurus catenatus tergeminus</i>)	E	B, R, U	sphagnum bogs, swamps, marshland, and flood plains to dry woodland in the East; grassy wetland, rocky hillsides, sagebrush prairie, into desert grassland in the West	
Ground Snake (<i>Sonora semiannulata semiannulata</i>)	E TB	B, R, U I, Rg, S, T, Up	dry open areas with loose sandy soil; rocky wooded or prairie hillsides, mesquite thickets along river beds, sand hummocks, vacant lots, brushy desert; sea level to 6000'	
Ground Snake X South Texas Ground Snake (<i>Sonora semiannulata semiannulata X S. s. taylori</i>)	E	U	dry open areas with loose sandy soil; rocky wooded or prairie hillsides, mesquite thickets along river beds, sand hummocks, vacant lots, brushy desert; sea level to 6000'	
Texas Brown Snake (<i>Storeria dekayi texana</i>)	E TB	B, R, U, S, T	moist upland woodland to lowland freshwater and saltwater marshes; margins of swamps, bogs, and ponds; vacant lots, gardens, golf courses	
Flatheaded Snake (<i>Tantilla gracilis</i>)	E TB	B, R, U, I, Rg, S, T	rocky prairie and wooded hillsides; sea level to 2000'	
Southwestern Black-headed Snake (<i>Tantilla hobartsmithi</i>)	E TB	B, R, U, I, Rg, S, T, Up	a burrowing snake usually found on the surface only where moisture has condensed under flat stones	
Plains Black-headed Snake (<i>Tantilla nigriceps nigriceps</i>)	E TB	B, R, U, I, Rg, S, T, Up	rocky and grassy prairie; hillsides where soil is moist	
Eastern Black-necked Garter Snake (<i>Thamnophis cyrtopsis ocellatus</i>)	E TB	B, R, U, I, R, S, T	mesquite-dominated desert flats to pine-fir forests; prefers canyon and mountain streams and spring seepages; sea level to 8750'	
Checkered Garter Snake (<i>Thamnophis marcianus marcianus</i>)	E TB	B, R, U, I, Rg, S, T, Up	arid and semiarid grassland near streams, springs, ponds, and irrigation sites; sea level to ca. 5000'	
Arid Land Ribbon Snake (<i>Thamnophis proximus diabolicus</i>)	TB	Up	weedy margins of lakes, ponds, cattle tanks, marshes, ditches, streams, rivers; sea level to 8000'	
Red-striped Ribbon Snake (<i>Thamnophis proximus rubrilineatus</i>)	E TB	B, R, U, I, S, T	weedy margins of lakes, ponds, cattle tanks, marshes, ditches, streams, rivers; sea level to 8000'	
Red-striped Ribbon Snake X Arid Land Ribbon Snake (<i>Thamnophis proximus rubrilineatus X T. p. diabolicus</i>)	TB	I, Rg, S	weedy margins of lakes, ponds, cattle tanks, marshes, ditches, streams, rivers; sea level to 8000'	

<i>Texas Garter Snake</i> (<i>Thamnophis sirtalis annectens</i>)	E TB	B, R, U, I, Rg, S, T, Up	near water--wet meadows, marshes, prairie swales, irrigation and drainage ditches, damp woodland, farms, parks; sea level to 8000'	
<i>Texas Lined Snake</i> (<i>Tropidoclonion lineatum texanum</i>)	E TB	B, R, U, I, Rg, S, T	open prairie hillsides, edges of woodland, and vacant suburban lots; sea level to ca. 5300'	
<i>Rough Earth Snake</i> (<i>Virginia striatula</i>)	E	B, R, U	dry coastal plain, woodland, exposed rocky wooded hillsides, and heavily timbered uplands and valleys	
<i>Western Earth Snake</i> (<i>Virginia valeriae elegans</i>)	E	B, R, U		
Turtles				
<i>Common Snapping Turtle</i> (<i>Chelydra serpentina serpentina</i>)	E TB	B, R, U I, Rg, S, T, Up	freshwater; likes soft mud bottoms and abundant vegetation; also enters brackish waters	
<i>Texas Tortoise</i> (<i>Gopherus berlandieri</i>)	E	B, R, U	scrub woodlands with sandy soils; also chaparral and mesquite	ST
<i>Cagle's Map Turtle</i> (<i>Graptemys caglei</i>)	E	B	streams and rivers with numerous stumps and logjams and an abundance of molluscs	ST, FC
<i>Texas Map Turtle</i> (<i>Graptemys versa</i>)	E TB	B, R, I, S, T	Colorado River system, Texas	
<i>Yellow Mud Turtle</i> (<i>Kinosternon flavescens flavescens</i>)	E TB	B, R, U, T, Up	prefers quiet or slow-moving bodies of freshwater with mud or sandy bottoms	
<i>Mississippi Mud Turtle</i> (<i>Kinosternon subrubrum hippocrepis</i>)	E	B, R	fresh or brackish water; prefers shallow, soft-bottomed, slow-moving water with abundant vegetation; often occupies muskrat lodges	
<i>Stinkpot</i> (<i>Sternotherus odoratus</i>)	E TB	B, R, U I, S, T	freshwater; prefers quiet or slow-moving shallow, muddy-bottomed waters	
<i>Texas River Cooter</i> (<i>Pseudemys texana</i>)	E TB	B, U, I, T	streams and rivers with moderate currents; large lakes, spring runs, and occasionally brackish tidal marshes	
<i>Three-toed Box Turtle</i> (<i>Terrapene carolina triunguis</i>)	E	B	moist forested areas, but also wet meadows, pastures, and floodplains	
<i>Ornate Box Turtle</i> (<i>Terrapene ornata ornata</i>)	E TB	B, R, U I, Rg, S, T, Up	primarily open prairies; also grazed pasturelands, open woodlands, and waterways in arid, sandy-soiled terrain	
<i>Guadalupe Spiny Soft-shelled Turtle</i> (<i>Trionyx spiniferus guadalupensis</i>)	E TB	B, R, U I, S, T	likes small marshy creeks and farm ponds as well as large, fast-flowing rivers and lakes	
<i>Western Spiny Soft-shelled Turtle</i> (<i>Trionyx spiniferus hartwegi</i>)	TB	I, Rg, Up	likes small marshy creeks and farm ponds as well as large, fast-flowing rivers and lakes	
<i>Red-eared Slider</i> (<i>Trachemys scripta elegans</i>)	E TB	B, R, U, I, T	sluggish rivers, shallow streams, swamps, ponds, and lakes with soft bottoms and dense vegetation	

¹E=Edward's (Bandera, Real, and Uvalde counties), TB=Twin Buttes (Irion, Reagan, Schleicher, Tom Green, and Upton counties).

²B=Bandera, I=Irion, R=Real, Rg=Reagan, S=Schleicher, T=Tom Green, Up=Upton, U=Uvalde. Bold font=counties with "dots" on a county map. Normal font=counties without dots, but within distribution boundaries (when boundaries are designated).

³FE=federally endangered, FT=federally threatened, I=introduced, G=game, PDL=proposed de-listing, PT=proposed threatened, SE=state endangered, ST=State Threatened.

Appendix E3. List of mammals in Edwards and Twin Buttes watersheds according to current distribution maps.

Family	Species	Watershed ¹	County(ies) ²	Habitat	Comments ³
Didelphimorpha					
Didelphidae (opossums)	Virginia Opossum (<i>Didelphis virginiana</i>)	E TB	B, R, U, I, Rg, S, T, Up	primarily inhabitants of deciduous woodlands but are often found in prairies, marshes, and farmlands. In the western part of their native range they generally keep to the woody vegetation along streams and rivers, a habit which permits them to penetrate the otherwise treeless grasslands and deserts of west Texas	
Insectivora					
Soricidae (shrews)	Least Shrew (<i>Cryptotis parva</i>)	E	B	an inhabitant of grasslands where it utilizes the surface runways of cotton rats (<i>Sigmodon</i>) and other grassland rodents. It seldom occurs in forests but occasional individuals have been found under logs and leaf litter in moist, forested areas	
Soricidae (shrews)	Desert Shrew (<i>Notiosorex crawfordi</i>)	E TB	B, R, U, I, Rg, S, T, Up	found in the more arid, western and southern parts of the state but do not appear to be restricted to any particular habitat. Specimens have been taken in cattail marshes, in beehives, under piles of cornstalks, among yuccas, in wood rat nests, and beneath piles of brush and refuse	
Talpidae (moles)	Eastern Mole (<i>Scalopus aquaticus</i>)	E	B	they occur largely in moist (not wet), sandy soils; deep, dry sands and heavy clays are avoided	
Chiroptera					
Mormoopidae (mormoopid bats)	Ghost-faced Bat (<i>Mormoops megalophylla</i>)	E	B, R, U	a colonial, cave-dwelling bat whose distribution is closely correlated with the distribution of caves, crevices, and abandoned mine tunnels which serve as daytime roosts; probably forages relatively high above the ground in areas unobstructed by tall vegetation	
Vespertilionidae (vespertilionid bats)	Cave Myotis (<i>Myotis velifer</i>)	E TB	B, R, U, I, Rg, S, T, Up	cave dwelling bat; they may also roost in rock crevices, old buildings, carports, under bridges, and even in abandoned cliff swallow nests	
Vespertilionidae (vespertilionid bats)	Silver-haired Bat (<i>Lasionycteris noctivagans</i>)	E TB	B, R, U, I, Rg, S, T, Up	denizens of forested areas and seldom are observed in xeric areas except in migration; cavities in trees and spaces under loose bark are favorite daytime retreats but these bats may also use buildings; typically forages in or near coniferous and/or mixed deciduous forests adjacent to ponds or other sources of water	

Vespertilionidae (vespertilionid bats)	Western Pipistrelle (<i>Pipistrellus hesperus</i>)	E TB	B, R, U, I, Rg, S, T, Up	associated chiefly with rocky situations along watercourses. Its daytime retreat is in the cracks and crevices of canyon walls or cliffs, under loose rocks, or in caves
Vespertilionidae (vespertilionid bats)	Eastern Pipistrelle (<i>Pipistrellus subflavus</i>)	E TB	B, R, U, S	retreats in caves, crevices in cliffs, buildings, and other man-made structures offering concealment; flutter and flit along watercourses or over pastures and woodlands; appear to favor watercourses as foraging grounds
Vespertilionidae (vespertilionid bats)	Eastern Red Bat (<i>Lasiurus borealis</i>)	E TB	B, R, U, I, Rg, S, T, Up	forest dwelling, solitary; roost in the open in trees; roosting sites are common in tree foliage or Spanish moss where the bats are concealed as they resemble dead leaves; generally forage near the forest canopy at or above treetop level
Vespertilionidae (vespertilionid bats)	Hoary Bat (<i>Lasiurus cinereus</i>)	E TB	B, R, U, I, Rg, S, T, Up	more or less solitary and frequents wooded areas where it roosts in the open by hanging from a branch or twig
Vespertilionidae (vespertilionid bats)	Evening Bat (<i>Nycticeius humeralis</i>)	E	B, R, U	frequent forested areas and watercourses, and utilize hollow trees as roosting sites and nurseries; they use the attics of houses and other man-made structures as roosts when natural sites are not available
Vespertilionidae (vespertilionid bats)	Townsend's Big-eared Bat (<i>Plecotus townsendii</i>)	E TB	R, I, Rg, S, T, Up	correlated largely with rocky situations where caves or abandoned mine tunnels are available; may occasionally inhabit old buildings
Vespertilionidae (vespertilionid bats)	Pallid Bat (<i>Antrozous pallidus</i>)	E TB	B, R, U, I, Rg, S, T, Up	inhabit rocky, outcrop areas where they commonly roost in rock crevices, caves, and mine tunnels but they also roost in the attics of houses, under the eaves of barns, behind signs, in hollow trees, and in abandoned adobe buildings; to some extent, terrestrial foragers
Molossidae (free-tailed bats)	Brazilian Free-tailed Bat (<i>Tadarida brasiliensis</i>)	E TB	B, R, U, I, Rg, S, T, Up	utilize caves, mine tunnels, old wells, hollow trees, human habitations, bridges, and other buildings
Molossidae (free-tailed bats)	Big Free-tailed Bat (<i>Nyctinomops macrotis</i>)	E TB	B, R, U, I, Rg, S, T, Up	seasonal inhabitants of rugged, rocky country in both lowland and highland habitats
Xenarthra				
Dasypodidae (armadillos)	Nine-banded Armadillo (<i>Dasypus novemcinctus</i>)	E TB	B, R, U, I, Rg, S, T, Up	In the rocky terrain of the Edwards Plateau, the animals tend to concentrate in the alluvial stream bottoms and den in the cracks and crevices of the numerous limestone outcroppings in that area
Lagomorpha				
Leporidae (hares and rabbits)	Desert Cottontail (<i>Sylvilagus audubonii</i>)	E TB	B, R, U, I, Rg, S, T, Up	adapted to a variety of habitats, varying from grassland to creosote brush and cactus deserts; wherever it may be, it frequents brushy areas or, where the vegetation is short, the underground burrows of prairie dogs, skunks, and so forth

Leporidae (hares and rabbits)	Eastern Cottontail (<i>Sylvilagus floridanus</i>)	E TB	B, R, U, I, Rg, S, T, Up	a denizen of brushland and marginal areas and seldom ventures far from brushy cover; in central Texas, it commonly frequents brush-dotted pastures, the brushy edges of cultivated fields, and well-drained streamsides; occasionally, it inhabits poorly drained bottom lands with the swamp rabbit; in many places it is common along country roads, especially where the sides are grown up to dense vegetation and adjoining areas are heavily grazed or farmed
Leporidae (hares and rabbits)	Black-tailed Jackrabbit (<i>Lepus californicus</i>)	E TB	B, R, U, I, Rg, S, T, Up	denizen of the hot, dry, desert scrubland; it occupies a latitudinal range from sea level to well over 2,500 m on the southwest slopes of some of the desert mountains but seldom inhabits coniferous forests (pinyon pine and juniper areas excepted), although occasionally it may stray into them; because of a preference for sparsely vegetated areas, this species often concentrates in pastures overgrazed by livestock, further depleting the vegetation
Rodentia				
Sciuridae (squirrels and allies)	Texas Antelope Squirrel (<i>Ammospermophilus</i> <i>interpres</i>)	TB	I, Rg, S, Up	live chiefly around the edges of the lower valleys and in the low hills. They seem to prefer hard-surfaced, gravelly washes or rocky hill slopes and are less common or entirely absent on level, sandy terrain
Sciuridae (squirrels and allies)	Mexican Ground Squirrel (<i>Spermophilus mexicanus</i>)	E TB	B, R, U, I, Rg, S, T, Up	inhabit brushy or grassy areas; in southern Texas, they are frequently associated with mesquite and cactus flats; in Kerr County, they are most common in pastures and along the highways; in Trans-Pecos Texas, they are frequently found in areas dominated by creosote-bush (<i>Larrea</i>)
Sciuridae (squirrels and allies)	Spotted Ground Squirrel (<i>Spermophilus spilosoma</i>)	TB	I, Rg, S, T, Up	prefer dry, sandy areas, but they are also found in grassy parks, open pine forests, scattered brush, and occasionally on rocky mesas
Sciuridae (squirrels and allies)	Rock Squirrel (<i>Spermophilus variegatus</i>)	E TB	B, R, U, I, Rg, S, T, Up	nearly always found in rocky areas — cliffs, canyon walls, talus slopes, boulder piles, fills along highways, and so forth — where they seek refuge and have their dens
Sciuridae (squirrels and allies)	Black-tailed Prairie Dog (<i>Cynomys ludovicianus</i>)	E TB	B, I, Rg, S, T, Up	typically inhabit short-grass prairies; they usually avoid areas of heavy brush and tall grass, possibly because visibility is considerably reduced. In Trans-Pecos Texas, favored habitat sites are alluvial fans at the mouths of draws, "hard pan" flats where brush is sparse or absent, and the edges of shallow valleys

Sciuridae (squirrels and allies)	Eastern Fox Squirrel (<i>Sciurus niger</i>)	E TB	B, R, U, I, S, T	Along the western parts of their range, fox squirrels are restricted more or less to river valleys which support pecans, walnuts, oaks, and other "required" trees	G
Geomyidae (pocket gophers)	Botta's Pocket Gopher (<i>Thomomys bottae</i>)	E TB	B, R, U, I, Rg, S, T, Up	occur in soils ranging from loose sands and silts to tight clays and in vegetative zones grading from dry deserts to montane meadows	
Geomyidae (pocket gophers)	Attwater's Pocket Gopher (<i>Geomys attwateri</i>)	E	B	typically inhabits sandy soils where the topsoil is 10 cm or more in depth; clayey soils are usually avoided	
Geomyidae (pocket gophers)	Plains Pocket Gopher (<i>Geomys bursarius</i>)	TB	I, T	typically inhabits sandy soils where the topsoil is 10 cm or more in depth; clayey soils are usually avoided	
Geomyidae (pocket gophers)	Llano Pocket Gopher (<i>Geomys texensis</i>)	E	B, U	typically inhabits sandy soils where the topsoil is 10 cm or more in depth; clayey soils are usually avoided	
Geomyidae (pocket gophers)	Yellow-faced Pocket Gopher (<i>Cratogeomys castanops</i>)	TB	I, Rg, S, T, Up	partial to deep, mellow soils that are relatively free from rocks	
Heteromyidae (pocket mice and kangaroo rats)	Merriam's Pocket Mouse (<i>Perognathus merriami</i>)	E TB	B, R, U, I, Rg, S, T, Up	most common on sandy soils where vegetation is sparse or at least short	
Heteromyidae (pocket mice and kangaroo rats)	Hispid Pocket Mouse (<i>Chaetodipus hispidus</i>)	E TB	B, R, U, I, Rg, S, T, Up	prefer areas of sand or other friable soil covered with scattered to moderate stands of herbaceous vegetation; the margins of brush fields and the rank growth in fence rows offer suitable cover	
Heteromyidae (pocket mice and kangaroo rats)	Nelson's Pocket Mouse (<i>Chaetodipus nelsoni</i>)	TB	Rg, Up	a rock-loving species	
Heteromyidae (pocket mice and kangaroo rats)	Desert Pocket Mouse (<i>Chaetodipus penicillatus</i>)	TB	Up	general occurs on sandy or soft alluvial soils along stream bottoms, desert washes, and valleys	
Heteromyidae (pocket mice and kangaroo rats)	Merriam's Kangaroo Rat (<i>Dipodomys merriami</i>)	TB	I, Rg, Up	can succeed equally well on sandy soils, clays, gravels, and even among rocks	
Heteromyidae (pocket mice and kangaroo rats)	Ord's Kangaroo Rat (<i>Dipodomys ordii</i>)	TB	I, Rg, S, T, Up	dwellers of wastelands where shifting sands constitute a conspicuous part of the landscape; they are one of the few pioneer mammals that move into shifting dunes and establish themselves with pioneer plants	
Heteromyidae (pocket mice and kangaroo rats)	Banner-tailed Kangaroo Rat (<i>Dipodomys spectabilis</i>)	TB	Rg, Up	limited in distribution to sparsely brush-covered slopes and low hills at elevations usually between 1,200 and 1,500 m	
Castoridae (beavers)	American Beaver (<i>Castor canadensis</i>)	E	B, R, U	essentially aquatic and require water in the form of a pond, stream, lake, or river for their well-being	
Muridae (mice and rats)	Fulvous Harvest Mouse (<i>Reithrodontomys fulvescens</i>)	E	B, R, U	occur chiefly in grassy or weedy areas dotted with shrubs, or in creek bottoms with their tangles of grasses, vines, and bushes	

Muridae (mice and rats)	Plains Harvest Mouse (<i>Reithrodontomys montanus</i>)	E TB	B, R, U, I, S, T, Up	prefer climax, or nearly climax, well-drained grassland
Muridae (mice and rats)	Texas Mouse (<i>Peromyscus attwateri</i>)	E TB	B, R, U, I, Rg, S, T, Up	inhabits the cliffs and rocky outcrops; seem to prefer rocky areas where the dominant vegetation is juniper; a habitat generalist and may be found not only in areas of rock ledges and leaf litter but also more open, grassy areas with only scattered rock cover
Muridae (mice and rats)	White-footed Mouse (<i>Peromyscus leucopus</i>)	E TB	B, R, U, I, Rg, S, T, Up	woodland dwellers; along the western border of their range they are restricted almost entirely to creek and river bottoms; they are adept at climbing and often den in hollow trees out of danger from overflow waters; in areas not subject to inundation, they live in dens under logs, in stumps, brush piles, burrows, or buildings
Muridae (mice and rats)	Deer Mouse (<i>Peromyscus maniculatus</i>)	E TB	B, R, U, I, Rg, S, T, Up	usually inhabit grasslands or areas of open brush, especially where weeds and grasses offer concealment and a source of food; weed-choked fence rows and washes offer almost ideal habitat
Muridae (mice and rats)	White-ankled Mouse (<i>Peromyscus pectoralis</i>)	E TB	B, R, U, I, Rg, S, T, Up	rock-dwelling species; they are associated with rocks in oak-juniper woodlands
Muridae (mice and rats)	Northern Pygmy Mouse (<i>Baiomys taylori</i>)	E TB	B, R, U, I, Rg, S, T, Up	have a preference for grassy areas, and they are commonly found in old fields, pastures, and along railroad and highway rights-of-way; if other types of ground cover such as rocks, cactus, and fallen logs are available, the pygmy mouse may be found in areas where grass is relatively sparse
Muridae (mice and rats)	Mearns' Grasshopper Mouse (<i>Onychomys arenicola</i>)	TB	Rg, Up	chiefly inhabits the low, arid, sandy or gravelly desert areas where vegetation in the form of creosote bush, mesquite, yucca, lechuguilla, condalia, and so forth is sparse and scattered
Muridae (mice and rats)	Northern Grasshopper Mouse (<i>Onychomys leucogaster</i>)	TB	I, Rg, S, T, Up	occur chiefly in association with sandy or powdery soils in grasslands or open brushlands
Muridae (mice and rats)	Hispid Cotton Rat (<i>Sigmodon hispidus</i>)	E TB	B, R, U, I, Rg, S, T, Up	inhabits tall-grass areas where such grasses as bluestem (<i>Andropogon</i>), cordgrass (<i>Spartina</i>), or sedges (<i>Carex</i>) offer both freedom of movement under a protective canopy and an adequate food supply; in western Texas, where grassy ground cover is not available, the rats live in dens at the bases of small, low clumps of mesquite in otherwise nearly barren terrain; preferred sites are old fields, natural prairie, unmolested rights-of-way for roads and railroads, and other places not subject to flooding and where the vegetation grows rank and tall

Muridae (mice and rats)	White-throated Woodrat (<i>Neotoma albigula</i>)	E TB	B, R, U, I, Rg, S, T, Up	characteristic of the brush lands of the southwestern deserts; the availability of such desert shrub vegetation as prickly pear, cholla cactus, mesquite, sotol, lechuguilla, and creosote bush which afford shelter for their houses, seems to affect their abundance more than the nature of the terrain; occasionally, their houses are built in the open or in sparse vegetation; in rocky situations the associated cracks and crevices afford the usual den site	
Muridae (mice and rats)	Eastern Woodrat (<i>Neotoma floridana</i>)	E	B, R	wide range encompassing habitats ranging from swamplands, forested uplands, to the arid plains; in central Texas, they frequently live in rocky canyon walls	
Muridae (mice and rats)	Southern Plains Woodrat (<i>Neotoma micropus</i>)	E TB	B, R, U, I, Rg, S, T, Up	characteristic of the brushlands in the semi-arid region between the timberlands and the arid deserts to the west; usually found associated with cactus or some of the thorny desert shrubs	
Muridae (mice and rats)	Norway Rat (<i>Rattus norvegicus</i>)	?	?	chiefly where vegetation is tall and rank and affords adequate protection	I
Muridae (mice and rats)	Roof Rat (<i>Rattus rattus</i>)	?	?	largely commensals and live in close association with man	I
Muridae (mice and rats)	House Mouse (<i>Mus musculus</i>)	?	?	may be found in fields, along watercourses, and in other places where vegetation is dense enough to afford concealment	I
Muridae (mice and rats)	Woodland Vole (<i>Microtus pinetorum</i>)	E	B	occur largely in woodland areas where ground cover in the form of leaf litter and lodged grasses offers suitable protection	
Erethizontidae (New World porcupines)	Porcupine (<i>Erethizon dorsatum</i>)	E TB	B, R, U, I, Rg, S, T, Up	largely an inhabitant of forested areas in the West and prefers rocky areas, ridges, and slopes. It is less common in flats, valleys, and gulches	
Myocastoridae (myocastorids)	Nutria (<i>Myocastor coypus</i>)	E TB	B, R, U, I, Rg, S, T	prefer a semiaquatic existence in swamps, marshes, and along the shores of rivers and lakes	I
Carnivora					
Canidae (canids)	Coyote (<i>Canis latrans</i>)	E TB	B, R, U, I, Rg, S, T, Up	from sea level to well over 3,000 m and habitats ranging from desert scrub through grassland into the timbered sections of the West	
Canidae (canids)	Swift or Kit Fox (<i>Vulpes velox</i>)	TB	I, Rg, S, T, Up	generally live in the open desert or grasslands where they often have dens and hunt mesa country along the borders of valleys, sparsely vegetated habitats on sloping plains, hilltops, and other well-drained areas. Also, they have adapted to pasture, plowed fields, and fencerows	
Canidae (canids)	Red Fox (<i>Vulpes vulpes</i>)	E TB	B, I, Rg, S, T, Up	mixed woodland uplands interspersed with farms and pastures; the den is usually an underground burrow, a crevice in a rocky outcrop, or a cavity under boulders	I

Canidae (canids)	Common Gray Fox (<i>Urocyon cinereoargenteus</i>)	E TB	B, R, U, I, Rg, S, T, Up	essentially an inhabitant of wooded areas, particularly mixed hardwood forests. It is common throughout the wooded sections east of the shortgrass plains and in the pinyon-juniper community above the low lying deserts	
Procyonidae (procyonids)	Ringtail (<i>Bassariscus astutus</i>)	E TB	B, R, U, I, Rg, S, T, Up	live in a variety of habitats within their range, but they have a decided preference for rocky areas such as rock piles, stone fences, canyon walls, and talus slopes; they occur less commonly in woodland areas where they live in hollow trees and logs, and they are also known to live in buildings	
Procyonidae (procyonids)	Common Raccoon (<i>Procyon lotor</i>)	E TB	B, R, U, I, Rg, S, T, Up	primarily inhabitants of broadleaf woodlands, although they are rather common in the mixed-pine forests of southeastern Texas; they seldom occur far from water, which seems to have more influence on their distribution than does any particular type of vegetation	
Procyonidae (procyonids)	White-nosed Coati (<i>Nasua narica</i>)	E	B, R, U	spend considerable time on the ground, but they climb trees; they also occur in some of the rocky canyons that enter the mountains from the lowlands	ST
Mustelidae (mustelids)	Long-tailed Weasel (<i>Mustela frenata</i>)	E TB	B, R, U, I, Rg, S, T, Up	occupy a variety of habitats in Texas. In general, they occupy a range nearly coextensive with the ranges of pocket gophers and ground squirrels on which they prey in large measure	
Mustelidae (mustelids)	Mink (<i>Mustela vison</i>)	E	B	closely associated with the waterways and lakes of North America, but the smaller streams are preferred to the large, broad rivers; they are most common along streams partly choked by windfalls and other debris which create numerous water holes and at the same time offer concealment	
Mustelidae (mustelids)	American Badger (<i>Taxidea taxus</i>)	E TB	B, R, U, I, Rg, S, T, Up	occupy a variety of habitats; most common in the prairie and desert sections of the West, but limited numbers venture into the mountains; in general, they occupy the entire range inhabited by ground squirrels and prairie dogs general, they occupy the entire range inhabited by ground squirrels and prairie dogs	
Mustelidae (mustelids)	Western Spotted Skunk (<i>Spilogale gracilis</i>)	E TB	B, R, U, I, Rg, S, T, Up	variety of habitats and often occurs in close association with man; most records of capture indicate that it is most often associated with rocky bluffs, cliffs, and brush-bordered canyon streams or stream beds. In the Edwards Plateau, rock fences seem to be especially attractive	

Mustelidae (mustelids)	Eastern Spotted Skunk (<i>Spilogale putorius</i>)	E	B	occur largely in wooded areas and tall-grass prairies, preferring rocky canyons and outcrops when such sites are available; they are less common in the short-grass plains; in areas where common, they have a tendency to live around farmyards and often den under or in buildings	
Mustelidae (mustelids)	Striped Skunk (<i>Mephitis mephitis</i>)	E TB	B, R, U, I, Rg, S, T, Up	inhabitants of wooded or brushy areas and their associated farmlands; rocky defiles and outcrops are favored refuge sites, but when these are absent the skunks seek out the burrows of armadillos, foxes, and other animals; in central Texas, favored refuge sites are under large boulders	
Mustelidae (mustelids)	Common Hog-nosed Skunk (<i>Conepatus mesoleucus</i>)	E TB	B, R, U, I, Rg, S, T, Up	inhabit mainly the foothills and partly timbered or brushy sections of their general range; the largest populations occur in rocky, sparsely timbered areas	
Felidae (cats)	Mountain Lion (<i>Felis concolor</i>)	E TB	B, R, U, I, Rg, S, T, Up	chief range preferences are rocky, precipitous canyons, escarpments, rimrocks or, in the absence of these, dense brush	
Felidae (cats)	Ocelot (<i>Felis pardalis</i>)	E	B, R, U	dense, almost impenetrable chaparral thickets	SE, FE
Felidae (cats)	Bobcat (<i>Lynx rufus</i>)	E TB	B, R, U, I, Rg, S, T, Up	have a decided preference for rocky canyons or outcrops when such are available; in rockless areas they resort to thickets for protection and den sites; they are associated more commonly with pinyon pines, junipers, oak, or chaparral in Texas but they also occur in small numbers in open pine forests	
Artiodactyla					
Suidae (pigs)	Feral Pig (<i>Sus Scrofa</i>)	?	?	diverse forests with some openings; the presence of a good litter layer to support soil invertebrates and/or the presence of ground vegetation affording green forage, roots, and tubers is desirable	I
Dicotylidae (peccaries)	Collared Peccary (<i>Tayassu tajacu</i>)	E TB	B, R, U, I, Rg, S, T, Up	occupy the brushy semidesert where prickly pear is a conspicuous part of the flora; they are commonly found in dense thickets of prickly pear, chaparral, scrub oak, or guajillo; also in rocky canyons where caverns and hollows afford protection and in barren wastelands	G
Cervidae (cervids)	Axis Deer (<i>Cervus axis</i>)	?	?	inhabitants of secondary forest lands broken here and there by glades, with an understory of grasses, forbs, and tender shoots which supply adequate drinking water and shade	I

Cervidae (cervids)	Fallow Deer (<i>Cervus dama</i>)	?	?	do much of their feeding in open, grassy areas but require tree cover and undergrowth for shelter and winter food; deciduous or mixed woodlands on gently rolling terrain are best, but conifer forests may be suitable in some places; the Edwards Plateau region, with its mosaic of oak mottes, juniper brushland, and grassy areas is well-suited	I
Cervidae (cervids)	Sika Deer (<i>Cervus nippon</i>)	?	?	characteristic of broad-leaved and mixed forests where snowfall does not exceed 10-20 cm and snow-free sites are also available; large forest tracts with dense understory and occasional clearings are ideal; the patchwork of brush cover and open grassland found in the Edwards Plateau and South Texas regions are well-suited	I
Cervidae (cervids)	Mule Deer (<i>Odocoileus hemionus</i>)	TB	Rg, Up	prefer the more arid, open situations in which sagebrush, juniper, pinyon pine, yellow pine, bitter brush, mountain mahogany, and such plants predominate; in western Texas, rocky hillsides covered with lechuguilla, sotol, juniper, and pinyon pine provide the essentials	G
Cervidae (cervids)	White-tailed Deer (<i>Odocoileus virginianus</i>)	E TB	B, R, U, I, Rg, S, T, Up	occur almost entirely in the hardwood areas within their general range	G
Antilocapridae (pronghorn)	Pronghorn (<i>Antilocapra americana</i>)	TB	I, Rg, Up	inhabits areas where both its sight and its running will be unimpaired by woodland vegetation; water in the immediate vicinity is not a requisite because the pronghorn is so adapted physiologically that it can go for long periods without drinking	G
Bovidae (bovids)	Barbary Sheep (<i>Ammotragus lervia</i>)	?	?	adapted to a dry, rough, barren, and waterless habitat	I

¹E=Edward's (Bandera, Real, and Uvalde counties), TB=Twin Buttes (Irion, Reagan, Schleicher, Tom Green, and Upton counties). ?=distribution not listed.

² B=Bandera, I=Irion, R=Real, Rg=Reagan, S=Schleicher, T=Tom Green, Up=Upton, U=Uvalde. Counties indicated with normal font are within the general range (distribution based on known county records). Counties indicated in bold font have a verified occurrence. ?=distribution not listed.

³FE=federally endangered, FT=federally threatened, I=introduced, G=game, PDL=proposed de-listing, PT=proposed threatened, SE=state endangered, ST=State Threatened,

Appendix F: Aquatic Community Sampling Field Data

Brush Control: Aquatic Community Sampling Field Data					
Sample #	Date	Time	IBI Score	Watershed	Site (location description)
BC-1	6182001	14:29	80	Twin Buttes	South Concho - south of San Angelo on Hwy 2335
BC-2	6182001	15:25	77	Twin Buttes	South Concho at Hwy 2335- riffle below bridge
BC-3	6182001	16:00	72	Twin Buttes	South Concho at Hwy 2335 just upstream of bridge; 10 m above BC-2
BC-4	6182001	16:30	71	Twin Buttes	South Concho east braid under Hwy 2335 bridge
BC-5	6182001	17:00	71	Twin Buttes	South Concho below east braid under Hwy 2335 bridge; 10 m downstream from BC-4
BC-6	6182001	17:20	70	Twin Buttes	South Concho - south of San Angelo on Hwy 2335; 10 m above BC-4
BC-7	6182001	17:45	86	Twin Buttes	South Conch at Hwy 2335
BC-8	6192001	8:20	81	Twin Buttes	Big Rocky Creek at Hwy 853 - big pool downstream
BC-9	6192001		74	Twin Buttes	(West) Big Rocky Creek at Hwy 853
BC-10	6192001		68	Twin Buttes	(West) Big Rocky Creek at Hwy 853
BC-11	6192001	8:35	57	Twin Buttes	(West) Big Rocky Creek at Hwy 853 - rock bt shallow pool above BC-10
BC-12	6192001	8:45	73	Twin Buttes	(West) Big Rocky Creek at Hwy 835 - shallow broad pool - channel to west of BC-11
BC-13	6192001	10:45	52	Twin Buttes	Middle Concho at Hwy 583 - below hwy - pool furthest down
BC-14	6192001	10:55	52	Twin Buttes	Middle Concho at Hwy 583 - below hwy - pool downstream - next furthest down
BC-15	6192001	11:15	45	Twin Buttes	Middle Concho at Hwy 583 - pool below hwy - isolated pool
BC-16	6192001	11:40	74	Twin Buttes	Middle Concho at Hwy 583 - pool site just above hwy
BC-17	6192001		79	Twin Buttes	Middle Concho at Hwy 583 - site furthest upstream
BC-18	6192001	13:20	59	Twin Buttes	Middle Concho - at county Rd 412 - pool just above crossing
BC-19	6192001	13:40	77	Twin Buttes	Middle Concho ~ 100 m upstream from county Rd 412 crossing
BC-20	6192001	14:20	62	Twin Buttes	Middle Concho about 150 m upstream from county Rd 412 crossing
BC-21	6192001	16:15	56	Twin Buttes	Middle Concho ca. 100 m upstream from hwy 163
BC-22	6192001	16:45	17	Twin Buttes	Drying riffle separating two large pools (lower pool is BC-21) above Hwy 163; 50 m upstream from BC-21
BC-23	6192001	17:40	39	Twin Buttes	Middle Concho isolated pool - several Km upstream from BC-20
BC-24	6192001	18:00	30	Twin Buttes	Middle Concho small isolated pool separated from BC-23 by 12 m (pool only 5.9 m long)
BC-25	6192001	18:10	68	Twin Buttes	Middle Concho isolated shallow pool ~ 40 m upstera from BC-24
BC-26	6202001	9:45	64	Twin Buttes	Spring Creek - large broad shallow pool - heavily influenced by spring - low impoundment
BC-27	6202001	10:11	49	Twin Buttes	Spring Creek - cutoff pool in a side channel ~ 20 below dam at BC-26
BC-28	6202001	10:00	0	Twin Buttes	Spring Creek - riffle in cobbles - narrow~ 30 m below dam
BC-29	6202001	11:00	52	Twin Buttes	Spring Creek lower end of pool directly below BC-28 site
BC-30	6202001	11:20	47	Twin Buttes	Spring Creek - Shallow pool at base of a bluff - downstream from BC-27
BC-31	6202001	11:40	44	Twin Buttes	Spring Creek - pool below BC-30
BC-32	6202001	12:11	41	Twin Buttes	Spring Creek - run in full sunlight
BC-33	6202011	12:30	61	Twin Buttes	Spring Creek - sunlit pool just below "1918" low water crossing
BC-34	6202001	13:30	52	Twin Buttes	Spring Creek - riffle draining pool at county Rd. 202 crossing
BC-35	6202001	14:00	65	Twin Buttes	Spring Creek - Pool (natural appearance compared to pool by county Rd.); ~ 60 m downstream from BC-34
BC-36	6202001	16:00	49	Twin Buttes	Dove Creek below Guinn Rd isolated pool 25 m long
BC-37	6202001	16:40	32	Twin Buttes	Dove Creek small isolated pool (5.18 m long); ~50 m upstream from BC-36
BC-38	6202001	17:00	54	Twin Buttes	Dove Creek isolated pool 14.4 m long
BC-39	6202001	17:00	61	Twin Buttes	Dove Creek - run habitat ~ 500 m downstream from Hwy 2335
BC-40	6202001	18:16	61	Twin Buttes	Dove Creek - small riffle ~ 525 m downstream of Hwy 2335
BC-41	6202001	18:30	71	Twin Buttes	Dove Creek - pool below riffle at BC-40
BC-42	6212001	9:30	66	Twin Buttes	Dove Creek ~200 m upstream from fm 2335 - 8 m long riffle below dam spillway
BC-43	6212001	9:35	89	Twin Buttes	Dove Creek broad shallow pool below dam
BC-44	6272001	14:23	76	Edwards	Cedar Creek @ 336 5 miles North of Leaky-larger
BC-45	6272001	14:30	55	Edwards	Cedar Creek @ 336 small pool downstream of road
BC-46	6272001	15:00	32	Edwards	Cedar creek @ 336 small pool

Appendix F: Aquatic Community Sampling Field Data

Sample #	GPS (N)	GPS (W)	Channel width (m)	Channel width (m)	Channel width (m)	Depth @1/4 (cm)	Depth @1/4 (cm)	Depth @1/4 (cm)	Depth @ middle
BC-1	31 14.02	100 29.93	8.6	10.0	9.8	60	69	56	55
BC-2	31 13.99	100 30.07	4.8	3.8	2.7	22	30	13	23
BC-3			6.4	8.7	8.7	20	5	10	18
BC-4	31 14.09	100 30.00	7.5	10.6	6.5	40	52	25	61
BC-5			6.8	7.5	7.5	28	25	48	26
BC-6			3.9	3.8	3.7	7	24	10	20
BC-7	31 14.09	100 30.01	7.8	4.5	5.6	13	10	12	16
BC-8	31 14.08	100 30.01	9.7	17.3	19.0	30	24	41	25
BC-9	31 14.08	100 30.01	5.9	5.9	5.6	17	42	28	41
BC-10	31 14.08	100 30.01	4.4	5.6	3.5	5	13	6	10
BC-11	31 14.08	100 30.01	11.3	7.0	3.2	30	11	3	21
BC-12	31 14.08	100 30.01	8.9	10.7	10.4	1	70	47	90
BC-13	31 25.03	100 48.06	11.2	15.4	15.8	17	30	30	47
BC-14	31 25.03	100 48.06	9.1	8.5	9.0	8	9	16	5
BC-15	31 25.03	100 48.06	6.7	6.7	5.9	13	11	10	20
BC-16	31 25.03	100 48.06	9.5	15.8	14.3	44	30	71	69
BC-17	31 25.03	100 48.06	18.3	16.8	16.3	40	43	23	49
BC-18	31 22.37	100 57.26	14.0	10.6	10.0	1	86	38	1
BC-19	21 22.40	100 57.32	6.0	5.1	4.4	30	27	36	27
BC-20	31 22.43	100 57.36	8.8	9.2	7.6	84	70	29	51
BC-21	31 25.70	101 05.91	16.2	14.5	12.6	110	65	22	100
BC-22			1.2	2.2	2.2	1	4	10	2
BC-23	31 23.58	101 01.28	6.6	7.5	7.2	57	71	80	49
BC-24	31 23.58	101 01.28	2.0	2.1	2.0	9	10	8	12
BC-25	31 23.58	101.01.28	10.1	8.7	7.7	38	29	16	62
BC-26	31 16.91	100 48.50	35.0	29.8	18.6	25	28	15	51
BC-27			2.4	2.5	2.7	11	19	13	8
BC-28			1.1	1.7	2.1	0	3	7	1
BC-29			6.1	6.0	5.2	50	45	19	40
BC-30			2.6	2.0	2.0	3	7	8	15
BC-31	31 16.96	100 48.53	5.0	5.0	5.9	41	30	27	26
BC-32			2.4	3.9	5.0	8	15	20	10
BC-33	31 16.99	100 48.51	9.9	8.5	9.3	40	38	70	41
BC-34	31 17.90		1.8	1.9	2.4	2	5	10	4
BC-35			6.4	8.1	7.3	48	61	70	17
BC-36	31 12.17	100 42.35	2.3	2.5	2.7	2	7	18	5
BC-37			2.5	2.4	2.0	9	10	10	10
BC-38	31 12.05	100 42.37	3.8	4.8	5.2	8	26	9	16
BC-39	31 17.12	100 37.83	3.5	5.5	5.8	1	19	20	10
BC-40	31 17.12	100 37.83	1.5	1.1	3.7	4	5	10	6
BC-41			5.1	6.2	11.8	29	34	22	21
BC-42	31 16.21	100 16.21	1.1	1.7	2.4	3	5	5	25
BC-43	31 16.21	100 16.21	19.2	22.0	23.5	10	39	56	13
BC-44	29 47.56	99 46.91	9.9	8.7	7.4	55	53	50	71
BC-45	29 47.56	99 46.91	2.8	3.1	2.5	10	9	8	10
BC-46	29 47.59	99 46.91	1.9	1.7	1.1	8	4	11	10

Appendix F: Aquatic Community Sampling Field Data

Sample #	Depth @ middle	Depth @ middle	Depth @ 3/4	Depth @ 3/4	Depth @ 3/4	Flow @ 1/4	Flow @ 1/4	Flow @ 1/4	Flow @ middle	Flow @ middle
BC-1	73	73	63	59	68	0.00	0.00	0.01	0.03	0.01
BC-2	23	13	18	18	12	0.02	0.02	0.12	0.18	0.13
BC-3	20	17	19	21	14	0.02	0.00	0.00	0.20	0.27
BC-4	52	39	38	29	21	0.16	0.08	0.04	0.02	0.06
BC-5	24	32	18	22	24	0.12	0.12	0.08	0.11	0.16
BC-6	19	7	18	22	24	0.12	0.39	0.27	0.50	0.55
BC-7	7	18	12	10	17	0.23	0.58	0.15	0.26	0.37
BC-8	23	50	25	49	60	0.00	0.00	0.00	0.00	0.00
BC-9	21	19	21	22	25	0.00	0.00	0.00	0.00	0.00
BC-10	6	5	5	1	12	0.00	0.00	0.00	0.00	0.00
BC-11	18	8	17	8	8	0.00	0.00	0.00	0.00	0.00
BC-12	35	52	70	49	20	0.00	0.00	0.00	0.00	0.00
BC-13	21	20	71	58	70	0.00	0.00	0.00	0.00	0.00
BC-14	6	20	13	9	10	0.00	0.00	0.00	0.00	0.00
BC-15	25	28	16	34	17	0.00	0.00	0.00	0.00	0.00
BC-16	68	64	44	34	49	0.00	0.00	0.00	0.00	0.00
BC-17	84	64	57	68	49	0.00	0.00	0.00	0.00	0.00
BC-18	80	34	60	0	0	0.00	0.00	0.00	0.00	0.00
BC-19	31	34	24	29	30	0.00	0.00	0.00	0.00	0.00
BC-20	67	25	30	41	16	0.00	0.00	0.00	0.00	0.00
BC-21	90	23	100	71	28	0.00	0.00	0.00	0.00	0.00
BC-22	10	13	1	5	6	0.00	0.00	0.00	0.00	0.00
BC-23	88	80	61	48	50	0.00	0.00	0.00	0.00	0.00
BC-24	12	13	10	13	7	0.00	0.00	0.00	0.00	0.00
BC-25	46	28	32	27	20	0.00	0.00	0.00	0.00	0.00
BC-26	36	34	36	21	23	0.00	0.00	0.00	0.00	0.00
BC-27	21	15	8	18	10	0.00	0.00	0.00	0.00	0.00
BC-28	4	4	2	2	1	0.00	0.00	0.00	0.20	0.07
BC-29	40	20	10	22	11	0.00	0.00	0.00	0.00	0.00
BC-30	26	24	12	34	30	0.00	0.00	0.00	0.00	0.00
BC-31	40	50	28	51	47	0.00	0.00	0.00	0.00	0.00
BC-32	20	22	9	8	29	0.00	0.00	0.00	0.00	0.00
BC-33	48	74	40	63	71	0.00	0.00	0.00	0.00	0.00
BC-34	5	10	1	2	1	0.05	0.23	0.05	0.18	0.28
BC-35	18	53	10	6	33	0.00	0.00	0.00	0.00	0.00
BC-36	16	23	5	12	22	0.00	0.00	0.00	0.00	0.00
BC-37	10	12	11	10	8	0.00	0.00	0.00	0.00	0.00
BC-38	29	21	21	30	28	0.00	0.00	0.00	0.00	0.00
BC-39	16	12	7	10	7	0.00	0.00	0.00	0.00	0.00
BC-40	8	7	2	2	6	0.02	0.00	0.00	0.01	0.18
BC-41	39	30	23	42	41	0.00	0.00	0.00	0.00	0.00
BC-42	23	14	8	14	18	0.00	0.06	0.05	0.06	0.12
BC-43	28	58	10	20	30	0.00	0.00	0.00	0.00	0.00
BC-44	82	30	40	51	10	0.00	0.00	0.00	0.00	0.00
BC-45	19	11	7	9	3	0.00	0.00	0.00	0.00	0.00
BC-46	13	14	7	3	8	0.00	0.00	0.00	0.00	0.00

Appendix F: Aquatic Community Sampling Field Data

Sample #	Flow @ middle	Flow @ 3/4	Flow @ 3/4	Flow @ 3/4	Sand	Mud	Clay	Pebble	Cobble	Bedrock	coarse detritus	Temp (C)	DO (mg/L)	pH	Cond (uS)
BC-1	0.04	0.00	0.00	0.01		55		20	25			31.5	10.9	8.0	632
BC-2	0.24	0.00	0.06	0.04	10	80		10				30.9	8.3	7.7	300
BC-3	0.07	0.02	0.05	0.25		80	10	10				31.9	10.0	8.0	320
BC-4	0.15	0.10	0.00	0.18		10		45	45			30.1	7.7	8.0	661
BC-5	0.10	0.09	0.10	0.02				40	40			29.5	7.2		600
BC-6	0.70	0.39	0.29	0.85				10	90			29.8	7.0	8.0	659
BC-7	0.43	0.22	0.39	0.30				5	95			29.3	6.3	8.1	659
BC-8	0.00	0.00	0.00	0.00					1	99		24.3	6.3	8.5	541
BC-9	0.00	0.00	0.00	0.00					2	2		23.6	3.6	8.3	620
BC-10	0.00	0.00	0.00	0.00				4	1	90		23.0	5.5	8.3	600
BC-11	0.00	0.00	0.00	0.00				1		99		24.2	4.6	7.8	620
BC-12	0.00	0.00	0.00	0.00						100		25.7	5.7	8.2	613
BC-13	0.00	0.00	0.00	0.00		10		75	15			26.3	7.4	7.6	600
BC-14	0.00	0.00	0.00	0.00								25.8	7.9	8.1	604
BC-15	0.00	0.00	0.00	0.00				50	50			25.8	7.2	8.2	571
BC-16	0.00	0.00	0.00	0.00				20	5		75	29.0	7.9	8.2	840
BC-17	0.00	0.00	0.00	0.00				25	5	70		28.6	8.0	8.3	840
BC-18	0.00	0.00	0.00	0.00		20		100				27.0	5.5	7.7	925
BC-19	0.00	0.00	0.00	0.00	5			93	2			28.0	7.6	7.7	761
BC-20	0.00	0.00	0.00	0.00				100				29.4	10.3	8.0	235
BC-21	0.00	0.00	0.00	0.00		100						29.5	6.8	8.1	468
BC-22	0.00	0.00	0.00	0.00				98	2			28.6	12.3	8.1	586
BC-23	0.00	0.00	0.00	0.00		50		45			5	29.0	7.4	8.1	660
BC-24	0.00	0.00	0.00	0.00				100			100	31.5	8.0	7.5	813
BC-25	0.00	0.00	0.00	0.00		100		100				31.7	10.3	8.7	380
BC-26	0.00	0.00	0.00	0.00		90			2	98		23.5	2.3	7.5	739
BC-27	0.00	0.00	0.00	0.00				100	80			22.2	2.5	7.4	784
BC-28	0.18	0.00	0.00	0.00				5	95			26.9	2.9	7.4	825
BC-29	0.00	0.00	0.00	0.00		50		75	25			22.9	2.0	7.2	762
BC-30	0.00	0.00	0.00	0.00		100		100				19.5	3.6	7.2	777
BC-31	0.00	0.00	0.00	0.00		99		100			99	22.8	1.9	7.3	850
BC-32	0.00	0.00	0.00	0.00				9	1	90		27.3	9.0	7.1	870
BC-33	0.00	0.00	0.00	0.00				75		25		26.0	5.4	6.9	843
BC-34	0.35	0.02	0.00	0.00				95	5			28.5	8.3	7.6	850
BC-35	0.00	0.00	0.00	0.00				100				27.6	6.3	7.8	875
BC-36	0.00	0.00	0.00	0.00				60	40			24.8	9.5	7.2	2220
BC-37	0.00	0.00	0.00	0.00		98					2	25.8	8.6	7.8	1830
BC-38	0.00	0.00	0.00	0.00		100						24.8	5.9	7.7	573
BC-39	0.00	0.00	0.00	0.00		100		90	10			30.0	7.0	8.1	673
BC-40	0.00	0.06	0.00	0.00			10	20	70			30.0	5.9	7.4	676
BC-41	0.00	0.00	0.00	0.00							100	29.4	5.9	7.7	675
BC-42	0.20	0.00	0.16	0.00				50	50			25.7	2.9	7.3	540
BC-43	0.00	0.00	0.00	0.00		100		99	1			26.2	4.9	7.3	544
BC-44	0.00	0.00	0.00	0.00								26.8	6.8	7.8	412
BC-45	0.00	0.00	0.00	0.00				80			20	34.1	6.6	7.7	470
BC-46	0.00	0.00	0.00	0.00				80			20	30.8	5.8	7.1	450

Appendix F: Aquatic Community Sampling Field Data

Sample #	Land Use	Collectors	Weather	Length of stream sampled (m)	% Riffle	% Run
BC-1	Fallow ranchland - new subdivision	KW, AA, SW, MM	partly cloudy	30		100
BC-2	Fallow ranchland - new subdivision but with hwy bridge	KW, AA, SW, MM	partly cloudy	30		
BC-3	Fallow ranchland - new subdivision but with hwy bridge	KW, AA, SW, MM	partly cloudy	30		50
BC-4	Fallow ranchland - new subdivision but with hwy bridge	KW, AA, SW, MM	partly cloudy	30		
BC-5	Fallow ranchland - new subdivision but with hwy bridge	KW, AA, SW, MM	partly cloudy	30		100
BC-6	Fallow ranchland - new subdivision but with hwy bridge	KW, AA, SW, MM	partly cloudy	30	100	
BC-7	undeveloped riparian woodland and cattle pasture	KW, AA, SW	partly cloudy	30	100	
BC-8	ranchland	KW, AA, SW, MM	clear/sunny	30		
BC-9	hwy just above pool - ranch	KW, AA, SW, MM	sunny	30	5	
BC-10	hwy just above pool - ranch	KW, AA, SW, MM	sunny	25	40	
BC-11	ranchland	KW, AA, SW, MM	sunny	30		
BC-12	ranch	KW, AA, SW, MM	sunny	30		
BC-13	sheep ranch	KW, AA, SW, MM	sunny	30		
BC-14	sheep ranch	KW, AA, SW, MM	sunny	30		
BC-15	sheep ranch	KW, AA, SW, MM	sunny	30		
BC-16	ranchland	KW, AA, SW, MM	sunny	30		
BC-17	ranch	KW, AA, SW, MM	sunny	30		
BC-18	Rangeland - no livestock visible	KW, AA, SW, MM	sunny	30		
BC-19	Rangeland - no livestock visible	KW, AA, SW, MM	sunny	30		
BC-20	Rangeland	KW, AA, SW, MM	sunny - few sm	30		
BC-21	Mesquite dominated pasture	KW, AA, SW, MM	partly cloudy	30		
BC-22	Cattle ranch (no cattle observed) but trails	KW, AA, SW, MM	sunny - some c	30	100	
BC-23	Rangeland - no livestock visible	KW, AA, SW, MM	partly cloudy	30		
BC-24	Rangeland - no livestock visible	KW, AA, SW, MM	partly cloudy	6		
BC-25	Rangeland	KW, AA, SW, MM	partly cloudy	30		
BC-26	Ranchland - no livestock seen, but cowpatties seen below dam	KW, AA, SW, MM	clear	30		
BC-27	riparian forest all around pool	KW, AA, SW, MM	clear	15		
BC-28	riffles in riparian forest	KW, AA, SW, MM	clear	20	100	
BC-29		KW, AA, SW, MM	clear	30		
BC-30	dense riparian forest	KW, AA, SW, MM	clear	20		
BC-31	same as BC-30	KW, AA, SW, MM	clear	30		
BC-32	Ranchland	KW, AA, SW, MM	partly cloudy	25		100
BC-33	Same as BC-32	KW, AA, SW, MM	partly cloudy	30		
BC-34	Residences on both banks (trailers)	KW, AA, SW, MM	partly cloudy	25		
BC-35	Same as BC-34	KW, AA, SW, MM	partly cloudy	20		
BC-36	ranch (presumably cattle)	KW, AA, SW, MM	partly cloudy	25		
BC-37	ranch (presumably cattle)	KW, AA, SW, MM	partly cloudy	5		
BC-38	ranch (presumably cattle)	KW, AA, SW, MM	partly cloudy	14		
BC-39	residential on west bank, sheep ranch	KW, AA, SW, MM	partly cloudy	25		100
BC-40	Ranch	KW, AA, SW, MM	partly cloudy	10	100	
BC-41	Ranch	KW, AA, SW, MM	partly cloudy	30		
BC-42	residential, ranch	KW, AA, SW, MM	clear, sunny	8	100	
BC-43	residential, ranch	KW, AA, SW, MM	clear, sunny	30		
BC-44		AA,HL,MM,SW	clear, sunny	20		
BC-45	grazing	AA,HL,MM,SW	clear, sunny	7		
BC-46	Ranching?	AA,HL,MM,SW	very sunny, hot	8		

Appendix F: Aquatic Community Sampling Field Data

Sample #	% Pool	Snag	sandbar	scour area	detritus	Surber Sample 1 Substrate	Surber Sample 1 Vegetation
BC-1		rare	absent	absent	rare	mud	chara
BC-2	100					mud	najas
BC-3	100					mud	chara
BC-4	100	rare		rare		silt-pebble	yes
BC-5						cobble and silt	
BC-6						cobble	
BC-7						cobble	Potamogeton
BC-8	100					bedrock	flocculent periphyton
BC-9	95					bedrock	flocculent periphyton
BC-10	60					bedrock	flocculent algae
BC-11	100						chara
BC-12	100					bedrock	flocculent periphyton
BC-13	100	rare				gravel	periphyton
BC-14	100					cobble	periphyton
BC-15	100	rare	absent	absent	rare	cobble/pebble	chara
BC-16	100					bedrock	filamentous algae
BC-17	100					bedrock	algae
BC-18	100					gravel	thin algae only
BC-19	100	rare				gravel	chara
BC-20	100					gravel	Chara
BC-21	100	common	absent	absent	common	gravel	filamentous algae
BC-22						gravel	filamentous algae mat
BC-23	100	common			rare	gravel	algae
BC-24	100						algae
BC-25	100					gravel	filamentous algae
BC-26	100					bedrock, mud	Chara (dead)
BC-27	100	common				gravel	detritus
BC-28		rare				cobble/gravel	
BC-29	100	common			rare	gravel	chara and filamentous algae
BC-30	100	rare			rare	mud over gravel	
BC-31	100	common			rare	gravel	flocculent debris
BC-32		rare				bedrock	course detritus
BC-33	100				common	bedrock	course detritus
BC-34	100	absent	absent	absent		gravel	coontail/cabomba
BC-35	100	common			rare	gravel	slight Chara and course detritus
BC-36	100	common			rare	gravel	macroalgae and fil green algae
BC-37	100	common				mud	
BC-38	100	rare			common	mud	course detritus
BC-39							Cabomba, algae
BC-40		absent	absent	absent	common	mud and cobble	course detritus
BC-41	100	rare	absent	absent	common	mud and pebbles	course detritus
BC-42		absent	absent		rare	gravel	filamentous algae
BC-43	100	rare			common	thick mud over pebbles	Potamogeton
BC-44	100	absent	absent	rare	common	pebble	periphyton/detritus
BC-45	100	absent	absent	absent	common	pebble	periphyton
BC-46	100	rare	absent	absent	common	bedrock	periphyton

Appendix F: Aquatic Community Sampling Field Data

Sample #	Surber Sample 2 Substrate	Surber Sample 2 Vegetation	Riparian veg. (% cover)
BC-1	mud	chara	70
BC-2	sand	no	95
BC-3	mud	chara and najas	
BC-4	cobble-silt	no	
BC-5	cobble covered with silt		100
BC-6	cobble	filamentous algae	50
BC-7	pebble		50
BC-8	bedrock	flocculent periphyton	100
BC-9	bedrock	flocculent algae	96
BC-10	bedrock, gravel	some chara	60
BC-11	bedrock	flocculent periphyton	100
BC-12	bedrock	flocculent periphyton	100
BC-13	gravel	periphyton	100
BC-14	cobble with pebble mixture		80
BC-15	pebble	chara	100
BC-16	cobble	filamentous algae	100
BC-17	bedrock	algae	100
BC-18	gravel	thin algae only	95
BC-19	gravel		100
BC-20			100
BC-21	gravel	filamentous algae and coarse detritus	65
BC-22	gravel	filamentous algae mat	100
BC-23	gravel	algae	100
BC-24		filamentous algae	100
BC-25			100
BC-26	bedrock	Chara (dead)	100
BC-27	gravel	coarse detritus	100
BC-28	cobble/gravel		80
BC-29	gravel	chara and filamentous algae	99
BC-30	mud over gravel	coarse detritus	100
BC-31	flocculent debris over gravel		80
BC-32	bedrock	coarse detritus	100
BC-33	bedrock	chara	75
BC-34	gravel	filamentous algae	
BC-35	gravel	slight algae plus coarse detritus	60
BC-36	gravel	Macroalgae and fil green algae	100
BC-37	mud	coarse detritus	100
BC-38	mud	coarse detritus	100
BC-39		Cabomba, algae	100
BC-40	mud and cobble	coarse detritus	100
BC-41	mud and cobble	coarse detritus	100
BC-42	gravel	filamentous algae	50
BC-43	mud	Potamogeton and chara	50
BC-44	pebble	periphyton/detritus	25
BC-45	pebble	periphyton	
BC-46	bedrock	periphyton	45

Appendix F: Aquatic Community Sampling Field Data

Sample #	Dominant Tree Sp.	Littoral veg. (% cover)	Dominant Littoral Sp.
BC-1	Pecans	0	
BC-2	Hackberry, elm	20	Leersia
BC-3	mesquite		
BC-4			
BC-5	elm	2	Ludwigia, Potamogeton
BC-6	Pecan, Elm	10	Ludwigia
BC-7	Pecan, Elm	5	Ludwigia
BC-8	mesquite, cedar, elm		segas
BC-9		6	sedges, broadleaf
BC-10	mesquite, baccharis, willow	1	Sedges, Eleocharis
BC-11	Baccharis, Willows	6	4 Iva, 2 Eleocharis
BC-12	button bush, Baccharis, Willow	3	Eleocharis, Iva
BC-13	mesquite, willow, pecan		
BC-14	mesquite, cedar	2	grasses
BC-15	Baccharis, mesquite		
BC-16	diverse riparian forest		
BC-17	diverse riparian forest		
BC-18	Baccharis, ash		
BC-19		1	sedges, grasses (Leersia)
BC-20	Willow, pecan, buttonbush		
BC-21	Willow, Pecan	30	Fillamentous Algae
BC-22	Button bush, Willow, Pecan		
BC-23	pecans, willow, cedar, button bush		
BC-24	button bush, elm, pecan, pecan		
BC-25	Pecans, buttonbush, willow		
BC-26	Willow, pecan	0	Chara beds, but they are dry because water level recently dropped
BC-27	Mixed hardwood, pecan, willow		
BC-28	Mixed hardwood, pecan, willow	1	Parrot feather
BC-29	pecans, buttonbush		
BC-30	mulberry and pecan		
BC-31	mulberry and pecan	1	Parrot feather
BC-32	pecan saplings, button bush	36	35 Iva like plant, Ludwigia, 1 parrotfeather
BC-33	Pecan, mesquite	5	Iva-like
BC-34	pecans, willows, mulberry	35	Iva-like
BC-35	Pecans, Willows, Iva-like	30	Iva-like
BC-36	Pecans, live oak, willow, cedar		
BC-37	live oak, pecan, button bush		
BC-38	pecans		
BC-39	pecans, willows	40	Iva-type
BC-40	Pecans, willow	1	Nupher
BC-41	pecans, willows	60	water lilly
BC-42	mostly pecans, few willows		
BC-43	pecans	0	
BC-44	Salt bush, salt cedar		
BC-45			
BC-46			

Appendix F: Aquatic Community Sampling Field Data

Sample #	Submerged veg. (% cover)	Dominant Submerged Sp.
BC-1	95	Chara
BC-2	70	Najas
BC-3	71	Najas, Chara, Potamogeton
BC-4		Cabomba, Potamogeton
BC-5	1	Cabomba, Hornwort
BC-6	5	Potamogeton
BC-7	60	Potamogeton
BC-8	1	Chara
BC-9	1	cabomba
BC-10	1	chara
BC-11	2	Chara
BC-12		
BC-13		
BC-14	5	Chara
BC-15		
BC-16		
BC-17		
BC-18		
BC-19	5	Chara
BC-20	40	Chara
BC-21		
BC-22		
BC-23		
BC-24	20	Chara
BC-25		
BC-26	97	chara (most is dead material), Cabomba
BC-27		
BC-28		
BC-29	31	parrotfeather, chara
BC-30		
BC-31	2	parrotfeather, cabomba
BC-32		
BC-33	52	Chara, Cabomba
BC-34	15	Cabomba
BC-35	2	Chara
BC-36	90	weird macroalgae
BC-37		
BC-38	15	Najas
BC-39		Cabomba, water lilly
BC-40		
BC-41		
BC-42	50	Najas, Potamogeton, Chara
BC-43	60	Chara, Potamogeton, Cabomba
BC-44		
BC-45		
BC-46		

Appendix F: Aquatic Community Sampling Field Data

					Brush Control: Aquatic Community Sampling Field Data
Sample #	Date	Time	IBI Score	Watershed	Site (location description)
BC-47	6272001		32	Edwards	West Frio River @ confluence of cedar creek 150 m downstream of Hwy 336
BC-48	6272001	16:30	52	Edwards	West Frio River @ River downstream of site BC-47
BC-49	6272001	16:45	54	Edwards	West Frio River adjacent to site BC-48
BC-50	6272001	18:30	67	Edwards	West Frio River at old rock springs road
BC-51	6272001	18:50	58	Edwards	West Frio River at old rock springs road
BC-52	6272001	19:15	79	Edwards	West Frio River at old rock springs road
BC-53	6272001	20:00	54	Edwards	West Frio River at old rock springs road
BC-54	6272001	20:25	60	Edwards	West Frio River at old rock springs road; 100 m below BC-53
BC-55	6282001	9:10	55	Edwards	Kent Creek @ 336 - upstream side-impounded
BC-56	6282001	9:50	75	Edwards	Kent Creek upstream from BC-55
BC-57	6282001	10:30	52	Edwards	Tributary creek of West Frio River downstream of Hwy 336 crossing
BC-58	6282001	10:50	57	Edwards	Tributary creek of West Frio River downstream of Hwy 336 crossing-20 m upstream form BC-57
BC-59	6282001	11:05	42	Edwards	Tributary creek of West Frio River downstream of Hwy 336 crossing-30 m upstream of BC-58
BC-60	6282001	11:45	66	Edwards	Tributary creek of West Frio River downstream of Hwy 336 crossing
BC-61	6282001	12:05	57	Edwards	Tributary creek of West Frio River downstream of Hwy 336 crossing; 20 m upstream of BC-60
BC-62	6282001	13:25	47	Edwards	West Frio upstream from intersectin with Bonner rd out of 336, 200 m upstream from BC-62
BC-63	6282001	12:55	59	Edwards	West Frio upstream from intersectin with Bonner rd out of 336
BC-64	6292001	9:08	67	Edwards	Old Rocksprings Rd crossing of West Fork of Frio River (or a tributary creek)
BC-65	6292001	9:50	58	Edwards	Old Rocksprings Rd upstream from 2nd creek crossing- adjacent to BC-64
BC-66	6292001	10:00	64	Edwards	Upstream 20 m of BC-65 - old Rocksprings upstream of 2nd low water crossing
BC-67	6292001	11:30	71	Edwards	West Frio River below 3rd low water crossing
BC-68	6292001	11:15	56	Edwards	West Frio River 3rd low water crossing
BC-69	6292001	10:45	67	Edwards	West Frio River on Old Rockspring Rd above 3rd low water crossing
BC-70	6292001	12:00	78	Edwards	West Frio or creek tributary (2 pictures) further on the same road as BC-69
BC-71	6292001	12:35	49	Edwards	40 m downstream from BC-70
BC-72	6292001	13:15	69	Edwards	20 m downstream from BC-71
BC-73	6292001	13:35	62	Edwards	20 m downstream from BC-72
BC-74	6292001	14:12	57	Edwards	Tributary creek of West Frio River off Rd- 2nd low water crossing
BC-75	6292001	16:00	69	Edwards	Spring at upper Bluff Creek
BC-76	6292001	16:35	46	Edwards	Spring about 500 m further on the road of BC-75 right after Quail Canyon Ranch
BC-77	6292001	17:15	52	Edwards	Pool on the side of the bluff creek road
BC-78	6292001	17:35	48	Edwards	Bluff creek at intersection with main road on the way to springs
BC-79	6292001	18:00	24	Edwards	Bluff creek 2n low water crossing downstream of 1st large dam
BC-80	6292001	18:55	72	Edwards	West Frio at the first bridge north of Leakey on Hwy 83
BC-81	6292001	19:05	72	Edwards	Downstream from BC-80
BC-82	6292001	19:10	63	Edwards	Downstream from BC-81
BC-83	6302001	9:10	74	Edwards	Sabinal River low water crossing on Hwy 187 south of Lost Maples State Park
BC-84	6302001	9:24	65	Edwards	Sabinal River low water crossing on Hwy 187 south of Lost Maples State Park
BC-85	6302001		48	Edwards	Sabinal River low water crossing on Hwy 187 south of Lost Maples State Park
BC-86	6302001		66	Edwards	Sabinal River low water crossing on Hwy 187 south of Lost Maples State Park
BC-87	7112001	15:00	73	Edwards	Hondo creek @ Hwy 462 2nd crossing south of Tarpley
BC-88	7112001	15:30	77	Edwards	Hondo creek @ Hwy 462 2nd crossing south of Tarpley 100 m downstream form BC-87
BC-89	7112001	16:00	59	Edwards	Hondo creek @ Hwy 462 2nd crossing south of Tarpley
BC-90	7112001	16:20	52	Edwards	Hondo creek @ Hwy 462 2nd crossing south of Tarpley
BC-91	7112001	17:00	59	Edwards	Hondo creek upstream from 2nd intersection with Hwy 462 south of Tarpley
BC-92	7112001	17:25	82	Edwards	Riffle on the side of BC-91 pool

Appendix F: Aquatic Community Sampling Field Data

Sample #	GPS (N)	GPS (W)	Channel width (m)	Channel width (m)	Channel width (m)	Depth @1/4 (cm)	Depth @1/4 (cm)	Depth @1/4 (cm)	Depth @ middle
BC-47			29.8	34.0	33.0	20	30	16	15
BC-48	29 47.53	99 46.81	2.0	5.2	4.0	69	48	43	38
BC-49	29 47.53	99 46.81	8.1	12.7	8.7	16	20	15	16
BC-50	29 50.76	99 46.31	6.0	8.3	7.9	5	10	10	14
BC-51	29 50.81	99 46.32	9.2	11.2	18.2	10	20	8	26
BC-52	29 50.77	99 46.30	3.0	2.9	8.5	3	18	18	22
BC-53	29 50.65	99 46.28	15.2	13.6	16.5	14	17	13	18
BC-54			20.0	21.8	2.9	12	5	20	20
BC-55	29 50.17	99 46.95	23.7	24.4	25.0	41	31	51	43
BC-56			5.8	6.2	5.7	28	51	51	20
BC-57	29 49.61	99 46.93	2.5	2.6	1.9	24	23	20	23
BC-58			1.9	0.9	0.8	10	3	2	11
BC-59	29 49.59	99 46.96	4.5	5.0	4.2	10	23	20	26
BC-60	29 49.57	99 46.96	3.0	3.9	3.1	7	62	28	28
BC-61			2.8	1.2	3.0	1	2	0	2
BC-62	29 46.82	99 46.07	2.5	3.7	3.7	10	13	11	13
BC-63	29 46.69	99 45.99	23.7	26.6	29.0	21	20	12	24
BC-64	29 51.28	99 46.18	7.0	11.5	3.4	40	26	10	39
BC-65	29 51.28	99 46.18	11.5	7.4	6.7	6	30	29	12
BC-66	29 51.29	99 46.17	40.0	42.0	38.0	50	48	67	42
BC-67	29 51.72	99 46.27	19.7	6.7	8.0	8	13	28	14
BC-68	29 51.72	99 46.28	14.6	13.3	5.3	8	7	8	9
BC-69	29 51.79	99 46.34	18.0	14.8	11.9	31	73	38	48
BC-70	29 52.68	99 45.68	7.6	7.3	6.6	36	20	34	30
BC-71	29 52.68	99 45.65	8.2	12.3	6.7	21	30	33	30
BC-72	29 52.66	99 45.66	7.3	5.4	3.9	7	28	12	20
BC-73	29 52.65	99 45.65	6.0	7.0	4.5	41	100	90	89
BC-74	29 51.62	99 46.09	4.7	11.8	10.0	8	38	83	88
BC-75	29 51.53	99 45.25	2.0	1.0	1.0	5	4	3	40
BC-76	29 51.23	99 44.75	2.0	2.0	2.0	40	38	43	41
BC-77	29 51.72	99 45.28	2.3	2.0	1.9	20	30	43	15
BC-78	29 51.68	99 45.56	14.9	15.0	14.8	3	7	5	5
BC-79	29 57.57	99 46.10	7.4	7.6	7.8	25	20	43	25
BC-80	29 44.81	99 45.08	6.4	7.0	11.2	18	18	20	13
BC-81			4.6	5.9	5.7	20	20	20	13
BC-82			11.1	12.7	13.3	27	23	30	1
BC-83	29 47.51	99 34.47	3.0	4.1	5.7	13	16	40	18
BC-84	29 47.51	99 34.47	5.7	6.9	6.3	5	20	10	10
BC-85	29 47.50	99 34.37	22.0	11.7	12.1	12	5	11	10
BC-86	29 47.46	99 34.33	10.4	11.0	16.0	37	38	24	43
BC-87	29 33.98	99 14.93	14.1	14.5	12.0	54	42	52	55
BC-88			11.5	13.0	15.8	15	22	11	29
BC-89	29 33.98	99 14.98	7.1	9.6	9.7	12	12	12	19
BC-90	29 33.95	99 15.01	5.3	5.5	7.5	29	10	9	10
BC-91	29 34.01	99 14.87	37.0	37.0	30.0	49	40	61	130
BC-92	29 34.01	99 14.87	5.8	3.3	4.2	0	15	8	9

Appendix F: Aquatic Community Sampling Field Data

Sample #	Depth @ middle	Depth @ middle	Depth @ 3/4	Depth @ 3/4	Depth @ 3/4	Flow @ 1/4	Flow @ 1/4	Flow @ 1/4	Flow @ middle	Flow @ middle
BC-47	30	29	10	18	28	0.04	0.00	0.03	0.11	0.10
BC-48	51	58	14	12	41	0.12	0.00	0.00	0.12	0.00
BC-49	11	12	11	9	10	0.24	0.28	0.32	0.20	0.39
BC-50	23	13	15	12	11	0.00	0.00	0.01	0.10	0.04
BC-51	31	18	22	10	30	0.07	0.48	0.18	0.17	0.38
BC-52	40	28	22	32	20	3.20	0.15	0.96	1.36	0.85
BC-53	21	16	14	22	17	0.17	0.28	0.24	0.21	0.22
BC-54	43	28	9	8	30	0.26	0.25	0.26	0.19	0.10
BC-55	60	12	48	80	78	0.00	0.00	0.00	0.00	0.00
BC-56	43	34	27	46	13	0.00	0.00	0.00	0.00	0.00
BC-57	18	18	13	12	13	0.00	0.00	0.00	0.00	0.00
BC-58	10	3	8	2	2	0.00	0.00	0.00	0.01	0.04
BC-59	31	35	30	32	30	0.00	0.00	0.00	0.00	0.00
BC-60	49	40	30	33	32	0.00	0.00	0.00	0.00	0.00
BC-61	2	9	1	4	1	0.00	0.00	0.00	0.04	0.17
BC-62	8	1	10	6	11	0.00	0.00	0.00	1.00	1.00
BC-63	38	25	22	28	13	0.00	0.00	0.00	0.00	0.00
BC-64	26	16	21	26	12	0.00	0.00	0.00	0.00	0.00
BC-65	30	31	4	26	26	1.02	0.05	0.13	0.99	0.58
BC-66	51	18	20	50	51	0.02	0.00	0.00	0.00	0.00
BC-67	12	4	9	27	14	0.69	0.50	0.18	0.75	0.61
BC-68	4	10	9	5	12	0.28	0.32	0.43	0.62	0.46
BC-69	67	40	50	76	36	0.03	0.00	0.07	0.07	0.00
BC-70	21	40	31	20	19	0.00	0.75	0.29	0.42	0.92
BC-71	29	30	41	23	13	0.37	0.38	0.37	0.13	0.12
BC-72	36	23	10	12	12	0.23	0.25	0.86	0.67	0.97
BC-73	60	60	90	20	30	0.00	0.12	0.11	0.02	0.14
BC-74	90	84	50	73	78	0.13	0.00	0.00	0.10	0.13
BC-75	10	6	3	2	5	0.18	0.00	0.00	0.15	0.00
BC-76	38	46	48	40	40	0.00	0.00	0.00	0.00	0.00
BC-77	48	48	10	48	30	0.15	0.00	0.00	0.18	0.00
BC-78	3	9	3	7	3	0.14	0.11	0.22	0.04	0.11
BC-79	20	46	20	13	41	0.00	0.08	0.00	0.17	0.13
BC-80	32	28	26	12	10	0.18	0.32	0.37	0.25	0.42
BC-81	23	23	17	9	26	0.28	0.45	0.26	0.26	0.49
BC-82	50	50	88	80	68	0.05	0.01	0.06	0.12	0.06
BC-83	21	21	18	20	20	0.43	0.15	0.23	0.32	0.23
BC-84	5	8	9	11	3	0.52	0.49	0.47	0.18	44.00
BC-85	8	13	3	12	4	0.37	0.53	0.37	0.18	0.01
BC-86	38	18	35	30	30	0.04	0.00	0.00	0.08	0.07
BC-87	46	48	38	45	50	0.04	0.00	0.01	0.11	0.06
BC-88	28	27	15	16	5	0.13	0.33	0.36	0.39	0.40
BC-89	11	17	10	8	12	0.20	0.12	0.10	0.37	0.45
BC-90	18	16	15	17	18	0.52	0.56	0.16	0.75	0.80
BC-91	122	89	89	130	60	0.00	0.00	0.00	0.00	0.00
BC-92	27	20	31	23	25	0.00	0.36	0.53	0.10	0.71

Appendix F: Aquatic Community Sampling Field Data

Sample #	Flow @ middle	Flow @ 3/4	Flow @ 3/4	Flow @ 3/4	Sand	Mud	Clay	Pebble	Cobble	Bedrock	coarse detritus	Temp (C)	DO (mg/L)	pH	Cond (uS)
BC-47	0.06	0.08	0.04	0.00				100				27.6	8.5	7.6	350
BC-48	0.05	0.07	0.04	0.02				40	40		20	27.3	7.1	8.2	345
BC-49	0.59	0.24	0.54	0.75				20			80	28.1	8.3	8.7	350
BC-50	0.00	0.07	0.01	0.00				50		50		29.0	7.2	9.1	275
BC-51	0.00	0.12	0.35	0.25				50		50		28.8	7.5	9.3	285
BC-52	1.05	0.93	0.84	0.91				100				28.6	7.0	9.3	284
BC-53	0.22	0.20	0.24	0.19				5		100		28.2	6.4	9.4	225
BC-54	0.00	0.19	1.11	0.04				20		80		27.9	6.4	9.3	280
BC-55	0.00	0.00	0.00	0.00				100			100	25.2	6.1	8.9	306
BC-56	0.00	0.00	0.00	0.00				40	40		20	25.2	6.1	8.9	306
BC-57	0.00	0.00	0.00	0.00			50	50			45	24.0	4.2	8.5	611
BC-58	0.10	0.00	0.00	0.00			40	20	40			23.6	3.9	8.3	610
BC-59	0.00	0.00	0.00	0.00			20		30	50		23.6	7.3	8.6	620
BC-60	0.00	0.00	0.00	0.00					20	60	20	24.1	5.9	8.9	627
BC-61	0.12	0.00	0.00	0.00					10	90		27.5	7.1	8.4	657
BC-62	1.00	0.00	0.00	0.00				100				25.7	7.2	8.6	371
BC-63	0.00	0.00	0.00	0.00			10	40	20		20	26.2	6.9	8.8	390
BC-64	0.00	0.00	0.00	0.00				20		90		26.0	3.8	8.6	285
BC-65	0.40	1.14	0.63	0.31				35	35	20		25.6	5.9	8.7	275
BC-66	0.00	0.00	0.00	0.00				20		80		25.8	6.6	8.8	280
BC-67	0.13	0.64	0.50	0.89				40	40	10		27.5	6.6	8.9	180
BC-68	0.33	0.36	0.40	0.52				10		90		27.5	6.6	8.9	180
BC-69	0.24	0.01	0.08	0.07				25		75		26.4	6.5	8.6	278
BC-70	0.50	0.50	1.05	0.78					100			26.8	6.9	8.8	270
BC-71	0.20	0.11	0.01	0.06				15	50		35	27.3	7.0	8.5	270
BC-72	0.96	0.69	0.27	0.55				40	60			27.7	7.1	9.0	274
BC-73	0.15	0.73	0.00	0.21	15			75	10			27.9	7.1	8.8	262
BC-74	0.00	0.17	0.00	0.00						100		28.5	6.4	8.7	330
BC-75	0.00	0.00	0.00	0.00						100		23.2	6.1	8.2	420
BC-76	0.00	0.00	0.00	0.00	20	5			5		70	25.1	5.6	7.7	460
BC-77	0.01	0.00	0.00	0.00					50		50	27.9	5.4	8.3	421
BC-78	0.20	0.25	0.21	0.26						95	5	27.2	6.7	8.5	365
BC-79	0.05	0.08	0.00	0.00						100	100	29.4	6.5	8.8	320
BC-80	0.39	0.30	0.35	0.27				50	50			25.5	6.9	8.3	390
BC-81	0.47	0.56	0.35	0.49				50	50						
BC-82	0.09	0.09	0.04	0.00				70	30						
BC-83	0.23	0.09	0.14	0.09				30	70			25.2	5.3	8.6	376
BC-84	0.46	0.39	0.35	0.39				20	80			25.2	5.3	8.6	376
BC-85	0.18	0.05	0.17	0.18				5		95		25.1	6.0	8.7	375
BC-86	0.00	0.00	0.00	0.06								25.0	6.1	8.8	376
BC-87	0.06	0.09	0.00	0.04	20			30	10	50		31.2	9.5	7.6	412
BC-88	0.20	0.42	0.20	0.47				60	40			31.8	8.8	8.0	417
BC-89	0.34	0.23	0.35	0.36	5					95		32.1	9.3	8.2	418
BC-90	0.73	0.64	0.30	0.22						100		32.5	8.2	8.0	419
BC-91	0.00	0.00	0.00	0.00	25			25		50		33.1	7.6	8.3	421
BC-92	0.42	0.75	0.68	0.80	20			80				33.2	8.4	8.2	420

Appendix F: Aquatic Community Sampling Field Data

Sample #	Land Use	Collectors	Weather	Length of stream sampled (m)	% Riffle	% Run
BC-47	Ranching	AA,HL,MM,SW	clear, sunny	30		100
BC-48	Ranching	AA,HL,MM,SW	clear, sunny	15		
BC-49	Ranching	AA,HL,MM,SW	clear, sunny	20	100	
BC-50	Ranching	AA,HL,MM,SW	clear	10		
BC-51		AA,HL,MM,SW	clear	20		100
BC-52	Ranching	AA,HL,MM,SW	clear	20	100	
BC-53	Ranching	AA,HL,MM,SW	clear	30		100
BC-54	Ranching	AA,HL,MM,SW	clear	15	100	
BC-55	Ranching	AA,HL,MM,SW	clear, sunny	20		
BC-56	Ranching, impounded downstream	AA,HL,MM,SW	clear, sunny	30		
BC-57	Ranching	AA,HL,MM,SW	clear, sunny	15		
BC-58	Ranching	AA,HL,MM,SW	clear, sunny	8	100	
BC-59	Ranching	AA,HL,MM,SW	clear, sunny	20		
BC-60	Ranching	AA,HL,MM,SW	clear, sunny	10	100	
BC-61	Ranching	AA,HL,MM,SW	clear, sunny	15	100	
BC-62	Ranching	AA,HL,MM,SW	clear, sunny	20	100	
BC-63	Ranching note: water goes belowground 20 m below site	AA,HL,MM,SW	clear, sunny	30		
BC-64	Ranching	AA,HL,MM,SW	clear, sunny	35		
BC-65	Ranching	AA,HL,MM,SW	clear, sunny	10	100	
BC-66	Ranching	AA,HL,MM,SW	clear, sunny	25		
BC-67	Ranching	AA,HL,MM,SW	clear, sunny	20	100	
BC-68	Ranching	AA,HL,MM,SW	clear, sunny	20		100
BC-69	Ranching	AA,HL,MM,SW	clear, sunny	40		100
BC-70	Ranching, secondary brush	AA,HL,MM,SW	clear, sunny	15	100	
BC-71	Ranching	AA,HL,MM,SW	clear, sunny	20		100
BC-72	Ranching	AA,HL,MM,SW	clear, sunny	15	100	
BC-73	Ranching/vacation homes	AA,HL,MM,SW	clear, sunny	15		
BC-74	Ranching, damed upstream 50m from site, w/o appantly altering natural flow	AA,HL,MM,SW	clear, sunny	50		
BC-75	Housing/Summer homes	AA,HL,MM,SW	clear, sunny	10		
BC-76	Roadside	AA,HL,MM,SW	clear, sunny	25		
BC-77	Roadside	AA,HL,MM,SW	clear, sunny	10		
BC-78	Ranching	AA,HL,MM,SW	clear, sunny	25		100
BC-79	?	AA,HL,MM,SW	clear, sunny	20		100
BC-80	Ranching	AA,HL,MM,SW	clear, sunny	15		100
BC-81	Ranching	AA,HL,MM,SW	clear, sunny	30	100	
BC-82	Ranching	AA,HL,MM,SW	clear, sunny	20		
BC-83	Housing	AA,HL,MM,SW	overcast/cool	15		100
BC-84	Housing	AA,HL,MM,SW	overcast/cool	15	100	
BC-85	Ranching	AA,HL,MM,SW	cloudy	30		100
BC-86	Ranching	AA,HL,MM,SW	overcast/cool	30		
BC-87	Ranchland, seemingly natural riparian vegetation in most part of the shore	AA, HL, YB, MP	clear, sunny	50		
BC-88	Ranchland, seemingly natural riparian vegetation in most part of the shore	AA, HL, YB, MP	clear, sunny	20	100	
BC-89	Ranchland, seemingly natural riparian vegetation in most part of the shore	AA, HL, YB, MP	clear, sunny	50		100
BC-90	Ranchland, seemingly natural riparian vegetation in most part of the shore	AA, HL, YB, MP	clear, sunny	50	100	
BC-91	no use, riparian vegetation	AA, HL, YB, MP	clear, sunny	50		
BC-92	no riparian vegetation	AA, HL, YB, MP	clear, sunny	40	100	

Appendix F: Aquatic Community Sampling Field Data

Sample #	% Pool	Snag	sandbar	scour area	detritus	Surber Sample 1 Substrate	Surber Sample 1 Vegetation
BC-47		rare	rare	absent	absent	pebble/cobble	periphyton
BC-48	100	absent	rare	rare	common	sand/pebble	periphyton
BC-49		absent	absent	absent	absent	pebble/cobble	periphyton
BC-50	100	absent	absent	rare	rare	pebble	periphyton
BC-51		rare	rare	rare	absent	pebble	
BC-52		rare	rare	rare	rare	pebble/cobble	
BC-53		rare	absent	rare	rare	bedrock	periphyton
BC-54		absent	absent	rare	rare	pebble	
BC-55	100	absent	absent	absent	rare	pebble/detritus	chara/potamogeton
BC-56	100	rare	absent	absent	common	pebble/cobble	periphyton/detritus w/some chara
BC-57	100	absent	absent	absent	common	pebble/detritus	chara/detritus
BC-58		absent	absent	absent	common	cobble	coarse detritus
BC-59	100	rare	absent	absent	common	pebble/clay	chara/periphyton
BC-60		rare	absent	common	common	pebbles	chara, filamentous algae and detritus
BC-61		absent	absent	common	absent	bedrock/pebble	very little periphyton
BC-62		absent	absent	absent	absent	pebble	
BC-63	100	absent	absent	absent	rare	cobble	detritus/fil. Algae
BC-64	100	rare	absent	absent	common	bedrock	detritus/fil. Algae
BC-65		absent	absent	absent	absent	pebble/cobble	
BC-66	100	rare	absent	rare	rare	cobble/pebble	detritus/chara
BC-67		rare	absent	rare	absent	pebble	
BC-68		absent	absent	absent	absent	bedrock	
BC-69		absent	absent	rare	common	bedrock	periphyton/detritus
BC-70		common	absent	absent	rare	cobble	
BC-71		common	absent	absent	common	pebble	detritus
BC-72		common	absent	common	absent	pebble	Potamogeton
BC-73	100	common	absent	common	rare	pebble/sand	
BC-74	100	absent	absent	rare	common	bedrock	periphyton/detritus
BC-75	100	absent	absent	absent	common	bedrock	periphyton
BC-76	100	common	absent	common	common	leaf litter	detritus
BC-77	100	absent	absent	absent	common	bedrock	
BC-78		rare	absent	rare	rare	bedrock	few detritus
BC-79		common	absent	common	common	bedrock	lots of fine detritus (from periphyton?)
BC-80		absent	absent	rare	absent	pebble/cobble	little fil. Algae
BC-81		rare	absent	common	absent	pebble/cobble	fil. Algae
BC-82	100	common	absent	common	rare	pebble	fine detritus/fil algae
BC-83		rare	absent	rare	common	pebble/cobble	potamogeton/detritus
BC-84		absent	absent	rare	rare	pebble/cobble	fil.algae/detritus
BC-85		absent	absent	rare	rare	bedrock	some coarse detritus
BC-86	100	rare	absent	common	rare	bedrock	fine detritus
BC-87	100	absent	rare	absent	common	pebble	
BC-88		absent	absent	absent	rare	pebble/cobble	
BC-89		absent	absent	rare	absent	bedrock	
BC-90		rare	absent	rare	rare	bedrock	
BC-91	100	rare	common	common	rare	sand/pebble	
BC-92		rare	rare	common	absent	pebble	

Appendix F: Aquatic Community Sampling Field Data

Sample #	Surber Sample 2 Substrate	Surber Sample 2 Vegetation	Riparian veg. (% cover)
BC-47	pebble/cobble	periphyton	100
BC-48	sand/pebble	periphyton	90
BC-49	pebble/cobble	periphyton	50
BC-50	bedrock	periphyton	
BC-51	pebble	chara	
BC-52	pebble/cobble		
BC-53	bedrock/pebbles	periphyton	90
BC-54	bedrock		80
BC-55	pebble/detritus	chara/polamocytion	70
BC-56	cobble	chara/detritus	50
BC-57	pebble/detritus	chara/detritus	45
BC-58	cobble	coarse detritus	40
BC-59	bedrock	chara	50
BC-60	bedrock	detritus	40
BC-61	bedrock	periphyton and detritus	25
BC-62	pebble	fil. Algae	
BC-63	cobble/pebble/clay	detritus	40
BC-64	bedrock	chara/detritus	75
BC-65	pebble/cobble		40
BC-66	bedrock	detritus/periphyton	100
BC-67	pebble		50
BC-68	bedrock/pebbles		45
BC-69	pebble	periphyton/detritus/chara	60
BC-70	cobble	some detritus	20
BC-71	pebble		
BC-72	pebble	potamogeton	100
BC-73	pebble/sand		90
BC-74	bedrock	coarse detritus	95
BC-75	bedrock	periphyton	100
BC-76	leaf litter	detritus	85
BC-77	bedrock/pebbles	detritus	15
BC-78	bedrock	few detritus	90
BC-79	bedrock	lots of detritus (from periphyton?)	100
BC-80	pebble/cobble	fil. algae	30
BC-81	pebble/cobble	fil. Algae	15
BC-82	pebble	fine det/fil algae	20
BC-83	cobble	detritus	85
BC-84	pebble	fil. Algae	35
BC-85	bedrock	some coarse detritus	50
BC-86	bedrock	coarse detritus	40
BC-87	bedrock	some detritus	75
BC-88	pebble/cobble		50
BC-89	bedrock		60
BC-90	bedrock		85
BC-91	gravel/sand	chara	90
BC-92	pebbles/sand		60

Appendix F: Aquatic Community Sampling Field Data

Sample #	Dominant Tree Sp.	Littoral veg. (% cover)	Dominant Littoral Sp.
BC-47	<i>Baccharis halimifolia</i> , <i>Cephalanthus occidentalis</i> , live oak, Sycamore		
BC-48	<i>Baccharis halimifolia</i> , live oak, sycamore		
BC-49	mostly pecans, few willows		
BC-50			
BC-51	button bush, Sycamore, pecan, juniper		
BC-52	Sycamore, salt bush		
BC-53	pecan, cypress, juniper		
BC-54	cedar, sycamore, pecan, juniper		
BC-55	Willow, pecan, live oak, Baccharis		
BC-56	Sycamore		
BC-57	Sycamore, Baccharis,	15	Eleocharis sp.
BC-58	Button bush, Baccharis	20	grasses
BC-59	Baccharis, juniper	20	grasses, eleocharis
BC-60	Sycamore, juniper		
BC-61	Sycamore, juniper		
BC-62			
BC-63	Baccharis		
BC-64	sycamore, willow, pecan	1	Potamogeton
BC-65	Baccharis, sycamore, grasses, cypress		
BC-66	sycamore, pecan, cypress, Baccharis		
BC-67	sycamore, Baccharis		
BC-68	sycamore, Baccharis		
BC-69	sycamore, Baccharis, willow, juniper		
BC-70	sycamore, willow		
BC-71	sycamore		
BC-72	sycamore, willow	5	willow
BC-73	willow, sycamore		
BC-74	cypress willow, juniper, Baccharis, sycamore		
BC-75	cedar, sycamore		
BC-76	juniper, red oak, sycamore		
BC-77	juniper, sycamore		
BC-78	Juniper, sycamore		
BC-79	cypress lined channel, cedar		
BC-80	Cypress, sycamore, Baccharis		
BC-81	cypress, sycamore		
BC-82	sycamore, cypress		
BC-83	cypress, sycamore, willow	15	sedges, grasses
BC-84	cypress, sycamore	40	grasses, sedges
BC-85	sycamore		
BC-86	sycamore, cypress, baccharis		
BC-87	Baccharis, sycamore, willow		
BC-88	sycamore		
BC-89	sycamore, live oak		
BC-90	sycamore, juniper		
BC-91	live oak, willow, sycamore		
BC-92	Ox-eye grass		

Appendix F: Aquatic Community Sampling Field Data

Sample #	Submerged veg. (% cover)	Dominant Submerged Sp.
BC-47		
BC-48		
BC-49		
BC-50		
BC-51	25	chara
BC-52	1	unknown
BC-53	5	chara
BC-54		
BC-55	75	chara/potamogeton
BC-56	10	chara
BC-57		
BC-58		
BC-59	80	chara, periphyton
BC-60	20	chara, filamentous algae
BC-61	5	chara
BC-62		
BC-63	10	chara
BC-64	10	chara/filamentous algae
BC-65	5	chara
BC-66	10	chara
BC-67		
BC-68		
BC-69	5	chara
BC-70		
BC-71		
BC-72	98	potamogeton, chara
BC-73	20	chara, potamogeton, najas
BC-74	5	potamogeton
BC-75		
BC-76		
BC-77	5	filamentous algae
BC-78		
BC-79	10	chara
BC-80	75	Filamentous algae
BC-81	80	Filamentous algae
BC-82	80	Filamentous algae
BC-83	10	chara/filamentous algae
BC-84	65	filamentous algae
BC-85	1	chara
BC-86	1	chara
BC-87	10	potamogeton, chara
BC-88	3	unidentified
BC-89	2	chara
BC-90		
BC-91	40	chara/potamogeton
BC-92	10	unidentified

Appendix F: Aquatic Community Sampling Field Data

Brush Control: Aquatic Community Sampling Field Data					
Sample #	Date	Time	IBI Score	Watershed	Site (location description)
BC-93	7112001	18:25	64	Edwards	Seco creek at intersection with Hwy 470
BC-94	7112001	19:10	75	Edwards	Seco creek at intersection with Hwy 470
BC-95	7112001		54	Edwards	Seco creek at intersection with Hwy 470
BC-96	7112001	20:25	42	Edwards	Sabinal River at intersection with Hwy 1050 just out of Utopia
BC-97	7112001	20:30	57	Edwards	Sabinal River at intersection with Hwy 1050 just out of Utopia
BC-98	7112001	9:45	54	Edwards	Sabinal River at intersection with Hwy 187
BC-99	7112001	10:15	69	Edwards	Sabinal River at intersection with Hwy 187
BC-100	7112001	6:50	55	Edwards	Sabinal River at intersection with Hwy 187
BC-101	7112001	11:20	45	Edwards	Sabinal River at intersection with Hwy 187
BC-102	7122001	11:50	56	Edwards	Sabinal river downstream from intersection with Hwy 187
BC-103	7122001	12:00	41	Edwards	Sabinal river downstream from intersection with Hwy 187
BC-104	7132001	9:40	56	Edwards	Medina river (North Prong) at first crossing on Mickle Creek Rd. (goes with BC-117)
BC-105	7122001	13:00	79	Edwards	Sabinal River at Lost Maples Natural Area
BC-106	7122001	13:10	69	Edwards	Sabinal River at Lost Maples Natural Area
BC-107	7122001	13:17	53	Edwards	Sabinal River at Lost Maples Natural Area
BC-108	7122001	13:24	56	Edwards	Sabinal River at Lost Maples Natural Area
BC-109	7122001	16:05	56	Edwards	Mill Creek Ranch Dos Arroyos-off Hwy 337
BC-110	7122001	16:54	69	Edwards	Mill Creek Ranch Dos Arroyos-off Hwy 337
BC-111	7122001	17:15	47	Edwards	Mill Creek Ranch Dos Arroyos-off Hwy 337
BC-113	7122001	17:49	54	Edwards	Evans Creek (?) just upstream of confluence with Mill Creek
BC-114	7122001	18:20	57	Edwards	Evans Creek (?) just upstream of confluence with Mill Creek
BC-115	7122001	19:35	66	Edwards	Ubanks Creek (lefthand) at the source
BC-116	7122001	19:47	42	Edwards	Ubanks Creek at the Ranch of William and Marylynn Spangler
BC-117	7132001	10:20	42	Edwards	Medina River (North Prong) at 1st crossing on Mickle Creek Rd.)
BC-118	1172001	19:48	58	Edwards	Medina River at 3rd crossing with 2107
BC-120	7132001	11:40	75	Edwards	Wallace Creek at 2nd intersection with Hwy 16 (tributary of Medina North Prong)
BC-121	7132001	12:13	57	Edwards	Medina River (north prong) at Benton Crossing Hwy 16
BC-122	7132001	12:45	91	Edwards	Medina River (north prong) upstream from intersection with Hwy 16 at Benton Crossing
BC-123	7132001	14:40	58	Edwards	Elam Creek at intersection with Hwy 337
BC-124	7132001	15:00	54	Edwards	Elam Creek at intersection with Hwy 337
BC-125	7132001	15:56	58	Edwards	Bauerlein Creek at intersection with Hwy 337
BC-126	7132001	17:05	77	Edwards	Winans Creek at intersection with Hwy 16
BC-127	7122001	18:45	73	Edwards	Medina River upstream from crossing at Hwy 16 (at a park)
BC-128	7122001	18:45	69	Edwards	Medina River upstream from crossing at Hwy 16 (at a park)
BC-129	7142001	8:20	80	Edwards	Medina River at Bandera
BC-130	7142001	8:35	65	Edwards	Medina River at Bandera
BC-131	7142001	9:00	69	Edwards	Medina River at Bandera

Appendix F: Aquatic Community Sampling Field Data

Sample #	GPS (N)	GPS (W)	Channel width (m)	Channel width (m)	Channel width (m)	Depth @1/4 (cm)	Depth @1/4 (cm)	Depth @1/4 (cm)	Depth @ middle
BC-93	29 39.95	99 25.47	9.0	7.0		41	88	0	150
BC-94	29 39.96	99 25.47	3.7	3.3	1.2	6	11	11	20
BC-95	29 39.96	99 25.49	4.2	4.0	2.9	7	5	14	12
BC-96	29 36.72	99 31.76	9.8	11.9	8.7	23	11	79	81
BC-97			4.2	6.6	6.4	17	10	12	35
BC-98	29 39.97	99 32.68	17.2	11.4	7.2	66	43	70	27
BC-99	29 39.93	99 32.65	6.5	4.0	8.0	35	21	18	45
BC-100	19 43.16	99 32.92	12.5	10.0	8.1	34	27	27	59
BC-101	29 43.14	99 32.96	6.4	7.6	8.9	20	21	21	18
BC-102	29 43.15	99 32.99	6.7	7.3	7.3	7	8	3	10
BC-103			8.5	10.2	12.0	57	74	63	75
BC-104	29 51.60	99 21.90	29.1	22.7	11.6	35	37	30	39
BC-105	29 48.92	99 34.49	9.9	9.8	10.0	40	46	43	50
BC-106	29 48.92	99 34.42	11.2	11.2	12.5	2	8	4	3
BC-107	29 48.92	99 34.39	1.0	0.8	1.0	5	4	5	6
BC-108	29 48.96	99 34.37	2.5	3.6	5.0	12	8	22	20
BC-109	29 45.08	99 31.91	6.2	6.7	8.2	25	50	88	110
BC-110	29 45.08	99 31.89	4.3	4.6	4.0	5	4	6	10
BC-111	29 45.10	99 31.86	5.2	5.4	5.2	25	34	55	38
BC-113	29 45.16	99 31.78	6.7	6.3	5.5	5	1	1	15
BC-114	29 45.21	99 31.79	3.0	2.0	3.5	90	82	36	96
BC-115	29 47.38	99 29.62	1.6	1.6	1.0	0	0	0	15
BC-116	29 47.36	99 29.59	1.3	4.6	4.3	33	21	7	42
BC-117	29 51.48	99 21.70	4.3	4.7	4.6	24	28	30	30
BC-118	29 52.59	99 20.92	5.4	5.9	5.8	25	15	25	17
BC-120	29 52.67	99 17.18				10	5	5	11
BC-121	29 49.01	99 15.55	8.6	7.2	7.5	70	61	60	73
BC-122	29 49.04	99 15.53	4.7	7.4	8.6	20	14	10	30
BC-123	29 46.96	99 22.95	2.3	3.7	1.7	17	16	6	15
BC-124	29 46.97	99 22.93	3.1	5.1	4.9	60	74	36	56
BC-125	29 47.28	99 21.62	14.4	7.3	3.8	31	26	27	48
BC-126	29 44.45	99 09.71	8.6	9.0	8.0	42	98	101	48
BC-127	29 44.32	99 07.41	18.7	10.4	9.0	30	25	20	15
BC-128	29 44.32	99 07.41	18.4	18.8	20.3	15	32	29	26
BC-129	29 43.19	99 03.68	8.0	8.1	9.1	14	20	15	25
BC-130	29 43.79	99 03.68	13.8	11.9	10.2	98	99	108	96
BC-131			15.5	15.4	14.2	24	40	75	76

Appendix F: Aquatic Community Sampling Field Data

Sample #	Depth @ middle	Depth @ middle	Depth @ 3/4	Depth @ 3/4	Depth @ 3/4	Flow @ 1/4	Flow @ 1/4	Flow @ 1/4	Flow @ middle	Flow @ middle
BC-93	108	0	87	34	0	0.00	0.00	0.00	0.00	0.00
BC-94	23	17	10	14	8	0.10	0.00	0.00	0.13	0.06
BC-95	13	18	9	8	2	0.29	0.06	0.02	0.10	0.12
BC-96	99	79	51	78	31	0.07	0.07	0.12	0.18	0.16
BC-97	22	20	17	21	16	0.00	0.26	0.55	1.36	1.20
BC-98	61	75	41	75	75	0.00	0.00	0.00	0.13	0.03
BC-99	24	21	21	19	11	0.15	0.18	0.12	0.17	0.25
BC-100	61	39	35	71	80	0.06	0.07	0.05	0.04	0.03
BC-101	30	14	15	15	10	0.00	0.20	0.12	0.42	0.02
BC-102	14	7	4	10	13	0.00	0.13	0.00	0.75	0.47
BC-103	160	165	25	36	84	0.70	0.00	0.00	0.00	0.00
BC-104	39	41	29	46	30	0.09	0.1	0.11	0.00	0.00
BC-105	49	42	51	44	40	0.00	0.00	0.00	0.00	0.00
BC-106	2	6	6	4	4	0.05	0.15	0.00	0.00	0.00
BC-107	10	7	6	8	7	0.04	0.10	0.40	0.11	0.35
BC-108	32	40	10	30	35	0.00	0.00	0.00	0.00	0.00
BC-109	100	97	75	28	34	0.04	0.00	0.00	0.07	0.00
BC-110	10	10	4	7	4	0.00	0.11	0.58	0.70	0.65
BC-111	50	76	19	31	60	0.07	0.07	0.07	0.12	0.04
BC-113	4	1	4	15	1	0.04	0.00	0.03	0.04	0.05
BC-114	90	29	102	75	0	0.00	0.00	0.00	0.00	0.00
BC-115	16	16	0	0	0	0.00	0.00	0.00	0.01	0.01
BC-116	26	18	41	37	31	0.00	0.00	0.00	0.00	0.00
BC-117	40	47	20	26	20	0.53	0.31	0.33	0.57	0.36
BC-118	20	25	16	17	22	0.34	0.50	0.35	0.68	0.68
BC-120	9	4	12	4	11	0.05	0.01	0.06	0.09	0.05
BC-121	110	58	60	110	91	0.11	0.04	0.13	0.17	0.16
BC-122	36	22	22	20	10	0.84	0.58	0.50	1.42	0.85
BC-123	13	11	190	10	14	0.47	0.11	0.13	0.25	0.31
BC-124	56	45	54	40	41	0.03	0.02	0.00	0.05	0.03
BC-125	53	50	62	58	36	0.00	0.00	0.00	0.00	0.00
BC-126	109	111	41	111	114	0.00	0.00	0.00	0.00	0.00
BC-127	28	16	15	4	15	0.04	1.36	0.25	0.66	0.77
BC-128	15	32	22	25	32	0.32	0.26	0.30	0.26	0.28
BC-129	18	24	32	36	30	0.57	0.90	0.33	1.68	1.52
BC-130	94	99	73	64	54	0.00	0.00	0.24	0.16	0.22
BC-131	83	95	92	85	94	0.14	0.11	0.18	0.20	0.08

Appendix F: Aquatic Community Sampling Field Data

Sample #	Flow @ middle	Flow @ 3/4	Flow @ 3/4	Flow @ 3/4	Sand	Mud	Clay	Pebble	Cobble	Bedrock	coarse detritus	Temp (C)	DO (mg/L)	pH	Cond (uS)
BC-93	0.00	0.00	0.00	0.00	5			75	20			27.6	5.7	7.8	532
BC-94	0.19	0.00	0.00	0.00				40	55			29.9	6.0	8.2	549
BC-95	0.17	0.69	0.12	0.00				65	30		5	29.9	6.0	8.2	549
BC-96	0.14	0.16	0.14	0.07	5			30	50	15		23.9	7.7	8.2	464
BC-97	1.40	0.43	0.85	1.30				60	40			24.0	8.0	8.2	463
BC-98	0.06	0.00	0.10	0.05				100				26.0	6.8	8.4	452
BC-99	0.35	0.06	0.16	0.10				100				26.0	6.8	2.4	452
BC-100	0.09	0.00	0.00	0.00	10			60		30		27.5	5.8	8.3	419
BC-101	0.23	0.32	0.13	0.14					10	90		27.7	6.4	8.2	420
BC-102	0.27	0.43	0.28	1.20						100		28.0	6.3	8.0	422
BC-103	0.00	0.00	0.00	0.00				15		85		27.7	6.4	8.2	420
BC-104	0.09	0.05	0.05	0.00						100	100	28	6.2	8.2	391.8
BC-105	0.00	0.00	0.00	0.00				5		95		30.8	7.5	8.2	460
BC-106	0.05	0.10	0.06	0.10						100		30.8	7.5	8.2	460
BC-107	0.38	0.15	0.41	0.20				100				30.8	7.5	8.2	460
BC-108	0.00	0.00	0.00	0.00				100							
BC-109	0.00	0.00	0.00	0.00						100		31.6	7.0	8.3	520
BC-110	0.56	0.00	0.21	0.21						100		32.1	5.6	8.5	524
BC-111	0.07	0.06	0.04	0.00	20			20	60			32.1	7.0	8.3	525
BC-113	0.01	0.09	0.20	0.04						100		27.2	6.9	8.2	485
BC-114	0.00	0.00	0.00	0.00			100					26.2	4.3	8.0	480
BC-115	0.10	0.00	0.00	0.00				20		80		20.3	6.7	7.6	418
BC-116	0.00	0.00	0.00	0.00	5			75		20		20.5	7.0	7.9	410
BC-117	0.38	0.45	0.22	0.31				40		60		28.3	6.1	8.0	398
BC-118	0.58	0.32	0.45	0.16				100				28.5	5.8	8.1	394
BC-120	0.00	0.00	0.16	0.07	10			90				24.6	5.6	7.8	595
BC-121	0.16	0.12	0.12	0.10				25	25	50		24.5	6.6	7.9	476
BC-122	0.82	0.95	0.22	0.52				100				24.9	6.4	7.9	477
BC-123	0.74	0.00	0.30	0.97				100				30.0	5.6	7.9	437
BC-124	0.06	0.04	0.00	0.00				50	40	10	90				
BC-125	0.00	0.00	0.00	0.00			40	60			60	30.2	4.3	8.0	441
BC-126	0.00	0.00	0.00	0.00	100						100	29.3	5.3	8.0	346
BC-127	1.55	0.18	0.33	0.53				60		40		29.8	8.0	8.0	572
BC-128	0.20	0.50	0.28	0.27				80		20	30	29.8	8.0	8.0	572
BC-129	1.18	0.23	0.99	1.15				70	30		80	27.3	7.4	8.1	540
BC-130	0.23	0.00	0.00	0.04	10			10		80		27.3	7.4	8.1	540
BC-131	0.13	0.11	0.00	0.00				10		90		27.3	7.4	8.1	540

Appendix F: Aquatic Community Sampling Field Data

Sample #	Land Use	Collectors	Weather	Length of stream sampled (m)	% Riffle	% Run
BC-93	Ranching	AA, HL, YB, MP	clear, sunny	30		
BC-94	Ranching	AA, HL, YB, MP	clear, sunny	18		
BC-95	Ranching	AA, HL, YB, MP	clear, sunny	25	100	
BC-96		AA, HL, YB, MP	clear, sunny	25		
BC-97	Riparian vegetation	AA, HL, YB, MP	clear, sunny	40	100	
BC-98	Ranching	AA, HL, YB, MP	clear, sunny	15		
BC-99	Riparian vegetation	AA, HL, YB, MP	clear, sunny	20		100
BC-100	Ranching/houses	AA, HL, YB, MP	clear, sunny	30		
BC-101	Ranchland/ riparian vegetation	AA, HL, YB, MP	clear, sunny	30		100
BC-102	Ranchland/ riparian vegetation	AA, HL, YB, MP	clear, sunny	30		100
BC-103	Ranchland/ riparian vegetation	AA, HL, YB, MP	clear, sunny	20		
BC-104	Ranching	AA, HL, YB, MP	clear, sunny	20		
BC-105	Natural park tourism	AA, HL, YB, MP	clear, sunny	60		
BC-106	Natural park tourism	AA, HL, YB, MP	clear, sunny	60		100
BC-107	Natural park tourism	AA, HL, YB, MP	clear, sunny	10	100	
BC-108	Natural park tourism	AA, HL, YB, MP	clear, sunny	15		
BC-109	Ranch	AA, HL, YB, MP	clear, sunny	20		
BC-110	Ranch	AA, HL, YB, MP	clear, sunny	40		100
BC-111	Ranch	AA, HL, YB, MP	clear, sunny	15		
BC-113	Cattle/Pasture/Wooded	AA, HL, YB, MP	clear, sunny	20		100
BC-114	Ranch	AA, HL, YB, MP	clear, sunny	20		
BC-115	Natural state	AA, HL, YB, MP	clear, sunny	4		
BC-116	Natural state	AA, HL, YB, MP	clear, sunny	15		
BC-117	Ranching	AA, HL, YB, MP	clear, sunny	15		100
BC-118	Ranching/Private homes	AA, HL, YB, MP	clear, sunny	10	100	
BC-120	Ranching	AA, HL, YB, MP	clear, sunny	10		100
BC-121	Ranching	AA, HL, YB, MP	clear, sunny	30		
BC-122	Ranching	AA, HL, YB, MP	clear, sunny	20	100	
BC-123	Ranching	AA, HL, YB, MP	clear, sunny	30	100	
BC-124	Ranching	AA, HL, YB, MP	clear, sunny	20		
BC-125	Ranching	AA, HL, YB, MP	clear, sunny	15		
BC-126	Natural riparian	AA, HL, YB, MP	clear, sunny	20		
BC-127	Ranching	AA, HL, YB, MP	clear, sunny	30	100	
BC-128	Ranching	AA, HL, YB, MP	clear, sunny	20		100
BC-129	Ranching/RV park	AA, HL, YB, MP	clear, sunny	40	100	
BC-130	Ranching/RV park	AA, HL, YB, MP	clear, sunny	30		100
BC-131	Ranching/RV park	AA, HL, YB, MP	clear, sunny	25		

Appendix F: Aquatic Community Sampling Field Data

Sample #	% Pool	Snag	sandbar	scour area	detritus	Surber Sample 1 Substrate	Surber Sample 1 Vegetation
BC-93	100	rare	common	common	rare	bedrock	chara
BC-94	100	rare	absent	rare	rare	pebble/cobble	detritus
BC-95		rare	absent	absent	rare	pebble/cobble	detritus
BC-96	100	commo	absent	common	rare	bedrock	potomogeton
BC-97		commo	absent	rare	absent	pebbles	
BC-98	100	rare	absent	rare	common	pebbles	chara
BC-99		commo	absent	absent	rare	cobble	ox-eye grass (?)
BC-100	100	absent	absent	rare	absent	pebbles	
BC-101		rare	absent	rare	rare	bedrock	
BC-102		absent	absent	rare	absent	bedrock	
BC-103	100	rare	absent	common	rare	bedrock	
BC-104	100	rare	absent	common	common	pebbles	chara
BC-105	100	absent	absent	common	common	bedrock	leaf litter
BC-106		rare	absent			bedrock	detritus
BC-107		absent	absent	rare	absent	bedrock/pebble	periphyton
BC-108	100	absent	absent	rare	common	pebbles	detritus
BC-109	100	rare	absent	common	rare	bedrock	detritus
BC-110		rare	absent	common	rare	bedrock	
BC-111	100	rare	absent	rare	rare	pebbles	
BC-113		absent	absent	absent	rare		
BC-114	100	commo	absent	common	common	mud	
BC-115	100	absent	absent	common	common	pebbles	
BC-116	100	rare	absent	common	common	pebbles	
BC-117		absent	absent	common	rare	pebbles	unknown microphyte
BC-118		absent	absent	common	rare	pebbles	unknown microphyte
BC-120		commo	absent	common	rare	pebbles	unknown microphyte
BC-121	100	commo	absent	rare	common	bedrock	unknown macrophyte/detritus
BC-122		commo	absent	common	absent	pebbles	unknown macrophyte
BC-123		absent	absent	rare	absent	pebbles	chara
BC-124	100	absent	absent	common	common	clay	detritus
BC-125	100	rare	rare	common	common	pebbles	chara and sedge
BC-126	100	commo	absent	common	common	sand/gravel	detritus
BC-127		absent	rare	common	absent	pebbles	
BC-128		rare	rare	common	rare	pebbles	
BC-129		commo	absent	common	common	pebble/cobble	detritus
BC-130		commo	absent	common		cobble	periphyton
BC-131	100	commo	rare	common	rare	pebbles	detritus

Appendix F: Aquatic Community Sampling Field Data

Sample #	Substrate	Vegetation	Riparian veg. (% cover)
BC-93	pebbles	utricularia and grass	
BC-94	pebble/cobble	detritus	60
BC-95	pebble/cobble	detritus	
BC-96	pebbles	tree roots	40
BC-97	pebbles	snags	50
BC-98	pebbles		
BC-99	cobble	ox-eye grass	95
BC-100	sand/pebble		90
BC-101	bedrock		60
BC-102	bedrock		70
BC-103	bedrock		
BC-104	bedrock	detritus	75
BC-105	pebbles	chara/detritus	60
BC-106	bedrock	detritus	50
BC-107	pebble/cobble	periphyton	25
BC-108			75
BC-109	bedrock	detritus	85
BC-110	bedrock	detritus	90
BC-111	pebbles		90
BC-113			80
BC-114	mud		75
BC-115	pebbles		30
BC-116	pebbles/sand		40
BC-117	pebbles	unknown microphyte	75
BC-118	pebbles		80
BC-120	pebbles	unknown microphyte	40
BC-121	bedrock	unknown macrophyte and detritus	90
BC-122	pebbles	unknown macrophyte	65
BC-123	pebbles		80
BC-124	clay	detritus	
BC-125	pebbles	Potamogeton	80
BC-126	sand/gravel	detritus/Unidentified Macrophyte	
BC-127	pebbles	Unidentified Macrophyte	60
BC-128	pebbles	detritus	80
BC-129	pebble/cobble	detritus	70
BC-130	cobble	periphyton	60
BC-131	pebbles	detritus	90

Appendix F: Aquatic Community Sampling Field Data

Sample #	Dominant Tree Sp.	Littoral veg. (% cover)	Dominant Littoral Sp.
BC-93	sycamore, juniper, live oak		
BC-94	sycamore, juniper		
BC-95			
BC-96	cypress, sycamore		
BC-97	cypress, sycamore		
BC-98	cypress, sycamore		
BC-99	sycamore, cypress		
BC-100	sycamore, cypress		
BC-101	cypress, mixed grasses, sycamore		
BC-102	cypress, juniper, red oad, sycamore		
BC-103	cypress, juniper		
BC-104	Cypress, willow, Sycamore	0	
BC-105	juniper, sycamore		
BC-106	sycamore, juniper, maples		
BC-107	saw grass, sycamore		
BC-108	saw grass, sycamore		
BC-109	fern, sycamore, juniper, cypress		
BC-110	cedar, juniper		
BC-111	juniper, cypress		
BC-113	sycamore, cypress	20	Eleocharis
BC-114	cypress, grass		
BC-115	juniper, sycamore, oaks		
BC-116	juniper, sycamore, elm, oaks		
BC-117	sycamore, juniper, willow, cypress		
BC-118	cypress, saw grass, sycamore		
BC-120	cypress, sycamore		
BC-121	cypress, sycamore		
BC-122	cypress, grasses		
BC-123	sycamore, mixed grasses		
BC-124	sycamore, mixed grasses, juniper		
BC-125	sycamore, willow, pecan, juniper		
BC-126	cypress, sycamore		
BC-127	cypress, sycamore		
BC-128	cypress		
BC-129	Willow, cypress, sycamore		
BC-130	willow, cypress		
BC-131	sycamore, cypress, button bush		

Appendix F: Aquatic Community Sampling Field Data

Sample #	Submerged veg. (% cover)	Dominant Sumberged Sp.
BC-93	30	chara/potamogeton
BC-94		
BC-95		
BC-96		
BC-97	60	periphyton on macrophytes
BC-98	15	chara, ox-eye grass (?)
BC-99	75	ox-eye grass (?)
BC-100	2	chara
BC-101		
BC-102		
BC-103		
BC-104	0	
BC-105	5	chara
BC-106		
BC-107		
BC-108	20	chara
BC-109		
BC-110		
BC-111	5	Potamogeton
BC-113		
BC-114	40	Cabomba, Utricularia
BC-115		
BC-116		
BC-117	5	unknown macrophyte, chara
BC-118	20	unknown macrophyte, filametous algae
BC-120	5	unknown macrophyte
BC-121	5	Bacopa, unknown macrophyte
BC-122	1	unknown macrophyte
BC-123	25	chara, grasses, unknown macrophyte, Bacopa morera, Potamogeton
BC-124	20	chara, Potamogeton
BC-125	40	chara, potamogeton, Bacopa monera, Cabomba, Eleocharis/Spartina (?)
BC-126	15	Unidentified macrophyte
BC-127	10	Unidentified Macrophyte
BC-128		
BC-129		
BC-130	60	periphyton
BC-131	60	periphyton

Appendix G. Fish Species and Abundance Sample Number

Species	BC-01	BC-02	BC-03	BC-04	BC-05	BC-06	BC-07	BC-08	BC-09	BC-10	BC-11	BC-12	BC-13	BC-14	BC-15	BC-16	BC-17	BC-18	BC-19	BC-20	BC-21
Ameirus natalis																					
Ameirus melas																					61
Astyanax mexicanus																					
Campostoma anomalum		6	11			1	3	26	48	39	139	1									
Cyprinella lutrensis													32	5		12	1	64	21	1	
Cyprinella lepida																					
Cyprinella venusta		12	1			23	44		2				2		1	8	9				
Cyprinus carpio																				7	
Dionda argentosa	4																		9		
Dionda serena																					
Dorosoma cepedianum													52		5						
Etheostoma lepidum				1		1	3	14		37		17				8		1	11	20	
Etheostoma spectabile		10	1		3		3	14						1			4		1		
Gambusia affinis	33	18	131	14	25	2	19	2		5		4	60	477	492	44	10	116	347	85	77
Herichthys cyanoguttatum																					
Ictalurus punctatus			3																		
Lepisosteus oculatus													2								
Lepomis auritus	2	2		11	6																
Lepomis cyanellus								11		5		9	1	6		9	6	1	5	142	4
Lepomis gulosus	4			1	3								1			1	1			2	1
Lepomis hybrid																			4		
Lepomis macrochirus	23	3	2	1	14		1	2				1	8			5	2	13	4	25	70
Lepomis megalotis	116	5	3	4	3		2		3			27					1			18	
Lepomis microlophus	1																				
Micropterus salmoides		2		1	7			9		11		5	9	2	16	157	93	29		65	20
Mircopterus punctulatus			7						10											167	
Mircopterus treculi	23																				
Moxostoma congestum																					
Notemigonus crysoleucas											1										
Notropis amabilis		1																			
Notropis ludibundus																					
Noturus nocturnus			1																		
Percina carbonaria																					
Pimephales vigilax													17			1	2	9	2	21	

Appendix G. Fish Species and Abundance Sample Number

Species	BC-22	BC-23	BC-24	BC-25	BC-26	BC-27	BC-28	BC-29	BC-30	BC-31	BC-32	BC-33	BC-34	BC-35	BC-36	BC-37	BC-38	BC-39	BC-40	BC-41	BC-42
Ameirus natalis																					
Ameirus melas				154																	
Astyanax mexicanus																					
Campostoma anomalum									3				1		85			1	7		
Cyprinella lutrensis		279		35																	
Cyprinella lepida																					
Cyprinella venusta																		4			
Cyprinus carpio		2		1																	
Dionda argentosa																					
Dionda serena																					
Dorosoma cepedianum																					
Etheostoma lepidum													27					12	29	7	
Etheostoma spectabile															9						
Gambusia affinis	12	11	1	105	51	85	10	15	41	58	151	11	170	12	390		139	341	2	39	96
Herichthys cyanoguttatum																					
Ictalurus punctatus		2																		3	
Lepisosteus oculatus																					
Lepomis auritus					42	2			2	10				9			24				
Lepomis cyanellus		500		38											1	16	8				
Lepomis gulosus				2		3		3		1										3	
Lepomis hybrid																					
Lepomis macrochirus		176		483	5	9			4		5	43					37	1		31	
Lepomis megalotis	1									2		x		4			56			18	
Lepomis microlophus																	5				
Micropterus salmoides						2		2	1		7							9			
Mircropterus punctulatus					87							26	2							22	
Mircropterus treculi																			7		1
Moxostoma congestum																					
Notemigonus crysoleucas																					
Notropis amabilis														991							
Notropis ludibundus				27																	
Noturus nocturnus																					
Percina carbonaria																					
Pimephales vigilax		12																			

Appendix G. Fish Species and Abundance Sample Number

Species	BC-43	BC-44	BC-45	BC-46	BC-47	BC-48	BC-49	BC-50	BC-51	BC-52	BC-53	BC-54	BC-55	BC-56	BC-57	BC-58	BC-59	BC-60	BC-61	BC-62	BC-63	
Ameirus natalis			2						1													
Ameirus melas																						
Astyanax mexicanus					4	2							2		1		105	36				
Campostoma anomalum		6			10	30	46	6		2		21			32	10	250	23	68	2	47	
Cyprinella lutrensis					47	54			1						2		5	84			20	
Cyprinella lepida		1					11		1	2	1	9										
Cyprinella venusta		4			45	16		21	72	4	30	3			8					4	3	
Cyprinus carpio																						
Dionda argentosa		18																				
Dionda serena					10	12	1		5			6	66				120	91		79	5	
Dorosoma cepedianum																						
Etheostoma lepidum	179				4	1	80													24	440	
Etheostoma spectabile	4																					
Gambusia affinis	22	91	256	34	70	20		2	6		4		1	12	1		10	1		73		
Herichthys cyanoguttatum		8	2		1	2	2		3													1
Ictalurus punctatus		1				4	1		1	1	3	1										
Lepisosteus oculatus																						
Lepomis auitus					2				1	2				2	4							
Lepomis cyanellus		4	2	1																		
Lepomis gulosus																						
Lepomis hybrid																						
Lepomis macrochirus	9												18	1								
Lepomis megalotis	13	27	2	1	21	2		4	3		3		5	14			6	5		1		
Lepomis microlophus													1	4								
Micropterus salmoides	38							1	4				15									
Mircopterus punctulatus																						
Mircopterus treculi																						
Moxostoma congestum																						
Notemigonus crysoleucas																						
Notropis amabilis	36	8												3							27	
Notropis ludibundus														1								
Noturus nocturnus					2			6														
Percina carbonaria																						
Pimephales vigilax																						

Appendix G. Fish Species and Abundance Sample Number

Species	BC-64	BC-65	BC-66	BC-67	BC-68	BC-69	BC-70	BC-71	BC-72	BC-73	BC-74	BC-75	BC-76	BC-77	BC-78	BC-79	BC-80	BC-81	BC-82	BC-83	BC-84
Ameirus natalis								1						3	1	3	1	1			
Ameirus melas																					
Astyanax mexicanus												3					3		1		
Camptostoma anomalum					1	1	4		3			33		42	2		30	24		81	19
Cyprinella lutrensis						1	1		1			15		10			4	10			
Cyprinella lepida	6				6	1	3														
Cyprinella venusta	15	18	1	3	3	37	8	34	7	85	77					45			17		
Cyprinus carpio																					
Dionda argentosa																					
Dionda serena				48							7			6		4	1	1	13		
Dorosoma cepedianum																					
Etheostoma lepidum		5	1		2	6			2			1				2	18	36	2		
Etheostoma spectabile													6								
Gambusia affinis	7		21	3			1	22			3			2	10	10			2		1
Herichthys cyanoguttatum			2													24					
Ictalurus punctatus						1			1												
Lepisosteus oculatus																					
Lepomis auritus		1	4	2				7		4	10					6					
Lepomis cyanellus											1										
Lepomis gulosus																					
Lepomis hybrid																					
Lepomis macrochirus			1								8										
Lepomis megalotis	26		12	15		1		3		1				11		1		1	15	1	
Lepomis microlophus											1										
Micropterus salmoides			2					1		1	2					3				5	4
Mircropterus punctulatus																			1		
Mircropterus treculi																					
Moxostoma congestum																					
Notemigonus crysoleucas																					
Notropis amabilis		17			32	40		52		47	11								13		
Notropis ludibundus				10	1	6															
Noturus nocturnus																					
Percina carbonaria																					
Pimephales vigilax														13							

Appendix G. Fish Species and Abundance Sample Number

Species	BC-85	BC-86	BC-87	BC-88	BC-89	BC-90	BC-91	BC-92	BC-93	BC-94	BC-95	BC-96	BC-97	BC-98	BC-99	BC-100	BC-101	BC-102	BC-103	BC-104	
Ameirus natalis			3	1																	
Ameirus melas																					
Astyanax mexicanus			5	1		20	6	6													
Campostoma anomalum	49			5		37	7	1	1	26	9				2			3	68		
Cyprinella lutrensis	5																	2	14		
Cyprinella lepida									2												
Cyprinella venusta			55	13	68	21	11	35	3					6				8	1	10	31
Cyprinus carpio																					
Dionda argentosa																					
Dionda serena													1								
Dorosoma cepedianum																					
Etheostoma lepidum		4																		4	
Etheostoma spectabile														1							
Gambusia affinis		2	4	1			13		2			9	1	2			3			3	
Herichthys cyanoguttatum			14				3										2	2			
Ictalurus punctatus			2	1		5															
Lepisosteus oculatus																					
Lepomis auritus		5	21			3	28		6				4		1	1	14			21	
Lepomis cyanellus																				1	
Lepomis gulosus	1	1																			
Lepomis hybrid														1							
Lepomis macrochirus			3				30		2			1			1	2				2	
Lepomis megalotis	2	9		2			11	1	21	1		1		10			5		4	6	
Lepomis microlophus							3		2												
Micropterus salmoides	3	3	6				10	1	282												
Mircopterus punctulatus												1									
Mircopterus treculi	3	2												4					1		
Moxostoma congestum																					
Notemigonus crysoleucas																					
Notropis amabilis														1	1					169	1
Notropis ludibundus	14			9	49	91	49	3	38					1			1			2	
Noturus nocturnus																					
Percina carbonaria																					
Pimephales vigilax																					

Appendix G. Fish Species and Abundance Sample Number

Species	BC-105	BC-106	BC-107	BC-108	BC-109	BC-110	BC-111	BC-113	BC-114	BC-115	BC-116	BC-117	BC-118	BC-120	BC-121	BC-122	BC-123	BC-124
Ameirus natalis																		1
Ameirus melas																		
Astyanax mexicanus									1									1
Campostoma anomalum		53	17	1		14		60					3	21		5	26	
Cyprinella lutrensis		47	9				2	1										
Cyprinella lepida																		
Cyprinella venusta					5	1	3					50	8		2			
Cyprinus carpio																		
Dionda argentosa													13					26
Dionda serena	5	1			6			4		1	161							
Dorosoma cepedianum																		
Etheostoma lepidum	4	4	2					4					3		2			1
Etheostoma spectabile												4	7	4		5	22	
Gambusia affinis	7					4		11	1								2	131
Herichthys cyanoguttatum													1		12			
Ictalurus punctatus					1													
Lepisosteus oculatus																		
Lepomis auritus					4			4		3								2
Lepomis cyanellus																		1
Lepomis gulosus										3								
Lepomis hybrid																		
Lepomis macrochirus								1		2					3			
Lepomis megalotis	48			9	1		3		1						5			5
Lepomis microlophus					1					2								
Micropterus salmoides					2					1								
Mircopterus punctulatus																		
Mircopterus treculi	5	1	1	2									1		4			
Moxostoma congestum																		
Notemigonus crysoleucas																		
Notropis amabilis					83	1							3					
Notropis ludibundus																		
Noturus nocturnus																		
Percina carbonaria																		
Pimephales vigilax																		

Appendix G. Fish Species and Abundance Sample Number

Species	BC-125	BC-126	BC-127	BC-128	BC-129	BC-130	BC-131
Ameirus natalis							
Ameirus melas							
Astyanax mexicanus			3				
Campostoma anomalum			1		1		
Cyprinella lutrensis							
Cyprinella lepida							
Cyprinella venusta			11	5	42	50	24
Cyprinus carpio							
Dionda argentosa							
Dionda serena							
Dorosoma cepedianum							
Etheostoma lepidum			2				
Etheostoma spectabile	2		1		7		
Gambusia affinis	4	1					
Herichthys cyanoguttatum						1	1
Ictalurus punctatus	1	1					
Lepisosteus oculatus							
Lepomis auritus	2			1		14	5
Lepomis cyanellus						1	
Lepomis gulosus	1						
Lepomis hybrid							
Lepomis macrochirus	16	4				13	7
Lepomis megalotis	11	1	1	4		11	3
Lepomis microlophus							
Micropterus salmoides	2	3					
Mircropterus punctulatus						4	
Mircropterus treculi		2		1			
Moxostoma congestum							1
Notemigonus crysoleucas							
Notropis amabilis			10	127			1
Notropis ludibundus				4			
Noturus nocturnus							
Percina carbonaria					11		1
Pimephales vigilax							

Appendix H. Aquatic Macro Invertebrate Taxa (A B are Duplicate Samples)

Order	Family	Sample Number		BC-001	BC-001	BC-002	BC-002	BC-003	BC-004	BC-004	BC-005	BC-005	BC-006	BC-006	BC-007	BC-007	BC-008	BC-008	BC-009
		A	B	A	B	A	A	B	A	B	A	B	A	B	A	B	A	B	A
Amphipoda		2	2	232	2	464							12				6	2	
Annelida	Hirudinea					1									1				
Annelida	Oligochaeta			7	8														
Anura																			
Coleoptera	Dryopidae																		
Coleoptera	Dysticidae																		
Coleoptera	Elmidae			3		2			3		1		20	1	6				
Coleoptera	Haliplidae	1	3							3									
Coleoptera	Hydrophilidae			1	1	2												1	
Coleoptera	Psephenidae																		
Coleoptera	Staphylinidae																		
Decapoda	Cambariidae																		
Decapoda	Palaemonidae	2																	
Diptera	Chironomidae		4	14	4	5				1	6		2			12	12	8	
Diptera	Culicinae																		
Diptera	Dixidae																		
Diptera	Empididae																		
Diptera	Heleidae									3								1	
Diptera	Rhagionidae																		
Diptera	Simuliidae																		
Diptera	Stratiomyidae																		
Diptera	Tabanidae																		
Ephemeroptera		55	177	31	5	59	1			23	179	3	120	2	10	35	10		
Gastropoda	Ancylidae																		
Gastropoda	Hydrobiidae								4	10	8	5	12		31				
Gastropoda	Lymnaeidae	2			1								1						
Gastropoda	Physidae	48	6	45	11	12	2	3					1	2	4		2		
Gastropoda	Planorbidae	16	12	1	8	20	5			4	3	1	1				1		
Hemiptera	Corixidae																		
Hemiptera	Gerridae																		
Hemiptera	Naucoridae		1	2		3						1	5	6	1				
Hydracarina																			
Lepidoptera	Pyralidae												1	3					
Megaloptera	Corydalidae												1		1				
Megaloptera	Sialidae																		
Nematoda																			
Odonata Anisoptera	Aeshnidae					1													
Odonata Anisoptera	Gomphidae			1					2						1				
Odonata Anisoptera	Libellulidae		1	2		2													
Odonata Anisoptera	Macromiidae																		
Odonata Zygoptera	Calopterygidae			1									2	1	2				
Odonata Zygoptera	Coenagriidae	10	7	6		16			2	3					1				
Odonata Zygoptera	Lestidae																		
Pelecypoda	Corbiculidae		1	1									3	243	20	8			
Pelecypoda	Sphaeriidae			21	6		6	9	49	1			7						
Trichoptera	Helicopsychidae			8		1							29	162	7	20			
Trichoptera	Hydropsychidae												3	31	2				
Trichoptera	Hydroptilidae						1							21					
Trichoptera	Limnephiliidae																		

Appendix H. Aquatic Macro Invertebrate Taxa (A B are Duplicate Samples)

	Sample Number	BC-001	BC-001	BC-002	BC-002	BC-003	BC-004	BC-004	BC-005	BC-005	BC-006	BC-006	BC-007	BC-007	BC-008	BC-008	BC-009
Order	Family	A	B	A	B	A	A	B	A	B	A	B	A	B	A	B	A
Trichoptera	Rhyacophilidae											1					
Turbellaria	Planariidae			8		12						32	2	1			

Appendix H. Aquatic Macro Invertebrate Taxa (A B are Duplicate Samples)

Order	Family	Sample Number		BC-009	BC-010	BC-010	BC-011	BC-012	BC-012	BC-013	BC-013	BC-014	BC-014	BC-015	BC-015	BC-016	BC-016	BC-017	BC-017
		B	A	B	A	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Amphipoda		39	1	9	25	192	9	4	4			1	2	23	29	29	15	18	36
Annelida	Hirudinea			1	1												1		4
Annelida	Oligochaeta																3	9	
Anura					1														
Coleoptera	Dryopidae																		
Coleoptera	Dysticidae			4	8														
Coleoptera	Elmidae																		
Coleoptera	Haliplidae				4														
Coleoptera	Hydrophilidae		1	9	2			1					4	1		1		1	
Coleoptera	Psephenidae																		
Coleoptera	Staphylinidae																		
Decapoda	Cambariidae																		
Decapoda	Palaemonidae																		
Diptera	Chironomidae	21	16	8	17	45	27	3	7			5	4	2		11	12	3	
Diptera	Culicinae																	1	
Diptera	Dixidae																		
Diptera	Empididae																		
Diptera	Heleidae										3		4		8	1	6		
Diptera	Rhagionidae																		
Diptera	Simuliidae																		
Diptera	Stratiomyidae																		
Diptera	Tabanidae																		
Ephemeroptera			5	21	42	74	40	38	72	28	148	39	36	95	31	37	108		
Gastropoda	Ancylidae																		
Gastropoda	Hydrobiidae																		
Gastropoda	Lymnaeidae			6														1	3
Gastropoda	Physidae	3	1	29	22	1		1		2	4	26	1	30	20	12	39		
Gastropoda	Planorbidae	2		5	16		1			1		1			2		2		
Hemiptera	Corixidae																		
Hemiptera	Gerridae																		
Hemiptera	Naucoridae																		
Hydracarina					2														
Lepidoptera	Pyralidae																		
Megaloptera	Corydalidae											1							
Megaloptera	Sialidae							1											
Nematoda																			15
Odonata Anisoptera	Aeshnidae				1														
Odonata Anisoptera	Gomphidae																		
Odonata Anisoptera	Libellulidae				4														1
Odonata Anisoptera	Macromiidae																		
Odonata Zygoptera	Calopterygidae																		
Odonata Zygoptera	Coenagriidae				11	3						1	1	5		2	1		
Odonata Zygoptera	Lestidae																		
Pelecypoda	Corbiculidae																		
Pelecypoda	Sphaeriidae	4		6	4		1					1					1		
Trichoptera	Helicopsychidae																		
Trichoptera	Hydropsychidae																		
Trichoptera	Hydroptilidae																		
Trichoptera	Limnephilidae																		

Appendix H. Aquatic Macro Invertebrate Taxa (A B are Duplicate Samples)

	Sample Number	BC-009	BC-010	BC-010	BC-011	BC-012	BC-012	BC-013	BC-013	BC-014	BC-014	BC-015	BC-015	BC-016	BC-016	BC-017	BC-017
Order	Family	B	A	B	A	A	B	A	B	A	B	A	B	A	B	A	B
Trichoptera	Rhyacophilidae						1								1	2	
Turbellaria	Planariidae				3												

Appendix H. Aquatic Macro Invertebrate Taxa (A B are Duplicate Samples)

Order	Family	Sample Number		BC-018	BC-018	BC-019	BC-019	BC-020	BC-020	BC-021	BC-021	BC-022	BC-022	BC-023	BC-023	BC-024	BC-024	BC-025	BC-026
		A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	A
Amphipoda		4	36					24	83	88	141	245	236	2		6		8	
Annelida	Hirudinea			3				1	1		52	36	10						1
Annelida	Oligochaeta															1		1	16
Anura												1							
Coleoptera	Dryopidae																		
Coleoptera	Dysticidae										36	8				5	1		
Coleoptera	Elmidae								1										
Coleoptera	Haliplidae										3	1						1	
Coleoptera	Hydrophilidae	1			1				3	6	7	6					3	1	
Coleoptera	Psephenidae																		
Coleoptera	Staphylinidae																		
Decapoda	Cambariidae																		
Decapoda	Palaemonidae																		
Diptera	Chironomidae		1	2	4	2	6	1					3		9				9
Diptera	Culicinae											2	1						
Diptera	Dixidae																		
Diptera	Empididae																		
Diptera	Heleidae														1				1
Diptera	Rhagionidae																		
Diptera	Simuliidae																		
Diptera	Stratiomyidae																		
Diptera	Tabanidae												2						
Ephemeroptera		22	1	46	59	14	5	49	4	51	49	32	140	21	17	38	73		
Gastropoda	Ancylidae																		
Gastropoda	Hydrobiidae																		
Gastropoda	Lymnaeidae			1															
Gastropoda	Physidae	4	1	2	1	31	11	1	4	21	70	1	3	137	92	9	63		
Gastropoda	Planorbidae					3	2	1	25	5	11			3	2		29		
Hemiptera	Corixidae														1	1			
Hemiptera	Gerridae															3			
Hemiptera	Naucoridae																		
Hydracarina																			
Lepidoptera	Pyralidae																		
Megaloptera	Corydalidae																		
Megaloptera	Sialidae										1				1		1		
Nematoda																			
Odonata Anisoptera	Aeshnidae																1		
Odonata Anisoptera	Gomphidae								1					1					
Odonata Anisoptera	Libellulidae					2		1							6	4	1	8	
Odonata Anisoptera	Macromiidae																		
Odonata Zygoptera	Calopterygidae																		
Odonata Zygoptera	Coenagriidae		1	1		3	1	1			3	3			1	1	3	16	
Odonata Zygoptera	Lestidae																		
Pelecypoda	Corbiculidae																		
Pelecypoda	Sphaeriidae		1							2	1								1
Trichoptera	Helicopsychidae																		
Trichoptera	Hydropsychidae																		
Trichoptera	Hydroptilidae																		
Trichoptera	Limnephiliidae																		

Appendix H. Aquatic Macro Invertebrate Taxa (A B are Duplicate Samples)

	Sample Number	BC-018	BC-018	BC-019	BC-019	BC-020	BC-020	BC-021	BC-021	BC-022	BC-022	BC-023	BC-023	BC-024	BC-024	BC-025	BC-026
Order	Family	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	A
Trichoptera	Rhyacophilidae																
Turbellaria	Planariidae									2		1					1

Appendix H. Aquatic Macro Invertebrate Taxa (A B are Duplicate Samples)

Order	Sample Number Family	BC-026	BC-027	BC-027	BC-028	BC-028	BC-029	BC-029	BC-030	BC-030	BC-031	BC-031	BC-032	BC-032	BC-033	BC-033	BC-034
		B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Amphipoda					53	82	778	40		4		12	100	35	120	87	17
Annelida	Hirudinea	1					4	1									
Annelida	Oligochaeta															1	
Anura																	
Coleoptera	Dryopidae																
Coleoptera	Dysticidae	1							8								
Coleoptera	Elmidae				2	3		1									
Coleoptera	Haliplidae							2							1		
Coleoptera	Hydrophilidae			1	1							1					
Coleoptera	Psephenidae																11
Coleoptera	Staphylinidae																
Decapoda	Cambariidae																
Decapoda	Palaemonidae																
Diptera	Chironomidae	4	23	19	3	15	17	3	2	5	110	11	26	18	7	12	35
Diptera	Culicinae																
Diptera	Dixidae																
Diptera	Empididae																
Diptera	Heleididae																
Diptera	Rhagionidae																
Diptera	Simuliidae																
Diptera	Stratiomyidae			1		1					1						
Diptera	Tabanidae																
Ephemeroptera		98	4	1		1	4	15	5	6	2		3	1	66	59	11
Gastropoda	Ancylidae												2				
Gastropoda	Hydrobiidae											1					
Gastropoda	Lymnaeidae				3								2		1		
Gastropoda	Physidae	47	10	12	31	22	22	53	15	14	24	49	207	7	28	60	1
Gastropoda	Planorbidae	4		14	3	5	11	8	1	6	19	16	55	6	44	28	
Hemiptera	Corixidae																
Hemiptera	Gerridae																
Hemiptera	Naucoridae																4
Hydracarina								2									
Lepidoptera	Pyralidae																
Megaloptera	Corydalidae																
Megaloptera	Sialidae																
Nematoda																	
Odonata Anisoptera	Aeshnidae																
Odonata Anisoptera	Gomphidae																
Odonata Anisoptera	Libellulidae	1						19		1						3	
Odonata Anisoptera	Macromiidae														2		
Odonata Zygoptera	Calopterygidae																
Odonata Zygoptera	Coenagriidae	11			1	5		11	1						1	3	
Odonata Zygoptera	Lestidae																
Pelecypoda	Corbiculidae											1	4				
Pelecypoda	Sphaeriidae		1	3		6					6	2	23				
Trichoptera	Helicopsychidae																
Trichoptera	Hydropsychidae					4											
Trichoptera	Hydroptilidae					3											
Trichoptera	Limnephilidae																45

Appendix H. Aquatic Macro Invertebrate Taxa (A B are Duplicate Samples)

	Sample Number	BC-026	BC-027	BC-027	BC-028	BC-028	BC-029	BC-029	BC-030	BC-030	BC-031	BC-031	BC-032	BC-032	BC-033	BC-033	BC-034
Order	Family	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Trichoptera	Rhyacophilidae					4											2
Turbellaria	Planariidae				45	58		2									44

Appendix H. Aquatic Macro Invertebrate Taxa (A B are Duplicate Samples)

Order	Sample Number Family	BC-034	BC-035	BC-035	BC-036	BC-036	BC-037	BC-037	BC-038	BC-039	BC-039	BC-040	BC-040	BC-041	BC-041	BC-042	BC-042
		B	A	B	A	B*	A	B	A	A	B	A	B	A	B	A	B
Amphipoda		82	79	50	953	1606		2	1		353	1		2	2	4	280
Annelida	Hirudinea	1	1	3			1	4						2			2
Annelida	Oligochaeta	3		1			9				2						
Anura																	
Coleoptera	Dryopidae																
Coleoptera	Dysticidae					4		4			1		1		40		
Coleoptera	Elmidae	15			1					5	16	1				1	
Coleoptera	Haliplidae				1										5		
Coleoptera	Hydrophilidae						1	3				2					
Coleoptera	Psephenidae	2															
Coleoptera	Staphylinidae																
Decapoda	Cambariidae																
Decapoda	Palaemonidae																
Diptera	Chironomidae		2	8			76	18	1	24	43			5	5	23	
Diptera	Culicinae																
Diptera	Dixidae																
Diptera	Empididae																
Diptera	Heleidae													1			
Diptera	Rhagionidae																
Diptera	Simuliidae																
Diptera	Stratiomyidae																
Diptera	Tabanidae																
Ephemeroptera		57	11	2			1	5		2	420	11	1				4
Gastropoda	Ancylidae																
Gastropoda	Hydrobiidae																
Gastropoda	Lymnaeidae						1			1				3			
Gastropoda	Physidae	2					7	16								1	
Gastropoda	Planorbidae	9		7			22	59	4	9	1	1		9	10	27	15
Hemiptera	Corixidae																
Hemiptera	Gerridae		1								1						
Hemiptera	Naucoridae																
Hydracarina																	
Lepidoptera	Pyralidae																
Megaloptera	Corydalidae																
Megaloptera	Sialidae							1			2	1	1				
Nematoda																	
Odonata Anisoptera	Aeshnidae																
Odonata Anisoptera	Gomphidae										1					2	
Odonata Anisoptera	Libellulidae																
Odonata Anisoptera	Macromiidae																
Odonata Zygoptera	Calopterygidae																
Odonata Zygoptera	Coenagriidae	11	1	2	1	2					6						
Odonata Zygoptera	Lestidae																
Pelecypoda	Corbiculidae									6	3	1		2	3		
Pelecypoda	Sphaeriidae						1	1				1	1	4			3
Trichoptera	Helicopsychidae																
Trichoptera	Hydropsychidae	3											1				
Trichoptera	Hydroptilidae																
Trichoptera	Limnephiliidae																

Appendix H. Aquatic Macro Invertebrate Taxa (A B are Duplicate Samples)

	Sample Number	BC-034	BC-035	BC-035	BC-036	BC-036	BC-037	BC-037	BC-038	BC-039	BC-039	BC-040	BC-040	BC-041	BC-041	BC-042	BC-042
Order	Family	B	A	B	A	B*	A	B	A	A	B	A	B	A	B	A	B
Trichoptera	Rhyacophilidae		1	2							1						
Turbellaria	Planariidae	13															

Appendix H. Aquatic Macro Invertebrate Taxa (A B are Duplicate Samples)

Order	Family	Sample Number		BC-043	BC-043	BC-044	BC-044	BC-045	BC-045	BC-046	BC-046	BC-047	BC-047	BC-048	BC-048	BC-049	BC-049	BC-050	BC-050
		A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Amphipoda		7	5					1	5	20	3							2	
Annelida	Hirudinea																		
Annelida	Oligochaeta																		
Anura																			
Coleoptera	Dryopidae																		
Coleoptera	Dysticidae																		
Coleoptera	Elmidae														2			4	3
Coleoptera	Haliplidae																		
Coleoptera	Hydrophilidae							1											
Coleoptera	Psephenidae																		
Coleoptera	Staphylinidae																		
Decapoda	Cambariidae		1																
Decapoda	Palaemonidae																		
Diptera	Chironomidae	1		9	19			7	20				2		4	5	11		1
Diptera	Culicinae																		
Diptera	Dixidae																		
Diptera	Empididae																		
Diptera	Heleidae			64	25			31	81	4	6	8	1	5	28	26			13
Diptera	Rhagionidae																		
Diptera	Simuliidae																		
Diptera	Stratiomyidae																		
Diptera	Tabanidae																		
Ephemeroptera			7				1	5	9		4			2	2			7	
Gastropoda	Ancylidae		1																
Gastropoda	Hydrobiidae																		
Gastropoda	Lymnaeidae	2														1			1
Gastropoda	Physidae	3	3					1	2					1		1	5		
Gastropoda	Planorbidae	14	48		1												1		2
Hemiptera	Corixidae																		
Hemiptera	Gerridae																		
Hemiptera	Naucoridae													2					
Hydracarina						2													
Lepidoptera	Pyralidae																		
Megaloptera	Corydalidae																		
Megaloptera	Sialidae																		
Nematoda																			
Odonata Anisoptera	Aeshnidae																		
Odonata Anisoptera	Gomphidae	1																	
Odonata Anisoptera	Libellulidae	1	2																
Odonata Anisoptera	Macromiidae																		
Odonata Zygoptera	Calopterygidae																		
Odonata Zygoptera	Coenagriidae	1	1						1		1			1	1			4	
Odonata Zygoptera	Lestidae																		
Pelecypoda	Corbiculidae		2																
Pelecypoda	Sphaeriidae	2	2															1	
Trichoptera	Helicopsychidae																		
Trichoptera	Hydropsychidae													2					
Trichoptera	Hydroptilidae													2		1			
Trichoptera	Limnephiliidae																		

Appendix H. Aquatic Macro Invertebrate Taxa (A B are Duplicate Samples)

	Sample Number	BC-043	BC-043	BC-044	BC-044	BC-045	BC-045	BC-046	BC-046	BC-047	BC-047	BC-048	BC-048	BC-049	BC-049	BC-050	BC-050
Order	Family	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Trichoptera	Rhyacophilidae												1				
Turbellaria	Planariidae																

Appendix H. Aquatic Macro Invertebrate Taxa (A B are Duplicate Samples)

Order	Family	Sample Number		BC-051	BC-051	BC-052	BC-052	BC-053	BC-053	BC-054	BC-054	BC-055	BC-056	BC-057	BC-057	BC-058	BC-058	BC-060	BC-060
		A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Amphipoda			12									4							
Annelida	Hirudinea																		
Annelida	Oligochaeta														4	4			
Anura			2												8				
Coleoptera	Dryopidae																		
Coleoptera	Dysticidae													2	2				
Coleoptera	Elmidae	1	9							6	1								
Coleoptera	Haliplidae														1				
Coleoptera	Hydrophilidae											2	1					1	
Coleoptera	Psephenidae																		
Coleoptera	Staphylinidae																		
Decapoda	Cambariidae																		
Decapoda	Palaemonidae																		
Diptera	Chironomidae		7				9	19				7	5		1			1	2
Diptera	Culicinae																		
Diptera	Dixidae																		
Diptera	Empididae																		
Diptera	Heleidae		58							1		10	13	62	10		2		
Diptera	Rhagionidae																		
Diptera	Simuliidae																		
Diptera	Stratiomyidae																		
Diptera	Tabanidae																		
Ephemeroptera		11	44	2	16	1			26			5	34						
Gastropoda	Ancylidae																		
Gastropoda	Hydrobiidae																		
Gastropoda	Lymnaeidae																		
Gastropoda	Physidae	2	3							2			12	91	30		3		
Gastropoda	Planorbidae	3	6							3			2	6	6	1		5	
Hemiptera	Corixidae																		
Hemiptera	Gerridae																		
Hemiptera	Naucoridae	3	1		4				4										
Hydracarina												1							
Lepidoptera	Pyralidae																		
Megaloptera	Corydalidae			3															
Megaloptera	Sialidae																		
Nematoda																			
Odonata Anisoptera	Aeshnidae																		
Odonata Anisoptera	Gomphidae																		
Odonata Anisoptera	Libellulidae											3							
Odonata Anisoptera	Macromiidae																		
Odonata Zygoptera	Calopterygidae																		
Odonata Zygoptera	Coenagriidae		7	1	2				3				1	1	1				
Odonata Zygoptera	Lestidae																		
Pelecypoda	Corbiculidae																		
Pelecypoda	Sphaeriidae		6									2							
Trichoptera	Helicopsychidae																		
Trichoptera	Hydropsychidae	5		1						3	1								
Trichoptera	Hydroptilidae		7																
Trichoptera	Limnephiliidae																		

Appendix H. Aquatic Macro Invertebrate Taxa (A B are Duplicate Samples)

	Sample Number	BC-051	BC-051	BC-052	BC-052	BC-053	BC-053	BC-054	BC-054	BC-055	BC-056	BC-057	BC-057	BC-058	BC-058	BC-060	BC-060
Order	Family	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Trichoptera	Rhyacophilidae		1	8	4			5		1					4		
Turbellaria	Planariidae		7					3									

Appendix H. Aquatic Macro Invertebrate Taxa (A B are Duplicate Samples)

Order	Sample Number Family	BC-061	BC-061	BC-062	BC-062	BC-063	BC-063	BC-064	BC-064	BC-065	BC-065	BC-066	BC-066	BC-067	BC-067	BC-068	BC-068
		A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Amphipoda					7			22	5					1			
Annelida	Hirudinea																
Annelida	Oligochaeta											1					
Anura									1								
Coleoptera	Dryopidae																
Coleoptera	Dysticidae																
Coleoptera	Elmidae			7	2		2	2						1			
Coleoptera	Haliplidae																
Coleoptera	Hydrophilidae	5						2									
Coleoptera	Psephenidae																
Coleoptera	Staphylinidae																
Decapoda	Cambariidae																
Decapoda	Palaemonidae																
Diptera	Chironomidae		2	14	9		5	10	1	1			3	1			
Diptera	Culicinae																
Diptera	Dixidae																
Diptera	Empididae																
Diptera	Heleidae		16	16	121		4	22	3				5				
Diptera	Rhagionidae																
Diptera	Simuliidae																
Diptera	Stratiomyidae		1				5										
Diptera	Tabanidae		1								1						
Ephemeroptera				23	4	14	96	5	2	13	17	4	40	7	1		6
Gastropoda	Ancylidae																
Gastropoda	Hydrobiidae																
Gastropoda	Lymnaeidae			1	1												
Gastropoda	Physidae			4	17	2		15	34								
Gastropoda	Planorbidae			2	6			2	15			1		2			
Hemiptera	Corixidae																
Hemiptera	Gerridae																
Hemiptera	Naucoridae						3			1	1						2
Hydracarina									1								
Lepidoptera	Pyralidae		1														
Megaloptera	Corydalidae																1
Megaloptera	Sialidae																
Nematoda																	
Odonata Anisoptera	Aeshnidae																
Odonata Anisoptera	Gomphidae							1									
Odonata Anisoptera	Libellulidae							6	2								
Odonata Anisoptera	Macromiidae																
Odonata Zygoptera	Calopterygidae																
Odonata Zygoptera	Coenagriidae			1			1	1			2						
Odonata Zygoptera	Lestidae																
Pelecypoda	Corbiculidae																
Pelecypoda	Sphaeriidae								1								
Trichoptera	Helicopsychidae																
Trichoptera	Hydropsychidae					22	30			2	6						9
Trichoptera	Hydroptilidae	1					8										
Trichoptera	Limnephiliidae																

Appendix H. Aquatic Macro Invertebrate Taxa (A B are Duplicate Samples)

	Sample Number	BC-061	BC-061	BC-062	BC-062	BC-063	BC-063	BC-064	BC-064	BC-065	BC-065	BC-066	BC-066	BC-067	BC-067	BC-068	BC-068
Order	Family	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Trichoptera	Rhyacophilidae		2				3			2	1				1		3
Turbellaria	Planariidae	1	3														

Appendix H. Aquatic Macro Invertebrate Taxa (A B are Duplicate Samples)

Order	Sample Number Family	BC-069	BC-069	BC-070	BC-070	BC-071	BC-071	BC-072	BC-072	BC-073	BC-073	BC-074	BC-074	BC-075	BC-076	BC-077	BC-077
		A	B	A	B	A	B	A	B	A	B	A	B	A	A	A	B
Amphipoda			1									3	1				
Annelida	Hirudinea																
Annelida	Oligochaeta				1					1							
Anura																	
Coleoptera	Dryopidae																
Coleoptera	Dysticidae																
Coleoptera	Elmidae				2	4	22			2	29						
Coleoptera	Haliplidae																
Coleoptera	Hydrophilidae																
Coleoptera	Psephenidae																
Coleoptera	Staphylinidae																
Decapoda	Cambariidae								1						1		
Decapoda	Palaemonidae																
Diptera	Chironomidae						4						1		2	1	
Diptera	Culicinae																
Diptera	Dixidae																
Diptera	Empididae																
Diptera	Heleidae						346			1		6					
Diptera	Rhagionidae																
Diptera	Simuliidae																
Diptera	Stratiomyidae																
Diptera	Tabanidae																
Ephemeroptera		2	2	1	4	17	60		10		3	1		2	7		
Gastropoda	Ancylidae																
Gastropoda	Hydrobiidae																
Gastropoda	Lymnaeidae										1						
Gastropoda	Physidae						5				7	2				1	
Gastropoda	Planorbidae						6			3	17					10	2
Hemiptera	Corixidae								1								
Hemiptera	Gerridae								1		1						
Hemiptera	Naucoridae				4	1					3						
Hydracarina							1					1					
Lepidoptera	Pyralidae																
Megaloptera	Corydalidae				1												
Megaloptera	Sialidae																
Nematoda																	
Odonata Anisoptera	Aeshnidae																
Odonata Anisoptera	Gomphidae																
Odonata Anisoptera	Libellulidae																
Odonata Anisoptera	Macromiidae																
Odonata Zygoptera	Calopterygidae																
Odonata Zygoptera	Coenagriidae				3		6			1							
Odonata Zygoptera	Lestidae								1								
Pelecypoda	Corbiculidae																
Pelecypoda	Sphaeriidae										2						
Trichoptera	Helicopsychidae																
Trichoptera	Hydropsychidae	2		2	2	1	1	1									
Trichoptera	Hydroptilidae						2										
Trichoptera	Limnephiliidae																

Appendix H. Aquatic Macro Invertebrate Taxa (A B are Duplicate Samples)

	Sample Number	BC-069	BC-069	BC-070	BC-070	BC-071	BC-071	BC-072	BC-072	BC-073	BC-073	BC-074	BC-074	BC-075	BC-076	BC-077	BC-077
Order	Family	A	B	A	B	A	B	A	B	A	B	A	B	A	A	A	B
Trichoptera	Rhyacophilidae						1				1						
Turbellaria	Planariidae					1	6										

Appendix H. Aquatic Macro Invertebrate Taxa (A B are Duplicate Samples)

Order	Family	Sample Number		BC-078	BC-078	BC-079	BC-080	BC-080	BC-081	BC-081	BC-082	BC-082	BC-083	BC-083	BC-084	BC-084	BC-085	BC-085	BC-086
		A	B	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Amphipoda				1		2			1	1	1								2
Annelida	Hirudinea	4																	
Annelida	Oligochaeta													1					
Anura																			
Coleoptera	Dryopidae									1									
Coleoptera	Dysticidae																		
Coleoptera	Elmidae			4		11			10				7	10	3	3		3	6
Coleoptera	Haliplidae																		
Coleoptera	Hydrophilidae																		1
Coleoptera	Psephenidae																		
Coleoptera	Staphylinidae														1				
Decapoda	Cambariidae																		
Decapoda	Palaemonidae																		
Diptera	Chironomidae			81		103			67				5		1		34	169	39
Diptera	Culicinae																		
Diptera	Dixidae																		
Diptera	Empididae															1			
Diptera	Heleidae			403		4	1	5	20	13	7	2	2						
Diptera	Rhagionidae			1									1						
Diptera	Simuliidae																		
Diptera	Stratiomyidae					6	1	1											
Diptera	Tabanidae																		
Ephemeroptera			2	16		377	16	206	4	12	5	4	2	3	1	6			143
Gastropoda	Ancylidae																		
Gastropoda	Hydrobiidae																		
Gastropoda	Lymnaeidae																		
Gastropoda	Physidae			24							5			1					3
Gastropoda	Planorbidae			1										1					4
Hemiptera	Corixidae																		
Hemiptera	Gerridae																		
Hemiptera	Naucoridae	2			4	3								1	1				
Hydracarina																			
Lepidoptera	Pyralidae																		
Megaloptera	Corydalidae						6												
Megaloptera	Sialidae																		1
Nematoda																			
Odonata Anisoptera	Aeshnidae																		
Odonata Anisoptera	Gomphidae													1		1		2	2
Odonata Anisoptera	Libellulidae															2			
Odonata Anisoptera	Macromiidae																		1
Odonata Zygoptera	Calopterygidae																		
Odonata Zygoptera	Coenagriidae														6				4
Odonata Zygoptera	Lestidae																		
Pelecypoda	Corbiculidae																		
Pelecypoda	Sphaeriidae			1															1
Trichoptera	Helicopsychidae																		
Trichoptera	Hydropsychidae					8	5	5							2				
Trichoptera	Hydroptilidae			2		2	1	2							3	1			
Trichoptera	Limnephilidae																		

Appendix H. Aquatic Macro Invertebrate Taxa (A B are Duplicate Samples)

	Sample Number	BC-078	BC-078	BC-079	BC-080	BC-080	BC-081	BC-081	BC-082	BC-082	BC-083	BC-083	BC-084	BC-084	BC-085	BC-085	BC-086
Order	Family	A	B	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Trichoptera	Rhyacophilidae		1	1			1						1	1			
Turbellaria	Planariidae					12		11			3	3					

Appendix H. Aquatic Macro Invertebrate Taxa (A B are Duplicate Samples)

Order	Sample Number Family	BC-086	BC-087	BC-087	BC-088	BC-088	BC-089	BC-089	BC-090	BC-090	BC-091	BC-091	BC-092	BC-092	BC-093	BC-093	BC-094
		B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Amphipoda							2					8			1	21	
Annelida	Hirudinea																
Annelida	Oligochaeta					4					1	1					
Anura																	
Coleoptera	Dryopidae																
Coleoptera	Dysticidae																
Coleoptera	Elmidae	2													1	1	
Coleoptera	Haliplidae																
Coleoptera	Hydrophilidae							1				1				1	
Coleoptera	Psephenidae																
Coleoptera	Staphylinidae																
Decapoda	Cambariidae																
Decapoda	Palaemonidae																
Diptera	Chironomidae	313	12	20	3		8	5	1	7	20	51	4			27	1
Diptera	Culicinae																
Diptera	Dixidae																
Diptera	Empididae																
Diptera	Heleidae	3		26	1		68	36	4	3	41	55			5	13	14
Diptera	Rhagionidae																
Diptera	Simuliidae																
Diptera	Stratiomyidae																
Diptera	Tabanidae																
Ephemeroptera		24	28	6		1	6	2	10		6	58		1		5	
Gastropoda	Ancylidae																
Gastropoda	Hydrobiidae																
Gastropoda	Lymnaeidae																
Gastropoda	Physidae	1						1				2					
Gastropoda	Planorbidae	2											2		1		
Hemiptera	Corixidae																
Hemiptera	Gerridae																
Hemiptera	Naucoridae	2															
Hydracarina																	
Lepidoptera	Pyralidae																
Megaloptera	Corydalidae																
Megaloptera	Sialidae																
Nematoda																	
Odonata Anisoptera	Aeshnidae																
Odonata Anisoptera	Gomphidae	1														2	
Odonata Anisoptera	Libellulidae																
Odonata Anisoptera	Macromiidae		1														
Odonata Zygoptera	Calopterygidae																
Odonata Zygoptera	Coenagriidae		8								14	9		1		3	
Odonata Zygoptera	Lestidae																
Pelecypoda	Corbiculidae																
Pelecypoda	Sphaeriidae												2				
Trichoptera	Helicopsychidae																
Trichoptera	Hydropsychidae																
Trichoptera	Hydroptilidae						1									1	1
Trichoptera	Limnephiliidae																

Appendix H. Aquatic Macro Invertebrate Taxa (A B are Duplicate Samples)

	Sample Number	BC-086	BC-087	BC-087	BC-088	BC-088	BC-089	BC-089	BC-090	BC-090	BC-091	BC-091	BC-092	BC-092	BC-093	BC-093	BC-094
Order	Family	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Trichoptera	Rhyacophilidae							1					1				1
Turbellaria	Planariidae																

Appendix H. Aquatic Macro Invertebrate Taxa (A B are Duplicate Samples)

Order	Sample Number Family	BC-094	BC-095	BC-095	BC-096	BC-096	BC-097	BC-097	BC-098	BC-098	BC-099	BC-099	BC-100	BC-100	BC-101	BC-101	BC-102
		B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Amphipoda														2			
Annelida	Hirudinea																
Annelida	Oligochaeta				1												
Anura																	
Coleoptera	Dryopidae																
Coleoptera	Dysticidae									1							
Coleoptera	Elmidae				4			1		1		1	2		1		
Coleoptera	Haliplidae									1							
Coleoptera	Hydrophilidae																
Coleoptera	Psephenidae																
Coleoptera	Staphylinidae																
Decapoda	Cambariidae																
Decapoda	Palaemonidae																
Diptera	Chironomidae	3			2	11				4	40	35	2	4		5	
Diptera	Culicinae																
Diptera	Dixidae										1						
Diptera	Empididae																
Diptera	Heleidae	80	6	2	76	9			24	116		13	32	102		164	
Diptera	Rhagionidae																
Diptera	Simuliidae										2	1					
Diptera	Stratiomyidae																
Diptera	Tabanidae																
Ephemeroptera		2	1		6	25	8	2	1	36	19	45	2	11		3	4
Gastropoda	Ancylidae																
Gastropoda	Hydrobiidae																
Gastropoda	Lymnaeidae																
Gastropoda	Physidae				13				4	4						1	
Gastropoda	Planorbidae								2					2			
Hemiptera	Corixidae																
Hemiptera	Gerridae																
Hemiptera	Naucoridae							1		1							
Hydracarina																	
Lepidoptera	Pyralidae					1	1				3	6					
Megaloptera	Corydalidae																
Megaloptera	Sialidae																
Nematoda																	
Odonata Anisoptera	Aeshnidae																
Odonata Anisoptera	Gomphidae									1		1					
Odonata Anisoptera	Libellulidae																
Odonata Anisoptera	Macromiidae																
Odonata Zygoptera	Calopterygidae																
Odonata Zygoptera	Coenagriidae	2	2		3	2				1	1	1					
Odonata Zygoptera	Lestidae																
Pelecypoda	Corbiculidae																
Pelecypoda	Sphaeriidae																
Trichoptera	Helicopsychidae																
Trichoptera	Hydropsychidae					5		2			80	10					11
Trichoptera	Hydroptilidae			1						1			1			3	
Trichoptera	Limnephiliidae									1							

Appendix H. Aquatic Macro Invertebrate Taxa (A B are Duplicate Samples)

	Sample Number	BC-094	BC-095	BC-095	BC-096	BC-096	BC-097	BC-097	BC-098	BC-098	BC-099	BC-099	BC-100	BC-100	BC-101	BC-101	BC-102
Order	Family	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Trichoptera	Rhyacophilidae		1								1						
Turbellaria	Planariidae																

Appendix H. Aquatic Macro Invertebrate Taxa (A B are Duplicate Samples)

Order	Family	Sample Number		BC-103	BC-104	BC-104	BC-105	BC-105	BC-106	BC-106	BC-107	BC-107	BC-108	BC-108	BC-109	BC-109	BC-110
		B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Amphipoda			4			16	1	2								1	
Annelida	Hirudinea					17		2									
Annelida	Oligochaeta						4										
Anura																	
Coleoptera	Dryopidae																
Coleoptera	Dysticidae																
Coleoptera	Elmidae	4		1	3	5				1	5	4				3	2
Coleoptera	Haliplidae																
Coleoptera	Hydrophilidae										1						
Coleoptera	Psephenidae																
Coleoptera	Staphylinidae																
Decapoda	Cambariidae																
Decapoda	Palaemonidae																
Diptera	Chironomidae	32	3		35	14	4		31	24			2	1	20	12	17
Diptera	Culicinae																
Diptera	Dixidae																
Diptera	Empididae																
Diptera	Heleidae	19	11	5	11	6	93			20		4	29	30	21	6	25
Diptera	Rhagionidae																
Diptera	Simuliidae				4												
Diptera	Stratiomyidae																
Diptera	Tabanidae																
Ephemeroptera		12	3	3	232	40	27	37	3	1		2			5	2	
Gastropoda	Ancylidae																
Gastropoda	Hydrobiidae																
Gastropoda	Lymnaeidae	1	1														
Gastropoda	Physidae		3				11	2					2			34	
Gastropoda	Planorbidae		1		15	14	2						7				
Hemiptera	Corixidae																
Hemiptera	Gerridae			1													
Hemiptera	Naucoridae	2								1							
Hydracarina						4											
Lepidoptera	Pyralidae																
Megaloptera	Corydalidae											1					
Megaloptera	Sialidae																
Nematoda																	
Odonata Anisoptera	Aeshnidae																
Odonata Anisoptera	Gomphidae	7															
Odonata Anisoptera	Libellulidae							1									
Odonata Anisoptera	Macromiidae																
Odonata Zygoptera	Calopterygidae																
Odonata Zygoptera	Coenagriidae					2						2	1	1		4	
Odonata Zygoptera	Lestidae																
Pelecypoda	Corbiculidae																
Pelecypoda	Sphaeriidae															2	
Trichoptera	Helicopsychidae																
Trichoptera	Hydropsychidae															1	2
Trichoptera	Hydroptilidae		2		1	1			7			2					3
Trichoptera	Limnephiliidae																

Appendix H. Aquatic Macro Invertebrate Taxa (A B are Duplicate Samples)

	Sample Number	BC-102	BC-103	BC-103	BC-104	BC-104	BC-105	BC-105	BC-106	BC-106	BC-107	BC-107	BC-108	BC-108	BC-109	BC-109	BC-110
Order	Family	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Trichoptera	Rhyacophilidae					2						6				3	
Turbellaria	Planariidae															1	

Appendix H. Aquatic Macro Invertebrate Taxa (A B are Duplicate Samples)

Order	Family	Sample Number		BC-110	BC-111	BC-111	BC-112	BC-112	BC-113	BC-113	BC-114	BC-114	BC-115	BC-115	BC-116	BC-116	BC-117	BC-117	BC-118
		B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Amphipoda											16	81							
Annelida	Hirudinea										1								
Annelida	Oligochaeta		3												1	2			
Anura																			
Coleoptera	Dryopidae																		
Coleoptera	Dysticidae																		
Coleoptera	Elmidae	1	4				5				3	1						2	
Coleoptera	Haliplidae																		
Coleoptera	Hydrophilidae										1								
Coleoptera	Psephenidae												7		5				
Coleoptera	Staphylinidae																		
Decapoda	Cambariidae													1					
Decapoda	Palaemonidae																		
Diptera	Chironomidae		5	1	5			77	48			10		2	4		3		
Diptera	Culicinae																		
Diptera	Dixidae																		
Diptera	Empididae																		
Diptera	Heleidae		46	9	1			3			15	61		1					
Diptera	Rhagionidae						1												
Diptera	Simuliidae																		
Diptera	Stratiomyidae	1																	
Diptera	Tabanidae																		
Ephemeroptera		11		2	3	20	2	2	1	15			2	36	12	2	5	4	
Gastropoda	Ancylidae																		
Gastropoda	Hydrobiidae																		
Gastropoda	Lymnaeidae													4					
Gastropoda	Physidae									4	1					1			
Gastropoda	Planorbidae									1	2								
Hemiptera	Corixidae																		
Hemiptera	Gerridae															1			
Hemiptera	Naucoridae	1						1									1		
Hydracarina																			
Lepidoptera	Pyralidae																	1	
Megaloptera	Corydalidae	2																	
Megaloptera	Sialidae																		
Nematoda																			
Odonata Anisoptera	Aeshnidae																		
Odonata Anisoptera	Gomphidae																		
Odonata Anisoptera	Libellulidae											3							
Odonata Anisoptera	Macromiidae																		
Odonata Zygoptera	Calopterygidae																		
Odonata Zygoptera	Coenagriidae										7	2						1	
Odonata Zygoptera	Lestidae																		
Pelecypoda	Corbiculidae																		
Pelecypoda	Sphaeriidae														1				
Trichoptera	Helicopsychidae																		
Trichoptera	Hydropsychidae	59				62	5										5	38	
Trichoptera	Hydroptilidae						1											1	
Trichoptera	Limnephiliidae																		

Appendix H. Aquatic Macro Invertebrate Taxa (A B are Duplicate Samples)

	Sample Number	BC-110	BC-111	BC-111	BC-112	BC-112	BC-113	BC-113	BC-114	BC-114	BC-115	BC-115	BC-116	BC-116	BC-117	BC-117	BC-118
Order	Family	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Trichoptera	Rhyacophilidae	1				2									5	4	
Turbellaria	Planariidae																

Appendix H. Aquatic Macro Invertebrate Taxa (A B are Duplicate Samples)

Order	Sample Number Family	BC-118	BC-119	BC-119	BC-120	BC-120	BC-121	BC-121	BC-122	BC-122	BC-123	BC-123	BC-124	BC-124	BC-125	BC-125	BC-126	
		B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	
Amphipoda															1	11	44	
Annelida	Hirudinea															1		
Annelida	Oligochaeta											2		8	1			
Anura																		
Coleoptera	Dryopidae																	
Coleoptera	Dysticidae																	
Coleoptera	Elmidae	8			1	5	1	13		4	3	44	3	3		4	6	
Coleoptera	Haliplidae																	
Coleoptera	Hydrophilidae																1	
Coleoptera	Psephenidae																	
Coleoptera	Staphylinidae																	
Decapoda	Cambariidae																	
Decapoda	Palaemonidae																	
Diptera	Chironomidae	6	1				10	19		15		27		14	6	18	28	
Diptera	Culicinae																	
Diptera	Dixidae																	
Diptera	Empididae																	
Diptera	Heleidae				6	20	12	8				3	88	82	5	11	22	
Diptera	Rhagionidae					1												
Diptera	Simuliidae								2	232		2						
Diptera	Stratiomyidae											32						
Diptera	Tabanidae																	
Ephemeroptera		42	1	1		2	20	16	1	20		83	45	49	58	61	6	
Gastropoda	Ancylidae																	
Gastropoda	Hydrobiidae																	
Gastropoda	Lymnaeidae												1		1			
Gastropoda	Physidae												8	13	4		1	
Gastropoda	Planorbidae											1	12	103	1			
Hemiptera	Corixidae																	
Hemiptera	Gerridae																	
Hemiptera	Naucoridae									2		6						
Hydracarina												4		2	5	9		
Lepidoptera	Pyralidae	1								1		14						
Megaloptera	Corydalidae	3		2						3	1	1						
Megaloptera	Sialidae																	
Nematoda																		
Odonata Anisoptera	Aeshnidae																	
Odonata Anisoptera	Gomphidae					1		1										
Odonata Anisoptera	Libellulidae								1									
Odonata Anisoptera	Macromiidae																	
Odonata Zygoptera	Calopterygidae	2																
Odonata Zygoptera	Coenagriidae								1	1	1		3	1	3	3	4	1
Odonata Zygoptera	Lestidae											3						
Pelecypoda	Corbiculidae																	
Pelecypoda	Sphaeriidae							1						2	4	12	6	
Trichoptera	Helicopsychidae																	
Trichoptera	Hydropsychidae	64		3	1	1			1	201	9	331						
Trichoptera	Hydroptilidae											1				1		
Trichoptera	Limnephiliidae																	

Appendix H. Aquatic Macro Invertebrate Taxa (A B are Duplicate Samples)

	Sample Number	BC-118	BC-119	BC-119	BC-120	BC-120	BC-121	BC-121	BC-122	BC-122	BC-123	BC-123	BC-124	BC-124	BC-125	BC-125	BC-126
Order	Family	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Trichoptera	Rhyacophilidae	3	1		2		9	11		6		2		9			2
Turbellaria	Planariidae																

Appendix H. Aquatic Macro Invertebrate Taxa (A B are Duplicate Samples)

	Sample Number	BC-126	BC-127	BC-127	BC-128	BC-128	BC-129	BC-129	BC-130	BC-130	BC-131	BC-131
Order	Family	B	A	B	A	B	A	B	A	B	A	B
Amphipoda		1										
Annelida	Hirudinea						4				1	
Annelida	Oligochaeta				1	8	1					2
Anura												
Coleoptera	Dryopidae											
Coleoptera	Dysticidae											
Coleoptera	Elmidae	10		1		4		1	1	4	2	
Coleoptera	Haliplidae											
Coleoptera	Hydrophilidae											
Coleoptera	Psephenidae											
Coleoptera	Staphylinidae											
Decapoda	Cambariidae											
Decapoda	Palaemonidae											
Diptera	Chironomidae	47				10			6	3		1
Diptera	Culicinae											
Diptera	Dixidae											
Diptera	Empididae											
Diptera	Heleidae	23				83			19	3	5	5
Diptera	Rhagionidae											
Diptera	Simuliidae											
Diptera	Stratiomyidae											
Diptera	Tabanidae											
Ephemeroptera		21	5	3	3	45	4		1		1	4
Gastropoda	Ancylidae											
Gastropoda	Hydrobiidae											
Gastropoda	Lymnaeidae	1							1			
Gastropoda	Physidae	3										1
Gastropoda	Planorbidae	2			1	3				2		1
Hemiptera	Corixidae											
Hemiptera	Gerridae		1									
Hemiptera	Naucoridae											
Hydracarina												
Lepidoptera	Pyralidae											
Megaloptera	Corydalidae											
Megaloptera	Sialidae											
Nematoda												
Odonata Anisoptera	Aeshnidae											
Odonata Anisoptera	Gomphidae											
Odonata Anisoptera	Libellulidae											
Odonata Anisoptera	Macromiidae	1										
Odonata Zygoptera	Calopterygidae											
Odonata Zygoptera	Coenagriidae								1		1	3
Odonata Zygoptera	Lestidae											
Pelecypoda	Corbiculidae	1					1					1
Pelecypoda	Sphaeriidae	14										
Trichoptera	Helicopsychidae											
Trichoptera	Hydropsychidae		11	3			27	5				1
Trichoptera	Hydroptilidae					1					1	
Trichoptera	Limnephiliidae											

Appendix H. Aquatic Macro Invertebrate Taxa (A B are Duplicate Samples)

	Sample Number	BC-126	BC-127	BC-127	BC-128	BC-128	BC-129	BC-129	BC-130	BC-130	BC-131	BC-131
Order	Family	B	A	B	A	B	A	B	A	B	A	B
Trichoptera	Rhyacophilidae		3	3			3					
Turbellaria	Planariidae											

Values for IBI scores and proportional landcover by categories for sub-basins under scenario IV.

Sub-basin Number	Calculated IBI Score (Complete Model)	Calculated IBI Score (Two Factor Model)	Min IBI Score	Mean IBI Score	Cedar	Mesquite	Mixed	Oak	Pasture	Urban	Cropland
2010301	67	63	60	76	0.1313	0.0162	0.1986	0.1195	0.0052	0.0000	0.0030
2010401	62	60	60	60	0.1668	0.0152	0.2056	0.1254	0.0068	0.0000	0.0013
2010501	71	68	53	68	0.0863	0.0175	0.1807	0.0998	0.0048	0.0000	0.0028
2010601	68	64	53	64	0.1237	0.0161	0.1954	0.1186	0.0062	0.0000	0.0045
2020201	70	68	66	66	0.0767	0.0184	0.1617	0.0936	0.0069	0.0000	0.0063
2020303	71	68	72	79	0.0743	0.0226	0.1654	0.0941	0.0091	0.0000	0.0104
6010101	71	71	77	77	0.0494	0.0160	0.1739	0.0678	0.0031	0.0000	0.0000
6010301	64	65	34	63	0.1127	0.0153	0.2049	0.0840	0.0065	0.0000	0.0000
6010501	63	63	37	61	0.1459	0.0082	0.2558	0.1038	0.0094	0.0000	0.0000
6010503	71	65	39	61	0.1164	0.0089	0.2248	0.1156	0.0089	0.0000	0.0000
6010801	76	69	70	75	0.0763	0.0138	0.2259	0.1063	0.0077	0.0000	0.0030
6060101	61	60	40	65	0.1739	0.0118	0.2224	0.1232	0.0081	0.0000	0.0000
6060201	60	59	52	62	0.1789	0.0097	0.2420	0.1170	0.0138	0.0000	0.0000
6060301	65	69	51	61	0.0775	0.0130	0.1840	0.0899	0.0085	0.0000	0.0276
6060501	59	72	56	59	0.0387	0.0230	0.1621	0.0695	0.0052	0.0000	0.0610
7060105	56	60	37	59	0.1722	0.0107	0.1856	0.1061	0.0060	0.0000	0.0000
MC 25	47	54	12	40	0.1483	0.1218	0.0139	0.0089	0.0075	0.0047	0.0152
MC 27	45	53	39	60	0.1510	0.1335	0.0157	0.0134	0.0075	0.0021	0.0110
SC 16	64	55	52	71	0.0967	0.1772	0.0199	0.0298	0.0382	0.0011	0.0315
SD 13	54	51	32	43	0.1358	0.1720	0.0212	0.0312	0.0041	0.0000	0.0019
SD 15	50	57	0	44	0.1276	0.1029	0.0151	0.0230	0.0420	0.0000	0.0279
SD 21	66	58	56	66	0.1179	0.0989	0.0200	0.0129	0.0141	0.0173	0.0433

Appendix I. Values for IBI scores and proportional landcover by categories for sub-basins under scenario V.

Sub-basin Number	Calculated IBI Score (Complete Model)	Calculated IBI Score (Two Factor Model)	Min IBI Score	Mean IBI Score	Cedar	Mesquite	Mixed	Oak	Pasture	Urban	Cropland
2010301	76	62	60	76	0.1408	0.0233	0.2529	0.1622	0.0052	0.0000	0.0030
2010401	69	59	60	60	0.1741	0.0205	0.2445	0.1580	0.0068	0.0000	0.0013
2010501	81	66	53	68	0.0993	0.0281	0.2668	0.1434	0.0048	0.0000	0.0028
2010601	78	63	53	64	0.1341	0.0237	0.2518	0.1671	0.0062	0.0000	0.0045
2020201	81	65	66	66	0.0977	0.0330	0.2534	0.1427	0.0069	0.0000	0.0063
2020303	81	65	72	79	0.0932	0.0379	0.2475	0.1430	0.0091	0.0000	0.0104
6010101	82	68	77	77	0.0672	0.0306	0.3126	0.1096	0.0031	0.0000	0.0000
6010301	75	64	34	63	0.1196	0.0210	0.2856	0.1263	0.0065	0.0000	0.0000
6010501	70	62	37	61	0.1503	0.0128	0.2924	0.1335	0.0094	0.0000	0.0000
6010503	79	64	39	61	0.1237	0.0148	0.2775	0.1528	0.0089	0.0000	0.0000
6010801	85	67	70	75	0.0858	0.0227	0.2960	0.1454	0.0077	0.0000	0.0030
6060101	67	59	40	65	0.1793	0.0158	0.2561	0.1512	0.0081	0.0000	0.0000
6060201	68	59	52	62	0.1821	0.0125	0.2674	0.1484	0.0138	0.0000	0.0000
6060301	73	66	51	61	0.0917	0.0258	0.2766	0.1229	0.0085	0.0000	0.0276
6060501	69	68	56	59	0.0565	0.0486	0.2613	0.1075	0.0052	0.0000	0.0610
7060105	67	59	37	59	0.1806	0.0191	0.2334	0.1566	0.0060	0.0000	0.0000
MC 25	16	36	12	40	0.3211	0.1391	0.0514	0.0097	0.0075	0.0047	0.0152
MC 27	17	36	39	60	0.3099	0.1511	0.0523	0.0134	0.0075	0.0021	0.0110
SC 16	43	39	52	71	0.2282	0.2190	0.0480	0.0307	0.0382	0.0011	0.0315
SD 13	28	36	32	43	0.2835	0.1942	0.0516	0.0320	0.0041	0.0000	0.0019
SD 15	19	39	0	44	0.3045	0.1225	0.0506	0.0237	0.0420	0.0000	0.0279
SD 21	41	41	56	66	0.2704	0.1355	0.0618	0.0129	0.0141	0.0173	0.0433